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Contents

Red Leaf Spot on "Toronto" Creeping Bentgrass

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Red leaf spot, caused by the fungus *Helminthosporium erythrospilum* Drechs. [*Dreschslera erythrospila* (Drechs.) Shoem.], was first observed infecting redtop (*Agrostis alba* L.) and autumn bent [*A. perennans* (Walt.) Tuckerm.] around 1920 in the New York City area [3]. By 1923, red leaf spot had been seen throughout the more humid areas of the United States from Massachusetts to Virginia and west to Ohio, Indiana, Michigan, and Wisconsin. The red leaf spot was attacking redtop and creeping bentgrass (*A. palustris* Huds.), and to a lesser extent Colonial bentgrass (*A. tenuis* Sibth.) and velvet bentgrass (*A. canina* L.) [1, 2, 3, 8]. The causal fungus was described in 1935 as an important pathogen causing leaf spot and crown rot of redtop and of most cultivated bentgrasses during prolonged periods of warm, wet weather [1, 2, 3, 8]. The disease has also been reported in Australia [6] and Great Britain [7].

Starting in 1973, or perhaps earlier, numerous golf courses in the Chicago area experienced a severe disease on putting greens of "Toronto" (C-15) and "Washington" (C-50) creeping bentgrass, in spite of applying regular preventive fungicide spray programs. Many of the fungicides known to effectively control diseases incited by species of *Helminthosporium* did little to improve the condition of the diseased greens [4, 5]. Meyer and Turgeon [4, 5] made numerous isolations from the leaves, crowns, and roots of diseased plants and obtained *H. erythrospilum* from 80 to 85 percent of the samples.

SYMPTOMS

Red leaf spot appears on the leaves as round to oval, tan to straw-colored spots 0.5 to 0.8 millimeter wide and 0.5 to 2.5 millimeters long, surrounded by a reddish-brown border of variable width. Sometimes the bleached centers are very minute or entirely absent. During prolonged wet weather, many of the russet-bordered lesions are surrounded by a water-soaked area giving a pseudozonate to halo-like appearance. Infected leaves wilt and wither from the tip toward the base in warm moist weather in a manner suggestive of drought injury. During dry weather the leaf-spot phase of the disease is much less evident [1, 2, 3, 4, 5, 8]. Typical leaf spotting is usually not evident before the fungus spreads into the crowns and tillers, causing the infected plants to die [3, 5].

The initial symptoms observed on "Toronto" putting greens in the Chicago area usually consisted of small spots of dead grass plants 1/2 to 1 inch in diameter, and orange to reddish-brown in color. Individual leaves may be completely withered or bleached. As the disease progresses during the season, the spots increase in number and merge, causing an extensive thinning of the turf [5].

Red leaf spot is a warm, wet-weather disease with symptoms that first appear in late spring [2, 5]. The severity of the disease increases as the temperature rises in June and July. The disease reaches its peak in July and August, if left unchecked by fungicide treatments [2, 5]. The leaf blighting, and especially the drought-stricken phase (crown and root rot) of the disease, is usually evident during the summer months, particularly following prolonged periods of wet weather [2, 3, 4, 5].

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CONTROL

In 1974, Meyer and Turgeon [4, 5] evaluated the effects of various fungicides commonly used on bentgrass in putting greens, in combination with several levels of fertilization, to control red leaf spot. Weekly applications of chlorothalonil (Daconil 2787) or alternate weekly applications of chlorothalonil and anilazine (Dyrene) at 6 ounces of formulated product per 1,000 square feet provided satisfactory control of the disease. Dyrene alone, and formulations containing cycloheximide (Acti-dione), Acti-dione RZ, Acti-dione--thiram) and thiram (Tersan LSR) plus benomyl (Tersan 1991) improved the percentage of turfgrass cover. However, an acceptable putting surface by the end of the growing season was not achieved. Weekly sprays of maneb (Tersan LSR) and maneb plus benomyl (Tersan 1991), along with a few of the Acti-dione RZ and Acti-dione/thiram treatments, were not significantly better than the untreated control areas [4, 5].

The greatest recovery of severely diseased turf occurred where fungicides were used in conjunction with early spring fertilization. Initiating a fungicide-fertilization program in July where the turf was already severely thinned was of little effect in helping the turfgrass recover by the end of the growing season [4, 5].

Nematicide applications on severely diseased "Toronto" bentgrass, where populations of plant-pathogenic nematodes the previous fall had been high, had no effect in turfgrass recovery [5].

MATERIALS AND METHODS

The same uniformly and severely diseased "Toronro" creeping bentgrass nursery, located in a southwest suburb of Chicago [4, 5], was used to conduct the following studies. The nursery had been severely damaged by *Helminthosporium erythrospilum* during the 1973-1975 seasons. The turf was mowed to a height of 1/4 inch five times a week. Irrigation was performed as needed to maintain normal color and growth.

The fungicides used were chlorothalonil (Daconil 2787) and an alternating schedule of Daconil and anilazene (Dyrene).

The plots to be treated were arranged in a completely randomized block design. All plots measured 6 by 10 feet, with three replications per treatment and a 1-foot untreated strip between plots. The fungicides used, application rates, spray interval, and timing are given in Table 1. Fungicide treatments were started on May 4 on most plots. These were continued to September 28 at weekly or 14-day intervals. A spray volume of 5, 10, or 20 gallons of water per 1,000 square feet were used to apply the fungicides (Table 1).

Fertilizer treatments were made in 5-foot strips across each plot using a water-soluble 10-8-4 ($N:P_2O_5:K_2O$) fertilizer. Applications were made on May 7, June 25, August 13, and September 10. The south half of all plots was given an equivalent of 10 pounds of nitrogen (high N) per season; the north half of the plots received 5 pounds of nitrogen for the season (low N), as indicated in Table 1.

The plots were rated as to their percentage of healthy turfgrass cover on April 28 before the start of the experiment and on May 18 and 25; June 1, 8 and 15; July 6, 20, and 27; August 3, 17, 24, and 31; and September 7, 13, 21, and 28.

RESULTS

When the fungicide treatments were rated on April 28, the healthy turfgrass cover was approximately 40 to 45 percent. Red leaf spot, primarily as a crown-root rot, was the only disease observed during the course of the experiment. The ratings of percentage of healthy turfgrass cover are considered to be an index of red leaf spot control.

The results of the trial are in Table 1. Daconil was applied at 3 or 6 ounces of formulated product in 5, 10, or 20 gallons of water per 1,000 square feet on a weekly basis throughout the season (May 4 to September 28). This provided excellent control. All plots were essentially covered with healthy turfgrass by August 24. The plots that received 20 gallons of water were a denser and healthier green than those that received 10 or 5 gallons of water.

The Daconil-Dyrene rotation treatments on a weekly basis were only slightly less effective than the Daconil alone. The Daconil treatment initiated on June 29 was not significantly

Table 1. Effect of Fungicide, Rate, Spray Interval/Timing, Gallonage, and Fertilization in Controlling Red Leaf Spot Disease on "Toronto" Creeping Bentgrass

Fungicide	Rate of formulation per gallon (oz./1,000 sq. ft.)	Spray interval (days)[a]	Fertilization[b]	April 28	Percentage of healthy turfgrass cover[c] May 25	June	July	Aug.	Sept.	Avg., May-Sept.[d]
Daconil	3/5 gal.	7	high N	40.0	78.3	91.0	95.7	94.6	99.6	91.8
			low N		73.3	78.0	96.3	93.7	99.4	88.1
	6/5 gal.	7	high N	45.0	75.0	86.6	95.6	94.0	99.6	90.2
			low N		71.7	74.4	96.0	94.7	98.0	87.0
	3/10 gal.	7	high N	46.7	80.0	90.6	93.9	89.3	96.5	90.1
			low N		72.8	76.1	94.6	94.4	99.0	87.4
	6/10 gal.	7	high N	45.0	73.3	87.2	93.8	92.6	98.6	89.1
			low N		68.3	66.0	92.0	90.2	98.8	83.1
	3/20 gal.	7	high N	45.0	80.0	91.7	95.8	96.2	99.9	92.7
			low N		78.3	81.1	83.3	94.7	99.1	87.3
	6/20 gal.	7	high N	40.0	73.3	93.3	96.8	94.7	100.0	91.6
			low N		66.7	71.7	91.4	93.6	98.8	84.4
Daconil	3/5 gal.	2 wks	high N	40.0	75.0	85.0	95.9	94.7	95.3	89.2
Dyrene	3.5/gal.	2 wks	low N		71.7	72.2	94.2	95.1	91.5	84.9
Daconil	6/5 gal.	2 wks	high N	42.0	75.0	86.1	94.6	95.5	96.7	89.6
Dyrene	6/5 gal.		low N		70.0	71.7	93.5	95.6	95.7	85.3
Daconil	6/5 gal.	late June	high N	41.7	76.7	87.7	84.6	74.9	87.3	83.5
			low N		71.7	66.1	79.7	75.3	86.2	75.8
Daconil	6/5 gal.	early Sept.	high N	41.7	76.7	88.3	85.9	67.1	64.8	76.6
			low N		68.3	63.9	81.1	68.9	61.3	68.7
Untreated	...	...	high N	40.0	76.7	87.8	77.7	67.1	66.7	75.2
			low N		71.7	67.2	79.4	63.2	55.0	68.6
Untreated	...	...	high N	41.3	75.0	86.9	89.6	68.3	74.7	78.9
			low N		70.0	68.9	81.3	61.3	64.2	69.1

[a]All fungicides were applied weekly starting May 4, with the exception of the late June treatment (first applied on June 28) and the early September treatment (first applied on September 7) and the rotations of Daconil and Dyrene which were put on at two-week intervals.

[b]A water-soluble, 10-8-4 fertilizer was applied to all plots on May 7, June 24, August 13, and September 10. Half of each plot received an equivalent of 10 pounds of nitrogen (high N) for the season, while the other half received 5 pounds of nitrogen (low N) for the season.

[c]The percentage of healthy turfgrass cover was estimated by recording the dead or discolored turf and substracting from 100. Visual estimations were made on each plot on April 28 and May 18, and for each subplot on May 25; June 1, 8, and 15; July 6, 20, and 27; August 13, 17, 24, and 31; and September 7, 13, 23, and 28, when the experiment was terminated.

[d]The figures given are the average of all visual estimations made between May 25 and September 28.

better than the untreated controls until early August. The Daconil treatment that began on September 7 was totally ineffective. This is essentially what Meyer and Turgeon found [4, 5].

Once the red leaf spot fungus infects the crown-root area of plants during the warmer periods of late spring and summer, fungicide applications are of little value in speeding turfgrass recovery. The half of all plots receiving the high rate of nitrogen (10 pounds of N per season) had a consistently higher and healthy turfgrass cover than the half containing the low rate of nitrogen (5 pounds of N per season). Meyer and Turgeon [4, 5] reported that the greatest recovery of severely diseased turf occurred where Daconil, or a rotation of Daconil and Dyrene, were applied weekly in conjunction with early spring fertilization.

CONCLUSIONS

1. Daconil at 3 or 6 ounces per 1,000 square feet applied on a weekly basis from early May to late September gives excellent control of red leaf spot on "Toronto" creeping bentgrass. Weekly treatments are probably not necessary during the first half of May and the latter half of September, if the weather is cool and dry. Using 20 gallons of water per 1,000 square feet resulted in turfgrass with a superior green color and density, compared to applications of only 10 and 5 gallons of water.

2. Daconil (3 or 6 ounces) and Dyrene (3 or 6 ounces) rotated on a weekly basis starting in early May did not give control as good as Daconil applied alone on a weekly basis. Dyrene alone has been reported to give excellent control of red leaf spot in Pennsylvania [4, 5].

3. Turfgrass recovery was consistently better when a high rate of nitrogen (10 pounds per season as compared to 5 pounds) was applied at intervals of about 4 to 6 weeks, starting in May.

4. A long-range solution to the problem of controlling red leaf spot appears to be the overseeding or stolonizing with a resistant, creeping bentgrass. Varieties of bentgrass that have shown good to excellent resistance (or immunity) in the Chicago area include Cohansey, Emerald, Evansville, Nimisilla, Penncross, and Pennpar creeping.

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Selective Control of Creeping Bentgrass

J.E. Haley and A.J. Turgeon

Creeping bentgrass forms a smooth, dense turf that is especially suited for golf greens when maintained under close mowing, frequent irrigation, and a preventative fungicide spray program. When creeping bentgrass occurs in a Kentucky bluegrass turf, however, it forms patches that are unsightly, dense, and puffy. These patches disrupt the uniform appearance of the turf and pose a serious weed problem.

In the past, spot treatments with the nonselective herbicides, dalapon and amitrole, have been used to control infestations of creeping bentgrass in Kentucky bluegrass turf. Due to the residual activity of these herbicides, however, a waiting period of several weeks was necessary between the herbicide application and the replanting of treated sites.

Recently, a new herbicide called glyphosate (Monsanto's Roundup) was introduced for nonselective weed control. It is a highly effective systemic herbicide with no residual activity in the soil. Although glyphosate is better suited to the spot treatment of weeds in turf than amitrole or dalapon, glyphosate lacks the selectivity desired in turfgrass herbicides.

Early studies with silvex revealed that bentgrasses will not tolerate this herbicide at rates necessary for broadleaf weed control. Thus, silvex was used principally on Kentucky bluegrass. However, attempts to control creeping bentgrass in Kentucky bluegrass turf were usually unsuccessful.

Other herbicides, including endothall, are also differentially phytotoxic to these two grass species. In a field experiment initiated during the summer of 1976, endothall and silvex were applied alone or in combination to Kentucky bluegrass turf containing plugs of creeping bentgrass. The application rates for each herbicide were 1, 2, or 4 pounds of active ingredient per acre. The plots measured 5 by 6 feet, with two 4-inch plugs of creeping bentgrass. Each herbicide treatment was replicated three times in a randomized complete block design. The herbicides were applied in a spray volume of 28.5 gallons per acre using a CO_2-propelled, small-plot sprayer. The plots were monitored for creeping bentgrass control and Kentucky bluegrass injury for 34 days following treatment.

Endothall alone provided very poor control of creeping bentgrass and caused a slight to moderate, but temporary, discoloration of Kentucky bluegrass. Greater discoloration occurred as the application rate of the herbicide increased. Silvex alone was more effective than endothall in controlling creeping bentgrass, but the control was not complete in any of the plots. Only slight injury was observed in Kentucky bluegrass from silvex.

The combination of silvex and endothall provided excellent bentgrass control in plots receiving at least 1 pound of active ingredient per acre of each herbicide. The combination of 2 pounds of silvex and 1 pound of endothall completely controlled creeping bentgrass with a moderate, but temporary, discoloration of Kentucky bluegrass.

Further research with this herbicide combination would be necessary before any definite conclusions can be made or recommendations given. Seasonal relationships between herbicide application and efficacy must be investigated, and the residual activity of each herbicide must be determined since the reseeding of some treated sites may be necessary. However, the herbicide combination of silvex and endothall does offer considerable promise for controlling one of the most serious and widespread weed problems in turf.

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Impact of Thatch on the Residual Activity of Herbicides Used in Turfgrass Renovation

K.A. Hurto and A.J. Turgeon

An effective renovation program involves the eradication of undesired species and the immediate reestablishment of turf in the treated area. This practice often requires the use of a herbicide that will eliminate the existing vegetation without any residual activity which delays or prevents reestablishment. Two herbicides which meet this need are paraquat and glyphosate. Paraquat is a contact nonselective herbicide; glyphosate, a systemic nonselective herbicide. Reports indicate that both herbicides are rapidly inactivated in the soil, thus allowing for a quick replanting of the treated area. [2,4,5] While studies have shown these herbicides lack any residual activity within the soil, no study to date has been reported on the impact of thatch--a tightly intermingled layer of living and dead stems, roots, and rhizomes occuring at the soil surface [1] on the residual activity of these two herbicides. Since thatch is often a component of deteriorated turf, studies were initiated to determine its effect on the residual activity of paraquat and glyphosate.

Field and greenhouse studies were conducted to evaluate the impact of thatch on the residual activity of herbicides as it affects the establishment of perennial ryegrass from seed. Paraquat at 1.1 and 2.2 kilograms per hectare and glyphosate at 2.2, 4.5, and 9.0 kg./ha. were applied to a mature Kentucky bluegrass turf at two sites: one with thatch 2 centimeters thick, and another with no thatch. The plots were cultivated four days later in the following manner: disk seeded; core cultivated, vertically mowed, and broadcast seeded; or vertically mowed and broadcast seeded.

Differences in coverage were observed between herbicide treatments and reestablishment methods. The reestablishment of thatch-free sites showed comparable coverage from either vertical mowing and seeding or from core cultivation plus vertical mowing and seeding. Disk seeding resulted in lower coverage, although less seed was used. Herbicide treatment had no adverse effect on stand coverage. However, under thatchy conditions, the residual activity of paraquat was observed, as evidenced by a reduction in stand coverage. Disk seeding into thatchy plots resulted in severe inhibition of seedling emergence. Injury was not as pronounced in the paraquat-treated plots that were planted following core cultivation or vertical mowing. The placement of the seed by disk seeding was within the thatch. The utilization of other establishment methods reduced paraquat injury by allowing for better contact between the seed and the soil, since cultivation methods removed most of the thatch layer(vertical mowing) or introduced soil at the site of seed germination (core cultivation).

Greenhouse studies showed that where clippings of paraquat-treated turf were placed on top of seed sown on soil, the seedling emergence of perennial ryegrass and Kentucky bluegrass was inhibited. Similar studies with glyphosate showed no inhibition of seedling emergence. These studies substantiate earlier findings by Klingman and Murray [3].

The studies also indicate that although paraquat has no residual activity in soil where thatch is present or where clippings from herbicide-treated turf may come in contact with seeded areas, seedling emergence may be inhibited. Removing the thatch by vertical mowing or the introduction of soil at the site of seed germination by core cultivation tend to mitigate paraquat injury. Differences in the amount of injury from paraquat between spring and late-summer studies suggest that environmental factors may also affect the residual activity of paraquat in thatch.

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Utilizing Dehydrated Pelleted Turfgrass Clippings As a Feed for Ruminant Animals

F.C. Hinds, D.L. Arndt, M.H. Wallace, A.R. Cobb, A.J. Turgeon, and J.M. Lewis

Renewed attention is being given to the possibility of increasing the proportion of roughage used in animal rations to produce cattle and lambs for market. Although the rising demands for red meat can be met presently by using grains, reduced levels of grain feeding are likely to be called for in the future, thus emphasizing the quality as well as the quantity of the roughages used.

Large yields of high-quality forages can be obtained from well-managed stands on good farm land. However, land capable of producing grain must and will be used for that purpose first. Hence, it is essential that present forage lands be managed for greater production and that new sources of forages and roughages be developed.

Recent studies plus observations obtained from research in progress, including efforts at the University of Illinois, show clearly that the turfgrass clippings produced by mowing could become a valuable source of roughage for livestock feed. In the samples studied, the levels of crude protein are high enough to make turfgrass clippings serve as a potential supplement in the rations of many ruminant animals.

The potential production of turfgrass clippings is staggering in view of the vast and increasing amount of land used for highway roadsides, parks, golf courses, cemeteries, lawn areas, sod farms, and so on. The potential of this resource ought to be examined in light of the coming needs for roughage and protein supplementation in animal rations.

Each year, the loss of agricultural land is over a million acres to highway development, urbanization, and industrialization. That loss need not be a total one, however, because the grass clippings from that land could be put to use to help feed the population, as outlined here.[1]

Urbanization and development take about 2.5 million acres each year, but approximately 1.25 million acres of land is also brought into agricultural production for the first time through swamp drainage, irrigation, and the like. So, the net loss to agricultural production is about 1.25 million acres. That same land, though, could still be used to help feed hundreds of thousands of people, despite the change in basic use, if the grass clippings were employed to supplement the diet of ruminant animals, such as cattle, hogs, and sheep.

The loss of over a million acres of agricultural land every year is real enough under current practices. By instituting changes in management and use, an untapped source of feed could be realized from that "lost" land, a source that would be valuable and renewable. The result would be another step forward in the production efficiency of Illinois and American agriculture.

[1]Most of the use would probably be in a dehydrated, pelleted form. In certain situations, though, fresh or ensiled clippings could be employed.

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UNIVERSITY OF ILLINOIS STUDIES

Four experiments were initiated to evaluate the potential value of turfgrass (Bluegrass) clippings that had been dehydrated and pelleted as a source of nutrients for finishing lambs. Two have been completed.

EXPERIMENT ONE. This was a digestion study. Six lambs were fed a sample of dehydrated, pelleted turfgrass (Kentucky bluegrass). For comparison, six similar lambs were given a sample of pelleted alfalfa hay from a field-cured second cutting. The *ad libitum* intake of each lamb was determined during a 21-day preliminary period in the study. Each lamb's feed intake was then restricted to 90 percent of its intake *ad libitum*, and feces were collected for 5 consecutive days. Appropriate samples of feed and feces were analyzed for their content of dry matter (DM), crude protein (CP), cell-wall constituents (CWC), acid detergent fiber (ADF), and lignin (PL). From these analyses, the levels of cellulose and hemicellulose could be determined. The pelleted, dehydrated turfgrass was provided by the Warren Turf Nursery, Suisun, California.

EXPERIMENT TWO. A feeding study was conducted at the Dixon Springs Agricultural Center involving 96 lambs. Three replicates of eight lambs per lot were assigned at random within the replicate to each of four treatments. The four treatments were: (1) turfgrass pellets; (2) a finishing ration containing 10 percent alfalfa hay; (3) a finishing ration containing 20 percent hay; and (4) a finishing ration containing 40 percent alfalfa hay (Table 1).

Table 1. Rations used in the DSAC Feeding Study, 1976

Ingredient	Ration 1	2	3	4
		percent		
Dehydrated turfgrass.	100	0.0	0.0	0.0
Ground shelled corn	0.0	81.0	62.5	45.5
Soybean meal (50 percent crude protein)	0.0	16.5	15.0	12.0
Ground alfalfa hay.	0.0	10.0	20.0	40.0
Bonemeal.	0.0	1.0	1.0	1.0
Feeding-grade limestone	0.0	1.0	1.0	1.0
Trace-mineralized salt.	0.0	0.5	0.5	0.5
Vitamins A, D, and E.	-	+	+	+
Antibiotic.	-	+	+	+

All lambs were self-fed their respective rations on slotted floors. Four square feet of space were provided per lamb. The study was conducted over a period of 83 days. At the end of the study, representative lambs (3 or 4) were marketed from 11 of the 12 lots. The carcass grade and observations on fat color were obtained by a federal grader. All lambs were weighed periodically. Feed intake was measured on a lot basis each time the lambs were weighed.

EXPERIMENT THREE. A second feeding study was conducted on the Urbana-Champaign campus using 12 lambs. The purpose of this study was to provide lamb carcasses from turfgrass-fed and conventionally fed lambs for evaluation by a taste panel. Initially, the lambs were divided into two groups of 6 each. One group received only turfgrass pellets; the other, a conventional finishing ration (same as Ration 2 in Table 1). The lambs were allowed their respective rations *ad libitum*, and were confined on slotted floors. Because of poor performance, four of the lambs initially receiving the turfgrass pellets were switched to a ration of 75 percent turfgrass pellets plus 25 percent finishing pellets (2 lambs), or half turfgrass pellets and half finishing pellets (2 lambs). All of the lambs have not been slaughtered; thus, no taste panel information is available. All lambs were weighed periodically. Feed intake was measured on a group basis each time the lamb were weighed. The pelleted, dehydrated turfgrass was provided by the Warren Turf Nursery, but was from the northern Illinois--southern Wisconsin area.

EXPERIMENT FOUR. Because of the possibility of differences between the turfgrass from California and the Midwest, a second digestion study was conducted. Four lambs were used. The digestibility of the material produced in the Midwest was studied at 90 percent of *ad libitum* intake.

RESULTS AND DISCUSSIONS

The results of the first digestion study are presented in Table 2. From the data it is apparent that in every respect, the turfgrass was more highly digestible than a good-quality alfalfa hay. Further, the voluntary intake of the turfgrass was considerably higher than for pelleted alfalfa hay. Based on the composition, digestibility, and intake of turfgrass pellets, turfgrass merits serious evaluation both as a source of nutrients for finishing (fattening) sheep and cattle and as a protein supplement for ruminant livestock. Again, based on the data in Table 2, pelleted turfgrass is very close to the nutritive value of oats and is, in fact, superior in the crude protein content.

As a result of the digestion study, we looked forward to evaluating turfgrass pellets as the sole source of nutrients for finishing lambs. Two experiments were designed. The first one was conducted at the Dixon Agricultural Center, comparing turfgrass pellets to rations containing various levels of alfalfa hay. The purpose of the first feeding experiment was to study the relative energy value of turfgrass pellets by comparing the performance of growing-finishing lambs fed turfgrass pellets to that of lambs fed conventional rations of varying digestible energy levels. Also, we wanted to obtain information on the carcasses obtained from the lambs fed the various rations. The second feeding experiment was conducted in Urbana mainly for the purpose of obtaining lamb carcasses to be used in taste panel evaluations of lambs fed to a standard finish on conventional rations, or on rations high in pelleted turfgrass content or made up entirely of such pellets.

The results of the feeding study conducted at Dixon Springs are presented in Table 3. The data on gain and feed required per pound of gain are very surprising, and were poorer than expected. Based on the data in Table 2, the turfgrass pellets should have allowed for performance much closer to the ration containing 40 percent alfalfa. There is no apparent reason for the poor performance, except that the data in Table 2 were obtained on a sample of pellets produced in California and the data in Table 3 were obtained from pellets produced in the Midwest. Although the plant species of the parent material of both samples of pellets is the same, the differences caused by variations in management, fertility, and climate may be substantial. Experiment 4 is in progress. From it, we will obtain digestion coefficients on material similar to that used in both Experiments 2 and 3. Carcass data from Experiment 2, not summarized or presented at this time, indicate that choice slaughter lambs can be produced on a ration of only pelleted, dehydrated turfgrass. Although turfgrass pellets produced lighter carcasses than the other dietary treatments, all 8 of the lambs slaughtered

Table 2. Composition and Digestion Coefficients for Pelleted, Dehydrated Turfgrass (Bluegrass) and Pelleted Alfalfa Hay

	Feed	
	Turfgrass	Alfalfa
Composition (percent, dry matter):		
Dry matter	88.9	90.4
Crude protein	23.7	14.9
Cell-wall constituents	51.3	62.2
Acid detergent fiber	23.3	44.6
Lignin	2.8	9.4
Cellulose	17.6	31.7
Hemicellulose	28.0	17.6
Digestion coefficients (percent dry matter):		
Dry matter	69.3	55.1
Crude protein	75.0	68.6
Cell-wall constituents	70.0	47.0
Acid detergent fiber	58.4	47.0
Cellulose	55.6	41.8
Hemicellulose	80.7	53.0
Voluntary intake:		
Grams of dry matter/per kilogram of weight$^{3/4}$	92.2	72.2

Table 3. Gain and Feed Required per Pound of Gain for Feeding Studies at Dixon Springs

Performance	Ration			
	Turfgrass	10% Alfalfa	20% Alfalfa	40% Alfalfa
Average daily gain (lb./day)				
Replicate 1.	.21	.48	.50	.51
Replicate 2.	.25	.56	.59	.57
Replicate 3.	.31	.57	.60	.58
Feed per pound of gain (lb.)				
Replicate[a] 1	11.9	5.4	5.3	6.8
Replicate 2	14.5	6.0	6.0	6.5
Replicate 3	11.0	5.9	5.8	6.7

[a]Each contained 8 lambs.

graded USDA choice or better (prime). Of the 8 lambs slaughtered, 5 had lower-than-normal internal fat; and only 1, more than normal. Of concern was the fact that 2 of the lamb carcasses exhibited "yellow" fat. This is uncommon in lambs, but would be expected if cattle were fed. The coloration was not excessive (i.e., orange fat) as can be found in some grass-feed beef.

