14TH ILLINOIS TURFGRASS CONFERENCE

NOVEMBER 29-30, 1973

Arranged and conducted by

COOPERATIVE EXTENSION SERVICE
COLLEGE OF AGRICULTURE
UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

In cooperation with

ILLINOIS TURFGRASS FOUNDATION

WELCOMING ADDRESS

Orville G. Bentley

We are pleased to welcome members of the turfgrass industry to the University of Illinois Annual Turfgrass Workshop and Conference. We hope that you find this College of Agriculture program both interesting and informative.

We constantly strive to keep College of Agriculture programs relevant to the contemporary needs of society. The growing enthusiasm with which this program is being accepted by turfgrass personnel gives us some confidence that this program is on target. We hope that we can continue to serve you as well or better in future years.

The challenges faced by the College of Agriculture today are many and diverse. In turfgrass culture alone, the development of new turfgrass cultivars, equipment, fertilizer carriers, and a variety of pesticides calls for a vigorous program of testing and evaluation to provide current information necessary for effective extension and teaching programs. The many problems faced by the turfgrass manager are all challenges for research personnel to develop new and more effective cultural methods.

The growth of our turfgrass teaching, research, and extension programs during the last ten years has been made possible largely by the continued support from the Illinois Turfgrass Foundation and other professional organizations in Illinois.

The interest of the general public in the visual environment suggest a strong future for the entire ornamental horticulture industry. Our number of horticulture majors doubled last year and increased another 50 percent this year. We now have three times as many majors as two years ago. This semester over 50 students are enrolled in our Turf Management Course.

This increase in students creates some problems with space and staffing, and many of our courses are filled during preregistration. We have a sympathetic administration and have confidence these problems will be resolved, although it is difficult to alter the situation with a status quo budget.

The increased number of students is a situation we must watch. But so far we have been able to place them all and many have received multiple job opportunities. I hope you believe, as I do, that giving young men and women excellent training in turf management is an important contribution to your industry.

We are happy to have you here and with your continued good counsel and cooperation, we hope to be able to serve you better in the future.

O.G. Bentley is Dean, College of Agriculture, University of Illinois.

CONTENTS

RESEARCH SESSION

SLOWLY SOLUBLE NITROGEN FERTILIZATION

T.D.Hughes

Interest in slow-release and slowly soluble nitrogen fertilizer materials is currently increasing among turfgrass managers. There are several reasons for this increased interest, but one of the most important is that turfgrass managers are often confronted with labor shortages. The possibility of maintaining attractive turfgrass areas without frequent fertilization, due to the slow-releasing or slow-solubilizing of the applied nitrogen source, is very appealing for reducing labor costs. Less frequent fertilization, along with the slow-acting nature of these materials, also greatly reduces the risk of foliar burning. This is an important advantage in situations where available labor forces do not possess necessary skills for the most successful use of readily soluble nitrogen fertilizer materials.

A recent development is the manufacture and sale of isobutylidene diurea (IBDU). This product is a synthetic organic condensation product of urea and isobutraldehyde. Theoretically, IBDU contains 32.19 percent nitrogen (guaranteed analysis is 31 percent).

Because IBDU is a high-analysis material which does not produce objectionable odors when moistened (and for several other reasons), much interest is currently centered around this material, and a thorough understanding of its behavior in soil is particularly pertinent.

The purpose of our studies is to characterize the nitrogen release rates in incubated soil samples at various soil pH levels and from various particle sizes. A study of soil pH effects on IBDU mineralization was needed to clarify inconclusive data reported in the literature indicating a possibly large decline in nitrogen release rates with increasing soil pH. Information about particle size effects is needed to facilitate mathematical descriptions of nitrogen release from this fertilizer material.

SOIL pH

A major difficulty in determining the effects of soil pH on release of nitrogen from IBDU is the change in soil pH resulting from the release of nitrogen. Our research indicates that when IBDU is added to a soil at a rate that approximates 1.5 pounds of N per 1,000 square feet the soil pH is reduced as much as 1 pH unit in about six weeks. In other words, soil at a pH of 7 will have a pH of 6, soil at a pH of 6 will have a pH of 5, etc., about six weeks following fertilizer application. However, it has been possible to determine that rates of release are significantly greater in soil with an original pH of 5.7 than 7.7. Comparisons of soils at these two pH's with a soil at pH 6.8 have not been significant and the release rate at pH 6.8 is approximately the average of the other two release

T.D. Hughes is assistant professor, Department of Horticulture, University of Illinois.

rates. It is also important that these differences exist only for the first four weeks following fertilizer application. Thus, it does appear that soil pH is important and that it should be taken into account in recommendations. The problem now is one of accurately determining the magnitude of importance of this effect. Work on this problem is continuing.

PARTICLE SIZE

The effects of particle size are quite dramatic and are directly related to the surface areas of the various particle sizes. However, for all particle sizes, the nitrogen release is extremely uniform for about four weeks following application. This is important because it means that the release is fairly predictable.

Our work indicates that the release of nitrogen from 0.6 to 0.7 mm. material is complete in about six weeks. This particle size is the smallest portion of the commercially available fertilizer material. The six-week release rate compares with a 50 percent release after 10 weeks for 1.7 to 2.0 mm. particles. It has been noted in studies over fairly long time periods (14 weeks) that losses of available nitrogen occur, but to date it has not been determined why or how and it is not known whether this loss would occur under field conditions. Work is also continuing in this area. It is hoped that this research will eventually result in a mathematical description of nitrogen release from this material which can be used for making recommendations. If successful, the resulting recommendations should be unusually accurate.

NITROGEN FERTILIZATION RESEARCH AT THE PENNSYLVANIA STATE UNIVERSITY

Donald V. Waddington

Soil fertility research is one of several areas of turfgrass research conducted at Penn State. Current research projects dealing with fertilizers and soil fertility include: evaluations of slow-release nitrogen fertilizers on Kentucky bluegrass and creeping bentgrass; use of soluble fertilizers on Merion Kentucky bluegrass and Pennlawn creeping red fescue; phosphorus and potassium fertilization on Merion bluegrass and Penncross creeping bentgrass; and potassium and magnesium fertilization on Merion bluegrass and Pennlawn creeping red fescue. Objectives in the studies are to determine the availability and rate of release of nutrients from various fertilizer sources; to determine the effect of various rates and sources of plant nutrients on the growth and seasonal carbohydrate status of turfgrasses; and to determine the interrelationships between applied fertilizers, soil nutrient levels, plant tissue nutrient content, and turfgrass response. Results of five studies dealing with nitrogen fertilization are present in this paper.

NITROGEN SOURCE TEST ON MERION KENTUCKY BLUEGRASS

This test was started in the spring of 1966, and was terminated in the summer of 1973. It has furnished us with a long-term evaluation of eight nitrogen sources. A complete report on this test is in preparation. The sources of nitrogen were as follows:

1. IBDU (30-0-0, or 31-0-0): isobutylidene diurea, a synthetic organic.

2. Urex (29-0-0): extruded urea-paraffin matrix. An experimental product in which paraffin slows the rate at which urea goes into solution.

3. Uramite (38-0-0): ureaform.

4. ADM (36-0-0): resin coated urea.

5. Milorganite (6-3-0): activated sewage sludge.

6. Urea (45-0-0): a soluble and readily available source of nitrogen.

7. 18-6-12 IBDU: a complete fertilizer in which two-thirds of the N is from IBDU and one-third is from soluble sources.

8. 18-6-12 UF: a complete fertilizer in which two-thirds of the N is from ureaform and one-third is from soluble sources.

IBDU and Urex were new products at the start of the test,and one of our goals was to evaluate their performance alongside some of the better known nitrogen sources.

D.V. Waddington is Associate Professor, Department of Agronomy, Pennsylvania State University.

Beginning in the spring of 1966, these materials were applied at rates equivalent to three or five pounds of N per 1,000 square feet per season in one, two, or three applications, except for urea which was applied nine times (every two weeks) at a rate of one-third pound of N per 1,000 square feet (three pounds of N per season) and a ureaform treatment of seven pounds of N per 1,000 square feet applied in the spring. Various combinations of fertilizer, rate, and frequency of application, and a non-fertilized check gave a total of 24 treatments.

Response to fertilization was measured by weekly determinations of clipping yields and color ratings.

Urex performed similarly to ADM, and response following application from these materials was quicker and greater than from IBDU, Uramite, and Milorganite. Performance of the 18-6-12 formulations was similar to that of the ADM and Urex. IBDU had good controlled-release characteristics, but response after fertilization was slow and delayed for several weeks. Residual effects from IBDU gave green color earlier in the spring than was obtained with the other treatments.

The urea treatment of frequent, light applications was included to obtain a relatively uniform growth pattern to which response from slow-release sources could be compared. Fewer applications, at higher rates, of Uramite, Milorganite, and IBDU gave similar growth patterns.

During the first two years of this study, the clippings were dried and analyzed for nitrogen so that the nitrogen recovered in the clippings could be calculated. Nitrogen recovery of the applied nitrogen ranged from about 20 percent for Uramite to over 50 percent for ADM, Urex, and Urea. The following relationships in nitrogen recovery generally held true:

ADM = urea = Urex > Milorganite = Uramite

ADM = urea > IBDU

Urex $\geq$ IBDU > Milorganite = Uramite

18-6-12 IBDU > 18-6-12 UF

Because yields and nitrogen recovery are highly correlated, the yield relationships were similar to those of nitrogen recovery. Over longer time periods, changes in these relationships would be expected due to subsequent nitrogen release from water insoluble components of some of the nitrogen sources. Yield data from the entire seven-year period show that sources containing water insoluble nitrogen gave relatively low response the first year or two, but yields eventually approached or equalled those obtained from more soluble sources. The changes in relative yields with time are illustrated in the table on the following page. For each year the total yield from urea has been designated as 100, and the other treatments are expressed relative to the urea value. As an example, the Uramite yield was only 61 percent of the urea yield in 1966 in spite of a greater nitrogen rate, but in 1970 the Uramite was 132 percent of the urea yield.

The last fertilizer applications to this test area were made in 1972. Observations made on yield and color during the spring and summer of 1973 indicated that greatest residual effects came from the Uramite treatments, which were the only ones with acceptable color during the summer months.

Relative Clipping Yields of Merion Kentucky Bluegrass

Material	lb. N/1,000 sq. ft. per season	No. of applications	Relative yield						
			1966	1967	1968	1969	1970	1971	1972
Urea	3	9	100	100	100	100	100	100	100
IBDU	3	1	77	86	88	87	95	88	93
IBDU	5	2	94	126	145	145	135	140	120
Uramite	5	2	61	71	105	122	132	112	126
Urex	5	2	135	114	130	143	137	128	122
Milorganite	5	3	91	91	111	119	117	100	118

N-71 FERTILIZER TEST

Kentucky bluegrass turf is being fertilized with 12 fertilizers having different amounts and sources of water insoluble nitrogen. Of particular interest in this test are two experimental materials: TVA sulfur-coated urea (30-0-0) and Charmin paper and pulp mill sludge (6-3-0). All materials are applied at a rate of 1.5 pounds of N per 1,000 square feet in the spring, summer, and fall. Initial applications were made in the fall of 1971. The area is mowed twice a week at a cutting height of one inch. Clipping weights and color are being used to evaluate turfgrass response.

The second-year data have not been completely analyzed for statistical comparisons. However, results from the first year indicated that both the sulfur-coated urea and the paper and pulp mill sludge are very promising as turfgrass fertilizers. Good slow-release characteristics were exhibited and the growth pattern from both of these materials closely paralleled that of the plots fertilized with Milorganite.

EVALUATION OF FERTILIZERS CONTAINING COMPOSTED REFUSE

A current problem in the United States is refuse disposal. It is most critical in urban areas where little land exists for sanitary landfill and where incineration of trash may lead to serious air pollution problems. An alternative disposal method is composting. The compost may then be used for various purposes such as a soil conditioner, fertilizer carrier, paper pulp, or in the manufacture of building materials. Ecology, Inc., of New York has utilized refuse compost in the manufacture of turfgrass fertilizers.

In a recently completed test, six fertilizers, three of which were produced by compacting N-P-K additives in composted refuse, were used to fertilize Pennstar Kentucky bluegrass. The following descriptions include the fertilizer grade (minimum guaranteed N-P_2O_5-K_2O), the total nitrogen content, and the percentage of total nitrogen that was water insoluble (WIN). Total N and WIN values were determined by chemical analyses. Three of the fertilizers are listed as having 0 percent WIN, although small amounts of it were detected.

Ecology 241 (8-2-4; 52 percent WIN): Lightweight fertilizer containing composted refuse. Total N, 8.91 percent.

Ecology 331 (12-3-6; 28 percent WIN): Lightweight fertilizer containing composted refuse. Total N, 13.32 percent.

Ecology 401 (16-4-8; 0 percent WIN): Lightweight fertilizer containing composted refuse. Total N, 16.32 percent.

Borden X-71 (30-5-8; 0 percent WIN): Homogenized, extruded lightweight fertilizer containing ground corncobs. Total N, 30.47 percent.

Borden Greens and Fairway (10-3-7; 0 percent WIN): Granular heavyweight fertilizer. Total N, 10.02 percent.

Scotts Turf Builder (23-7-7; 51 percent WIN): Lightweight fertilizer containing vermiculite. Total N, 23.75 percent.

Total nitrogen contents as determined by chemical analyses were used to calculate application rates. The fertilizers were applied at rates to supply two pounds of N per 1,000 square feet in May and again in August, 1970. Clipping weights and color ratings were used to determine turfgrass response to fertilization. Turf injury from fertilizer burn was also determined.

Fertilizers containing composted refuse produced yields and color ratings similar to those produced by fertilizers containing similar percentages of water-insoluble nitrogen. Ecology 241, an 8-2-4 containing compost and having 52 percent WIN, gave clipping yields similar to those produced by Scotts 23-7-7, which had 51 percent WIN. Scotts produced slightly better color ratings. Ecology 401, a 16-4-8 containing compost and having 0 percent WIN, gave turfgrass response similar to that of Borden's 30-5-8 and 10-3-7, which also had 0 percent WIN. The 16-4-8 and 30-5-8, both lightweight fertilizers, gave greater response than the heavyweight 10-3-7 in the fall of 1970 and the spring of 1971, indicating a higher residual effect from the lightweights. Yields and color ratings obtained with Ecology 331 (28 percent WIN) tended to be higher than those produced by Ecology 241 and Scotts 23-7-7, and lower than those produced by the fertilizers containing 0 percent WIN. This trend was attributed to the delayed availability of nitrogen as the percentage of WIN was increased.

In fertilizer burn tests, the fertilizers containing composted refuse produced less injury than other fertilizers containing similar amounts of WIN. Ecology 241 (51 percent WIN) was nonburning and was safer than Scotts (52 percent WIN), which was similar to Ecology 331 (28 percent WIN) in producing injury. Greatest injury occurred with materials containing 0 percent WIN. Of these materials, the 10-3-7 resulted in substantially more injury than 30-5-8 and Ecology 401, and Ecology 401 was safer than the 30-5-8.

In addition to serving as a partial solution to metropolitan refuse disposal, fertilizers produced by the Ecology process appeared to be a useful addition to the family of lightweight fertilizers.

A built-in safety factor has been observed with other lightweights in previous experiments at Penn State. Fertilizers made with peat or vermiculite carriers caused less burning injury than regular chemical fertilizers having approximately the same amount of WIN.

IBDU-UF TEST

This test was started on Kentucky bluegrass turf in the fall of 1971. Response to the following factors is being investigated.

1. Ratio of IBDU-nitrogen to ureaform-nitrogen:
   - (a) 1:0
   - (b) 3:1
   - (c) 1:1
   - (d) 1:3
   - (e) 0:1
2. Particle size of IBDU and ureaform:
   - (a) -6, + 16 mesh IBDU
   - (b) -10, + 25 mesh IBDU
   - (c) -16, + 60 mesh IBDU
   - (d) granular Uramite
   - (e) sprayable Uramite
3. Time of application:
   - (a) spring; five pounds of N per 1,000 square feet
   - (b) fall; five pounds of N per 1,000 square feet
   - (c) spring plus fall; 2.5 + 2.5 pounds of N per 1,000 square feet.
4. Irrigation:
   - (a) only when needed to prevent wilting
   - (b) more frequent applications than under (a).

Observations from the first year's results follow. The delay in response from IBDU was apparent in this test. Earlier spring growth and color were favored by fall-applied IBDU. Plots receiving a single fall application of IBDU in 1972 were severely hit by leafspot in the spring of 1973. We have used this rate on another area for a number of years with no trouble, but 1973 conditions were about perfect for leafspot and the high nitrogen added to the problem.

The two finer IBDU particle sizes gave more growth than the coarse IBDU, indicating faster release of N. No significant difference occurred in growth from the sprayable and granular forms of Uramite.

High amounts of rainfall, including more than 10 inches during hurricane Agnes, eliminated the irrigation variable for most of the 1972 season. However, during the weeks when there was a moisture differential, increases in growth due to more water tended to be greater on IBDU plots than on ureaform plots.

EVALUATION OF SLOW-RELEASE FERTILIZERS ON PENNPAR CREEPING BENTGRASS

In May, 1971, a study was initiated on Pennpar creeping bentgrass putting green turf to evaluate single applications of four slow-release fertilizers: Osmocote resin-coated fertilizer (19-6-13); sulfur-coated urea, an experimental product from the Tennessee Valley Authority, (33.5-0-0); IBDU (31-0-0); and Uramite (38-0-0). The area was aerified, fertilized at a rate of six pounds of N per 1,000 square feet, and topdressed. A urea (45-0-0) treatment consisting of 10 applications of 0.6 pounds of N per 1,000 square feet at two-week intervals was also used. Treatments were repeated in 1972 and 1973.

Greatest initial response came from IBDU. This finding was contrary to the delay in response observed on bluegrass turf. No doubt the release of N under putting green conditions was enhanced by a wetter environment due to more frequent irrigation and also to the placement of the fertilizer in the soil following aerification.

The resin-coated fertilizer was slow to start in 1971 and 1972, but after about six weeks its response was equal to or greater than that of the other slow-release materials. Release of nitrogen from this material increases with temperature, and warmer soil temperatures were probably the main reason for greater early response in 1973. Results with sulfur-coated urea were similar to those from the resin-coated fertilizer.

In 1971 initial response from Uramite was slow, but residual effects were apparent in 1972 and 1973 when early response was similar to that of other materials.

A single application of these slow-release fertilizers did not give acceptable season-long performance. In the fall they gave lower yields and poorer color than the urea treatment.

1973 TURFGRASS INSECT CONTROL

Roscoe Randell

GRUB CONTROL IN TURFGRASS

Annual white grubs damaged many home lawns and other areas of turfgrass during the fall of 1973. This insect has a one-year life cycle with eggs hatching in June and half-grown or larger grubs feeding on grass roots until cold soil temperatures cause them to go below the frost line to overwinter. Damage was most apparent in September.

White grub damage was present this fall where chlordane had been applied in 1972. Also, there were instances of poor or no control from chlordane applications made in 1973 to moderate or severely damaged lawns. Diazinon as a soil drench had been tried on grub-damaged lawns in 1972 with success. The ground maintenance crew at the University of Illinois in 1972 switched from chlordane to diazinon treatment of infested turfgrass areas with improved results.

During September, 1973, a total of 18 different lawn areas were treated for moderate to severe grub infestations. Chlordane, diazinon, Dursban, trichlorfon, and Primicid were applied to one or more of these infested areas. Spray formulations of all five insecticides were used, as well as granular applications of diazinon and Dursban. In all instances, the treated area was irrigated to soak the insecticide into the soil.

Chlordane at the application rate of five pounds active ingredient per acre gave poor control of severe grub infestations. Primicid also did not control grubs. Dursban at four pounds active ingredient per acre gave some control of grubs but not sufficient enough for recovery of the infested turf. Dylox at four pounds per acre gave satisfactory control. Diazinon as either a spray or granules provided satisfactory control of grubs. Recovery from damage had begun a week after treatment. Diazinon was applied at the rate of five pounds active ingredient per acre.

Six insecticides were tested in the laboratory for control of annual white grubs. Grubs were placed in the bottom of one-gallon ice cream cartons. One thousand grams of insecticide-treated soil was poured over the grubs and a layer of sod was placed on top of the soil. Insecticides used and parts per million incorporated with the soil are as follows: chlordane, 2.5 p.p.m.; diazinon, 2.5 p.p.m.; Dursban, 2 p.p.m.; trichlorfon, 4 p.p.m.; Aspon, 2 p.p.m.; and Imidan, 2 p.p.m. Treatments were replicated five times. Live and dead grubs were counted every 48 hours and live grubs returned to the bottom of the cartons. Results are given in the table on the following page.

Roscoe Randell is assistant professor of agricultural entomology, University of Illinois.

Insecticide	*Percent reduction of grubs after 2 weeks*
Chlordane	9.3
Diazinon	97.5
Dursban	42.7
Trichlorfon (Dylox, Proxol)	76.0
Aspon	21.3
Imidan	17.3
Untreated	4.9

Diazinon gave excellent control of grubs in these small soil sample tests. Dylox or Proxol gave acceptable control. Diazinon and Dursban are labelled for control of grubs.

INSECTICIDE EVALUATION FOR CUTWORM CONTROL ON PUTTING GREEN TURF

A Pennpar creeping bentgrass turf was selected for successive applications of various insecticides for controlling cutworms and other destructive insects. Insecticides under evaluation include: carbaryl (Sevin), trichlorfon (Proxol), diazinon (Spectracide), chlorpyrifos (Dursban), and chlordane.

Results suggest that effective cutworm control is achieved by timely applications of all materials. Plots treated with trichlorfon (Proxol) and chlorpyrifos (Dursban) exhibited the least insect- and bird-feeding damage.

EFFECT OF INSECTICIDES ON THATCH ACCUMULATION AND LOCATION OF RESIDUES IN SOIL

Dieldrin and chlordane applied three times a year over a five-year period resulted in a build-up of thatch on the soil surface in bluegrass turf. One inch of thatch was present in all replicates of chlordane and dieldrin. No build-up occurred in plots treated with carbaryl (Sevin) three times yearly for the past five years. Untreated plots exhibited no thatch accumulation.

The thatch build-up in the dieldrin and chlordane plots had an effect on the location of insecticides in the soil. Almost all of the insecticide residue had accumulated in the thatch layer (see Table 1).

Table 1. Insecticide Residue Levels in Insecticide-Thatch Plots, April, 1972

Site of residue sample	Chlordane, p.p.m.[a]	Dieldrin, p.p.m.[a]
Thatch layer	980.1	291.7
0-1 inch deep	5.28	2.47
4-5 inches deep	.61	.38

[a]Average of three replicates.

After 14 applications of insecticides in the spring of 1972, the 10- by 10-foot plots were divided in half in one direction. One half was dethatched. The thatch was left on the other half. Also, each 10 by 10 plot was divided in half in the other direction, with one-half of the plot continuing to receive insecticide treatments and the other half receiving no treatments. In summary, each 10- by 10-foot plot was divided into four 5- by 5-foot plots. On one plot the thatch remained and insecticide treatments continued; on another the thatch was removed and the treatments continued. Thatch was removed on the third plot and the treatments continued, while on the fourth plot the thatch was removed and treatments were stopped. Table 2 shows the average level of chlordane and dieldrin residues in the four plots in June, 1973, or 14 months after dethatching one-half of each plot.

Insecticide levels were highest in the top one inch of soil where thatch was removed and treatments continued. There was very little difference in residue amounts in the layer 4 to 5 inches deep. Thatch continued to contain high amounts of insecticide even where treatments had ceased for 14 months.

Table 2. Insecticide Residue Levels in Insecticide-Thatch Plots, June, 1973

Site of residue sample	Chlordane, p.p.m.				Dieldrin, p.p.m.			
	Plot: A[a]	B[b]	C[c]	D[d]	Plot: A[a]	B[b]	C[c]	D[d]
Thatch layer. . .	520.1	...	333.3	...	222.6	...	90.48	...
0-1 inch deep . . .	9.87	23.83	8.72	11.83	7.42	13.27	7.33	12.83
4-5 inches deep . .	1.29	1.09	1.0	.63	1.70	.88	1.15	.83

[a]Plot A--Insecticide applied at 5 pounds per acre, 2 applications in 1967, 3 applications per year 1968 through 1972, plus 1 application in 1973 (18 applications, thatch not removed).

[b]Plot B--Same as A above except thatch removed from plots prior to 3 applications in 1972 (14 applications before dethatching and 4 afterward).

[c]Plot C--Same as A above except applications ceased after 1971 (14 applications, thatch not removed).

[d]Plot D--Same as B above except applications ceased after 1971 (14 applications, thatch removed in 1972).

FUNGICIDE EVALUATIONS ON TURF

T. H. Bowyer, M. C. Shurtleff, and A. J. Turgeon

CONTROL OF SCLEROTINIA DOLLAR SPOT AND RHIZOCTONIA BROWN PATCH

A total of 11 commercial and experimental fungicides were tested at several rates and spray intervals for control of *Sclerotinia* dollar spot and *Rhizoctonia* brown patch. The test plots of Penncross creeping bentgrass (total area 5,600 square feet) were maintained at 1/4-inch cut. The randomized plots were each 7 x 10 feet and individual treatments were replicated four times.

Sclerotinia dollar spot first appeared in early June and the incidence of disease gradually increased during the season. Only one mild attack of *Rhizoctonia* brown patch occurred in late July, with notes taken on July 31 (Table 1).

Chemical companies who contributed fungicides for evaluation, as well as valuable technical assistance, included: the Chemagro Chemical Corporation (BayDam 18654 and Dyrene); Diamond Shamrock Corporation (Daconil 6F); E.I. duPont deNemours & Company (Tersan 1991 and Tersan LSR); Mallinckrodt Chemical Works (Fungo 50, Koban, and MF-568); Rhodia, Incorporated (RP-26071); and the Rohm and Haas Company (RH-3928).

All 11 fungicides and combinations, at all application intervals, provided good to excellent control of *Sclerotinia* dollar spot (Table 1).

Fungicides providing good to excellent control of *Rhizoctonia* brown patch included MF-568, Tersan 1991, Fungo 50, Daconil 6F, and the mixture of Fungo 50 and Koban. The 1:3 mixture of Tersan 1991 and Tersan LSR did not provide as good control as did Tersan 1991 alone. Dyrene, when added to BayDam 18654, provided better control than BayDam alone. The 1/8-pint rate of Daconil 6F, when applied at 10-day intervals, was insufficient to check brown patch, while the 7-day schedule of Daconil at the 1/8-pint rate, and the higher application rate of Daconil (1/4 pint per 1,000 square feet), applied at 7- and 10-day intervals, completely controlled the disease.

The incidence of brown patch on the plots receiving Koban and RP-26071 was comparable to that of the unsprayed check. However, Koban is registered only for the control of *Pythium* blight; its effectiveness in controlling dollar spot was somewhat unexpected. Due to a lack of fungicide, RP-26071 was last applied on May 17. Its systemic action against the brown patch fungus apparently did not last until the end of July although RP-26071 was still giving good protection against dollar spot over two months after its last application (Table 1).

CONTROL OF FUSARIUM BLIGHT

A severe attack of *Fusarium* blight occurred on Kenblue-type Kentucky bluegrass turf at the Ornamental Horticulture Research Center in Urbana in mid- to late August,

---

T.H. Bowyer and M.C. Shurtleff are Graduate Extension Assistant and Professor, respectively, Department of Plant Pathology, and A.J. Turgeon is Assistant Professor, Department of Horticulture, University of Illinois.

