WINTER SURVIVAL OF BERMUDAGRASS (*CYNODON* SP.) AS INFLUENCED BY TRAFFIC, MINERAL NUTRITION, PLASTIC COVERS, CULTURAL TREATMENTS, OVERSEEDING AND FREEZING IN LATE-WINTER DORMANCY

by

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(ABSTRACT)

The most important problem in using bermudagrass (*Cynodon* sp.) for turf at the northern limit of its adaptation is winter survival. Bermudagrass used for athletic complexes is exposed to the additional problem of uncontrolled or excessive traffic. This research was conducted to determine the effects of: 1) traffic and mineral nutrition; 2) clear plastic covers and cultural treatments and; 3) overseeding and late winter freezing on bermudagrass winter survival.

Four separate experiments were conducted on field cultured Midiron bermudagrass. Various regimes of traffic, N and K fertility, clear plastic covers, cultural treatments and growth regulators were utilized to determine their affect on bermudagrass winter survival. A laboratory freeze was used, in two experiments, on plant samples taken from the field. Following the freezing procedure, the samples were then grown in the greenhouse.

From these experiments, it was found that traffic applied just as turf growth initiates in the spring was the most damaging. Potassium fertility had no effect on

post dormancy growth. Nitrogen did improve post dormancy growth of bermudagrass exposed to a late winter laboratory freeze and when plastic covers were applied during winter dormancy. Plastic covers enhanced post dormancy growth and offset the detrimental effect of imposed traffic. `Stayz Green´ turf colorant did increase early post dormancy growth. While, the cultivation treatments using a vertical mower alone and with an aerifier reduced early green up. Flurprimidal reduced early post dormancy growth of bermudagrass; while, mefluidide had no detrimental effect. Both growth regulators reduced the growth of the overseeded ryegrass, and mefluidide enhanced the competitiveness of bermudagrass in the ryegrass canopy.

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INTRODUCTION

Bermudagrass (*Cynodon* sp.) grown at it´s northern limit of adaptation is difficult to maintain on high use areas, such as, sport fields. This can be especially critical when much of this traffic is imposed when the turf is either dormant or in a reduced growth period. It is, therefore, imperative that maintenance and use schedules be developed to offset the detrimental effect of traffic.

Traffic on turfgrass swards affects soil porosity as well as plant growth. The extent of wear damage to the plant canopy and soil is dependent on four factors: type of usage, intensity of usage, frequency at which the traffic intensity occurs and whether or not the wear leads to a specific pattern (Canaway, 1975). Turf growing on compacted soils is more susceptible to injury. Winter injury is the most common source of damage of warm season grasses growing at the northern limit of their adaptation (Schroder, 1970).

Potassium nutrition has proven to be effective in reducing winter kill (Adams and Twersky, 1959). Nitrogen : potassium ratios have proven to be important. A fertilizer ratio of 4-1-6 increased winter hardiness of "Tifgreen" bermudagrass in North Carolina (Gilbert and Davis, 1971). Also, Gilbert and Davis (1971) recommend a a balanced fertility program with late summer potassium applications. Cold hardiness levels are not static, varying with season, temperature, day length, maturity, moisture content, mineral nutrition, and physiological age (Stushnoff, 1972). Maximum hardiness in bermudagrass appears to occur during early winter but declines severely during late winter (Dunn and Nelson, 1974).

Experiments for this thesis were conducted in the field and laboratory using Midiron bermudagrass (*Cynodon dactylon* (L.)Pers). The objectives of these experiments were as follows:

1. To study the effect of traffic on bermudagrass early post dormancy growth.

2. To determine the influence of mineral nutrition in lessening the effect of traffic on post dormancy growth of bermudagrass.

3. To determine the influence of plastic covers, installed over turf, on the post dormancy growth of bermudagrass.

4. To determine the effect of various cultural treatments on the post dormancy growth of bermudagrass.

5. To ascertain the influence of overseeded perennial ryegrass on spring recovery of bermudagrass.

6. To study the survival of bermudagrass when subjected to a freeze in a late-winter dormant condition following various traffic and cultural treatments.

LITERATURE REVIEW

"Turfs were developed by modern man in order to enhance his environment. The more technologically advanced the civilization, the more widely turfs are used. Turfs are important in human activities from the (a) functional, (b) recreational, and (c) ornamental standpoint" (Beard, 1973). Field sport participation, especially in the urban centers, has increased with the development of quality recreational programs. The recurring problem in maintaining quality turfgrass on these sport fields has been excessive wear. This is especially critical when semi-tropical species are used in their northern area of adaptation, since much of the traffic is imposed when the turf is either dormant or in a reduced growth period.

Canaway (1975) reports that the extent of wear damage to the plant canopy and soil is dependent on four factors: type of usage, intensity of usage , frequency at which the intensity occurs and whether or not the wear leads to a specific pattern. Some examples include football fields, where the most intense wear occurs in the center of the playing field. This intensity varies with the level of play with the greatest damage occurring with the greatest size and ability of the players. Also, hash marks are closer in pro football resulting in more play in the center of the field (Canaway, 1975). Patterns that develop vary with the sport: with soccer the greatest damage occurs in the goal areas, baseball where the outfielders are positioned; while, in golf the locations of greatest wear are the carts paths, greens and tees (Beard, 1973). Therefore, wear stress will range in severity based on factors such as grass species, soil type, field design, sport or activity and maintenance practices.

Various compaction machines have been uses to simulate wear on turf areas (Gross, et al. 1964, Shearman, 1974).

Wear or traffic affects soil porosity as well as plant growth. The intensity of traffic influences these two components and determines the success or failure of the turf sward (Beard, 1973, Canaway, 1975). Although the visual damage to the turf canopy is noticed first, the problems associated with soil compaction and structure damage result in long lasting effects on turf vigor and growth (Beard, 1973, Canaway, 1975). As soil compaction increases soil particles are pressed into a more dense soil mass (Brady, 1974). Initially little structural damage occurs but with increased compaction soil aggregates are deformed and ultimately destroyed (Soane, 1970, Canaway, 1975). Compaction on turfgrass areas is most severe in the top two to three inches of the soil profile (Burton, 1962). In general, water infiltration, percolation and soil aeration are decreased in proportion to the degree of compaction (Soane, 1970). Infiltration rate and percolation of water decreases, with increasing compaction, resulting in the increase of water runoff at the soil surface (Cordukes, 1966, Soane, 1970). Therefore, the turf sward suffers as water is prevented from suitable movement into the root system where it can be utilized for growth processes. As compaction increases drought stress to the turf sward results. As soil aeration decreases, the soil atmosphere becomes more and more saturated with carbon dioxide (Morgan, et al. 1965, Brady, 1974). Carbon dioxide is toxic to turf root systems reducing both growth and vigor (Duble, et al. 1973).

As soils become compacted, there is an enhanced heat conductivity tnat occurs as compared to the uncompacted soil. This leads to greater temperature extremes in the surface two to three inches of the soil profile (Beard, 1973). Therefore, turf stands are more susceptible to freezing injury on compacted soils (Schroder, 1970). This poses significant problems when trying to maintain warm season species in northern limits of their range of adaptation during the winter months.

The degree to which of compaction occurs is based on soil texture, soil water content, frequency and severity of pressure applied, and amount of vegetation (Beard, 1973). These factors also effect the speed with which soil compaction occurs and are the problems dealt with in determining the proper steps for turf establishment and management (Shoulders, et al. 1979).

The two extrinsic factors most directly involved in soil compaction are the intensity and frequency of applied pressure. Generally, as the intensity and frequency of pressure is increased soil compaction is increased. Of course, the compaction in a given situation varies with the weight of the object imposing the pressure divided by the surface area of the object in contact with the soil (Beard, 1973). Ferguson (1974), testing three types of golf shoes; conventional spikes, rippled soles and modified spikes (shoulder of the spike is recessed into the shoe sole) found that the conventional type inflicted the greatest damage because the golfer´s weight rested on the shoulders of the spikes instead of the shoe sole. Therefore, the conventional spike caused the greatest compaction because it had the greatest weight per surface area. When comparing football shoes with street shoes, Beard (1973) found with cleated football shoes a 200 pound man exerts 150 pounds per square inch of static pressure versus 6.25 pounds per square inch with street shoes. Therefore, when considering wear intensity and frequency one must look at multiple factors including equipment used, weight of person or machines imposing traffic and how often the stress is imposed.

Wear on the turf canopy occurs both on the individual plant and on the entire sward. Turf wear causes damage by crushing, tearing and scuffing the turf plant (Beard, 1973). The interaction of traffic on the soil and on the turf canopy has tremendous effect on turf vigor. As turf is worn, the biomass of the canopy cover is thinned decreasing the cushioning effect of the canopy and increasing soil compaction, that results in a reduction of vigor and overall growth of the turf canopy (Duble, et al. 1973).

The cushioning effect of the canopy is determined by height of cut, shoot density and thatch layer (Meinhold, et al. 1973). Some turf species provide greater cushion than others, with stoloniferous and rhizomatus grasses generally exceeding clump type grasses (Beard, 1973). Age of the turf sward also plays a significant role, with young seedlings being less effective in providing cushioning effects than established, mature plants. Young seedlings have less recuperative potential than mature turf because of the susceptability of the growing points to damage and limited root systems. Young turf swards have little or no thatch layer which in the presence of traffic can result in a mechanical shearing of the plants against the soil surface (Beard, 1973). This shearing action also occurs in established stands with low shoot densities. With traffic, leaves and stems are bruised, crushed and scuffed; while roots, rhizomes and stolons may be broken. With increasing wear, entire plants may be removed (divots) or buried. Finally growing points may be killed mechanically or be predisposed to other stresses (Burton, 1962, Canaway, 1975). The extent to which the canopy is injured depends on species composition, the sward´s age and vigor and outside factors such as management and environment.

Beard (1965), Shearman and Beard (1975), and Perry (1958) have studied and classified turf species according to wear tolerance. In general, in their areas of adaptation, actively growing warm season grasses have greater wear tolerance than cool season species.

Shearman and Beard(1975) studied seven turf species correlating wear tolerance with cell wall constituents, physiological, morphological and anatomical characteristics. On a dry matter per unit area basis they found the combined effect of percent total cell wall, lignocellulose, cellulose and lignin accounted for 96% of the observed wear tolerance variation among the seven grasses. The combined effect of percent total cell wall, lignocellulose, cellulose and hemicellulose accounted for 97% of the variation in inter-species wear tolerance. Total cell wall accounted for 78% of the variation among the species. In looking at morphological and anatomical characteristics, they found that these factors had significant roles to play in variation of wear tolerance among the species when looking at their combined effect. This was especially true for leaf tensile strength and leaf width. To date there is little experimental evidence to corrolate the effect of physiological factors on wear tolerance.