The main purpose of Experiment 3 was to obtain carcasses from lambs finished on 100 percent turfgrass or taste panel evaluation. Since the lambs were weighed periodically and all feed consumed was measured, data on gain as well as on the average daily intake of feed have been calculated. The data represent only 2 lambs for each treatment, except for lambs on the finishing pellet (6 lambs). The taste panel evaluation has not been conducted yet.

Lamb performance is presented in Table 4. The lambs fed the finishing pellet gained well as did those fed a 50:50 ration of finishing pellets and turfgrass pellets. The lambs that

Table 4. Comparative Performance of Four Rations

Performance	Ration[a]			
	1	2	3	4
Average daily gain (lb./day).	.69	.64	.38	.26
Average daily intake (lb./day). . . .	3.7	4.5	3.9	3.7
Feed required per unit of gain. . . .	5.7	7.1	10.1	14.2
Average days to grade choice.	42	48	131	159

[a]Ration 1--100 percent finishing pellets containing 10 percent alfalfa hay.
Ration 2-- 50:50, finishing pellets and turfgrass pellets.
Ration 3-- 25:75, finishing pellets and turfgrass pellets.
Ration 4--100 percent turfgrass pellets.

received more than half of their daily feed as turfgrass pellets did not perform well. The level of performance of lambs fed all turfgrass pellets was very much like similar lambs fed at Dixon Springs (see Table 3).

The time required to obtain a sufficient finish to grade choice increased markedly for lambs receiving more than half of their daily feed as turfgrass pellets. Observing the carcasses after slaughter, it was apparent that carcasses from lambs finished on 100 percent turfgrass pellets contained much more pigment (orange color) than normal slaughter lambs. Such coloring, although not a factor in flavor, is objectionable and is not common.

As the intake of turfgrass pellets increased (expressed as a percentage of the daily ration), total daily intake decreased. This was not expected, and may reflect a problem with the acceptability of turfgrass pellets.

The results from Experiment 4 indicate that turfgrass produced in the Midwest was less digestible (56.6 percent of the dry matter) than that from California (69.3 percent of the dry matter). The reason for this difference is not presently apparent. The pellets from the Midwest were consumed at a slightly higher level (95.8 grams of dry matter per unit of metabolic mass per day) than those from California (92.2 grains of dry matter per unit of metabolic mass per day). The poorer-than-anticipated gains by the lambs fed high levels of turfgrass pellets seems to be due largely to a lower-than-anticipated digestibility of the turfgrass pellets produced in the Midwest.

SUMMARY

The results obtained thus far suggest that pelleted, dehydrated turfgrass may be a valuable feed ingredient in ruminant rations. We have a great deal yet to learn about the variability in samples and the influence of management practices on nutritive value. It would appear that the potential benefits from using clippings from presently unproductive areas require special attention to the full development of the technology necessary to utilize such a vast and valuable renewable resource more efficiently.

Kentucky Bluegrass Cultivar Management

A.J. Turgeon

The introduction of many new cultivars of Kentucky bluegrass has had a substantial impact on the marketing of seed and sod for turfgrass establishment. Advertisements for these cultivars imply that once the new grass is established, better turfgrass quality can be obtained regardless of the cultural program employed. Although this may be true in some cases, such a generalization is not consistent with field evaluations in which various cultivars have been sustained under a range of cultural intensities for several years.

1973 CULTIVAR MANAGEMENT STUDY

Six cultivars of Kentucky bluegrass were used: Windsor, Nugget, Merion, Fylking, Pennstar, and Kenblue. These were planted in 1972 and maintained at a height of 1-3/4 inches through the season. In April of 1973, all of the cultivars except Windsor were clipped at 1-1/2 inches or 3/4 inch three times per week and fertilized at an annual rate of 2, 4, 6, or 8 pounds of nitrogen per 1,000 square feet, applied in 1- or 2-pound increments during May, June, August, and September. In the fall of 1973, A 20 sod was planted in an adjacent area and was included in the study along with Windsor.

Thus, seven cultivars were observed at eight cultural intensities through 1974, 1975, and 1976. The nitrogen source was a 10-6-4, water-soluble fertilizer. Each treatment combination (mowing height and fertility level) was replicated three times with 4- by 6-foot plots within each cultivar block.

1975 CULTIVAR MANAGEMENT STUDY

Twenty-one cultivars of Kentucky bluegrass were planted in 15 replicate plots in September, 1974. Twelve replications of the cultivars were planted in the northwest section of the OHRC turfgrass experimental site and three replications were located north of the east-west road leading into the OHRC. In 1975, five different cultural intensities were imposed so that three replications of each cultivar were maintained under one of the following programs: 0.75 inch mowing with 4 pounds of nitrogen per 1,000 square feet per year; 0.75-inch mowing with 8 pounds of nitrogen per 1,000 square feet per year; 1.5-inch mowing with 4 pounds of nitrogen per 1,000 square feet per year; 1.5-inch mowing with 8 pounds of nitrogen per 1,000 square feet per year; and 3-inch mowing with 1 pound of nitrogen per 1,000 square feet per year. The mowing was performed two or three times a week at 0.75 inch or 1.5 inches, and once per week at 3 inches. Fertilization was performed in 1- or 2-pound nitrogen increments in April, May, August, and September. The 3-inch plots were fertilized in April. Irrigation was performed as needed to prevent wilting, except in the 3-inch plots which were unirrigated. The plots measured 5 by 6 feet. The cultivars within the cultural level were arranged in a randomized complete block design.

The results from these studies indicate that turfgrass quality largely depends on the incidence of disease. This, in turn, is associated with the mowing height and fertilization rate within each cultivar (Tables 1 and 2). Generally, close mowing and low fertility favored dollar spot incidence, while high fertility was conducive to Fusarium blight and stripe smut.

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In previous years, highly fertilized plots of Kenblue were seriously thinned by *Helmintho-sporium*. Large infestations of annual bluegrass were associated with close mowing and high fertility. However, the cultivars differed widely in their relative susceptibility to annual bluegrass invasion.

In the 1973 study, Windsor and A-20 were moderately resistant to annual bluegrass invasion. Nugget and Merion were less resistant. The Pennstar, Fylking, and Kenblue turfs were dominated by annual bluegrass under the most intensive cultural programs (Table 1). In the 1975 study, A-34, Brunswick, and Touchdown had less than 10 percent annual bluegrass. The plots of Majestic, Nugget, Rugby, and Vantage under intensive culture (8 pounds of nitrogen, 0.75-inch mowing height) were 40 to 50 percent annual bluegrass (Table 2). Under moderate fertilization, most cultivars had very little annual bluegrass.

Under a moderate cultural intensity (4 pounds of nitrogen, 1.5-inch mowing height), most of the cultivars performed well. Of particular interest was the relative ranking of cultivars under a low cultural intensity (1 pound of nitrogen, 3-inch cutting height, and no irrigation). Birka and Code 95 ranked better than most cultivars in overall quality.

The thatching tendency varied with cultivar and mowing height, but no significant effect was observed from the fertilization rate (Table 1). The A-20 turf was the most thatch-prone of the seven cultivars in the 1973 study; Kenblue has the least amount of thatch; and Nugget, Merion, Fylking, Pennstar, and Windsor were intermediate. The higher mowing height (1.5 inches) resulted in 16 to 40 percent more thatch than that observed at the lower mowing height (0.75 inch) in all cultivars except Kenblue.

The data indicate that the selection of specific cultivars for planting should be based on their relative performance at the specific cultural intensity intended on the planting site. The cultivars best suited for use on golf-course tees and fairways may not be the best choices for cemetaries, parks, and other "low-maintenance" sites. For lawns sustained under a moderate intensity of culture, there are many good choices. A blend of superior cultivars that are compatible in color, texture, and vigor would probably provide the best possible turfgrass quality for many years.

Table 1. Quality of Kentucky bluegrass cultivars under different mowing and fertilization regimes

Mowing Height in.	Fertilization lb N/1000 sq ft/yr	Dollar Spot[1] 8/13/76	Stripe Smut[1] 8/27/76	Thatch Depth in.	% Annual Bluegrass	Quality[2] 5/18/76	7/13/76	8/13/76	9/17/76	10/18/76
Windsor										
0.75	2	3.0	1.0	1.6	0.3	3.0	3.3	3.3	3.3	3.7
0.75	4	2.0	1.3	1.7	2.0	4.0	3.0	3.7	2.3	3.0
0.75	6	1.0	2.0	1.5	3.3	4.0	3.0	3.3	2.3	3.0
0.75	8	1.0	1.7	1.4	5.7	4.0	3.3	3.3	2.3	3.0
1.5	2	2.3	1.0	2.0	0	3.7	3.7	3.3	3.3	3.7
1.5	4	1.3	1.7	2.0	0	4.0	2.3	3.3	1.3	2.7
1.5	6	1.0	2.7	2.2	0	3.3	3.0	3.3	2.0	2.7
1.5	8	1.0	3.0	2.2	0.3	3.0	3.3	3.7	2.7	3.0
A-20										
0.75	2	3.7	1.0	2.5	8.7	3.3	4.7	4.7	3.3	3.7
0.75	4	2.3	1.0	2.5	6.7	3.3	3.0	3.3	2.7	3.0
0.75	6	1.3	1.0	2.4	7.0	3.0	3.3	3.0	2.0	3.0
0.75	8	1.7	1.0	2.6	13.3	3.0	3.3	4.0	4.0	4.0
1.5	2	2.3	1.0	3.3	0	4.0	4.0	4.3	2.7	3.0
1.5	4	1.7	1.0	3.0	0	4.0	4.0	3.7	1.7	2.3
1.5	6	1.0	1.0	2.9	0	3.3	4.0	2.0	1.0	2.3
1.5	8	1.3	1.0	2.9	0	3.3	3.7	3.0	1.0	2.3
Nugget										
0.75	2	5.7	1.0	1.4	2.3	2.7	3.7	5.3	4.3	4.3
0.75	4	2.3	1.0	1.7	12.0	2.3	3.3	5.3	3.7	4.3
0.75	6	2.7	1.3	1.5	30.0	1.3	4.0	5.7	4.7	5.0
0.75	8	3.3	1.7	1.6	26.7	2.0	4.7	5.0	5.3	5.0
1.5	2	4.3	1.3	2.1	0	4.7	4.3	5.3	2.7	3.0
1.5	4	1.7	2.3	2.2	0	4.7	3.7	5.3	2.3	3.0
1.5	6	2.7	2.3	2.2	0	5.3	3.3	4.0	2.0	3.0
1.5	8	2.7	2.7	2.1	3.3	5.3	3.3	4.0	1.3	3.3
Merion										
0.75	2	3.0	1.0	1.5	12.0	3.3	4.7	5.0	4.0	4.3
0.75	4	1.3	1.0	1.7	26.7	3.0	4.0	4.7	3.7	4.7
0.75	6	1.7	1.3	1.8	32.7	2.7	5.0	5.3	5.3	4.7
0.75	8	1.3	1.7	1.6	40.0	3.0	5.0	5.7	5.3	5.3
1.5	2	2.0	1.3	1.9	3.7	4.0	4.0	4.0	2.7	3.0
1.5	4	1.0	2.3	2.0	2.3	4.3	3.0	3.7	2.7	3.0
1.5	6	2.0	2.3	1.9	6.7	4.0	3.0	3.3	2.7	2.7
1.5	8	1.0	2.7	2.1	12.0	4.3	3.0	3.3	3.0	3.7

Continued

Table 1. continued

Mowing Height in.	Fertilization lb N/1000 sq ft/yr	Dollar Spot[1] 8/13/76	Stripe Smut[1] 8/27/76	Thatch Depth in.	% Annual Bluegrass	Quality[2]				
						5/18/76	7/13/76	8/13/76	9/17/76	10/18/76
Fylking										
0.75	2	4.3	1.0	1.9	16.7	3.7	4.0	6.3	5.3	5.0
0.75	4	2.0	1.3	1.9	40.0	3.0	4.7	5.3	5.0	5.7
0.75	6	1.3	1.7	1.8	68.3	3.3	5.7	7.3	7.0	6.7
0.75	8	1.0	1.3	1.9	81.6	3.3	6.0	7.3	7.3	7.3
1.5	2	1.7	1.7	2.3	16.7	4.7	3.0	4.0	3.7	3.7
1.5	4	1.3	2.0	2.2	16.7	5.0	3.0	4.3	3.3	4.7
1.5	6	1.3	1.7	2.1	20.0	5.3	3.0	4.0	3.0	4.7
1.5	8	1.0	2.0	2.3	33.3	5.3	4.0	4.3	3.7	4.7
Pennstar										
0.75	2	3.3	1.0	1.6	43.3	3.7	4.0	5.7	5.3	6.0
0.75	4	1.7	1.0	1.9	68.3	3.0	4.7	6.7	7.0	7.0
0.75	6	1.0	1.0	1.8	68.3	3.3	6.0	7.3	7.7	8.0
0.75	8	1.0	1.0	1.6	85.0	3.3	6.0	8.0	8.7	8.3
1.5	2	2.3	1.0	2.2	26.7	5.0	3.7	4.3	4.3	4.0
1.5	4	1.3	1.3	2.2	23.3	5.3	4.0	4.7	5.0	4.7
1.5	6	1.3	1.3	2.1	30.0	6.0	3.7	4.3	4.7	4.7
1.5	8	1.0	1.0	2.2	36.7	6.0	4.7	5.7	6.0	6.0
Kenblue										
0.75	2	2.7	1.0	0.3	55.0	5.3	7.0	6.3	7.3	6.7
0.75	4	1.3	1.0	0.8	71.7	5.7	8.3	8.0	8.0	8.3
0.75	6	1.0	1.0	0.6	81.7	6.3	8.3	9.0	9.0	8.7
0.75	8	1.0	1.0	0.2	97.7	6.7	9.0	9.0	9.0	9.0
1.5	2	2.3	2.0	0.6	25.0	7.3	5.0	4.7	6.0	4.7
1.5	4	1.7	2.0	0.4	36.7	7.3	7.0	6.3	6.3	5.3
1.5	6	1.0	2.0	0.5	43.3	7.7	7.0	7.0	6.3	6.3
1.5	8	1.0	1.0	0.3	50.0	8.0	7.7	7.7	7.0	7.0

[1] Disease severity was rated using a scale of 1 through 9 with 1 representing no disease and 9 representing complete necrosis of the plot.

[2] Quality ratings were made using a scale of 1 through 9 with 1 representing perfect quality and 9 representing very poor quality.

Table 2. New Kentucky bluegrass cultivar management study

Culitvar	Cultural Intensity[1]	Dollar Spot[2] 8/13/76	Fusarium Blight[2] 8/13/76	% Annual Bluegrass	Quality[3] 7/14/76	8/13/76	9/21/76	10/19/76
A-20	M .75, F4	4.3	2.7	6.7	4.0	5.0	7.3	7.0
	M .75, F8	1.3	4.7	25.0	3.7	5.0	8.7	8.3
	M 1.5, F4	2.7	2.0	0	3.7	4.7	6.0	6.3
	M 1.5, F8	3.0	3.0	0	4.0	4.7	6.0	5.7
	M 3.0, F1	1.3	1.0	0	4.3	4.7	5.0	5.3
A-34	M .75, F4	2.3	1.0	1.0	3.0	3.7	4.0	4.7
	M .75, F8	1.0	3.3	8.7	3.7	3.3	6.3	5.3
	M 1.5, F4	2.7	1.3	0	3.0	3.7	4.3	4.7
	M 1.5, F8	1.3	1.0	0	3.7	4.0	5.0	4.0
	M 3.0, F1	3.7	1.0	0	4.7	5.0	5.7	5.7
Adelphi	M .75, F4	2.7	2.7	5.0	3.3	5.0	6.0	6.3
	M .75, F8	1.0	4.3	36.7	3.7	6.0	8.0	7.3
	M 1.5, F4	2.0	2.3	0	3.3	4.3	5.7	5.7
	M 1.5, F8	1.3	2.7	0	4.0	4.7	6.0	5.0
	M 3.0, F1	1.3	1.0	0	4.7	4.3	5.3	5.7
Aquilla	M .75, F4	4.3	1.3	3.3	3.7	5.0	5.0	5.7
	M .75, F8	1.0	4.0	26.7	3.0	3.7	8.0	8.0
	M 1.5, F4	5.3	1.0	0	3.7	5.7	6.0	5.3
	M 1.5, F8	2.0	2.7	0	3.3	4.0	6.7	5.3
	M 3.0, F1	4.0	1.0	0	4.3	4.3	4.0	4.3
Baron	M .75, F4	3.7	1.0	1.0	4.3	4.7	5.3	5.7
	M .75, F8	1.3	5.0	30.0	4.0	5.0	7.7	7.7
	M 1.5, F4	2.7	1.0	0	3.0	4.3	5.0	5.0
	M 1.5, F8	1.3	2.7	0	3.0	3.7	7.0	5.7
	M 3.0, F1	2.0	1.0	0	5.0	4.0	5.0	5.0
Birka	M .75, F4	4.0	1.7	0.3	3.3	5.0	6.0	6.0
	M .75, F8	1.0	4.7	23.3	2.7	4.3	8.3	8.0
	M 1.5, F4	3.7	2.0	0	3.0	4.7	5.3	5.7
	M 1.5, F8	1.0	2.0	0	3.0	4.0	7.3	6.3
	M 3.0, F1	2.7	1.0	0	4.0	3.7	4.3	4.0

Continued

Table 2, continued

Cultivar	Cultural Intensity[1]	Dollar Spot[2] 8/13/76	Fusarium Blight[2] 8/13/76	% Annual Bluegrass	Quality[3] 7/14/76	8/13/76	9/21/76	10/19/76
Bonnieblue	M .75, F4	2.7	2.0	7.0	3.3	4.7	5.7	5.7
	M .75, F8	1.3	4.0	28.3	3.3	4.7	7.7	6.7
	M 1.5, F4	3.3	2.0	0	3.3	4.7	5.3	5.3
	M 1.5, F8	1.7	3.0	0	3.7	4.7	5.3	4.7
	M 3.0, F1	1.3	1.0	0	4.7	4.0	4.7	5.0
Brunswick	M .75, F4	2.0	1.0	1.0	2.7	3.7	3.7	5.3
	M .75, F8	1.0	3.0	8.7	3.0	3.3	5.3	4.7
	M 1.5, F4	2.3	1.0	0	3.0	4.7	4.0	5.3
	M 1.5, F8	1.3	2.0	0	3.0	4.0	3.7	4.0
	M 3.0, F1	2.0	1.0	0	4.0	4.7	5.7	6.3
Cheri	M .75, F4	3.3	2.3	13.7	4.0	4.7	6.0	6.0
	M .75, F8	2.0	5.3	30.0	4.3	5.3	7.3	6.7
	M 1.5, F4	3.3	1.7	0	3.3	4.3	4.7	5.3
	M 1.5, F8	1.7	1.3	0	3.3	4.0	5.3	5.0
	M 3.0, F1	2.0	1.0	0	5.0	4.7	5.0	5.0
Code 95	M .75, F4	2.0	2.7	1.0	4.3	4.7	6.7	6.3
	M .75, F8	1.0	4.3	18.3	3.7	5.0	8.0	7.7
	M 1.5, F4	1.7	4.0	0	3.7	4.3	5.7	5.7
	M 1.5, F8	1.3	4.7	0	3.3	5.7	6.3	5.3
	M 3.0, F1	1.3	1.0	0	3.7	4.7	5.0	6.0
Glade	M .75, F4	3.7	1.0	0.7	3.7	5.0	5.0	5.0
	M .75, F8	1.0	3.7	33.3	4.3	3.7	7.7	7.0
	M 1.5, F4	3.0	1.0	0	3.0	4.3	5.0	4.7
	M 1.5, F8	1.3	1.0	0	2.7	4.0	6.7	5.0
	M 3.0, F1	1.3	1.0	0	4.3	4.3	4.3	4.0
Majestic	M .75, F4	4.3	3.0	23.3	5.0	6.0	7.7	7.3
	M .75, F8	1.3	5.0	40.0	4.7	5.7	8.7	8.0
	M 1.5, F4	2.7	2.0	1.0	4.3	5.7	7.0	7.0
	M 1.5, F8	1.7	2.3	0	3.7	5.0	6.3	6.0
	M 3.0, F1	2.0	1.0	0	5.7	5.3	5.7	5.7

Continued

Table 2, continued

Cultivar	Cultural Intensity[1]	Dollar Spot[2] 8/13/76	Fusarium Blight[2] 8/13/76	% Annual Bluegrass	Quality[3] 7/14/76	8/13/76	9/21/76	10/19/76
Merion	M .75, F4	3.3	1.7	2.3	3.7	4.3	5.7	5.7
	M .75, F8	1.7	3.3	26.7	4.7	4.3	5.3	5.0
	M 1.5, F4	4.0	1.3	0	3.3	4.7	5.0	5.3
	M 1.5, F8	1.3	3.0	0	3.3	4.3	5.3	3.7
	M 3.0, F1	2.3	1.0	0	5.0	5.3	5.3	6.0
Nugget	M .75, F4	4.7	2.3	2.0	4.3	4.7	6.3	6.0
	M .75, F8	1.3	4.3	40.0	4.0	4.7	7.7	8.0
	M 1.5, F4	6.0	2.0	0	4.0	7.0	7.0	6.7
	M 1.5, F8	1.7	3.3	0	4.0	5.0	7.0	6.3
	M 3.0, F1	3.0	1.0	0	4.3	4.7	4.7	5.3
Parade	M .75, F4	3.0	2.0	2.3	4.0	5.0	6.0	6.0
	M .75, F8	1.7	3.0	23.3	4.0	4.3	7.0	6.0
	M 1.5, F4	2.7	1.0	0	4.0	5.0	5.7	5.7
	M 1.5, F8	1.3	2.7	0	3.7	4.7	5.3	5.0
	M 3.0, F1	2.0	1.0	0	4.3	5.0	5.0	5.0
Pennstar	M .75, F4	4.0	2.0	2.3	4.0	5.3	6.3	6.0
	M .75, F8	1.0	4.7	21.7	3.3	5.0	9.0	9.0
	M 1.5, F4	4.3	1.7	0	3.3	5.7	5.7	6.0
	M 1.5, F8	2.3	4.7	0	3.7	6.0	7.3	6.3
	M 3.0, F1	2.3	1.0	0	4.7	4.0	4.3	4.3
Rugby	M .75, F4	2.7	2.0	3.7	4.3	4.7	5.0	5.7
	M .75, F8	1.3	4.0	40.0	5.0	5.0	7.7	6.3
	M 1.5, F4	2.3	1.0	0	3.3	4.0	4.7	4.3
	M 1.5, F8	1.7	1.3	0	4.0	4.0	5.3	3.7
	M 3.0, F1	1.0	1.0	0	5.0	5.3	5.3	5.0
Sydsport	M .75, F4	4.0	1.7	0.7	4.3	4.3	5.3	5.3
	M .75, F8	1.3	4.0	11.7	4.0	4.3	6.7	6.3
	M 1.5, F4	4.3	1.0	0	3.3	5.3	5.3	4.7
	M 1.5, F8	1.0	1.7	0	3.3	4.0	5.0	3.3
	M 3.0, F1	2.3	1.0	0	4.3	4.7	4.7	5.3

Continued

Table 2, continued

Cultivar	Cultural Intensity[1]	Dollar Spot[2] 8/13/76	Fusarium Blight[2] 8/13/76	% Annual Bluegrass	Quality[3] 7/14/76	8/13/76	9/21/76	10/19/76
Touchdown	M .75, F4	3.3	1.7	1.0	3.0	4.3	4.3	5.3
	M .75, F8	1.0	2.0	8.7	3.0	3.0	6.0	5.3
	M 1.5, F4	4.0	1.7	0	3.3	5.0	4.3	5.0
	M 1.5, F8	1.0	1.0	0	2.7	3.0	3.0	3.7
	M 3.0, F1	1.3	1.0	0	4.7	5.0	5.0	5.0
Vantage	M .75, F4	4.7	2.7	1.0	4.7	5.7	7.3	6.3
	M .75, F8	1.3	4.7	50.0	4.7	5.3	8.7	8.3
	M 1.5, F4	3.0	2.3	0	4.3	5.0	6.0	5.3
	M 1.5, F8	1.3	3.7	0	3.7	5.3	7.7	6.0
	M 3.0, F1	2.3	1.0	0	4.3	4.7	5.0	4.7
Victa	M .75, F4	4.7	2.3	1.0	4.3	5.0	6.3	6.3
	M .75, F8	1.0	4.3	28.3	4.7	4.7	7.7	7.3
	M 1.5, F4	3.7	4.0	0	3.7	5.0	5.3	5.7
	M 1.5, F8	1.3	3.3	0	3.3	4.3	6.0	5.7
	M 3.0, F1	2.0	1.0	0	4.0	4.0	4.0	4.7

[1] Cultural intensities: mowing at 0.75-in (M .75), 1.5-in (M 1.5), and 3.0-in (M 3.0); fertilization with 10-6-4 to supply an annual total of 4 lb N/1000 sq ft (F4), or 8 lb N/1000 sq ft (F8), with equal increments applied in April, May, August and September. F1 equals 1 lb N/1000 sq ft applied in May.

[2] Dollar spot and Fusarium blight diseases rated using a scale of 1 through 9, with 1 representing no disease and 9 representing complete necrosis of the plot.

[3] Quality ratings were made using a scale of 1 through 9, with 1 representing perfect quality and 9 representing very poor quality.