Table 1. Fungicidal Control of Sclerotinia Dollar Spot and Rhizoctonia Brown Patch on Penncross Creeping Bentgrass at the Ornamental Horticulture Research Center, Urbana, Illinois

Fungicide	Rate[a] (oz./1,000 sq. ft.)	Application interval (days)[a]	*Sclerotinia* dollar spot[b]			*Rhizoctonia* brown patch[c]
			June 4	June 22	July 31	July 31
RP-26071[d]	1.5	14	.02	.02	.22	21.0
RP-26071	3.0	14	.00	.00	.02	5.2
Daconil 6F	1/8 pt.	7	.02	.02	.10	.0
Daconil 6F	1/8 pt.	10	.00	.00	.20	9.2
Daconil 6F	1/4 pt.	7	.00	.00	.10	.0
Daconil 6F	1/4 pt.	10	.00	.00	.80	.0
RH-3928	0.5	14	.00	.00	.00	2.0
MF-568	4.0	14	.00	.00	.00	.2
Tersan 1991	2.0	14	.00	.00	.00	.2
Fungo 50	2.0	14	.00	.00	.00	.2
Koban	4.0	14	.00	.00	.00	16.0
BayDam 18654	2.0	14	.00	.00	.00	3.0
BayDam 18654 and Dyrene	2:2	14	.00	.00	.00	1.4
Tersan 1991 and Tersan LSR	1:3	14	.00	.00	.00	3.0
Fungo 50 and Koban	2:4	14	.00	.00	.00	.0
Check (untreated)	...	...	.34	.86	2.40	20.0

[a]Rate of application and application intervals were determined by label instructions or manufacturer's suggestion.
[b]Dollar spot ratings were based on a scale of 0 to 5 (0 = no dollar spot; 5 = severe dollar spot).
[c]Brown patch ratings were based on the percent of plot area diseased.
[d]Due to lack of fungicide, RP-26071 was last applied on May 17.

1973. Five commercially available and two experimental fungicides were applied to replicated plots on August 22 to evaluate their effectiveness in controlling further spread of the disease. In addition, a Jacobsen Sod-Master Sub-Air, fitted for injection of soil fumigants, was used to apply DBCP (Fumazone) into the soil to control nematodes. Evidence by Dr. Joseph Vargas at Michigan State University has shown that a high incidence of *Fusarium* blight is frequently associated with high nematode populations. The Sub-Air was also used without injecting nematicide for comparison.

The specific treatments and their single rate of application to 1,000 square feet of turf were: Tobaz (2 oz.); Fore (8 oz.); Fungo 50 (4 oz.); Tersan 1991 (8 oz.); Tersan LSR (8 oz.); BayDam (4 oz.); R-24952, a Stauffer Chemical Company systemic fungicide (4 oz.); the Sub-Air with and without Fumazone; and the untreated check.

The only treatment that provided control was Tersan 1991. By mid-September, the 1991 plots were almost completely healed, while all other treatment plots were still severely blighted. Research workers have reported good control of *Fusarium* blight with Fore and Tersan LSR at the rates used. In this curative test, however, these fungicides gave no control.

ILLINOIS TURFGRASS VARIETAL EVALUATION

A.J.Turgeon

One of the most important factors affecting turfgrass quality is the environmental adaptation of component grasses within the turfgrass community. Properly selected varieties can provide high-quality turfs even if the cultural program is less than optimal, while poorly adapted varieties may fail under the most expert management. For this reason, many universities and agricultural experiment stations have instituted turfgrass varietal evaluation programs to determine, first, which varieties and experimental selections will produce quality turfs under the prevailing environmental conditions; second, the cultural requirements of these grasses; and third, their adaptation to different levels of cultural intensity. The information reported herein is from a short-term, first-phase evaluation of varieties within three turfgrass species.

KENTUCKY BLUEGRASS

Kentucky bluegrass is a general-purpose turfgrass throughout Illinois. It is a grass species with considerable variation in density, texture, color, growth habit, disease susceptibility and tolerance of environmental and mowing stresses. There are now 51 varieties under test at this station. Of these, approximately 17 are commercially available. In addition, there are 10 blends (combinations of varieties) and 4 mixtures (combinations with other species) under evaluation. The varieties were planted in April, 1972. Plots measure 6 by 8 feet and each variety is replicated three times. Fertilizer is applied four times per year to supply a total of four pounds of nitrogen per 1,000 square feet, using a 10-6-4 analysis fertilizer. Mowing is performed two or three times per week at 1.5 inches. The turf is irrigated as needed to prevent wilt.

Many of the varieties have shown fair to good *Helminthosporium* leaf spot resistance during a spring in which leaf spot incidence was quite severe (Table 1). Notable exceptions were Kenblue (common), Park, and three experimental selections--K1-157, K1-158, and RAM #1.

Most varieties greened up fairly well in early spring except Nugget, which comes out of winter dormancy slowly. Seedhead production in May varied substantially among varieties. Seedheads were especially abundant in Baron, Victa, Ba 61-91, and Ba 62-55, followed by Adelphi, Parade, P-59, K1-132, and K1-155. These parameters are useful when evaluating blends of several varieties to determine which varieties have become dominant. For example, the Merion-Kenblue blend rated G (good) on spring green-up and 1 (low) in seedhead production. In comparison, Merion ranked only F (fair) and Kenblue G (good) in spring green-up; and Merion ranked low in seedhead production, while Kenblue had no seedheads. Also, the leaf spot rating was 1.7 for Merion, 5.7 (poor) for Kenblue, and 3.0 for the Merion-Kenblue blend. Hence, the Merion-Kenblue combination appears to be a fairly stable blend in its second year.

A.J. Turgeon is assistant professor, Department of Horticulture, University of Illinois.

Another interesting blend is the Nugget-Pennstar combination. The blend ranked fair in spring green-up while Nugget, alone, was poor and Pennstar was good. The Nugget-Park blend ranked good in leaf spot resistance and good in spring green-up. In comparison, Nugget was poor in spring green-up and good in leaf spot resistance, while Park was poor in leaf spot resistance and good in spring green-up.

The Fylking Kentucky bluegrass-red fescue (Pennlawn, Jamestown) mixtures ranked poor in turfgrass quality during the summer due to the brown out of the fescues. These mixtures would be expected to perform better in a moderately shaded environment. In contrast, the Fylking-C-26 hard fescue mixture held up fairly well under summer stress. This is consistent with results from the fine-leaf fescue evaluation.

FINE-LEAF FESCUE

Fine-leaf fescues (creeping red, chewings, hard, and sheep) have traditionally found use as shade grasses or for drouthy, sandy sites. In the past, their performance in sunny locations on fine-textured Illinois soils has generally been less than satisfactory. *Helminthosporium* leaf spot and other diseases have been responsible for the typical summer brown out of these species.

The fine-leaf fescue varieties were planted in April, 1972. Plots measure 6 by 8 feet and each is replicated three times. Fertilizer is applied twice yearly to supply a total of two pounds of nitrogen per 1,000 square feet.

The best varieties this year were the two hard fescues: Scaldis and C-26 (Table 2). Their fine texture and summer color make them promising for use as low-maintenance turfs along highways and other areas where these qualities may be desirable.

PERENNIAL RYEGRASS

Perennial ryegrass is usually considered a temporary lawn grass, or a nurse grass in seed mixtures. In Illinois deterioration during the summer months has prevented perennial ryegrass from becoming an important permanent turfgrass. Improved varieties with better color, density, mowing quality, and disease resistance have challenged the traditional image of perennial ryegrass.

Through the spring of 1973, the varieties NK-200, Manhattan and Pennfine appeared superior in density, color, and mowing quality (Table 3). As the season progressed, Pennfine held its color somewhat better than Manhattan or NK-200. By late August Manhattan and NK-200 regained their color and appeared comparable to Pennfine. As the season progressed into the fall, Manhattan improved further to become the best variety of those under test. Pennfine was fair, while NK-200 deteriorated appreciably.

These improved ryegrasses used alone or in blends offer promise for use on athletic fields and other turfs where their rapid establishment rate may be of importance in quickly repairing wear injury.

Table 1. Turfgrass Varietal Evaluation Results With Kentucky Bluegrass Varieties, Blends, and Mixtures, Planted in April, 1972

	Variety	Spring green-up[a]	Fall color[a]	Leaf spot rating[b]	Rust disease[c]	Seedhead production[d]	Quality rating[e] 6/29/73	Quality rating[e] 8/26/73	Quality rating[e] 11/16/73
1	A-20.	F	F	2.0		1	2.7	3.3	3.3
2	A-34.	G	F	2.0		1	2.0	2.7	3.0
3	Adelphi (P-69).	G	G	2.3		3	2.7	2.7	2.3
4	Baron	F	F	3.3		4	2.7	3.0	3.0
5	Bonnieblue (P-106). . . .	G	G	2.0	*	1	2.3	4.0	3.0
6	Brunswick (P-57).	G	F	1.7		0	2.3	2.3	3.3
7	Campina	G	F	4.3	*	2	3.0	3.7	3.3
8	Delft	G	F	3.3	*	0	3.0	4.0	4.7
9	Fylking	F	G	2.7		1	2.0	4.0	2.7
10	Galaxy (P-27)	G	G	1.7	*	2	2.3	3.7	3.0
11	Geronimo.	F	P	1.7	*	1	3.0	3.7	4.3
12	Glade (P-29).	F	P	3.0		0	2.3	3.0	3.0
13	Kenblue	G	F	5.7	*	0	5.0	5.0	3.7
14	Merion.	F	P	1.7	**	1	2.3	3.7	3.7
15	Monopoly.	F	F	2.7		2	3.0	2.7	3.7
16	Nugget.	P	P	2.0		1	1.7	4.0	3.7
17	Parade.	G	G	2.0		3	2.7	3.0	2.7
18	Park.	G	F	6.0		0	4.7	5.3	4.7
19	Pennstar.	G	G	2.0	*	1	2.7	3.7	3.0
20	Sodco	G	G	3.0		1	3.0	3.3	2.7
21	Sydsport.	F	G	2.0		0	1.7	3.3	3.0
22	Vantage	G	F	4.0	*	2	3.3	3.0	3.7
23	Victa	F	F	2.7		4	3.0	3.0	3.0

Table 1 (continued)

24	Windsor	G	G	3.0		0	2.7	2.7	3.7
25	P-59.	F	F	2.0		3	2.7	3.7	3.7
26	P-84.	G	G	1.0	*	1	3.0	3.3	2.7
27	P-133	F	F	2.7		0	2.7	2.7	3.3
28	P-140	G	G	3.7	*	0	2.0	3.3	3.3
29	P-142	F	P	2.0	**	1	2.3	2.7	4.0
30	PSU-150	F	F	2.0		1	3.0	3.3	4.0
31	PSU-169	F	F	2.3		1	3.3	3.3	3.3
32	PSU-190	F	G	2.0		0	2.3	3.3	3.0
33	PSU-197	F	P	2.0	**	1	3.0	3.3	4.3
34	EVB-282	F	F	2.0		2	2.7	3.0	3.0
35	EVB-305	F	F	2.3	*	2	3.0	3.3	4.0
36	EVB-307	F	G	2.7		2	3.0	2.7	3.3
37	EVB-391	F	F	2.0	**	1	2.7	3.0	3.3
38	Ba 61-91.	F	G	2.3		4	2.7	3.3	3.0
39	Ba 62-55.	F	G	3.0		4	2.7	2.7	3.3
40	K1-131.	F	G	2.0		1	3.0	3.7	3.3
41	K1-132.	F	G	2.0		3	3.0	3.3	3.0
42	K1-133.	F	G	2.3		1	3.3	4.3	3.0
43	K1-138.	F	P	3.3	**	4	4.0	5.0	4.0
44	K1-143.	F	G	2.7		1	3.3	3.0	3.0
45	K1-155.	F	G	2.0		3	3.0	3.0	3.3
46	K1-157.	G	G	5.0		0	4.7	3.7	3.3
47	K1-158.	G	P	6.0		0	4.3	2.3	4.3
48	K1-187.	F	F	2.3	*	1	3.0	3.0	3.3
49	RAM #1.	F	G	5.0		0	3.7	3.3	3.3

Table 1 (continued)

50	RAM #2.	F	P	3.0	*	1	3.0	3.7	3.3
51	MLM-18001	F	F	2.7		2	3.3	3.0	3.3
BLENDS									
52	Merion + Kenblue.	G	F	3.0	*	1	3.0	4.0	3.3
53	Merion + Pennstar	F	F	2.0		1	3.0	4.0	3.0
54	Merion + Baron.	F	F	2.0	*	3	3.0	3.0	3.7
55	Nugget + Pennstar	F	G	2.0		0	3.0	4.0	3.0
56	Nugget + Park	G	P	2.3		0	3.3	5.0	4.3
57	Nugget + P-29	F	G	2.3		0	2.7	3.3	3.0
58	Nugget + Adelphi.	F	G	2.0		3	2.7	4.0	2.3
59	Victa + Vantage.	F	F	2.7	*	4	3.0	3.0	2.7
60	P-59 + Brunswick. . . .	G	F	2.0		3	3.0	2.3	3.0
61	BLEND 38.	F	F	3.0		2	3.3	3.0	3.7
MIXTURES									
62	Fylking + Jamestown . . .	G	P	1.7		0	4.3	6.0	5.0
63	Fylking + Pennlawn. . . .	G	G	2.0		1	3.3	4.3	3.3
64	Fylking + C-26.	F	F	2.3		1	2.7	3.0	3.3
65	Fylking + Pennfine. . . .	G	F	1.0		1	3.3	3.3	3.0

[a]Spring green-up and fall color ratings are: P = poor; F = fair; and G = good.

[b]Leaf spot ratings were made on 4/25/73 using a scale of 1 through 9 with 1 representing no evidence of disease; 2 and 3 indicate some thinning of the turf; 4 to 6 indicate some blighting of the turf; and 7 to 9 indicate severe blighting of the turf.

[c]Rust disease rating is * for moderate incidence and ** for severe incidence.

[d]Seedhead production was rated on a scale of 0 to 4 with 0 indicating no seedheads and 4 as heavy seedhead production.

[e]Visual quality was measured on a scale of 1 through 9 with 1 representing best quality and 9 representing poorest quality.

Table 2. Fine-Leaf Fescue Varietal Evaluation Results

Variety	Quality rating[a] 6/29/73	8/26/73	11/16/73	Variety	Quality rating[a] 6/29/73	8/26/73	11/16/73
1 Barfalla. .	5.7	4.0	3.7	15 Polar.	4.3	4.3	4.0
2 Barok . . .	6.0	3.3	4.7	16 Roda	6.3	4.3	5.7
3 Dawson. . .	4.0	6.0	4.3	17 Scaldis. . . .	3.7	2.3	3.7
4 Durlawn . .	6.0	4.7	4.7	18 Scarlet. . . .	6.0	6.3	7.0
5 Encota. . .	7.0	5.7	6.3	19 Waldorf. . . .	4.3	5.0	4.3
6 Flavo . . .	5.0	4.0	4.7	20 C-26	4.0	2.3	3.0
7 Highlight .	6.7	5.7	7.7	21 Cebeco S70-2 .	7.0	5.7	7.0
8 Horritine .	4.7	4.3	3.7	22 Cebeco Hz71-4.	7.0	8.0	7.7
9 Jamestown .	5.0	4.3	4.7	23 ERG-11	6.7	5.0	6.3
10 Koket . . .	5.7	5.3	5.0	24 F-84	5.3	4.7	4.3
11 Menuet. . .	5.7	5.3	6.0	25 HF-11.	6.3	6.7	7.3
12 Novarubra .	4.7	4.0	3.0	26 RU-45C	5.0	4.7	5.0
13 Oregon-K. .	5.0	3.7	4.7	27 C-26+Jamestown	4.3	3.7	4.3
14 Pennlawn. .	4.3	4.0	4.3				

[a]Visual quality was measured on a scale of 1 through 9 with 1 representing best quality and 9 representing poorest quality.

Table 3. Turfgrass Quality of Perennial Ryegrasses Planted in August, 1972

Variety	Quality ratings[a] 6/29/73	8/26/73	10/26/73
1 Pelo.	5.0	4.3	5.3
2 NK-100.	5.0	4.3	5.0
3 NK-101.	5.3	4.0	6.3
4 NK-200.	3.7	3.0	6.3
5 Manhattan	3.7	3.0	2.0
6 Pennfine.	3.7	2.3	3.3
7 Common.	6.3	5.7	7.0
8 K8-137.	4.7	4.3	3.3
9 K8-142.	5.0	4.3	5.7

[a]Quality ratings were made on a scale of 1 through 9 with 1 representing best quality and 9 representing poorest quality.

HERBICIDES FOR VEGETATIVE ESTABLISHMENT OF KENTUCKY BLUEGRASS

E.G. Solon and A.J. Turgeon

As a continuation of work done on the vegetative establishment of Kentucky bluegrass, studies were made in the spring and summer of 1973 to evaluate preemergence herbicides as to their effect on the growth and development of the Kentucky bluegrass plant and to observe their effectiveness in controlling *Poa annua.*

Greenhouse studies were conducted in February, March, and April to look at the effects of the following herbicides on single-plant cultures of A-20 Kentucky bluegrass: Dacthal, 12 and 24 lb./A.; Balan, 2 and 4 lb./A.; Betasan, 12 and 24 lb./A.; Chip Cal, 261 and 522 lb./A.; and Ronstar (formerly RP-17623) at 2 and 4 lb./A. All herbicides were applied using granular formulations with the low rate for each herbicide representing the manufacturer's recommended application rate.

Parameters looked at in evaluating the herbicides were root and shoot weights, rhizome numbers, and density (number of shoots per pot). The results showed that the herbicides reduced rhizome numbers, with Chip-Cal causing the least reduction. Dacthal had little or no effect on root and shoot growth and density, while Betasan and Ronstar caused the greatest reduction of these parameters and rhizome number as well. After reviewing the results of the greenhouse work, a decision was made to conduct a field study to observe the effects of these herbicides and endothall on A-20 plugs and at the same time to evaluate their ability to control *Poa annua.*

On May 21, 1973, *Poa annua* was broadcast at the rate of 1 pound per 1,000 square feet over a prepared seedbed. The following day A-20 plugs approximately 2 square inches in size were planted on six-inch centers using a plugging machine. Herbicides were applied after planting using the low rate of each of the herbicides that had been used in the greenhouse work. Postemergence applications of endothall were made starting eight weeks after planting using the granular formulation at 4 pounds per acre and the liquid (potassium salt) formulation at 1 pound per acre. Four applications of the endothall formulations were made over the following five weeks. A second application of Chip-Cal at 261 pounds per acre was made on August 28, 1973, to see if the arsenic toxicity level could be reached for the *Poa annua.*

Fertilizer was applied at the rate of 1 pound of N per 1,000 square feet every three weeks. The turf was maintained at a mowing height of 2-1/2 inches and irrigation was provided as necessary to prevent wilting of the turf.

The herbicides were evaluated throughout the summer and fall months as to the percentage of A-20 and the percentage of *Poa annua* in each plot. During the summer months crabgrass and broad-leaved weeds were found in all plots except the Ronstar-treated plots and this necessitated using a mixture of 2,4-D, dicamba, and MAMA.

Results to date indicate that Ronstar is superior to the other herbicides. The plots treated with Ronstar had no weeds present, while allowing the greatest

E.G. Solon and A.J. Turgeon are graduate research assistant and assistant professor, respectively, Department of Horticulture, University of Illinois.

percentage of the A-20 Kentucky bluegrass plugs. Betasan and Balan provided good control of the *Poa annua*, but they were more inhibitory to the spread of the A-20 plugs than Dacthal which gave poorer control of the *Poa annua*. Postemergence applications of endothall provided poor weed control and were inhibitory to the spread of the A-20 plugs.

The results of this work indicate that the use of Ronstar in combination with Kentucky bluegrass plugs may provide a good method of changing the nature of a turfgrass community from *Poa annua* to a desirable Kentucky bluegrass cultivar. In addition, the screening of herbicides under greenhouse conditions is not necessarily a good indication of their performance under field conditions, i.e., Ronstar was very inhibitory to the growth of the A-20 plants in the greenhouse, but gave superior results in the field.

HERBICIDES FOR TURFGRASS RENOVATION

D.W. Black and A.J. Turgeon

An ideal herbicide for renovating turfs infested with bentgrass or other weedy perennial grasses would have the following characteristics: safety to the user, effectiveness against weeds, and no soil residual activity to preclude successful reestablishment of desirable turfgrasses. An herbicide that comes closest to fitting those requirements is glyphosate--a material that has recently become commercially available from Monsanto under the trade name Roundup. Glyphosate is a foliar-applied herbicide that is readily absorbed and translocated to the roots, stolons, and rhizomes of perennial grasses. It is quickly and strongly adsorbed onto soil clay particles so that it is essentially unavailable to plants once it has contacted the soil. Glyphosate is also safe to use since its LD_{50} has been determined to be in excess of 5,000 mg./kg.

Initial field testing in the summer of 1972 showed that glyphosate applications at 1 to 2 pounds per acre provided fair to good control of several perennial weedy grasses. Following this, an experiment was initiated in September, 1972, to determine whether a solid stand of creeping bentgrass could be converted to a Kentucky bluegrass turf by a combination of seeding and glyphosate treatment. Portions of the area were seeded with Windsor Kentucky bluegrass using a Rogers Seeder (a combination vertical mower and disc seeder), then treated with glyphosate at 1 pound per acre applied in 28 gallons of water per acre. Adjacent plots were first sprayed with glyphosate and seeded two weeks later. By April, 1973, the plots that were seeded and sprayed immediately afterwards were approximately fifty percent bentgrass, while the plots that were sprayed first and seeded two weeks later averaged only seven percent bentgrass. The substantial difference in bentgrass recovery, between the two treatment combinations, was attributed to the interference of vertical mowing with basipetal (downward) translocation of the herbicide. Severing the bentgrass stolons by vertical mowing apparently reduced the effectiveness of glyphosate in controlling this species. In contrast, allowing the herbicide to translocate before vertical mowing resulted in nearly complete control of the bentgrass. However, ninety-three percent control of bentgrass is not good enough if climatic conditions favor the recovery of this grass. By November, 1973, these same plots had become approximately fifty percent bentgrass. Thus, two or more successive applications of glyphosate would probably be necessary for complete elimination of bentgrass. This was further supported by results from additional studies performed in the summer of 1973. Even two applications of glyphosate, at two week intervals, did not completely eradicate bentgrass in all plots.

The difficulties encountered in attempts to eradicate bentgrass indicate the need for more intensive research to optimize the response from glyphosate applications. A more accurate determination of application rates, timing, spray volumes, and the need for surfactants must be made before the best possible results can be obtained from using this herbicide. Yet, results to date suggest that glyphosate will probably become an important herbicide for use in turf.

D.W. Black is graduate research assistant and A.J. Turgeon is assistant professor, Department of Horticulture, University of Illinois.

NEW CHEMICALS FOR NUTSEDGE CONTROL IN TURF

James A. Tweedy

Nutsedge is becoming a serious weed problem in many turfgrass areas. It is not effectively controlled by any of the pre- or postemergence herbicides commonly used for weed control in turf areas. Several new chemical herbicides have been introduced during the past two to three years that show considerable promise for the selective control of nutsedge in turfgrass.

For a chemical to effectively control nutsedge, it must control not only the shoot portion, but also the underground vegetative portions called rhizomes and tubers. One nutsedge tuber can produce many new plants in a few weeks, resulting in a large area infested with the weed. The tubers can be dormant for long periods making it more difficult to eradicate the entire population.

In the past, the organic arsenicals DSMA and MSMA have been used with limited success in suppressing nutsedge growth in turfgrasses. Major problems with the organic arsenicals have been poor control and herbicidal injury on many turfgrass species, especially when applied during high temperatures.

Two herbicides that were evaluated for nutsedge control in turf in 1973 were bentazon and S21634. Bentazon was applied at 2 and 3 pounds per acre in a single treatment, and 4 and 6 pounds per acre in split applications. The split applications were applied at 2 and 3 pounds per acre, followed by repeat applications at the same rate approximately two weeks later. The split applications of bentazon gave excellent control of nutsedge with no injury to the Kentucky bluegrass turf. The single applications did not give complete control of the nutsedge.

The experimental chemical S21634 was also applied in single and split applications as in the study with bentazon. The single rates were 2 and 3 pounds per acre and the split application was 4 and 6 pounds per acre. The split applications of S21634 gave excellent control of the nutsedge in Kentucky bluegrass.

These two new herbicides appear to be promising for nutsedge control in established turf. No injury was observed on the Kentucky bluegrass at any of the rates tested. More data from these plots on control the following season will help in evaluating the degree of control of the underground tubers and rhizomes.

J.A. Tweedy is professor, Department of Plant and Soil Science, Southern Illinois University.

GOLF TURF SESSION

PUTTING GREEN CONSTRUCTION—A REVIEW

Donald V. Waddington

The subject of putting green construction may bring to mind completely different thoughts depending on an individual's background. Some would immediately consider the various methods used in the actual construction of a green, including surveying, grading, mixing and placement of materials, fertilization, and seeding. Others would think of greens design from the playing and aesthetic viewpoints, and would draw importance to factors such as shape, size, contouring, and elevation.

Greens construction brings to my mind another component of design: the physical composition of a green, which is the subject of this presentation. Although normally hidden by the grass growing on the green, this component may often express itself indirectly as various undesirable features such as standing water, hardness, algae, or unhealthy grass. Physical composition includes the kind of soil, modifying materials, sand and gravel layers, and provisions for drainage, all of which may be present in varying amounts. Construction methods and the other components of design are equally as important as the physical makeup of a green and are also worthwhile subjects for discussion. We should keep in mind that a green with perfect soil conditions and a dense cover of grass isn't the only answer to good playing conditions. Musser wrote: "Good turf will not compensate for the monotony of consecutive holes of similar yardage and character nor eliminate the irritation of poorly placed hazards, blind shots, and other items that unfairly penalize the average golfer." We could add that good design for aesthetics and player ability won't compensate for a shot being buried in a soggy green or bouncing off the green as though it had landed on Interstate 74.

We've come a long way in some phases of putting green construction. And if you don't believe it, consider this recommendation written in 1902 by Walter J. Travis:

> "Where the natural conditions are favorable it is advisable to build up a green from the old turf. But if coarse grass exists to any extent, then it is better in the long run to resort to sodding. In the event of good sod not being available, there is but one thing left to do, and that is to plough up the surface to a depth of a foot or so and remove all loose material. Then proceed to fill in a layer of sand a few inches in depth, and cover it with good loam about an inch or so thick; on top of this put a thin crust of well-rotted manure, and then another layer of loam of two or three inches. At this stage apply a dressing of bone-dust, with a touch of slaked lime. Cover this with a suggestion of sand, superficially only, and top off with loam, the surface being raked and finely pulverized. Sow liberally with a mixture of recleaned Red Top, Rhode Island Bent, Creeping Bent, Crested Dog's Tail, and Kentucky Bluegrass, and level off and roll with a very light roller."

D.V. Waddington is associate professor, Department of Agronomy, Pennsylvania State University.

Today we play on greens built by about every method imaginable. I recall seeing one green with a mound in the middle that supposedly covered a truck that 'died' during the construction of the green. And today we continue to build greens using every method imaginable--perhaps due to ignorance, lack of funds, or a little of both. Several methods of construction are presented in this paper. Various combinations, some sound and some not, can be made from these methods.

METHODS OF CONSTRUCTION

I. Native soil; no modification

The existing terrain may be used as is or reshaped using the native soil. This method is often used by the novice or when funds are limited. It may prove satisfactory on well-drained sandy loams, loamy sands, and sands. On medium- or fine-textured soils, good surface drainage design is important because of slower rates of infiltration and internal drainage, especially under heavy play conditions.

II. Native soil; surface modified

As in the first method, reshaping may or may not be used. Amendments are applied to the surface and then mixed with the native soil by various kinds of tillage equipment. Although soil, peat, or other amendments could be added to improve the moisture retention properties of a sandy soil, usually the native soil receives additions of sand, other coarse amendments, or peat to improve the permeability. If added in the proper proportions, the amendments will help maintain good permeability even under compacted conditions. Hopefully, the underlying noncompacted native soil will be permeable enough to carry away the water that percolates downward from the modified layer.

III. Modified soil with underdrainage

This method evolved because native soils did not generally remove excess drainage water rapidly enough. After initial grading is completed, a 4- to 8-inch layer of gravel or crushed rock is put into place and the greens soil mixture, ideally mixed off-site, is placed on top.