Turf that is dormant has little or no recuperative potential and can be greatly injured when subjected to wear. Actively growing turf can consistently recover from wear, thus, retaining ground cover and lessening surface soil compaction and injury to roots, rhizomes and growing points (Beard, 1965). With semitropical turfgrass species, great amounts of traffic can be imposed during dormancy. This problem becomes more critical at the northern limits of their adaptations were they are subjected to shorter growing seasons and longer dormancy periods and reduced growth.

Beard (1965), found that the shearing damage to roots and rhizomes, was intensitfied on winter dormant temperate bentgrass when the surface was thawed while the subsurface was still frozen. Also, turf stands covered with wet slush when subjected to traffic were completely killed when the ground was subsequently frozen. Another factor, is the turfgrass´s tolerance of cold temperature. The cold hardiness of plants vary during the winter period. Maximum cold tolerance of turfgrass generally occurs during early winter, with decreasing tolerance in February and severe reductions in tolerance during late winter (Beard, 1973). Davis and Gilbert (1970) achieved LT50´s (low temperature which caused a 50 percent reduction in growth when compared to unfrozen checks) for `Tifgreen´ bermudagrass (Cynodon sp.) at -2.2^{O}C in September, -8.1^{O}C in February, -5.6^{O}C in April, and -2.5^{O}C in May. Therefore, semitropical turfgrasses exposed to wear in late Fall and early Spring have no immediate recuperative potential and also have minimum cold tolerance.

Nutrition has been studied to determine its positive and/or negative effects on plant responses to stress (Reeves et al. 1970). Mineral nutrients are important factors in winter survival (Juska and Murray, 1973, Thompson, 1977). Nutrition has been studied to determine its positive and/or negative effects on plant responses to stress (Reeves et. al. 1970). Use of heavy applications of nitrogen in the fall reduced the cold tolerance of 15 turfgrass (Carroll, 1943). Winter kill of `Coastal´ bermudagrass (Cynodon sp.) was decreased by increasing levels of potassium while holding nitrogen constant (Adams and Twersky, 1959). The effect of nitrogen rates on winter survival of bermudagrass was investigated by Mathias et al. (1973). Nitrogen : potassium ratios have received attention; as nitrogen rates increase, potassium uptake by the plant increases (Reeves, et. al. 1970, Gilbert and Davis, 1971, Reeves et. al. 1972). A fertilizer ratio of 4-1-6 increased winter hardiness of \`Tifgreen´ bermudagrass in North Carolina (Davis and Gilbert, 1970).

To improve the cold tolerance of \`Tifdwarf´ and \`Tifgreen´ bermudagrasses (Cynodon spp.), Gilbert and Davis (1971) recommend a balanced fertility program with late summer potassium applications. In Maryland, Juska and Murray (1973) found more winter injury on bermudagrass where potassium was not applied than on plots treated with potassium. Matoda (1977) and Keisling et al. (1979) studed the effect of potassium fertilization on Coastal bermudagrass.

GENERAL MATERIALS AND METHODS

Four field experiments were conducted to determine the influence of various traffic treatments, cultural practices (ie. aerification, vertical mowing and combination of both), use of clear plastic covers, fall over seeding with perennial ryegrass (*Lolium perenne*) (L.) growth regulators, turf colorant and fertility on the spring recovery of Midiron bermudagrass (*Cynodon dactylon* (L.) Pers.). Also, laboratory controlled freeze studies were conducted on dormant bermudagrass that had been exposed to different treatments in the field.

Field Site

Two sites were established to Midiron bermudagrass in June 1978 at Blacksburg, Virginia on a Lodi silt loam soil (typic, Hapludult clayey, kaolinitic, mesic family). This soil had a high content of extractable P (1.0 kg are^{-1}) a medium level of extractable K (1.8 kg are^{-1}) and a pH of 6.0. Soil samples from these sites were analyzed at the Virginia Polytechnic Institute and State University Extension Soil Testing Laboratory according to the procedures described by Donohue and Gettier (1979). An application of 10.0 kg are^{-1} of a 10-10-10 fertilizer and 20.0 kg are^{-1} of dolomitic limestone was broadcast and incorporated prior to establishment with Midiron bermudagrass sprigs (experiments 1 & 2) and sod (experiments 3 & 4). Immediately after sprigging or sodding both sites were rolled, to insure good soil contact. Irrigation was implemented during establishment and throughout the growing season to maintain plant growth. Both swards were maintained at a 2.5 cm clipping height through August and then at 3.75 cm cut until growth stopped each growing season. Clippings were not removed from the sward except when yield data were collected. Nitrogen as NH_4NO_3 and K as K_2SO_4 were used for fertilizer treatments in the studies designated as experiments 1 and 2. In experiments 3 and 4, 2 kg N are^{-1} $year^{-1}$ were applied as IBDU (Isobutylidene diurea). At the completion of data collection each spring the areas were cored with 2 passes of a Dedoes mechanical aerifier to a depth of 3.75 cm and fertilized with 0.5 kg N are^{-1} as NH_4NO_3.

Description of Measurements

All clipping yields were measured as fresh weights. Field clipping yields were collected with a 55 cm rotary mower set at a height of 2.54 cm. Greenhouse clipping yields were collected by hand shearing the turf canopy to a height of 2.54 cm. Turf quality estimates were based on density and color using a scale of 1 to 9, 1 having very low turf quality, 9 having excellent turf quality and 6 being acceptable quality. Quality ratings were only compared on the date that the data was collected. For percent ground exposed and percent living bermudagrass ground cover, each plot was divided into 4 equal quadrants, percentage was then estimated for each quadrant and averaged. Frost damage estimates were based on percent of leaf scorching using a scale of 1 to 9, with 1 having no leaves scorched, 9 having all leaves scorched and 6 being 50% of leaves scorched.

Imposed Traffic

In experiments 1, 2, and 3 traffic was applied using a 45 cm diameter studded traffic roller. The roller was 90 cm wide with 200 1.25 cm x 2.5 cm hexhead bolts which were screwed into the roller from the inside. Bolts 7.6 cm apart were placed in rows uniformly around the roller. Approximately 1.25 cm of each bolt was exposed on the outside of the steel roller mounted to a 12 HP tractor. An electrically powered hydraulic cyclinder was attached to the roller to permit quick pick up of the roller and provided constant downward pressure on the roller during use. Traffic treatments were applied by making a predetermined number of passes, with the traffic roller, over the designated plots. Traffic intensity was designated as light and heavy treatments on pre-selected strips. The heavy treatment received twice as many passes as the light treatment each time traffic was applied. The wear imposed by light traffic was similiar to that seen along the sidelines of a football field; while, wear from heavy traffic was similiar to that seen in the middle of the football field. Traffic was not applied within 24 hours of rainfall or irrigation.

Laboratory Freezing Procedure

Dormant bermudagrass plugs 10 cm in diameter and 5 cm deep were removed in March from selected treatments of field experiments 1 and 2. Plugs were then separated from the soil, washed, cleaned, and placed in small plastic bags and held at 7.5^{o}C for 24 hours. Following this period of bringing each sample to equilibrium, a 24 gauge copper-constantan thermocouple was inserted into the plant tissue in the bags. The plastic bags were then submerged in tubs of 30% eythelene glycol solution and placed in a freezer maintained at -15^{o}C. Plant sample temperatures were monitored with a Leeds and Northrup multipoint recorder. Samples were cooled at approximately 1.5^{o}C per hour. After the interior of the bags reached the desired temperature of -3^{o}C, the plant samples were removed and immediately returned to a refrigerator maintained at 2^{o}C to thaw for a minimum of 24 hours. After thawing, the plants were transferred to 10 cm diameter plastic containers that were 14.5 cm deep filled with soil (Lodi silt loam) so that the plant material was flush with the top of the container. The soil had a medium level of extractable P (0.7 kg are^{-1}), a high content of extractable K (2.0 kg are^{-1}), and a pH of 6.1. Plants were pressed into the soil surface by hand to insure good soil contact. Holes in the bottom of the containers provided adequate drainage. The bermudagrass was then placed in a greenhouse maintained at $32^{o}C/24^{o}C$ (day/night temperature) and set under a mist system that provided surface irrigation for 15 minutes which provided 0.6 cm water, twice a day. Post dormancy growth was measured by counting the emergence of bud shoots and weighing the clipping yields.

Experiment 1 — Post dormancy growth of Midiron bermudagrass (*Cynodon dactylon* (L.) Pers) as influenced by nitrogen and potassium fertility and various traffic treatments.

Description of the Experiment

In June, 1978 a light and a heavy traffic study were intiated on a 450 square meter area of Midiron bermudagrass. This was arranged into a split strip plot design. The main plots were the K treatments with the N treatments as the sub plots. Traffic treatments were applied in strips across the fertility treatments. Potassium sulfate was applied at 0 and 0.74 kg K are^{-1} in July, September, and April. Three nitrogen regimes, using ammonium nitrate were applied at 0.245 kg N are^{-1} in July and August; 0.33 kg N are^{-1} in July and August plus 0.65 kg N are^{-1} in September; 0.65 kg N are^{-1} in July and August plus 0.74 kg N are^{-1} in September. All treatments were replicated three times.

Traffic was imposed by driving the wear roller over the separate plots at various frequencies in the fall of 1978 and the spring of 1979. Light and heavy traffic regimes of 5 and 10 passes respectively, were applied as follows: treatment 1 received no traffic; treatment 2 had traffic applied 5 times between 28 September and 11 October, 1978 (before dormancy); treatment 3 had traffic applied 2 times in December 1978 and on 20 March 1979 plus a doubled rate of traffic on 17 March 1979 (during dormancy); treatment 4 had traffic applied 5 times between 28 September and 11 October 1978 (before dormancy) plus 2 times in December 1978 (during dormancy). Begining the fall of 1979, the heavy traffic regime constituted passing over turf with the traffic roller 10 times. Light traffic regime had half as many passes. Traffic regimes were applied as follows:

a. treatment 1 received no traffic.

b. treatment 2 received heavy traffic 8 times between 8 September 1979 and 26 October 1979 (before dormancy).

c. treatment 3 received heavy traffic 2 times in November 1979 plus 20 passes each 3 times between 19 November 1979 and 11 December 1979 (during dormancy).

d. treatment 4 received 40 passes of traffic on 23 March 1980 and 3 April 1980 (during dormancy).

e. treatment 5 received light traffic 8 times between 8 September 1979 and 26 October 1979 (before dormancy) plus light traffic 2 times in November 1979 and 10 passes each 3 times between 19 November 1979 and 11 December 1979 (during dormancy).

f. treatment 6 received light traffic 8 times between 8 September 1979 and 26 October 1979 (before dormancy) plus 20 passes of traffic on

23 March 1980 and 3 April 1980 (during dormancy)

g. treatment 7 received light traffic 8 times between 8 September 1979 and 26 October 1979 (before dormancy) plus light 8 times between 24 April 1980 and 9 May 1980 (after initiation of spring growth).

h. treatment 8 received heavy traffic 8 times between 8 September 1979 and 26 October 1979 (before dormancy) plus 40 passes of traffic on 23 March 1980 and 3 April 1980 (during dormancy).

