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1987 USGA ANNUAL RESEARCH REPORT

The following report will detail our results in 1987 concerning the project on annual bluegrass and creeping bentgrass competition. This is the last year of our project and the May report will serve as our final report on this project. The main field study in this project was completed in the fall of 1986. This report contains our final analysis of the data and some very useful and interesting results. We have prepared an article for publication which we intend to submit to the Crop Science journal. Appendix 1 contains this article. We will also prepare an article for Golf Course Management magazine within the next two months. Please see appendix 1 for a complete presentation of the results and discussion of our findings on annual bluegrass and creeping bentgrass competition. The term interference, as used in the article in appendix 1, is meant to describe competition plus allelopathic effects and since our study did not eliminate the possibility of allelopathy playing a role in the interaction of these species; we use the term interference to be technically correct although competition is still a more common and perhaps meaningful term.

In 1986, we also completed a study on the effects of flurprimidol (trade name Cutless) on the competition between annual bluegrass and creeping bentgrass. This study was initiated in 1985 and consisted of placing three four inch diameter plugs into plots of annual bluegrass. Treatments consisted of various rates and timings of flurprimidol (Table 1). Encroachment of creeping bentgrass into annual bluegrass was measured by tracing the outline of the bentgrass plug onto clear acetate film. The area of the trace was then determined using a planimeter.

The study was terminated in October of 1986 and the results are displayed in table 2. There were no significant differences among any of the treatments tested. In fact, the control plots had the greatest bentgrass spread of any of the rates and timings of flurprimidol tested.

Flurprimidol and another very similar product, Scott's TGR, are being advertised as Poa control products. Our research in Michigan does not support this claim. Both the five factor field study (Table , appendix 1) and the encroachment study show no benefit to using flurprimidol in the conversion to bentgrass.

There are several possible explanations for our results. First, all of the rates in the encroachment study were either 1.0 or 1.5 lbs ai/A. Elanco Corp. is now stating that the use range should be between 0.5-1.0 lbs ai/A. This may be a case where more is not necessarily better. Too high a rate may suppress both species while lower rates may permit spread of the bentgrass while still suppressing the annual bluegrass. Secondly, all of our field work was done in small plots which were mowed under normal (i.e. 3 times per week) fairway maintenance practices. When grasses are under growth regulation, mowing frequency is reduced and the reduction in mowing frequency may benefit creeping bentgrass, effectively giving the bentgrass more time to spread before being cut. The mowing frequency in our studies may reduce the spread of bentgrass when compared to large fairway areas under PGR suppression, which would be mowed as dictated by the grass growth rate.

On the other hand, our plots, when under growth regulation, look as if the bentgrass is taking over. However, actual quantitative data taken at the end of the growing season doesn't support those observations. It is our belief that the results observed in many instances are perceptual and not significant. We have begun further studies under golf course conditions to determine the effectiveness of these PGR's as a means of selectively altering the competition process.

Appendix two discusses field research project designed to investigate additional fairway management practices and to examine an overall program to rapidly convert fairways from annual bluegrass to creeping bentgrass. Please see appendix 2 for a discussion of these results.

Prograss (common name - ethofumesate) is a recently labeled product for pre and postemergence annual bluegrass control in turf. This herbicide offers what turf managers have needed for nearly 40 years - safe and effective annual bluegrass control. We have been testing this herbicide since 1984. The data presented are two of our tests that were initiated in the fall of 1986.

The first study was designed to examine the effectiveness of Prograss and tridiphane for removal of annual bluegrass from established Kentucky bluegrass turf. Prograss is most effective when two applications are made 30 days apart. The current label recommendations for Kentucky bluegrass are 0.75 + 0.75 lbs ai/A. We were interested in testing higher rates to observe the safety margin on Kentucky bluegrass. Thus, our rates went from 2 + 1 to 3 + 2 lbs ai/A. Prograss was very effective at all rates tested (Table 3). Annual bluegrass control ranged from 95% for the 2 + 2 and 3 + 2 lbs ai/A rates to 83% for the 3 + 1 lb ai/A rates. Tridiphane also was very effective with the 6 and 3 lb ai/A rates giving 90 and 84% control, respectively. The higher rates of Prograss caused some injury to the Kentucky bluegrass in the fall, turning the turf a steel blue color, but by spring the injury had disappeared.

The second study was designed to determine whether the initial or final rate was more important for controlling annual bluegrass. Rates of 0.75, 1.0, 1.25, and 1.5 lbs ai/A were selected and tested in all possible combinations (Table 4). The most important observation was that second rate is much more important than the initial rate.

A rate of 1.0 + 1.5 lbs ai/A gave 56.7% annual bluegrass kill but when the rates were reversed to 1.5 + 1.0 lb ai/A only 26.7% kill was observed. The first application of Prograss seems to set up the annual bluegrass for injury from the second application. This exact same study was repeated on 'Penncross' creeping bentgrass with no significant visual injury observed. A similar study was conducted on greens height bentgrass with excellent results. A rate of 0.75 plus 0.75 lbs ai/A of Prograss on a practice putting green at Blythefield Country Club in Grand Rapids, MI gave over 90% annual bluegrass control with little injury to the bentgrass. A study was also conducted to determine the rates and timings for Prograss use on overseeded 'Penncross' creeping bentgrass. Rates of 0.75 + 0.75 lbs ai/A with the first application 5 weeks after planting were too injurious to the bentgrass seedlings. However, the rate of 0.75 + 0.75 lbs ai/A applied 7 weeks after planting saw little damage and complete establishment of the creeping bentgrass without any annual bluegrass present.

The unique aspect of Prograss is its pre and postemergence activity. That is, it will kill the annual bluegrass that is present and prevent the soil seed reservoir from reinfesting the treated area. Further testing of Prograss is needed, but this herbicide shows tremendous potential for the turfgrass market.

Table 1. EL-500 rates and dates of application for bentgrass encroachment study. Hancock Turfgrass Research Center. East Lansing, MI.