The underdrainage layer may be used with or without tile drainage. Swales cut in the subgrade or tile placed in swales or trenches can be used to direct the flow of drainage water. Not only does the drainage layer provide rapid removal of water entering it, it also changes the moisture retention in the soil mixture above it. Due to differences in the unsaturated conductivity properties of the two layers, the soil mixture retains more water than it would if it were placed on a base of similar texture. In other words, as water drains from such a system the soil water tension increases, and a tension is reached at which the coarse layer with large pores ceases to conduct water. Then the soil layer which normally conducts water at that tension cannot drain and remains wetter than if underlain by more soil.

Be sure to remember the following facts concerning water retention in layered greens (methods III and IV).

A. Soil underlain by coarse material will retain more water than a similar depth of the soil alone.

B. The differential in texture between the soil and coarse layer influences the change in water retention. A soil over gravel will hold more water than soil over sand.

C. A sharp interface between the soil and coarse material favors increased retention. Movement of soil into the coarse layer decreases retention in the soil.

D. The deeper the soil over the coarse layer, the lower the water content near the surface after excess water ceases to flow from the system.

If the native soil is unsatisfactory for inclusion in the mixture, the use of a commercially prepared mixture serves as an alternative to bringing in separate shipments of sand, soil, and organic materials. Various off-site mixing methods insure a more uniform mix than can be obtained by on-site mixing. On-site mixing is accomplished by placing the mixture components in layers on the porous base and then mixing with a rotary hoe, disk, or other suitable tillage equipment. It is difficult to mix more than 4 to 6 inches of material at one time, therefore mixing must be done in two or three steps to insure good mixing throughout the entire depth of about 10 to 15 inches. The first additions above the porous layers of gravel or rock should be in the order of sand, peat or other organic material, soil, and sand. During mixing, the heavy sand tends to work down and the lighter peat tends to work toward the surface. Additional layers should be in the order of peat, soil, and sand. Problems often associated with on-site mixing are the presence of undesirable pockets or layers of amendments due to partially mixed materials or components that were placed too deep to be reached by the tillage equipment.

IV. USGA method; laboratory tested, modified soil with underdrainage

The USGA Green Section has prepared specifications which are backed by considerable research effort as well as field observations. This method differs from the preceding method in that tile is always used in the underdrainage layer and a sand layer is used on top of the underdrainage layer to prevent inwashing of the greens mix, which is prepared off-site and which must meet certain permeability and porosity requirements in laboratory testing. From the surface to the subgrade a USGA green would show the following profile of:

A. A top layer of at least 12 inches of the modified soil;

B. A 1 1/2- to 2-inch layer of very coarse sand;

C. At least four inches of gravel (preferably pea gravel, 1/4 to 3/8 inch in diameter) or crushed stone covering the tile and subgrade.

D. Four-inch diameter tile placed in trenches cut into the subgrade.

The laboratory testing is an important step that insures that the mix will have acceptable water intake and drainage properties under compacted conditions. The false water table created at the soil-sand interface provides greater moisture retention in the modified soil. Highly modified soils approach a single-grain structure, with low cohesive forces and with little or no binding of particles by clay. In such soils the tendency for particle migration into porous sublayers is greater than with most native soils; thus the need for the sand layer. A general rule is that the diameter of particles in an underlying layer should not be greater than five to seven times the diameter of particles in the overlying layer.

Based on evaluations of existing USGA greens and additional research, the Green Section recently made refinements in the acceptable limits used in the laboratory testing of putting green soils. Perhaps the most significant change was the increase of the acceptable water percolation rate from a range of 0.5 to 1.5 in./hr. to a range of 2 or 3 to 10 in./hr.

V. Sand greens or "Soil-less" greens

Those who consider a sand green to be one with a sand rather than grass putting surface may prefer the term "soil-less" green, which actually may be more accurate because components other than sand are sometimes used. Researchers at the University of California and Purdue University are responsible for much of the development work on this type of greens construction.

Initial work at California was involved with construction of greens in which about 20 to 22 inches of sand, composed mainly of medium and fine sand sizes, was placed directly over the subgrade and tile system. Small amounts of well-aggregated clay and peat were mixed with the surface 4 or 5 inches, keeping the sand content at about 85 to 90 percent. These greens performed satisfactorily; however, high construction costs due to mixing operations and the depth of sand required led to the development of a shallower sand green. This green is constructed by placing 12 inches of sand directly on the subgrade and a gravel-covered tile system. No amendments are used with the sand, which must meet rather narrow specifications to be satisfactory for these greens. On a weight basis, at least 60 percent must be medium sand (0.5 to .25 mm.) and 85 to 95 percent should be in the coarse, medium, and fine sand ranges (1.0 to 0.1 mm.). From 2 to 8 percent is allowed below 0.1 mm., and 0 to 10 percent may be present as very coarse sand and fine gravel (2.8 to 1.0 mm.). Fortunately, a good number of native sands in California meet these specifications due to sorting by wind or water action during their deposition. In Pennsylvania we would have to wash and screen most of our sands in order to meet these specifications.

At Purdue University a construction method of using sand over a plastic barrier has been developed, and is referred to as the PURR-WICK root zone system (named for the Plastic Under sand Reservoir Root zone and the wick or capillary movement of water upward from the area of low moisture tension maintained at the plastic barrier).

Steps in the construction of a Purr-Wick green are as follows:

A. Shaping of the subgrade; including the construction of vertical barriers that delineate different elevations and minimize lateral flow of water from higher to lower tiers.

B. Placement of the impervious plastic barrier (6 to 10 mil polyethylene sheeting) to cover the sides, base, and vertical barriers. Edges can be overlapped and taped to provide a good seal.

C. Installation of two-inch, slitted drainage tubing. The drainage tubing is connected to an adjustable outlet located on the outside of the plastic barrier. The height of the discharge pipe can be adjusted to cause different levels of reserve water in the green.

D. Addition of sand. A uniform sand, with most of the particles in the medium size range (0.25 to 0.5 mm.), is essential. Sand is compacted when moist and the final depth should be a minimum of 10 inches. Where several tiers are used, sand depth above vertical barriers should allow enough depth for cup placement.

E. Modification of surface two inches. To improve nutrient retention, a prepared mix, such as 50 percent sand, 20 percent peat, 20 percent calcined clay, and 10 percent vermiculite, can be spread on the surface, or the amendments can be worked into the surface of the sand layer.

Compared with a sand green on a soil subgrade, the Purr-Wick green offers an advantage of water-level control, which makes possible the conservation of water and less frequent irrigation.

SELECTING A METHOD

Selection of a method for putting green construction is an activity in which a little knowledge may lead to disastrous results. An example of misunderstanding is that which has unfortunately occurred in the case of USGA greens. Some think they are greens in which the soil has been highly modified with sand. Others consider the cross-sectional profile, with layers of soil, coarse sand, and gravel, to be the distinguishing characteristic. Actually, both the modified soil (which must pass laboratory testing) and the layered profile are integral parts of the USGA green, and one feature without the other surely doesn't guarantee satisfactory results. Most native soils will be too wet if placed on a sand layer, and a highly modified soil placed on topsoil or subsoil may be quite drouthy. Substitution of a coarser sand for the prescribed sands of sand greens would result in an excessively drained, drouthy green. A lot of experience and research has gone into the development of the newer ways to construct greens. Don't alter specifications unless you are sure how the alteration will affect the performance of the green.

In making your choice you must take into consideration the variations in costs of design, materials, labor, equipment, and laboratory testing. The availability of materials or equipment may be an influencing factor. Professional opinions may also play a part in the final decision. But a word of warning: ask four experts and you may get five different, equally valid answers.

Your goal is a green which will provide a good putting surface with a minimum of maintenance problems. Practices which seem most important in providing such a green are as follows:

A. Use a modified soil or sand which will retain good physical conditions even when severely compacted.

B. Because soil modification or the use of sand to increase permeability also decreases the water-holding properties, it is essential to provide greater water retention by using construction methods in which the soil mix or sand is placed over a sand, gravel, or crushed-rock layer, or in some cases on an impervious base such as plastic sheeting.

C. Some laboratory testing will be needed. It may be as simple as a particle-size analysis to determine the suitability of a sand for a "soil-less" green. More involved are the procedures used to determine the amount of amendments required to adequately modify a soil. Although laboratory data may not always be translated into exact field results, recommendations based on existing and properly conducted and interpreted laboratory tests are more dependable and offer much more promise than the so called "mud-pie" tests or "rule-of-thumb" recommendations.

D. Provide adequate underdrainage to remove drainage water. If natural features are inadequate, man-made structures involving gravel or crushed-rock layers or drainage tile must be constructed.

REFERENCES

Bingaman, D.E., and H. Kohnke. 1970. Evaluating sands for athletic turf. Agron. Journ. 62:464-467.

Daniel, W.H. 1972. Purr-Wick root zone system for turf. Midwest Turf News and Research, Dept. of Agronomy, Purdue Univ. No. 40 (revised), 6 pp.

Davis, William B. 1973. Sands and their place on the golf course, pp. 57-63; Examples of real solutions--the fine sand green, pp. 71-79. Proc. 1973 Calif. Golf Course Supt. Inst. University of California, Davis.

Davis, W.B., J.L. Paul, J.H. Madison, and L.Y. George. 1970. A guide to evaluating sands and amendments used for high-trafficked turfgrass. Agr. Ext. AXT-n 113, 93 pp.

Ferguson, M.H., H.L. Howard, and M.E. Bloodworth. 1960. Laboratory methods for the evaluation of putting green soil mixtures. USGA Jour. and Turf Mgt. 13(5): 30-32.

Harper, J.C. 1972. Putting green construction. Agronomy Ext. Publ. The Pennsylvania State Univ. 8 pp.

Miller, D.E. 1969. Flow and retention of water in layered soils. Conservation Res. Rpt. 13. ARS, USDA. 28 pp.

Musser, H.B. 1950. Turf Management. McGraw-Hill Book Co., Inc. New York. 252 pp.

Travis, Walter J. 1902. Practical Golf. Harper and Brothers Publ. New York. pp. 160-161.

USGA Green Section Staff. 1960. Specifications for a method of putting green construction. USGA Jour. and Turf Mgt. 13(5):24-28.

USGA Green Section Staff. 1973. Refining the Green Section specifications for putting green construction. USGA Green Section Record 11(3):1-8.

DRAIN TILES: WHAT THEY CAN DO

Bruno Vadala

During the drouth years of the early sixties, drainage was the farthest thing from my mind. That old saying "Out of sight--out of mind" certainly applied here. The drouth became so critical that all clubs using city water were notified to find their own source of water for the following year. After receiving this notice, we immediately called in contractors for bids. We had our existing lake deepened and a new one dug south of the old lake. We also had to put in a pumping station.

After the drouth broke, we went through the opposite extreme--constant rain. It seems as though we had at least one heavy, damaging rain storm every year for five years. These wet spells brought out the weaknesses in our drainage system. In checking out these wet areas, we found broken tile lines, clogged lines, and in some places no lines at all.

In 1969 we decided on a poa eradication program. At the time the idea was to make light-rate applications of chip cal while correcting a few drainage problems each year. Most of you have probably seen areas under treatment and in need of drainage especially after a heavy rain storm, followed by extremely high temperatures. If I could turn back the clock, I would definitely correct all drainage problems first. Although it has been a rough experience these past few years, the increase in our bent population from 25 percent to 75 percent clearly shows me what the poa program can do in conjunction with improved drainage.

We know that a wet soil is a cold soil. The action of underdrainage in removing the excess water in the soil causes growth to start earlier in the spring and continue later in the fall. Poor drainage causes shallow roots. Grass with shallow roots is more apt to wilt on hot, windy days. Poor drainage also destroys soil structure which reduces the ability of the soil to store air and moisture.

Saturated soil affects playing conditions. It's no fun playing on wet, soggy fairways, let alone trying to work on them. Mechanical injury due to skid marks and scalping can be avoided with better drainage.

From another point of view, the caddy shortage in our area increases the need for golf carts to be used in all kinds of weather. Better drainage and cart paths in one form or another in key areas have solved this problem. When our members drive up to the club for a round of golf, they're really not interested in how much rain fell. They want to know two things: "Is the course open and how about carts?" With an improved drainage system working properly, you can say yes with pride to both of these questions.

To help correct our drainage problems, we have used just about all types of drain tile. We have used four-inch farm tile, orange burg, porous wall, and corrugated

---

Bruno Vadala is superintendent, Metropolis Country Club, White Plains, New York.

plastic pipe. We have also used, with great success, 15- and 18-inch aluminum corrugated perforated pipe. We used 55-gallon steel drums and concrete to make catch basins. In using the steel drums as an inside form, as the steel rotted, the concrete would be there indefinitely. These basins, placed in key low spots, helped remove excess surface water very rapidly.

A 15-inch line was used on our sixth fairway to correct a series of problems. We had surface, sub-surface, and seepage problems. This line, with catch basins in key spots, transformed our wettest, poorest fairway into one of our best on the golf course. To pick up all rain water from our new club house, we asked the architect if all drains could be directed toward our driving range. An 18-inch line and a few catch basins carried thousands of gallons of water from the club house, club grounds, and eight acres of fairways and roughs.

I'd like to sum up by quoting a few lines from Hanson and Juska's book, "Turfgrass Science." They say "With irrigation, good drainage becomes of paramount importance, especially where rainfall is a factor. In keeping the soil near field capacity with sprinklers, stringent provisions must be made to handle excess rainfall. Surface drainage is by far the most important. In hilly country, provision has to be made sooner or later to stop seepage. Slit-trench drains are used successfully to remove excess water from pocketed and relatively level fairway areas. Another area where intercepting lines can be used to good advantage is in front of pitched greens that seep to cause a wet, soggy approach."

These last fews lines have hit home for us and we have taken steps to correct our problems. I think we have finally completed our drainage work and we are looking forward to healthy turf and a happy membership.

CONVERTING TO ZOYSIA

Albert A. Linkogel

Back in 1930 when I was Superintendent of a private golf course in the St. Louis area, Dr. John Montieth, then head of the United States Golf Association Greens Section, sent a group of new grasses for me to test in the St. Louis area. Among these grasses were Bermuda and Zoysia. I did a lot of work with these grasses, and as the U-3 Bermuda seemed to be superior to other Bermudas for our St. Louis climate, I then began to find different methods of introducing it into an existing fairway turf without interfering too much with play. One club tilled up half of each fairway, cut up their Bermuda stolens, spread them with a manure spreader, disked and rolled them in, and kept them watered. Since Bermuda is a fast grower, in a short time the fairway was again in play. They then did the other half, but the golfers were not too happy with this method; it interfered with their play too much. I then developed a machine to plant sprigs. This worked out very well, sprigging in rows two feet apart. Under proper care there would be a complete cover within two years.

Practically all of the private clubs went to Bermuda; but after four to five years, Spring Dead Spot became a problem, along with some winter kill. The clubs became a little discouraged with Bermuda, and started to think about Zoysia on fairways. We tried the same method of planting with Zoysia, and here we ran into a little trouble. We found out sprigging Zoysia was quite a bit different from Bermuda. We could sprig a whole fairway with Bermuda, and then apply water. With Zoysia you needed to sprig small areas, and then apply water immediately for it to work well. If you did not get water to the stolons within an hour you lost a lot of sprigs, so we discarded sprigging Zoysia into fairway turf.

Plugs worked out much better, but there was the labor cost involved and with the shortage in labor this was prohibitive. Checking different plugging machines on the market I found none of them very practical. So with the help of Dr. Bill Daniel, we revamped my sprigging machine to plant plugs. The first machine was hand fed, but we found this was too slow, so we worked out a two-row semi-automatic machine. It is a 2 point hook-up. It takes a man to drive the tractor, and two men on the machine. Three men can plant up to 1-1/2 acres per day, with rows and plugs one foot apart.

This machine consists of a hopper on top that holds about 3,000 plugs and a conveyer on each side. As the man standing on a platform feeds the plugs from the hopper to the conveyer, it conveys the plugs down a chute. At the bottom we have a coulter that cuts a slit through the sod, and a winged shoe opens the slit so the plug can fall into the slit.

A V-shaped slide follows in the rear to prevent old sod from flipping over so as to keep a smooth surface; then a six-inch rubber tire wheel with the weight of the machine on it compresses the small ridge and the plug in firmly.

A.A. Linkogel is president, Link's Nursery Inc., St. Louis, Missouri.

This leaves a smooth playing surface, and as far as I am concerned this is the cheapest and best method of converting to Zoysia. With proper feeding and watering you can convert bluegrass fairways to Zoysia within two years. If clubs have Bermuda, then it will take a little longer for Zoysia to take over.

Now some clubs used the Hydro mulch and tilled up their fairways. This was costly and the golfers were very dissatisfied. Some used strips 12-inches wide to strip sod; others cut four-inch strips, and strip-sodded. Still others took a small area at a time, slit the old sod, put in sprigs, and kept it well watered.

No matter what method is used it will take several years to establish a solid turf. The cost is what makes the difference.

GOLF COURSE TEES — SELECTION AND MANAGEMENT

Fred Opperman

Just what is a tee and its purpose? What should a perfect tee be like? These questions should be answered before we can discuss the management and selection of the turf that is to cover a tee in our climatic zone.

Webster's dictionary defines a tee as "the place from which a player makes the first stroke on each hole". The USGA in its "Rules of Golf" defines the "teeing ground" as "the starting place for the hole to be played. It is a rectangular area two club-lengths in depth, the front and the sides of which are defined by the outside limits of two markers. A ball is outside the teeing ground when all of it lies outside the stipulated area." Now we know what a tee is and what its purpose is.

But what should a perfect tee be like? I put the question to George Archer, the PGA touring pro, who played our course this past fall. He said a tee should be level and firm for a good footing. He did not seem to care if he teed it up on bentgrass or bluegrass as long as he could get a clean stroke at the ball without grass coming between it and the clubhead.

My idea of a perfect tee would be of the following characteristics:

1. Level for an even stance;
2. Firm so the feet do not twist when swinging;
3. A close-cut turf that heals fast;
4. Pleasing to the eye.

Pleasing to the eye really covers a lot of items. I take it to mean a tee that blends into the surrounding terrain, is landscaped, has a healthy stand of turf, and adds to the golf hole.

Let me describe my own "home grounds" at Glen Oak C.C. Ours is a private 18-hole club organized in 1911. Our main turf is bent with our share of *Poa annua* sprinkled in. We are completely watered and at the present are in the process of installing a new automatic irrigation system. We have a good native soil which is mainly a rich loam with better than average drainage overall.

TEES AT THE GLEN OAK COUNTRY CLUB

Our tees have always been of a bent grass variety up to about six years ago or about 1968. Then one tee was sodded to A-20 (Warren's Turf Nursery) but this tee happened to be in the shade most of the day. Consequently the poa and bents came in and overtook it. Today it is 60 percent poa/bent and 40 percent A-20. In the fall of 1971 we rebuilt one tee and resurfaced two others. On these tees we laid A-20. The following year in the fall, 1972, we resurfaced two more tees with A-20. All of these tees are in the full sun and look really good. This gives us six tees with A-20.

Fred Opperman is Superintendent, Glen Oaks Country Club, Glen Ellyn, Illinois.

MOWING

In comparing our two strains of turf, I will run thru our maintenance practices one at a time. Let's start with the most time-consuming practice and that is the mowing. I mow all our tees and collars with a Hahn Westpoint riding triplex mower. Our bedknives are set at 1/2 inch on the shop floor for the bent grass tees, and 5/8 inch for the A-20 tees. The Hahn has a quick height adjustment on the rear roller and that is what we use to get the 5/8 inch for the A-20 tees. The tees are cut three times a week, Monday, Wednesday, and Friday. Where space permits on the tees we mow in a different direction each time. Also all turns are done off the tee where it is possible. Combs are used on these mowers year around to help pick up the runners and cut down on the grain. Like most greens and tees, there always seems to be the grain around the edges where the grass is only mowed in two directions, clockwise and counter-clockwise.

Our mowing time with the rider takes five hours on a normal day. This is mowing 74,000 square feet of tee area, 18 collars on the greens, 2,000 square feet of bent nursery, and 500 square feet of A-20 nursery. In mowing we always take more grass off the A-20 tees due to their vigorous growth habit. For the A-20 tees to really look sharp they should be mowed daily. By the second day the A-20 greens are starting to look shaggy, while the bents do not impress you as being long just yet. The A-20 starts growth earlier and does not seem to go dormant as soon as the bent tees.

CHANGING TEE MARKERS

The next maintenance procedure is the changing of the tee markers. Here the size of the tee has a tremendous amount of importance on what the tee will look and be like. For if you have a small tee on a Par 3 hole that takes only iron shots, no super strain of grass, no amount of fertilizer, and no amount of special management will be able to keep turf under such conditions. The tee size should be correlated with the type of course you have and the number of rounds of golf played during the season. But back to the changing of the tee markers. We have a regular schedule that we like to follow, as I'm sure most superintendents do if they want to have some turf left on their tees. We try to give the golfers a varied course every time they play. So we try to have six short, six medium, and six long tee placements each day. The markers are moved from the front to the back. The man changing them knows at a glance that if the markers are in the middle then they are moved to the rear of the tee, and from there they go up to the front. On most tees we go down one side and then the other side.

Very seldom do we allow the golfers to use the full width of the tee to tee up their ball. Usually it is a week or better before the markers are back in the same section. On the bents the scars/divots are quite visible, while on the A-20 there is little sign of wear on the Par 4's, but on the Par 3 where I have only 1,700 square feet of space the divots are not quite as bad as the bent tees.

REPAIRING DIVOTS

On the subject of divots, we usually try to get out once a week to soil and seed our bent tees. We pre-mix the seed and soil using a mixture of seed that is 50 percent Seaside, 35 percent Highland, and 15 percent annual rye. Usually about two wheelbarrows will handle our needs. This soil and seed mixture is then tossed into the divot holes and all the old dead divots are picked up. This is done on all the bent tees; on the A-20 tees we carry a bucket of topdressing with no seed mixture. If there is a divot on the bluegrass tees, just the soil is placed in it and stepped down. Seldom are there any divots to repair on the A-20 tees except on the short Par 3 hole I mentioned earlier.

WATERING

Watering comes up next on our list, and here we have no set schedules. When the tees need water, we water. Usually that is twice a week during normal temperatures. Please do not ask me what that means. But it is extremely rare that the greens or tees get water two nights in a row, even in a stress period. This is especially true for the tees. Here again we have a big difference in maintenance procedures. The A-20 tees will go twice as long or longer without water as the bents. Also, the A-20 can take the traffic better in a drouth condition. I have no figures on the number of times our A-20 tees were watered, but I'll tell you it was seldom. I would always wait till they would turn black and blue so to speak and then give them twice as much water as the bents at any one time.

FERTILIZATION

Fertilization of the tees is similar, I imagine, to most other golf courses. We like to fertilize early in the season--about the first of April. Here we apply a complete chemical fertilizer of about a 3-1-2 ratio. One pound of actual nitrogen is applied at this time. The next application of fertilizer depends mainly on the weather and how the grass is responding. During the hot weather we fertilize with only an organic fertilizer and apply only about two- to three-tenths of a pound at any one time. Our bent tees will average from a low of four pounds to a high of seven pounds per thousand square feet per year. The last application of fertilizer is applied no later than September 20. This feeding is a chemical fertilizer and totals one pound of nitrogen per thousand square feet. The bluegrass tees receive an average of one to two pounds more nitrogen per season than the bent tees. We try to give the A-20 a complete fertilizer of about one-half pound of nitrogen during late June when the rhizome activity of bluegrasses is greatly increased.

FUNGICIDES

Our fungicide programs vary greatly from year to year depending of course on the weather, temperature, and humidity. This past year we used little fungicide on our tees. Our bent tees were sprayed only three times, or four times if you count the snow-mold treatment. In the spring we sprayed Acti-dione for leaf spot. Then around the first of June we sprayed with Tersan 1991 for Sclerotinia dollar spot. In the middle of August we sprayed with Daconil 2787 when we noticed some Rhizoctonia brown patch. The A-20 tees just received the one spray of Acti-dione in the spring for leaf spot. Consequently, the A-20 tees caused us almost no worry about diseases except for some leaf spot. We do not spray on a truly preventive basis or on a given weekly schedule, with the exception of the fairways which I spray two to three times with a systemic fungicide.

HERBICIDES

Our herbicide control program is next to nil on the tees. This year we did spray our clover which had made some inroads into the bent tees. The chemical used was MCPP at 1-1/2 ounces per thousand square feet.

TRAFFIC

So far I have been talking about the various cultural practices and management of the tees, but one important management point hasn't been brought up yet--foot and golf cart traffic. It all boils down to compaction. Compaction means a poor stand of turf, which in turn means bare ground in the future. Any way in which the traffic can be distributed over a wider, larger area will benefit the turf. Our course was built in the early 1900's, and basically it is still somewhat the same. It is a course built for the golfer who walks, rather than the golfer who rides around in a golf cart. We have many tees that still have heavy clumps of shrubs along their sides. This channels the traffic onto the tee in a couple of places, and in some cases there is only one way onto the tee. This is a problem not only with the foot traffic walking to and from the tee, but with the carts when they have to drive out around these shrubs on their way to the green. It is not only the strain of grass, the amount of fertilizer, or proper timing of the fungicide application that makes a tee look good. Tees also look good because of where you build that cart path and plant that tree or shrub so the traffic can be spread out and not wear down any one certain area.

Also contributing to the appearance of the tee are the placement and care of the ballwasher, the bench, and the litter basket, if these are on or around your tees. These items on our course are moved daily and wiped down not only to give a neat appearance, but also to distribute the traffic around the tee and to guide the golfer. Usually there is a drinking fountain near a tee.

BENT GRASS VS. BLUEGRASS TEES

In going back and reviewing the selection of a bent grass tee compared with a modern new low-cut bluegrass tee, we seem to come up with advantages for both sides. The low-cut bluegrasses today need less water and fewer fungicide treatments, have fewer divots to be repaired, and can take the traffic. The bents can stand a lower height of cut, need not be cut as often to look neat, and do not need as much fertilizer. It almost looks like a draw except for one thing with the bluegrasses. It is extremely difficult to keep the *Poa annua* and bents from invading and taking over in the long run.

The bluegrass tees that I have had for two full seasons are starting to show patches of bent and Poa. This past summer, in early June we plugged out all these weeds, so to speak, and again had a true stand of A-20. This fall the tees are worse than ever. I have never applied preemergence or other chemicals to retard or kill off the bents or Poa. I realize that to have a perfect stand of a low-cut bluegrass on your tees some sort of a program will have to come about to keep the weed grasses out. Any time a turf takes the abuse that a normal tee takes, it is bound to start getting an infestation of these weed grasses. Next year I know that I will be testing various chemicals on my bluegrass tees to see just what will work on this problem.

SUMMARY

To summarize on the selection and management of a golf course tee, one has to remember its definition and the qualities that make up a good tee, which are levelness, firmness, and a close-cut turf that heals and recovers fast. These I feel have to be the basic requirements and anything else that is added has to be handled by the labor force at hand and the amount of money in the budget.

It is my opinion that the bents have been the prestige grass for tees since time began, because the bluegrasses used on tees have not had the desirable low height of cut needed for a good tee. It seems too, that all the "name" private clubs have bent tees, and the bluegrass tees are mostly found on the daily fee courses. This I feel is due to the extreme amount of maintenance and money needed to maintain the bent grass tees. Only recently have new strains of short-height-of-cut bluegrasses been developed. Possibly if we would have had the short-cut bluegrasses years ago, there would not be as many bent tees around as there are.

Only by testing various strains of grasses, whether they be bent or bluegrasses or both, under your conditions of play, on your soil, and under your type of management procedures, can any one superintendent then decide just what grass will give him the most desirable teeing surface at his golf course.

PROBLEMS IN EQUIPMENT DISTRIBUTION

Robert L. Short

You know as well as I that no one makes equipment like we had in the good old days.