Visual estimates of percent living bermudagrass ground cover from the entire plot and clipping yields from a 130 cm strip made through each plot with a 55 cm rotary mower were obtained to ascertain the influence of fertility and traffic. Also, on 27 March 1979, 10 cm diameter dormant samples were taken from the 0.49 kg are^{-1} and 2.22 kg are^{-1} N blocks of the following heavy traffic treatments; (1) control, (2) fall before dormancy 50X (number of passes with with roller) and fall during dormancy 20X and (3) fall and spring during dormancy 50X. The samples were then frozen at -3^{o}C . Following freezing the samples were slowly thawed and grown in the greenhouse for two weeks after which live bud counts and clipping yields were obtained. These measurements were used to illustrate the influence of the controlled freeze in combination with the fertility and traffic treatments on post dormancy growth. Data from laboratory freeze were analyzed using the same statistical procedure as the field experiments.

During 1979, similar treatments were again applied except the medium N regime was increased to a total of 1.31 kg N are^{-1}.

A 1.25 cm diameter penotrometer was used during the fall 1979 and spring 1980 to measure soil compaction resulting from the imposed traffic. During October 1979 an estimation of Poa annua content was made to illustrate the effect of N fertilization on the invasion of this grass. Visual estimates of percent living bermudagrass ground cover and clipping yields were used to measure treatment effects in the spring 1980 on the field plots. A laboratory freeze that was conducted on samples taken from all 3 N regimes in March 1980 from the following traffic treatments: (1) control, (2) fall during dormancy 80X (number of passes with roller), and (3) fall before dormancy 80X. Live bud counts and clipping yields were obtained as in 1979.

RESULTS AND DISCUSSION

Experiment 1

Traffic intensity as well as timing of traffic influenced post dormancy growth. Both light and heavy traffic applied in the fall of 1978 significantly reduced the 8 May 1979 clipping yields when compared to their controls (Tables 1&3). However, by 16 May 1979 imposed traffic had less influence on clipping yields. In both tests of the 1978/79 season, the poorest recovery occurred on those plots receiving traffic before dormancy and additional traffic after dormancy in the fall of 1978.

The heavier the imposed traffic in the fall of 1979 and spring of 1980 the lower the post dormancy growth obtained (treatments 6 & 8 in Table 5). However, the yields for the treatment involving traffic after initiation of spring growth (treatment 7) were statistically similar to the treatments consisting of twice the total traffic pressure applied before fall dormancy plus during spring dormancy (treatment 8). Traffic applied in the spring as the bermudagrass was breaking dormancy (treatment 7) evidently caused serious injury to the newly developing shoots than when traffic was applied before growth started. Spring traffic delayed until after initiation of spring growth reduced clipping yields 94% of the control in May; whereas spring traffic applied while

Table 1. Post dormancy growth clipping yields of Midiron bermudagrass as influenced by light traffic treatments, averaged over fertility treatments.

Treatment No.	Traffic Description	Clipping Yields 8 May 79	16 May 79
		—kg are^{-1}—	
1.	Control	5.13a†	7.95a
2.	5 passes 5 times Sept.-Oct.‡	2.86b	7.18a
3.	5 passes 3 times Dec.& Mar. + 10 passes 1 time Mar.§	2.71b	6.33ab
4.	5 passes 5 times Sept.-Oct. + 5 passes 2 times Dec	1.89b	3.98b

†Means in the same column with a letter in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.
‡Fall dormancy occurred by 20 October 1978.
§Post dormancy growth occurred by 22 April 1979

Table 2. F-tests for clipping yields of Midiron bermudagrass as influenced by a light traffic test and nitrogen and potassium fertility in 1978/79.

Parameter	Clipping Yields 8May	Clipping Yields 16May
Traffic (T)	***	**
Potassium (K)	N.S.†	N.S.
T X K	N.S.	N.S.
Nitrogen (N)	N.S.	N.S.
T X N	N.S.	N.S.
K X N	N.S.	N.S.
K X N(T)	N.S.	N.S.

*,**,*** Denotes significance at 10, 5, and 1% levels respectively.
† Non-significant

Table 3. Post dormancy growth clipping yields of Midiron bermudagrass as influenced by heavy traffic treatments, averaged over all fertility treatments.

Treatment No.	Traffic Description	Clipping Yields 8 May 79	16 May 79
		——kg are^{-1}——	
1.	Control	4.18a†	5.54a
2.	10 passes 5 times Sept.-Oct.‡	1.89ab	5.47a
3.	10 passes 3 times Dec.&Mar. + 20 passes 1 time Mar.§	1.66b	5.46a
4.	10 passes 5 time Sept.-Oct. + 10 passes 2 times Dec.	1.34b	3.88a

† Means in the same column with a letter in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.
‡ Fall dormancy occurred by 20 October 1978.
§ Post dormancy growth occurred 22 April 1979.

Table 4. F-tests for clipping yields of Midiron bermudagrass as influenced by a heavy traffic test and nitrogen and potassium fertility in 1978/79.

Parameter	Clipping Yields 8May	16May
Traffic (T)	*	N.S.
Potassium (K)	N.S.†	N.S.
T X K	N.S.	N.S.
Nitrogen (N)	N.S.	N.S.
T X N	N.S.	N.S.
K X N	N.S.	N.S.
K X N(T)	N.S.	N.S.

*,**,*** Denotes significance at 10, 5, and 1% levels respectively.
† Non-significant

Table 5. Plant post dormancy growth clipping yields of Midiron bermudagrass as influenced by traffic treatments.

Treatment No.	Traffic Description	Ground Exposed 9Apr80	Clipping Yields 14May80	Clipping Yields 11Jun80
		——%——	——kg are^{-1}——	
1.	Control	6.7d†	0.39a	7.33a
2.	10 passes 8times Sept-Oct.	11.7cd	0.21bd	4.15bd
3.	10 passes 2times Nov.‡ + 20 passes 3times Nov-Dec.	18.3cd	0.26ac	5.13ac
4.	40 passes 2times Mar-Apr.	36.7ab	0.33ab	4.89ac
5.	5 passes 8times Sept-Oct. + 5 passes 2times Nov. + 10 passes 3times Nov-Dec.	13.3cd	0.16cd	2.87cd
6.	5 passes 8times Sept-Oct. + 20 passes 2times Mar-Apr.	25.0bc	0.19bd	6.09ab
7.	5 passes 8times Sept-Oct. + 5 passes 8times Apr-May §	10.0d	0.02e	3.05cd
8.	10 passes 8times Sept-Oct. + 40 passes 2times Mar-Apr.	46.7a	0.11de	1.56d

† Means in the same column with a letter in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

‡ Fall dormancy occurred by 1 November 1979.

§ Began imposing traffic 24 April 1980 at 15%-20% greenup.

Table 6. F-tests for clipping weights of Midiron bermudagrass influenced by traffic, nitrogen and potassium fertility in 1979/80.

Parameter	% Living Ground Cover	Clipping Yields	
	9Apr	14May	11Jun
Traffic (T)	***	***	**
Potassium (K)	N.S.†	N.S.	N.S.
T X K	N.S.	N.S.	N.S.
Nitrogen (N)	N.S.	N.S.	N.S.
T X N	N.S.	N.S.	N.S.
K X N	N.S.	N.S.	N.S.
T X K X N	N.S.	N.S.	N.S.

*,**,*** Denotes significance at 10, 5, and 1% levels respectively.
† Non-significant

the bermudagrass was still dormant reduced the clipping yields only 51% in May. It appears that traffic is most detrimental to bermudagrass when new shoots are forming.

When compared to the control, traffic applied while the turf was dormant had less effect on post dormancy growth than when traffic was imposed while the turf was not dormant. The 14 May 1980 and 11 June 1980 clipping yields from plots subjected to traffic either in the fall or spring while the turf was dormant were not significantly lower than the control. The opposite was true when traffic was applied before the bermudagrass became dormant in the fall, 1979.

When subjected to a controlled freeze in March 1979, heavy traffic, when compared to the control, tended to reduce post dormancy clipping yield when traffic was applied before dormancy. Heavy traffic caused a significant reduction in clipping yields when applied during fall dormancy when compared to the control (Table 7). When subjected to a controlled freeze in March of 1980, fall traffic treatments applied both before and during dormancy significantly reduced post dormancy growth when compared to the control (Table 9). However, the initial emerging live bud shoot counts and the earliest clipping yields (9 April) did show significant difference between traffic treatments at the highest nitrogen level.

Since the "during dormancy traffic" treatment did not

Table 7. Post dormancy foliar growth of field grown Midiron bermudgrass as influenced by traffic pressure and a late March laboratory freeze ($-3^{o}C$). Subsequent greenhouse yields averaged over fertility treatments.

Treatment No.	Traffic Description	Clipping Yields 23 April 79
		kg are^{-1}
1.	Control	47.6a†
2.	10 passes 3 times Dec.& Mar. + 20 passes 1 time Mar. §	37.4a
3.	10 passes 5 times Sept.-Oct.‡ + 10 passes 2 times Dec.	25.5b

† Means in the same column with a letter in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.
‡ Fall dormancy occurred by 20 October 1978.
§ Post dormancy growth occurred by 22 April 1979.

Table 8. F-tests for clipping yields of Midiron bermudagrass. Plugs of grass were removed from the field traffic-fertility study, frozen and grown in the greenhouse, 1979.

Parameter	Clipping Yields 23Apr
Traffic (T)	**
Potassium (K)	N.S.†
T X K	N.S.
Nitrogen (N)	N.S.
T X N	N.S.
K X N	N.S.
K X N (T)	N.S.

*, **, *** Denotes significance at 10, 5, and 1% levels respectively.
† Non-significant

Table 9. Post dormancy foliar growth of field cultured Midiron bermudagrass grown in the greenhouse after a late March laboratory freeze (-3°C) as influenced by previously applied nitrogen and and traffic regimes.