Soil Mixes for Golf Green Construction

L. Art Spomer

Plants grow by accumulating raw materials (carbon dioxide, water, minerals, and energy) from their environment. Therefore, our cultural practices for the maintenance of turf on golf greens are oriented toward providing an optimal supply of raw materials to the turfgrass community.

In relation to these cultural practices, the plant and its environment may be partitioned into above-ground (shoot and aerial environment) and below-ground (root and soil environment) portions. The growth of the entire plant depends on the interaction between these different portions. Shoots function as energy (light) and carbon dioxide absorbers, while roots function as water and mineral absorbers.

The turfgrass shoot is well-exposed to its supply of energy and carbon dioxide; however, the root exists in a relatively unfavorable supply environment where replacement of absorbed water and minerals near the root's surfaces occurs very very slowly. So plants have evolved with extensive root systems which often have over a hundred times as much surface as the shoot (even though the shoot may be two or three times heavier than the root), in order to survive their inherently unfavorable terrestrial environment. Thus, the development of an extensive, functioning root system is essential for turfgrass growth and survival.

The development and functioning of this essential root system necessitates an adequate soil environment. Unfavorable soil environmental factors such as poor aeration, compaction, or a lack of water will inhibit proper or sufficient root development and functioning. Actually, many many biological, chemical, and physical factors directly and indirectly affect plant root growth and function. These factors affect soil water retention and movement or plant root growth and absorption.

The primary soil physical factors directly affecting plant water absorption are soil water content and soil aeration. Water content is important because it directly indicates how much water is potentially available for plant use and indirectly how tightly it is held in the soil. Soil aeration (the exchange of oxygen and carbon dioxide between the soil and above-ground atmospheres) is important in maintaining the constant supply of the oxygen required for good root growth and absorption. Both aeration and water retention depend primarily on soil structure or the kind and arrangement of particles in the soil.

This paper briefly considers the optimizing of the golf green soil physical environment through soil mixes.

DRAINED GOLF GREENS

Most drained golf greens have two important features that distinguish them from other golf-course turf sites: (1) they are subject to severe foot and mower traffic; and (2) they are drained. The effects of the traffic are obvious (soil compaction, poor root growth and absorption); however, the effects of the shallow drainage (excess soil water content and poor soil aeration) are less obvious. These effects are generalized in Figure 1. A perched water table forms at the drainage level in such a green following irrigation and drainage [1]. Under these circumstances, any good, medium-textured natural soil is likely to be saturated throughout, and grass growth will probably be poor.

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Both problems are minimized in practice by amending the soil with coarse-textured materials (e.g., bark, calcined clay, gravel, perlite, sand, scoria, vermiculite, etc.) to increase the soil's resistance to compaction and the amount of large or aeration pores which drain in spite of the water table [2]. Unfortunately, too little amendment reduces both soil aeration and water retention without increasing the soil's resistance to compaction. Too much reduces water retention excessively. The "optimum amount" of soil amendment should maximize soil compaction resistance and at the same time provide soil aeration and soil water retention that closely match the requirements for good turfgrass growth and water absorption.

SOIL AMENDMENT: SOIL PHYSICAL CHANGES

Figure 2 shows what happens as a coarse-textured amendment is mixed with soil in increasing proportions. Beginning with a 100-percent soil mixture, porosity decreases then increases with the addition of amendments in increasing proportions. Porosity initially decreases because the amendment "floats" in the soil or excludes soil solids and porosity without adding any large amendment pores. The minimum porosity occurs at the threshold proportion, which is the mixture in which the green is exactly full of amendment and in which the large pores between the amendment particles are exactly full of soil.

In other words, the threshold proportion is determined primarily by the amendment's interporosity. This is called the "threshold proportion" because it delimits the minimum proportion of amendment required before further amendment begins to improve soil aeration. At the threshold proportion, the amendment particles first exhibit particle-particle contact. This also delimits the amount of amendment required to improve the soil's resistance to compaction.

As the proportion of amendment is increased beyond the threshold, the large pores between the amendment particles (amendment interporosity) become voided of soil and both total and aeration porosity increase. This picture suggests a simple mathematical model which can be used to predict mixture total and aeration porosities [2]. This theoretical model has been compared with actual total and aeration porosities of selected amendment soil mixtures. The results demonstrated that the model accurately predicts mixture physical properties. This model is further discussed in a second paper by this author.

CONCLUSION

This article does not recommend any specific soil mixture for putting greens, but briefly describes what happens when an amendment such as sand is added to a soil. The "take-home lesson" is that drained golf greens are different from other turf sites, and therefore require special soil mixes to maintain an adequate soil physical environment for continued root growth and function. Unless these mixes are designed properly, the results can be worse than by using the original site soil.

A certain minimum amount of amendment, the threshold proportion, is required before soil physical improvement is effected, and this amount is usually quite high (75 to 90 percent of the total bulk volume of the components). The optimum soil mixture depends on soil, amendment, climate, drainage depth, and plant species and is, therefore, difficult to determine without professional assistance and previous experience under similar conditions.

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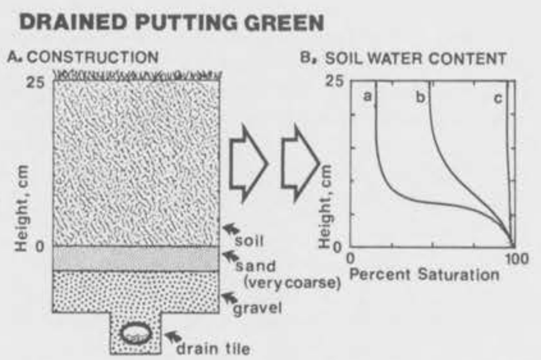

Figure 1. Water distribution pattern (B) for three different soils in a typical drained golf green (A). Soil a = coarse-textured sand; b = A mixture of a and c; c = silty clay loam. All three soils are saturated at the drainage level (perched water table), and the water content decreases with height above this level.

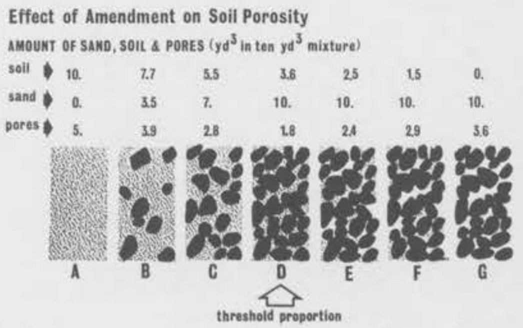

Figure 2. Pictorial diagram illustrating the effect of increasing proportions of coarse-textured amendment on soil water retention, aeration, and compaction resistance.

Golf Green Soil Amendment: Controlling Soil Water and Aeration

L. Art Spomer

Drained golf greens must be backfilled with special soil mixtures during construction in order to avoid excessive water retention (poor aeration) and compaction. The relatively shallow drainage and heavy traffic on these drained greens renders "natural" soils unsuitable for these sites. The purpose of special media is to insure the proper balance between water retention and aeration through control of the pores. This paper briefly discusses a method by which this can be done predictably.

A perched water table forms at the bottom (drainage level) of a drained green soil following irrigation and drainage (Figure 1). Any media in such a green will be saturated at the bottom, and water content will decrease with height above the bottom. Most medium- or fine-textured "natural" soils remain saturated throughout their entire depth following drainage. Turf growing in soil-filled greens is likely to suffer from poor aeration. At the other extreme, a very coarse-textured medium will be saturated at the bottom but will be essentially dry at the top, and turf growing in greens filled with such media will probably suffer from drought.

The main difference between these two media is that the soil contains primarily small water-retention pores, whereas the coarse-textured medium contains primarily large aeration pores which drain despite the water table at the bottom. A well-drained green medium is a compromise between these two extremes. In practice, this is usually attained by mixing very coarse-textured amendments such as sand, calcined clay, perlite, etc. with soil in order to provide enough large aeration pores, while at the same time retaining sufficient water-retention pores to insure adequate growth. Unfortunately, insufficient amendment decreases both water retention and aeration. Excess amendment decreases water retention excessively.

This concept is well-illustrated in Figure 2 which shows the effects of adding amendment to soil in increasing proportions. Insufficient amendment (B, C, D) merely excludes soil volume without adding any aeration pores, so total porosity decreases. At the threshold proportion (D), the green is exactly full of amendment and the aeration pores between the amendment particles are exactly full of soil; consequently, total porosity is at a minimum. Therefore, this is the worst possible soil mixture for growing plants.

As the amendment proportion is increased above the threshold (E, F, G), aeration pores are voided and aeration and total porosity both increase. Looking at this in another way, at and below the threshold (A, B, C, D), amendment particles merely occupy volume in the green without adding any porosity. At and above the threshold (D, E, F, G), the small soil particles fill in the large pores between the amendment particles to varying degrees. This effect of soil amendment on porosity and aeration is summarized in Figure 3.

This same principle holds true in "soilless" golf-green media where one component's particle size is several times larger than those of the other component (e.g., bark and fine-sand mixtures).

The threshold proportion is the minimum amount of amendment that must be added before any improvement in aeration can be expected. The threshold proportion depends on amendment particle shape and, to a lesser extent, on size; and it is a direct function of the aeration porosity of the amendment alone. The threshold proportion for sand, perlite, calcined clay, and similar amendments is approximately 10 volumes of amendment mixed with 4 volumes of soil.

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Therefore, a "safe" golf-green medium should be about 10 volumes of amendment plus about 2-1/2 or 3 volumes of soil. Organic amendments such as peat, bark, and others generally require less amendment to reach the threshold proportion, but are also less desirable for long-term installations if they tend to decompose with time.

This is not a new concept; however, it has only recently been put into a potentially useful form for mixing soils. In the past, golf green media have been developed through inefficient and inaccurate "soil trials," in which plants are grown in a series of media containing different proportions of various components. A simple mathematical model is now being developed which will predict total, aeration, and water-retention porosities for any mixture of soil and amendment if their volumes and original porosities are known [1]. In other words, it is possible to develop media with specific, predictable properties.

Although the mathematics involved is very simple, this model would probably not be directly useful to most golf-course superintendents in its mathematical form; however, Figure 4 illustrates a graphical form which can be constructed if the porosities of the soil alone and the amendment alone are known. The construction of this graphical form will be detailed in future trade and society publications.

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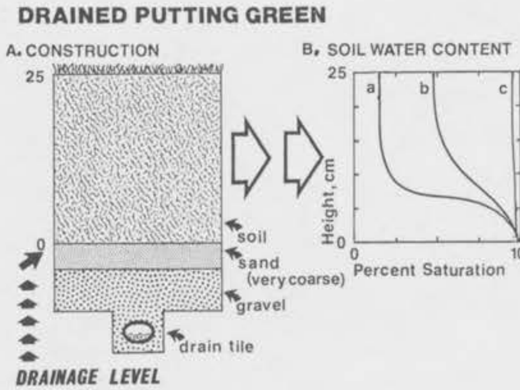

Figure 1. Water distribution pattern (B) for three different "soils" in a typical drained golf green. Soil a equals very coarse-textured sand; c equals silty clay loam; and b equals a mixture of a and c.

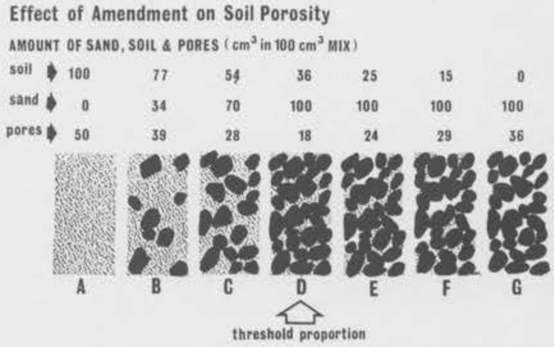

Figure 2. Effect of amendment on soil porosity. The sand is a very coarse-textured river sand. The soil is a slity clay loam. The total bulk volume on the mixture was kept constant.

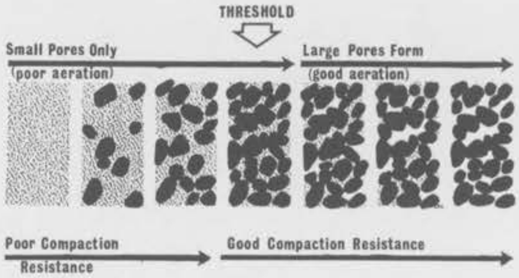

Figure 3. A generalization of Figure 2.

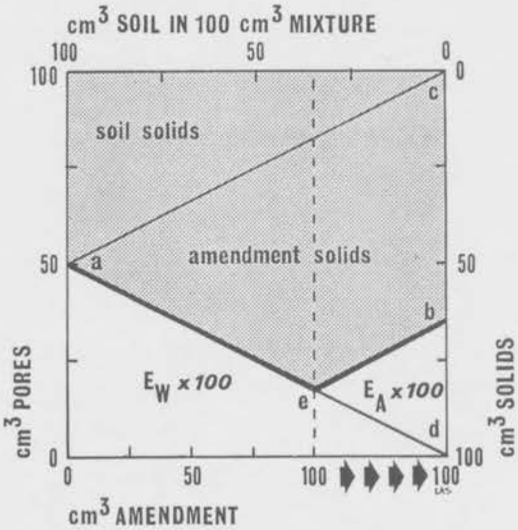

Figure 4. Graphical form of model used to predict soil-mixture physical properties. E_W equals water retention porosity (in drained golf green); E_A equals aeration porosity; a equals soil porosity; and b equals amendment porosity. The dashed line (e) is the threshold proportion. The amount of soil in the mix decreases from left to right (proportion of amendment increases). Total porosity equals E_W plus E_A.

Turfgrass Research at Southern Illinois University—Carbondale

H.L. Portz

The present turfgrass research program at SIU-C was begun in 1974. Because of the geographic location of SIU in the transition zone of United States, the research emphasis there is on the adaptation, management, and low-temperature problems of this area. Last year, the overall program was described. Today, preliminary results on several of the experiments will be given. Most experiments should have additional years for meaningful and reliable results.

A comparison of Kentucky bluegrass cultivars and blends indicates that the blends have better general appearance ratings than the individual component cultivars (Table 1).

Table 1. Comparison of Selected Kentucky Bluegrass Cultivars and Blends, 1976, SIU-C

Cultivars	General appearance[a]	Blends	General appearance
Adelphi	3.6		
Aquila[b]	3.1	A[b]	3.0
Parade	3.1		
Adelphi	3.6	AA	2.9
Aquila[b]	3.1		
Aquila[b]	3.1	AV	2.7
Vantage	3.3		
Common[b]	3.6	C	2.5
Baron	3.1		
Pennstar	3.2		
Majestic	3.2	P	3.2
Nugget	4.5		
Windsor	3.3		
Vantage	3.3	W	3.0
Victa	3.0		
All cultivars	3.4	All blends	3.0

[a]General appearance rating: 1 = best; 9 = poorest.
[b]Represents the average of two experiments.

A dry summer placed considerable stress on cool-season turfgrasses. A number of Kentucky bluegrass cultivars showed very good tolerance to these conditions. Others showed considerable wilt. Many went almost completely dormant (Table 2). The tall fescues showed very good drouth and heat tolerance.

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Table 2. Heat and Drouth Stress Tolerance of Kentucky Bluegrass Cultivars and Blends, Carbondale, Illinois, September 3, 1976

Very good	Good	Fair	Poor
Adelphi	Baron	Majestic	Aquila
Brunswick	Vantage	Pennstar	Touchdown
Merion	Victa	Windsor	Common
Sydsport	Warren's A-20	Ky. blends	Birka
	Warren's A-34	Cheri	Newport
		Code 95	
		Nugget	
		Parade	

Several tall fescue cultivars were equal to or better in general appearance than Ky 31 (Table 3). Tall fescue and Kentucky bluegrass mixtures in a ratio of 95:5 by seed weight were superior to a 70:30 mixture. Baron Kentucky bluegrass was the best of individual cultivars at 10 percent of a tall fescue/Kentucky bluegrass mixture (Table 3). Pennfine perennial ryegrass was a better component in a tall fescue/Kentucky bluegrass/Perennial ryegrass mixture than either Manhattan or Yorktown. The latter two were severely thinned by dollar spot. Kenwell tall fescue was somewhat better in the above mixtures than Ky 31 tall fescue (Table 3).

Table 3. Summary of Tall Fescue Cultivars and Mixtures, Carbondale, Illinois, 1976

A. Tall fescue cultivars		Grams per 35 sq. ft.	Rating[a]
Ky 31 (3 expts.)		90 to 100[b]	3.9
Kenwell		90	3.6
Kenhy (T. fescue x P. ryegrass)		90	3.6
K8-108 (NK)		90	3.4
K4-206 (NK)		90	3.5
B. Tall fescue and Kentucky bluegrass mixtures			
Ky 31	Vantage, Victa	70/30	3.5
Ky 31	Vantage, Victa	85/15	3.5
Ky 31	Vantage, Victa	95/15	3.3
Ky 31	Common	90/10	3.8
Ky 31	Majestic	90/10	3.7
Ky 31	Nugget	90/10	3.7
Ky 31	Baron	90/10	3.3
C. Tall fescue, Perennial ryegrass, and Kentucky bluegrass mixtures[c]			
Ky 31	Pennfine	60/20/7	4.1
Ky 31	Manhatton	60/20/7	4.9
Ky 31	Yorktown	60/20/7	4.8
Kenwell	Pennfine	60/20/7	4.1
Kenwell	Manhattan	60/20/7	4.5
Kenwell	Yorktown	60/20/7	4.4

[a]General appearance rating: 1 = best; 9 = poorest.
[b]Approximately 6.3 lb./1,000 sq. ft.
[c]Kentucky bluegrass was a blend of Baron 50 percent, Bonnieblue 25 percent, and Majestic 25 percent.

Late-fall nitrogen fertilization of Kentucky bluegrass was tested for its effect on winter color and carbohydrate reserves. It is generally accepted that a complete-analysis fertilizer applied in the cool, sunny days of fall helps build a large plant storehouse especially favoring good root growth. Soluble nitrogen applied in the late fall when the weather is cold and shoot growth is greatly retarded fills the storehouse. In this fertilization study, 1 pound of N per 1,000 square feet of 12-12-12 was applied on October 1. Soluble N (ammonium nitrate) was applied at different dates and two rates throughout the fall and winter of 1975-76. In most of the fall and early winter applications, early spring greenup and good uniform growth until May were noted. Visual color ratings taken on March 10 and carbohydrate reserves as determined by clippings from a dark test were evaluated. Although green color was better with the rate of 3 pounds of nitrogen per 1,000 square feet rate at nearly all dates, the carbohydrate reserves were considerably lower than from the 1.5-pound rate. A November 13 date and a 1.5-pound rate seemed most desirable in 1975-76.

Eighteen Bermudagrass cultivars and nine zoysiagrass cultivars were established by sprigging and plugging at Carbondale in 1975. Twelve Bermudagrass and ten zoysiagrass cultivars were established at the Old Warson Country Club in 1975. In addition to winter hardiness, these cultivars are being checked for rate of establishment, general appearance, disease susceptability, and other qualities. In 1976, vegetative propagation by stolonizing was very successful with Meyer zoysiagrass and Tufcote bermudagrass; the latter being more aggressive than U-3, Tiflawn, or Tiffine bermudagrass cultivars. Preemergence herbicides were tested on Meyer zoysiagrass. Simazine showed very good weed control, but was somewhat phytotoxic. Tupersan and Kerb were good in weed control and not excessively phytotoxic. Treating the stolons with activated charcoal before stolonizing and using preemergence and postemergence herbicides will be tested next year.

Color loss in fall in both bermudagrass and zoysiagrass occures when temperatures approach 32° F. Color retention by use of several chemicals and nitrogen fertilization is being tested. Late-summer and early-fall nitrogen treatments gave a dark-green color prior to fall frosts, but the severe freezing starting about October 8 quickly killed the leaf tissues. Gibberellic acid-treated plots seemed to hold color slightly longer than plots treated with other chemicals. Cold tolerance will be checked in the spring to see if N fertilization and/or chemicals adversely affected winter survival.

Cool- and warm-season turfgrass mixtures also have potential for providing acceptable winter color and other characteristics. Meyer zoysiagrass and Ky-31 tall fescue and Midwest zoysiagrass and Ky-31 tall fescue mixtures have been successfully established. Common bermudagrass and a Kentucky bluegrass blend were seeded in July and the Kentucky bluegrass was reseeded in the fall after verticutting. Different cultural and fertilizer practices will be imposed to see if acceptable turf can be maintained with these mixtures during the season.

New Approaches to Annual Bluegrass Control

Ralph E. Engel

What is the role of annual bluegrass in turf? Usually, the annual bluegrass is unwanted, which keeps us on a search for control measures. While we are oriented toward annual bluegrass control, we must remember that this grass often occurs as our major turfgrass. This means there are occasions when we should back off on control and temporarily, at least, grow annual bluegrass. In some of the milder temperate latitudes, the loss of annual bluegrass is less common because of more complete maintenance; sometimes, it may be the best grass for the site. Its failure often assumes disastrous proportions where severe weather occurs, during the winter or summer.

The methods of controlling annual bluegrass may be classified as cultural, herbicidal, or a combination of both. What is new on these subjects varies with the person, but the new should fit with the old.

Preemerge herbicides such as benefin, bensulide, and DCPA are available for annual bluegrass control; but their use is not appealing when effectiveness is weighed against the cost and the risk to the turf. These chemicals do not pose the risk of calcium arsenate, which has been the most widely used and successful chemical control. While calcium arsenate is not marketed, it is of interest because the control achieved with it occurred, in part, because of its postemerge action. Since more successful preemerge herbicides have been found for annual bluegrass control in bermudagrass, there is hope that better preemergance herbicides will be discovered for cool-season turf. In our northern climates, the annual bluegrass herbicide of the future will need to have postemergence as well as preemerge action to eliminate annual bluegrass.

If a herbicide program is contemplated, the use of postemergence types should be a part of the program in order to destroy those plants that survive vegetatively from year to year. Let us consider the postemerge types. In the 1950's, we found that early spring treatments of endothal gave worthwhile reductions in our area. Dr. Turgeon did some work with this chemical more recently. It has never caught on significantly with the growers. However, I still believe it can be useful in our area when two or three light applications are applied before the warmer spring weather arrives. This program will control clover. At the time we used endothal, we applied maleic hydrazide as a spring treatment at a rate of 1 to 1-1/2 pounds per acre with good results on annual bluegrass. However, we found this was too damaging to bentgrass. Maleic hydrazide is liked by some for fall treatments of annual bluegrass. Recently, we used maleic hydrazide at 3 pounds per acre in the fall. This gave good action on annual bluegrass, but I am not sure if fall treatment has adequate selectivity over bentgrass. I know it does not on the turf-type ryegrasses which are coming into greater use in areas troubled with annual bluegrass.

We need better postemergance herbicides to supplement those with preemergance action. One of the problems with postemergance herbicides on annual bluegrass sites is that an effective chemical which eliminates the weed necessitates either a fabric of desirable grasses on the site or the quick introduction of the desired species.

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A review of the potential for herbicidal control of annual bluegrass forces us to accept management as the major tool. In the Northeast, management can go a long way in reducing annual bluegrass problems. This approach can take two courses: directing all effort at reducing annual bluegrass or doing everything to save the annual bluegrass. I would follow the second course only when survival of the annual bluegrass is a necessity for use of the turf site. While management of the first type will not eliminate annual bluegrass under a close-cut program, it can provide enough of the permanent-type grasses to minimize the high risk of annual bluegrass turf.

Using the management tools to control annual bluegrass is the real test of the fine-turf superintendent. These tools can be summarized as follows:

1. Use the minimal amount of water to save the desired grass. Frequent watering aids annual bluegrass, especially in the late summer and early fall.

2. Use only enough nitrogen to give the required amount of growth for the desired species. Use small applications of nitrogen when bentgrass is the one desired.

3. Avoid nitrogen stimulation in the late winter and early spring periods; also, in the late summer and fall if possible.

4. Small applications of nitrogen are desirable from late spring through mid-summer if they do not lead to serious truf loss.

5. Some who are located in the open winter belt like dormant fertilization on annual bluegrass-bentgrass type turf. I am not enthusiastic about this procedure where bentgrass is concerned. If dormant fertilizer should be desirable, our tests support the use of urea over IBDU, ureaform, or activated sewage sludge. I do not know how other carriers would fit in.

6. Control diseases.

7. Spread out the traffic to avoid serious thinning or loss of turf.

8. Maintain continuous cover and assure maximum density from late summer through the fall season. Do this through:

   a. Disease control.

   b. Assuring good growth and cover at the end of summer.

   c. Avoiding thinning and cultivating in the late summer and fall, except to introduce seed.

   d. Promptly revegetating bare areas.

   e. Raising the height of the cut slightly in the late summer and fall, if necessary, to keep good cover against annual bluegrass. Certainly do not markedly lower the height of the cut during that season.

9. Watch new grasses for their ability to compete with annual bluegrass.

In summary, the total domination of annual bluegrass on New Jersey turf areas need not be accepted as a fact of life. In my opinion, we should do all that is reasonable to minimize annual bluegrass and at the same time avoid abrupt, large-scale loss of this grass. Over a period of time, this prodecure shifts the sward toward the permanent type grasses.

Managing Bent Greens for Summer Quality

A.J. Powell, Jr.

If you were to survey golf-course superintendents concerning their main summer problems, summer disease would rank high on the list. Yet, basically, we have very good fungicides that are effective against most diseases. However, fungicides are not miracle products. If we control one disease, another occurs. If we control the second disease then an insect or nematode problem may occur, and the story goes on.

To find a solution, however, we must realize that these outside agents may not be the real problem. The bentgrass plant is under severe stress during the summer. The overall problems relate to a poor summer root system, low energy reserves, and possibly lush summer growth. All of these factors relate to the annual management program.

We must stop and ask ourselves what can be done in previous growth seasons to make the turf better or stronger during the summer. There is definitely more to this matter than just reacting to the problem. Many times we try and manage our greens by the seat of our pants. If the grass is not growing, you fertilize it; if it is wilting, you water it; if it is diseased, you dope it; but taking revenge on the problem will not keep it from occurring again.

We need to look at our management program season by season, to determine how one management factor will affect the turf during the next summer. For example, determining turf nitrogen needs only by looking at the grass is not the answer. If you rely totally on this method, you tend to over-fertilize during the spring and summer and do not develop a plant that is able to withstand summer stress. The detrimental affects of heavy nitrogen fertilization during the spring are great, but the misuse of spring nitrogen does not manifest itself until the summer. On the other hand, if you follow a rigid program for nitrogen fertilization, that will not always give you optimum plant-growth. There are too many variables, such as the weather, soil type, and the desired use of the turf.