Remember when you bought a new car, and it worked? How about the old, heavy Mixmaster your wife or mother had with the big, heavy bowls; hey, that thing lasted forever in comparison with the new ones.

Now think for a minute. I have heard several Ph.D.'s as well as chemical technical representatives warn us of what is ahead next year for weeds.

Haven't you heard this? "X" brand of chemical will control 90 percent of your weeds. This year let's say there were ten weed seeds in a square foot, so we only had one weed left or 10 percent. Next year in the same given square foot, because of all the rain this season, there could be 1,000 weeds, and with 90 percent control, 100 weeds will be growing.

With these examples of cars, household equipment, and herbicides, the point I'm trying to make is this: I firmly believe the equipment we sell today is far superior to that sold in the good old days.

It is lighter, stronger, and more durable than ever before. For building the modern, complex equipment of today and the future, the industry has smarter and better educated workers than ever before. It's a fact that major items are more expertly engineered than ever before, but the best design can't overcome careless workmanship and operation.

Stop blaming the other guy. This doesn't mean we should be willing to accept low standards. Just don't expect more from others than you expect from yourself.

Then, why, for heaven's sake, do we have so many breakdowns?

Look atyour own operation. Who operates your $11,000.00 tractor with nine precision-cut mowers and your $3,500.00 hydraulic precision-made and precision-cutting riding greens mower. Does your board let you pay $1.45 an hour for inexperienced summer help and then try to hire him again in the spring, or are you paying $250.00 a week and having a factory-trained man maintain this equipment for the full year?

I have heard estimates of between $10,000.00 to $15,000.00 for a green. In the good old days the estimate was $2,000.00 to $5,000.00. With this increase in cost per hole came a responsibility to maintain it better than ever before. To do this you have had to use more equipment to cut labor costs.

Just look in your maintenance buildings and see what is there that wasn't there ten years or even five years ago. Stop for a second--it has really changed, hasn't it? Also, there is more equipment, isn't there?

R.L. Short is general manager, Leon Short and Sons, Inc., East Peoria, Illinois.

The problem we had last year in equipment distribution was one ofreceiving enough equipment to sell, and this will become worse. We have to order in October what is required for the next year. If we don't order enough equipment it could be like this year and cause a four-week to four-month waiting period. If we order too much equipment, all the profit is in the warehouse and we don't eat very well.

In the very near future, we will have to order two years in advance, and without your help it will be almost impossible to have what you want when you want it.

This, of course, applies to all equipment, whether it be Jacobsen, Toro, Ford, International, and on down the line. The equipment is becoming bigger, better, and more expensive, and we just cannot "guesstimate" your requirements nor can you afford to wait all year for what you want and need.

What then is the answer? At this time I believe the only thing that can be done is for you to order four months prior to your needs to assure arrival on time.

There arereally no problems--only challenges.

One of the really big challenges is MONEY. In October the prime rate for borrowing money was 10 percent. And, of course, only the giants like General Motors, Ford, Caterpillar, etc., could borrow for 10 percent. The rest of us had to pay more.

With money at this high a rate of interest, there is only one answer--borrow less. Borrowing less means less inventory, and less inventory means less service; therefore, this cannot be the true answer. Planning has to be the key word, but without your advanced orders, planning is a "guesstimate" again.

Evidently, planning, orders, and cooperation between the user and distributor are the ultimate and final challenges.

PROBLEMS IN PARTS DISTRIBUTION

Robert G. Johnson

We are again in an era of availability of materials and products similar to World War II--no steel, no gas, no rubber, and now even no paper.

Then there was an excuse--the famous last words when you expressed anger over not being able to purchase something were, "Don't you know there is a war on?"

Today we can say the same thing, only it is an economic war and the enemy is harder to determine. There are no sides--(you and I are the enemy and the dollar is the weapon). There are more people and more dollars than there are supplies; therefore, we are each fighting for what we can get, not always what we need, but what we can get along with for now.

Most of you people in this audience are mainly end users and have the ability to substitute to a degree; however, the distributor or supplier of certain commodities and lines of parts for equipment, such as Illinois Lawn Equipment, must maintain supplies for the highly specialized, low-volume, hand-made equipment, and he depends almost entirely on the original manufacturers for his supplies.

The guessing of what parts you will want has to be made six months in advance when we place our booking order. It is supposed to be three-fourths of all the parts we will need for the year. In the case of complete equipment, we must order one year in advance and, even then, this year we did not receive all we ordered. Now these lead times I have given you are the way it was up until June of 1973.

As of this moment, we have some suppliers who will not provide any price list at all. Since each load of steel or raw material comes into them at higher prices, costs are uncontrollable to us and, therefore, we cannot give long-term quotes to you. Prices are only a minor problem compared with availability. Let me read you a bulletin from one of our suppliers.

"SUBJECT: PARTS LEAD TIME

"All indications are that 1974 will bring continued shortages of materials and extended lead times by suppliers, causing back orders due to conditions beyond our control.

"Distributors can help protect sales, provide prompt parts delivery, and protect profits by increasing minimum and maximum quantities of fast-moving parts, and by entering substantial Weekly Stock Orders to insure coverage for extended lead times.

"New shortages of material and fabrication delays are being experienced by every company in the industry. The problem is real, and we are being affected by it now, as evidenced by some of our back-ordered items on which we cannot quote a firm availability date.

R.G. Johnson is president, Illinois Lawn Equipment, Inc., Orland Park, Illinois.

"Some examples of present reasons for parts delivery delay follow:

1. Shortages of raw stock.
2. Delay in fabrication.
3. Vendor strikes.
4. Delays in producing minimum quantity orders due to high production costs.
5. Shortages of skilled labor.
6. Limiting output: The price freeze forced many firms to absorb higher costs and to cut back on production.
7. Paper and container shortages resulting in packaging delays.
8. Transportation: 'Constipated' situations at carrier docks and vendor docks where there are not enough incoming trucks to ship out-going goods.

"Our factory is now on the alert to set heating thermostats at 60 degrees, and if gas supply is cut off and oil reserves are depleted, there will be no alternative than to suspend plant operations.

"If the factory is being affected, then the distributors are being affected. We are concerned about your parts inventory! We urge you to keep your parts inventory at a substantial level.

"We constantly press our suppliers for firm delivery dates and follow up on delays to avoid back-order conditions.

"Help avoid back orders! Your increased order commitments will enable the factory to forecast requirements in line with your needs."

The problems just outlined are not peculiar to our industry by any means. In fact, I believe the established local turf grass supplier, who is stocking up greater than ever before, putting his money on the line to serve you, has made our industry one of the less critical in the country.

FLOWERS FOR USE AROUND THE GOLF COURSE

M. C. Carbonneau

The use of flowers in public areas such as parks and golf courses is becoming increasingly popular. Newer varieties of flowering plants have made it much easier to get a lot of color to add interest in the landscape. Plants are available in most communities so obtaining plants is no longer a problem. Early planning for the plants and a minimum amount of care will certainly be rewarded.

CHOICE OF PLANT MATERIAL

Annuals. These are by far the most common plant materials for large bed areas. Annuals must be planted every year, but this gives one the advantage of changing colors in the bed every year. These plants also will flower throughout the growing season and this will be very important for keeping the area in color. Petunias, marigolds, celosia, zinnias, geraniums, salivia, and snapdragons are but a few plants that will grow well in a sunny location. For shade areas, plants such as impatiens, begonias, coleus, and pansies will perform well throughout the summer months.

Perennials. Very few perennial plants can be used to good advantage in public places. In most cases perennials only flower profusely for a few weeks or flower only in one period of the growing season. In areas that are used daily by the public, such as entrance or patio areas, it would be much better to have color throughout the growing season. Perennials, however, can be used as background material for large beds. Peonies, day lilies, and hardy chrysanthemums are very useful for this purpose. Peonies flower in late spring. Daylilies flower during the summer months. In the fall chrysanthemums add color until heavy frost.

Bulbs. Spring-flowering bulbs such as tulips, hyacinths, or narcissi are excellent for a lot of color during early spring. These are planted in the fall during October and November. They can be left in the bed after flowering and will flower again the following year. In areas of frequent use it is usually recommended that the bulbs be pulled after the flower period because the foliage on spring bulbs is not attractive. In order for the bulbs to have enough stored food for return bloom the next season it is necessary to allow the foliage to develop fully and dieback naturally. This process takes from six to eight weeks after flowering, thus we usually recommend that one discard bulbs from public areas after the flowering period.

LOCATION OF BEDS

Light. For best success, it is important to plant according to light (sun or shade) requirements. Many plants that require full sun will only perform to a limited extent if planted in an area that is partially shaded during the daylight hours. The same is also true for plants that require partial or full shade. Remember to check for sunlight prior to planting.

M.C. Carbonneau is associate professor of Horticulture, University of Illinois.

Wind. In many areas in Illinois wind can be a problem, especially during the summer months. Hot dry winds can severely damage plants if water is not readily available. Tall growing flowers can also be damaged by strong winds. Select low-growing plants for windswept areas. Develop windbreaks in extremely open areas.

Drainage. Poorly drained areas are not the best locations for flowering plants. If water stands in an area for an extended period of time after rain or irrigation, take the necessary steps to improve the drainage. It may be necessary to add topsoil to raise the bed area to improve the drainage. If plants do not have good root development, good flowers will not be produced.

SOIL PREPARATION

pH Requirement. Most flowering plants require a slightly acid soil pH (6.0-7.0). It is at this pH level that most of the fertilizer nutrient elements needed for plant growth and development will be available in the soil for root uptake. Take several samples in large beds and have them tested. This should be done periodically (every two or three years). An acid soil (4.0-6.0 pH) should be limed the fall before planting. Usually three to five pounds of ground agricultural limestone for each 100 square feet will be sufficient to raise the pH to a more favorable range. If the soil is alkaline (7.0-8.0 pH) the area should be treated with sulfur. One to two pounds of sulfur for each 100 square feet will lower the pH to a more favorable range. The use of acid sphagnum peat moss will also lower the pH of an alkaline soil. Two or three inches of this material worked into the bed will lower the pH and also increase the drainage.

Drainage. Most Illinois soils require some attention to drainage. Tile-drained areas are usually sufficiently well drained for most flowering plants. Plants that have very fine or fibrous roots will require soils that have more than natural aeration. If plant root development is sparse, it is necessary to amend the soil. Use sphagnum peat moss, calcined clay or coarse sand liberally (two to three inches) in the top six to eight inches of the bed area. Organic material will breakdown during the growing season, so it is necessary to add this material every year or every other year. Calcined clay or coarse sand will not break down, so apply these materials only once every four or five years.

Soil fertility. Flowering plants require fertilizer nutrient elements available from planting time and throughout the growing season. Most soils in Illinois require extra phosphorus applications. New beds especially should be tested for available phosphorus. Super phosphate (0-20-0) is recommended at the rate of three to five pounds for each 100 square feet of bed area. This should be worked into the soil to a depth of six to eight inches. A complete fertilizer such as a 10-6-4 or 10-10-10 or 12-12-12 should be used at the rate of two to three pounds for each 100 square feet of bed area prior to planting.

PLANTING

Space. Each plant requires full space in the bed to develop properly. In most cases plants are small when planted. Annuals should be spaced according to their final development. Petunias and geraniums require a 12 inch space for full development. Begonias can be spaced closer (8 inches) for full development.

Check the final size of the plants when you plan the beds. Ask your supplier for information on rate of plant development.

Planting depth. Plants should never be planted deeper than they were grown in the seedling or transplant stage. In most instances flowering plants will not develop roots along the stems. If the plants are placed too deep in the planting holes the roots will be too low in the bed and will not be in an area of maximum soil aeration. The plant roots must have air to carry on the process of growth. Poor root development usually means poor plant growth.

SUMMER CARE

Water. Watering during dry periods is necessary, especially just after planting. Usually 1 to 1-1/2 inches of water each week will be necessary for establishing the plants in the beds. As the plants develop, the soil will be shaded so less water will be lost. Enough water should be applied to moisten the soil to a depth of 8 to 12 inches. Most of the roots will be located in the top six to eight inches, so moisture should be available to support this growth. Dry or sparsely watered plants will develop roots only in the top two or three inches of the bed. The plant material will not develop top growth and occasionally the plants will die at the first stress period.

In order to keep the disease problems at a minimum, try to irrigate early in the day (before noon) so the plant material is dry by the evening hours.

Fertilizer. Summer fertilizing is necessary for prolonged growth and flowering. If you use inorganic fertilizer, be careful not to get the fertilizer on the foliage or flowers. If you do, use plenty of water after application to wash the plants and to dilute the material immediately.

Organic fertilizers are not as dangerous to use on plants growing in beds. Summer temperatures aid in the breakdown of the fertilizer material. Be sure to water thoroughly for most rapid availability.

Plants in pots or large planters should be fertilized with a soluble or liquid fertilizer. This material should be used on a regular basis to maintain rapid plant development.

Follow directions on the bag for best results. *Never use* a weed and feed material on or near flower beds. Most herbicides will damage flowering plants.

Weed control. Summer mulches are readily available for use in flower beds. Choose a mulch that is attractive and one that will last throughout the season.

If the weather is cool when the bed is planted, wait a few weeks until the plant roots are developing then apply the mulch. Be sure that the mulch is applied to a depth of two to three inches.

A properly applied mulch will inhibit weed seed germination and development. It will also insulate the soil (less water loss and also keep it cooler).

Common mulch materials are shredded or chunk bark, pecan shells, cocoa bean hulls, crushed corncobs, buckwheat bulbs, pine needles, or any other material available locally.

If a mulch is not used, shallow cultivation will be necessary every week or ten days. Weeds wil develop rapidly and many hours will be needed to pull the weeds if left in the beds after the seedling stage. Remember that weeds will grow just as fast as the flowers in properly prepared soil.

Few herbicides can be recommended without reservation at the present time. If perennial weeds are a problem, remove them prior to planting. Mulching and cultivation will often increase the growth of perennial weeds. In most cases it is safer to use a mulch than to apply an herbicide.

Flower removal. Occasionally throughout the growing season it will be necessary to remove faded or dead flowers from the plants. This practice will help to keep the plants flowering throughout the season. It is usually a necessary practice on large-flowered plant material.

LAWN TURF SESSION

HOME LAWN IRRIGATION

David Craig

Home lawn irrigation is an integral part of lawn care operations. Irrigation can be thought of as a tool to be used in your daily operations. We now employ a wide variety of pesticides to enhance and insure our business. Irrigation can also be used as a tool to enhance and gain business.

The advantage in using irrigation is apparent when we look at precipitation records. June and July of this year averaged enough or too much rain to grow quality turf. But the totals can be misleading. For example, Urbana had 9.21 inches total for July, but for 15 days only a trace was reported. More than one-half of the total fell on three consecutive days. August offered even more evidence of the need for irrigation because the monthly totals were below the one-inch per week recommended precipitation. Effingham reported a 6.66-inch total, but 5.66 inches fell on one day. We can summarize rainfall data by the rule of thumb that one out of three years there is either too much, too little, or just enough rainfall to grow quality turf.

The practical value of irrigation can be realized by looking at a typical landscaping job. Sod cost is approximately $9,400. Irrigation would cost around $4,400 to $5,000 less than sod replacement. The system also adds directly to the homeowner's property value.

Aesthetic value of irrigation also increases property value. Business properties, where first impressions are important, are enhanced by irrigation in conjunction with good lawn care. Architects models always include green turf areas which cannot be guaranteed without irrigation.

TYPES OF IRRIGATION SYSTEMS

The turf irrigation system consists of a network of pipes and valves which carry water to various types of sprinklers for distribution over the surface of the soil. Virtually all systems for lawn and turf are permanently installed underground. While there are many types of sprinklers utilized, these systems are much the same in basic design, varying primarily in the size and type of equipment and piping used, the spacings of the sprinklers, and the method of controlling their operation. These variances are often intermixed in a single system to accommodate different types of areas on a given property. Thus, classification is necessarily somewhat vague and often overlapping as in the case of manual or automatic control options which are applicable to most system types.

Spray systems are generally thought of as those systems which distribute water through sprinklers having a fixed nozzle orifice and resultant pattern in the form of a fine spray. Lawn sprays fall into two categories, stationary and pop-up,

---

David Craig is Sales Engineer, Sprinkler Irrigation Supply Co., Bloomington, Illinois.

both of which are designed to be used in lawn areas and are installed flush with the soil surface. Shrub sprays utilize the same basic nozzle types in a small stationary housing for placement above ground level in cultivated bed areas. Actual placement is determined by the plantings to be watered. Also falling into this category are the so-called bubblers. These flood type heads are normally installed above ground level in extremely small areas.

The common denominator which brings all of these various types of sprinklers together under the spray system category is the relatively small area of coverage plus versatility for maximum control of water application. This type of system is used primarily on landscaped areas of residential and smaller commercial properties.

The rotary system also derives its name from the type of sprinkler used. The rotary sprinkler is so named because one or more nozzles, attached to a sprinkler with a rotating mechanism, discharge a relatively long, narrow pattern of spray that covers a circular area as it turns. Pop-up rotary sprinklers are used almost exclusively in turf applications, although there are some types which do not pop up, but discharge water through nozzles set in a rotating cover plate which remains level with the ground. The rotary system is used primarily for irrigation of large, open turf areas.

The quick-coupler system is actually a variety of the rotary system. It has declined in favor in recent years due to the great amount of labor required. The system is now being incorporated into irrigation systems as supplemental irrigation.

The terms manual or automatic might be referred to as subtypes. They are commonly used to describe the method of operation of any of the basic types of turf irrigation systems.

Installation

The installation of any type of sprinkler system for turf, whether it be a small residential spray system or a large rotary system for a park or golf course, is a project of permanent underground construction which must be performed with skill and efficiency. Installation must be in accordance with the plans and specifications.

The first step in construction should be the staking of the actual locations of the sprinkler heads, main lines, valve manifolds, and other pertinent construction features. This serves the double purpose of providing an installation guide for the crew and a concrete verification of the accuracy of the plan. Accuracy is essential.

Trenching must be deep enough in all cases to accommodate the height of the sprinkler and riser, to assure proper surface grading, and to provide ample cover for the protection of the piping, valves, and other components that may be installed underground. In freezing areas trenches should be sloped to provide drainage, and suitable sumps should be located for the discharge from the drain valves. Rocks and debris must be removed from the trench. Backfill after pipe installation must be compacted. Trench width should not be wider than necessary to allow workmen to accomplish their jobs.

A number of piping materials may be used in turf irrigation. The pressure-rated plastics are the most common. Among these, polyethylene (PE) and polyvinyl chloride (PVC) are the most popular. PE pipe is widely used where freezing is severe. PVC can be used in freezing areas if they are properly drained. Its greater tensile strength provides greater working pressures while retaining better flow characteristics.

Pipe installation is generally started at the source of water supply. The main lines are installed, valves set in place, and then the lateral piping to the sprinklers is completed. Sprinkler heads should not be installed until after water has been applied to the system and all piping thoroughly flushed of dirt and debris.

Sprinkler heads installed on existing turf are carefully set so that the cover plate is flush with the soil and is level. On new installations where the system is installed during rough grading, the turf sprinklers are often installed above the grade. They are left to operate from this position until finished grade and initial turf are established.

Pressure tests and final visual checks of the operating system complete the installation process. The owner should then be instructed in the proper use of the system.

CUSTOM LAWN CARE — A NEW CHALLENGE

Milan Vydareny

Custom lawn care is a term easily misunderstood or even unknown to many professional turf men. The purpose of this discussion is to examine this segment of the turf industry and to suggest areas with which we in custom lawn care ought to be concerned.

Rather than attempt a precise definition of custom lawn care, a brief discussion follows which it is hoped will offer an intuitive understanding of this particular segment of the turf industry. To say that custom lawn care includes anything dealing with taking care of turf is too broad a definition. Mowing and irrigation, for example, while important are not included as a part of this discussion. For present purposes activities such as planning a fertilization program, applying a fungicide, or diagnosing a problem do fall within the definition of custom lawn care. In other words, activities which require some depth of contemporary turf knowledge, activities which require skills acquired through training and experience, or activities requiring the use of equipment which the average lawnowner finds impractical to acquire and operate himself, might properly be called custom lawn care activities. Custom lawn care is a service, usually performed for homeowners or consumers, although there are many businesses and institutions that find it preferable to hire the services of a custom lawn care firm rather than hire their own employees to perform the service.

Custom lawn care is not a totally new challenge. For about 10 years this business has been actively in operation on the Eastern seaboard. In the metropolitan Chicago area one firm has been offering custom lawn care service for 15 years. However, in terms of public acceptance, and in terms of the average age of all businesses in the Chicago area offering services, it is a new challenge. A telephone survey conducted in the Chicago area revealed that two-thirds of all custom lawn care firms had been in operation less than five years.

How important is custom lawn care? One way of answering that question is to examine the economic data concerning custom lawn care activities. No statistics are readily available which deal with what we have discussed as custom lawn care. Figures are available, however, for a more inclusive category of activities called "lawn and garden services." The U.S. Census of Agriculture for 1969 contains information for "Agricultural Services" and, among the classifications of agricultural services, "lawn and garden services" appears. One of the most striking things about the statistics is that lawn and garden services account for over 10 percent of gross receipts for all agricultural services, both farm related and non-farm related. Indeed, horticultural services, which include such things as tree and shrub services, as well as lawn and garden services, account for over 25 percent of the total. In terms of dollars, of the $2.1 billion spent on agricultural services in the U.S. in 1969, $545 million was spent on horticultural services in general, and $222.6 million was spent on lawn and garden services in

Milan Vydareny is owner, Lawn Medic of the North Shore, Highland Park, Illinois.

particular. Statistics for the state of Illinois are even more impressive. Of the $80.8 million spent in Illinois for agricultural services, $26.6 million or 33 percent was for horticultural services and $13.6 million or 16.9 percent was for lawn and garden services.

From these statistics it can be safely concluded that large markets exist for horticultural and lawn and garden services in the United States, and in Illinois in particular. These markets are a significant part of the total market for agricultural services, again Illinois demonstrates this to a greater degree than the United States as a whole. We may also conclude, with less sureness however, that custom lawn care has assumed some share of the market for lawn and garden services and, based on the optimism of turfmen in this segment of the industry, will increase its share of the horticultural service market.

Just what is the demand for custom lawn care services? What are consumers seeking? Evidence would suggest that consumers are looking for professional guidance. Dr. Joseph E. Howland, writing in Turf-Grass Times, gives us some insights. The new lawnowner has high interest and enthusiasm, and almost no success for the first three years of his efforts. After that he begins to lose interest and may simply give up after facing repeated failures. Furthermore, "At all ages (and intensities of interest) there is a great hunger for the leadership of a 'father image' advisor." Howland characterizes the lawnowner by saying: (1) he considers himself a realist, but he really is overly pessimistic; (2) he resists "educating," yet craves for a set of easy-to-follow magic rules; (3) he envies the "good luck" of his neighbors, but labels the lawn enthusiast and hobbyist "a nut."

Lawn & Garden Marketing magazine has compiled statitics covering retail sales of lawn and garden products by type of retail outlet for 1972. "Growing things" and "chemicals and fertilizers" are sold mainly through garden centers, retail nurseries, and farm supply stores. The remaining two categories, "power equipment" and "supplies," are dominated by department stores, equipment dealers, and chain stores. This suggests that when a consumer is seeking guidance about what to grow, how to plant it, how to take care of it, or any other advice regarding the intricacies and mysteries of live plant material, he goes to his local specialty store where he can obtain the more professional help he needs as well as the products he wants.

In short, the consumer wants professional help. Professional in this sense is used to mean a high level of technical knowledge, a high level of skill required for execution, and the high ethical standards expected by consumers. This is the challenge that we in the custom lawn care field must meet.

In recent years, technical knowledge about turf has increased dramatically. We now have at our disposal the answers to many questions about which we could only guess previously. However, turf science is relatively young, and for every answer we find, we probably get at least one new question. A lot of work remains to be done, and this means that new information and new techniques will be released at a rapid pace. What this tells us is simply that to be professional, we must acquire a great deal of knowledge about turf, and to stay professional we must keep that knowledge current.

Similar statements could be made regarding the level of skill required for execution. As new techniques are developed, we may be called upon to develop new skills to perform adequately.

Finally, what about ethical standards. Each individual must account for himself, and no data is available, but this writer strongly suspects that a great number of consumers are being misled through one means or another. Statistics indicate that U.S. consumers use more drugs of various kinds than most other nations. It is possible to observe some individuals "over drugging" their lawns, or their customers' lawns. And as a professional, selling a consumer something he doesn't need, a pesticide for an imaginary pest for example, has no justification. No doubt many services are unnecessarily performed through legitimate error on the part of the person performing the service. The way to remedy that situation is to improve professional knowledge. There still remains an overabundance of questionable services and products on the market. These are in any case foisted on the consumer by the very people to whom he turns for professional help.

Assuming responsibility for activities performed by another individual might seem to be a bit much to ask. Yet, as a professional it would seem ethically sound to use the best means available to insure that turf under one's care receives proper maintenance. This means that one must learn to observe the turf and pay attention to all problems. If a turf is suffering because of improper watering or mowing, the lawnowner should be so advised and then told in simple language (remember that consumers want easy-to-follow magic rules) how to remedy the situation. In short, follow through. Your best efforts are easily thwarted by careless or improperly performed operations not directly under your control.

There is a tendency among consumers to measure value in terms of tangibles. The temptation for us in custom lawn care is to emphasize the fertilizer, the herbicide, and other materials we use. These are important, but what about your skill and your knowledge? Remember, as a professional you are in a position to offer these intangibles which a consumer could only acquire for himself with considerable time and effort. Sell yourself as well. You are the professional and that is what consumers want and are willing to pay for.

BUDGETING FOR ECONOMY TURF

Frank Smith

First, let me say that I have never been asked or required to make or work with a budget. I wondered why Dr. Turgeon would ask a salesman of equipment and supplies to discuss this subject. When I asked him, he told me he believes I have spent more time calling on men who have low-budget problems than any other salesman he has ever known.

Without a doubt there must be many who thought I have been foolish to find and give so much time to those who had rather little to spend with our company. Well, it was not a waste of time for me; and just as importantly, it was not a waste of my customers' time.

Many of our largest accounts today were among the so-called low-budget accounts a few years ago. So, let's consider this problem of being short of help and money to be only temporary, and enjoy the satisfaction of doing the very best we can with what we have to work with at this time.

The objective then is to improve the appearance of our grounds, and to do it, as much as possible, without an increase of help or money. That must be as big a challenge as any man could ask for.

Now to get to this subject of "Budgeting for Economy Turf." Regardless of whether the budget is adequate or limited, I have never known of a successful, efficient grounds maintenance operation that was not headed by a good man who was determined to do a good job, and it would seem therefore that adequate wages for the man in charge, and for the good help he needs, would be the most important item in any budget.

Invariably, the cost of labor is by far the greatest single expense. On the average 18-hole golf course labor is generally in the range of 70 percent of total expenses for maintenance, and equipment, chemicals, and fertilizer each take about 10 percent.

These percentages could be quite different among park and school districts, cemeteries, and other large properties, but in all likelihood, the amount required for wages would exceed 70 percent. In any case, being the largest part of the budget, close scrutiny of all operations performed by your men will undoubtedly reveal some opportunities for real cost cutting.

Very often the advantage gained by the use of more efficient equipment, and the benefits of a thorough weed-control program, result in a very sizable reduction in man-hours. What you save in wages will not only pay for the required equipment and herbicides, but also allow you to pay higher wages for the reduced number of good workmen required.

Frank Smith is vice president, George A. Davis, Inc., Chicago, Illinois.

Superintendents who pay on the basis of ability and experience have the fewest headaches, the most beautiful grounds, the best facilities, and the most reasonable manpower budgets.

The following notes were made a few years ago at a meeting such as this, and I believe these suggestions, if followed, will result in much less "downtime" and equipment repair expenses.