Treatment No.	Traffic Description	Nitrogen Rates (kg are^{-1})§ 0.49	1.31	2.22	means
		Live Bud Shoots 21Mar80(100cm^2)			
		counts			
1.	Control	67.5a†	87.9a	59.5a	56.2a
2.	10 passes 2X Nov + 20 passes 3X Nov-Dec	41.8b	48.0b	51.6a	37.0b
3.	10 passes 8X Sept-Oct	48.8b	47.1b	32.1a	33.5b
	means	52.7x‡	47.9x	47.7x	
		Clipping Yields 9Apr80			
		kg are^{-1}			
1.	Control	34.7a	46.6a	30.4a	37.2a
2.	10 passes 2X Nov + 20 passes 3X Nov-Dec	13.3b	26.9b	28.4a	22.9b
3.	10 passes 8X Sept-Oct	16.7b	22.7b	16.1a	18.5b
	means	21.6y	32.0x	25.0y	
		Clipping Yields 22Apr80			
		kg are^{-1}			
1.	Control	34.9a	38.9a	31.2a	35.0a
2.	10 passes 2X Nov + 20 passes 3X Nov-Dec	17.9b	29.3a	30.4a	25.8b
3.	10 passes 8X Sept-Oct	22.3b	26.9a	19.0b	22.7b
	means	25.0y	31.7x	26.9y	

† Means in the same column of each data set with the same letter (a or b) in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

‡ Means in the same row with the same letter (x or y) in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

§ Nitrogen was applied as follows: 1) 0.49 kg are^{-1} regime - 0.245 kg are^{-1} in Jul & Aug; 2) 1.31 kg are^{-1} regime - 0.33 kg are^{-1} in Jul & Aug + 0.65 kg are^{-1} in Sept: 3) 2.22 kg are^{-1} regime - 0.65 kg are^{-1} in Jul & Aug + 0.74 kg are^{-1} in Sept.

Table 10. F-tests for live bud shoots and clipping yields of Midiron bermudagrass. Plugs of grass were removed from field Traffic - Fertility plots, frozen and grown in the greenhouse, 1980.

Parameter	Live Bud Shoots 21Mar	Clipping Yields 9Apr	 22Apr
Traffic (T)	**	**	*
Potassium (K)	N.S.†	N.S.	N.S.
T X K	N.S.	N.S.	N.S.
Nitrogen (N)	N.S.	**	*
T X N	*	**	N.S.
K X N	N.S.	N.S.	N.S.
T X K X N	N.S.	N.S.	N.S.

*,**,*** Denotes significance at 10, 5, and 1% levels respectively.
† Non-significant

cause a significant post dormancy yield decrease in the field experiment in spring 1980, results of the controlled freeze study indicate the impact of cold stress in addition to traffic can have on the winter survival of bermudagrass. As bermudagrass growth slows down going into fall dormancy, the turf is less able to recover from traffic imposed during this reduced growth period.

Estimates of frost damage were recorded following a heavy frost in mid-May 1980. All traffic treatments had significantly less damage when compared to the control (Table 11). Frost injury corresponded to the degree of post dormancy growth. This further illustrates the impact traffic had reducing post dormancy growth of the bermudagrass. The only incidence where frost damage was significantly higher than the control occurred under the high N regime when light traffic was applied in the fall before dormancy and in the spring after the initiation of growth (treatment 7).

In addition to the influence on post dormancy growth, traffic applied in the fall prior to dormancy reduced late fall turf quality (Table 13). The heavier the traffic the larger the reduction of turf quality. At the 1.31 kg N are^{-1} rate turf quality was never significantly lower than either the lower or higher N rates for any traffic treatments. Under the no traffic treatment turf quality was higher at the higher than lower N rate. The reverse

Table 11. Spring 1980 frost damage estimates to post dormancy growth of Midiron bermudagrass as influenced by previously applied nitrogen and traffic regimes.

Treatment No.	Traffic Description	Nitrogen Rates (kg are^{-1})§ 0.49	1.31	2.22	means
		Frost Damage 14May80			
		rank¶			
1.	Control	3.00a†	3.33a	1.83b	2.72a
2.	10 passes 8X Sept-Oct	2.33ab	2.17b	1.17cd	1.89b
3.	10 passes 2X Nov # + 20 passes 3X Nov-Dec	1.83bc	1.67bc	1.67bc	1.72bc
4.	40 passes 2X Mar-Apr	1.17cd	1.00c	1.17cd	1.11d
5.	5 passes 8X Sept-Oct + 5 passes 2X Nov + 10 passes 3X Nov-Dec	1.83bc	1.33c	1.00d	1.39cd
6.	5 passes 8X Sept-Oct + 20 passes 2X Mar-Apr	1.17cd	1.33c	1.33bcd	1.28cd
7.	5 passes 8X Sept-Oct + 5 passes 8X Apr-May ‡‡	2.33ab	1.50bc	2.50a	2.11b
8.	10 passes 8X Sept-Oct + 40 passes 2X Mar-Apr	1.00d	1.00c	1.00d	1.00d
	means	1.83x‡	1.67x	1.46y	

† Means in the same column of each data set with the same letter (a or b) in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

‡ Means in the same row with the same letter (x or y) in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

§ Nitrogen was applied as follows: 1) 0.49 kg are^{-1} regime - 0.245 kg are^{-1} in Jul & Aug; 2) 1.31 kg are^{-1} regime - 0.33 kg are^{-1} in Jul & Aug + 0.65 kg are^{-1} in Sept: 3) 2.22 kg are^{-1} regime - 0.65 kg are^{-1} in Jul & Aug + 0.74 kg are^{-1} in Sept.

¶ Rank - 1 to 9 with 1 having no leaves scorched and 9 having all leaves scorched.

Fall dormancy occurred by 1 November 1979

‡‡ Began imposing traffic 24 April 1980 at 15%-20% greenup.

Table 12. F-tests for frost damage of Midiron bermudagrass influenced by traffic, nitrogen and potassium fertility in 1979/80.

Parameter	Frost Damage 14May
Traffic (T)	***
Potassium (K)	N.S.†
T X K	N.S.
Nitrogen (N)	N.S.
T X N	**
K X N	N.S.
T X K X N	N.S.

*,**,*** Denotes significance at 10, 5, and 1% levels respectively.
† Non-significant

Table 13. Turf quality of field cultured Midiron bermudagrass influenced by nitrogen and traffic regimes.

Treatment No.	Traffic Description	Turf Quality 9Oct70 Nitrogen rates (kg are^{-1})§ 0.49	1.31	2.22	means
		rank¶			
1. Control		7.7z	9.0x	8.3y	8.3a†
2.	5 passes 5X Sep-Oct	6.5y	7.5x	7.2x	7.1b
3.	10 passes 5X Sep-Oct	6.0x	5.8x	5.2y	5.7c
	means	6.7y‡	7.4x	6.7y	

† Means in the same column of each data set with the same letter (a,b or c) in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

‡ Means in the same row with the same letter (x,y or z) in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

§ Nitrogen was applied as follows: 1) 0.49 kg are^{-1} regime - 0.245 kg are^{-1} in Jul & Aug; 2) 1.31 kg are^{-1} regime - 0.33 kg are^{-1} in Jul & Aug + 0.65 kg are^{-1} in Sept: 3) 2.22 kg are^{-1} regime - 0.65 kg are^{-1} in Jul & Aug + 0.74 kg are^{-1} in Sept.

¶ Turf quality based on density and color using a scale 1 - 9, 1 having very low turf quality and 9 having excellent turf quality.

Table 14. F-tests for turf quality of Midiron bermudagrass influenced by traffic, nitrogen and potassium fertility in 1979/80.

Parameter	Turf Quality 9Oct
Traffic (T)	***
Potassium (K)	N.S.†
T X K	N.S.
Nitrogen (N)	*
T X N	**
K X N	N.S.
T X K X N	N.S.

*,**,*** Denotes significance at 10, 5, and 1% levels respectively.
† Non-significant

was true under the heaviest traffic treatment.

Traffic causes reduction in plant growth not only through the direct damage of inflicted pressure on the plant but also by compaction of soil (Beard, 1973, Canaway, 1975). Compaction in the upper 5cm of the soil profile was significantly increased by the greatest traffic frequencies (Table 15). Spring traffic tended to increase compaction over traffic applied in the fall. Soil moisture content was higher during the spring because of freeze/thaw conditions and low evaporation and transpiration losses which enhanced the effects of compaction.

Studies conducted by Carroll (1943), Adams and Twersky (1959), and Davis and Gilbert (1970) have shown the effect of K and the interaction of N and K on the winter hardiness of bermudagrass. However, K fertilization in my study did not produce a significant effect on spring yield. Several factors may have been involved. Existing soil test levels of K prior to this study´s initiation were at a medium level. Juska and Murray (1973) reported that because of the winter hardy nature of Midiron bermudagrass, K fertility had little effect on increasing winter survival of this cultivar as compared to other cultivars. In addition, the winters of 1978/79 and 1979/80 were relatively mild; not providing a very harsh environment for testing cold hardiness of bermudagrasses.

Table 15. Pressure required to penetrate to a soil depth 5 cm with a 1.25 cm diameter penetrometer as influenced by traffic treatments.

Treatment No.	Traffic Description	Penetrometer Readings 17 Oct 79	27 Jun 80
		——Pa 10^4——	
1.	Control	38.9cd †	54.9d
2.	10 passes 8 times Sept.-Oct.	53.4ab	61.2cd
3.	10 passes 2 times Nov. ‡ + 20 passes 3 times Nov.-Dec.	38.5d	57.9cd
4.	40 passes 2 times Mar.-Apr.	40.7cd	69.4ab
5.	5 passes 8 times Sept.-Oct. + 5 passes 2 times Nov. + 10 passes 3 times Nov.-Dec.	44.0bd	60.6cd
6.	5 passes 8 times Sept.-Oct. + 20 passes 2 times Mar.-Apr.	49.7ac	70.4ab
7.	5 passes 8 times Sept.-Oct + 5 passes 8 times Apr.-May §	42.8bd	63.2bc
8.	10 passes 8 times Sept.-Oct. + 40 passes 2 times Mar.-Apr.	58.7a	76.7a

† Means in the same column with a letter in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.
‡ Fall dormancy occurred by 1 November 1979.
§ Began imposing traffic 24 April 1980 at 15%-20% greenup.

Table 16. F-tests for compaction of Midiron bermudagrass influenced by traffic, nitrogen and potassium fertility in 1979/80.