NITROGEN FERTILIZATION

Fall is certainly the best time to fertilize temperate grasses with nitrogen. Fall nitrogen increases color and growth as well as root development, tiller initiation, and tiller development--all adding to turf density. Likewise, in most climates, nitrogen applied in the winter increases the density and root growth of cool-season grasses and certainly lengthens the early spring playing season.

Nitrogen applied in the spring and summer may result in a big yield, but will also tend to decrease root growth and to increase problems with diseases, weeds, thatch, and wilt.

Spring nitrogen forces growth but makes the turf weak. The best nitrogen program is one in which you make "planned" applications of nitrogen during the fall and winter and then follow an anti-spring and summer N program. Obviously, you cannot always eliminate nitrogen in the spring and summer, but you should make N applications only when it is necessary to increase top growth. Some top growth during the summer is necessary so the turf can repair itself or can recover from the normal wear and use stresses. If a lack of color is the problem, foliar applications of iron can correct that. During the spring and summer, one can easily watch the amount of clippings removed and only make light N applications when growth is insufficient.

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SPRING AERIFICATION

One of the main benefits of coring greens is to improve the exchange of air and water between the soil and the atmosphere. Coring encourages deeper and more extensive rooting. The roots are growing in the spring, but the water infiltration problems that we normally confront occur in the summer.

If greens are aerified in the early spring, the beneficial effects may be completely lost by summer; if so, the greens often become very compacted and impervious. If greens are to receive only one spring aerification, then delay the aerification until the late spring. This maximizes the water infiltration rates during summer and minimizes localized dry spots.

IRRIGATION MANAGEMENT

No one can tell you how to water your greens. They are all different. You have control of the irrigation program in the spring and fall, but the grass itself dictates the irrigation program during the summer. A minimum irrigation frequency is very important to obtain maximum root growth during the spring and fall; but in the summer when roots are normally short and evapotranspiration rates are high, a frequent irrigation program is necessary. If you do not get maximum root growth in the fall, winter, and spring, you can expect an excess of summer irrigation troubles.

MOWING MANAGEMENT

The golfers themselves greatly influence our mowing heights and frequencies. On some courses the greens must be mowed daily, yet on others the membership seems to be satisfied with three to four cuttings a week. In order to get maximum top and root growth, remember that a less-frequent mowing pattern is usually superior. Anytime the grass is under stress, delayed mowing can be very beneficial. Excessive frequency and very short mowing heights in the spring can result in shorter and less vigorous roots in the summer.

SUMMARY

If we neglect or over-manage greens during the cool seasons of the year, we can expect more problems during the summer. Look at each management practice and determine how it may affect the bentgrass as it enters the summer stress period.

Bent Grass Response to Aquatic Herbicides In Irrigation Water

R.C. Hiltibran and A.J. Turgeon

In November of 1972 at the annual Illinois Turfgrass Conference, a discussion was presented about the control of aquatic plants in bodies of water that may serve as sources of irrigation. Suggestions were also presented then for the use of aquatic herbicides. In 1972, however, we did not know what effects aquatic herbicides in irrigation water might have on turf grasses. Later, a cooperative investigation was initiated by the Department of Horticulture and the Natural History Survey to determine the effects of aquatic herbicides contained in a simulated irrigation water on creeping bent grass turf. A preliminary report was presented in November of 1974. Additional studies were conducted in 1975.

Research on aquatic plant control has continued, and suggestions for the use of aquatic herbicides have been revised. The current suggestions are included here. Since the use of aquatic herbicides in irrigation ponds and lakes depends on what aquatic plants are present, a discussion follows on plant groupings and herbicide applications.

For convenience in presenting suggestions about the use of aquatic herbicides, aquatic plants have been grouped according to their distribution in water. There are four main groupings.

EMERGENT AQUATIC PLANTS

These plants are rooted in the hydrosoil. The foliage, flowers, and fruiting bodies extend above the surface of the water. Emergent aquatic plants primarily inhabit the shallow water around the margins of ponds and lakes. A typical example of such plants is the common cattail, *Typha latifolia* L. Additional examples are shown in Figures 16 and 17.

SUBMERSED AQUATIC PLANTS

Usually, these plants are also rooted in the hydrosoil. Their leaves, flowers, and fruiting bodies may reach the water surface. The flowers and fruiting bodies may extend above the surface for short periods, then later floating on or just below the surface of the water. To help with identification, these submersed plants have been divided into three groups based on the attachment of the leaves to the center stem.

SUBMERSED AQUATIC PLANTS WITH AN ALTERNATE ATTACHMENT OF THE LEAVES. An excellent example is shown in Figure 9. This grouping of aquatic plants consists primarily of the *Potamogeton* family, which in general is not susceptible to the phenoxy type of aquatic herbicides. Representative examples are shown in Figures 4, 16, 13, and 14. Species in the *Potamogeton* family are controlled easily by using potassium endothall.

SUBMERSED AQUATIC PLANTS WITH AN OPPOSITE ATTACHMENT OF THE LEAVES. Two leaves are attached to the center stem. There are representatives of several families of aquatic plants in this group, and different aquatic herbicides can be used to control them. Examples of plants in this group are shown in Figures 3, 10, 11, and 12. (In Figure 8, the opposite leaf was removed before the photograph was taken).

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SUBMERSED AQUATIC PLANTS WITH A WHORLED ATTACHMENT OF THE LEAVES. This group of plants is characterized by four leaves attached to the center stem at the same point. The leaves may be complex or simple, and can vary in texture and shape. Again, several families of aquatic plants are represented in the group. Examples are shown in Figures 1, 3, and 18.

AQUATIC PLANTS WITH FLOATING LEAVES

This group is characterized by various-shaped leaves that float on or near the surface of the water. Some aquatic plants may also have submersed leaves of a different texture and structure. The common water lily, *Nymphaea odonata* Ait., probably is the most common example of the plants in this group. The water lily is noted for its large round leaves. Examples of other plants in the group are shown in Figures 4 and 5.

FREE-FLOATING AQUATIC PLANTS

The main characteristic of this group is that these plants float freely on or near the surface of the water. Two examples of aquatic plants in this group are common duckweed, *Lemna minor* L., and watermeal, *Wolffia columbiana* Hurst. The common duckweed consists of two leaf-like structures called fronds, with a single root attached to each frond. Each duckweed plant produces 3 to 7 seeds. The duckweed develops from a seed into a seed-producing plant in three days. It is difficult to control duckweed and watermeal because of the large number of small plants and their reproductive potential. Repeated applications of aquatic herbicides may be necessary in order to realize control.

AQUATIC PLANTS WITHOUT A VASCULAR SYSTEM

The primary family in this group is algae, another kind of troublesome aquatic plant. In contrast to the well-developed vascular systems of the plants discussed above, algae have no vascular system. There are three main types of algae.

FILAMENTOUS ALGAE. These plants consist of single-filament cells. The individual filaments attach themselves to other filaments, debris, or other aquatic plants in the water. Soon, a mat of algae may float on the surface or occupy the water space. These mats of filamentous algae are responsible for the unsightly appearance of many bodies of water in Illinois during the late summer. Removing the stand of submersed aquatic plants will often reduce the filmentous algae present in the late summer.

PHYTOPLANKTON ALGAE. This group consists of small single cells that remain suspended in the water. They have various shapes, and some phytoplankton algae form clusters or clumps of cells. The plytoplankton algae are responsible for the so-called "blooms" of algae that cause many bodies of water to have a green or yellow-green color by late summer. Plytoplankton provide some benefits, in that they produce shade and prevent the development of submersed aquatic plants. When the density of the algae cells becomes sufficient, however, layers of algae cells will float on the surface of the water.

HIGHER-BRANCHED ALGAE. The distinction here is that these algae form highly branched structures that resemble vascular plants in appearance; hence, higher-branched algae are frequently misidentified as vascular aquatic plants. In the higher-branched algae, there are two primary families, *Chara* and *Nitella*. *Chara vulgaris* is commonly called muskgrass. It has a pungent odor and is coarse or rough to the touch. *Chara vulgaris* is shown in Figure 3. Plants in the *Nitella* family are smooth and do not produce a pungent odor.

Many aquatic herbicides are not effective against algae. Hence, when treating algae, one must be careful to use an aquatic herbicide that will be effective. (See Table 1.)

AQUATIC PLANTS FOUND IN ILLINOIS

The seventeen plants commonly found in the water of Illinois are shown in the accompanying set of figures. Please note that Figures 4 and 14 show the fine-leaved pondweed as a young and a mature plant, respectively.

A particular aquatic plant may not be shown in the figures, which cover only the seventeen common ones, or may not be included in the suggestions for aquatic herbicide usage. If so, contact the Illinois Natural History Survey, Aquatic Section, in Urbana or your county Extension Adviser in Agriculture.

The following list of the eighteen figures gives the common and technical names of the seventeen aquatic plants found most often in Illinois waters.

Figure 1--coontail, *Ceratophyllum demersum* L.
2--chara, *Chara vulgaris*
3--northern water milfoil, *Myriophyllum exalbescens* Fernald
4--leafy pondweed, *Potamogeton foliosus* Raf. (young plant)
5--American pondweed, *Potamogeton nodosus* Poir.
6--sago pondweed, *Potamogeton pectinatus* L.
7--water buttercup, *Ranunculus trichophyllus* Chaix
8--cabomba, *Cabomba caroliniana* Gray
9--curly leaf pondweed, *Potamogeton crispus* L.
10--southern naiad, *Najas guadalupensis* (Sgreng.) Magnus
11--bushy pondweed, *Najas gracillima* (A. Br.) Magnus
12--slender naiad, *Najas flexilis* (Willd.) Rostk. & Schmidt
13--small pondweed, *Potamogeton pusillus* L.
14--leafy pondweed, *Potamogeton foliosus* Raf. (mature plant)
15--vasey pondweed, *Potamogeton vaseyi* Robbins
16--hard stem bulrush, *Scirpus acutus* Muhl.
17--water willow, *Justicia americana* (L.) Vahl
18--elodea, *Elodea canadensis* Mich.

AQUATIC HERBICIDES ON TURFGRASS

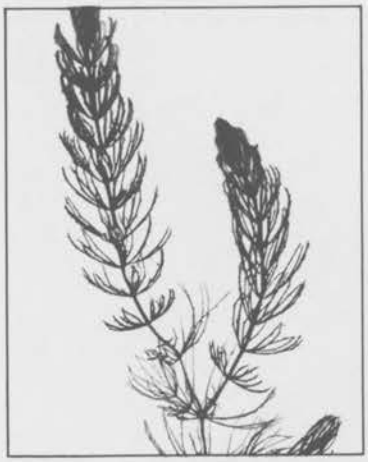
The suggested application rates for various aquatic herbicides are summarized in Table 1. To estimate the effects of aquatic herbicides on turfgrasses, these rates were added to 9.8 gallons of water and applied in triplicate to plots of creeping bentgrass putting-green turf. The plots were 30 feet square. Such an application is equivalent to half an inch of irrigation water. An inch of irrigation water was applied per week. Several application sequences were utilized. Single spring applications of simulated irrigation water were made on May 30 and June 6, 1974. Spring-summer applications were made on May 30, June 6, and July 29-30; summer-summer applications, on July 27 and on August 1, 7, and 8. A multiple-summer application consisting of six consecutive weekly applications was initiated on August 14.

The aquatic herbicides did not cause any damage to the bentgrass following the single spring application. Dichlobenil, diquat, and silvex caused some damage after the spring-summer and summer-summer applications. The damage was greater after the summer-summer application sequence than following the spring-summer applications. Aquatic herbicide formulations containing dichlobenil, diquat, silvex, 2,4-D, and simazine caused damage to the turfgrass following the multiple-summer application sequence.

The application rates used in our study for simazine and dichlobenil produced greater-than-normal concentrations of these aquatic herbicides in the pond water. The investigation was extended in 1975, and the application rates of these herbicides were at concentrations normally expected in pond water following treatment. Additional simazine was applied to a small pond at 0.5 milligram per liter. The water was removed and applied to turfgrass. In these experiments, dichlobenil did not cause any damage to the bentgrass, but injury was observed following the application of water containing simazine.

The potential hazards for turfgrass from using aquatic herbicides are summarized in Table 1. Recommendations for controlling specific aquatic plants are given in Table 2.

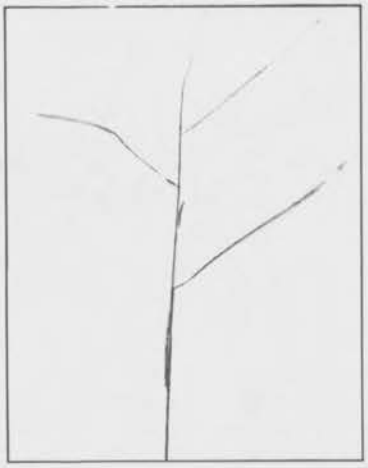
The actual hazard associated with using aquatic herbicide-treated pond water for irrigating turfgrass largely depends on the placement and residual toxicity of the herbicides in the aquatic environment. Dichlobenil is a highly toxic to turfgrass when uniformly distributed



Coontail
Figure 1

Chara (an Alga)
Figure 2

Water Milfoil
Figure 3



Fine-leaved Pondweed
Figure 4

Floating-leaved Pondweed
Figure 5

Sago Pondweed
Figure 6

Aquatic Buttercup
Figure 7

Fanwort
Figure 8

Curly-leaved Pondweed
Figure 9

Najas guadalupensis
Figure 10

Najas gracillima
Figure 11

Najas flexilis
Figure 12

BUSHY PONDWEEDS

Potamogeton pusillus
Figure 13

Potamogeton foliosus
Figure 14

FINE-LEAVED PONDWEEDS

Potamogeton vaseyi
Figure 15

FLOATING-LEAVED PONDWEED

Bulrush
Figure 16

Water Willow
Figure 17

Elodea
Figure 18

in the pond water. However, dichlobenil is usually applied in a granular formulation, which rests at the bottom of the pond. Consequently, very little dichlobenil can be detected in water taken from treated ponds. This explains why no turfgrass injury resulted from using irrigation water containing expected concentrations of dichlobenil following pond treatment in the 1975 study.

Other moderately toxic to highly toxic herbicides--including 2,4-D ester, diquat, and silvex--are tied up quickly by the hydrosoil after pond treatment. Therefore, a one- to two-day waiting period between pond application and subsequent irrigation with the water from the pond should be adequate to prevent injury to turfgrass.

Simazine was the only herbicide that was injurious to the turf in all studies. Apparently, this herbicide can accumulate in turf irrigated with simazine-treated water, eventually causing severe injury.

Table 1. Potential Hazard From Aquatic Herbicides In Irrigation Water to Creeping Bentgrass Turf

Aquatic herbicide	Rate, ppm[a]	Hazard[b]
Copper sulfate	1 (Copper)	Low
Copper-triethanolamine complex[c]	1 (Copper)	Low
Diuron	0.25	Low
Endothall		
potassium salt	1	Low
N,N-dimethylalkylamine salt[d]	1	Low
mono (dimethyltridecylamine oxide)	1	Low
di (dimethyltridecylamine oxide)	1	Low
Fenac	2	Low
2,4-D		
dimethylamine salt	2	Low
butoxyethanol ester	2	Moderate
butoxyethanol ester	4	Moderate
Diquat	1	Moderate
Diquat + copper-triethenolamine	1+1 (copper)	Moderate
Dichlobenil	2	High
	1	Moderate
Silvex		
butoxyethanol ester	2	High
potassium salt + endothall[e]	2+1	Moderate
Simazine	0.5	High

[a]Rates expressed as acid equivalent or active ingredient of each herbicide rather than as salt or ester formulation.
[b]Hazards expressed as: low (little likelihood of turfgrass injury from use), moderate (some thinning and discoloration of turf), and high (severe injury or loss of turf).
[c]Cutrine Plus
[d]Hydrothol-47
[e]Aquathol Plus

Table 2. Chemical Control of Some Aquatic Plants

Group and species	Chemical, active ingredient, or free acid equivalent	Rate of application	Remarks
EMERGENT AQUATIC PLANTS			
Arrowhead (*Sagittaria* spp.)	Use one of the following:		
	2,4-D		
	ester (20% G)	1 lb./440 sq. ft.	Spread on water
	ester (4 lb./gal.)	1/4 cup/2 gal.	Wet foliage
	amine (4 lb./gal.)	1/4 cup/2 gal.	Wet foliage
	silvex		
	ester (4 lb./gal.)	1/4 cup/2 gal.	Wet foliage
	potassium salt (6 lb./gal.)	1/4 cup/2 gal.	Wet foliage
	potassium salt (20% G)	1 lb./440 sq. ft.	Spread on water
	diquat cation (2 lb./gal.)	1/4 cup/gal.	Wet foliage
Bulrush (*Scirpus acutus*)	Use one of the following:		
	2,4-D		
	ester (20% G)	1 lb./440 sq. ft.	Spread on water
	ester (4 lb./gal.)	1/2 cup/2 gal.	Wet stems
	diquat cation (2 lb./gal.)	2 tbsp./3 gal. and 1 tsp. nonionic wetting agent	Wet foliage to point of runoff
	dichlobenil (aquatic granules 4%)[a]	100 lb./A.	Apply in March to exposed bottom soil
Cattails (*Typha* spp.)	Use one of the following:		
	dalapon	4 oz./gal. and 3 caps detergent	Wet foliage
	amitrole	2 oz./gal. and 3 caps detergent	Wet foliage
	2,4-D ester (4 lb./gal.)	1/2 cup/gal. and 3 caps detergent	Wet foliage
	diquat cation (2 lb./gal.)	2 tbsp./3 gal. and 1 tsp. nonionic wetting agent	
Creeping water primrose (*Jussiaea repens* var. *glabrescens*)	Use one of the following:		
	2,4-D		
	ester (20% G)	1 lb./440 sq. ft.	Spread on water
	ester (4 lb./gal.)	1/4 cup/2 gal.	Wet foliage
	amine (4 lb./gal.)	1/4 cup/2 gal.	Wet foliage
	silvex		
	ester (4 lb./gal.)	1/4 cup/2 gal.	Wet foliage
	potassium salt (6 lb./gal.)	1/4 cup/2 gal.	Wet foliage
	potassium salt (20% G)	2 lb./440 sq. ft.	Spread on water
	diquat cation (2 lb./gal.)	1/4 cup/2 gal.	Wet foliage
Spatterdock (*Nuphar advena*)	dichlobenil	6 lb.a.i./A 3 lb.4% granules[a] per 440 sq. ft.	Spread on water

(cont'd)

[a]The formulation currently available may contain 10-percent dichlobenil; therefore, the amount of granular formulation used will have to be adjusted.

Group and species	Chemical active ingredient, or free acid equilavent	Rate of application	Remarks
Waterwillow *(Justicia americana)*	Use one of the following:		
	2,4-D		
	ester (20% G)	1 lb./440 sq. ft.	Spread on water
	ester (4 lb./gal.)	1/4 cup/2 gal.	Wet foliage
	amine (4 lb./gal.)	1/4 cup/2 gal.	Wet foliage
	silvex		
	ester (4 lb./gal.)	1/4 cup/2 gal.	Wet foliage
	potassium salt (6 lb./gal.)	1/4 cup/2 gal.	Wet foliage
	potassium salt (20% G)	1 lb./440 sq. ft.	Spread on water
	diquat 2 lb./gal.)	1/4 cup/2 gal.	Wet foliage
SUBMERSED AQUATIC PLANTS WITH ALTERNATIVE LEAF ATTACHMENT			
Curlyleaf pondweed *(Potamogeton crispus)*	Use one of the following:		
	endothall (potassium salt, 4.23 lb./gal. or 10% G)	0.3 ppm (total or large-scale application) 1.0 ppm (marginal application)	Apply on or below surface
	diquat (2 lb./gal.)	0.5 ppm or 1 gal./ surface A.	Same as above
	dichlobenil (aquatic granules 4%)	200 lb./A.	Preemergent application
	fenac	See manufacturer's directions	Must be applied to exposed pond bottom
	diquat/copper-triethanolamine complex	0.25 ppm diquat plus equal volume of copper-triethanolamine complex	Apply on or below water surface
	di (N,N-dimethylalklamine) salt of endothall (Hydrothol-47); (L)	0.5 ppm (endothall content)	Apply on or below water surface
	Hydrothol-47 (10% G)	100 lb./A	Spread on water
	simazine (80-WP)	0.5 ppm	Apply to total water volume
Leafy pondweed *(P. foliosus)*	Use one of the following:		
	endothall (potassium salt, 4.23 lb./gal. or 10% G)	0.3 ppm (total or large-scale application) 1.0 ppm (marginal application)	Apply on or below water surface
	diquat cation (2 lb./gal.)	0.5 ppm, or 1 gal./ surface A.	Same as above
	dichlobenil (aquatic granules 4%)	300 lb./A.	Preemergent application[b]
	fenac (10% G)	See manufacturer's directions	Must be applied to exposed pond bottom

(cont'd)

[b]The preemergent herbicides have not given satisfactory season-long control of leafy pondweed.

Group and species	Chemical, active ingredient, or free acid equivalent	Rate of application	Remarks
Leafy pondweed (*P. foliosus*) (continued)	Hydrothol-47 (10% G)	100 lb./A.	Spread on water
	simazine (80-WP)	0.5 ppm	Apply to total water volume
Sago pondweed (*P. pectinatus*)	Use one of the following:		
	endothall (potassium salt, 4.23 lb./gal. or 10% G)	0.3 ppm (total or large-scale application) 1.0 ppm (marginal application)	Apply on or below water surface
	diquat cation (2 lb./gal.)	0.5 ppm, or 1 gal./surface A.	Same as above
	dichlobenil (aquatic granules 4%)	100 lb./A.	Preemergent application
	fenac (10% G)	See manufacturer's directions	Must be applied to exposed pond bottom
	simazine (80-WP)	0.5 ppm	Apply to total water volume
Small pondweed (*P. pusillus*)	Use one of the following:		
	endothall (potassium salt, 4.23 lb./gal. or 10% G)	0.3 ppm (total or large-scale application) 1.0 ppm (marginal application)	Apply on or below water surface
	diquat cation (2 lb./gal.)	0.5 ppm	Same as above
	dichlobenil (aquatic granules 4%)	200 lb./A	Preemergent application
	fenac (10% G)	See manufacturer's directions	Must be applied to exposed pond bottom
	Hydrothol-47 (10% G)	100 lb./A	Spread on water
	simazine (80-WP)	0.5 ppm	Apply to total water volume
Waterstar grass (*Heteranthera dubia*)	diquat cation (2 lb./gal.)	1 ppm, or 2 gal./surface A.	Apply on or below water surface
	endothall (potassium salt, 4.23 lb./gal. or 10% G)	5 ppm	Same as above
SUBMERSED AQUATIC PLANTS WITH OPPOSITE LEAF ATTACHMENT			
Buttercup (*Ranunculus* spp.)	diquat cation (2 lb./gal.	5 ppm	Apply below water surface
Cabomba (*Cabomba caroliniana*)	di (N,N-dimethylalkylamine) salt of endothall (Hydrothol-47); (L)	2 ppm	Same as above, small-scale application only
Slender naiad (*Najas flexilis*)	Use one of the following:		
	diquat cation (2 lb./gal.)	1 ppm, or 2 gal./surface A.	Same as above
	endothall (potassium salt, 4.23 lb./gal. or 10% G)	3 ppm (total or large-scale application) 4 ppm (marginal application)	Same as above

(cont'd)

Group and species	Chemical, active ingredient, or free acid equivalent	Rate of application	Remarks
Slender naiad *(Najas flexilis)* (continued)	Hydrothol-47 (L)	2 ppm (endothall content)	Apply on or below water surface
	dichlobenil (aquatic granules 4%)	200 lb./A.	Preemergent application
Southern naiad *(N. guadalupensis)*	Use one of the following:		
	diquat cation (2 lb./gal.)	1 ppm, or 1.5 gal./ surface A.	Apply below water surface
	endothall (potassium salt, 4.23 lb./gal. or 10% G)	3 ppm (total or large-scale application) 4 ppm (marginal application)	Same as above
	Hydrothol-47 (L)	2 ppm (endothall content)	Apply on or below water surface
	dichlobenil (aquatic granules 4%)	200 lb./A.	Preemergent application
SUBMERSED AQUATIC PLANTS WITH WHORLED LEAF ATTACHMENT			
Coontail *(Ceratophyllum demersum)*	Use one of the following:		
	endothall (potassium salt, 4.23 lb./gal. or 10% G)	2ppm	Spread on water
	2,4-D ester (20% G)	2 ppm	Spread on water
	silvex ester (4 lb./gal.)	2 ppm	Spread on water
	diquat cation (2 lb./gal.)	1 ppm, or 2 gal./ surface A.	Apply below water surface
	diquat/copper-triethanolamine complex	0.5 ppm diquat plus equal volume of copper-triethanolamine complex	Apply on or below water surface
Elodea *(Elodea canadensis)*	diquat cation (2 lb./gal.)	1 ppm, or 2 gal./ surface A.	Apply below water surface
Watermilfoil *(Myriophyllum* spp.*)*	2,4- ester (20% G)	2 ppm	Spread on water
	silvex		
	ester (4 lb./gal.)	2 ppm	Apply below water surface
	potassium salt (6 lb./gal.)	2 ppm	Apply below water surface
	potassium salt (20% G)	2 ppm	Spread on water
	endothall (potassium) salt, 4.23 lb./gal.	3 ppm	Apply below water surface
	or 10% G)	3 ppm	Spread on water
	diquat cation (2 lb./gal.)	1 ppm	Apply below water surface
	dichlobenil (aquatic granules 4%)	240-375 lb./A. or 2.5-3.8 lb./ 400 sq. ft.	Spread on water
	fenac (10% G)	See manufacturer's directions	Must be applied to exposed pond bottom

(cont'd)

Group and species	Chemical, active ingredient, or free acid equivalent	Rate of application	Remarks
FLOATING-LEAVED AQUATIC PLANTS			
American pondweed *(Potamogeton nodosus)*	Use one of the following:		
	endothall (10% G)	1 ppm	Spread on water
	endothall (4.23 lb. potassium salt/gal.)	1/2 cup/gal.	Apply to leaves
Waterlilies *(Nymphaea* spp.*)*	dichlobenil	5 lb.a.i./A.	Spread on water
FREE-FLOATING AQUATIC PLANTS			
Duckweed *(Lemna minor)*	Use one of the following:		
	endothall (potassium salt, 4.23 lb./gal. or 10% G)	1 cup/4 gal.	Apply to leaves
	diquat cation (2 lb./gal.)	1 cup/4 gal.	Apply to leaves
	simazine (80-WP)	0.5 ppm	Apply to total water volume
Watermeal *(Wolffia* spp.*)*	simazine (80-WP)	1 ppm	Apply to total water volume
ALGAE			
Chara (has cylindrical, whorled branches and resembles, in form, some of the plants mentioned above) *(Chara* spp.*)*	Use one of the following:		
	dichlobenil (aquatic granules 4%)	100 lb./A.	Preemergent application only
	copper sulfate[c]	1 ppm	Postemergent
	Hydrothol-47	0.2 ppm	Postemergent
	Mariner[d]	15-25 lb./A.	Apply on water surface
Filamentous algae	copper sulfate[c]	1 ppm	Postemergent
	Hydrothol-47	0.2 ppm	Postemergent
	Mariner[d]	15 lb./A.	Spread on water
	simazine (80-WP)	0.5 ppm	Apply to total water volume

[c]Crystalline copper sulfate can be used. However there are several copper-containing formulations that contain copper-chelating compounds, which prevent the immediate precipitation of copper as copper carbonate. Check the label for instructions concerning their uses and rates of application. A lower rate or application of copper can be used with these latter formulations. Their copper contents may vary.