1. Train your men thoroughly in the safe and proper operation of machines.

2. Equipment operators should be given some responsibility for the care and maintenance of the machines assigned to them.

3. Train operators to report immediately missing parts and unusual sounds, noises or rattles, or changes in the handling or performance characteristics of their equipment.

4. Suggest to mechanics the importance of reporting any evidence of parts that are beginning to wear, so that replacement parts can be ordered in advance and therefore you can avoid problems of emergency breakdowns and prolonged downtime for repairs.

5. Require your mechanic to determine the causes for failure of equipment, and to give you his recommendations for improving equipment operating methods to minimize downtime and reduce repair expenses.

6. Emphasize the extreme importance of using proper lubricants and maintaining correct levels in all crankcases, gear boxes, and all other moving parts.

7. Be certain that those who make adjustments on equipment are trained to keep the tolerances recommended by the manufacturer.

8. Remind everyone that clean equipment is safer and lasts longer, and therefore you insist that machines be kept in reasonably clean condition and repainted when necessary.

9. Keep a record of each piece of equipment, listing all repairs and parts bills, so you will know at replacement time whether a machine has given you good, low-cost, dependable service.

10. Give preference, when buying equipment, to those suppliers who maintain an adequate stock of repair parts, and who have a good reputation for providing good repair service when needed.

Mistakes, abuse, and neglect by operators can be costly, but I believe the foregoing suggestions can be used as guides to reduce the cost of equipment.

I would like to give just two examples of what can be saved by the use of more efficient equipment and a good weed-control program.

One of the most beautiful and well-maintained properties I know of is Mount Emblem Cemetery at Elmhurst, Illinois. It has the appearance that results from good organization and planning, excellent landscape design, and the care given by workmen who take pleasure in performing every operation to the best of their ability.

A few years ago, and for many years previous to then, the 90 to 100 acres at Mount Emblem were mowed beautifully, once weekly, by three men operating 76-inch triplex-type reel mowers. For the last few years the job has been done just as well or better by one man operating an 88-inch riding-type rotary mower. They are saving an average of 80 man-hours per week during the mowing season, and if you figure a total wage cost of $4.00 per hour times only 20 weeks, you arrive at a figure of $6,400.00 saved on expenses in one year, or almost three times the cost of the 88-inch mower. Take note--the men at Mount Emblem never swing a dull axe or cut with dull rotary mower blades. There are those who might grind and sharpen blades once a year, some once a month, and many do it once a week or even once a day. At Mount Emblem rotary mower blades are sharpened every four hours, and that also contributes to the exceptionally fine appearance of their grounds.

Waveland Golf Course, nine holes, is at Lincoln Park in Chicago. It used to take two men three full days a week, with small rotary mowers, to trim the grass around all of the trees, along fence-lines, walls, and other small areas inaccesible to the large gang mower and the triplex mower. Three or four years ago they used a soil sterilant for the first time, and sprayed a 6-inch wide band along their fences, walls, around all of their trees, etc. The men did their work very carefully, knowing that any mistakes would result in bare soil for a period of two or more years. The result of the program has been a reduction of time required for trimming from 48 hours down to only 2 man-hours per week. That is 46 hours saved per week, but they did not discharge a man, the time saved is used now to make Waveland a better looking and better maintained course than it was before.

Remember that trimming is one of the greatest costs in mowing expense, and therefore it offers you a great opportunity to find ways to reduce man-hours, lower the overall cost of mowing, and have funds available for other improvements you would like to make, such as in the fertilization program.

It is strange how liberal some people are with money for grass seed and how reluctant they are to initiate a fertilization program. We recognize that good grass seed is essential in many situations where turf areas require repair or renovation, but it is wasteful to use seed alone on areas that have never been properly fertilized. Additional grass seed on poor, weak turf will only provide more competition to grass plants trying to survive in poor soils. On the other hand, the right fertilizer, and enough of it, will enable the existing grass plants to thrive and develop the good density you want in your turf, and at a lower cost per acre than you would spend on seed alone. If you are not sure which fertilizer meets your requirements, have your soil tested and spend your money on the kind of fertilizer suggested by results of the soil analysis.

FLAIL MOWERS — HOW DO THEY COMPARE?

Joseph Berdych

Commercial turf is big business today. Maintenance is technical and expensive. Professionsals in the business may find themselves charged with the greenbelt area of a shopping center or with the vast sodded areas of an airport. These turf areas plus golf courses, factory lawns, city median strips, parks, highway and utility rights-of-way, athletic fields, and a host of other turfgrass areas have led to development of a $5 billion industry.

Commercial turfgrass areas today range from very small to vast, smooth or rough, clean or trashy, level or steeply banked. Vegetation may range from fine lawn-type grasses regularly cut and closely cropped to tough field grass growing thick, high, and intermittently cut, to weeds and brush, or even to revenue-producing seed or hay crops. Mositure conditions may range from dry to "liquid wet"!

A mower must be capable of meeting these conditions. Further, and most important, it must do so with complete safety. Commercial turf areas may involve many people and autos. A misguided object, thrown out by a mower, can result in extremely serious bodily injury or expensive property damage.

To meet these conditions, the commercial mower must have many qualities. Some, such as width of swath, maneuverability, and steep slope stability relate to individual model design and have no bearing as to type. The reel, the rotary, and the flail all are available in sizes ranging from small, compact, highly maneuverable units to wide-swath gangs.

Other mowing performance factors are directly related to mower type. These include cutting effectiveness on all types of growths (fine lawn grass, tough field grass, weeds and brush, short or high) on all types of terrain (smooth or rough, clean or trashy, wet or dry): mowing speed; simplicity of operation; and safety.

The cutter bar, the reel, and the rotary have been around so long most people are quite familiar with their capabilities and limitations. I am not so sure there is the same degree of understanding about the flail, and inasmuch as this is "The Case for the Flail," I will direct my comments mostly to it.

Flail has come to mean a type of mower consisting basically of a horizontal shaft designed to rotate at moderately high speeds and attached to it are a number of free-swinging knives, cutters, blades, beaters, chains, or the like--referred to as flails. These rotate in a vertical plane about the horizontal shaft, centrifugal force holding them straight out during operation.

Just as there are variations within the families of "reel," "rotary," and "cutter bar" mowers, so there are within the family of "flail" mowers. Dependability or structural integrity is a matter of design detail and will vary depending upon the manufacturer and model offered.

Joseph Berdych is national sales manager, Mott Corporation, LaGrange, Illinois.

Versatility of performance, cutting ability, and power requirements also will vary depending upon the style or type of the individual cutters or "flails" used. Generally speaking, the sharpened knife type of flail, mounted to cut with an edgewise slicing action, cuts more efficiently, takes less power, is lighter, and therefore operates with a greater degree of safety than other types of flails. Even so, all flail types of mowers provide far greater operational safety than do rotary types of mowers. The reason is a simple matter of physics. Both types cut with an impact action rather than with a shearing action such as the reel and cutter bar types of use. Indeed, the flail mower is sometimes referred to as a "vertical rotary."

The impact force imparted by the cutting blade upon contact with an object, whether it be the vegetation to be cut, or a rock, is dependent upon the mass (weight) of the blade and the square of the impact velocity. Thus, a rotary blade weighing 10 pounds and moving with a tip speed of 150 m.p.h. has over 400 times the impact force of a flail blade weighing 1 1/2 ounces and traveling with a tip speed of 75 m.p.h.

The point is that the lightweight 1 1/2 ounce flail blade traveling 75 m.p.h., especially the thin sharpened knife type of blade, does impart enough impact force to cut the heaviest grass and weeds and even light brush up to about one inch in diameter, but does not deliver excessive forces that can hurl a struck object with the speed of a bullet.

Another factor that adds to the safety aspect of the flail mower is its vertical mode of operation. A horizontally acting rotary tends to move cuttings and struck objects out horizontally in all directions and, to be rendered usable with some degree of safety, must be heavily guarded with solid sheet metal or flexible chain shields which extend down to the ground on all sides. However, a discharge chute of some sort is needed to provide a means of ejection of cuttings, so complete guarding is nearly impossible.

On the other hand, the flail, operating vertically, has no tendency to move cuttings or struck objects sideways, an excellent feature when moving along roadways, as nothing is ejected onto the roadway. Most flails rotate so as to cut down on the front and back along the bottom of the cut. Height is usually controlled by a full-span roller, riding on the ground close behind the cutter. Any object that does happen to be moved by impact of the flail knife would normally be stopped immediately by the roller. The curved cutter housing and rear shields effectively deflect anything discharged rearward high enough to clear the roller, directing it down toward the ground. The flail mower cutter housings are also designed so that anything that might possibly be picked up and carried over the cutter to be discharged forward is deflected at an angle of approximately 45 degrees downward and returned almost immediately to the ground.

Thus, the low-impact force action of the lightweight free-swinging flails, their vertical mode of operation, the guard action of the roller, and the deflecting features of the cutter housing all combine to make the flail mower by far the safest of all impact-action mowers.

The basic design conformation of the flail mower, as outlined above contains features that provide for natural cutting superiority. Thin sharp knives cut cleaner and use less power. The vertical flail knife is highly adaptable to cutting either fine lawn grass or tough field grass, as well as weeds and light brush. The cylindrical shape of the flail cutter with knives extended results in cutting occurring on a line rather than over a large area as with a rotary. With the roller set in close behind this line of cut, control of the height of cut is very accurate. The cutter can follow the ground contour closely with very little problem of scalping. Performance is therefore very good, even on rough or uneven ground. Height of cut is controlled by adjusting the roller. There is no adjustment needed or possible on the knives. Their position on the shaft is fixed.

Because there is no need to completely encase the cutter to provide operational safety, the flail cutter housing is open on both the front and the rear. Grass enters over the full width of the cutter without being flattened. The knives cut the grass in an upright position.

The capacity of a mower depends upon the volume of vegetation it can process through its cutter mechanism in a given time. The flail mower, with its open full-span intake and discharge areas can handle higher volumes of cuttings than other types of mowers.

This same "open" feature of the flail mower also provides top performance in wet--even "liquid wet"--conditions.

One of the basic claims upon which the Mott flail mower patents were based was the discovery of its self-cleaning capabilities. The self-cleaning aspects, coupled with the "pass through" features of the flail mower cutter housing allow wet grass to be cut, shredded, and discharged without problem. This wet-cutting ability is very important. Often after a heavy dew the grass remains wet for long periods and there just is not time to wait for everything to dry up.

Mowing speed also is important. Again, because of the high-volume capabilities of the flail mower, mowing speeds of 10 m.p.h. over smooth terrain are not uncommon. One Mott model is equipped with torsion bar spring suspension, shock absorbers, and forward rotation of the cutter shaft. This unit was designed specifically to be pulled in gangs for wide-swath, high-speed mowing of wide-open field areas.

While each of the various specific types of mowers are indeed best suited for certain mowing jobs, the flail mower is without a doubt the most versatile and capable all-around mower that can be had for many mowing jobs.

VEGETATION CONTROL WITH SOIL STERILANTS

M.D.McGlamery

Soil sterilants are nonselective chemicals or nonselective rates of selective chemicals used to control all vegetation in noncropland areas, such as parking lots, drive-in theaters, driveways, patios, and certain industrial sites.

Soil sterilants can be classified by their length of control. Those with little or no residual activity are the fumigants and the contact herbicides. Fumigants affect the viability of weed seeds as well as existing growth. Contact herbicides control only the existing vegetation which the spray contacts.

Amitrole, dalapon, 2,4-D, and DSMA give temporary control for four months or less. Semi-permanent control is provided by some inorganic salts, such as sodium borate and sodium chlorate. Organic compounds that provide semi-permanent control are the uracils (bromacil), phenylureas (monuron, diuron), and the s-triazines (atrazine, simazine, and prometone).

There are a variety of particular uses for soil sterilants including (1) drives and parking lots, (2) around buildings as a means of preventing the growth of weeds that are unsightly or present a fire hazard, and (3) along fences to control weeds. However, it may be preferable to establish desirable, competitive vegetation along a fence in order to discourage weed growth and to provide protective soil and wildlife cover. Short-term herbicides, such as 2,4-D and dalapon, might be used for temporary control until desirable vegetation can be established.

PRECAUTIONS AND GENERAL PROCEDURES

Several precautions must be observed when using non-selective chemicals. You must know what weeds are to be controlled and must select the correct chemical for those particular problems. A survey of the area must be made, noting any desirable vegetation in the immediate or adjacent areas that could be affected by spray drift, chemical runoff, or leaching into the root zone.

Appropriate precautions should be taken to prevent damage to desirable plants. The risk of injury with some of these materials may be too great to allow their use in some areas. Be certain that you are familiar with the product, and are aware of the risks before using these materials. Some treatments should be made only by professional applicators.

The type of vegetation to be controlled will affect your decision in selecting a chemical. Perennial grasses can be controlled with dalapon, amitrole, or DSMA; woody perennials, with 2,4,5-T, silvex, or picloram. Deep-rooted vines such as bindweed can be controlled with fenac, 2,3,6-TBA, dicamba, or picloram.

Application time is very important. The best time to apply non-selective, soil-residual herbicides is early in the spring before herbaceous weeds have emerged.

M.D. McGlamery is associate professor, Department of Agronomy, University of Illinois.

If vegetation is heavy, it may be necessary to remove existing vegetation or to add a contact or foliar herbicide to speed topkill. Mixing the herbicides with diesel fuel will also do this. After existing vegetation is under control, the rate can be reduced for maintenance applications in the future.

Adjust the application rates according to the soil types. Also, rates are often adjusted for the desired length of control. When a span of two or three years is desired, maintenance applications are better than an initial application that is too high.

LONG-TERM RESIDUAL CONTROL

Spray Applications

Many of these chemicals are wettable powders and will require thorough agitation for spray application. The rates listed are for the different types of weeds to be controlled. Initial applications are often made at the high rate, with subsequent treatments at the lower rate.

Herbicide	Rate of formulation per acre		
	Annuals	Shallow perennials	Deep perennials
Hyvar-X (80 pct.).	3 to 6 lb.	7 to 12 lb.	15 to 30 lb.
Hyvar-X-L (2 lb./gal.) . .	1 to 2 gal.	3 to 6 gal.	6 to 12 gal.
Tandex (80 pct.)	4 to 8 lb.	3 to 16 lb.	16 to 30 lb.
Princep (80 pct.).	6 to 12.5 lb.	12.5 to 25 lb.	25 to 50 lb.
AAtrex (80 pct.)	6 to 12.5 lb.	12.5 to 25 lb.	25 to 50 lb.
Karmex (80 pct.)	8 to 20 lb.	20 to 40 lb.	20 to 60 lb.
Casoron (50 pct.).	8 to 12 lb.	12 to 25 lb.	25 to 40 lb.
Pramitol 25E (2 lb./gal.).	5 to 7.5 gal.	7.5 to 15 gal.	15 to 30 gal.
Urox 22 (22 pct.).	50 to 75 lb.	75 to 150 lb.	150 to 200 lb.
Sodium chlorate.	300 to 500 lb.	500 to 750 lb.	750 to 1,300 lb.
Amizine.	6 lb.	12 lb.	20 lb.
Krovar I (80W)	2 to 6 lb.	7 to 18 lb.	14 to 40 lb.

Granular or Pellet Application

Granulars are often more convenient for spot treatment and for small areas. Many granules are on a sodium chlorate-borate base.

Herbicide	Number of pounds per:	
	100 square feet	square rod
Concentrated Borascu	4 to 6	12 to 15
Sodium chlorate.	1.5 to 3	4 to 6
Sodium chlorate-modified	2 to 4	6 to 10
Sodium chlorate-borate	3 to 4	8 to 10
Ureabor.	2 to 4	6 to 9
Chlorea-3 (3 pct. monuron + borate-chlorate) . . .	1 to 2	3 to 5
Vacate	1 to 2	3 to 5
Benzabor	.5 to .5	1 to 2
Atratol 8P	.5 to 1	2 to 3
Pramitol 5P.	1 to 2	3 to 5
Tandex 4G.	.25 to .5	1 to 2
Casoron-10P.	.5 to 1	3 to 5

BROADLEAF WEEDS

Broadleaf weeds are often best controlled with foliar applications. Deep-rooted perennials can usually be controlled best when they are at the early bud to early bloom stage. The materials listed below can move through the air and damage nearby desirable broadleaf plants. They are quite soluble and mobile in the soil, and can move into the soil and damage trees or other desirable shrubs and broadleaf plants.

Herbicide	Rate of formulation per acre: Annual and shallow perennials	Rate of formulation per acre: Deep-rooted perennials
2,4-D and/or 2,4,5-T	1 to 2 qt.	2 to 4 qt.
Silvex	1 to 2 qt.	2 to 4 qt
Banvel (dicamba)	.5 to 1 qt.	1 to 4 qt.
Tordon 212 (picloram + 2,4-D)	2 to 4 qt.	4 to 12 qt.
2,3,6-TBA.	2 to 5 gal.	5 to 20 gal.
Fenac.	2 to 5 gal.	10 to 15 gal.
Tritac (2,3,6-TBP)		10 to 20 gal.

UNDESIRABLE WOODY PLANTS

Most of the materials used to control undesirable woody plants are applied to the foliage, but can be applied (1) as basal bark treatments if the trees are less than 3 inches in diameter or (2) as a frilled treatment if the trees are larger. The basal treatment can be applied during the dormant season in fuel oil. Foliar treatments are usually applied as soon as the brush or trees have leaves fully expanded.

Herbicide	Method of application	Rate of formulation
2,4-D and/or 2,4,5-T	Foliar or basal	2 to 4 qt./A.
Silvex	Foliar or basal	2 to 4 qt./A.
Tordon 212 (picloram + 2,4-D). . .	Foliar or basal	1 gal./A.
Banvel (4 lb./gal. dicamba). . . .	Foliar	2 to 4 qt./A.
Ammate-X (ammonium sulfamate). . .	Foliar	60 lb./A.
Habco 10B (10 pct. bromacil) . . .	Soil	1 to 2 tbsp./sq. ft.

WEEDY GRASS CONTROL

Weedy grass control is often best accomplished with the herbicides listed below. The use of a spreader-sticker (surfactant) often helps.

Herbicide	Rate of formulation per acre: Annuals	Rate of formulation per acre: Perennials
Dowpon	5 to 10 lb.	10 to 30 lb.
Sodium-TCA	20 to 50	100 to 150
Cytrol, Amitrol-T.	1 gal.	2 to 3 gal.
Glytac (TCA ester)	2.5 gal.	5 gal.
Ansar 529HC.	1 to 2 qt.	2 to 4 qt.
Daconate	2 to 3 qt.	3 to 5 qt.

CONTACT WEED CONTROL

Contact herbicides kill the plant tissue with which they come in contact. Thus, adequate spray volume is needed for full coverage. The use of a surfactant often helps the spray spread on the plants.

Herbicide	Rate per acre
Paraquat	1 to 3 qt./A.
Fuel oil + dinoseb	50 gal. + 2 qt.
Herbicidal naphtha	30 to 50 gal.

COMMENTS

Availability, formulations, tradenames, and federal clearance for the use of herbicides change from time to time. Always refer to the most recent product labels for precautions, directions for use, and rates to use. Use herbicides with appropriate precautions to avoid injury to desirable vegetation, to protect the user, and to assure the safety of humans and animals. Store herbicides properly so that children and persons who may not be responsible for their own actions do not have access to them. Store herbicides only in the original, well-marked containers. Properly dispose of used herbicide containers and old herbicides.

There are both benefits and risks associated with the use of herbicides. Used properly, the benefits can far exceed the risks, and the quality of our environment can be improved by controlling undesirable vegetation. Do not neglect the opportunities for using desirable vegetation to compete with and replace undesirable vegetation. For some areas, mechanical control may sometimes be quite practical and the most appropriate method.

UNIQUE ORNAMENTAL SHRUBS FOR USE IN CENTRAL ILLINOIS

M.A.Dirr

Too often woody ornamental shrubs are overlooked for residential, commercial, highway, and golf course use. Trees dominate the landscaping pattern, whereas integration of shrubs with trees would create an aesthetically more satisfying landscape.

I prefer to think in terms of "naturalized" landscape plantings. This term does not mean a return to wild flowers, mosses, ferns, or the prairie, which has been advocated by some idealistic people. My idea of "naturalized" is simple to make the plant look as if it belongs. Consider the yellow- and red-leaf forms of plants; they are impossible to blend into a landscape and consequently do not belong. The most beautiful landscapes are a composite of trees, shrubs, ground covers, perennials, annuals, and turf blended into a picture which nature could not duplicate. If this seems an impossibility, consider for a moment how NATURE has limited the ornamental tree and shrub selection in central Illinois. Many of our most beautiful ornamental shrubs are not indigenous to this part of the country or, for that matter, to the United States; yet does this mean that they should or cannot be successfully utilized? I would answer unequivocally no.

The following woody ornamental deciduous shrub species are among the best at our disposal in Illinois and the Midwest. These shrubs possess, in addition to insect and disease resistance, two, three, or four-season ornamental features. This means that the particular species affords excellent summer foliage, flower, fruit, fall color, or winter texture. These multi-seasoned shrubs should always be considered over the over-used, over-rated and over-priced deutzias, forsythias, honeysuckles, mockoranges, privets, and spireas.

Aesculus parviflora--Bottlebrush Buckeye. This is perhaps the most showy member of the buckeye and horsechestnut group blooming from mid- to late-July into early August when few other woody shrubs flower. The white flowers are borne in long (12 inches or larger) cylindrical panicles. The plant is quite shrubby in habit (12 feet in height) and often wide spreading due to the ability to freely sucker from roots. This buckeye performs maximally when sited in a partially shady situation in a soil with adequate drainage. This species is relatively free from insects and diseases and quite resistant to powdery mildew and leaf blight which are so serious on Ohio Buckeye and Common Horsechestnut. It is a handsome specimen which should be allowed to follow the contours of the landscape and should be given adequate area because of its spreading habit.

Chionanthus virginicus--White Fringetree. Many Europeans consider this the most handsome of the native American shrubs. Often reaching heights of 30 feet, however in central Illinois 10 to 15 feet is more common, the fringetree in late May or early June produces masses of fleecy white flowers borne in 6-inch long pendulous panicles. Male and female plants produce flowers of similar quality

M.A. Dirr is assistant professor, Department of Horticulture, University of Illinois.

with the male showier than the female. The foliage is dark green and relatively free of problems. Fall color is often bright yellow. The winter habit is extremely handsome with clean gray stems presenting a warm picture against the bleak winter landscape. The plant does best in acid (pH 6.5 or below) and well-drained soils.

Cornus mas--Cornelianchery Dogwood. Although overshadowed by the more floriferous *Cornus florida*, this dogwood deserves wider planting. The small yellow flowers (bracts) are borne in March (effective for two to three weeks) before the leaves. The scarlet fruit arrives in June-July and, although extremely ornamental, is quickly consumed by birds or rapidly falls from the plant. The foliage is an excellent dark green and often assumes purplish tints in fall. This species exists as a multi-stemmed shrub or low-branched tree, with a rounded form, and 15 to 25 feet in height. It is much more easily cultured than *Cornus florida* and *Cornus kousa* because of its adaptability to less acid and heavier soils. It is an excellent plant for screens, massing, backgrounds, and borders.

Cotoneaster multiflora calocarpa--Manyflowered Cotoneaster. This variety is often overlooked when considering the cotoneasters for landscape use. A large shrub, 10 feet or greater in height and wider than tall at maturity, it has the most handsome white flowers and bright red fruits of the cotoneaster group. The foliage is a unique bluish green and is little troubled by insects and diseases (especially fireblight) which afflict many cotoneasters. It is an excellent plant for massing, screening, specimen, shrub border, and grouping. This species is adaptable to many soil types and does uncommonly well in central Illinois. It is a bit difficult to transplant, and should be moved balled and burlapped or as a small container plant. The winter character is unique because the young stems are purple and contrast nicely with the gray-colored older stems. It is a unique plant which will be a conversation piece in May and October when the flowers and fruits, respectively, are at their peaks.

Hamamelis species--Witchhazel. This group of plants is well adapted to central Illinois landscape use because of durability, clean foliage, flower, fall color, and winter habit. *Hamamelis vernalis*, the Vernal Witchhazel, native to the Missouri-Oklahoma-Lousiana region, is perfectly hardy in this part of Illinois. This is the first shrub to bloom in the spring and, depending on weather conditions, the yellowish to reddish fragrant flowers appear in January and February. The flowers are small with ribbon-like petals which persist for several weeks. This species is a rounded, multibranched shrub reaching 10 feet in height. The medium green summer foliage is free of insect and disease problems and changes to yellow in the fall. It is tolerant of shady conditions and prefers a moist, well-drained soil. It is an excellent plant for naturalized plantings, shrub borders, and screening. The Chinese Witchhazel, *Hamamelis mollis*, usually flowers in February or March and offers golden yellow fragrant flowers. It is similar to the preceding species in many respects, except it is a much more open and larger growing shrub (30 feet). *Hamamelis virginiana*, Common Witchhazel, is the latest flowering shrub in the North to bear flowers. It has flowered around November 20 the last two seasons in Champaign-Urbana. The yellow fragrant flowers and yellow fall color make this Eastern North American shrub worth the effort of incorporating it into the landscape. The witchhazels perform admirably in this region, are easy to propagate, and grow and offer so much more character and grace to the landscape compared to forsythia, mockorange, deutzia, or privet.

Hydrangea quercifolia--Oakleaf Hydrangea. A small, shrubby (6 feet), spreading, rather coarsely branched shrub with large leaves (10 inches long) which resemble those of the red oak. The flowers are handsome, especially those of the cultivars Harmony and Snowflake which were selected by Professor J.C. McDaniel of the University of Illinois. These cultivars possess the excellent dark green summer foliage, the reddish purple fall color, and handsome cinnamon-brown exfoliating bark of the species, yet are literally covered with large (to 14 inches) panicles of snow white sterile flowers in July. The flowers persist for a considerable period of time changing from white to pinkish and finally brown. Relatively easy to transplant, this plant does best in rich, moist, well-drained soils and is tolerant of shady situations. This plant is difficult to blend with other plants but when used in groups or masses is a unique addition to any large area landscape.

Ilex decidua and *Ilex verticillata*--Possumhaw and Black-alder or Winterberry, respectively. The Possumhaw is a large, to 30 feet, multistemmed shrub. As is the case with most hollies, the sexes are separate (dioecious) and consequently both male and female plants are necessary to insure fruiting. The bright red fruits appear in fall and persist into winter. The striking gray twigs provide a definite winter accent against dark-colored backgrounds. This species does quite well in many soil types, moist and dry situations, as well as alkaline soils. It is an excellent plant for massing, shrub borders and groupings.

The Winterberry is a smaller, rounded shrub reaching heights of 9 feet. The foliage is handsome, dark green, and free of insect and disease problems. The leaves hold late and usually turn brown to black after a heavy freeze. The bright red fruits are outstanding and remain on the plants late into fall, depending on the bird populations. This species does exceedingly well in wet swampy areas, however it thrives in any good moist soil. Native to much of the Eastern United States, this plant should be more widely used. It is excellent for wet areas, massing, borders and foundation plantings. There is a yellow-fruited form as well as a dwarf form about 4 feet tall with fruits twice the size of the species.

Myrica pensylvanica--Northern Bayberry. One truly must "live" with this plant in order to appreciate its attributes. Native to the Eastern United States along coastal areas and often growing and proliferating in poor, sandy soil, this species is worthy of wider use in the Midwest because of its handsome dull gray fruits which persist into spring, semi-evergreen aromatic foliage, and irregular yet neat growth habit. It is an excellent plant for partial shade and sandy poor soils where little else will grow. The plant ranges from 5 to 12 feet in height and spreads irregularly, forming a handsome mass. This species should be looked at more closely in the Midwest. Currently it is being grown on the Chicago freeway system and is performing admirably under the most adverse conditions.