Parameter	Penotrometer Reading 17Oct	27Jun
Traffic (T)	**	***
Potassium (K)	N.S.†	N.S.
T X K	N.S.	N.S.
Nitrogen (N)	N.S.	N.S.
T X N	N.S.	N.S.
K X N	N.S.	N.S.
T X K X N	N.S.	N.S.

*,**,*** Denotes significance at 10, 5, and 1% levels respectively.
† Non-significant

Reeves, et. al. (1970), Gilbert and Davis, (1971), Reeves, et. al. (1972) found that as N levels increase K uptake increases resulting in improved winter survival.

In the spring of 1979, N fertility had no significant effect on spring clipping yields in the field or when turf was subjected to a controlled freeze. However in 1980, we observed in the field that the medium rate of N tended to produce larger spring yields than the low and high N rate. When subjected to a controlled freeze, bermudagrass associated with the medium N fertility level significantly increased post dormancy clipping yields over the highest and lowest N rate (Table 9). This is in agreement with Carroll, (1943) and Reeves et. al., (1970) on the positive and negative effect of N nutrition on winter survival. In my study, the effect of the high N treatment was no different than the low N treatment on bermudagrass post dormancy growth. The high N treatment was beneficial in reducing the invasion of *Poa annua* when compared to the medium and low N treatments (Table 17). The higher rate of N resulted in a thicker, more aggressive turf canopy that reduced *Poa annua* invasion.

Table 17. *Poa annua* content in Midiron bermudagrass turf as influenced by nitrogen fertility. Averaged over all potassium and traffic treatments.

Nitrogen N are^{-1}	Treatments $month^{-1}$	Total Nitrogen	*Poa annua* 17 Oct 79
		kg are^{-1}	——%——
0.245 kg	Jul.+Aug.	0.49	11.75a†
0.33 kg	Jul.+Aug.	1.31	12.33a
+0.66 kg	Sept.		
0.74 kg	Jul.+Aug.+Sept.	2.22	1.50b

† Means in the same column with a letter in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

Table 18. F-tests for percent *Poa annua* of Midiron bermudagrass influenced by traffic, nitrogen and potassium fertility in 1979/80.

Parameter	% *Poa annua* 17Oct
Traffic (T)	N.S.†
Potassium (K)	N.S.
T X K	N.S.
Nitrogen (N)	***
T X N	N.S.
K X N	N.S.
T X K X N	N.S.

*,**,*** Denotes significance at 10, 5, and 1% levels respectively.
† Non-significant

Experiment 2 Post dormancy growth of Midiron bermudagrass (*Cynodon dactylon* (L.) Pers.) as influenced by various traffic treatments, nitrogen and potassium fertility and plastic covers.

Description of the Experiment

A 175 m^2 area of Midiron bermudagrass was arranged in a split strip plot design for this experiment. The main plot treatments were plastic covers with K fertilization as sub plots, and N fertilization as sub-sub plots. Traffic treatments were applied in strips across the clear plastic covers and fertility treatments plots.

Four mil clear plastic sheets with 0.95 cm holes on 7.62 cm centers mounted on 2.75m x 2.75m wooden frames were used as turf covers. Covers placed on assigned plots in the fall prior to complete dormancy were removed in November and replaced on assigned plots in the spring during dormancy as listed in Table 29. Potassium sulfate, K was applied at 0, 0.49 kg are^{-1} and 0.98 kg are^{-1} in August and October 1979. Ammonium nitrate, N was applied at 0.245 kg are^{-1} and 0.98 kg are^{-1} in August and September 1979. All treatments were replicated three times.

Traffic was imposed by driving the wear roller over the plots at various frequencies during the fall of 1979. Traffic was applied mid September through early November simulating wear during a typical fall football season. On selected strips, a light traffic treatment of 5 passes was applied while those selected for heavy treatment received 10 passes on September 8, September 17, September 19, September 26, October 3, October 9, October 21, October 26, October 30 and November 7, 1979.

Visual estimates of percent living bermudagrass ground cover were made in the fall and spring. Frost damage estimates and clipping yields, collected with a 55 cm rotary mower over a 61 cm strip, were obtained in the spring from April to June to ascertain the influence of the treatments on post dormancy growth. Also, in March of 1980 10 cm diameter x 5 cm deep plugs of the dormant bermudagrass were taken from the 100x traffic treatment on plots covered with plastic from 9 October 1979 to 22 April 1980 and plots not covered with plastic. These plugs, from all N and K treatments were subsequently frozen at -3^{o}C. Following freezing, the samples were slowly thawed and grown in the greenhouse for several weeks at which time live bud shoot counts and clipping yields were obtained to determine the influence of the controlled freeze in combination with the plastic covers, fertility and traffic treatments on post dormancy growth. Data from laboratory freeze was analyzed using the same statistical procedure as the field experiments.

RESULTS AND DISCUSSION

Experiment 2

Applying traffic, N and K and covering with clear plastic signficantly affected post dormancy yields. Both the light (50X) and heavy (100X) traffic intensities reduced post dormancy yields when compared to the control (Table 19). In late April, only the highest traffic intensity significantly reduced post dormancy growth. While, May and June clipping yields were significantly reduced by both light and heavy traffic intensities when compared to the control. This illustrates the long lasting effects of traffic damage to the turfgrass sward as reported by Beard, (1973) and Canaway, (1975).

Nitrogen rates differed in their affect on post dormancy growth (Table 19). The 0.245 kg N are^{-1} regime in August and September significantly increased the April clipping yields over the 0.98 kg N are^{-1} regime. However, in May and June the high N rate significantly increased post dormancy growth over the low N rate. It appears that N nutrition stimulates foliage growth once post dormancy growth has been well established. According to DiPaola and Beard (1982) bermudagrass initiates a new root system following initial post dormancy growth in the spring. The higher N rate may have provided more energy to stimulate more aggressive top growth in May and June once roots are

Table 19. Post dormancy clipping yields of Midiron bermudagrass as influenced by nitrogen and traffic regimes

Nitrogen N are⁻¹	Treatments month⁻¹	Clipping Yields Traffic Treatments§ 1	2	3	means
		kg are^{-1}			
			17Apr80		
0.24 kg	Aug.+Sept.	1.39a†	0.40a	0.26a	0.69a
0.98 kg	Aug.+Sept.	1.35a	0.43a	0.27a	0.68a
	means	1.37x‡	0.42x	0.27x	
			25Apr80		
0.24 kg	Aug.+Sept.	1.12a	0.80a	0.49a	0.80a
0.98 kg	Aug.+Sept.	1.01b	0.76a	0.50a	0.76a
	means	1.07x	0.78xy	0.50y	
			29May80		
0.24 kg	Aug.+Sept.	2.57bx	1.58ay	0.78by	1.54b
0.98 kg	Aug.+Sept.	4.20ax	2.16ay	1.32ay	2.56a
	means	3.38x	1.73y	1.04y	
			11Jun80		
0.24 kg	Aug.+Sept.	14.50bx	12.69by	10.70by	12.64b
0.98 kg	Aug.+Sept.	20.00ax	14.97ay	12.40ay	15.72a
	means	17.25x	13.73y	11.56y	

† Means in the same column of each data set with the same letter (a or b) in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

‡ Means in the same row with the same letter (x or y) in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

§ Traffic applied as follows: 1) 0 - passes; 2) 5 passes 10 times 8 Sept. to 7 Nov.1979; 3) 10 passes 10 times 8 Sept. to 7 Nov.1979.

Table 20. F-tests for clipping yields of Midiron bermudagrass as influenced by traffic, plastic covers, nitrogen and potassium fertility in 1979/80.

	Clipping Yields			
Parameters	17Apr	25Apr	29May	11Jun
Traffic (T)	N.S.†	**	***	**
Plastic Cover (P)	**	***	**	***
T X P	N.S.	N.S.	N.S.	N.S.
Potassium (K)	N.S.	N.S.	*	**
T X K	N.S.	N.S.	N.S.	N.S.
P X K	N.S.	**	N.S.	*
T X P X K	N.S.	N.S.	N.S.	N.S.
Nitrogen (N)	N.S.	N.S.	***	N.S.
T X N	N.S.	N.S.	**	***
P X N	N.S.	N.S.	N.S.	N.S.
T X P X N	N.S.	N.S.	N.S.	N.S.
K X N	N.S.	N.S.	N.S.	N.S.
T X K X N	N.S.	N.S.	N.S.	N.S.
P X K X N	N.S.	N.S.	N.S.	N.S.
T X P X K X N	N.S.	N.S.	N.S.	N.S.

*,**,*** Denotes significance at 10, 5, and 1% level respectively.
† Non-significant

well established. Also, N offset the detrimental effect of traffic. Clipping yields on 29 May and in June were significantly larger with the high N rate than the low rate over the three traffic treatments. With plastic covers, the high N rate increased 29 May and June clipping yields over the low rate. At higher N rates, K uptake by the plant is increased (Reeves,et. al. 1970, Gilbert and Davis, 1971, Reeves et. al. 1972). Therefore, the higher N rate, in this study, may have improved the May and June clipping yields by improving K uptake. The significant traffic x nitrogen interaction that was obtained for clipping yields measured on 29 May and 11 June was because high nitrogen fertilization increased yield over low nitrogen fertilization to a greater extent under no traffic than when traffic was applied.

Potassium has been proven to increase winter hardiness (Adams and Twersky, 1959). However, the 0.49 kg are^{-1} and 0.98 kg are^{-1} K treatments in this study significantly reduced post dormancy growth when compared to the control in the 29 May clipping yields. While, the 0.98 kg K are^{-1} rate significantly reduced clipping yields on 11 June (Table 21). Clipping yields obtained on 25 April were higher with the spring placed plastic cover when compared with the fall placed plastic cover treatment except at the high potassium rate. On this date the high potassium rate under the fall placed plastic yielded the

Table 21. Post dormancy clipping yields of Midiron bermudagrass as influenced by potassium and clear plastic cover regimes.¶

Potassium K are^{-1}	Treatments month^{-1}	Clipping Yields Plastic Treatments§ None	Fall+Spring	Spring	means
		kg are^{-1}			
			25Apr80		
Control		0.0a†	1.06a	1.37a	0.81a
0.49 kg	Aug.+Oct.	0.0a	0.94a	1.46a	0.80a
0.98 kg	Aug.+Oct.	0.0a	1.10a	1.10a	0.73a
	means	0.0z‡	1.03y	1.31x	
			29Apr80		
Control		2.27a	3.45a	1.50a	2.41a
0.49 kg	Aug.+Oct.	1.70b	2.45b	1.69a	1.95b
0.98 kg	Aug.+Oct.	1.49b	2.59ab	1.76a	1.95b
	means	1.81y	2.83x	1.65y	
			11Jun80		
Control		7.92a	18.51a	18.38a	14.94a
0.49 kg	Aug.+Oct.	6.31a	18.81a	18.73a	14.62a
0.98 kg	Aug.+Oct.	6.12a	18.88a	14.24b	13.08b
	means	6.79y	18.73x	17.11x	

† Means in the same column of each data set with the same letter (a or b) in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

‡ Means in the same row with the same letter (x,y or z) in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

§ Clear plastic covers applied as follows: 1) None - no plastic cover; 2) Fall + Spring - 9 Oct. to 30 Nov. 1979 + 19 Mar. to 22 Apr. 1980; 3) Spring - 19 Mar. to Apr. 1980.