[d]A copper-containing formulation developed by the 3M Company.

For additional information, see:
"The Chemical Control of Some Aquatic Plants." Mimeographed leaflets A5-16, Section of Aquatic Biology, Illinois Natural History Survey 61801.
Aquatic Plants and their Control. Fishery Bulletin No. 4, Illinois Department of Conservation, Springfield 61707.

The GCSAA Today

Douglas H. Fender

Without a doubt, the Golf Course Superintendents Association of America (GCSAA) and the golfing world in general have become more active, as an association and as an industry. Many people feel that September 13, 1976, the 50th anniversary of GCSAA, marked the real change--the coming of age of both the superintendents' profession and the golf industry. Indeed, many things have happened, but not all on or near last September 13.

Many people are responsible for the increased activity. Much of the work has been accomplished through GCSAA's 27 committees, including Membership, Education, Certification, Conference and Show, Publications, Public Relations, and the strong and growing Allied Associations Committee. Each one has a vital function.

Two advisory councils were added recently: the Educational Advisory Council and the Industrial Advisory Council. These groups comprise the leading educators and industrial personnel in the nation. The price for their expertise, if we had to pay for it, would be phenomenal. For example, gentlemen like Dr. James B. Beard, professor of turfgrass physiology at Texas A & M University in College Station, and Dr. A.J. Turgeon, associate professor of turfgrass science here at the University of Illinois donate their services. Their fees are usually $500 a day or more. Their work is fantastic.

I think one of the best ways to describe the GCSAA today is to relate to you what is happening in Lawrence, Kansas, where the headquarters office is located. The items I will discuss are being worked on today by the headquarters staff, under the leadership of the present GCSAA Executive Committee and the President. From this, you will get some idea of the vastness of the organization, the type of work it is doing, and the many areas in which it is involved.

This time of year (November), most of the staff's attention, and probably part of yours too, shifts to the conference and show. The 1977 GCSAA conference, February 6-11 in Portland, is rapidly approaching. There are many things to be done. Those of you who are members have received promotional materials, registration forms, and so on, as have nonmembers who requested them. Registrations are being processed. We expect more than 5,000 people. We have reserved sixteen hotels this year, and the hall has 100,800 square feet of exhibition space, which we expect to sell out. (We are about 85 percent sold out now.) There should be 150 to 160 exhibitors. At the same time, registrations are coming in quickly for the 1977 GCSAA National Golf Tournament, February 3 and 4 in Monterey, California.

We have a membership newsletter which is about ready to be sent to the printer. We have five special publications in progress now, two of which are new. One is called "How to Present Yourself." We envision this as a handbook for members on how to write letters, give speeches, make presentations, draw up proposals--in short, a businessman's handbook. Another folder we are preparing is the "Guide to Speaker Relations." Many chapters and organizations find it very difficult to know how to find speakers and how to plan successful meetings.

A third new publication is being prepared. It is a math manual that will contain the essence of math for golf course superintendents. Some of you might say: "That's simple. Why put it into a manual?" We have found, through various seminars and certification and testing procedures, that math is a very weak area. So we think the manual will be valuable to many of

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our members. Another publication being generated is a management manual to accompany the Management I Seminar. It will comprise material sent to us by members about budgets, ways of making a proposal, and the like.

The membership directory is another important publication. We have more than 4,200 members. Looking at the directory, you might think that superintendents are a pack of gypsies. Directory changes must be made for about 30 percent of our members each year. These are not all changes in addresses or jobs. We have great stability in this profession. The changes are in classification, home addresses, and affiliations. We plan to have the membership directory in the mail by the first of December.

Another of the publications we are working on is the January issue of *The Golf Superintendent*. The articles for that issue should be sent to the printer this week, and we are making every attempt to have the magazine out of the Topeka Post Office between the first and fifth of each month. In order to do that, copy for the January issue has to be sent to the printer in November. The January issue will contain preconference coverage, in addition to what we think is a very exciting article called "Review/Forecast 1976-77," which will discuss what is happening in the turf industry. The lead article in the February issue will be an insect update, which will discuss new insect problems and treatments. In the March issue, we will cover the conference. We are working very hard on these three issues and the advertising to pay for them. At this stage of the game, no membership dues are allocated to underwrite the operation of *The Golf Superintendent*. The magazine is being supported by advertising sales alone. We try to keep a 50/50 ratio of advertising to editorial material. The September/October Golden Anniversary issue was about 70 percent editorial and 30 percent advertising. We lost our shirts on it, but I think it was one of the best issues we have turned out in quite some time.

In addition to these ongoing projects, our editorial calendar has been completed through January, 1978. This is a list of the major items scheduled for publication in the magazine. We must work with this kind of lead time, in order to get the quality articles you people deserve.

We are receiving many articles, ideas, and suggestions from the membership and the readership. We vitally need this. Perhaps you do not consider yourself an author; but if you have an idea for an article, put it down in five or ten words or give me a telephone call. We need to know what the readers want. The best way for us to find this out is for you to tell us.

If you can give me or one of my staff members the basis for an article, we will expand on it, edit it, and work very closely with you. If you have a suggestion for an article or a topic but have no other ideas on it, give us that. If you know of an author, or speaker, who can write, let us know. We are vitally concerned about giving you the information you want. We feel we do a reasonably good job of that, but we can do an even better job with your input.

Public relations is a growing aspect of the life of the association. The Portland conference provides us with a fantastic opportunity to sell the association, the profession, and the industry. We are working very diligently on that public relations program. A great number of news releases have already been mailed. We have many more in progress.

In the area of education, we are eagerly awaiting the arrival of Palmer Maples, Jr., our new Director of Education. I think having an experienced superintendent in that position will be a tremendous advantage for the association.

While I was on my way here, Jim Brooks, our Director of Membership Services, was on his way back from New Jersey, where he had helped with a landscape seminar. Our seminar program is a growing one. It now includes five different seminars. We are getting many requests to conduct seminars, and will present several right before the Portland conference.

Another growing area is of our lending library of films, slide shows, and other audio-visual aids. Even if you were not able to attend the anniversary celebration at Sylvania, you may have heard about some of audio-visual presentations given there and would like to see them. All of these will be offered to chapters and individual members through our lending library.

In addition to these items, we receive many requests for speakers. We are eager to let people know what the association is all about and to work with chapters in arranging to provide speakers for a meeting.

Conference speaker arrangements are now being made. With more than 70 speakers this year, the job is a bit hectic. It is difficult to communicate with people from all over the continent and to make arrangements to be in the right place at the right time, but I think the job is being handled very well.

The Scholarship Research Fund is closely allied to our educational efforts. You probably just received notice of the annual membership fund drive from the S & R Fund. At the banquet this evening, I will recognize two people from this area who have received funds from this drive. They receive the money, but I think the association and the profession are the true beneficiaries.

In our Membership Services Department, new memberships are being processed right now. Last year we gained about 350 members. Of course, we have an attrition rate--members who leave the industry, die, or fail to renew their memberships. But the area we are covering in total new members is obvious. This is a daily process.

Along with the newsletter that is being prepared now, you will receive a small green card called "Every Member Recruit a Member." This is probably one of the best ways any association has of building its membership and of strengthening the entire organization. When you speak to potential members and demonstrate through your sincerity the value of this association, he is likely to join. With your encouragement, he can become a strong member. I encourage all of you to look seriously at your clubs, chapters, and friends who deserve to be members of this association, individuals who could benefit from being members and who could also help the existing membership. Use the "Every Member Recruit a Member" cards. Just fill in the name of a potential member. We will take it from there and send him some material about GCSAA. It is extremely important for you to encourage potential members to complete the application. Help him out, explain whatever needs explaining.

Our Membership Department is also involved in preparing the annual meeting voting procedure for the conference. A successful program was initiated last year. It involves the new member orientation and reception prior to the opening ceremonies on Monday, in which the Membership Department will be involved.

Administratively, we receive about 200 telephone calls from across the nation every day. Our incoming lines are often busy, as those of you who have tried to call us know. The questions we answer or attempt to answer are extremely broad.

We have a staff of 19 persons. The budget approaches a quarter of a million dollars. This is not some rag-tag outfit that came up out of nowhere. It is a highly respectable, cherished organization that has shown its strength and has come through some tough times in 50 years. We know it is going to get better during the next 50 years.

Kentucky Bluegrass Seed Production Changes in Fifty Years

Earl M. Page

The assigned subject, "History of Turfgrass Seed Technology," was too broad for the time. So with your indulgence, we will concentrate on Kentucky bluegrass seed production.

Of 200 known species of Poa, 65 are native to North America but probably are not the most important ones we know: Kentucky (*Poa pratensis*); Canada (*Poa compressa*), useful on poor dry soils; and *Poa trivialis*, the shade grass. These were probably native to Europe.

Kentucky bluegrass is an extremely interesting, useful, and widespread species, so widespread that most persons think of it as native. The 1948 USDA Yearbook on Grass says that Kentucky bluegrass is a native to the Old World and probably introduced to North America by early settlers in mixtures with other seed. Bailey's Cyclopedia of Horticulture sidesteps the question by placing the origin as "the cooler areas of the Northern Hemisphere."

The apomictic nature of Kentucky bluegrass, with its many clones and greatly differing numbers of chromosomes, probably accounts for its vigor and aggressiveness under such a wide range of conditions of soil, climate, and geography. Kentucky bluegrass also provides a field day for those interested in developing new varieties by selection--as attested by the many new varieties introduced, some single-clone varieties and some deliberate blends of several clones.

Fortunately for the serious plant breeder, apomixis is not absolute but ranges from 80 percent upward. Within that 1 to 20 percent of the plants which carry on actual sexual reproduction, there is the difficult possibility of developing new varieties by hybridizing--followed by intensive study, selection, and finally "fixing" the desired characteristics. Several new varieties now on the market were bred in this way.

No attempt will be made here to evaluate any variety. That is being actively pursued in trials now under way at several locations through the cooperative effort of the University of Illinois, Southern Illinois University, the University of Missouri, and the Southern Illinois Golf Course Superintendents Association. While we may not have a breakthrough in Kentucky bluegrass or other turfgrasses comparable to the one achieved with hybrid corn, and now with many other food and feed crops, through male sterility, the restorer gene, incompatability, and other genetic manipulation, the turfgrass breeders have been busy and successful.

Entering the seed business in 1927, I found that our company and its predecessors were already exporting substantial quantities of Kentucky bluegrass seed. That beautiful bluegrass region of Kentucky was still producing much of the commercial seed. With an increasing demand from both Europe and North America, the seed harvest from the lush Midwestern pastures and meadows was rapidly expanded. Starting in Northern Missouri, this area included Iowa, eastern Nebraska, Minnesota, and both South and North Dakota--known then as the "Western" district.

This is a vast region, and one important in livestock production. Bluegrass seed was a minor byproduct. Livestock was removed from the fields about a month before the seed matured and returned to the pastures immediately after seed harvest, with almost no loss of forage value.

The fieldmen for seed companies covered the area intensively in the late spring as the seed was forming. Usually they made deals with the farmer by paying him a flat price for the privilege

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Earl M. Page is Vice-President (retired), Cornelli Seed Company, St. Louis, Missouri. The presentation was accompanied by a series of slides.

of harvesting the seed. This varied from about $2 to a maximum of about $8 per acre. The companies supplied the stripping machines and frequently hired the farmer to pull them with his own horses or tractors. The yields per acre of clean dry seed ranged from 20 to 50 pounds; but arriving at that clean dry seed required a series of expensive operations.

In the late 1950's, there were as many as 15,000 strippers in the Midwest. Each of several companies operated as many as 1,000, with many smaller operators. The harvest started in Missouri in early June, and was completed in Minnesota and the Dakotas about mid-July. Machines were transported northward with the season. Each area offered only 5 or 6 days of prime harvest time, after the seed matured and before the heavy shattering loss. After stripping the rough green seed, it was cured or dried for a week or more in closely mowed and raked fields, where the green seed was spread 6 to 8 inches deep and turned frequently with tedders or side-delivery rakes. Then it was put into long stacks 5 or 6 feet high to further cure or go through the sweat. After that it was bagged or baled and taken to the seed house for threshing and cleaning.

Poa annua was not a problem with Midwest seed because of a combination of fortunate circumstances. Its probable absence in planting seed, the climate, and stripping only the top seed heads (usually 18 to 24 inches above the soil line) helped avoid that problem. Seed analysts readily identify *Poa annua* seed in the laboratory. Our analyst reported that all lots of bluegrass seed grown in western Europe and examined in our laboratory contained some *Poa annua*. This may be due to the cool moist climate and the method of harvesting there (mowing near the soil line).

Kentucky bluegrass seed production has now moved farther west, where it is a major crop and not a byproduct. That development did not come easily or quickly. After production started there, the output remained small for 10 or 12 years, accounting for about 1 percent of the total seed production during that time in the United States.

In northeast Washington and northwest Idaho, some early seed crops were transplanted in rows and cultivated, a practice followed now only for selection or improvement work. Seed crops are grown by drilling in rows 6 inches apart. Modern herbicides make cultivating unnecessary. There is a keen awareness in both Washington and Idaho of the danger of *Poa annua*. Both states forbid the importation or planting of seed with any *Poa annua*.

In that area, many seed fields are irrigated--producing excellent seed crops with very near certainty. For others grown without irrigation, production is less certain. Most seed crops are mowed and windrowed. After curing, a combine moves through the field picking up the windrows and threshing out the seed, much as is done with beans and some other crops. The shattering loss by this method is usually 5 percent or less. Crops harvested directly by combine with a cutter bar must be riper and drier, and the shattering loss is 25 to 30 percent.

Under controlled seed-production practices in the Northwest and because of the active cooperation between seed producers and plant breeders in many consuming areas, we can expect continued development of new and improved varieties and strains. They will not all survive; but the new Plant Variety Protection Act increases the incentive to develop and produce the "perfect" variety. Perhaps the ultimate answer will continue to be a series of varieties, each offering advantages for certain uses. The competition will continue to be the "old original."

Contract Turfgrass Maintenance

Gregory R. Oltman

Since a great many professional turfgrass managers harbor dreams of someday parlaying their knowledge and expertise into a profitable business, I will direct my remarks toward the business side of turfgrass management. I believe it is safe to assume that those assembled here have a fairly thorough knowledge of the horticultural aspects of turf management. But, as some of our predecessors have proven, technical knowledge is seldom sufficient to insure success in this or any other business.

Contract turfgrass management today requires the utilization of the techniques employed by businesses in all fields. Accurate bidding and accounting are every bit as important as fertilizer calibration. Advertising and marketing must take their place alongside the management of herbicide and fungicide applications. With these factors in mind, let us look at the business possibilities within the field of contract turfgrass management.

First of all, we will assume that the necessary capital is available, along with the usual assortment of turfgrass maintenance equipment. The array of equipment, and the investment in it, will vary with each business, of course, depending on personal preference.

Now comes the task of soliciting business. What types of properties are available for contract management?

The first, and probably most common one, is home-lawn maintenance. That is a good place for a young company with a small crew to start. However, the home lawn business is also fiercely competitive. A great deal of customer contact must be expected.

Apartment and condominium operations also offer good opportunities for a young company. Such operations are proliferating at an astonishing rate, especially in large metropolitan areas. As the saturation point is reached in a given population area, the management firms begin to look for ways to differentiate their complex from the others. One of the most obvious ways is to capitalize on the exterior appearance. So, more and more real estate management firms are looking to professional landscape maintenance companies.

Commercial and industrial properties have long been considered the "cream of the crop." Rumor has it that is where the healthy budgets are. Certainly, that is also where the top landscape maintenance companies operate. Gaining a foothold is difficult, but extremely worthwhile.

One fairly new area of contract maintenance is with golf courses. Such contracts require a great deal of equipment and a sizeable labor force. Competitive bidding would no doubt trim the budget expenses at some golf courses; and this is a very important consideration, as land taxes and other expenses continue to climb.

With these areas to explore for possible contracts, how can you go about getting permission to bid on specific properties? If you have been called on as turfgrass consultant at some time in your career, you may already have the names of persons or institutions that could require the services of a turfgrass maintenance contractor periodically. If no friendship would be strained, perhaps some of these contacts could be turned into business accounts.

Gregory Oltman is Vice-President, Northern Illinois Landscape Company, Inc., Hoffman Estates, Illinois.

Another method would be to compile a list of the properties you would like to service among your contracts. From that point, the task becomes one of making telephone calls sometimes dozens of calls, to locate the person in charge of landscape maintenance at each institution or property. Unfortunately, you probably will not get a return call if you merely leave your name and telephone number. It is up to you to make the calls. Hopefully, all the telephoning will eventually produce some requests for bids. If so, you should probably be prepared to produce a list of business references.

At that point, as a new businessman, you will encounter one of the most frustrating stumbling blocks. If this is your first year in business, it is rather difficult to produce a list of people who will testify to your abilities as a landscape maintenance contractor, based on past performance. Establishing your credibility as a businessman is a huge step towards success. Almost invariably, you must convince someone to "take a chance" on your company. This places you in the position of having to perform at all costs; also, occasionally perhaps, in the unfavorable position of "owing" someone within a corporation or management firm. Avoid owing favors if at all possible.

Given that you have gathered some requests for bids, we now come to the process of bidding a job. This topic, by itself, could occupy several seminars. We will touch on it here only briefly.

First of all, know every detail of the specifications, if you are not supplying the specifications yourself. Be absolutely sure you understand every requirement to which you will be bound, should you win the contract.

The actual figuring of the bid price is a combination of measuring, calculating, checking reference material, praying, and guessing "by the seat of the pants." There is no such miraculous tool as a fool-proof bidding equation. Every bid has its own idiosyncrasies and will require adjustment accordingly.

As you bid each new job, situations will arise that have been encountered before. You will come to know the time requirements of various operations and hence, the bidding operation gradually becomes easier.

To this point, I have spoken based on the assumption that your company would offer a full maintenance program. As several firms are pointing out, however, there is much to be said for entering into only a limited phase of turfgrass management, such as fertilizer and herbicide application.

The determination of just what to offer in your particular program must be your decision, based on available time, capital and manpower.

Let's now assume that you have won some contracts. If you are satisfied with all terms of the agreement, get it in writing. As wonderful as it would be, it is just not possible to do business on a handshake. Every detail of the contract, including terms of payment should be explicitly outlined. At this point, a lawyer, though costly, could save you a great deal of money and headaches.

Actual performance of the contract is all that remains. If the sun shines every day, if it rains every fifth night, if no diseases show up, if all insect pests take a year off, and if everyone pays their bill within thirty days, we should all have a magnificent season!

Bedding Plants in the Landscape

G.M. Fosler

A vast majority of the flowering plants now used for massed color effects in public and private plantings are seed-grown annuals, or tender perennials handled as annuals. Many of the once-familiar vegetatively propagated bedding plants, of both the flowering and foliage types, are seldom offered for sale now and are infrequently seen in ornamental plantings. Although attractive and useful, they were relatively expensive to produce and cannot compete in today's market with items grown from seed. The geranium is a major exception. Yet even with this important crop, seed lines are very rapidly increasing in importance.

WHAT BEDDING ANNUALS GIVE US

Our most reliable and important bedding annuals provide us with a good display of color over a relatively long season--perhaps four to five months. It would be difficult to achieve comparable continuity of color with hardy perennials. Many perennials are spring-blooming. Individually, their main blooming seasons are usually only several weeks in duration. Because most annuals do not come into their own until late June or early July, it may be necessary to provide spring color in the flower beds with bulbs or pansies. It is then entirely feasible to make followup plantings with bedding annuals to complete the season.

Seed-grown annuals, which are short-term greenhouse crops, are now relatively inexpensive to produce and can be sold at reasonable prices. Add to this the advantages of an amazing array of different types from which to choose--almost every conceivable color, flower form, and plant height you could want. In the last several decades, our plant breeders the world over have outdone themselves in expanding the list of available varieties. Great improvements have been seen in expanded color ranges and in vigor, uniformity, growth habit, flower form and substance, and disease resistance. Even entirely new species have become important. The future for bedding annuals also looks bright, considering the advanced breeding techniques now being employed.

Very prominent are the F_1 hybrids, particularly in petunia, ageratum, snapdragon, dianthus, geranium, zinnia, pansy, marigold, nicotiana, impatiens, and fiberous-rooted begonia. Although F_1 hybrid seed is comparatively expensive, these varieties rank as some of our very best performers. Needless to say, the competition is so keen that inferior varieties--whether they be hybrids or ordinary cross-pollinated varieties--have a way of dropping by the wayside rather quickly.

In addition to the above advantages, bedding annuals are quite undemanding in their cultural requirements. Disease and insect problems are seldom encountered. The fact that the plants must be replaced each year is more than offset by the real garden value we receive from them.

SHOULD YOU BUY PLANTS?

Generally speaking, you will be money ahead by buying started plants for the flower beds you have planned. In many cases, it would be well to consider having them contract-grown, with the particular varieties you have chosen to be delivered at the date(s) you specify. Plants received in prime condition can then be set out immediately. In a few weeks, they will begin to provide real color.

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Be sure to find out what the recommended planting-out time is in your area. Here in Champaign-Urbana, we aim at May 15, although the average date of the last frost is April 25. You cannot afford to have the plants killed by a late frost; furthermore, their development is slow until the ground has warmed up. Once they are established, you can usually be assured of good performance with a minimum of maintenance and care until frost in the fall, or later. As you probably know, quite a number of our popular bedding annuals withstand hard freezes, continuing to bloom even well into November.

Considering the comparative costs of seed and plants, there is a temptation sometimes to economize by trying to direct-seed the flower beds. You may have fair success with some of the larger-seeded, vigorous-growing types. But with petunias and most other small-seeded items, the results will be spotty; and your investment in seeds usually lost. Another point to keep in mind is that plants from direct-sown seed will often bloom considerably later than thrifty, well-started plants from a greenhouse.

If you have greenhouse space and a grower who is competent to do the job, you might consider producing your own plants. If makeshift facilities are the only ones at your disposal, I hardly think that is worth the gamble. It is possible, however, to buy flats of started seedlings in the spring. These could be pricked-off and spaced-out in flats, packs, or individual pots and finished in a heated coldframe.

DEMAND GOOD PLANTS

Whether you have your bedding annuals contract-grown or whether you shop around at local greenhouses, always insist on good-quality plants. Be sure they are healthy and insect-free. Above all, look for low-branched specimens of uniform height--not ones that are stunted, yellowish, or hardened.

Most customers will pass up flats or containers of plants that are not in bloom. It is always good to know that you are getting the correct variety, as evidenced by the flowers. But it is far more important to get quality plants, even if it has been necessary to pinch out the stem tips (and flowers) to induce low branching.

Whether you buy or grow your own plants, most bedding annuals should be "pinched" before they are set out. That is, the stem tips should be broken out to encourage the lower axillary buds to "break." With petunias and snapdragons, for example, this pinch should be such that only several inches of the stem remain. If left unpinched, you will inevitably have the spindly, straggly sort of plants that are all too familiar.

While pinching is a must with most bedding annuals, there are several exceptions to the rule. Celosia (cockscomb) and balsam sometimes do not break well if the terminal growing points are removed.

Your florist uses various means to produce the quality of plants you seek. Proper greenhouse temperature levels for different crops are particularly important. But now, the progressive grower also manipulates daylengths, utilizes injection fertilization, and may artificially increase the carbon dioxide content of the air for better plant growth. In addition, you may have heard about several new growth-retardant chemicals, such as B-Nine, that are quite effective. When properly applied, they give us low, compact growth and desirable base branching, yet flowering is not impaired. Lush, deep-green foliage color is an added advantage. Experiments indicate, too, that the effects of these retardants are rather temporary, in no way hindering the performance of the plants once they are set out in flower beds.

Also, insist that the plants you buy have been properly "hardened-off." By this we mean that they have been gradually subjected, during the last several weeks before sale, to cooler temperatures and more-rigorous environmental conditions. This is often accomplished in coldframes. Certain physiological changes occur in the plants, making them better able to withstand the shock of being planted. A plant grown under ideal greenhouse conditions, without hardening-off, would take considerable time to recover from being suddenly subjected to outdoor conditions in our changeable spring weather.

PLANT CONTAINERS

In what kind of container should you buy plants? Large flats will cost you the least per plant. The smaller community packs containing 4 to 12 plants are convenient to handle, but are designed largely for cash-and-carry sales to home gardeners. With these flats or packs, it is necessary to remove the plants by carefully cutting downward into the soil between them, then lifting out each plant with a block of soil surrounding its roots and setting into the planting hole. The newer cell-pak container (a number of individual pots, usually of plastic, joined together) is a better way to purchase plants, since the root systems are completely undisturbed when removed for planting.

Individually potted plants can also be handled with a minimum of root damage, yet such containers probably will cost the most. With peat pots, Jiffy 7's, Jiffy-9's, or Kys-Kubes, there is virtually no damage to the roots since the unit is set directly into the soil and not removed. To remedy the difficulty some people have encountered with peat pots, most brands are now treated with a wetting agent. It is also a very good idea to tear off the rim and bottom of each peat pot before setting it into the bed.

What about plants being grown in artificial mixes--such as half peat and half vermiculite, or half peat and half perlite? High-quality bedding annuals are being precision-grown in these synthetic nonsoil mixtures. Once set out, the plants will perform fully as well as those grown by more conventional methods.

SELECTING VARIETIES

It is beyond the scope of this brief presentation to go into the landscape uses of bedding annuals. If you have the services of a landscape architect, by all means get his suggestions about types and varieties for the effect you want. Even without professional help, you can often do quite well by consulting experienced gardeners and by viewing plantings in parks or other public areas. Seed catalogs, magazines, and many books also provide helpful hints, along with pictures of successful combinations.

When deciding on varieties to buy or grow, a great many aids are at your disposal. Above all, plan to visit one or more of the trial gardens. Among those within driving distance are the plantings maintained by Geo. J. Ball, Inc. in West Chicago; Kishwaukee Junior College at Malta (in cooperation with the Vaughan-Jacklin Corp.); and the Boerner Botanical Garden in Hales Corners, Wisconsin. By visiting the trials several times a season, you can note those varieties that perform best in our area and are best suited to your particular needs. In addition, these gardens may present a number of demonstration landscape settings utilizing some of our best bedding annuals.