Flurprimidol Rate ($kg\ ha^{-1}$)	Date of Application 1985	1986
1.68	5/14	4/29
1.68	8/15	8/20
1.12	5/14	4/29
1.12	8/15	8/20
0.56 + 0.28 + 0.28	5/14, 5/31, 6/17	4/29, 5/13, 5/30
0.56 + 0.28 + 0.28	8/15, 8/30, 9/15	8/20, 9/6, 9/21
0.56 + 0.56	5/14, 5/31	4/29, 5/13
0.56 + 0.56	8/15, 8/30	8/20, 9/6
1.12 + 1.12	5/14, 8/15	4/29, 8/20
CONTROL	----------	----------

Table 2. Mean area of creeping bentgrass cores in annual bluegrass following EL-500 treatment.

Flurprimidol Rate ($kg\ ha^{-1}$)	Area 1985 Aug.	Nov.	1986 July	Oct.
	($10^2\ mm^2$)+			
1.68 (Spring)	76	88	260	259
1.68 (Fall)	84	80	207	291
1.12 (Spring)	77	79	238	272
1.12 (Fall)	78	85	263	282
0.56 + 0.28 + 0.28 (Spring)	78	89	287	310
0.56 + 0.28 + 0.28 (Fall)	68	86	217	332
0.56 + 0.56 (Spring)	77	79	243	344
0.56 + 0.56 (Fall)	77	81	281	319
1.12 (Spring) + 1.12 (Fall)	87	89	254	298
CONTROL	72	88	308	398
C.V. (%)	12.1	14.4	30.9	30.8

+Mean area of three cores/plot with three replications (n = 9)

Table 3. Response of Annual Bluegrass to ethofumesate applications.

Rates (lbs ai/A)[a]	Injury[b]		% Bareground[c]
	10/20/86	11/4/86	5/27/87
0.75 + 0.75	8.7	7.3	5.0
0.75 + 1.0	8.7	7.3	13.3
0.75 + 1.25	8.7	6.7	23.3
0.75 + 1.5	8.7	7.0	26.7
1.0 + 0.75	8.3	7.3	6.7
1.0 + 1.0	8.0	6.7	15.0
1.0 + 1.25	8.7	6.7	13.3
1.0 + 1.5	8.7	6.7	56.7
1.25 + 0.75	8.7	8.7	6.7
1.25 + 1.0	9.0	8.0	21.7
1.25 + 1.25	8.7	7.8	33.3
1.25 + 1.5	9.0	7.7	58.3
1.5 + 0.75	9.0	8.3	15.0
1.5 + 1.0	9.0	8.0	26.7
1.5 + 1.25	9.0	7.7	41.7
1.5 + 1.5	9.0	8.0	66.7
Control	7.2	7.8	0
0.75 + x[d]	8.4	7.1	17.1
1.0 + x	8.4	6.8	22.9
1.25 + x	8.8	8.0	30.0
1.5 + x	9.0	8.0	37.5
x + 0.75[e]	8.4	7.9	8.3
x + 1.0	8.4	7.5	19.2
x + 1.25	8.4	7.3	27.9
x + 1.50	8.4	7.4	52.1

a - Initial application on 9/16/86 and second application on 10/17/86.

b - Injury on a scale of 1-9 with 9 = no phytotoxicity and 1 = completely dead turf.

c - % Bareground was a visual estimate of annual bluegrass kill.

d - The means reported are averaged over all values of the 2nd rate. (e.g. the means for 0.75 + x are the average of (0.75 + 0.75) + (0.75 + 1.0) + (0.75 + 1.25) + (0.75 + 1.5).

e - The means reported are averaged over all values of the 2nd rate.

Table 4. Control of Annual Bluegrass in established Kentucky Bluegrass.

Herbicide[a]	Rate (lbs/A)	% Annual Bluegrass Control
Prograss	2 + 2	95
Prograss	3 + 2	95
Prograss	2 + 1	92
Tridiphane	6	90
Tridiphane	3	84
Prograss	3 + 1	83
Control		14
	$LSD_{.05}$	20

a - Initial application on 9/16/86 with second Prograss application on 10/15/86.

INFLUENCE OF CULTURAL FACTORS ON ANNUAL BLUEGRASS/CREEPING BENTGRASS INTERFERENCE

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INTRODUCTION

Annual bluegrass (Poa annua L.) is a major grass component in most irrigated, close-cut, golf course fairways north of the transition zone (1,28). This is especially true on creeping bentgrass (Agrostis palustris Huds.) fairways which are maintained at clipping heights favorable for annual bluegrass (1,2,3). Annual bluegrass is normally not desirable but is present as an invasive species. The initial invasion of annual bluegrass occurs via annual bluegrass seed present in the soil or carried in by foot traffic or machinery (3,11,15). Once established annual bluegrass can, over time, become the dominant component of the turf stand (27). Cultural practices have been found to influence the species dominance in mixed stands containing annual bluegrass.

Engel (10) found cold weather applications of nitrogen to increase annual bluegrass in creeping bentgrass. Heavy spring nitrogen applications and activated sewage sludge, when compared to urea or ammonium nitrate, have been found to encourage annual bluegrass encroachment into Merion Kentucky bluegrass (Poa pratensis L.) (1). Mahdi and Stoutemeyer (18) found increasing rates of nitrogen to decrease the invasion of annual bluegrass into a mixed stand of 'Merion' Kentucky bluegrass and 'Common' bermudagrass (Cynodon dactylon L.). Eggens and Wright (9) observed that, in polystands, the competitive ability of annual bluegrass was greater than 'Penncross' creeping bentgrass, but this competitive edge decreased as the ratio of NH_4^+ to NO_3^- increased. Waddington et al. (26) found annual bluegrass invasion was favored by P and K fertilization and the effect of one was enhanced by the other. Juska and Hanson (16) reported high levels of P to reduce the efficacy of preeemergence herbicides for annual bluegrass control. In a mixed stand of of annual bluegrass and creeping bentgrass, Goss (14) found a P rate of 86 kg ha^{-1} significantly increased annual bluegrass invasion and sulfur fertilization at 168 kg ha^{-1} produced better bentgrass turf with less annual bluegrass.

Sprauge and Evaul (23) found higher soil moisture levels were associated with more annual bluegrass. Youngner (29) reported high, frequent irrigations which maintained high soil moisture levels favored the persistence of annual bluegrass in bermudagrass turf in southern California. Decreasing irrigation levels during periods optimal for annual bluegrass growth has been found to deter encroachment (19).