Viburnum burkwoodii--Burkwood Viburnum. A handsome semi-evergreen, upright, 8- to 10-foot shrub which bears semi-snowball (hemispherical cymes), pinkbudded to white, fragrant flowers. The flowers are borne in late April and early May at the time the leaves are unfolding. The dark glossy green foliage which persists throughout the summer and into late fall is outstanding. An excellent plant for screens, masses, borders, and anyplace where early spring flowers and fragrance are desirable. This plant is easily propagated and grown; however, it should be moved balled and burlapped in larger sizes. The winter habit is exceptionally clean with the dark gray stems contrasting nicely with a snowy background.

Viburnum plicatum tomentosum--Doublefile Viburnum. An outstanding variety with distinct horizontal branching habit, dark green summer foliage, purplish red fall color, and clean winter habit. The plant assumes a neat, broad, rounded habit tapering off at 8 to 10 feet in height. The white, flat clustered (cymes) flowers are borne upright on the branches, creating a milky way effect. The inner flowers are fertile and not particularly showy while the outer flowers are sterile, clear white, and outstandingly ornamental. The flowers are borne in mid-May about the time of flowering dogwood. Many consider this viburnum a lovelier specimen plant than dogwood. The fruit is brilliant red changing to black and frequently devoured by birds before changing colors. The fruit is one of the first to ripen among the viburnums, usually appearing in July. An excellent specimen, border, or grouping plant which is a valuable asset in any landscape. This viburnum, as is the case with most viburnums, demands a well-drained soil and given this it will highlight the landscape.

Viburnum rhytidophyllum--Leatherleaf Viburnum. This species is often overlooked in the Midwest because of hardiness considerations, but undeservedly so. If this species is properly sited it will proliferate. The foliage is rugose, lustrous dark green above, semi-evergreen to evergreen, and not affected by insects and diseases. The flowers, although not as showy as the previous viburnums, are yellowish white and borne in 4- to 8-inch flat-topped clusters (cymes). The fruit is bright red changing to black and is often borne in such quantity as to weight the branches down. A relatively large, upright, and rounded shrub which is excellent when used with broadleaf evergreens for textural effect. An easily transplanted species which does well in sun or partial shade.

GENERAL SESSION — THE SOIL ENVIRONMENT

PLANT-SOIL-WATER RELATIONS

L. Art Spomer

Water is probably the most important nutrient required for turfgrass growth and survival. Turfgrass plants contain and use more water than any other nutrient. Even though these plants appear solid and almost woody, over 90 percent of their weight is water and only 10 percent is the solid material which we see and feel. A heavy cardboard container, such as a mailing tube, filled with water also contains about 90 percent water and only 10 percent cardboard; turfgrass plants are therefore literally living, growing containers of water. Actually billions of microscopic "cardboard" (cellulose) containers are cemented together to form a plant (Fig. 1). Plants not only contain large amounts of water, they often require hundreds of times this amount during growth. This tremendous amount of water required by plants is more than just an inert filler; water is an essential part of the living plant system and probably directly or indirectly influences every aspect of growth. Since water is so important for turfgrass growth and survival, a lack of water (water deficit, water stress) will reduce growth and may even injure or kill the plants.

All water used by turfgrass plants is absorbed from the soil which functions as a reservoir storing water (and minerals) for plant use. Since water is essential for plant growth and since the soil is the only source of water, any factor which affects the availability of soil water also affects turfgrass growth. Because of this, it is essential for anyone concerned with the production or maintenance of turfgrass to have an understanding of plant-soil-water relations.

THE PHYSICAL CHARACTER OF SOIL

In a physical sense, all soils consist of three distinct parts or phases: (1) a *solid phase,* or *soil matrix,* consisting of mineral and organic particles; (2) a *liquid phase,* or *soil moisture,* consisting of water and dissolved substances; and (3) a *gas phase,* or *soil air,* consisting of the same gases as found in the atmosphere. The interrelationship among these three phases determines the overall physical character of the soil.

The *soil matrix* is the framework or backbone of the soil and dominates the soil's physical character. The soil matrix is made up of minute mineral and organic particles of various types and sizes packed into a relatively rigid, sponge-like body honeycombed with holes, or *pores* which form an interconnected network of tunnels or channels permeating the soil mass and in which water and air are held and move through the soil (Fig. 2). Since water is stored in the pores, the nature of soil pores plays an important part in determining the soil's suitability as a water storage reservoir. The nature of the pores depends upon the size and packing of the particles or on the texture and structure of the soil.

L. Art Spomer is assistant professor of plant physiology in Horticulture, Department of Horticulture, University of Illinois, Urbana.

Soil texture refers to the sizes of the particles that make up the soil. Most soils are mixtures of different sizes of particles and are classified according to the amount of each size they contain. Knowledge of soil texture alone is usually not sufficient to determine a soil's suitability as a water reservoir, unless the soil is pure sand, because mixtures of particles, particularly those containing colloids, tend to stick together into *aggregates*. Soil structure is the soil characteristic based on aggregation or packing arrangement (Fig. 3). Open-structured soils have many large pores as opposed to closed-structured soils, which have few. In general, the optimum soils for turfgrass production and maintenance have a combination of both large and small pores.

Soils are also often classified as *organic* or *inorganic*, depending on the proportions of organic or mineral particles they contain. *Organic* particles are plant and animal residues in various stages of decay. *Inorganic* or mineral particles are tiny bits of bedrock material *(primary minerals)* or products of chemcial alteration of bedrock material *(secondary minerals)*. Organic soil physical character differs markedly from and generally changes more readily than that of mineral soils.

The second most important factor affecting the physical character of soil is *soil moisture*, which is the water retained in the soil following irrigation, precipitation, or in some cases movement upward from a water table. It consists of a solution of water and dissolved gases and minerals that wet soil particles and fill soil pores.

When a turfgrass area is irrigated (or it rains), water fills or saturates the upper layers of soil and gradually moves or drains downward through the pores in response to gravity. Some of this water is retained near the surface and some drains completely out of the root zone (Fig. 4). The water which drains out of the root zone is called *gravitational water* and is unavailable for plant use. Some of the water is retained as the humidity in the soil air *(water vapor)*; but this is such a small amount that it is generally not a significant source of supply for turfgrass use. Another form of retained water, hygroscopic water, is absorbed so tightly to the particle surfaces that it is also unavailable for plant use. The main source of water for turfgrass use is the liquid water or *capillary water* which is retained in the soil following irrigation and drainage.

In relation to plant growth, soil moisture is best described in terms of the *amount* of water retained and the *tightness* with which it is held in the soil. The amount of water is expressed as percentage of soil volume, and the tightness of retention is expressed as *soil suction*, *soil moisture tension*, or *soil water potential*. As water is removed from the soil, the remaining water is more tightly held and is less available for plant use. The relationship between the amount and tightness of retention is called the *soil moisture characteristic* and is probably the single most useful physical measure of a soil's suitability as a water reservoir (Fig. 5).

Soil air is the least dominant factor affecting the physical character of the soil; yet, it is still very important in determining the suitability of the soil as a water reservoir. Soil air is found in the soil pores not filled with water. Soil air contains the same gases as the atmosphere, except in different proportions (Fig. 6). Atmospheric air composition remains essentially constant; however, since plant roots and soil microorganisms utilize oxygen and produce carbon dioxide during their life processes, both soil oxygen and carbon dioxide contents vary significantly over short periods of time (soil carbon dioxide concentrations are almost always higher than atmospheric). Since oxygen is essential to maintain root growth and activity, oxygen must be continually resupplied to the soil. This resupply is carried out through the process of *soil aeration* which is the exchange of carbon dioxide and oxygen between the soil and atmosphere. Since aeration occurs mainly through open, air-filled pores, maximum aeration occurs in dry or open-structured soils that drain quickly following irrigation (Fig. 7). However, a soil with too many large pores may not hold sufficient water to be suitable as a soil reservoir.

The interrelationship between these three soil phases determines a soil's suitability as a water storage reservoir for turfgrass. This interrelationship can be illustrated by a simple soil model (Fig. 8). If a large glass jar represents a volume of soil, the empty jar represents 100 percent of the volume as soil air. When a dry, sieved soil is added to the jar, the solid particles fill approximately 70 percent of the volume, leaving 30 percent soil air, or *open pore space*. When water is added to the soil, it fills a portion of the pores and further reduces soil air volume. The maximum water content when the soil is *saturated* or maximum air content when the soil is completely dry is determined by total pore volume (30 percent in this example). If this soil contains 25 percent water, it has only 5 percent of its volume available for soil air. In other words, the total capacity of the soil reservoir is determined by the matrix, and the amount of air in a soil depends upon both the amount of pores and the water content.

WATER ABSORPTION BY PLANTS

Although the soil initially determines the availability of the water which it contains, the growth and permeability of the turfgrass roots are also highly important. The path of water through grass plants begins when it is absorbed from the soil by the roots and ends when it is either incorporated into the plant tissues or evaporated *(transpired)* from the leaves (Fig. 1).

Water absorbed by the roots moves along cell walls, intercellular spaces, or directly through cells toward the center of the root. Most of the water (and minerals) used by turfgrass plants is absorbed through the *root hair zone* located just behind the growing root tip. The root hairs are hair-like extensions from the surface cells of the root. Root hairs increase the total absorbing surface of the root one to five times and also increase the effective diameter of the root several times. Water absorbed by the tip is used primarily for the growth of the root and little is translocated to the above-ground portions of the plant. The older, maturing root behind the root hair zone becomes impermeable to water. All absorbed water passes through at least one layer of living cells, *endodermis*, in its path through the root. Water movement through this layer is affected by the health or physiological activity of the root which, in turn, can be affected by a number of factors, including soil aeration, temperature, physical injury to cells, and nutrition. This absorbed water eventually enters the plant's vascular system (xylem and phloem tissues), which is a network of pipe-like cells extending to all parts of the plant. It is then rapidly distributed within the various plant tissues by moving from cell to cell along intercellular spaces or directly through cell walls.

Transpiration occurs primarily through tiny pores *(stomata)* in the leaf's surface. The rate of transpiration by grass depends on the intensity and duration of sunlight, relative humidity of the air, rate of wind movement, and various other internal and external plant characteristics. The amount of water in the plant is regulated by the balance between water absorption and transpiration. Under conditions favoring high transpiration rates (i.e. high sunlight, low relative humidity) or low absorption rates (i.e., dry soils, poor aeration), the probability of a severe water deficit, wilting, reduced growth, and injury is quite high.

The movement of water through plants as just described is well known, but the actual mechanism responsible for its movement is still not completely understood. The main facts to remember are: if water is available in the soil and the grass plant roots are healthy and growing, the water is readily absorbed and distributed throughout the entire plant body.

THE SOIL WATER RESERVOIR

The suitability of the soil as a water reservoir depends on its capacity to retain water and supply it to the plant. This includes the effect of the soil environment upon root growth and permeability (aeration). Since soil air and water are mutually exclusive (as water content increases, aeration decreases) (Fig. 8), turfgrass irrigation management requires the maintenance of a balance between adequate soil water content and adequate aeration.

Maximum water content occurs in soils with many small pores that hold water against gravitational forces (drainage) following irrigation. However, a soil with too great a proportion of small pores may not provide sufficient aeration. To maintain an optimum balance between water content and aeration for turfgrass growth, one must know the physical character of the soil, practice good soil and irrigation management, and have experience with the particular grass and environmental conditions involved.

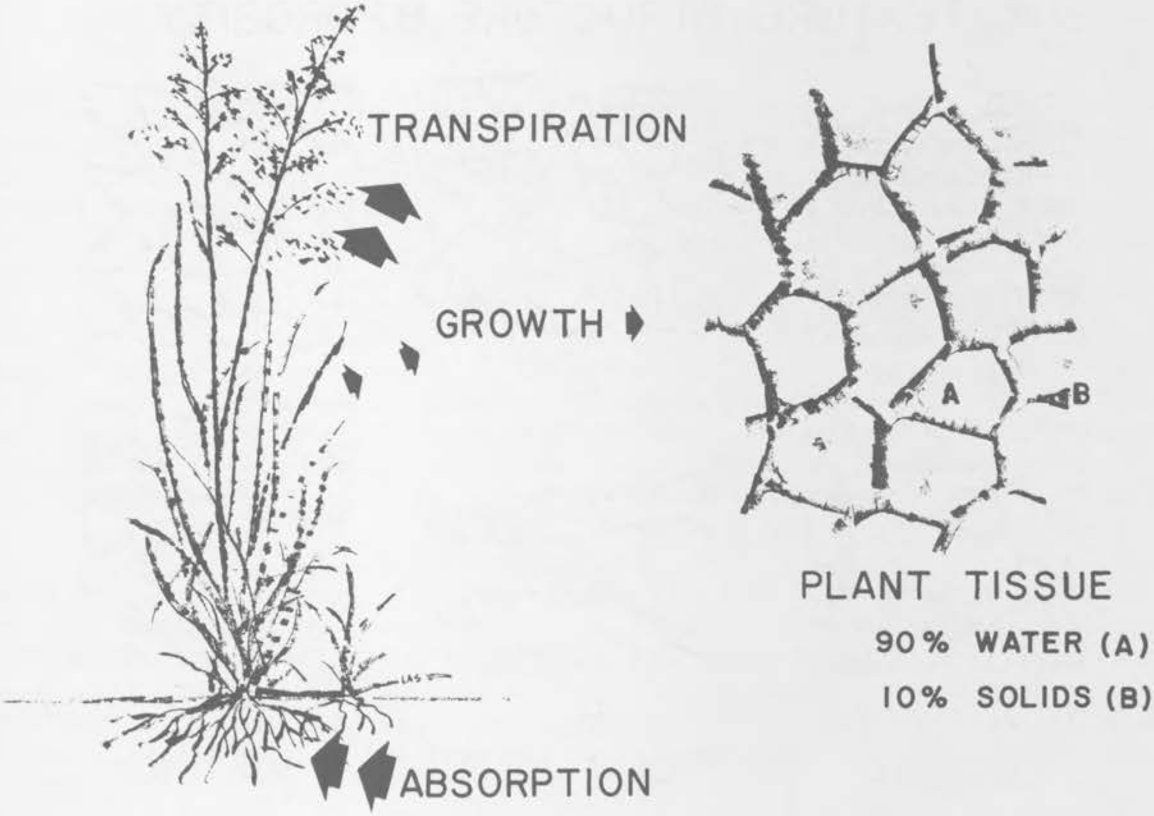

Figure 1. Actively growing grass tissue consists of 85 to 95% water and often requires over 100 times this amount for growth. All of this water is absorbed from the soil and most of it is lost to the atmosphere by transpiration. A lack of water (water stress) will reduce growth or kill the plant.

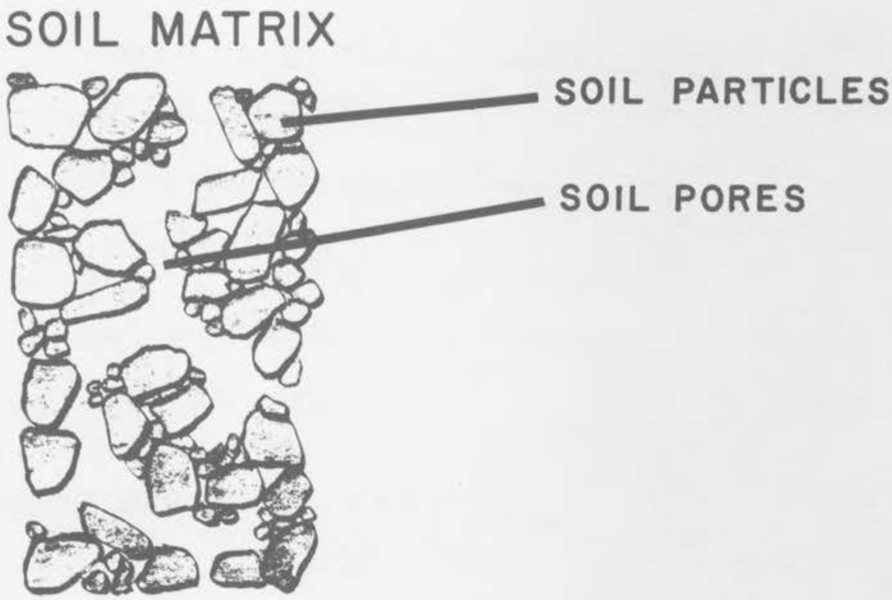

Figure 2. The soil matrix, the solid part of the soil, consists of tiny solid particles packed into a porous, semi-rigid mass. The soil water and air are stored in and move through the pore network.

SOIL TEXTURE, STRUCTURE, & POROSITY

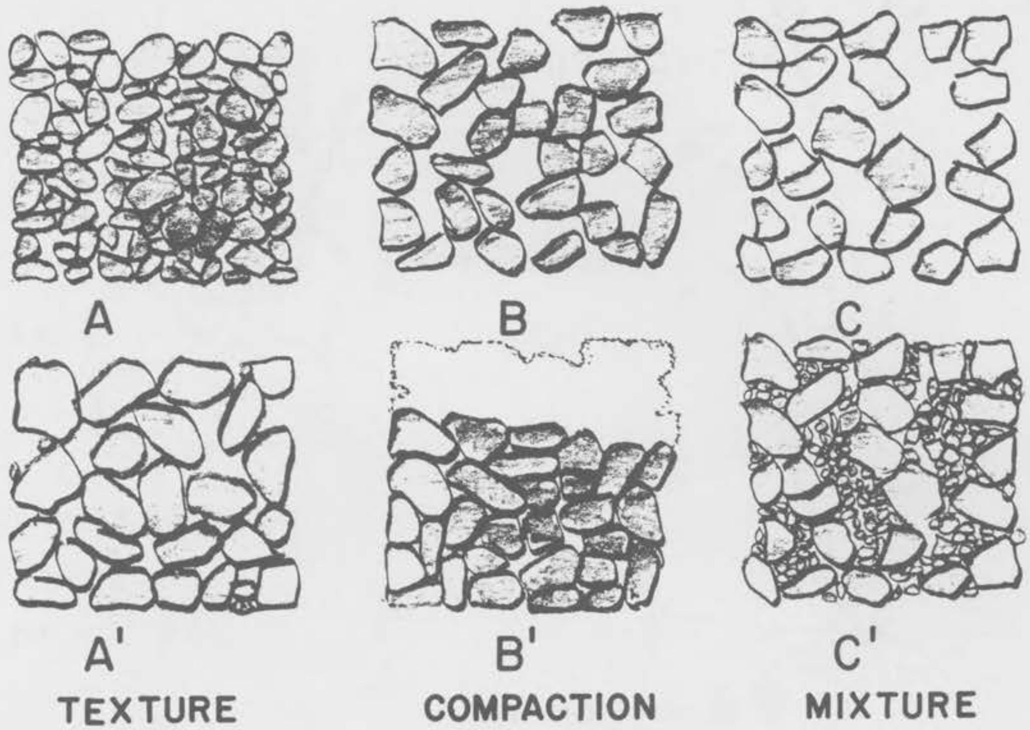

Figure 3. Soil texture (A), compaction (B), and mixture (C) all influence both the total amount and size of soil pores. Soils A, B, and C have greater total porosity than the corresponding soils A', B', and C'.

SOIL MOISTURE

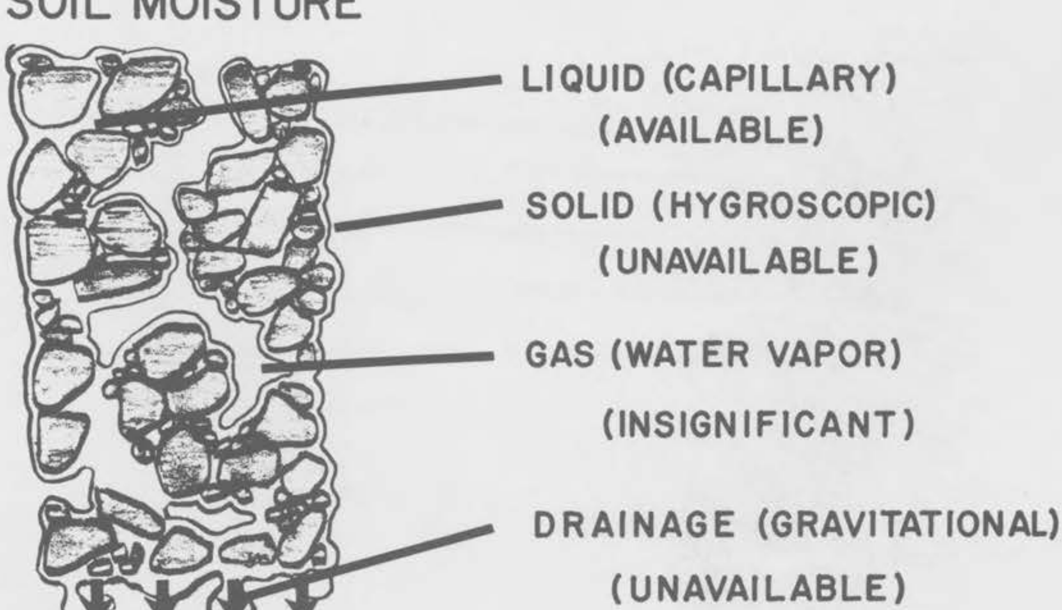

Figure 4. There are 4 different classes of soil moisture: capillary, hygroscopic, vapor, and drainage water. Only capillary water is a significant source of water for plant use.

SOIL WATER AVAILABILITY

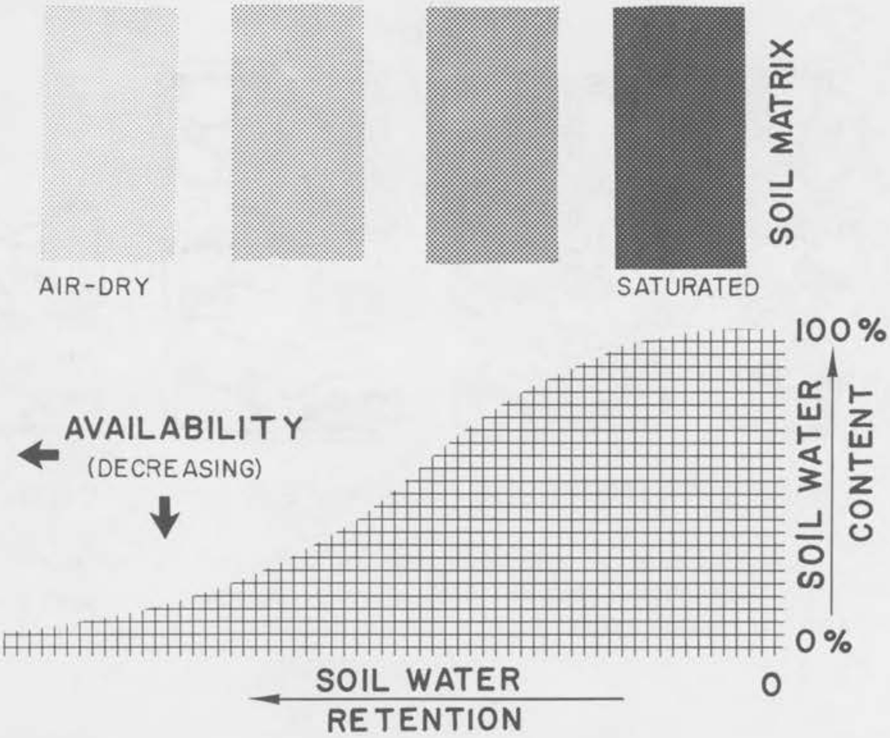

Figure 5. Soil water availability is best described by soil water retention and content. The relationship between these two factors is called the soil moisture characteristic. Availability decreases as soil water content decreases and soil water retention increases.

SOIL AIR

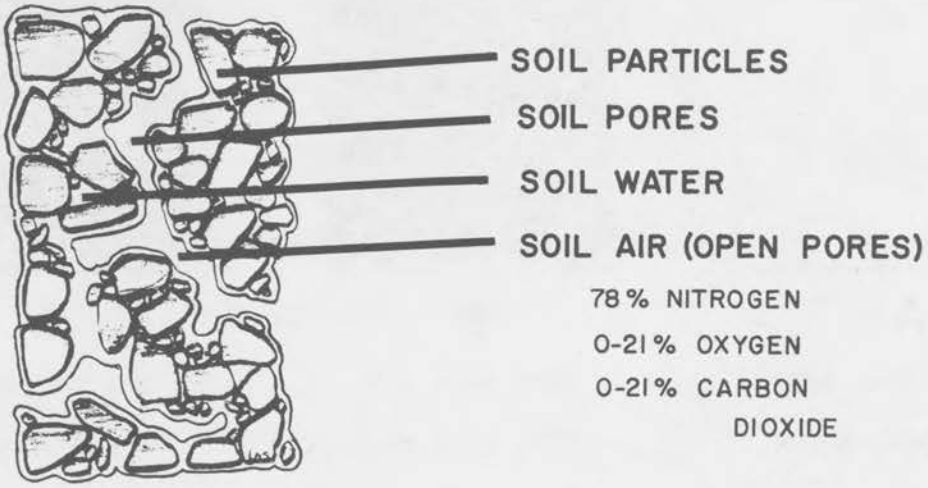

Figure 6. Soil air occupies the open or non-water-filled pores. The soil carbon dioxide concentration is usually higher and the oxygen content lower than in the above-ground air.

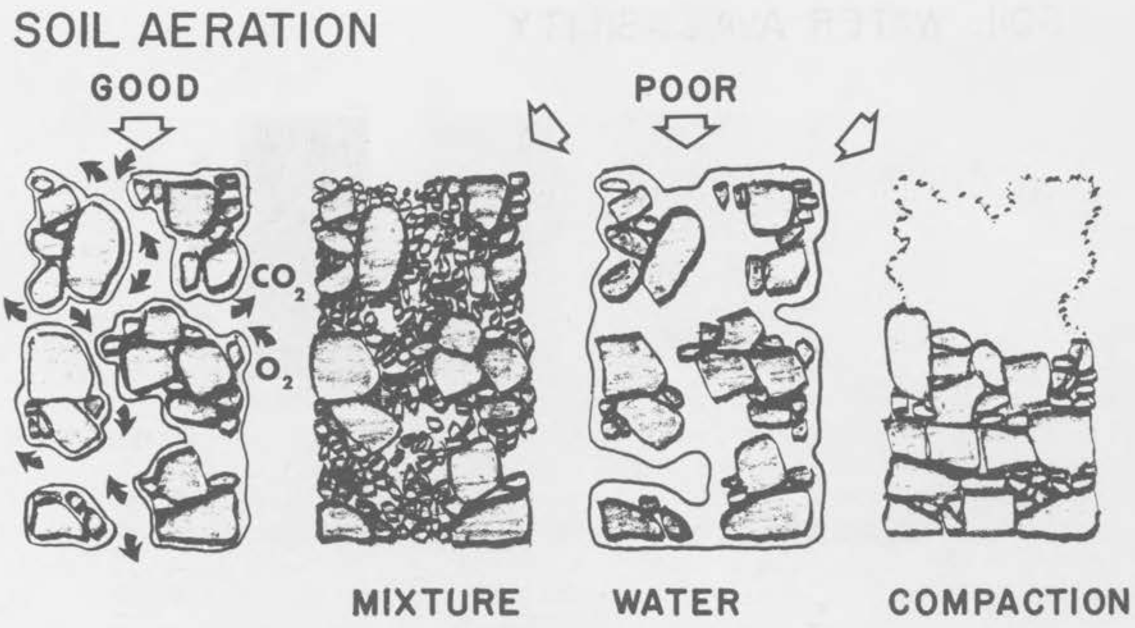

Figure 7. Soil aeration is the exchange of oxygen and carbon dioxide between the soil and above-ground atmospheres through the open soil pores. Any factor which reduces the amount of open pores will reduce soil aeration.