You are welcome, also, to visit the extensive University of Illinois Trial Garden of Annuals and Bedding Plants here on the campus, located near the intersection of Florida and Lincoln Avenues in Urbana. The Garden is maintained by the Department of Horticulture, and is open to the public every day of the week from dawn to dusk. Each season it includes roughly 1,300 varieties, secured from major seedsmen and hybridizers in the United States and a number of foreign countries. The U. of I. Trial Garden also usually displays approximately 325 varieties of our No. 1 bedding annual--the petunia. Most of these are F_1 hybrids.

In addition to the trial gardens, recommendations from seed catalogs are generally good. Depend heavily on the advice of your florist as well (although he may be more concerned with how a variety looks at sale time than with how it performs outside). Fieldmen or salesmen from the larger seed wholesalers can give you much helpful information. Your own experience from previous plantings is invaluable. It might be well to run a few limited trials of your own on new items that you think may have potential in the ornamental plantings for which you are responsible.

You are aware, I am sure, of the much publicized "All-America Selections" program. Since 1966, the University of Illinois plantings have been designated as an official AAS Trial Garden, and includes the current entries each season. The entries are submitted by both professional and amateur hybridizers from all parts of the world and are grown in competitive trials in about 30 different locations in the United States and Canada. If the panel of judges grants a particular entry a sufficient average number of points (based on its merits), it rates a Bronze, Silver, or Gold Medal. This variety then receives extensive promotion and publicity as an AAS award winner. Generally speaking, these AAS varieties are excellent and represent the best of their types to date.

Reprints of the annual publication, "Garden Annuals--Varieties Recommended For Use in Home Plantings," are available each year. Your requests for single copies (free) should be addressed to: 100 Ornamental Horticulture Building, Urbana, Illinois 61801.

CULTURAL TIPS

SUN VERSUS SHADE. Although we have a long list of reliable bedding annuals from which to choose, nearly all of them perform best in full sun. Fortunately, there are some items that require light to moderate shade in this area: impatiens, fibrous- and tuberous-rooted begonia, browallia, seed-grown coleus, lobelia, and exacum. Caladiums, although not seed-grown, also fit into this group of shade plants. Certain other annuals can be grown in light shade (although they ordinarily perform better in full sun): petunia, alyssum, annual phlox, salvia, snapdragon, verbena, aster, cleome, periwinkle, pansy, carnation, pinks, and balsam.

SOIL PREPARATION. The point has been stressed that bedding annuals are easy to grow. Yet, as with all other ornamentals, you should take no shortcuts as far as soil preparation is concerned. Plow or spade the area deeply (preferably the previous fall), working in generous amounts of organic matter--manure, compost, leafmold, peat moss, etc. Leave it rough during the winter. Then work up, level, and rake the bed smooth a week or so before the planting date. At the same time, incorporate peat moss, fertilizer, and lime as needed. Make certain, too, that the flower beds are well-drained. If drainage is a problem, you should remedy the situation with drainage tiles or channels, or by elevating the beds a few inches above the surrounding area.

Your chances of success with flowering annuals are far greater if the soil has a good physical structure--loose, friable, well-aerated, and with good humus content. Over-pulverizing the soil, either by hand or with a rototiller-type implement, actually destroys soil structure.

FERTILIZATION. There is a grain of truth in the old adage that any soil that will grow a good crop of weeds will also grow good annuals. But you will be more pleased with plants grown in soil that has been properly prepared and judiciously fertilized.

While adequate amounts of phosphorus (P) and potassium (K) in the soil are essential, "caution" is the word with nitrogen (N). If in doubt, have soil tests made; then base your fertilization program on the results. Many annuals bloom best with rather low amounts of N in the soil. With excessive N, they may produce lush foliage and rank stems, with all too few flowers. The soil pH should be near neutral (6.0 to 6.8); therefore, do not apply lime or limestone unless tests indicate that the soil is too acid.

When working up the flower beds in the spring, I would recommend incorporating a complete dry fertilizer (such as 5-10-5 or 6-10-4) into the soil. Use about 2 pounds per 100 square feet. At about monthly intervals through the spring and summer, more fertilizer can be applied as a light side-dressing. Use only about 1 pound per 100 square feet. It may be more convenient to inject a fertilizer stock solution into the water line, thus fertilizing as you water the beds.

Allowing fertilizer to be carelessly scattered over portions of the flower beds when adjacent turf areas are fertilized can lead to difficulties. Similarly, if N washes down into the beds in drainage water from a lawn area, you may also be disappointed in the performance of the affected plants.

Using a starter or booster solution is advised when setting out the plants, in order to get them off to a quicker start. A soluble, complete fertilizer high in P is often used, such as 10-52-17 or 10-50-10. Mix the fertilizer in water (about 2 tablespoonsful per gallon of water), then put 1 cup of this solution around the roots of each plant. If you have a fertilizer injector, water-in the newly set plants with a dilute fertilizer solution.

WATERING. If there are any real secrets for success with bedding annuals, proper watering is one of them. Visitors to our Trial Garden often ask how many times a week we water. Actually, there are many weeks when we do not water at all. During an average season, the sprinklers may be turned on no more than 6 to 10 times.

If would be wonderful if we could depend on rainfall entirely. But if rain does not come at the right time and the soil has become moderately dry, it is time to water--and to water heavily. With our "Rainbird" irrigation system, we water continuously for periods of 4 to 6 hours. The length of the watering period, however, is not the important point. Water should be applied slowly and long enough so that it can all penetrate the soil and soak down through the root zone, perhaps 8 to 12 inches deep. Once this has been achieved, do not rewater again until the soil is on the dry side. But do not wait until you see wilting. That never benefits any plant. One inch of moisture per week, whether from irrigation and/or rain, is usually ample for most flowering annuals.

Frequent light waterings result in shallow root formation. With this situation, plants wilt rather quickly on hot, dry days. If you continue with insufficient applications of water, you needlessly get yourself into a vicious circle and one that is hard to break. Plants should have extensive root systems, so they can tap the moisture reserves deeper down during periods of drouth.

One hears many arguments among gardeners about the proper time of day to water. The majority of us have to consider convenience above most other factors. It is true that water loss from evaporation will be greatest during the heat of the day. On the other hand, watering during the evening or night may encourage foliar disorders. My recommendation is to water when it can be accommodated into your daily work schedule, but shut off the sprinklers early enough so that the foliage has a chance to dry before nightfall.

KEEPING DOWN WEEDS. The day of frequent and deep cultivation is past. Whether done with a hand hoe or a power implement, cultivation should be shallow--serving mainly to shave off weeds and to break up the surface crust. Working up the soil to any depth does great damage to the root systems and also turns up countless weed seeds that will give you trouble later on. The old dust-mulch theory has been fairly well debunked by our scientists, and the age of minimum tillage is here.

In our experience, weeding and cultivating at 10- to 14-day intervals is sufficient. Generally speaking, herbicides are not recommended for controlling weeds in plantings of annuals.

If feasible, use a mulch around your bedding annuals. In addition to holding down weeds and eliminating the need for cultivation, a good mulch conserves moisture, aids water penetration, prevents soil compaction and crusting, keeps the soil cooler, and may add organic matter to the soil. Many different mulch materials are being used: peat moss, ground corncobs, pecan shells, tobacco stems, shredded hardwood bark, cocoa bean hulls, compost, peanut hulls, etc. All of these are good, but each has its own advantages and disadvantages. If a rapidly decaying type of mulch is used (such as straw, sawdust, or even finely ground corncobs), you may need to fertilize somewhat more heavily with nitrogen.

INSECTS AND DISEASES. Even though we are dealing with a large and diversified group of plants, most of them are usually not plagued by insects or serious diseases. Quite a number are especially susceptible to damping-off in the seed flats; but once in the garden, seldom give us much trouble. Powdery mildew on zinnias is almost inevitable every summer. In some cases, we can take advantage of varieties that show resistance to certain diseases, e.g., rust-resistant snapdragons and wilt-resistant asters. Soil fumigation is a means of eradicating certain soil pests. Rotation of plantings, so the same types of plants do not grow in the same spot year after year, is another helpful way to circumvent certain disease difficulties. In the fall, rake off and burn all plant debris from the beds, rather than spading it under. This material often harbors insects and disease organisms. Appropriate sprays or dusts are usually called for to ward off or control insects or foliar diseases. If you need help with a specific insect or disease problem, do not hesitate to call on your Extension Adviser or Extension Specialist for recommendations.

MAINTENANCE PRACTICES. Aside from the points already covered, bedding annuals require little other special care. The young plants should have been pinched back before, or shortly after, they were planted. A second pinch is rarely necessary or advised. With a few items, careful shaping of the plants through the season will keep them in a more-presentable condition. Generally it is not even necessary to remove the old flower heads, unless they are taken off because of unsightliness. There are a few types of bedding annuals, however, that may fail to rebloom satisfactorily unless the seed heads or spikes are removed. The snapdragon is a good example.

The finest bedding annual we have--the petunia--is one plant that may need some extra attention. You have all noticed that some varieties tend to become opencentered, rangy, and matteddown in midsummer. When they reach this stage, pruning back will rejuvenate them for better performance in late summer and fall. The stems are cut back to 8 or 9 inches from the base. This can be done all at once, or a few stems at a time so that there is no drastic disruption in flowering. In a surprisingly short time, new shoot growth will occur along with a fine showing of blooms.

Annual Bluegrass Control in Sod Production

P.L. Jacquemin

IN NEARLY ALL AREAS OF THE UNITED STATES, *Poa annua* is usually considered a serious weed. *Poa annua* has long been a serious problem in turf, especially on the fairways and greens of golf courses. *Poa annua* has also become a serious weed in the sod fields of Kentucky bluegrass in the northern United States.

In the sod industry, a crop is often harvested every year. This management practice does not lend itself to a multiple-year control program. Yet, most of the current control programs for *Poa annua* are based on gradually removing the pest over several years. Hence, a single-application herbicide program is desired which will provide postemergence control of existing *Poa annua* and preemergence control of germinating *Poa annua* seed for a short period of time. This will allow for an increase in the density of Kentucky bluegrass before *Poa annua* can reestablish itself.

INVESTIGATION

Scotts initiated a program in 1970 to develop a product that would selectively remove *Poa annua* from Kentucky bluegrass. Early in the testing program, linuron gave selective postemergence control of *Poa annua* and a short period (one to three months) of preemergence control at rates of 2.25 to 6 pounds per acre on different soil types. An extensive study with linuron was then undertaken in an attempt to determine the: (1) optimum rates for controlling *Poa annua* on organic and mineral soils; (2) tolerance of various desirable cool-season turfgrasses; (3) timing of the application; and (4) desirable maintenance practices to follow before and after making an application.

The testing program included experimental plots located at the Scott Research Farm in Marysville, Ohio, and on-site testing at sod farms in a ten-state area. Two typical tests are described in the following paragraphs.

The first experiment was conducted on a sod farm near Union Grove, Wisconsin. The testing site was on an organic soil with a Baron-Merion Kentucky bluegrass sod contaminated with *Poa annua*. The second experiment was conducted in Marysville, Ohio, on a silt loam soil which had been sodded with seven different grasses the preceeding fall in strips 18 inches wide and 180 feet long. The sod strips were laid in the following order: (1) Penncross bentgrass; (2) Windsor Kentucky bluegrass; (3) K-31 tall fescue; (4) Merion Kentucky bluegrass; (5) Biljart hard fescue; (6) *Poa annua*; and (7) Manhattan perennial ryegrass.

The results of the sod-field experiment showed that all rates of linuron except the ones at 2.3 pounds per acre significantly reduced the coverage of *Poa annua*. Concurrently, there was an improvement in Kentucky bluegrass density. The minimum dosage with linuron that gave adequate control of *Poa annua* was 4.5 pounds per acre. A number of other experiments conducted on organic soils confirmed the dosage of 4.5 pounds per acre as the minimum one that would be effective.

The results of the second experiment indicated that among the grasses evaluated, Kentucky bluegrass has the greatest tolerance to linuron. Selective control of *Poa annua* on a mineral soil at linuron rates of 2.3 and 3 pounds per acre would appear to be feasible in Kentucky bluegrass and possibly in tall fescue. Removing *Poa annua* from bentgrass, ryegrass, and hard fescue would not be possible because of a lack of selectivity.

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PRODUCT INFORMATION

The product developed in this research program is a 3.5-percent linuron granular corncob formulation called ProTurf Selective *Poa annua* Control. It is registered for use on Kentucky bluegrass sod fields in Ohio, Michigan, Indiana, Illinois, Wisconsin, Minnesota, Nebraska, Iowa, Colorado, Pennsylvania, New York, and New Jersey.

The product can be applied to either moist or dry foliage. The recommended rates are at a 2.9 pound of product per 1,000 square feet for organic (muck, peat) soils and 1.9 pound of product per 1,000 square feet for mineral soils. The linuron application was to be watered in immediately to move the chemical into the root zone area. Water only as fast as the soil will absorb the water. Avoid flooding.

The best treatment period is from late spring to early fall when the daytime temperatures are consistently in the 70's or higher. The soil moisture must be sufficient to maintain active growth by the bluegrass. If cool weather should prevail after treatment or if new *Poa annua* is observed, a second application in eight to ten weeks may be necessary to obtain satisfactory control. However, the second treatment should be applied no later than mid-September, in order to take advantage of warm daytime temperatures.

ProTurf should be used only where good turfgrass maintenance practices include regular fertilization, sufficient watering to maintain active bluegrass growth, and regular mowing.

Precautions should be taken not to treat a new bluegrass seeding until after the third mowing. Also avoid treating turf when there is danger of frost and freezing temperatures. Mixtures of Kentucky bluegrass and fine fescue should not be treated, since ProTurf will thin the fescue.

The result which can be expected with this unique product when used as directed is the selective removal of *Poa annua* without damage to the Kentucky bluegrass. Both *Poa annua* and Kentucky bluegrass will turn light green 10 to 14 days after ProTurf is applied. During the next 7 days, the bluegrass will start returning to its original color. The *Poa annua* yellows and eventually dies. Once the *Poa annua* is removed, the treated area could appear to be thin. There could also be brown areas, which were formerly patches of *Poa annua*. A well-watered and fertilized stand of Kentucky bluegrass will grow fast enough to fill in these bare areas during a period of 1 to 3 months of good growing weather.

Tall Fescue Management

John R. Street

Tall fescue, *Festuca arundinacea* Schreb., is a perennial, cool-season turfgrass species that originated in Europe. Among individuals in the turfgrass industry, some diversity of opinion exists about the potential use of tall fescue for turf purposes. Tall fescue has been used extensively along Illinois roadsides and for "low maintenance" turf areas, such as playgrounds, airfields, parks, and to some extent home lawns.

Much interest has been expressed over the past few years in using tall fescue more in home lawns, particularly in the transition zone. Little documented research is available, however, on managing tall fescue for acceptable turfgrass appearance over a period of several years.

Tall fescue has some serious disadvantages which have limited its acceptance and use. The leaf texture of tall fescue is coarser than that of any other commonly used cool-season turfgrasses. Where a high-quality turf is desired, the coarse texture has been a major objection. Although possessing short rhizomes, tall fescue has a bunch-type growth habit with very weak sod-forming characteristics. As a result, it tends to become clumpy if not established and managed correctly. Tall fescue possesses an upright growth habit and a relatively rapid rate of shoot growth, making it a poor choice in mixtures with Kentucky bluegrass. In a Kentucky bluegrass lawn, tall fescue becomes a very unsightly weed. Tall fescue is also prone to low-temperature injury, which restricts its use in the cooler portions of the cool humid region. Low-temperature damage results in a gradual thinning of the turf, until only scattered clumps remain. Tall fescue is well adapted to climatic conditions in southern Illinois; however, its lack of cold tolerance frequently results in poor-quality turf in northern Illinois. Many of these disadvantages can be overcome to a certain extent with proper management practices. Programs for breeding improved varieties of tall fescue are presently underway at several institutions in the United States.

Tall fescue has many advantages which should also be recognized. It has been used successfully in low management situations because of its adaptation to a wide range of soil types and pH values. Tall fescue tolerates soils of low fertility but does respond to fertilization. It grows well in sunny or moderately shaded areas, and has excellent resistance to summer heat and drought. Tall fescue frequently sustains growth and remains green in the transition zone, when Kentucky bluegrass goes dormant. Tall fescue is also tauted as having excellent wear tolerance and good disease resistance. In general, this grass will endure somewhat more mismanagement than Kentucky bluegrass. If tall fescue is selected, one must turn to cultural practices to realize the maximum potential quality over an extended period of time.

The first step in successfully managing tall fescue concerns proper establishment practices. Two key points in establishing tall fescue are the seeding date and the rate. As with other cool-season turfgrasses in Illinois, late-summer seeding is most desirable. Later seeding increases the chances for frost heaving or a direct low-temperature kill of young seedlings. Therefore, tall fescue must be seeded early for best results. For acceptable turf quality, a heavy seeding rate of 6 to 8 pounds per 1,000 square feet is preferred. This will produce a dense turf that helps to compensate for the lack of rhizomatous and stoloniferous growth. Significantly lighter seeding rates can result in a clumpy stand of turfgrass. Lighter seeding can be used when establishing a good cover is the primary objective and when the appearance of the turf is of secondary importance.

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Proper mowing height and frequency are important factors that must also be emphasized for the successful management of tall fescue. Turfgrass species vary greatly in their tolerance to cutting height. The cutting height of a given species is a function of the growth habit, which includes both stem and leaf growth characteristics. Tall fescue is an erect, or upright-growing, turfgrass with a rapid rate of vertical-shoot elongation. As a result, tall fescue cannot tolerate a cutting height as low as the more prostrate, low-growing turfgrasses such as bentgrass or bermudagrass.

Present recommendations on tall fescue call for a cutting height of 2 to 3 inches. Closer mowing reduces shoot density to an unacceptable level. If this happens, a weed invasion frequently becomes a problem. Results from research on tall fescue management at the University of Illinois show severe infestation of annual bluegrass and Kentucky bluegrass at mowing heights of 1-1/2 inches or less under moderate irrigation [4]. The crown and shoot survival for tall fescue was greater at a 3-inch cut, compared to a 2-inch mowing height under various cold treatments [3]. In mixtures of tall fescue and Kentucky bluegrass or in situations where an infestation of volunteer Kentucky bluegrass may occur, lower cutting heights are likely to favor the growth of Kentucky bluegrass.

The mowing frequency depends on the rate of shoot growth, environmental conditions, the species involved, and the cutting height used. A common practice of home owners is to cut their grass too close and too infrequently. Mowing frequency must be adjusted to the shoot growth rate so that an excessive amount of leaf surface is not removed at any one time. It is not advisable to remove more than 30 percent of the leaf area at any one mowing. The rapid shoot-growth rate of tall fescue in combination with higher management will require mowing more often than would otherwise be the case. Infrequent, close mowing will significantly contribute to poor stands of tall fescue over a short time.

Although tall fescue has a relatively low nitrogen requirement, research has shown that it does respond to nitrogen fertilization. However, there is little research concerning fertilizer recommendations for tall fescue. A common fertility recommendation for tall fescue is 2 to 4 pounds of actual nitrogen per 1,000 square feet per year, split between spring and fall. Another alternative is to apply nitrogen according to the appearance desired and the level of management used. Applying high rates of nitrogen (more than 4 pounds) to tall fescue requires caution. Doing so may increase the tendency for winter injury (*Helminthosporium* spp., *Rhizoctonia* brown patch, and *Fusarium* blight) to develop [1,3].

The performance of tall fescue is being evaluated presently under various cultural intensities (three mowing heights, five nitrogen levels, and moderate irrigation) at the University of Illinois [4]. A significant interaction among nitrogen fertility, mowing height, and community dynamics in a stand that was initially pure tall fescue has been noted under moderate irrigation. At a 3/4-inch mowing height, annual bluegrass averaged between 82.5 and 99.0 percent, the increasing proportions being associated with greater nitrogen fertility. At a mowing height of 1-1/2 inches, Kentucky bluegrass and annual bluegrass both gained coverage with increasing levels of nitrogen fertility. No annual bluegrass was observed in 3-inch plots; however, Kentucky bluegrass composed slightly over half of the turf as long as some fertilizer was applied. Miller also noted that as the nitrogen fertility increased on mixtures of Kentucky bluegrass and tall fescue, the bluegrass portion of the stand increased and the tall fescue component decreased dramatically [3].

Results from research at Beltsville, Maryland, indicate that tall fescue responds well to relatively high fertilization levels [2]. Even though tall fescue may respond to increasing fertilization, however, our studies indicate that regular applications of fertilizer apparently favor Kentucky bluegrass and annual bluegrass more than tall fescue under moderate irrigation. Presumably, regular irrigation as well as fertility were highly favorable for sustaining the bluegrass as a competing turfgrass species to tall fescue.

The appearance of tall fescue during the dryer months can certainly be improved by irrigation. However, such irrigation should be practiced judiciously. As previously indicated, infestations of other turfgrass species into tall fescue stands appear to be high under moderate irrigation--even at low fertility. Because of tall fescue's excellent drought tolerance and deep root system, the interval between irrigations can be extended--especially if deep watering is practiced. Disease development may also be greater under a management program that favors higher fertility and regular irrigation.

Overseeding may be another way of sustaining tall fescue quality over the years. Tall fescue is noted for its tendency to form unsightly clumps when the stands become thin. Competition among tall fescue plants should provide for a finer leaf texture and a more pleasing turf appearance. Frequency of overseeding will be determined primarily by the extent of turfgrass thinning, the level of management, and the appearance desired.

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Net Sod Production: A New Approach in Growing Turf

James B. Beard

In the summer of 1970, Mr. Fred Loads experimented in England with a technique for growing sod more rapidly using a net mesh produced by the Netlon Company of Blackburn, in Lancashire, England. The procedure he developed involved placing a Netlon mesh on top of a polyethylene film and then spreading a root zone mix over the mesh. The grass seed was incorporated into the soil root zone mix prior to spreading over the Netlon mesh. Utilizing this technique the seedling grass was securely rooted into the Netlon mesh within 14 days, at which time it could be readily handled and transplanted.

Based on these initial findings, a research program was initiated at Lancaster University under a grant from Mr. F.B. Mercer, of Blackburn, England. These studies were initiated in 1971 and continued into 1973. The results of this work confirmed the earlier observations of Mr. Loads and brought about further refinements in the techniques involved in producing turf by this Tuft 1 system.

In 1972, Mr. Mercer contacted the author at Michigan State University concerning this net sod production technique and possible research that could be conducted in relation to commercial sod production in the United States. As a result, 14 greenhouse studies and 18 field experiments were conducted at Michigan State University from 1972 through 1974, under a grant from Mr. Mercer.

The detailed results of these experiments cannot be covered in this brief article. Thus, a summary of the findings as they apply to conditions in the United States will be presented. Two basic systems of net sod production will be discussed.

Tuft 1 involves a Netlon mesh and underlying polyethylene film over which the root zone-seed mix is added. The polyethylene film functions as a barrier to downward root growth which enhances the intertwining of roots with the Netlon mesh. The result is the formation of a seedling sod much more rapidly than by normal means. Harvesting involves rolling the sod up within the underlying polyethylene film, which has been precut in long narrow strips for ease of handling. This product with the surrounding polyethylene film is particularly desirable for marketing in modest quantities through nursery outlets.

Tuft 5 involves placing the Netlon mesh at a shallow depth in the soil combined with seed application and subsequent rolling to provide good seed-soil contact and to stabilize the Netlon mesh in the soil. No polyethylene root barrier is utilized. Harvesting is accomplished with a standard sod cutter.

TUFT 1 STUDIES

Extensive greenhouse and field experiments were conducted on the Tuft 1 system of sod production. These tests involved seeding rates, seed placement, seed mixtures, and the evaluation of 6 Kentucky bluegrass, 4 fine-leafed fescue, and 5 perennial ryegrass cultivars. The results showed no difference between soil incorporation and placement of the seed in the surface quarter inch of the soil root zone. Net sod could be produced in 2 to 3 weeks after

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planting under greenhouse conditions. The sod could be readily handled, but of course the turf was still in a seedling stage. Under field conditions net sod could be produced in 4 to 6 weeks utilizing the Tuft 1 sod system. Higher seeding rates were required to produce net sod by the Tuft 1 system in this period of time.

The most rapid rate of Tuft 1 sod production was achieved utilizing polystands of fine-leafed fescue/Kentucky bluegrass, perennial ryegrass/Kentucky bluegrass, and perennial ryegrass/fine-leafed fescue/Kentucky bluegrass. Most of the root binding with the Netlon mesh was attributed to the fine-leafed fescue and perennial ryegrass components of the polystands, rather than the Kentucky bluegrass. These polystands formed an acceptable seedling net sod within 3 weeks, while monostands of Kentucky bluegrass required two to three times as long, depending on the individual cultivar utilized. Among the perennial ryegrass cultivars tested, Manhattan formed the most rapid net sod followed by Pennfine. In a monostand, an acceptable perennial ryegrass seedling net sod could be produced in 8 to 10 days using the Tuft 1 system.

The Tuft 1 system grown under field conditions is prone to soil erosion during intense rainfalls and to rapid desiccation during periods of high evapotranspiration, due to the shallow root zone depth for water retention. The former problem was minimized by the spray application of a surface soil binder of the elastomeric polymer type. The tendency to desiccation makes it necessary to use a mist-type irrigation system, applying water at intervals from two to six times per day depending on the evaporative power of the atmosphere. It is also important to avoid excessive water applications which can result in conditions favorable to such seedling blight diseases as Rhizoctonia and Pythium. The best nutritional responses were achieved by foliar applications of a complete analysis fertilizer at regular intervals during the 3- to 6-week production period. The use of soil which is free of weed seeds and vegetative propagules is also a very important consideration.

TUFT 5 STUDIES

Most of the Tuft 5 studies were conducted under field conditions on a Houghton muck soil at the Michigan State University Much Experimental Farm. Preliminary tests in the fall of 1972 showed that Tuft 5 Merion Kentucky bluegrass net sod was produced in 8 weeks under favorable moisture conditions. The sod possessed more than adequate sod strength for easy handling and the above-ground turf had reached a level of visual quality and maturity comparable to that from standard field production. The sod cutter was operated through the net sod with no difficulty at all, which could be attributed to the presence of the Netlon mesh.

One of the obvious observations from this test was the need for preplant weed seed eradication. In these short production periods, there is not sufficient time to achieve postemergence chemical control of broadleaf and annual weedy grasses. Their presence can seriously reduce the visual quality of the turf. Thus, it is critical to control weed seeds and vegetative propagules prior to planting.