Eggens (7) found no significant increase in Kentucky bluegrass after three years of overseeding an annual bluegrass fairway. Treatment of annual bluegrass fairways with mefluidide (N-[2,4-dimethyl-5 [[(trifluoromethyl) sulfonyl] amino] phenyl] acetamide) prior to overseeding has increased the success of perennial ryegrass (Lolium perenne L.) overseedings (8).

Removal of clippings from a polystand of annual bluegrass and Kentucky bluegrass can significantly suppress annual bluegrass invasion when compared to clippings returned treatments (1). Pierce et al. (18) found clipping removal to significantly increase the creeping bentgrass population in a mixed stand of annual bluegrass and creeping bentgrass.

Breuninger and Watschke (5) determined EL-500 (α-(1- methylethyl)-α-[4-trifluoro methoxy)phenyl] 5-pyrimidine methanol) significantly decreased the annual bluegrass population in perennial ryegrass, while mefluidide suppressed seedhead production but not populations of annual bluegrass. Schoop et al. (21) reported a significant visual decrease in annual bluegrass populations in an annual bluegrass/creeping bentgrass fairway after EL-500 treatment.

The literature indicates that cultural practices play a significant role in the persistence of annual bluegrass in mixed stands. However the literature is limited on the effects of cultural practices and particularly their interactions on the species composition of mixed stands of annual bluegrass and creeping bentgrass. The objectives of this research were to evaluate the effects of five management practices and their interactions on the species composition of a mixed stand of annual bluegrass and creeping bentgrass and to evaluate the effect of clipping removal on annual bluegrass soil seed reservoir and soil and plant tissue P and K nutrient levels.

Materials and Methods

Research was conducted at the Hancock Turfgrass Research Center, East Lansing, MI on a mixed stand of annual bluegrass and creeping bentgrass. Plot size was 1.8 x 1.2 meters. Fungicides and broadleaf herbicides were applied as needed to prevent broadleaf weed invasion and disease. Treatments were initiated May of 1984 and terminated October of 1986. Experimental design was a randomized complete block with three replications. Treatment design was a 3 x 2 x 2 x 3 x 2 factorial with two splits, with irrigation treatments as main plots, clipping removal treatments as subplots and nitrogen fertility, PGR and overseeding factors as sub-sub plots.

CULTURAL TREATMENTS

Irrigation treatments were started the first week in June and terminated the second week in September in all years of the study. Treatments were applied via sprinkler irrigation through quarter-circle heads which delivered 20 mm hr^{-1}. Two of the treatments were based on daily evaporation readings obtained from a Class A evaporative pan located adjacent to the treatment area. These treatments were daily irrigation at 75 % of open pan evaporation (OPE) and triweekly irrigation at 110% OPE. Rainfall was subtracted from the required irrigation amount prior to application. A third treatment was applied when the plots exhibited moderate to severe wilt symptoms (i.e. footprinting and/or a blueing of the plot area). Irrigation and rainfall amounts are shown in Table 1.

Clipping treatments consisted of mowing with (clippings removed) or without (clippings returned) the catch baskets on a triplex greens mower. Mowing frequency was three times per week with a height of cut of 13 mm (bench setting). Clipping treatments were started in early May and ended in late September of each year of the study.

Nitrogen fertility treatments were 98 kg ha^{-1} yr^{-1} (low-N) and 293 kg ha^{-1} yr^{-1} (high-N). High-N treatments were applied the 15th of May through September and November at 49 kg ha^{-1} per application. Low-N treatments were applied the 15th of June, July, September and November at 24.5 kg ha^{-1} per application. Fertilizer carrier was urea (46-0-0).

PGR treatments consisted of mefluidide, EL-500 and a control. Mefluidide treatments were applied 15 May 1984, 30 April 1985, and 25 April 1986 at 0.14 kg ha^{-1}. Due to the late application timing in 1984 mefluidide treatments were applied with 0.5 % HA-89 surfactant. EL-500 treatments were applied 15 May 1984 at 1.68 kg ha^{-1} and 14 May 1985, and 30 April 1986 at 1.12 kg ha^{-1}. Treatments were applied with a hand held CO_2 sprayer calibrated to deliver 467 L ha^{-1} at 0.21 MPa.

In August of each year overseeding treatments (overseeded or not overseeded) were applied. The overseeding treatment was a broadcast overseeding of Penncross creeping bentgrass at 49 kg ha^{-1}. Prior to overseeding the entire experimental area was verticut with a triplex mower equipped with verticut reels. The verticut reels were set to a depth which cut through the turf and thatch but just lightly into the soil. Overseeding treatments were than applied and brushed in with a nylon bristle broom. Immediately after overseeding the area received 5 mm irrigation.

Data were collected on the population of annual bluegrass in each plot. The annual bluegrass population was estimated by modification of the "vertical point quadrat" method described by Tinney et al. (24). A PVC frame 1.8 x 1.2 m with an internal monofilameint grid of 112 intersections on 100 mm centers was placed over an individual plot. The presence of annual bluegrass under an intersection was recorded as a "hit". The number of hits per plot was divided by 112 and multiplied by 100 to obtain an estimate of the percentage annual bluegrass in each plot. The precision of this method was validated by recounts of randomly selected plots. At no time did the recounts deviate more than 5% from the original estimates. Initial population estimates were made in the spring of 1984 and yearly annual bluegrass population changes were calculated from counts obtained in the fall of 1984, 1985, and 1986. The change in annual bluegrass populations for each year and the sum of the population shift for three years was used in data analysis.

STATISTICAL ANALYSIS

To control error and increase precision in the analysis the initial annual bluegrass population estimates obtained in 1984 were used as a covariate and the experiment analyzed by analysis of covariance. Data were analyzed with SAS (Statistical Analysis System, SAS Institute Inc., Cary NC.), utilizing the General Linear Models procedure. Planned comparison of means were performed by orthogonal contrasts.