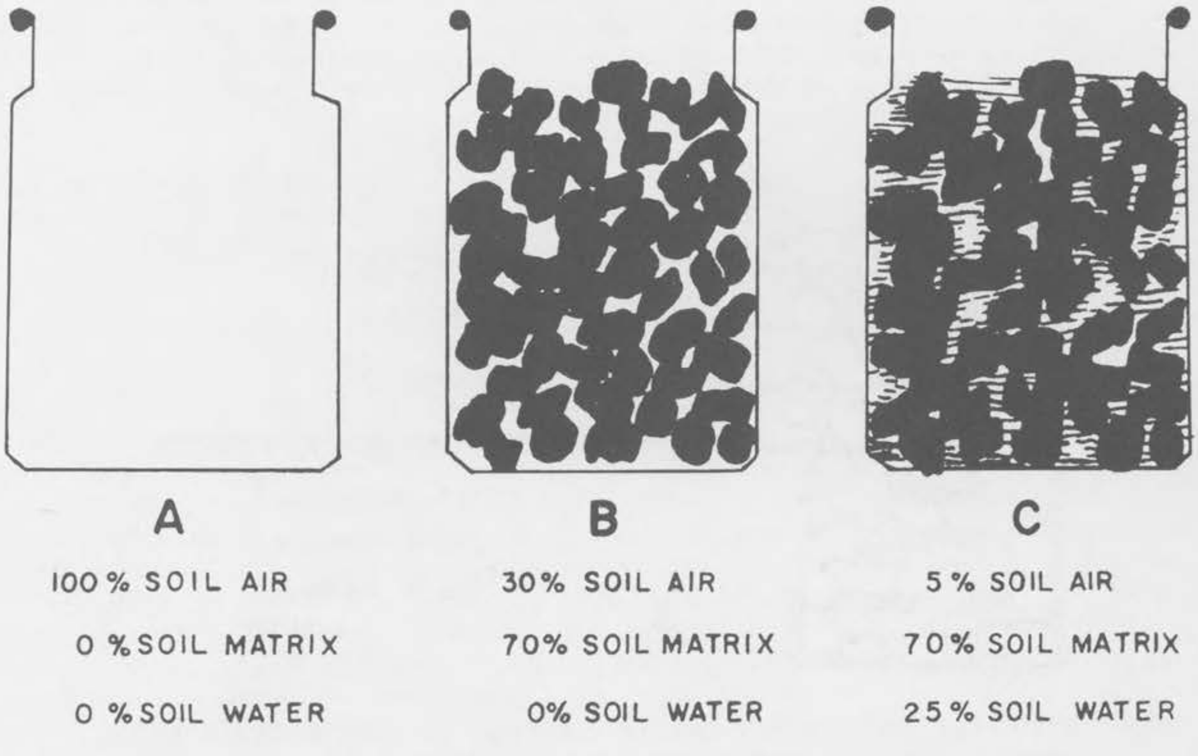

Figure 8. Simple soil model illustrating the interrelationship between soil air, water, and solids.

MODIFYING THE SOIL PHYSICAL ENVIRONMENT

Donald V. Waddington

Soil modification is an essential practice on most golf greens, athletic fields, and other intensively used turfgrass areas. On other areas soil modification may be necessary to improve inherently poor soil physical conditions. Modification may also be needed when natural soil structure is destroyed by heavy equipment or excessive tillage during seedbed preparation. Poor soil physical conditions, whether natural or due to compaction, may limit grass growth, normal use of a turfgrass area, and performance of essential maintenance operations. Bulk density, heat conductivity, mechanical resistance to root penetration, and usually moisture retention will increase with compaction, whereas air porosity, infiltration, percolation, and oxygen diffusion will decrease. If water movement into and through soils is slow, the surface may remain too wet for satisfactory use for long periods following rain or irrigation. Poor soil aeration may affect root development and growth of some grasses, and some beneficial microbial processes are inhibited by anaerobic conditions in poorly drained soils. Therefore, good soil physical conditions should be established and maintained on turfgrass areas to obtain maximum performance of the turfgrass and maximum use of the area.

Turfgrass areas are expensive to construct, and poor initial construction brings additional costs in the form of increased maintenance problems, renovation, or reconstruction. Several types of aerating equipment, coarse-textured amendments, and wetting agents are used to combat and, hopefully, overcome the effects of compaction on established turf areas. On new turf areas a soil can be modified by adding physical amendments which will produce a soil mixture that has acceptable physical properties even when compacted.

Various organic and inorganic amendments are available for use in modifying physical properties of soils. The effectiveness of these amendments depends on the properties of the amendment, the amount added, the properties of the soil to which it is added, and the uniformity of mixing of the components.

ORGANIC AMENDMENTS

Peat is the most popular organic amendment. Sawdust, bark, and chemically treated wood products, as well as various wastes and by-products, such as digested sewage sludge, tannery waste, manures, cocoa shells, and other seed hulls, can also be used as soil amendments. Organic amendments which decompose rapidly produce soil humus, which is important in aggregate formation and the development of desirable soil structure. Richer et al. (1949) reported that cocoa shells decayed more rapidly than peat, but still produced good soil physical conditions because the products of decomposition increased aggregation. However, on heavily used areas, natural aggregation or structure is soon destroyed (Alderfer, 1951). Organic amendments such as peat which resist decomposition give longer effects than readily decomposed materials (Sprague and Marrero, 1932). Fine materials are less effective

D.V. Waddington is associate professor, Department of Agronomy, Pennsylvania State University, University Park, Pa.

than coarse or fibrous materials in opening up compacted or fine-textured soils. The finer forms may plug pores rather than create larger ones, and would be effective in decreasing permeability of coarse-textured soils and sand.

Fibrous peats are preferred over woody and sedimentary peats. Woody peats are granular in nature and are low in moisture-holding capacity. Sedimentary peats are very fine and colloidal in nature, and may contain considerable amounts of fine soil (silt and clay). When dry, sedimentary peats become extremely hard and absorb water very slowly.

Common fibrous peats are reed-sedge peat, hypnum moss peat, and sphagnum moss peat. Decomposed peats are referred to as peat humus. Peat humus, having undergone initial decomposition, is more stable in the soil than undecomposed or slightly decomposed peats. It also has finer texture and is less fibrous. Reed-sedge peat is more resistant to decomposition than hypnum moss peat, and hypnum is more resistant than sphagnum moss peat (Lucas et al., 1965).

Peats can be used to improve both fine-textured and coarse-textured soils (Lucas et al., 1965; Sprague and Marrero, 1931). They increase moisture retention and slow down water movement in sandy soils, and they increase the permeability of fine-textured soils. Peats increase microbial activity, increase cation exchange capacity, serve as a slow-release source of plant nutrients, and usually increase soil acidity.

As a component in modified soils, peat is usually added in the amount of 10 to 20 percent on a volume basis. Peat increases the resiliency of mixtures, and during turf establishment it helps maintain moisture levels favorable for seed germination and rooting of stolons. The need for peat or other organic materials in topdressing may be questioned because established turf usually has adequate organic matter. In fact, one purpose of topdressing is to reduce organic matter (thatch). Possibly the greatest value of organic amendments in topdressing is their conditioning effect on the mixture--keeping the soil from caking, and maintaining a free-flowing, easily spread material. This need for conditioning decreases as the soil content in mixtures decreases; however, decreased water and nutrient retention with less soil may give a good argument for the need for organic amendments.

Sawdust has value as a soil amendment (Allison and Anderson, 1951; Anderson, 1957; Bollen and Glennie, 1961; Lunt, 1955, 1961; White et al., 1959). Favorable changes that can be expected from sawdust additions are increases in humus, cation exchange capacity, aggregation, moisture-holding capacity, and aeration porosity. On the other hand, the possibility of adverse effects exists. Nitrogen and phosphorus deficiencies often occur as sawdust is decomposed by microorganisms. This condition can be corrected by adding nitrogen and phosphorus fertilizers. About one pound of nitrogen and 0.2 pound of phosphorus are required for each 100 pounds of sawdust. Sawdust from hardwoods decomposes more rapidly than that from softwoods, thus the nitrogen tie-up and the need for supplemental nitrogen is greater with hardwood sawdust. Fresh sawdust from some species has been shown to decrease germination and seedling growth of turfgrasses (Waddington et al., 1967); therefore, it is advisable to use weathered or well-rotted materials.

In some cases sawdust or ground bark is fortified with nitrogen and then composted prior to marketing as an amendment. Such is the case with lignified redwood, which has been shown to be better than sphagnum peat for increasing oxygen diffusion (Letey et al., 1966). The contribution of redwood to soil salinity was greater than that of peat (Valoras et al., 1966).

Organic materials other than peat and wood products are not used extensively on turfgrass areas, but they have been included in research studies. Sprague and Marrero (1931) reported benefits from additions of well-rotted manure and spent mushroom compost, and Richer et al. (1949) reported soil improvement from mushroom compost and cocoa shells. Davis et al. (1970) recently evaluated nine organic amendments including ammoniated rice hulls; an organic compost derived from sewage sludge and other organic residues; peats; and various products from sawdust and bark.

Some properties to look for in an organic amendment are: (1) coarse or fibrous structure, few fines; (2) resistance to decomposition; (3) high organic content, at least 90 percent; (4) good moisture retention, at least 400 percent for peats; (5) freedom from toxic compounds, disease organisms, insects, and weed seeds; and (6) ease of handling and mixing.

INORGANIC AMENDMENTS

Various natural and processed inorganic amendments are available for modifying soil. Most are coarse amendments, although finer forms of some are available. Inorganic amendments are usually used to increase permeability; however, some may be used to decrease permeability. In research conducted on loamy fine sand in Florida, colloidal phosphate and vermiculite additions decreased aeration porosity and water movement (Smalley et al., 1962).

Examples of coarse amendments are sands of various sizes and origins; calcined clays, such as "Turface," "Terra-Green," and "LuSoil"; expanded shale, such as "Weblite" (used in soil modification research by R.E. Schmidt at VPI and SU); vermiculite, expanded mica minerals such as "Terra-Lite"; perlite, an expanded obsidian-like volcanic rock available as "Perl-Gro," "Perl Lome," and "Sponge Rok"; diatomite, a calcined hydrated silica mineral such as "Dialoam"; and water-quenched slag.

Important characteristics of coarse amendments are particle size, uniformity of particle size, and durability. Particles which break down or alter their shape due to weathering or compaction are not satisfactory for intensively used turf areas, although some materials in this category may have exceptional value in greenhouse and potting mixes. For instance, the brittle nature of perlite and the ease of collapse of vermiculite particles could make these materials unsuitable as coarse amendments on intensively used turf areas. Also, some calcined clays may not be hard and stable enough for use as soil amendments.

The objective of coarse amendment additions is to create large pores. The quantity used should be such that amendment particles are in contact with each other in the mixture, so that the bridging formed by the contact can create stable pores. When added in quantities less than needed to obtain bridging, non-porous amendments such as sand may adversely affect physical properties. The amount needed will vary with the soil texture and the particle size of the amendment. Kunze et al. (1957) reported that 85 to 90 percent sand was needed to give adequate modification of a clay soil. Swartz and Kardos (1963) concluded that the total sand content of the mixture should approach 70 percent.

The most effective modification (greatest change in physical properties with the least amount of added amendment) has been obtained from sands in the 0.25 to 2.0 mm. size range, with most of the particles falling into two sand separates (very coarse and coarse sands, or coarse and medium sands). Kunze (1956) concluded that sand of a uniform size, 0.5 to 1.0 mm. in diameter, appeared to be most desirable for soil modification. Howard (1959) reported that sand with 50 percent of the particles between 0.25 and 0.5 mm. was most desirable in sand-soil-peat mixtures ranging from 5-4-1 to 8.5-0.5-1.0 parts by volume. Swartz and Kardos (1963) found the size range of 0.25 to 2.0 mm. to be the dominant fraction in controlling percolation rates. In organic matter-sand mixtures, Davis et al., (1970) obtained greatest modification with uniform sands: one having 94 percent of the particles between 0.25 and 1.0 mm. and the other having 79 percent between 0.5 and 2.0 mm. and 94 percent between 0.25 and 2.0 mm. Unpublished data from Penn State indicate that uniform amendments with particles larger than 2.0 mm. will also effectively modify soil; however, large particles in a putting green may clog aerator tines or interfere with the ease of cutting a core of soil for cup placement. Large particles also create problems when topdressing is worked in. An exception would be when particles are being worked into holes produced by aerators which remove cores of soil.

Some of the finer sands and non-uniform sands which are available may be acceptable as amendments, but larger quantities are usually required to obtain desirable results. Non-uniform amendments contain many different sizes of particles and the beneficial effect of bridging may be lost as smaller particles fill the voids created by larger particles. Lotspeich (1964) reported that a multi-component sand composed of several size fractions favors compaction, and that maximum compaction occurs when the particle sizes are such as to allow tetrahedral packing with mutual contact of all grains. Uniform sands having a large percentage of particles in the fine sand (0.1 to 0.25 mm.) and medium sand (0.25 to 0.5 mm.) sizes may have limitations as amendments to improve a soil, but they are excellent for "soil-less" greens, which are usually constructed using only sand and an organic matter source. Bingaman and Kohnke (1970) reported that compacted fine to medium sand (0.1 to 0.5 mm.) was a satisfactory growth medium for athletic turf. Two sands evaluated by Davis et al. (1970) showed characteristics suitable for "soil-less" greens. One contained 39 percent medium sand and 50 percent fine sand, and the other contained 68 percent medium sand and 25 percent fine sand. Coarser materials can be used in "soil-less" greens if they are underlain by a plastic liner to increase water retention (Ralston and Daniel, 1973).

With the wide range of soil amendments available, it is essential for those involved in the construction and maintenance of turfgrass areas to be aware of the properties of amendments as well as knowing of their availability.

PENN STATE SOIL MODIFICATION PROJECT

A soil modification study was started at The Pennsylvania State University in 1960. One of the objectives of this study was to determine the effectiveness of various amendments for modifying soil physical properties. After preliminary laboratory testing, 81 mixtures were selected for field evaluation.

Materials Used in Field Study

Materials used in the field study were:

Soil--Silt loam (22% sand, 59% silt, 19% clay) from the A_p horizon of Hagerstown soil, a deep, well-drained soil developed from limestone. Surface horizons generally have a silt loam texture, whereas B and C are usually clays. Source: experimental site at The Pennsylvania State University.

Peat--Well-composed, fine-textured, reed-sedge peat, which contained 76 percent organic matter. Source: Boyd Humus Company, New Wilmington, Pa.

Coarse Sand--(5 Q-Rok Sand) Sharp quartz sand derived from quartzite rock. Uniform particle size, with 95 percent of the particles between 0.5 and 2.0 mm. in diameter. Source: Pennsylvania Glass Sand Corporation, Mapleton Depot, Pa.

Concrete Sand--Nonuniform washed river sand with particles ranging from gravel to silt, and with 62 percent of the particles between 0.25 and 1.0 mm. Source: Lycoming Sand Company, Williamsport, Pa.

Mortar Sand--Washed river sand similar to the concrete sand but with most gravel removed, and with 73 percent of the particles between 0.25 and 1.0 mm. Source: Lycoming Sand Company, Williamsport, Pa.

USS Slag--Water-quenched blast furnace slag. A porous product consisting essentially of silicates and alumino-silicates of calcium and other bases, and with 65 percent of the particles between 0.5 and 2.0 mm. Source: United States Steel Corporation, Pittsburgh, Pa.

Wunderley Slag--Water-quenched blast furnace slag that has been treated with steel pickling liquor. The liquor contains 0.5 to 2.0 percent free acid and 15 to 22 percent ferrous sulfate, and gives the slag increased iron and sulfur contents and a lower pH. Product had 75 percent of the particles between 0.5 and 2.0 mm. Source: Wunderley Processing Company, McKeesport, Pa.

Perl-Lome--Horticultural grade of material obtained from a siliceous volcanic rock called perlite, a variety of obsidian. The very porous and fragile particles are formed by the expansion of raw perlite when it is heated to a temperature of approximately 1,700° F. Fifty percent of the particles were between 0.5 and 2.0 mm., and 23 percent were greater than 2.0 mm. Source: Perlite Corporation, Carnegie, Pa.

Turface--Granular calcined clay produced by calcining montmorillonite clay at temperatures above 1,300° F. A hard, porous material having 72 percent of the particles between 0.5 and 2.0 mm. Source: Wyandotte Chemical Corporation, Wyandotte, Michigan.

Fert-Soil--Commercially available mixture of composted soil, sand, and organic matter which is heat-treated and contains approximately 16 percent organic matter and 70 percent sand. Source: Fertl-Soil Company, Rahway, New Jersey.

Particle size analyses and physical properties of these materials are shown in Tables 1 and 2, respectively.

Sand content in the mixtures varied between 40 and 80 percent on a volume basis. Slag was used at 30, 40, and 60 percent levels, alone and in combination with coarse sand. Perl-Lome and Turface were used at 10, 20, and 40 percent, alone and in combination with sand. Peat content was either 10 or 20 percent. When peat was increased from 10 to 20 percent, another component was decreased by 10 percent, and thus the ratio of components other than peat also changed.

Establishment of Field Plots

During the summer of 1960 the Hagerstown silt loam topsoil was stripped from the area and stockpiled. The subsoil was graded to a 0.5 percent slope, and a 6-inch layer of 1B (1/2-inch) limestone chips was spread on the area. Beginning in July of 1961, the materials for the various mixtures were mixed off-site and the

Table 1. Particle Size Distribution of Materials Used in Soil Modification Field Study (Shoop, 1967)

	Percent by weight						
Material	Fine gravel >2.0 mm.	Very coarse sand 2.0-1.0 mm.	Coarse sand 1.0-.5 mm.	Medium sand .5-.25 mm.	Fine sand .25-.1 mm.	Very fine sand .1-.05 mm.	Silt .05-.002 mm.
Coarse sand.	.0	14.7	80.7	4.4	.2	.0	.0
Mortar sand.	.1	4.3	22.5	50.4	19.6	2.8	.3
Concrete sand. . . .	14.3	6.3	18.4	43.2	14.8	2.1	.6
USS slag	5.4	26.1	39.1	19.0	6.3	3.4	.8
Wunderley slag . . .	6.0	38.2	36.6	10.0	3.2	2.4	3.6
Perl-Lome.	23.0	37.1	13.2	7.1	8.7	7.5	3.3
Turface.	5.3	35.4	37.2	20.2	1.7	.2	.0
Hagerstown soil[a] . .	.0	1.2	2.0	1.5	3.6	14.3	58.8

[a]Also contained 18.6 percent clay.

Table 2. Physical Properties of Materials Used in Soil Modification Field Study (Shoop, 1967)

Material	Particle density g./cc.	Bulk density g./cc.	Weight lb./cu. ft.	Moisture retained at various tensions, percent by volume: 60 cm.	1/3 atm.	15 atm.
Coarse sand.	2.66	1.47	91.8	4.2	.8	.4
Mortar sand.	2.74	1.61	100.5	9.3	5.5	2.6
Concrete sand.	2.77	1.70	106.1	7.7	6.1	2.8
USS slag	2.79	.77	48.1	15.6	13.3	12.3
Wunderley slag	2.78	.74	46.2	29.5	16.5	14.1
Perl-Lome.	2.33	.13	8.1	27.2	8.8	14.5
Turface.	2.55	.68	42.4	38.4	36.3	32.9
Peat	1.71	.27	16.9	36.8	28.0	21.0
Hagerstown soil. . . .	2.63	1.16	72.4	43.4	32.6	8.7

prepared mixtures were then placed on the stone base in 10- by 18-foot plots. To insure containment of individual mixtures in each plot, boards were temporarily placed between plots during placement of the mixtures. Depth of mixtures was approximately 12 inches. The mixtures were allowed to settle over the winter, and in the spring of 1962 the settled depth was adjusted to approximately 10 inches by either removal or addition of mixture. The seedbed was prepared and plots were seeded in June and July with Penncross creeping bentgrass (*Agrostis palustris* Huds.) at a rate of one pound per 1,000 square feet. Since establishment, the plots have been maintained as golf green turf.

Compaction and Aerification Treatments

Beginning in 1963 a compaction machine was used to apply traffic to half of each plot. The machine was a converted West Point Aerifier with spiked golf shoe soles mounted on a rotating water-filled drum. The total machine weight was 400 pounds and, based on area of the shoe soles, pressures up to 38 p.s.i. were obtained. The compaction treatment was applied from 21 to 60 times per season. Compaction was usually applied after irrigation or rainfall, and was concentrated during spring and early summer as well as prior to and during periods when soil physical properties were being measured. The noncompacted area received only the compaction associated with normal maintenance of the area.

In the fall of 1964, the main plots were split perpendicular to the compaction treatment for an aerification treatment. Half of the plot was not aerified and the other half was aerified with a Ryan Greensaire aerator, which was equipped with 3/8-inch hollow tines. Cores were extracted on two-inch centers to a depth of approximately three inches. The plots were aerified once in 1964, 1965, 1966, 1969, 1970, and 1972, and twice in 1967 and 1968. Except when used for topdressing in 1970 and 1972, cores were removed from the area.

Measurements of Soil Physical Properties

Samples taken at the time of establishment were used for laboratory determinations of percolation rate and air porosity on compacted and noncompacted mixtures. Moisture retention at various tensions and the permanent wilting percentage were also determined.

In the field, infiltration rates were measured each year (1963 to 1972) using a double ring infiltrometer, consisting of two concentrically placed cylinders (one 8 inches and the other 14 inches in diameter and 3.5 inches in height) driven into the soil to a depth of about 1 1/2 to 2 inches. Air porosity, bulk density, and water retention were also measured under field conditions.

Percolation and Infiltration Rates

The effects of the amount and kind of amendment on percolation and infiltration rates are shown in Tables 3 and 4. Laboratory percolation rates were significantly affected by mixtures and were decreased by compaction. Low levels of modification were ineffective in bringing about an increase in permeability under compacted conditions. In general, compacted mixtures needed 60 percent or more coarse amendments to have percolation rates greater than 1 inch per hour. Similarly, little change in value of infiltration rate and air porosity occurred until the coarse amendment level reached 50 to 60 percent. Thus, a general statement that additions of coarse amendments increase permeability cannot be made; however, once a threshold level is reached, where bridging of coarse particles begins to occur, increases in coarse amendment did increase permeability.

Table 3. The Effect of Coarse Sand and Peat Contents of Soil Mixtures on Percolation and Infiltration Rates

Parts by volume			Laboratory percolation rate,[a] in./hr.		1963 Infiltration rate,[a] in./hr.		1972 Infiltration rate, in./hr.			
Coarse sand	Soil	Peat	NC	C	NC	C	NC	C	NCA	CA
8	0	2	>60.0	53.9	50.4	37.0	8.0	3.0	21.9	13.3
8	1	1	>60.0	23.9	36.5	23.8	6.0	1.1	12.6	9.0
6	2	2	30.1	11.1	20.1	12.4	1.6	.4	4.2	1.5
6	3	1	23.0	2.3	15.9	5.5	3.3	1.1	2.5	1.4
5	3	2	29.8	1.0	18.5	11.4	1.5	.5	2.0	.8
5	4	1	28.5	3.1	12.7	7.8	2.5	.3	3.7	1.4
4	4	2	29.1	.9	7.4	3.6	.7	.3	2.4	.9
4	5	1	3.7	.1	5.0	1.9	.4	.2	1.5	.5
0	8	2	3.7	.0	3.8	1.2	.4	.5	1.4	.3

[a]From Shoop (1967).
NC - noncompacted
C - compacted
NCA - noncompacted, aerified
CA - compacted, aerified

Table 4. The Effect of Various Amendments on Percolation and Infiltration Rates of 4-5-1, 6-3-1, and 8-1-1 Mixtures of Amendment, Soil, and Peat

Amendment	Laboratory percolation rate,[a] in./hr.		1963 Infiltration rate,[a] in./hr.		1972 Infiltration rate, in./hr.			
	NC	C	NC	C	NC	C	NCA	CA
4-5-1 mixtures								
Coarse sand	3.7	.1	5.0	1.9	.4	.2	1.5	.5
Mortar sand	7.1	.3	1.3	.0	.6	.3	.9	.6
Concrete sand	3.6	.2	2.7	.1	.9	.5	1.9	.6
USS slag.	30.6	3.4	5.7	1.0	.8	.3	2.6	.6
Perl-Lome	2.8	.1	.7	.4	.4	.5	.6	.4
Turface	1.2	.2	5.3	2.7	1.7	.3	2.0	.6
6-3-1 mixtures								
Coarse sand	23.0	2.3	15.9	5.5	3.3	1.1	2.5	1.4
Mortar sand	19.1	5.6	8.7	4.0	2.5	.6	2.5	.6
Concrete sand	11.4	3.3	8.7	2.2	.8	.6	1.5	1.0
USS slag.	>60.0	10.2	15.7	3.4	1.6	.6	8.7	1.6
8-1-1 mixtures								
8 coarse sand	>60.0	23.9	36.5	23.8	6.0	1.1	12.6	9.0
6 USS slag + 2 coarse sand. .	>60.0	>60.0	37.2	23.0	5.7	1.6	17.8	9.7
4 Perl-Lome + 4 coarse sand .	47.0	7.0	28.0	11.6	3.7	.5	6.4	2.1
4 Turface + 4 coarse sand . .	14.6	18.7	35.0	36.5	10.6	4.5	22.5	8.4

[a]From Shoop (1967).
NC - noncompacted
C - compacted
NCA - noncompacted, aerified
CA - compacted, aerified

On compacted coarse sand mixtures, increasing peat from 10 to 20 percent at the expense of soil (8-1-1 vs. 8-0-2; 6-3-1 vs. 6-2-2; etc.) increased percolation except at the 50-percent sand level. Increasing peat at the expense of sand (6-3-1 vs. 5-3-2 and 5-4-1 vs. 4-4-2) decreased percolation.

Infiltration rate is one of the best measures of soil physical condition, and in most instances it should be the primary criterion in evaluating the various treatments. Significant differences in infiltration rates were caused by mixtures, compaction, aerification, and time. The coarser textured mixtures had the higher rates; however, the effects of these treatments were influenced by the mixtures. Infiltration rates of some mixtures decreased rapidly with time and leveled off, while others still show a decreasing trend after 10 years. Rates of fine-textured mixtures tended to level off earlier than those of coarse-textured mixtures, although the magnitude of decreases with time has been greater with the coarse mixtures, which initially had very high rates. Decreases with time were favored by compaction, whereas aerification tended to slow the decrease.

Differences in infiltration rates due to compaction treatments decreased over the years. It had taken longer for the noncompacted plots to approach or reach an ultimate soil compaction level which is characteristic of the mixture. Aerification tended to increase infiltration rates, and may improve the acceptability of an insufficiently modified putting green mixture. The beneficial effect of aerification may be dependent on whether the poor permeability is caused by a poor physical condition which exists throughout the depth of the mixture, or by a compacted surface layer which can be penetrated by aerator tines or spoons. In contrast to a beneficial effect, there was a tendency with several mixtures toward lower infiltration rates with the aerified, noncompacted treatment than with the nonaerified, noncompacted treatment.

When added in adequate amounts, either alone or with other amendments, coarse amendments increased infiltration. When various coarse amendments were used at a 40-percent rate, the 1972 infiltration rates were quite low; whereas at a 60-percent rate USS Slag and coarse sand gave greater increases than mortar and concrete sands (Table 4). In general, coarse sand and Turface were the most effective materials for increasing infiltration, followed by the slags and concrete and mortar sands. Perl-Lome was relatively ineffective. Results for coarse sand mixtures show that increasing peat at the expense of sand decreased infiltration in 1972, while no consistent trend existed for increasing peat at the expense of soil (Table 3).

Infiltration rates should be high enough to allow irrigation water to infiltrate without runoff. In other words, the infiltration rate should be equal to or greater than the application rate to obtain efficient water use. High intensity rain storms may exceed infiltration rates, but if the area is properly designed, excess water will be removed by surface drainage.

Infiltration rates on a green will vary, with lower rates occurring in the high traffic areas such as cupping areas and areas used to enter and leave a green. Higher rates will occur at the rear of the green and in non-cupping areas. Ideally, the lowest infiltration rate will be high enough to accommodate the irrigation rate, which usually falls within the range of 0.5 to 1.0 inch per hour.