¶ See Table 20 for f-tests.

same as spring placed plastic. On 11 June high potassium treatments caused a decrease in yield only under the spring placed plastic.

Winter protection with plastic covers did enhance post dormancy growth (Table 21 & 22). Glyphosate was applied on 19 March 1980 to control *Poa annua*. On plots covered from 9 October 1979 to 22 April 1980, post dormancy growth had begun and was injured by the glyphosate. As a result, data was not collected on this treatment for spring field evaluations. The other plots covered with clear plastic had earlier post dormancy growth than the non covered plots. However, plots covered only from 19 March to 22 April 1980 had better early spring growth than those plots covered from 9 October to 30 November as well as from March to April. Apparently, the bermudagrass covered in the fall was not cold hardened enough when the covers were removed in November, and subsequently may have suffered some cold injury.

Plastic covers caused earlier and more succulent spring growth which was more succeptible to late spring frost injury than the unprotected plots. Frost injury was related to the amount of initial spring growth. Plots covered only from March to April had the highest late April clipping yields, and had significantly more injury from a 14 May 80 frost than the non protected plots (Tables 21 & 24). This frost injury was reflected in the

Table 22. Post dormancy living ground cover of Midiron bermudagrass as influenced by nitrogen and clear plastic cover regimes.

Nitrogen N are^{-1}	Treatments $month^{-1}$	Living Ground Cover Plastic Treatments§ None	Fall+Spring	Spring	means
		%			
		11Apr80			
0.24 kg	Aug.+Sept.	0.0a†	16.1a	29.8a	15.3a
0.98 kg	Aug.+Sept.	0.0a	14.3a	20.9b	11.7b
	means	0.0z‡	15.2y	25.4x	
		17Apr80			
0.24 kg	Aug.+Sept.	0.0a	34.4a	47.2a	27.2a
0.98 kg	Aug.+Sept.	0.0a	30.2b	40.4b	23.5b
	means	0.0z	32.3y	43.8x	

† Means in the same column of each data set with the same letter (a or b) in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

‡ Means in the same row with the same letter (x,y or z) in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

§ Clear plastic covers applied as follows: 1) None - no plastic cover; 2) Fall + Spring - 9 Oct. to 30 Nov. 1979 + 19 Mar. to 22 Apr. 1980; 3) Spring - 19 Mar. to 22 Apr. 1980.

Table 23. F-tests for living ground cover on Midiron bermudagrass as influenced by traffic, plastic covers, nitrogen and potassium fertility in 1979/80.

Parameters	% Living Ground Cover	
	11Apr	17Apr
Traffic (T)	N.S.†	N.S.
Plastic Cover (P)	***	***
T X P	N.S.	N.S.
Potassium (K)	N.S.	N.S.
T X K	N.S.	N.S.
P X K	N.S.	N.S.
T X P X K	N.S.	N.S.
Nitrogen (N)	***	***
T X N	N.S.	N.S.
P X N	***	***
T X P X N	N.S.	N.S.
K X N	N.S.	N.S.
T X K X N	N.S.	N.S.
P X K X N	N.S.	N.S.
T X P X K X N	N.S.	N.S.

*,**,*** Denotes significance at 10, 5, and 1% levels respectively.

† Non-significant

Table 24. Frost damage to field grown Midiron bermudagrass as influenced by potassium and clear plastic cover regimes.

Potassium K are^{-1}	Treatment month^{-1}	Frost Damage Plastic Treatments¶ None	Fall+Spring	Spring	means
		rank§			
Control		1.78a†	6.39a	6.11a	4.76a
0.49 kg	Aug.+Oct.	2.00a	6.56a	6.22a	4.93a
0.98 kg	Aug.+Oct.	2.00a	6.56a	6.22a	4.93a
	means	1.93y‡	6.50x	6.19x	

† Means in the same column of each data set with the same letter (a) in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

‡ Means in the same row with the same letter (x or y) in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

§ Rank - 1 to 9 with 1 having no leaves scorched and 9 having all leaves scorched.

¶ Clear plastic covers applied as follows: 1) None - no plastic cover; 2) Fall + Spring - 9 Oct. to 30 Nov. 1979 + 19 Mar. to 22 Apr. 1980; 3) Spring - 19 Mar. to 22 Apr. 1980.

Table 25. F-tests for clipping yields and frost damage of Midiron bermudagrass as influenced by traffic, plastic covers, nitrogen and potassium fertility in 1979/80.

Parameters	Frost Damage 14May
Traffic (T)	***
Plastic Cover (P)	N.S.†
T X P	N.S.
Potassium (K)	N.S.
T X K	N.S.
P X K	*
T X P X K	N.S.
Nitrogen (N)	N.S.
T X N	N.S.
P X N	N.S.
T X P X N	N.S.
K X N	N.S.
T X K X N	N.S.
P X K X N	N.S.
T X P X K X N	N.S.

*,**,*** Denotes significance at 10, 5, and 1% level respectively.
† Non-significant

late May clipping yields. On 29 May, plots covered only in the spring had similar clipping yields to the non covered plots. Whereas, the plots covered in both fall plus spring and in the spring had significantly higher late May yields than the non covered plots.

The 11 June clipping yields show that the frost injury was only temporary. On this date both cover treatments produced significantly more yields than the non covered treatment. These results indicate that plastic covers can be used effectively to delay fall dormancy and hasten bermudagrass spring post dormancy growth without serious injury from late spring frost.

Protective covers by increasing the temperature in the turf canopy and the soil enhanced winter survival and early spring green-up. Recent unpublished results at Virginia Tech have confirmed that soil temperatures are not only increased under clear plastic covers even during periods of low solar radiation, but during the night they slow down heat loss from the plant material and the soil.[1]. This was found to occur during the coldest winter months.

Protective covers helped to reduce the detrimental influence of traffic (table 26). Clipping yields on 29 May and 11 June reflect the benefit of the covers.

[1] Personal memo from, Dr. R. E. Schmidt, Associate Professor, Va. Tech Agronomy Department, April, 1985.

Table 26. Post dormancy clipping yields of Midiron bermudagrass as influenced by traffic and clear plastic cover regimes.

Treatment No.	Traffic Description	Clipping Yields Plastic Treatments§ None	Fall+Spring	Spring	means
		kg are^{-1}			
			29May80		
1.	Control	3.56a†	4.04a	2.55a	3.38a
2.	5 passes 10X Sept-Oct	1.03b	3.07a	1.50ab	1.86b
3.	10 passes 10X Sept-Oct	0.87b	1.38a	0.90b	1.05c
	means	1.82y‡	2.83x	1.65y	
			11Jun80		
1.	Control	11.76a	19.62a	20.41a	17.25a
2.	5 passes 10X Sept-Oct	4.80b	19.58a	17.07b	13.83b
3.	10 passes 10X Sept-Oct	3.79b	17.01a	13.86c	11.55b
	means	6.78y	18.73x	17.12x	

† Means in the same column of each data set with the same letter (a or b) in common do not significantly differ at the 10% level of probability using Duncan´s Multiple Range Test.

‡ Means in the same row with the same letter (x or y) in common do no significantly differ at the 10% level of probability using Duncan´s Multiple Range Test.

§ Clear plastic covers applied as follows: 1) None - no plastic cover; 2) Fall+Spring - 9 Oct. to 30 Nov. 1979 + 19 Mar. to 22 Apr. 1980; 3) Spring - 19 Mar. - 22 Apr 1980.

Although the yields decreased with increasing traffic, both cover treatments resulted in higher yields than the non covered treatment. With the light and heavy traffic treatments, plots covered both fall and spring had greater clipping yields than the plots covered only in the spring.

Bermudagrass post-dormancy growth from plugs collected from the field plots on 11 March 1980, frozen to -3^{o}C, and subsequently grown in a greenhouse was influenced by the previous plastic covering. Plugs taken from the fall to spring covered plots had significantly more viable buds and clipping yields than plugs not covered (Table 27). These data indicate that plastic covers placed over bermudagrass before dormancy in the fall to extend fall growth and protect the grass from low winter temperature did not cause the bermudagrass to be more susceptible to freezing injury. In fact post dormancy growth after freezing was enhanced where the turf growth had been extended into the fall and protected from low winter temperatures by covering.

Table 27. Post dormancy growth of Midiron bermudagrass plugs sampled from field plots on March 1980 and subjected to -3°C laboratory freeze and subsequently grown in the greenhouse as influenced by plastic covers. Data averaged over all traffic and fertility treatments.

Treatment	Period Covered	Live Bud Shoots (100cm^2) 21 Mar 80	Clipping Yields 1 Apr 80	Clipping Yields 15 Apr 80
		counts	kg are^{-1}	
Control	-------	22a	10.06b†	22.42b
Plastic Cover	9Oct-22Apr	70a	31.08a	41.66a

† Means in the same column with a letter in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

Table 28. F-tests for live bud counts and clipping weights of Midiron bermudagrass. Plugs of grass were removed from field treated plots, frozen and grown in the greenhouse in Spring of 1980.

Parameters	Living Bud Shoots	Clipping Yields	
	21Mar	1Apr	15Apr
Plastic Cover (P)	N.S.†	**	*
Potassium (K)	N.S.	N.S.	N.S.
P X K	N.S.	N.S.	N.S.
Nitrogen (N)	***	**	N.S.
P X N	*	N.S.	N.S.
K X N	*	N.S.	N.S.
P X K X N	**	N.S.	N.S.

*,**,*** Denotes significance at 10, 5, and 1% levels respectively.
† Non-significant

Experiment 3 Post dormancy growth of Midiron bermudagrass (*Cynodon dactylon* (L.) Pers) as influenced by cultivation treatments (ie. turf coloring, covering with clear plastic, aerification and dethatching) and traffic treatments.