SEED RESERVOIR AND TISSUE AND SOIL P AND K CONCENTRATIONS

In November of 1985 and 1986 samples were obtained from the clipping treatments with a core sampler 91 cm in diameter to a depth of 7.6 cm. In 1985 two samples per replication were obtained for each treatment (n=6). In 1986 three samples per replication were obtained for each treatment (n=9). The core samples were air-dried and broken up over a flat in the greenhouse. The flats were irrigated twice daily for four minutes with an automatic misting system. Temperature in the greenhouse fluctuated between 10° and 24° C. After 25 days the number of annual bluegrass plants in each flat were counted. Data were expressed as the number of viable annual bluegrass seeds per 100 g soil, based on a soil bulk density of 1.5 g cm^{-3}3. Clipping treatments were compared using a Student's t test.

Clippings and soil samples were collected from the clipping treatments and analyzed for P and K. Clipping samples were obtained 6 June and 25 October, 1986. Soil samples were taken 21 June, 1985 and 27 October, 1986 to a depth of 76 mm with a 25 mm diameter soil probe. Both clipping and soil samples were analyzed by the Soil Testing Laboratory, Michigan State University. Treatments were separated using a Student's t test.

Results and Discussion

The results of the analysis of covariance are shown in Table 2. Main effects or interactions not shown were not significant at any time in the study. Discussion of results will be confined to significant yearly and combined year main effects and significant interactions for the combined year analysis.

After three years, clipping removal significantly decreased the annual bluegrass population when compared to plots where clippings were returned. For individual years clipping removal reduced the annual bluegrass population in 1984 and 1986 but not in 1985 (Table 3). These results concur with the findings of others (1,20). Several explanations are possible for the clipping treatment response. Fales and Wakefield (12) observed that suppression of the growth of forsythia and flowering dogwood by three turfgrasses may involve chemical inhibition. Annual bluegrass clippings may contain allelo-chemicals which selectively inhibit the growth of creeping bentgrass or enhance the growth of annual bluegrass. Brede and Harris (4) reported that annual bluegrass seeds may secrete a water insoluble toxin which significantly inhibits creeping bentgrass seedlings. High P and K levels have been shown to favor annual bluegrass (26). Removing clippings decreases specific soil nutrient levels which may favor annual bluegrass over creeping bentgrass. Finally the prolific seed production of annual bluegrass (1) and its ability to produce viable seed on excised panicles (17) coupled with seed production throughout the growing season (11) indicate that the returning of clippings may, in effect, be annual bluegrass overseeding.

Nitrogen fertility significantly affected the annual bluegrass population in only one year of the three year investigation. In 1985 plots that received 98 kg ha^{-1} yr^{-1} had significantly less annual bluegrass than plots which received 293 kg ha^{-1} yr^{-1} (Table 3). Beard et al. (1) and Waddington et al. (26) found urea treated plots to have less annual bluegrass than plots which received activated sewage sludge. The increase in the annual bluegrass in sewage sludge treated plots was postulated to be due the P present in the sewage sludge and absent in the urea (26). Engel (10) reported that nitrogen fertility procedures were unlikely to be the major cause of the encroachment of annual bluegrass into creeping bentgrass in New Jersey.

PGR's did not significantly affect the annual bluegrass population in any one year of the study, but when the data were combined over all three years PGR's were a significant source of variability. In the combined year analysis mefluidide had significantly more annual bluegrass than either the control or EL-500 treated plots (Table 4). Mefluidide inhibits annual bluegrass seedhead production (6,27). Spring applications of mefluidide coincide with a period when annual bluegrass seedhead production is very high (11). After mefluidide applications, the assimilates and reserves normally allocated to seedhead production may be reallocated to other portions of the plant such as roots or crown tissue. In perennial ryegrass (Lolium perenne L.) flower production has been found to limit the initiation of main root axes (25). Soper (22) observed an increase in the summer survival of ryegrass (Lolium spp.) when the ratio of vegetative to reproductive culms increased. Cooper et al. (6) found mefluidide treated annual bluegrass to have deeper roots and greater root elongation rates than untreated annual bluegrass. The inhibition of seedhead formation by mefluidide may increase the persistence of annual bluegrass by promoting new root initiation or reducing summer root deterioration.

Plots which were not overseeded and irrigated daily at 75% of OPE had significantly more annual bluegrass than the non-overseeded plots irrigated at 110% OPE 3 times per week or at wilt (Table 5). Continuous high soil moisture levels have been observed to encourage annual bluegrass (23,29). In this study the frequency of irrigation (daily vs. triweekly or at wilt) may have influenced the dominance of annual bluegrass more than irrigation amount. Daily irrigation maintains soil moisture levels in the upper regions of the soil profile at levels which may favor the existing annual bluegrass plants or germination of new plants from annual bluegrass seed present in the soil. Table 5 also shows that for bentgrass overseeding to be effective plots must be irrigated daily.

The response of mefluidide was significantly affected by N-fertility while the EL-500 and control treated plots were unaffected (Table 6). High N-fertility in combination with mefluidide increased annual bluegrass populations.

Table 7 displays the data for the PGR X Clipping Removal X Overseeding interaction for the combined year analysis. Within the mefluidide, overseeded plots, clipping removal significantly decreased annual bluegrass when compared to the clippings returned plots. Within the control and EL-500 plots the clippings removed treatment, overseeded or not, had significantly less annual bluegrass than the corresponding clippings returned plots. Within the EL-500 clippings returned treatments, the overseeded plots had less annual bluegrass than the non-overseeded plots. The application of EL-500 may have suppressed the spring growth of the polystand enough to allow successful establishment of bentgrass from seed, or suppressed the spring germination of annual bluegrass seed present in the soil. EL-500 has been shown to exhibit preeemergence activity on both annual bluegrass and creeping bentgrass (13), when applied at time of seeding. Within the overseeded plots PGR applications had no effect in the clippings returned plots, but in the clippings removed plots the mefluidide treatments had significantly more annual bluegrass than the control plots. This was also true of the non-overseeded plots. The non-overseeded, clippings removed plots treated with EL-500 also contained less annual bluegrass than the corresponding mefluidide treated plots but did not differ from the corresponding control plots.