Regular Tuft 5 plantings were made throughout the growing season for a 2-year period. Results of these tests showed that the time required to produce Tuft 5 net sod varied seasonally under Michigan conditions. Early spring plantings required 13 to 14 weeks, early summer plantings 10 to 12 weeks, and late summer-early fall plantings 8 to 10 weeks to produce an easily handleable net sod of acceptable visual quality comparable to standard sod now in commercial production in Michigan. These production times can be achieved only if adequate soil moisture levels are maintained through irrigation during droughty periods. Sod strength values for the Kentucky bluegrass Tuft 5 net sod ranged from 180 to the more than 200 pounds required to tear. These results indicate that the scheduling of planting times relative to the projected sales-harvest date will have to be varied seasonally, primarily in relation to temperature conditions.

Acceptable Merion Kentucky bluegrass Tuft 5 net could be produced at the standard seeding rate of 40 pounds per acre. In the net placement studies, five soil coverage depths were compared (0, 0.25, 0.33, 0.5, and 0.75 inch). No significant differences in sod formation rate were evident among the five placement depths, including placing the Netlon mesh on the surface. Rolling, following placement of net and seed into the soil, was particularly beneficial.

All the above results were based on monostand plantings of Merion Kentucky bluegrass or blends of Kentucky bluegrass. Polystand comparisons involving the addition of either Pennlawn red fescue or Manhattan perennial ryegrass were also conducted. The addition of either of these species to the seed mix resulted in an increase in the seedling emergence rate, seedling height, sod strength, and the rate of net sod production plus a reduction in the weed content. The degree of this response increased as the proportion of Pennlawn or Manhattan was increased up to 70 percent by seed weight.

TRANSPLANT ROOTING COMPARISONS

The transplant rooting capabilities of Netlon net sod were compared using both the root observation boxes and the Michigan Transplant Rooting Test. The results showed that the presence of the net in the sod had no negative effects on transplant rooting. The transplant rooting tests were conducted under both summer and fall growing conditions. Eight-week-old Tuft 5 net sod and year-old sod produced under the standard commercial methods used in Michigan had comparable transplant rooting rates. By contrast, 4-week-old Tuft 1 net sod had a much greater transplant rooting rate and extent than sod from the other two production methods. The transplant rooting advantage of Tuft 1 net sod was attributed to the root tips not being severed or disturbed and thus being able to grow rapidly into the underlying soil. However, harvesting sod from the other two production methods involved severing the roots. Thus, a specific period of time was required before new roots were initiated from the meristematic areas of crowns and lateral stems. The Tuft 1 net sod is in a more succulent, delicate seedling stage than either of the other two sod types and therefore is more easily subject to traffic injury. This necessitates withholding traffic from the area until the turfgrass stand has reached a more mature state.

FUTURE POTENTIAL

The experiments which have been briefly described here confirm the potential for these two net sod production methods as well as some of their limitations. The cost of the net and its installation must be evaluated from an economic standpoint relative to the additional length of time during which the land is tied up in production and the additional maintenance costs for producing sod without a net.

The advantages of the Tuft 1 net sod production system are: (1) an extremely rapid production time; (2) flexibility to produce sod with prescribed root-zone mixes, which can be of particlar importance on sport fields and greens where root-zone modification is utilized; (3) more efficient utilization of the available land in locations where the land area available is extremely limited (such as in parts of Japan and England); (4) the capability to produce sod in areas where the existing soil is extremely rocky or is in a condition unfavorable for sod production; and (5) an attractive method of producing moderate quantities of sod for marketing through direct nursery outlets with a grass composition and soil mix specifically suited for the local conditions and demand.

The primary disadvantage is the high labor requirement for production, which is of greatest concern in the United States, but is of much less concern in other parts of the world relative to the previously cited advantages. The Tuft 1 net sod system is now in commercial production in England.

The Tuft 5 net system has more immediate promise as a new, innovative method of sod production in the United States and Canada. The advantages compared to the existing method of commercial sod production include: (1) a much more rapid rate of production, which places less demand on land use and reduces maintenance costs; (2) the ability to produce sod rapidly from such species as tall fescue, perennial ryegrass, bahiagrass, red fescue, and chewings fescue which have been problems in the past due to their weak sod-forming characteristics; and (3) the flexibility for growers who are producing a majority of their sod by standard methods to expand their production in a relatively short period of time by net sod methods in order to adjust to unexpected increases in market demand.

The exposure of the net to the ultra-violet rays of sunlight can cause rapid degradation, thus the use of UV inhibitor in production of the net is important. Several methods of mechanically placing the net into the soil have been developed by individual growers. From the standpoint of viable commercial production, there is more than 300 acres of sod now in production using the Tuft 5 net sod system. The growing use of this method can be anticipated.

A Practical Approach to Kentucky Bluegrass Fertilization

A.J. Powell, Jr.

Information used in the not-too-distant past for turf fertilization came mostly from the forage area. That is, if you applied nitrogen at 90 pounds per acre as a 10-10-10 formulation in the spring you could expect an extra 2 to 3 tons of palatable forage. We applied the nitrogen in the spring mainly because that is when the grass is most responsive to nitrogen. This has certainly had an effect on how many of us, some of us who were farmers previously, have fertilized turf. That is, what is good for the cow turf, is also good for the people turf.

The fact is, however, that we do not measure turf quality in tons per acre or by how good it tastes. Most turf quality is measured in density and uniformity. Color is a third quality factor in many situations, but certainly not all. Most homeowner surveys indicate that weeds are the main problem; but in reality, this is more of a uniformity problem than a weed problem. Any homeowner is distracted by seeing a blooming broadleaf weed next to the narrowleaf grasses.

Using uniformity and density, instead of growth and color, as the major quality factors, it is easy to understand the difficulty many people have with fertilization. The obvious grass responses to nitrogen are growth and color.

In order to be practical about fertilization, we must make certain sacrifices. We are not likely to have a dark-green, lush turf twelve months of the year. The quality aspect to sacrifice should depend on the situation and on the use of the turf.

Cow turf does not require any applied nitrogen fertilizer in order to live. People turf does. When we apply nitrogen, we get more density and growth and better color and texture. As we increase the nitrogen levels, we start a doomsday trend toward lush, soft, shallow-rooted turf that is prone to attack by diseases and insects. Such turf looks great until it is hit by the stresses of summer.

Let us take a different attitude toward nitrogen fertilization--a practical program that sacrifices some summer color, but produces a turf that requires less mowing and is more resistant to diseases, insects, weeds, and drought stress.

Most general turf areas should be fertilized three or four times a year if a soluble (readily available) nitrogen fertilizer is used, or one that has half or less water-insoluble nitrogen (WIN). The preferred dates and rates would be:

Date	Actual N lbs./Acre
September	50
October to mid-November	50 to 65
mid-November to January	50 to 65
late May	0 to 30

Many times, it is not possible to justify this amount of nitrogen or that number of applications. Therefore, if only one application can be made, make it one in October to mid-November,

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as suggested above. If only *two applications* can be made, apply the nitrogen in October to mid-November and again in December-January period at the suggested rates given above.

The advantages of such a fall and winter fertilization program over spring fertilization are:

1. A denser turf. Density is not only important from the use and aesthetic viewpoints, but also in improving the ability of the grass to compete with weed species.

2. Improved root system. The maximum rate of root growth occurs in the early spring. When you apply nitrogen in the spring, you encourage top growth and greatly reduce root growth.

3. Fewer spring mowing problems. Nitrogen applied during spring causes a flush of growth that makes it difficult to properly maintain the turf, especially when soils are wet.

4. A much-improved color in the fall, winter, and early spring.

5. Better competition by the grass against the weeds.

6. A turf that is better able to overcome drought.

7. Fewer disease problems.

The cool-weather response described here can be expected with any of our agricultural or specialty nitrogen fertilizers that contain more than 50 percent water-soluble nitrogen (WSN). Since the microbial activity necessary for nitrogen release from urea-formaldehyde (UF) fertilizers is greatly decreased during the winter, so only the more water-soluble forms of nitrogen will produce the winter response.

In northern climates where the direct, low-temperature kill of Kentucky bluegrass is a problem, late-fall nitrogen that stimulates growth and plant succulence should be avoided. In that situation, it may be best to withhold nitrogen applications for about a month before winter dormancy in order to insure maximum low-temperature hardiness. After dormancy, however, an application of nitrogen will insure early spring greenup, improved root growth, and maximum tiller development.

Thatch: Its Causes and Control

James B. Beard

The use of thatch and mat terminology has varied from writer to writer over the years. In this article, "thatch" is defined as an intermingled organic layer of dead and living shoots, stems, and roots that develops between the zone of green vegetation and the soil surface. Thatch accumulation can occur in a wide range of species from the intensively maintained, vigorous cultivars of Kentucky bluegrass, bermudagrass, creeping bentgrass, and St. Augustinegrass to the low-intensity-maintenance and slower-growing red fescues, chewings fescues, and zoysiagrasses.

In some situations, the thatch becomes intermixed with soil as a result of regular topdressings, such as on greens, making it appropriate to describe that by a distinctly different term. So, "mat" is defined here as a tightly intermingled layer of living and partially decomposed stem and root material; "thatch," as stated above.

The intermixed layer of thatch and soil provides a certain degree of resiliency, which is important on sport turfs, and thus has also been termed "cushion." There is also a surface layer of leaf clippings which does not become a long-term component of the thatch or mat body. This is called "pseudo-thatch," and is defined as the uppermost surface layer of the thatch, which is composed primarily of relatively undecomposed leaf clippings.

PROBLEMS WITH THATCH OR MAT LAYERS

An excessive accumulation of thatch or mat can lead to numerous problems and to increased difficulties in terms of turfgrass culture. These include: localized dry spot; increased disease and insect activity; chlorosis; proneness to scalping; greater heat, cold, and drought injury; more footprinting; and pesticide inactivation.

LOCALIZED DRY SPOT. This results from a condition where the thatch layer is allowed to dry out and subsequently becomes rather hydrophobic, or resistant to rewetting, and sheds water from the area. This, in turn, results in the development of localized dry spots under such thatched areas.

INCREASED DISEASE AND INSECT ACTIVITY. Many of the disease-causing pathogens which are active on turfgrasses are rather weak parasites, which survive as saprophytes in the lower thatch and mat zone until the environmental conditions are right for rapid infection and disease development. A thatch or mat accumulation provides a readily available medium for survival in the saprophytic stage as well as a favorable microclimate, particularly in terms of moisture, which enhances the conditions for the proliferation of disease-causing organisms. The diseases that have been documented as being greater where thatch accumulations exist include *Helminthosporium* leaf spot, *Typhula* blight, stripe smut, dollar spot, and brown patch. Insect activity responds in a similar way.

CHLOROSIS. The relative degree of chlorosis development depends on the particular species involved. This development seems to be greater in stoloniferous turfgrasses.

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PRONENESS TO SCALPING. An excessive thatch or mat accumulation tends to become less firm, or unstable, during the hot periods of midsummer. As a result, the mower bedknife may drop somewhat lower than normal causing a severe scalping of the turf.

INCREASED PRONENESS TO HEAT, COLD, AND DROUGHT INJURY. Thatching tends to raise the vital crowns, lateral stems, and roots up out of the protective layer of the soil and into the thatch or mat zone. This position is a less-protected one; thus, more exposed to environmental extremes and stresses.

INCREASED FOOTPRINTING. Footprinting is a problem on heavily thatched, puffy greens where it can seriously interfere with the proper roll of the golf ball.

PESTICIDE INACTIVATION. Thatch and mat layers can tie up fungicides and insecticides, making them essentially unavailable for the use intended. Thus, a normal application rate may not prove to be effective on a particular target disease-causing organism or insect. Through experience, the turf manager will have to adjust his application rate upward so that the desired degree of control is achieved. The extent of this pesticide tieup among a range of insecticides and fungicides is not well documented. Such efforts are needed.

BENEFITS OF THATCH OR MAT LAYERS

There are also some beneficial aspects to a thatch or mat layer when present in controlled and moderate amounts. The wear tolerance of turfgrasses is increased by the presence of a thatch or mat. In the same vein, the proneness to soil compaction is reduced by the cushioning effect of a thatch or mat layer. The wear-tolerance response is very striking, as shown in Table 1. There is an additional benefit, particularly in the case of a mat on areas used as greens. The resiliency provided can be of importance on greens and sport fields where the bounce of a ball is cushioned; also, from the safety standpoint of the participants falling on the surface.

Table 1. Influence of Five Mat Depths on the Wear Tolerance of a Creeping Bentgrass Green

Bentgrass mat		Number or revolutions of wear simulator needed to reach the same endpoint
Depth in mm (inches)	Organic weight (MG/CM^2)	
-0-	-0-	86 A
5.6(0.22)	78.4	212 B
9.3(0.37)	210.5	1,217 C
21.0(0.94)	450.0	2,831 D
35.5(1.42)	652.1	3,550 E

SOURCE: D. Duncan and J.B. Beard.

PHYSICAL STUDIES OF THATCH

A detailed physical examination of thatch under a microscope reveals that distinguishable leaf fragments are present only in the upper surface layer, previously defined as pseudothatch. Stem fragments constitute the major portion of many thatch and mat layers. Tissues in more advanced states of decay still exhibit distinguishable nodes and sclerified leaf sheath tissues that persist the longest in their original structures. Many fine fibrous roots are also evident throughout the thatch and mat layers--some living, some dead.

The relative proportions of crown fragments, lateral stems, and roots which constitute the bulk of the thatch or mat layer vary with the turfgrass species involved. There are also differences at the intraspecies level, as shown in Table 2.

Twelve-year-old turfs of Cohansey, Evansville, Penncross, and Toronto creeping bentgrasses were utilized in a comparison of the major physical components constituting the mat layer. These turfs had been maintained under typical cultural practices used on putting greens. The turfs had received two topdressings per year, spring and fall.

Table 2. The Comparative Dry Weights in Grams of Green Shoots, Nongreen Lateral Shoots, and Surface Roots of Four Creeping Bentgrass Cultivars

Morphological grouping	Creeping bentgrass cultivars			
	Cohansey	Penncross	Toronto	Evansville
(A) Green shoots	11.4	11.1	10.2	12.7
(B) Nongreen lateral shoots	13.5	13.8	14.2	15.8
(C) A + B.	24.9	24.9	24.4	28.5
(D) Roots.	54.3	68.4	34.5	91.8
(E) Depth of mat (inches)	0.2	0.9	1.1	2.2

SOURCE: J.B. Beard.

Distinct differentials in mat accumulation had occurred, as shown in Table 2. The mat depths ranged from 0.2 inch in the case of Cohansey to 2.2 inches with Evansville. No major differentials were evident in the relative amounts of green shoots and nongreen lateral shoots.

The most striking differential was found in the root development of Evansville. Root accumulation was the major component that contributed to the much greater mat accumulation in the case of Evansville creeping bentgrass. No doubt studies of cultivar groupings within other species would show differentials in the component parts of the grass plant that are major contributors to thatch or mat accumulation.

CHEMICAL COMPOSITION STUDIES OF THATCH

Extensive characterization of the chemical constituents persisting in the thatch layer as well as originally present in the living tissues of three major turfgrass species were conducted. The chemical constituents analyzed included total cell wall content, hemicellulose, cellulose, and lignin. The upper and lower halves of thatched turfs were compared in terms of these chemical constituents as was the living leaf, stem, and root tissue of Toronto creeping bentgrass, Merion Kentucky bluegrass, and Pennlawn red fescue.

A similar study was subsequently conducted by Dr. Duble on bermudagrass. The results revealed lignin to be the most significant component in terms of high contents in those species more prone to thatch accumulation and in persistence within the existing accumulated thatch (Table 3).

Greater amounts of lignin occurred in the leaf sheath and roots than in the leaf blade. This supports earlier observations concerning the pseudo-thatch, where the leaves are subject to rapid decomposition and do not persist for any length of time. Measurements made in actual thatch layers indicated that lignin also occurred in the greatest amount in the thatch and mat, particularly in the lower portion which was in the more advanced stage of decay.

These data will not provide the professional turfman with information which he can utilize tomorrow in controlling thatch. However, the data do have major long-term significance in that the lignin content can be used as a biochemical marker to be used in a breeding program to select cultivars with a lower lignin content, and thus less of a tendency to thatch development.

THATCH CONTROL

"Dethatching" is defined as the procedure of removing an excessive thatch or mat accumulation (a) mechanically, by practices such as vertical mowing, or biologically, such as topdressing

Table 3. The Percent of Hemicellulose, Cellulose, Total Cell Wall, and Lignin Content in the Leaves, Stems, and Roots of Three Turfgrass Species

	Plant structure	Hemicellolose	Cellulose	Total cell wall	Lignin
Creeping bentgrass.	Leaf	34.2	18.5	56.3	3.7
	Stem	29.8[a]	22.5[a]	56.5	4.2
	Root	35.8	26.6[a]	76.3[a]	13.9[a]
Kentucky bluegrass.	Leaf	25.7	17.6[a]	45.6	2.3
	Stem	39.3[a]	27.5	71.7[a]	4.8[a]
	Root	33.9[a]	27.1	70.8[a]	9.8[a]
Red fescue.	Leaf	26.7	21.2[a]	50.6	2.7
	Stem	28.9	35.2	75.2[a]	11.1[a]
	Root	33.9[a]	33.1	79.6[a]	12.6[a]

[a]Significantly different at the 5-percent level, using Turkey's test.
SOURCE: D. Martin and J.B. Beard.

with soil. In Figure 1, the orderly process is shown whereby turf produces organic material. When the production rate exceeds the decomposition rate, thatch is formed. When the accumulated thatch has soil from topdressing added it becomes mat. If the biological decomposition processes are not excessively impaired, the mat eventually decays into organic matter. The net result of this process is an improvement of the physical and chemical properties of the soil, including increased soil water infiltration and penetration.

TOPDRESSING ↓

TURF ——→ THATCH ——→ (MAT) ——→ ORGANIC MATTER

Figure 1. Phases in thatch accumulation and decomposition.

As plant tissues die, they go through a series of decomposition processes. Initially, the leaching of soluble materials from tissue is involved. Our studies show that the nitrogen can: be leached from the leaves into the soil; move to the roots through the soil solution; be taken up by the root system; be translocated internally to the leaves and eventually to the chloroplasts, where the nitrogen is incorporated into chlorophyll molecules and visually expressed in terms of green color. This process can occur in as short a time as 14 days within the turfgrass community.

The second phase involves the activity of earthworms and insects. These soil animals digest portions of the organic thatch. By their movement up and down through the soil, insects also relocate some of this organic matter into the lower portions of the soil profile, further enhancing the physical properties of the soil. A third phase concerns the activity of fungi, nematodes, actinomycetes, and microorganisms, which are involved in various phases of the decomposition processes. Restricting this soil flora and fauna activity will result in a reduced thatch decomposition rate and a greater thatch accumulation.

The factors which contribute to thatch accumulation include: vigorous turfgrass cultivars; excessive nitrogen fertilization; acidic or alkaline soils; fine-textured soils; excessive irrigation; and pesticide effects.

VIGOROUS TURFGRASS CULTIVARS. When the turfgrass breeder selects grasses that will survive under the intense traffic conditions existing today, he chooses those that are more vigorous and capable of persisting longer under intense turfgrass wear, as well as those possessing a rapid recuperative rate. These same characteristics, which are so important in intense traffic areas, also contribute to excessive thatch accumulation in areas that do not receive intense wear.

EXCESSIVE NITROGEN FERTILIZATION. Raising the amount of nitrogen applied above the moderate level required for general root growth and recuperative potential only results in more leaf and shoot production. This, in turn, contributes to greater thatch accumulation.

ACIDIC OR ALKALINE SOILS. The earthworms, fungi, and microorganisms involved in the decomposition process are impaired under extremes in soil reaction. The most favorable pH range is from 6 to 7.

FINE-TEXTURED SOILS. Fine-textured soils such as clays may result in an environment that does not favor thatch decomposition, thus contributing to increased thatch problems compared to coarse-textured, sandy soils. However, thatch will form on sandy soils if other conditions are favorable.

EXCESSIVE IRRIGATION. Excessive water, like nitrogen which stimulates shoot growth, will only result in a thatch buildup.

PESTICIDE EFFECTS. Certain pesticides can cause increased thatch accumulation. Others will impair thatch buildup, as shown in Table 4. In this study, the calcium arsenate probably impaired the activity of earthworms and insects, thus furthering thatch accumulation. Certain other preemergence herbicides on test plots resulted in lesss thatch accumulation than on the untreated area. This is interpreted as being the result of a partial phytotoxicity that restricted shoot growth and, therefore, reduced the rate of thatch accumulation.

Table 4. Thatch Accumulation of Kentucky Bluegrass Resulting from Six Preemergence Herbicide Applications During an Eight-Year Period

Herbicide	Annual application rate (kg./ha.)	Thatch depth (in.)
Benefin	2	1.3
Bensulide	22	1.7
Siduron	11	1.7
Untreated	..	1.8
DCPA	11	2.0
Calcium arsenate	683	2.1

SOURCE: Turgeon, Beard, Martin, and Meggitt.

BIOLOGICAL CONTROL OF THATCH

A number of procedures can be utilized in the biological control of thatch. Two basic principles are involved: (1) adjusting the cultural practices, which slow the shoot growth rate and therefore the amount of organic material being produced; or (2) providing an environment in which the thatch decomposition processes can occur as rapidly as possible. In most situations, the turfgrass manager uses a combination of both approaches. The five major dimensions of biological thatch control are summarized in the following paragraphs.

SHOOT GROWTH CONTROL. Cultural systems can be adjusted in terms of the nitrogen nutrition and irrigation levels so that only enough growth is provided to maintain the shoot density, color, and recuperative rate of the turfgrass, but at the same time avoiding an excessive accumulation.

TOPDRESSING WITH SOIL. Over the years, this method has been most effective in the biological control of thatch, particularly on greens. Topdressing provides intimate contact with the accumulated organic material in terms of favorable moisture and pH conditions for decomposition. If the topdressing soil has been produced by composting, there can also be a major addition of soil microorganisms, which are so vital in thatch decomposition. This is particularly significant on greens and other turfgrass areas where fungicides and other pesticides are used extensively, thus restricting many of the beneficial soil microflora. The future trend will probably be to increase the composting of soils for topdressing, thereby providing a favorable biological dimension for thatch decomposition.

SOIL pH ADJUSTMENT. A study of thatch decomposition was conducted by Dr. Martin under *in vitro* conditions. Thatch was ground, placed in test tubes, and various environments superimposed on the thatch. The resulting rate of carbon-dioxide evolution was used as a measure of microorganism activity.

The effects of pH on microorganism activity during thatch decomposition are shown in Table 5. The most microorganism activity was in the pH range of 6 to 7, which is also the most desirable one in terms of overall turfgrass growth as well as for earthworm activity. It is important to check the pH of the topdressing material to be sure it is in the appropriate range.

Table 5. Effects of pH on Microorganism Activity in Red Fescue Thatch

pH	Percent CO_2 accumulated in a 24-hour period: First day	Second day
3	2.00	5.27
4	1.75	6.62
5	2.46	8.06
6	4.35	10.41
7	3.01	6.13
8	1.30	1.89
9	1.60	1.80

SOURCE: D. Martin and J.B. Beard.

SOIL CULTIVATION. Cultivation by coring, slicing, grooving, spiking, or shattering provides improved soil oxygen conditions, which can contribute to greater activity by the soil microflora and fauna population. A cultivation method such as coring, which brings soil to the surface, is particularly beneficial in enhancing thatch decomposition. Thus on fairways and sport fields where one must cultivate to correct soil compaction and thatch problems, it may be more desirable to use a procedure like coring that brings soil to the surface where it acts similarly to a topdressing. Additional research needs to be done in this area. The total picture is not well documented.

CARBON-NITROGEN RATIO. The rate of thatch decomposition by soil flora is greatest when the carbon-nitrogen ratio is in the 15 to 20 range. Ratios up to three times that level have been monitored, as shown in Table 6. No specific research has been conducted on this aspect of biological thatch control; but it is possible that manipulating the frequency of nitrogen application or using a type of nitrogen carrier which would maintain a higher nitrogen level in the thatch layer could be beneficial in thatch decomposition.

Table 6. The Carbon-Nitrogen Ratio for the Upper and Lower Thatch Layers of Three Turfgrasses

Turfgrass species	Thatch layer	C/n Ratio[a]
Creeping bentgrass	Upper	24
	Lower	27
Kentucky bluegrass	Upper	41
	Lower	48
Red fescue	Upper	29
	Lower	28

[a]A C/n ratio of 15 to 20 is preferred.
SOURCE: J.B. Beard.

SOIL ANIMAL ACTIVITY. The value in earthworms in thatch decomposition should not be underestimated. A study was conducted at Michigan State University on Merion Kentucky bluegrass to evaluate a range of cultural systems in terms of which one would be least likely to produce thatch accumulation. The treatments included: cutting heights of 1 and 2 inches;

clipping removal versus return; an annual vertical mowing versus none; and nitrogen fertility levels of 4, 6, 8, 10, 12, and 14 pounds of nitrogen per 1,000 square feet per year. The treatments were included in all possible combinations in three replications. The study was conducted over a twelve-year period. The results showed no significant thatch development from 1961 to 1973. This was true even at a 2-inch cutting height, with 14 pounds of nitrogen per 1,000 square feet per year, and with the clippings returned, no thatch mechanically removed, and the plot under irrigation. The adjacent, turfed alley just 2 feet off the actual plot area contained a 1-inch accumulation of thatch. In checking the records and studying the situation, the only difference between the two areas was that chlordane had been applied to the turfed alleys in 1963 and 1966. Thus, the lack of soil earthworm and insect activity was considered to be the main cause of this differential in thatch accumulation.

Earthworm activity cannot be allowed on greens, however. On fairways and sport fields, though, it can be a low-cost approach to thatch control. Avoid or minimize the use of insecticides which would impair earthworm activity. Rather than a program of a constant preventive insecticide applications, the alternative is to apply an insecticide only when a serious insect problem occurs that is damaging the turf. Also, the insecticide application rate should be no higher than is absolutely necessary to control a particular target insect pest. The net result will be an enhancement of earthworm activity, which can be further assured by maintaining the soil pH in the range of a 6 to 7 along with modest irrigation.

MECHANICAL CONTROL OF THATCH

The most commonly used mechanical thatch-control method involves vertical mowing. The procedure now most often used on greens is a frequent, light vertical mowing to remove excessive leaf accumulation from the surface. This is particularly effective in the case of the more vigorous bermudagrass cultivars. The availability of interchangeable vertical mowing units on the riding mowers has greatly facilitated the speed and frequency with which this type of vertical mowing can be accomplished. Rather than a very severe vertical mowing once or twice a year that destroys the surface characteristic of greens, it is now possible to achieve the same objective on a regular basis with a minimum of disturbance to the surface qualities of the green.