Description of the Experiment

In the fall of 1979 a 39 m^2 area of Midiron bermudagrass was divided into a randomized strip plot design. Coloring, plastic covering, aerating and vertical mowing treatments were applied on main plots. Traffic treatments were applied on selected strips across the main plots. All treatments were replicated four times.

All treatments were applied on 16 April 1980. \`Stayz-Green´ turf colorant was mixed at 251 ml l^{-1} of water and applied at 7.56 l 90 m^{-2} of diluted spray. A Ryan Ren-o-thin vertical mower with 0.3 cm blades on 2.54 cm centers and a Ryan aerifier with 1.3 cm diameter spoons on 5.1 cm centers were adjusted to penetrate to a 2.54 and 5.1 cm depth, respectively, used separartely and in combination. One pass was made with each machine per treatment. Four mil clear plastic sheets with 0.95 cm holes on 7.62 cm centers attached to 1.24m x 1.86 m, 5cm x 5cm wooden frames were placed over undisturbed sub plots from 16 April to 28 April 1980.

Traffic was imposed by driving the traffic roller in strips over the main and sub plots during the fall of 1979 and spring of 1980. The fall before dormancy treatment received 5 passes of traffic 7 times between 8 September and 21 October 1979. Five passes of traffic were applied 3 times between 1 November and 19 November 1979 as the fall after dormancy treatment. The spring during dormancy treatment received 20 repetitions of traffic on 23 March 1980.

Visual estimates of percent living bermudagrass ground cover and frost damage as well as clipping yields collected with a 55 cm rotary mower over a 76 cm strip were obtained during May of 1980 to ascertain the influence of cultural treatments and traffic on bermudagrass post dormancy growth.

RESULTS AND DISCUSSION

Experiment 3

The traffic treatments reduced bermudagrass post dormancy growth by 46% in mid-May to 24% in late May (Table 29).

Covering with clear plastic sheets or coloring with green dye significantly increased early turf green up when compared to the control under both traffic regimes (Table 31). However, living ground cover differences between plots covered with clear plastic and the control were less under traffic than under no traffic treatment. Vertical mowing alone or in combination with aerification significantly inhibited early spring green up and caused lower yields until late May. This indicates that early spring vertical mowing damages and destroys early bud development and growth much the same as the traffic treatments. Although mechanical coring with an aerifier did not enhance early spring growth it did not significantly reduce green ground cover or clipping yields. However, coring should be avoided in early spring as this practice could possibly increase *Poa annua* infestations (Schmidt and Shoulders, 1972).

A late frost in mid May after the plastic sheets were removed caused the bermudagrass of the previously plastic covered plots to be injured significantly. There was no

Table 29. Post dormancy growth of Midiron bermudagrass as influenced by traffic and cultural treatment regimes.

Treatment¶ No.	Cultural Description	Clipping Yields Traffic Treatments§ 1	2	means
		kg are^{-1}		
		15May80		
1.	Control	1.29bc†	0.63b	0.96bc
2.	Turf Colorant	2.00b	0.66b	1.33b
3.	Clear Plastic Cover	3.73a	1.95a	2.84a
4.	Aerification	0.69c	0.48b	0.58cd
5.	Vertical Mowing	0.55c	0.51b	0.53d
6.	Aerification + Vertical Mowing	0.55c	0.46b	0.51d
	means	1.47x‡	0.78y	
		22May80		
1.	Control	3.80ab	1.77ab	2.79a
2.	Turf Colorant	4.82a	1.98a	3.40a
3.	Clear Plastic Cover	2.53bc	1.27ac	1.90b
4.	Aerification	2.43c	1.57ab	1.98b
5.	Vertical Mowing	0.81d	0.71c	0.76c
6.	Aerification + Vertical Mowing	1.01d	1.12c	1.06c
	means	2.57x	1.40y	
		30May80		
1.	Control	20.40a	13.08b	16.76ab
2.	Turf Colorant	19.65a	16.53a	18.09a
3.	Clear Plastic Cover	9.18d	7.38c	8.28e
4.	Aerification	18.03ab	12.27b	15.15bc
5.	Vertical Mowing	13.59c	10.78b	12.19d
6.	Aerification + Vertical Mowing	14.15bc	12.32b	13.24cd
	means	15.84x	12.06y	

† Means in the same column of each data set with the same letter (a-e) in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

‡ Means in the same row with same letter (x or y) in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

§ Traffic treatments were applied as follows: 1) no traffic; 2) 5 passes 7 times Sept-Oct 79 + 5 passes 3 times Nov 79 + 20 passes 1 time March 80.

¶ Cultural treatments applied 16 April 1980.

Table 30. F-tests for clipping yields on Midiron bermudagrass as influenced by traffic and cultural treatments in 1979/80.

Parameters	Clipping Yields 15May	22May	30May
Traffic (T)	**	**	**
Treatment (Tr)	***	***	***
T X Tr	**	**	N.S.†

*,**,*** Denotes significance at 10, 5, and 1% levels respectively.
† Non-significant

Table 31. Post dormancy growth of Midiron bermudagrass as influenced by traffic and cultural treatment regimes.

Treatment¶ No.	Cultural Description	Traffic Treatments§ 1	2	means
		Living Ground Cover 1May80		
		%		
1.	Control	23.8c†	23.8b	23.8c
2.	Turf Colorant	33.8b	27.5b	30.6b
3.	Clear Plastic Cover	72.5a	60.0a	66.3a
4.	Aerification	21.3c	22.5b	21.9c
5.	Vertical Mowing	12.5d	15.0c	13.8d
6.	Aerification + Vertical Mowing	12.5d	11.3c	11.9d
	means	29.4x‡	26.7x	
		Frost Damage 15May80		
		rank#		
1.	Control	1.0b	1.0b	1.0b
2.	Turf Colorant	1.0b	1.0b	1.0b
3.	Clear Plastic Cover	6.8a	6.0a	6.4a
4.	Aerification	1.0b	1.0b	1.0b
5.	Vertical Mowing	1.0b	1.0b	1.0b
6.	Aerification + Vertical Mowing	1.0b	1.0b	1.0b
	means	2.0x	1.8x	

† Means in the same column of each data set with the same letter (a or b) in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

‡ Means in the same row with the same letter (x) in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.

§ Traffic treatments were applied as follows: 1) no traffic; 2) 5 passes 7 times Sept. to Oct. 1979 + 5 passes 3 times November 1979 + 20 passes 1 time March 1980.

¶ Cultural treatments applied 16 April 1980.

Rank - 1 to 9 with 1 having no leaves scorched and 9 having all leaves scorched.

Table 32. F-tests for living ground cover and frost damage on Midiron bermudagrass as influenced by traffic and cultural treatments in 1979/80.

Parameters	% Living Ground Cover 1May	Frost Damage 15May
Traffic (T)	N.S.†	N.S.
Treatment (Tr)	***	***
T x Tr	***	*

*,**,*** Denotes significance at 10, 5, and 1% levels respectively.
† Non-significant

difference in frost damage between traffic regimes for any cultural treatment except slightly less frost injury occurred with traffic on plots covered with clear plastic. Initially the plastic covers stimulated bermudagrass growth causing significantly larger clipping yields than other treatments when measured on 15 May (Table 29). There were larger 15 May yield differences between plots covered with plastic and those vertical mowed under no traffic when compared to traffic treatments. In late May the yield of the plots covered with plastic was significantly less than all treatments. The early growth promoted by the protective cover produced earlier than normal growth which was succeptible to frost injury. It appears this early growth will require protection against late spring frost if good turf vigor and quality is to be maintained. Data in Experiment 2 shows this damage to be only temporary. Mid June clipping yields, in Experiment 2, illustrated the turf sward´s full recovery from the mid May frost.

Coloring the dormant turf in spring enhanced early green up, but did not stimulate early spring growth as much as the plastic cover treatment. Consequently, the enhanced growth on the colored plots was not as susceptible to injury by the late frost.

Although traffic reduced bermudagrass post dormancy growth, plastic covers significantly increased the 15 May clipping yields over all other treatments at both traffic treatments. This earlier than normal growth was then severely injured by the mid May frost. As a result, on 22 May the colored control plot yielded significantly more clipping yields than the other 4 treatments. Larger 22 May yield differences occurred between plots colored and those vertical mowed under no traffic as compared to traffic treatments.

Experiment 4 Post dormancy growth of Midiron bermudagrass (*Cynodon dactylon* (L.) Pers.) as influenced by overseeding with Pennfine perennial ryegrass (*Lolium perenne* L.) and use of various growth regulators.

Description of the Experiment

On 25 September 1978 thatch was removed from a 79 m^2 area of Midiron bermudagrass with a Ryan Ren-o-thin vertical mower. After the debris was removed Pennfine perennial ryegrass was overseeded at 4.2 kg are^{-1} on alternating 0.91 m strips. On 2 April 1980 the perennial ryegrass was clipped to 2.54 cm and growth regulator chemicals were applied to the perennial ryegrass and adjacent non overseeded strip while the bermudagrass was still dormant. Mefluidide (N-[2,4-dimethyl-5-[[(tri Fluoromethyl) sulfonyl] amino] -phenyl] acetamide) was applied at 2.41 g are^{-1}, 4.84 g are^{-1} and 9.68 g are^{-1} of active ingredient. Flurprimidal (a-(1 methylethyl)-a-[4(trefluomethoxy) phenol] s-pyrimidinemethanol) was applied at 1.21 g are^{-1}, 2.42 g are^{-1} and 4.83 g are^{-1} of active ingredient. All treatments were replicated three times and arranged in a strip plot experimental design.

Visual estimates of percent living bermudagrass ground cover were made on the non overseeded bermudagrass 1 May 1980, 12 May 1980 and 22 May 1980. Clipping yields were harvested from a 183 cm strip made through the non-overseeded and overseeded plots with a 55 cm rotary mower on 22 May and 30 May 1980. To determine the influence of the growth regulators, on overseeded and non-overseeded plots, a 10 point inclined point quadrant was used to determine the percent of bermudagrass in the ryegrass sward on 10 June 1980. One setting consisting of 10 points was taken per plot. Leaves of each species were counted as each point was moved through the canopy to the soil surface. This measurement estimated the species composition in the turf canopy. These measurements helped to determine the effect of the growth regulators on the ryegrass and enhancement of the post dormancy growth of the bermudagrass.

In addition, 15 cm diameter x 5 cm deep plugs were taken from the non- overseeded plots and transferred to a greenhouse 16 April 1980. The sod was cut off 0.6 cm below the soil surface, placed in soil filled plastic containers and grown for 16 days. Clipping yields were taken at various intervals after post dormancy growth was initiated.