SEED RESERVOIR AND TISSUE AND SOIL P AND K CONCENTRATIONS

Clipping returned plots had significantly more viable annual bluegrass seeds than the clippings removed plots. In 1985 clippings returned plots had 42 viable annual bluegrass seeds per 100 gms of soil vs. 16 seeds per 100 gms for the clippings removed plots. In 1986 clipping returned plots contained 13 seeds per 100 gms of soil vs. 5 seeds per 100 gms of soil for the clipping removed plots. Although the amount of viable annual bluegrass seeds in the clipping removed plots is still quite high, these plots contained 60% less annual bluegrass seeds than the clippings returned plots. The difference between the two treatments should increase the establishment of annual bluegrass plants from seed in the clippings returned treatment. The data supports the hypothesis that the returning of clippings is a passive form of annual bluegrass overseeding.

Clipping removal significantly lowered the soil K levels when compared to clippings returned plots (Table 8). The K levels in tissue samples were also reduced by clipping removal on the 6 June, 1986 sampling date, but not on the samples obtained in October. Waddington et al. (26) found high K levels to enhance the encroachment of annual bluegrass into creeping bentgrass. The reduction of K concentrations in the clipping removed plots may have been a factor in the reduction of annual bluegrass populations in the clipping removal plots. P levels in both the soil and tissue samples were unaffected by clipping removal.

The results of this investigation indicate that cultural practices can play a significant role in enhancing or detering the encroachment of annual bluegrass in close-cut creeping bentgrass. Clipping removal reduced the encroachment of annual bluegrass into creeping bentgrass, and also reduced annual bluegrass soil seed reservoir and soil and plant tissue K concentrations. High N fertility increased annual bluegrass in one year of the study but did not prove to be a significant factor over time. Treatment with mefluidide, singly or in combination with high N fertility increased annual bluegrass populations. Overseeding was effective in increasing creeping bentgrass only when plots were treated with EL-500 or irrigated daily. However, daily irrigation without overseeding increased annual bluegrass. The numerous interactions observed indicate that the persistence of annual bluegrass can not be easily isolated to any one management practice but depends on the overall cultural program.

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Table 1. Irrigation and precipitation amounts for irrigation treatments applied to annual bluegrass/creeping bentgrass interference study.

	IRRIGATION TREATMENT†											
	75%	110%	WLT	PPT	75%	110%	WLT	PPT	75%	110%	WLT	PPT
MONTH/YR		1984					1985				1986	
						-------mm-----						
APRIL-MAY	0	0	0	171	0	0	0	164	0	0	0	143
JUNE	147	221	20	10	66	137	27	52	86	80	0	193
JULY	102	168	13	45	115	198	17	52	52	140	8	61
AUGUST	91	74	0	94	46	69	30	91	55	96	7	62
SEPT	48	28	0	77	0	33	0	93	18	0	0	208
TOTALS	388	491	33	397	227	437	74	452	211	316	15	667

† Irrigation treaments; daily irrigation at 75% of open pan evaporation (OPE), 3 times per week at 110% of OPE and irrigation at wilt (WLT).

Table 2. Analysis of covariance. Influence of cultural practices on annual bluegrass (*Poa annua* var. *reptans*) and creeping bentgrass (*Agrostis palustris*) interference.

	YEAR			
	1984	1985	1986	COMB.
MAIN EFFECTS				
CLIPPING TRTMNTS (CR)	**	NS	*	**
N-FERTILITY (F)	NS	**	NS	NS
PLANT GROWTH REG (PGR)	NS	NS	NS	*
COVARIATE-INITIAL ANNUAL BLUEGRASS POPULATION	**	NS	NS	**
INTERACTIONS				
IRRIGATION (I) x CR	**	NS	NS	NS
I x OVERSEEDING (O)	*	NS	NS	*
I x F	NS	**	NS	NS
PGR x F	NS	NS	NS	*
PGR x F x CR	NS	NS	*	NS
O x I x CR x F	NS	*	NS	NS
O x PGR x CR	NS	NS	*	*

*, **, or NS indicate significance at P = 0.05, P = 0.01 and non-significant, respectively.

Table 3. Main effect means for clipping and N-fertility treatments averaged across all other factors (n = 108). Means for 1984 and combined year analysis are adjusted for the covariate (initial annual bluegrass population).

	YEAR 1984	1985	1986	COMBINED
Clippings:				
Returned	0.7†	-7.5	-3.4	-10.0
Removed	-5.3	-8.1	-8.8	-22.1
N-Fertility:				
98 kg ha^{-1} yr^{-1}	-2.0	-10.1	-4.8	-16.1
293 kg ha^{-1} yr^{-1}	-2.6	-6.2	-7.5	-16.1

†Data represent % change in annual bluegrass population.

Table 4. Main effect means for plant growth regulator treatments averaged across all other treatments (n = 72). Means for 1984 and combined year are adjusted for the covariate (initial annual bluegrass population).

	YEAR 1984	1985	1986	COMBINED
PGR Treatment				
Mefluidide	-0.5†	-8.4	-5.6	-13.4
EL-500	-3.3	-8.7	-4.9	-17.4
Control	-3.2	-7.3	-7.7	-17.5

Orthogonal comparisons for combined year adjusted means

	OSL‡
Mefluidide vs Control	0.03
Mefluidide vs EL-500	0.03
EL-500 vs Control	0.96

†Data represent % change in annual bluegrass.

‡Observed significance level

Table 5. Irrigation x Overseeding interaction means for combined year analysis. Means are adjusted for covariate (initial annual bluegrass population).

	IRRIGATION TREATMENT†		
	75%	110%	WILT
Overseeded‡	-17.5§	-14.1	-20.8
Non-Overseeded	-9.7	-15.6	-18.7

Orthogonal comparisons

	OSL¶
Non-Overseeded;	
75% vs 110%	0.03
75% vs WILT	<0.01
Overseeded vs Non-Overseeded;	
at 75%	<0.01
at 110%	0.56
at WILT	0.42

†Irrigation treatments were daily irrigation at 75% of open pan evaporation (OPE); 3 times per week at 110% of OPE; and irrigation at severe wilt.

‡ Plots were overseeded in mid-August with Penncross creeping bentgrass at 49 kg ha^{-1}.

§Data represent % change in annual bluegrass populations.

¶Observed significance level.

Table 6. Plant Growth Regulator x N-Fertility interaction means for combined year analysis.