There are situations where a deeper vertical mowing must be accomplished once or twice a year for thatch control, particularly in turfs where the cut is higher than on a green. In this case, it is important to do the vertical mowing in order to avoid times when the potential for weed invasion, particularly the annual grasses such as crabgrass, goosegrass, and annual bluegrass, will be the highest. Also, it is desirable to have three weeks of favorable temperature and moisture conditions following vertical mowing for a rapid recovery of the desirable turfgrass species.

SUMMARY

Considerable progress has been made in building up our knowledge about thatch, its causes and prevention, in the last eight to ten years. However, we do not have all the answers. Some work still needs to be done. Products might become commercially available which can be utilized in thatch prevention or control. What these might be one can only guess.

Characterization of Thatch as a Turfgrass-Growing Medium

K.A. Hurto and A.J. Turgeon

A small amount of thatch in a turf has been considered advantageous because it provides some resiliency and increased wear tolerance. Thatch also insulates the underlying soil against temperature extremes. However, an excessive thatch accumulation has been associated with increased disease incidence, localized dry spots, poor response to fertilization, greater susceptibility to injury from temperature extremes, and proneness to scalping [1]. Where these conditions prevail, steps should be taken to remove or reduce the thatch layer. However, on parks and fairways or other large acreages, this practice is often not feasible.

An excessive thatch layer has the net effect of elevating the turfgrass crowns above the soil surface. Consequently, the root and rhizome growth from these crowns is within the thatch, with little rooting into the underlying soil. As a result, the thatch becomes the primary growing medium for the turfgrass community while the soil may be of only secondary importance (Figure 1). In the past, testing the soil for nutrients has been conducted with little regard for the presence of thatch [6]. The thatch is often discarded when a thatchy soil sample is sent to a lab for analysis. Thus, a series of investigations by Hurto and Turgeon [2] were initiated to accurately characterize thatch as a growing medium using standard soil-testing procedures.

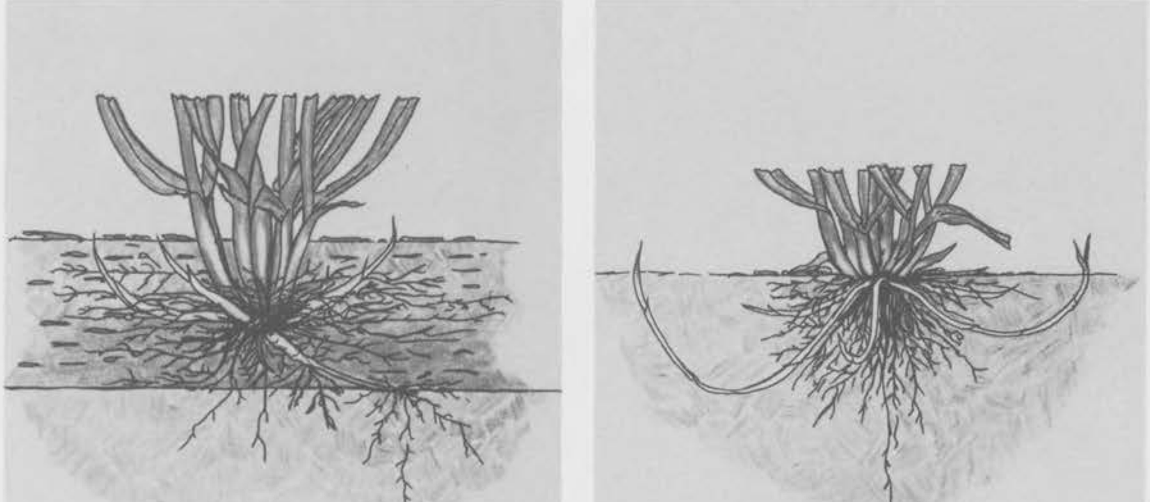

Figure 1. The positioning of the turfgrass crown, root, and rhizome development in thatchy turf (a) and thatch-free turf (b).

PHYSICAL CHARACTERISTICS

Measurements of thatch and the surface inch of soil from a thatchy and a thatch-free Kentucky bluegrass turf were made to determine their bulk density, porosity, and moisture characteristics.

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Since the structural arrangement of solids and pores directly affects the aeration and water content of a medium, these studies were conducted to evaluate thatch physically as a medium for growing turfgrass.

Jansen and Turgeon [3] reported that the bulk density of soil underlying thatch was higher than that of the surface inch of soil from thatch-free turf. Presumably, this is due to most of the roots being confined to the thatch layer. Also, based on observations of pesticide-induced thatch, the presence of thatch may also be associated with the lack of earthworm activity [5]. With increased bulk density, the aeration and water-holding capacity of this soil were less than where no thatch was present.

In contrast, thatch is a very porous medium with a very low bulk density. The generally accepted definition of thatch is a tightly intermingled layer of living and dead roots, stems, and leaves of grass located between the soil surface and the green vegetation above it. However, based on seasonal observations of various sites, it was evident that thatch may contain substantial amounts of soil.

Presumably this is a result of vertical movement of earthworms through the thatch-soil profile, particularly in the spring and fall. Much like topdressing, such a thatch formation may favor the decomposition of the organic debris by allowing for better moisture retention, greater microbial activity, as well as physical deterioration due to the abrasive action of soil particles on thatch fibers. As a result of the intermixing of soil in thatch, the bulk density increased from 0.22 to 0.63 gram per centimeter. However, total porosity was not reduced. In conclusion, although the infusion of soil increased the bulk density of thatch, the soil was loosely arranged in the thatch and appeared to have no impact on total porosity.

At saturation, the water content of thatch was substantially higher than soil as a result of its greater total porosity. However, most of this water is not held very tightly by the thatch since thatch is composed mainly of large (noncapillary) pores. Therefore, much of the water contained in thatch is lost by downward movement into the underlying soil and by evapotranspiration soon after irrigation.

Traditionally, irrigation is practiced to provide deep watering of the soil profile, promote deep rooting, and reduce the potential for soil compaction. However, thatchy sites which have roots confined primarily to the thatch layer require more frequent irrigation to maintain the moisture content necessary to sustain plant growth. Since thatch is a porous and fibrous medium, its resiliency resists compaction. Thus, a shallow and frequent irrigation schedule to prevent the thatch from drying out appears to have a minimal impact on its aeration porosity, and is actually essential for sustaining the turfgrass community growing in it.

CHEMICAL CHARACTERIZATION

The nutrient status of soils from turfgrass sites has been extensively studied; however, no study to date has reported the nutrient availability of thatch. Where a substantial accumulation of thatch is present, turfgrass crowns and roots are located in the thatch. Therefore, the thatch must serve as the primary source of nutrients for the plants. Several investigations were initiated to compare thatch and the surface inch of soil underlying five Kentucky bluegrass cultivars for their nutrient retention and supplying ability.

These studies revealed that thatch is substantially higher in nutrient retention when expressed on a weight basis. Although the thatch accumulation varied between cultivars, the results were comparable for the cation-exchange capacity (CEC), percentage of base saturation, exchangeable bases, and phosphorous. The CEC did not differ between fall and summer sampling dates; however, the base saturation was higher in the fall. Physically, thatch of Kenblue, Merion, and Nugget Kentucky bluegrasses was intermixed with soil, whereas this did not occur in P-140 and Touchdown. The significance of this was that in the soil underlying P-140 and Touchdown, the exchangeable base content was higher than in soils underlying the other three cultivars. This suggests that intermixing the soil with thatch increases its nutrient retention; whereas in thatch layers free of soil, there is a greater nutrient mobility. Measurements of pH revealed that thatch was not more acidic than soil; but the thatch probably contains materials supplied through irrigation, fertilization, and other cultural practices.

Frequently, thatch is not homogeneous throughout its profile. The upper portion receives clippings and senescing leaves. The lower portion, which is in contact with the soil, is composed of living and partially decomposed roots and stems. A series of studies was initiated to characterize the upper and lower profiles of thatch in terms of CEC and other chemical parameters. Results indicated a trend of higher nutrient values in the upper thatch layer. This suggests a greater degree of decomposition in the upper thatch, presumably due to the topical addition of leaf tissue.

From the discussion so far, thatch seems to be a favorable medium for plant growth. However, CEC and other values have been expressed on a weight basis. Mehlich [4] says that expressing soil test results on a weight basis is invalid. This assumes that the soil has a bulk density of 1.32 grams per centimeter, and that an acre furrow slice contains 2 million pounds of soil. Conversely, on a weight basis, thatch has approximately five times the volume of a soil. Mehlich proposed that a more accurate measure of nutrient values should be on a volume basis, even when comparing different soils. The nutrient retention of thatch when expressed on a volume basis is actually much lower than that of many soils.

SUMMARY COMMENTS

Thatch is not a highly favorable growing medium for turfgrasses. However, by recognizing its physical and chemical characteristics, cultural practices can be modified to partially compensate for the physical and chemical differences between thatch and soil.

Thatch is a fibrous and porous medium. Because of its poor moisture retention, thatch requires frequent irrigation. However, due to its high aeration porosity and resiliency, thatch resists compaction under traffic. Chemically, the nutrient retention of thatch is poor. Thus, more frequent fertilizer applications would be required to sustain a desired level of turfgrass growth. This is especially true where water-soluble nitrogen carriers are used in conjunction with frequent irrigation.

An alternate approach to fertilization may lie in the use of slowly soluble carriers to take advantage of the gradual release of nitrogen from these materials. Additional factors must also be considered in developing cultural programs for thatchy sites. Disease and insect problems may be more prevalent. Pesticide application methods may require some alteration to insure proper efficacy, and safety for turfgrass.

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Cultural Practices for Controlling Thatch

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Thatch is a tightly intermingled layer of living and dead stems, leaves, and roots of grasses that develops between the layer of green vegetation and the soil surface and interferes with the best growth of the turf. The interference with the growth phase distinguishes thatch from cushion. Possibly, my use of the word "cushion" is a way of saying that not all surface accumulation of turf is bad. It can serve to absorb shock from equipment or during use. It also has insulating value with regard to moisture and temperature.

Thatch is harmful primarily because of its interference with water movement, and because it harbors disease and insects. I cannot visualize thatch as a killing agent by itself.

When considering thatch control, thoughts seem to center on removing thatch. Our first thought, though, should be to avoid thatch by these means:

1. Watering less frequently, which will mean fewer surface roots.
2. Using the lowest acceptable level of fertilization.
3. Mowing at the higher cuts acceptable to the grass.
4. Not destroying earthworms unless necessary. After World War II, we observed no thatch where earthworms were abundant. Dave Moote spoke on this in the early 1950's, while he was a graduate student at Rutgers. Recent data from Illinois and Michigan support this view.
5. Encouraging the soil organisms to do their work by maintaining the proper soil pH of 6.
6. Tolerating earthworms if possible.
7. Being alert to pesticides that are established as ones interfering with decay organisms, and avoiding their use if possible.
8. Using any new grass varieties that prove to be less prone to thatch than previous ones.

Thatch removal is a realistic and effective way of dealing with thatch on small areas. This type work can be done in two ways:

1. Infrequent denuding of the turf cover.
2. Thinning on a frequent and regular basis.

Denuding the turf is a lot of work. It endangers the turf stand, and it leaves the turf unsightly for a period of time. The less severe and more frequent thinning will not remove the thatch as completely; but it does make room for some new shoots, and it permits a quicker turf recovery.

Turfgrass cultivation should not be classed with thinning for thatch control. Cultivation has more than a thinning effect because of its soil removal from the sod and redistribution on the surface of the turf. The remixing of soil with cultivation is akin to topdressing, which is a most effective cure for thatch. Topdressing will inoculate, introduce nutrients, and most importantly prevent the drying-out process that arrests decay. Of course, topdressing turf is impractical except for small, highly valued areas.

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Thatch will continue to accumulate on many sites. This means living with it. Where high-quality turf is necessary, it may be desirable and necessary to redig the turf. Remixing the thatch with the soil causes quick decomposition. In most cases, thatch-troubled turf cannot be redug; thus, the task is to grow adequate turf by paying the price. Watering must be more frequent and slower to assure penetration. Disease control becomes more costly. Care must be used to get insecticides to penetrate sufficiently. Maintain the proper pH in the thatch layer. Apply the fertilizer in smaller and more frequent applications to give a steady influx of new growth. Some would use a wetting agent to get water through thatch. This can be helpful at the moment, but it can be misleading because wetting agents do not reduce thatch.

It is not likely that a simple, easy cure for thatch will be found. We may find grasses that are less thatchy, but we must continue to minimize the development of thatch and make the best use of known techniques for control.

Thatch-Preemergence Herbicide Interactions in Turf

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Preemergence herbicides interact with thatch in two important ways: some herbicides can induce thatch development in a turf; and thatch, when present, can have important effects on the activity of herbicides that have been applied to the turf. The thatch-inducing effect of calcium arsenate and bandane was first reported by Turgeon, Freeborg, and Bruce in 1975 [5].

They found that two annual applications of the herbicides resulted in thatch development in a Kenblue-type Kentucky bluegrass turf that was virtually thatch-free in untreated plots. Other effects of the thatch-inducing herbicides included: elimination of earthworm activity in the soil underlying the thatchy turf; increased *Helminthosporium* disease activity in the spring; a greater tendency to wilt during mid-summer stress conditions; and an apparent reduction in water infiltration in the soil following sod removal.

A subsequent study on these same plots by Jansen and Turgeon [3] confirmed that water infiltration was substantially lower in the thatchy plots compared to the thatch-free, untreated turf. Other effects of the thatch-inducing herbicide treatments on soil physical properties included a: reduced hydraulic conductivity, lower content of soil organic matter, higher bulk density, and substantial reduction in the amount of extractable water at various tension levels.

A third study by Cole and Turgeon [1] revealed that the thatch-inducing herbicides inhibited the activity of several microorganisms in the soil underlying the thatchy turf.

The principal conclusions from these studies are: (1) calcium arsenate and bandane induced thatch development by inhibiting the activities of several soil-inhabiting organisms that are important decomposers of organic debris; (2) this caused an imbalance in the normal production-decomposition relationship that existed in the turf prior to the application of these herbicides, so that organic debris accumulated at the soil surface; (3) thatch development probably resulted from the response of Kentucky bluegrass community to the layer of organic debris. Likely responses include: adventitious rooting within and above the organic debris; tiller development and subsequent root and rhizome formation from tiller crowns within the organic debris; and crown formation at rhizome terminals arising above the soil surface to a position within the organic layer, with subsequent root and rhizome formation from these crowns.

Since thatch formation was associated with shallow rooting in the underlying soil, most of the roots were restricted to the thatch layer. Thus, thatch apparently functions as the primary growing medium of the turfgrass plants.

Recently completed investigations by Hurto and Turgeon [2] have shown that thatch is a very porous medium, with a poor ability to retain water and nutrients. Thus, the thatch can dry out more rapidly than the soil, so that turfgrasses growing in thatch are more susceptible to wilting under mid-summer stress conditions.

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Based on research by Jansen and Turgeon [3], the higher bulk density of soil underlying thatch, compared to surface soil in a thatch-free turf, is probably the result of the restrictions of most root and rhizome growth to the thatch with very few of these organs in the underlying soil. Also, since earthworms are known to have beneficial effects on soil physical conditions, their absence in the calcium arsenate- and bandane-treated plots is probably related to the higher bulk density of these soils. Differences in earthworm activity and in root and rhizome growth may also account for the measured differences in the organic-matter content of the soil.

The recognition that thatch can actually be the primary growing medium for turfgrasses led to subsequent studies by Hurto and Turgeon [2] in which the investigators attempted to characterize thatch as a growing medium and to determine its effect on the activity of herbicides applied to the turf. Field studies were initiated during the spring of 1976 in which several preemergence herbicides were applied to thatchy and thatch-free Kentucky bluegrass turfs.

During the summer, the thatchy plots treated with oxadiazon, benefin, and bensulide exhibited slight-to-moderate injury. These same treatments applied to thatch-free Kentucky bluegrass resulted in no injury. None of the plots receiving DCPA treatments showed injury symptoms, whether thatch was present or not.

Solon and Turgeon [4] reported that the use of oxadiazon, benefin, and bensulide severely reduced the shoot and root growth of single-plant, sand cultures of Kentucky bluegrass in the greenhouse, while DCPA did not inhibit the growth of these plants. Thus, the inherent susceptibility of Kentucky bluegrass to injury from these preemergence herbicides varies with the herbicide and with the rate of application. However, where Kentucky bluegrass is growing in soil, very little injury results from applications of these herbicides.

Presumably, this is due to the relative immobility of preemergence herbicides in a silty clay loam soil. Since the herbicides are retained in a position above and separate from the roots and rhizomes in the soil, the potential for herbicide injury is less than if the plants were growing in a porous, sandy medium.

Based on information from physical and chemical measurements of thatch (bulk density, porosity, water retention, and cation-exchange capacity), preemergence herbicides seem likely to be more mobile in thatch than in soil. Given that most of the roots and rhizomes of a thatchy turf are located within the thatch layer, greater injury to Kentucky bluegrass from some preemergence herbicides is more likely in thatchy than in thatch-free turfs. Further studies to determine herbicide mobility and its metabolism in thatch and soil media are in progress. However, it is apparent from work already completed that the existance of thatch can predispose a turf to injury from preemergence herbicides to which the turfgrass is inherently susceptible. Control of thatch or the infusion of soil into the thatch by topdressing or core cultivation followed by dragging the soil cores into the turf are possible means of reducing the potential for this injury.

Herbicides are valuable tools for use in a turfgrass cultural program. Their misuse, however, can result in a loss of turf or a reduction in turfgrass quality. Sometimes, misuse occurs because of a lack of understanding about the subtle and undesirable effects of some herbicides in a turfgrass ecosystem. Greater knowledge from research on herbicide-thatch interactions can help the turfgrass manager avoid errors in his turfgrass cultural program and sustain better turf.

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The Role of Silica in Thatch Development

John R. Street

Excessive accumulation of undecomposed surface organic matter is a major problem in the management of turfgrasses. This layer of plant debris, generally referred to as "thatch," is a tightly intermingled layer of living and dead stems, leaves, and roots of grass that develops between the layer of green vegetation and soil surface.

Many factors contribute to an excessive buildup of thatch. In general, thatch develops when the accumulation rate of dead and living organic debris from the actively growing turf exceeds the rate of decomposition. Thus, any cultural or environmental factor that stimulates excessive vegetative growth or that impairs decomposition increases the potential for thatch accumulation. Likewise, any chemical factor which slows down the decomposition of plant debris favors thatch accumulation.

The decomposition of plant debris involves mechanical fragmentation by soil fauna, primarily earthworms [3], and chemical breakdown by soil microorganisms, such as actinomycetes, bacteria, fungi, and yeasts. The activity of earthworms seems to increase the surface area of litter, thus making it more susceptible to attack by soil microbes. Earthworms may also help the process of decomposition by physically mixing soil with thatch or with plant debris. More thatch than elsewhere has been found on turf areas with low earthworm populations resulting from the application of certain pesticides [6,7].

Chemical constituents within the turfgrass plant vary in their susceptibility to microbial decay. Simple sugars and proteins are readily decomposed by soil microbes. However, chemical components such as hemicellulose, cellulose, and lignin are more resistant to decay [1]. The higher the content of these chemical constituents in the turfgrass tissue, the slower the rate of decomposition. Hemicellulose, cellulose, and lignin are complex carbon-containing compounds that make up the cell walls of plants. Lignin encrusts the cell walls to form wood-like tissues and serves as a major component of conducting vessels, fibers, and tracheids which strengthen plants. Lignin content has been reported as highest in turfgrass roots, followed by stems and then leaves [5]. This information correlates with physical observations by Ledeboer [4] and the author, which showed sclerified vascular strands, leaf sheaths, nodes, and crown tissue as the most resistant ones to decay according to amounts found in thatch. Martin [5] and Ledeboer [4] reported the lignin content of thatch as high as 16.3 and 23.5 percent, respectively.

Silica is an inorganic constituent of grasses, one that reportedly has a depressing effect on the digestibility of forage grasses [7]. The nature of this inhibitory effect of silicon compounds on the digestibility of grasses is not clearly understood. The encrustation of silica within cell-wall constituents is considered as the primary factor. This theory simply implies that the encrusting of silica within the cell acts as a physical protectant, limiting the microbial attack on the organic cell wall components. A second hypothesis is that part of the inhibition may be due to the effects of soluble silicon compounds, possibly a soluble cellulolytic inhibitor.

Interest has increased in soil mixes of higher silicate content (e.g., sand) for golf greens and other turfgrass areas subject to heavy traffic. Also, there is the reported effect of silica on lowering the digestibility of grasses. Hence, an investigation was undertaken into the possible role of this element in thatch development.

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Kentucky-31 tall fescue and Pennstar Kentucky bluegrass were cultured in hydroponics at rates ranging from 0 to 100 parts per million of silica oxide, concentrations considered as representative of those reported for various soil types. Turfgrass leaf, stubble, and root yields were not affected by the silica rates during a four-month period. No deficiency symptoms or other adverse effects on growth were observed. The silica concentrations of the various turfgrass components within a given species, was greatest in stubble, followed by leaves and then roots. The silica concentrations of the various plant components increased linearly with higher silica rates. Thus, greater concentrations of silica can be expected in turfgrass tissue as the silicate content of the growth medium increases.

The dry-matter components of Pennstar Kentucky bluegrass and Kentucky-31 tall fescue with established gradients in silica content (0.35 to 5.47 percent) were incorporated into the soil (whole or ground tissue) or were layered on the soil surface to form an artificial thatch layer. Decomposition was measured during an eight-week period. At the highest silica rate, the decomposition of Kentucky-31 tall fescue was reduced 9, 12, and 16 percent in the mixed, layered, and ground soil-plant systems, respectively. A similar trend for reduced decomposition of Pennstar Kentucky bluegrass was noted, although the reduction was much less.

These results indicate that silica lowers the decomposition of turfgrass tissue and, therefore, becomes an additional chemical factor contributing to thatch development. The magnitude of this effect depends on the turfgrass species or variety, involved, the soil type, and the concentration of tissue silica.

The silica content of thatch from a mature stand of Merion Kentucky bluegrass under different rates of nitrogen fertility ranged from 4.96 to 8.66 percent. The values were quite high compared to the silica content of the leaf tissue from the respective plots. The silica percentages of thatch were similar to silica values of tissue samples in the decomposition study which resulted in lower decomposition rates. Thus, the silica content of thatch would appear to be high enough to lower decomposition.

The chemical composition (i.e., nitrogen, carbon, cellulose, and lignin) was determined for all bluegrass and fescue decomposition samples to further substantiate the direct role of silica on decomposition. No significant effects of silica rates or tissue concentrations were noted. Thus, the effects of silica on lowering the decomposition rate of turfgrass tissue appears to be a direct one.

It is interesting to note that decomposition between the mixed and layered soil-plant systems did not differ for either species after eight weeks. This result contradicts the commonly accepted idea that the physical separation of grass debris from the soil is a major factor in thatch development. The physical separation of thatch from the soil is suggested to involve lower microbial populations in the layer. However, Cole and Turgeon [2] indicate comparable, if not higher, microbial populations in thatch compared to the underlying soil. Thus, cultural practices such as topdressing that introduce soil into thatch may improve the pH level, carbon-nitrogen ratio, and moisture relations of thatch more than those practices would be likely to directly increase the microbial populations. This has some interesting implications with respect to principles underlying the mechanism of thatch reduction by biological thatch-control products. More information on the properties of thatch and on the mechanisms of thatch development would be required in order to fully understand this complex problem.

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The Relationship of Thatch and Insect Activity in Turfgrass

Roscoe Randall

Thatch appears as undecomposed organic matter that builds up on the soil surface in turfgrass areas. The adverse affects can be many. Repeated applications of some residual pesticides, such as chlordane and dieldrin, have been observed to promote the growth of thatch. No matter what the cause, however, an accumulation of thatch can increase the survival of insect pests of turf as well as the damage caused by their feeding.

First, let us consider the two groups of turfgrass insects for which thatch can play a part in survival. The soil-infesting grubs constitute one group.

There are many different species in this group. The two considered here are the *Cyclocephla immaculata* (annual white grub) and the *Ataenius spretulus*. The annual white grub is a large C-shaped grub about 5/8 of an inch long when full grown. It lives in the soil by feeding on the roots of bentgrass and bluegrass. The *Ataenius* species is a small grub that feeds on the roots of annual bluegrass and bentgrass turf.

The second group of turfgrass insects is the grass-feeding caterpillars, including webworms and cutworms. They chew off the grass blades close to the soil surface.

There are two important ways in which thatch plays a part in the survival and increase of insect pest populations. First, thatch provides a protective zone for grass-feeding insects and a similar covering over soil-inhabiting grubs.

Webworms and cutworms commonly feed on grass blades at night and hide in burrows during the day. These burrows are on the surface of the soil, not in it. The sod webworm spends the winter in such a silken-lined burrow on the soil surface. Thatch provides a protective cover during the feeding months in the summer as well as during the hibernating months in the winter. This cover protects the worms from major predators such as birds and ground beetles, which feed on the webworms and cutworms. Robins devour or destroy a great many webworms and cutworms. Although black cutworms usually do not survive the winter temperatures in Illinois, they migrate into the state during the spring and increase their number throughout the summer.

Thatch also provides protection for soil grubs from predator birds and insects. The thatch becomes a thermal insulating layer that allows the grubs to feed on roots close to the soil surface during high daytime temperatures.

The second way in which thatch helps insects survive and reproduce is by preventing the penetration of insecticides to the places where the pests live, especially soil-inhabiting grubs. The penetration of and insecticide through thatch cover largely depends on the solubility of the chemical. Insecticides such as aldrin, dieldrin, heptachlor, and chlordane are essentially insoluble. So they tend to remain in the thatch and the soil. Repeated applications are added to the existing residues. For example, repeated applications of chlordane have resulted in a buildup of 1,200 parts per million in thatch, with about 5 p.p.m. in the first inch of soil and 0.5 p.p.m. at the four-inch level.

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The organic phosphate insecticides are more soluble. This group includes diazinon, trichlofon (Dylox and Proxol), chlorpyrifos (dursban), Dasanit, Dyfonate, and Aspon. However, there is a variation in the degree of solubility. The carbamates such as carbaryl (Sevin) and carbofuran (Furadan) are less soluble in sprays since they tend to remain in suspension in the water. Some phosphates such as the trichlorfon formulations form true solutions in water.

In summary, a thatch accumulation helps the buildup of potential insects pests in turfgrass areas. Preventing the growth of thatch or periodically removing it will help hold down the number of insects while also improving the results obtained with chemical control measures.