RESULTS AND DISCUSSION

Experiment 4

Flurprimidal reduced the early post dormancy growth of bermudagrass. Field clipping yields on 22 May were significantly reduced by 55% and 69% with the low and high flurprimidal treatments when compared to the control (Table 33). Mefluidide on the other hand did not reduce bermudagrass post dormancy growth. There was no significant yield difference between either growth regulator at any application rate or the control with the clipping yields on 30 May.

Visual estimates of percent living bermudagrass ground cover taken in the field on the differently treated bermudagrass further illustrated the detrimental effect of the flurprimidal (Table 35). There was significantly less green turf where flurprimidal was applied when compared to the control or the melfuidide treatments. This effect was observed up to seven weeks after treatment. Mefluidide treated plots did not differ significantly in percent bermudagrass living ground cover from the control during this time.

Clipping yields from treated non-overseeded plugs brought into the greenhouse to insure rapid post dormancy growth also gave similar results. The 2 May clipping yields of the greenhouse grown bermudagrass were reduced

Table 33. Clipping yields of non overseeded field grown Midiron bermudagrass treated with 2 growth regulators prior to post dormancy growth when measured from samples grown in the greenhouse.

		Clipping Yields			
	Rate §	Greenhouse		Field	
Treatment ‡	g are^{-1}	2May80	13May80	22May80	30May80
		kg are^{-1}			
Control	----	21.43a†	22.70a	0.80ab	3.14a
Flurprimidal ¶	1.21	6.72b	18.45ab	0.37cd	1.70a
Flurprimidal	2.42	2.27b	11.83b	0.41bd	2.25a
Flurprimidal	4.83	1.04b	4.73c	0.25d	2.00a
Mefluidide #	2.41	20.48a	19.72a	0.70ac	2.59a
Mefluidide	4.84	23.98a	19.39a	1.04a	4.08a
Mefluidide	9.68	20.48a	17.97ab	1.04a	4.02a

† Means in the same column with a letter in common do not significantly differ at the 10% level of probability using Duncan´s Multiple Range Test.
‡ Applied 2 April 1980.
§ Rates expressed as active ingredient.
¶ Formulation - 50% WP.
# Formulation - .24 kg l^{-1}.

Table 34. F-tests for clipping yields on Midiron bermudagrass, in the field and plugs of grass removed from field plots and placed in the greenhouse, as influenced by 2 growth regulators in the spring of 1980.

	Clipping Yields			
	Greenhouse		Field Study	
Parameters	2May	13May	22May	30May
Overseed (OS)	N.S.†	N.S.	N.S.	N.S.
Treatment (Tr)	***	***	**	N.S.
OS X Tr	N.S.	N.S.	N.S.	N.S.

*,**,*** Denotes significance at 10, 5, and 1% levels respectively.
† Non-significant

Table 35. Percent living bermudagrass ground cover on field plots of Midiron bermudagrass treated with 2 growth regulators prior to post dormancy growth.

Treatment‡	Rate§ g are^{-1}	Living Ground Cover 1May80	12May80	22May80
		%		
Control	----	36.7a†	51.7a	81.7a
Flurprimidal¶	1.21	21.7b	31.7b	70.0bc
Flurprimidal	2.42	16.7b	23.3bc	61.7c
Flurprimidal	4.83	6.7c	16.7c	46.7d
Mefluidide#	2.41	31.7a	43.3a	78.3ab
Mefluidide	4.84	35.0a	43.3a	81.7a
Mefluidide	9.68	36.7a	46.7a	81.7a

† Means in the same column with a letter in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.
‡ Applied 2 April 1980.
§ Rates expressed as active ingredient.
¶ Formulation - 50% WP.
# Formulation - .24 kg l^{-1}.

Table 36. F-tests for percent living ground cover of Midiron bermudagrass as influenced by 2 growth regulators in the spring of 1980.

Parameters	% Living Ground Cover 1May	12May	22May
Overseed (OS)	N.S.†	N.S.	N.S.
Treatment (Tr)	***	***	***
OS X Tr	N.S.	N.S.	N.S.

*,**,*** Denotes significance at 10, 5, and 1% levels respectively.
† Non-significant

by 69% and 95% with the low and high flurprimidal treatments as compared to the control (Table 35). The 13 May yields of the low and high flurprimidal treatments were reduced by 19% and 79%. Yields from mefluidide treatments did not significantly differ from the control on either date.

Both growth regulators significantly reduced the the growth of the overseeded perennial ryegrass in the field (Table 37). Field clipping yields on 10 April were significantly reduced by 46% and 50% with the low and high flurprimidal treatments when compared to the control; followed by a reduction of 49% and 60% on 17 April. While, the low and high melfuidide treatments significantly reduced the 10 April clipping yields by 66% and 75% when compared to the control; followed by a reduction of 74% and 90% on 17 April.

Mefluidide, by suppressing the growth of the perennial ryegrass, enhanced the competitiveness bermudagrass in the ryegrass canopy (Table 37). Mefluidide is able to suppress the growth of perennial ryegrass without injury to the bermudagrass. These data illustrate that the presence of perennial ryegrass does suppress initiation and development of post dormancy bermudagrass growth. Using a growth regulator to reduce the perennial ryegrass competition, in the spring, appears to favor competition from bermudagrass.

Table 37. Percent bermudagrass as determined by a 10 point inclined point quadrant and clipping yields of Pennfine perennial ryegrass fall seeded over Midiron bermudagrass and spring treated with 2 growth regulators.

Treatment‡	Rate§ g are^{-1}	Clipping Yields 10Apr80	Clipping Yields 17Apr80	Clipping Yields 22May80	Percent Bermudagrass 10Jun80
		kg are^{-1}			%
Control	----	8.15a†	5.77a	5.96b	21.1b
Flurprimidal¶	1.21	4.41b	2.95bc	5.23b	23.8b
Flurprimidal	2.42	4.27b	3.32b	4.86b	26.4b
Flurprimidal	4.83	4.07b	2.34bd	4.81b	25.6b
Mefluidide#	2.41	2.78b	1.49bd	8.21a	36.3a
Mefluidide	4.84	3.19b	1.01cd	8.93a	35.8a
Mefluidide	9.68	2.05b	0.59d	7.92a	36.1a

† Means in the same column with a letter in common do not significantly differ at the 10% level of probability using Duncan's Multiple Range Test.
‡ Applied 2 April 1980.
§ Rate expressed as active ingredient.
¶ Formulation 50% WP.
# Formulation .24 kg l^{-1}.

Table 38. F-tests for clipping yields on Perennial ryegrass overseeded in Midiron bermudagrass and percent Midiron bermudagrass in the perennial ryegrass canopy as influenced by 2 growth regulators in the spring of 1980.

Parameters	Clipping Yields 10Apr	Clipping Yields 17Apr	Clipping Yields 22May	% Bermudagrass 10Jun
Overseed (OS)	N.S.†	N.S.	N.S.	N.S.
Treatment (Tr)	***	***	***	**
OS X Tr	N.S.	N.S.	N.S.	N.S.

*,**,*** Denotes significance at 10, 5, and 1% levels respectively.
† Non-significant

Cold hardiness of bermudagrass declines severely during late winter (Dunn and Nelson, 1974). Chalmers and Schmidt, 1979, showed that prolonging the dormancy period in spring decreases post dormancy bermudagrass viability. Therefore, the quicker bermudagrass dormancy is broken and growth initiated the greater the chance of bermudagrass persistance.

SUMMARY AND CONCLUSIONS

Winter kill is the main deterrant in using bermudagrasses (Cynodon sp.) for athletic turf in the Northern most region of of the United States where semitropical grasses are adapted. Often, wear from play occurs during those seasons of the year when bermudagrass is going into dormancy, during dormancy and/or during early post dormancy growth.

Effects of traffic, mineral nutrition, plastic covers, cultural treatments, overseeding with perennial ryegrass and late-winter freezing were investigated to ascertain their influence on winter survival of bermudagrass. Four experiments were conducted in the field and laboratory. Data were collected on spring recovery from bermudagrass field plots: 1) subjected to traffic prior to dormancy, during dormancy and during the spring as the bermudagrass was breaking dormancy; 2) fertilized with various ratios of nitrogen and potassium; 3) covered with clear plastic covers at different time intervals; 4) treated with various cultural practices; 5) overseeded with perennial ryegrass and treated with two growth regulators; and 6) subjected to a late- winter dormancy freeze.

Traffic, regardless of timing or intensity, influenced post dormancy growth. Traffic applied during the fall and spring seasons of the year and traffic applied at the inititation of post dormancy growth in the spring were the most damaging.

Potassium fertility at the rates used in this investigation had no positive affect on post dormancy growth. However, nitrogen application did improve post dormancy growth of bermudagrass exposed to a controlled freeze in late winter dormancy. Also, bermudagrass growth was improved on plots receiving higher nitrogen rates and covered with plastic covers.

Plastic covers enhanced post dormancy growth of the turf sward and offset the detrimental affect of imposed traffic. These covers help to moderate the temperature, in the turf canopy, during the winter months and enhanced earlier spring green-up.

\`Stayz Green´ turf colorant enhanced early spring greenup; while, the cultivation treatments using a vertical mower alone or in conjunction with an aerifier reduced early greenup. Aerification alone did not reduce spring greenup

Flurprimidal reduced early post dormancy growth of bermudagrass; while, mefluidide had no detrimental affect. Both growth regulators reduced the growth of the overseeded ryegrass, and mefluidide enhanced the competitiveness of bermudagrass in the ryegrass canopy.

Late-winter freezing of dormant bermudagrass increased the detrimental affect of traffic. Plastic covers offset the detrimental affect of the late-winter freeze.

The conclusions that can be made from these studies are as follows:

1. Traffic applied after the iniation of spring growth proved the most detrimental to post dormancy growth. In order to minimize the detrimental effect of traffic, traffic must be controlled at this time.
2. Protective covers can improve post dormancy growth of bermudagrass.
3. Cultural practices that reduce the period of winter dormancy enhance post dormancy performance of bermudagrass.
4. Overseeding bermudagrass fields with perennial ryegrass can delay post dormancy growth and reduced the percentage of the bermudagrass in the turf canopy.
5. Growth regulators can vary in there growth suppression of bermudagrass which in turn can affect the spring competitiveness of bermudagrass in turf swards where cool season species are fall overseeded.
6. Protecting bermudagrass from late-winter freezes will improve post dormancy growth.

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