Plant Growth Regulator	N-Fertility ($kg\ ha^{-1}\ yr^{-1}$) 98	293
Mefluidide	-16.2†	-10.6
EL-500	-15.4	-19.4
Control	-16.7	-18.3

<u>Orthogonal comparisons</u>

	OSL‡
Control: Low N vs High N	0.54
Mefluidide: Low N vs High N	0.04
EL-500: Low N vs High N	0.13
High N:	
Mefluidide vs Control	<0.01
Mefluidide vs EL-500	<0.01
EL-500 vs Control	0.07
Low N:	
Mefluidide vs Control	0.84
Mefluidide vs EL-500	0.76
EL-500 vs Control	0.62

† Data represent % change in annual bluegrass populations.

‡ Observed Significance Level

Table 7. Overseeding x Plant Growth Regulator x Clipping Treatment interaction means for combined year analysis. Means are adjusted for covariate (initial annual bluegrass population).

	Plant Growth Regulator Treatment					
	Mefluidide		EL-500		Control	
Clipping Treatment†	C+	C-	C+	C-	C+	C-
Overseeding Treatment‡						
OS	-10.1§	-20.5	-14.4	-23.3	-8.2	-28.4
Non-OS	-9.6	-13.3	-6.8	-25.1	-11.1	-22.2

Orthogonal comparisons

	OSL¶
Mefluidide: OS(C-) vs OS(C+)	<0.01
Control:	
OS(C-) vs OS(C+)	<0.01
Non-OS(C-) vs Non-OS(C+)	<0.01
EL-500:	
OS(C-) vs OS(C+)	0.02
Non-OS(C-) vs Non-OS(C+)	<0.01
OS(C+) vs Non-OS(C+)	0.04

	OS	Non-OS
Clippings Returned:		
Control vs EL-500	0.09	0.25
Control vs Mefluidide	0.39	0.67
Mefluidide vs EL-500	0.24	0.46
Clippings Removed:		
Control vs EL-500	0.18	0.44
Control vs Mefluidide	0.04	0.02
Mefluidide vs EL-500	0.47	<0.01

† C+ and C- designate clippings returned and clippings removed, respectively.

‡ Overseeding treatments were overseeded (OS) in mid-August with Penncross creeping bentgrass at 49 kg ha^{-1} or not overseeded (Non-OS).

§ Data represent % change in annual bluegrass populations.

¶ Observed Significance Level

Table 8. Clipping removal effects on tissue and soil P and K concentrations of an annual bluegrass creeping bentgrass polystand.

	Element							
	P	K	P	K	P	K	P	K
	$mg\ kg^{-1}$				$kg\ ha^{-1}$			
	Sample Date							
	6/6/86		10/25/86		6/21/85		10/27/86	
Clipping Treatment	Tissue				Soil			
Removed	488a	2451a	477a	1063a	133a	96a	74a	87a
Returned	509a	2751b	493a	1100a	129a	145b	75a	113a

Numbers within columns followed by different letters are significantly different based on a paired t test (P=0.05)

MANAGEMENT PRACTICES USED ON ANNUAL BLUEGRASS / CREEPING BENTGRASS FAIRWAYS

Introduction

Clipping removal on golf course fairways has been observed to result in a shift in species composition from annual bluegrass to creeping bentgrass. With this discovery, many golf course superintendents are trying to establish creeping bentgrass fairways.

Three field studies were initiated to examine management practices which will be helpful in the conversion of annual bluegrass fairways to creeeping bentgrass fairways. One study examined nitrogen fertility, potassium fertility, and clipping removal or return. A second study examined practices involved in overseeding annual bluegrass fairways with creeping bentgrass. A third study was designed to determine which management practices best control thatch in fairways and which cultivation practices leads to the most encroachment of annual bluegrass.

In all field studies reported here, the turf was maintained at 1.28 cm with a Toro Greensmaster Triplex mower. Irrigation and fungicide were applied as needed to maintain a healthy turf.

<u>Field Experiment 1:</u> The effects of Nitrogen fertilization and cultivation practices on thatch development and encroachment of invading species.

This study was initiated at the Hancock Turfgrass Research Center (HTRC), during the fall of 1985 in two turfgrass species: Penncross and Penneagle creeping bentgrass, and Annual bluegrass. At the beginning of this study all areas used were composed of re stands of the respective species. The purpose of this experiment was to examine which method of cultivation and amount of nitrogen fertilizer has the most effect on thatch development and the encroachment of another species, especially annual bluegrass, into Penncross and Penneagle creeping bentgrass.

The treatments for this study consisted of nitrogen fertilization at rates of 2,4, and 6 lb/M/yr, and cultivation treatments which consist of: coring in the spring, coring in the fall, coring in the spring and fall, vertical mowing 3 to 4 times in the spring and 3 to 4 times in the fall, and no cultivation.

The method for determining the thatch thickness consisted of taking a 1.8 cm diameter soil probe and removing three plugs chosen at random from each plot, then measuring the thatch thickness of each plug and averaging the three measurements. The average of the three measurements was used as the thatch thickness for the plot. To determine the amount of invasion of other species, a grid consisting of 90 points was placed on top of each plot. The plant beneath each intersection was determined if it was an invading species it was counted. An invading species was defined in this study as 1) an annual bluegrass plant invading into the Penncross or Penneagle (underirable invasion), and 2) creeping bentgrass invading into the annual bluegrass (desirable invasion). This method was used to estimate the amount of invading species present.

The results of this study are summarized in Tables 1-6. Table 1 indicates that there was a significant difference in thatch thickness due to species but not affected by method of cultivation, nitrogen fertilization, or the interactions of nitrogen fertilization and cultivation. Annual bluegrass had significantly less thatch than the Penncross or Penneagle (Table 2). The analysis of variance (Table 3) invasion of annual bluegrass into creeping bentgrass indicates that cultivar had a significant influence on the amount of invasion. Penncross with 6.1% invasion had significantly less annual bluegrass than did Penneagle with 10.4% (Table 4). Although cultivation nor the interaction of cultivation and cultivar did not result in significantly more annual bluegrass invasion, it is interesting to note that Penncross had relatively the same amount of invasion regardless of cultivation treatment. While the Penneagle had more invasion with the coring in the spring and vertical mowing treatments (Figure 1).

The analysis of variance on the amount of creeping bentgrass invasion into annual bluegrass (Table 5) indicates that the method of cultivation influences the amount of creeping bentgrass invading annual bluegrass. Coring in the spring results in significantly more creeping bentgrass invasion than any of the other treatments (Table 6).

Coring in the spring may cause the canopy to open up more resulting in an increase in encroachment. The residual seed in the soil may also come into better contact with soil as a result of falling into the hole created by coring or by the soil which is brought up by coring. Vertical mowing may also cause many of the same things to occur, resulting in a greater increase of encroachment.

<u>Field Experiment 2:</u> Effects of Clipping Removal and Nitrogen and <u>Potassium Fertility</u> on Annual Bluegrass/Creeping Bentgrass Competition

This study was initiated in the spring of 1986 at the HTRC. The purpose of this experiment was to look at the influence of nitrogen and potassium fertility and clipping removal on the competitive ability of creeping bentgrass in an annual bluegrass stand. This study is a randomized complete block design with factors 2 and 3 split on factor 1. The factors in this study include:

Factor 1: Clippings removed or clipping returned
Factor 2: Nitrogen level, 0,1,2,6 lb N/M/Yr
Factor 3: Potassium level, 0,2,6 lb/M/Yr.

The Nitrogen used in this experiment was urea with an analysis of 46-0-0 and the potassium used had an analysis of 0-0-64.

At the beginning of the experiment Fusilade (fluazifop-butyl) was applied at a rate of 0.39 kg /ha to the areas of wild type creeping bentgrass to remove them from the study area. Standard cup cutter plugs (10 cm in diameter) of Penncross creeping bentgrass were transferred to the study area which was divided in half, with clippings returned to one half and removed from the other half.

To analyze the effects of the treatments, the area of the creeping bentgrass plugs were recorded on acetate sheets at the beginning of the study and again in the fall. The area of the tracings was determined using a planimeter. The change in area of creeping bentgrass was the difference between the fall measurement and the spring measurement.

The results of this experiment are summarized in Tables 7-10. The analysis of (Table 7) variance indicates that there was no a significant difference in the change in area of the creeping bentgrass plugs due to any of the treatments.

There are, however, several trends which can be noted from this study. First, in most instances nitrogen resulted in a greater increase of creeping bentgrass when the clippings were removed than when the clippings were returned. The 6 lb rate with clippings removed had nearly twice the increase in area than did the 6 lb rate with clippings returned. Secondly, there was only a slight amount of change in area of creeping bentgrass in response to different levels of potassium fertilizer. The 2 lb K/M/yr exhibited the greatest increase of creeping bentgrass regardless of clipping treatment.

Field Experiment 3: The Effects of Cultivation, Seeding Rate, and Chemical Treatment on Successful Overseeding with Creeping bentgrass into Annual Bluegrass

A third study was initiated at HTRC, in August 1986 on an area consisting of annual bluegrass with small patches of wild type creeping bentgrass. The areas of wild type creeping bentgrass were treated with Fusilade at 0.39 kg /ha to remove them from the study area. The study was a completely randomized block design with the following factors:

Factor 1: Seeding rate consisting of 1,2, and 4 lb. creeping bentgrass seed / M

Factor 2: Cultivation treatment consisting of vertical mowing, coring, and no cultivation

Factor 3: Chemical treatment which consisted of:
- Embark at 0.28 kg ai/ha
- Embark + Prograss at 0.28 kg ai/ha + 1.12 kg ai/ha
- Round-Up at 0.36 kg/ha
- Round-Up + Prograss at 0.36 kg/ha + 1.12 kg ai/ha
- No Chemical

The Embark and Round-Up were applied on August 4, 1986 with Prograss treatments being applied 4 weeks following germination. The Prograss was applied in 2 applications, each at the rate given above and seperated by thirty days. One week prior to seeding a complete fertilizer with an analysis of 12-12-

12 was applied to the study area at a rate of 1/2 lb N/M.

The cultivation treatments were applied just prior to seeding. The vertical mowing treatment was done in two directions using a Ryan Ren-O-Thin walk behind vertical mower adjusted to penetrate the ground approximatily 1/8 inch. The coring treatments (one pass) were done with a Ryan Greensaire aerifer with 1/2 inch tines. The cores were allowed to dry then broken up using the vertical mower with the blades set deep enough to break up the cores, but not the soil surface.

The plots were overseeded by hand with Penncross creeping bentgrass on August 14,.1986. Following seeding a complete starter fertilizer was applied at a rate of 1/2 lb N/M. A drag mat was used to incorporate the seed into the soil, rolled to ensure good seed to soil contact, and irrigated to keep the soil moist.

The results of this experiment are summarized in Tables 11-13. The analysis of variance of percent cover of creeping bentgrass (Table 11) indicates that seeding rate and chemical treatment significantly influenced the amount of creeping bentgrass present. The 2 and 4 lb seeding rate resulted in significantly more creeping bentgrass than the 1 lb seeding rate (Table 12). However, the 2 and 4 lb. rates were not found to be significantly different. This would indicate that overseeding with the 2 lb rate would be as successful as the 4 lb rate.

Treating with Round-Up prior to seeding results in a greater percentage of creeping bentgrass cover due to overseeding. It should be noted however, that in some of the Round-Up plots there were large areas of bare ground which would be unacceptable to the golf cource superintendent. Treatment with Embark resulted in less creeping bentgrass cover than did the plots receiving no chemical treatment.

Treatment with Embark was believed to reduce the competitiveness of the annual bluegrass, allowing the creeping bentgrass seeed to germinate. Then treatment with Prograss, which appears to have both preemergence and postemergence herbicidal activity on annual bluegrass, would further weaken the annual bluegrass and allow the creeping bentgrass to get the competitive advantage.

In both instances when Prograss was applied (Embark + Prograss and Round-Up + Prograss) there was a decrease in the amount of creeping bentgrass present when compared to the plots which received no chemical treatment. Initial greenhouse studies had indicated that Prograss could be applied 2 weeks following creeping bentgrass germination. Prograss was applied 4 weeks after germination but appears to be too soon resulting in the death of the creeping bentgrass seedlings.

Although, initially, it appeared that vertical mowing resulted in greater germination of creeping bentgrass, the results did not support this observation.

TABLE 1 ANALYSIS OF VARIANCE OF THATCH THICKNESS FOR FAIRWAY MANAGEMENT STUDY

ANALYSIS OF VARIANCE TABLE

SOURCE	df	THATCH THICKNESS
REPLICATION	2	N.S.
SPECIES (A)	2	**
ERROR	4	N.S.
NITROGEN LEVEL (B)	2	N.S.
A X B	4	N.S.
CULTIVATION TRTM (C)	4	N.S.
A X C	8	N.S.
B X C	8	N.S.
A X B X C	16	N.S.
ERROR	84	N.S.

** SIGNIFICANT AT 1 PERCENT LEVEL

TABLE 2 MEAN THATCH THICKNESS IN FAIRWAY MANAGEMENT STUDY

SPECIES	THICKNESS (cm)
ANNUAL BLUEGRASS (*Poa annua .L*)	0.8
PENNEAGLE CREEPING BENTGRASS (*Agrostis palustris cv.penneagle Huds.*)	1.5
PENNCROSS CREEPING BENTGRASS (*Agrostis palustris cv. penncross Huds.*)	1.5
LSD (0.05)	0.10

TABLE 3 ANALYSIS OF VARIANCE OF ANNUAL BLUEGRASS INVASION INTO PENNCROSS AND PENNEAGLE CREEPING BENTGRASS

ANALYSIS OF VARIANCE TABLE

SOURCE	df	% INVADING SPECIES
REPLICATION	2	N.S
SPECIES (A)	1	*
ERROR	2	N.S.
NITROGEN LEVEL (B)	2	N.S.
A X B	2	N.S.
CULTIVATION TRTM (C)	4	N.S.
A X C	4	N.S.
A X B X C	8	N.S.
ERROR	56	N.S.

* INDICATES SIGNIFICANCE AT THE 5 PERCENT LEVEL

TABLE 4 MEAN PERCENT ANNUAL BLUEGRASS INVASION INTO CREEPING BENTGRASS

CULTIVAR TYPE	% INVASION
PENNEAGLE	10.4
PENNCROSS	6.1

TABLE 5 ANALYSIS OF VARIANCE OF PERCENT INVASION OF CREEPING BENTGRASS INTO ANNUAL BLUEGRASS

SOURCE	DF	PERCENT INVASION
REPLICATION	2	N.S.
NITROGEN LEVEL (A)	2	N.S.
CULTIVATION	4	*
A X B	8	N.S.
ERROR	28	N.S.

* INDICATES SIGNIFICANCE AT 5 PERCENT LEVEL

TABLE 6 MEAN PERCENTAGE OF CREEPING BENTGRASS INVADING INTO ANNUAL BLUEGRASS DUE TO CULTIVATION TREATMENT

TREATMENT	MEAN
NO CULTIVATION	0.0
CORE SP & FA	0.5
CORE FALL	0.5
VERTICAL MOW	0.7
CORE SPRING	3.9
LSD (0.05)	2.44

TABLE 7 ANALYSIS OF VARIANCE OF CHANGE IN AREA OF CREEPING BENTGRASS DUE TO NITROGEN AND POTASSIUM FERTILITY AND CLIPPINGS RETURNED OR REMOVED

ANALYSIS OF VARIANCE TABLE

SOURCE	df	MS	% CHANGE
REPLICATION	2	382.6	N.S.
CR+ OR CR- (A)	1	151.7	N.S.
ERROR	2	492.9	N.S.
NITROGEN LEVEL (B)	3	94.7	N.S.
A X B	3	26.8	N.S.
POTASSIUM LEVEL (C)	2	37.5	N.S.
A X C	2	13.1	N.S.
B X C	6	57.4	N.S.
A X B X C	6	30.7	N.S.
ERROR	44	82.2	N.S.

N.S.= NOT SIGNIFICANT AT 5 PERCENT LEVEL

TABLE 8 MEAN PERCENT CHANGE IN AREA OF CREEPING BENTGRASS (FOR ALL TREATMENTS)

	% CHANGE
CLIPPINGS REMOVED (CR-)	11.0
CLIPPINGS RETURNED (CR+)	8.0

TABLE 9 MEAN CHANGE IN AREA OF CREEPING BENTGRASS DUE TO NITROGEN FERTILIZATION

RATE (LB/M/YR)	CR +	CR -
0	11.4	13.7
1	7.2	11.7
2	7.1	6.8
6	6.5	11.6

TABLE 10 MEAN CHANGE IN AREA OF CREEPING BENTGRASS DUE TO POTASSIUM FERTILIZATION

RATE (LB/M/YR)	CR +	CR -
0	7.5	8.8
2	8.5	12.8
6	8.1	11.3

TABLE 11 ANALYSIS OF VARIANCE FOR PERCENT COVER OF CREEPING BENTGRASS IN OVERSEEDING STUDY

ANALYSIS OF VARIANCE TABLE

SOURCE	df	% CREEPING BENTGRASS
REPLICATION	2	N.S.
CULTIVATION (A)	2	N.S.
SEEDING RATE (B)	2	**
A X B	4	N.S.
CHEMICAL TRMT (C)	4	**
A X C	8	N.S.
B X C	8	N.S.
A X B X C	16	N.S.
ERROR	88	N.S.

** SIGNIFICANT AT 1 PERCENT LEVEL

TABLE 12 MEAN PERCENT OF CREEPING BENTGRASS ON OVERSEEDED PLOTS

SEEDING RATE (LB/M)	% CREEPING BENTGRASS PRESENT
1	6.2
2	9.6
4	10.1
LSD (0.05)	2.44

TABLE 13 MEAN PERCENT CREEPING BENTGRASS ON OVERSEEDED PLOTS DUE TO CHEMICAL TREATMENT

CHEMICAL TREATMENT	% CREEPING BENTGRASS PRESENT
EMBARK (EMB)	3.2
EMB+PROGRASS (PRO)	2.3
ROUND-UP (RND)	20.3
RND+PRO	11.6
NO CHEMICAL	5.7
LSD (0.05)	3.15

FIGURE 1. PERCENT INVADING SPECIES
(ANNUAL BLUEGRASS)