Variations in infiltration rate also occurred on the small, relatively uniform subplots in this study; thus, some values were above and others below the reported average value. Therefore, there is some risk in designating an average of 0.5

inch per hour as an acceptable rate, and a value of 1.0 inch per hour is recommended as the minimum acceptable value. Rates for compacted, or compacted and aerified plots would be typical of high-traffic areas such as putting greens. Some unacceptable compacted mixtures become acceptable when aerified.

Due to low water-holding capabilities, mixtures with high levels of modification may create establishment and maintenance problems. Based on 1963 infiltration data, drying during establishment and drouth susceptibility of established turf were not problems on mixtures that had infiltration rates less than 12 inches per hour following compaction.

Bulk Density and Porosity

In the field it was found that bulk density, total porosity, and air porosity varied with depth and that the magnitude of variation depended on the mixture. Air porosity was lowest in the 0- to 1-inch depth and increased with depth, indicating that the greatest effect of compaction was near the surface. There was a trend toward highest bulk density and lowest total porosity in the 1- to 2-inch depth, rather than the 0- to 1-inch layer. Closeness to the zone of maximum compaction combined with a greater mineral content may have contributed to this trend. Greater root content and higher organic matter content would result in a lower bulk density, even though air porosity was lowest in the 0- to 1-inch layer. Clogging of pores by roots is another factor to consider when interpreting porosity results. No data were collected on this effect.

Some effects of the amount and kind of amendment on bulk density, total porosity, and air porosity are shown in Tables 5 and 6. Both total porosity and air porosity were decreased by compaction. Air porosity usually decreased to a greater extent, indicating a greater effect on large pores than small pores.

For a given soil, bulk density is a satisfactory indicator of compaction; however, in this study it was a poor indicator because mixtures had different inherent bulk densities due to differences in the densities of amendments and in the ratio of components. Addition of peat at the expense of soil or sand decreased bulk density, and the use of low-density amendments such as slag, Perl-Lome, and Turface decreased bulk density. The internal pore space (within a particle) of these low-density materials also resulted in a higher total porosity than when sand was the sole coarse amendment in a mixture.

Air porosity, a measure of the larger pores, was a good indicator of physical condition, and results compared favorably with those found with infiltration rate. Increasing sand, slag, or Turface content increased air porosity. Only a slight effect was obtained with Perl-Lome. In the laboratory tests, increasing peat at the expense of soil or sand decreased air porosity. The effect of peat on air porosity was not as apparent in the field data. Air porosity tended to increase with Turface substitution for sand and decrease with Perl-Lome subsitution for sand. The effect of USS slag substitution for sand was variable.

Available and Unavailable Water

Amendments differed in their influence on unavailable water (permanent wilting percentage) and available water (Tables 5 and 6). Sand additions decreased both available and unavailable water, with coarse sand having the greatest effect. The slags decreased available water, but did not affect unavailable water. When substituted for coarse sand in the 8-1-1 mixtures, Turface greatly increased unavailable

Table 5. The Effect of Coarse Sand and Peat Contents of Soil Mixtures on Bulk Density, Total Porosity, Air Porosity, Available Water, and Permanent Wilting Percentage

Parts by volume			Field; 0-1 inch depth (Zimmerman, 1973)						Laboratory (Shoop, 1967)			
			Bulk density, g./cc.		Total porosity, %		Air porosity, %		Air porosity, % at 60 cm. tension		Available water at 60 cm. tension, NC	Permanent wilting percentage, NC
Coarse sand	Soil	Peat	NC	C	NC	C	NC	C	NC	C		
											Inches H_2O/ft. of soil	
8	0	2	1.24	1.27	50.7	49.4	29.2	24.4	29.9	17.6	1.0	.4
8	1	1	1.25	1.37	50.6	46.0	22.1	15.2	31.9	21.9	1.2	.4
6	2	2	1.26	1.30	50.1	48.6	16.1	14.6	27.9	13.6	1.8	.6
6	3	1	1.23	1.34	50.4	46.2	21.5	17.5	30.3	17.6	1.7	.5
5	3	2	1.20	1.27	53.2	50.4	20.2	15.5	18.9	1.3	2.5	1.0
5	4	1	1.32	1.33	48.0	48.0	18.8	17.1	25.5	13.5	2.0	.4
4	4	2	1.17	1.29	54.0	49.4	16.2	13.0	25.6	.0	2.4	.7
4	5	1	1.26	1.39	50.8	46.3	16.1	11.7	13.9	.9	3.3	.9
0	8	2	1.20	1.25	53.7	52.0	11.9	10.9	6.5	.0	4.3	1.4

NC - noncompacted
C - compacted

Table 6. The Effect of Various Amendments on Bulk Density, Total Porosity, Air Porosity, Available Water, and Permanent Wilting Percentage of 4-5-1, 6-3-1, and 8-1-1 Mixtures of Amendment, Soil, and Peat

Amendment	Field; 0-1 inch depth (Zimmerman, 1973): Bulk density, g./cc., NC	Bulk density, g./cc., C	Total porosity, %, NC	Total porosity, %, C	Air porosity, %, NC	Air porosity, %, C	Laboratory (Shoop, 1967): Air porosity, % at 60 cm. tension, NC	Air porosity, % at 60 cm. tension, C	Available water at 60 cm. tension, NC	Permanent wilting percentage, NC
									Inches H_2O/ft. of soil	
4-5-1 mixtures										
Coarse sand . . .	1.26	1.39	50.8	46.3	16.1	11.7	13.9	.9	3.3	.9
Mortar sand . . .	1.35	1.43	48.3	45.3	11.9	7.6	21.3	2.5	2.5	.9
Concrete sand . .	1.28	1.35	51.1	48.5	14.6	11.6	18.3	1.7	2.6	1.0
USS slag.	1.10	1.17	57.7	54.2	14.4	10.0	33.8	9.8	2.1	1.1
Perl-Lome	.95	1.06	60.9	57.7	7.9	9.5	16.5	1.9	4.3	1.2
Turface	1.01	1.09	62.1	59.4	16.5	13.1	15.8	3.1	3.1	2.3
6-3-1 mixtures										
Coarse sand . . .	1.24	1.34	50.4	46.2	21.5	17.5	30.3	17.6	1.7	.5
Mortar sand . . .	1.29	1.33	50.6	49.3	17.3	14.8	25.0	13.9	1.4	1.3
Concrete sand . .	1.29	1.40	50.9	46.4	16.7	12.3	23.3	11.0	1.9	.7
USS slag.	1.08	1.12	59.0	57.0	14.8	13.7	38.8	16.5	1.8	1.1
8-1-1 mixtures										
8 coarse sand . .	1.25	1.37	50.6	46.0	22.1	15.2	31.9	21.9	1.2	.4
6 USS slag + 2 coarse sand .	1.08	1.11	57.7	56.2	22.9	18.1	38.7	25.6	1.2	1.3
4 Perl-Lome + 4 coarse sand .	1.03	1.15	59.1	54.2	20.8	11.9	25.4	11.1	2.6	.8
4 Turface + 4 coarse sand .	.96	1.03	64.0	62.0	36.1	29.9	26.6	17.8	1.7	1.8

NC - noncompacted
C - compacted

water, while Perl-Lome substitution doubled both the unavailable and available water. Of the 4-5-1 mixtures, those containing Perl-Lome had more available water than those containing sands, slag, or Turface; and those containing Turface had the most unavailable water, but more available water than those containing mortar sand, concrete sand, or slag.

Turface additions at the expense of soil increased unavailable water and decreased available water, and Perl-Lome additions had little or no effect on both unavailable and available water. These trends are not the same as when these amendments were substituted for sand. Thus, when statements are made concerning the effects of one amendment, it is important to consider which of the other components are also changed.

CONCLUSIONS

Soil modification can be used to obtain mixtures of soil and amendments which retain good soil physical conditions even when severely compacted.

The physical properties of physically modified soils depended on the kind and amount of soil amendments used. Coarse sand and Turface ranked highest in effectiveness for increasing soil permeability of compacted mixtures. They were followed by Wunderley and USS slags, and concrete and mortar sand. Perl-Lome was the least effective material used in this study. At least 50 to 60 percent of coarse amendment was required to modify the Hagerstown silt loam soil effectively. Decreases in water retention were associated with increased levels of modification.

Compaction decreased soil permeability; however, the coarser textured mixtures exhibited greater resistance to compaction than did the finer textured mixtures. Compaction effects were greatest in the surface inch or two of soil. Aerification increased infiltration rates of most mixtures, and appears to be an essential practice with some mixtures to make them acceptable for intensively used turf areas.

This study illustrated the importance of long-term experimentation in the evaluation of soil amendments. Permeability decreased over the years and the magnitude of change was affected by the mixture, as well as by compaction and aerification. With time, physical properties of soils receiving compaction from maintenance operations approached those of the soils more severely compacted with a compaction machine. This result was more apparent in mixtures with low levels of modification. The low level of compaction resulting from maintenance operations was more severe on the finer textured mixtures. The resistance of the coarser mixtures to compaction was seen in wider differences in soil permeability and air porosity between the compaction treatments.

LITERATURE CITED

Alderfer, R.B. 1951. "Compaction of Turf Soils--Some Causes and Effects," USGA J. and Turf Mgt. 4(2):25-28.

Allison, F.E., and M.S. Anderson. 1951. The Use of Sawdust for Mulches and Soil Improvement. USDA Circular No. 891.

Anderson, M.S. 1957. Sawdust and Other Natural Organics for Turf Establishment and Soil Improvement. USDA. ARS 41-18.

Bingaman, D.E., and H. Kohnke. 1970. "Evaluating sands for athletic turf." Agron. Jour. 62:464-467.

Bollen, W.B., and D.W. Glennie. 1961. "Sawdust, Bark, and Other Wood Wastes for Soil Conditioning and Mulching. Forest Products Jour. 11:38-46.

Davis, W.B., J.L. Paul, J.H. Madison, and L.Y. George. 1970. A Guide to Evaluating Sands and Amendments Used for High-Trafficked Turfgrass. Univ. of California Agr. Ext. AXT-n 113.

Howard, H.L. 1959. The Response of Some Putting-Green Soil Mixtures to Compaction. M.S. thesis, Texas A. and M. College.

Kunze, R.J. 1956. The Effects of Compaction of Different Golf Green Soil Mixtures on Plant Growth. M.S. thesis, Texas A. and M. College.

Kunze, R.J., M.H. Ferguson, and J.B. Page. 1957. "The Effects of Compaction on Golf Green Mixtures." U.S. Golf Assoc. Jour. and Turf Management. 10(6):24-27.

Letey, J., W.C. Morgan, S.J. Richards, and N. Valoras. 1966. Physical Soil Amendments, Soil Compaction, Irrigation, and Wetting Agents in Turfgrass Management: III. Effects on Oxygen Diffusion Rate and Root Growth. Agron. Jour. 58:531-535.

Lotspeich, F.B. 1964. "Strength and Bulk Density of Compacted Mixtures of Kaolinite and Glass Beads. Soil Sci. Soc. Amer. Proc. 28:737-740.

Lucas, R.E., P.E. Reike, and R.S. Farnham. 1965. Peats for Soil Improvement and Soil Mixes. Michigan State Univ. Ext. Bul. No. 516.

Lunt, H.A. 1961. Improving Nursery Soil by Addition of Organic Matter. Connecticut Agr. Exp. Sta. Circ. 219. 8 pp.

Ralston, D.S., and W.H. Daniel. 1973. "Effect of Porous Rootzone Materials Underlined With Plastic on the Growth of Creeping Bentgrass (*Agrostis palustris* Huds.)." Agron. Jour. 65:229-232.

Richer, A.C., J.W. White, H.B. Musser, and F.J. Holben. 1949. Comparison of various Organic Materials for Use in Construction and Maintenance of Golf Greens. Pennsylvania Agr. Exp. Sta. Progress Report No. 16.

Shoop, G.J. 1967. The Effects of Various Coarse-Textured Materials and Peat on the Physical Properties of Hagerstown Soil for Turfgrass Production. Ph.D. dissertation, Pennsylvania State Univ.

Smalley, R.R., W.L. Pritchett, and L.C. Hammond. 1962. "Effects of Four Amendments on Soil Physical Properties and on Yield and Quality of Putting Greens." Agron. Jour. 54:393-395.

Sprague, H.B., and J.F. Marrero. 1931. "The Effect of Various Sources of Organic Matter on the Properties of Soils as Determined by Physical Measurements and Plant Growth." Soil Sci. 32:35-47.

Sprague, H.B., and J.F. Marrero. 1932. "Further Studies on the Value of Various Types of Organic Matter for Improving the Physical Condition of Soils for Plant Growth." Soil Sci. 34:197-208.

Swartz, W.E., and L.T. Kardos. 1963. "Effects of Compaction on Physical Properties of Sand-Soil-Peat Mixtures at Various Moisture Contents." Agron. Jour. 55:7-10.

Valoras, N., W.C. Morgan, and J. Letey. 1966. "Physical Soil Amendments, Soil Compaction, Irrigation, and Wetting Agents in Turfgrass Management: II. Effects on Top Growth, Salinity, and Minerals in the Tissue." Agron. Jour. 58:528-531.

Waddington, D.V., W.C. Lincoln, Jr., and J. Troll. 1967. "Effect of Sawdust on the Germination and Seedling Growth of Several Turfgrasses." Agron Jour. 59:137-139.

White, A.W., Jr., J.E. Giddens, and H.D. Morris. 1959. "The Effect of Sawdust on Crop Growth and Physical and Biological Properties of Cecil Soil." Soil Sci. Soc. Amer. Proc. 23:365-368.

Zimmerman, T.L. 1969. Infiltration Rates and Fertility Levels of Physically Amended Hagerstown Soil. M.S. thesis. Pennsylvania State Univ.

Zimmerman, T.L. 1973. The Effect of Amendment, Compaction, Soil Depth, and Time on Various Physical Properties of Physically Modified Hagerstown Soil. Ph.D. dissertation. Pennsylvania State Univ.

SOIL CULTIVATION UNDER TURF

A.J.Turgeon

Soil cultivation under turf is any measure designed to alleviate soil compaction or the effects of soil compaction without destroying the turfgrass community. Cultivation is especially important on turfs growing in fine-textured soils and subjected to intense traffic. Examples of such turfs include: golf course greens, tees and fairways, football and soccer fields, and some lawn turfs.

SOIL COMPACTION

Soil aggregation and permeability are generally improved over time where a grass community is maintained. However, this natural improvement of soil conditions is reduced, and may be more than offset, by traffic. The result is compacted soils in which soil particles are packed closely together and soil porosity is characterized by a minimum or absence of large pore spaces. When a soil is compacted, reductions occur in aeration, water infiltration and percolation, root growth, and the activity of many beneficial soil organisms, while bulk density and moisture retention are increased.

CULTIVATION

Specific benefits of soil cultivation include:

Improved water infiltration;
Enhanced penetration of fertilizer and lime into the soil;
Improved wetting of dry soils and faster drying of wet soils;
Improved soil aeration;
Allows toxic gases to escape from the soil;
Partial destruction of undesirable soil layers and thatch;
Facilitates replacement of poor soil with a more suitable growing medium through topdressing;
Deeper, more extensive rooting of the turf;
Improved shoot growth and density.

Some disadvantages of soil cultivation include:

Creation of sites for weed and insect invasion;
Increased compaction of soil adjacent to the penetrating spoon, tine, or knife;
Increased potential for desiccation of turfgrass plants adjacent to sites of penetration (i.e., hole, slit, groove, etc.);
Destruction of the continuous "chemical blanket" provided by preemergence herbicides and other pesticides;
Disruption of surface smoothness and playability of the turf.

TYPES OF CULTIVATION

The specific effects of cultivation depend, in part, upon the particular cultivation technique employed. Severe cultivation may be feasible and highly beneficial if conducted during mild weather and when a period of favorable growing conditions

A.J. Turgeon is assistant professor, Department of Horticulture, University of Illinois.

follows. However, performing an intensive cultivation during periods of high climatic stress may result in severe and prolonged injury to the turf.

The earliest type of turfgrass cultivation is referred to as forking. This involved the insertion of a fork or similar solid-tined device into the turf. The benefits of this type of cultivation are partially offset by the soil-compacting effect of the procedure. The soil displaced by the solid tine is pressed into the adjacent space resulting in some compaction of the soil surrounding the channel of insertion. The degree of compaction is related to the diameter of the solid tine, and is further increased if the tines are also moved laterally in addition to the vertical insertion and removal operations. Forking is occasionally practiced with thin-tined forks for correcting localized dry spots on greens and other turfs.

Contemporary soil cultivation techniques generally employ hollow tines or spoons for extracting cores of soil from the turf and depositing them on the surface. The cores are subsequently removed, or pulverized and dragged into the turf as a topdressing. Coring machines vary in their method of soil extraction. One type employs tines, mounted on a vertical-motion shaft, that remove soil cores without much disturbance of the adjacent soil. This is widely used on greens as it does not seriously reduce the playability of the turf. A second type has tines or spoons mounted on circular plates that rotate about a horizontal shaft. With this type, both vertical and lateral disturbance of the soil occurs as the tines move in an arc under the turf during rotation of the circular plates. The soil should be moist, but not wet, during coring to facilitate maximum penetration of the tines.

In preliminary tests at the University of Illinois, penetrometer readings of the soil profile under a putting green turf consistently revealed a zone of compacted soil located approximately 3.5 inches below the surface. This corresponded to the extent of penetration of the hollow tines from a coring machine. As coring was practiced once or twice each year for a period of at least eight years, it was concluded that coring may actually compact the soil at the maximum penetration depth of the tines. If this does prove to be true, then it may be desirable to vary the coring depth or to perform some complementary operation designed to break up the subsurface zone of compaction. Otherwise, less extensive rooting and reduced turfgrass quality during the summer may result.

Spiking and slicing are alternatives to coring. These involve cutting slits into the turf with knives mounted on circular plates that rotate about a horizontal shaft. Spiking causes shallow perforations and is frequently practiced on greens during early to mid-summer when coring may not be practical. Slicing involves deeper cutting with V-shaped knives that penetrate the soil to a depth of three to four inches. This is performed on greens and higher cut turfs when the more severe coring operation is considered too injurious, or turfgrass recovery is slow. The potential benefits from spiking and slicing are less than those achieved with coring; however, these less severe operations can be performed frequently without seriously detracting from the appearance or utility of a turf. Consequently, they can be considered auxiliary practices to a core cultivation program that is restricted to periods in which climatic conditions favor a maximum rate of turfgrass recovery.

Grooving is a less popular type of cultivation employing the conventional "vertical mower" to create grooves down to four inches in the soil. The potential injury from this operation is related to the amount of thatch present and the root depth of the turf. Deep vertical mowing is generally confined to periods of mild weather when favorable growing conditions are likely to persist. On shallow-rooted, thatchy turfs, it can be a very injurious operation requiring a long period of recovery and perhaps some replanting.

None of the previously discussed types of soil cultivation results directly in a general improvement in soil aeration. Instead, localized improvements in the growing conditions for turfgrass plants occur as evidenced by the mass of new roots in holes, slits, or grooves resulting from cultivation. This is frequently observed on greens or other closely clipped turfs as a regular pattern of brighter green, more vigorous clusters of turfgrass plants distributed throughout an otherwise unthrifty turf. With repeated cultivations, localized improvements may approach a generalized improvement of the turf and its underlying soil.

A new concept of soil cultivation emerged with the development of the subsurface cultivator.1/ This machine employs vertical knives, with enlarged ends, that penetrate the soil to a depth of five or seven inches. The knives vibrate fore and aft while being pulled forward in the soil. The presumed effects of this operation are lifting and shattering of the compacted soil mass, with an immediate and dramatic improvement in soil aeration. Initial results from tests at the University of Illinois suggest that aeration of the soil between lines of penetration, may not be affected appreciably unless the soil is quite dry. Furthermore, the smoothness of a putting green surface may be seriously disrupted necessitating rolling and/or topdressing to restore the turf to a playable condition. Also, desiccation along lines of penetration is a serious concern unless the turf is immediately topdressed and irrigated after cultivation. One probable benefit of subsurface cultivation is the disruption of subsurface zones of compacted soil resulting from repeated core cultivations. Continued observation and experimentation will eventually clarify the specific benefits and limitations of subsurface cultivation. However, it is reasonable to conclude at this time that coring and subsurface cultivation can be complementary operations that constitute important components of a cultivation program for improving heavily trafficked turfs.

1/ Commercially available as the Sod Master Sub-Air from the Jacobsen Manufacturing Company.

SOIL — A LIVING ENVIRONMENT

F.J.Stevenson

The soil has traditionally been thought of as a medium for the growth of higher plants, but it is far more than that. It is a body which is inhabited by innumerable living organisms, most of which are microscopic and can only be seen under high-power magnification. This "living phase" is the peculiar characteristic which distinguishes soil from weathered rock, and it is the component in soil of greatest importance from the standpoint of productivity.

THE SOIL MICROFLORA

The microscopic plant world in soil is represented by the bacteria, actinomycetes, fungi, and algae. Numbers of these organisms in soil are astronomical and, for this reason, populations are usually expressed in terms of 1 gram (g.) of soil (0.035 ounce, or less than 1/500 of a pound). Typical distribution patterns for a productive agricultural soil are given below:

Organisms	*Numbers per gram of soil*
Bacteria	
Plate count method	2,000,000 - 15,000,000
Microscopic method	100,000,000 - 2,500,000,000
Actinomycetes	100,000 - 100,000,000
Fungi	20,000 - 1,000,000
Algae	100 - 50,000

Total numbers of microorganisms fluctuate widely, depending on soil type and such environmental factors as moisture, temperature, pH, aeration, and supply of readily decomposable organic matter.

Bacteria are the smallest and most divergent group of microorganisms in soil. Their numbers range from as few as 2 million per gram in a sandy soil to several billions in a loamy soil in which plant residues are undergoing active decay. Despite their high numbers, it is estimated that the bacteria occupy no more than about 1 percent of the theoretical living space.

The actinomycetes, sometimes referred to as the "ray fungi," are microscopic organisms which resemble the bacteria except that they form long, threadlike, branched filaments. They are generally one-tenth to one-fifth as numerous as the bacteria. Numbers are relatively low in cold, wet soils, particularly those that are acidic. In contrast, relatively high numbers are found in warm, neutral to slightly alkaline soils. The actinomycetes have been reported to constitute as much as 70 percent of the total microorganisms in desert soils. A unique feature

F.J. Stevenson is Professor, Department of Agronomy, University of Illinois.

of the actinomycetes is their ability to degrade resistant organic substrates that are not easily attacked by bacteria. The rich, earthy smell of newly plowed land is normally attributed to the actinomycetes.

Numerically, the fungi are fewer in soil than either the bacteria or actinomycetes. Unlike actinomycetes, the fungi are sufficiently large that details of structure can be seen, if not by eye, by use of a magnifying glass. However, fungal filaments in mineral soils are commonly not easily seen. In the organic layers of forest soils, the fungal network dominates the microbial protoplasm, and masses of filaments can be seen holding partially decomposed plant parts together.

A few special items regarding fungi in soil are given below:

1. Fungi are more acid tolerant than bacteria and actinomycetes. Thus, the relative amount of the biomass present as fungal tissue is highest in acidic soils. Fungi are often the dominant organism in the acid humus layer of forest soils.

2. Most soil fungi are saprophytes and are thus of importance in the decay of organic residues. A group of fungi called the Basidomycetes are especially important in the degradation of lignin.

3. Practically all crop plants, as well as many trees and shrubs, have fungi which form a beneficial association with plant roots. They are called the "mycorrhizal fungi."

4. Fungi are responsible for the mysterious *fairy rings* which occur in lawns, golf courses, and grassland soils. Several types are known, including those where the grass is killed or damaged, those where the grass is stimulated, and those showing no visible effect but which produce fructifications in the ring.

Algae are also universally distributed in soil, but in relatively few members. Being photosynthetic, they are dependent on sunlight and are thus concentrated in the surface layer. Their presence in the lower horizons of the soil is attributed to vertical transport by percolating rain and through earthworm activity. It is unlikely that the algae contribute appreciably to the fertility of grassland soils.

THE RHIZOPHERE

Erudates from roots and sloughed-off root cells provide excellent substrates for bacteria, actinomycetes, and fungi. Thus, microbial numbers in soil near plant roots are often many times higher than in soil away from the root. This zone of high microbial activity is called the *"rhizosphere."*

Recent research indicates that the rhizosphere may be the site for significant fixation of molecular nitrogen by free-living nitrogen-fixing bacteria (*Azotobactor* and *Clostridium*).

FAUNAL COMMUNITIES

A vast number of small invertebrate animals also live within the first few inches below the soil surface. For example, the soil under an area of one square yard may contain as many as 1,000,000 arthropods alone. Populations of earthworms up to 500 per square yard are common in productive agricultural soils. The biomass of soil faunal organisms under a square yard of soil may amount to as much as 500 grams or more than one pound. The most important soil animals are the earthworms and related enchytraeid worms along with mites, woodlice, millipedes, springtails, protozoa, nematodes, termites, and others. Although the greatest number of soil organisms are found within three inches of the surface, many spend much of their lives below 12 inches. The pattern of faunal organisms in the soil varies from one species to another. Typical populations are listed below:

Earthworms:	To 500 per square yard.
Enchytraeid worms:	From 10,000 to 290,000 per square yard.
Nematodes:	About 1,500,000 per square yard, but higher numbers have been reported.
Protozoa:	Populations of 450,000 to 45,000,000 per pound of *wet* soil are common, but considerably higher counts have been recorded.
Others (woodlice, mites, etc.):	Variable but values exceeding 1,000,000 per square yard are not uncommon.

The significance of earthworms and other faunal organisms in soil arises from their ability to move soil, construct channels, and incorporate litter within the mineral layer of the soil. A particularly important function of soil animals is that they bring about the disintegration of plant debris and incorporate the end products into the soil, thereby aiding in the circulation of plant nutrients. Earthworms in particular have a desirable effect upon soil structure. In this way, soil aeration is improved, penetration of plant roots and rain water is facilitated, and the soil is better able to resist erosion.

Evidence for the importance of faunal organisms in the decomposition of plant litter comes from the following:

1. Formation of mull humus under decidious or mixed forests that are reasonably supplied with calcium. The net result is that the organic material becomes mixed with the mineral layer of the soil.

2. Conversion of mor humus to mull humus through the introduction of earthworms.

3. Formation of surface mats in copper-sprayed orchards, due apparently to poisoning of earthworms.

4. Formation of surface mats (thatch) in turf when soils become acidic or faunal organisms are poisoned by sprays. Repeated applications of chlordane and dieldrin appear to be particularly deleterious to earthworms and other faunal organisms, with subsequent build-up of thatch.

EFFECT OF PESTICIDES ON SOIL ORGANISMS

Numerous studies suggest that herbicides and insecticides, when used at recommended rates, do not seriously affect the activities of bacteria, actinomycetes, and fungi. Both increases and decreases in microbial numbers have been observed in laboratory studies, but the changes have been slight with little evidence of permanent damage to the soil. Extent of kill depends upon a variety of factors, including type of chemical, dosage rate, soil type, temperature, pH, and method of application. Bacteria involved in nitrogen transformations, such as the nitrifiers, seem to be more seriously affected by pesticides than other microorganisms.

The response of the soil microflora to any given pesticide can be divided into approximately four phases, as follows:

<u>Initial phase</u>: This is the period immediately following treatment, during which time numbers of bacteria, actinomycetes, and fungi can be drastically reduced, but not necessarily in the same proportion.

<u>Secondary phase</u>: A period, sometimes extending for several months, in which a variety of microbial types multiply and reach numbers in excess of the original numbers. The magnitude of the increase depends upon the type of soil, herbicide, and application rate.

<u>Adjusting phase</u>: Numbers of microorganisms decline and approach the original "equilibrium" level. Rate of change will vary with floral type.

<u>Final phase</u>: A climax community characteristic of the original soil is achieved.

Soil faunal organisms are generally more sensitive to pesticides than bacteria, actinomycetes, or fungi. The former are particularly vulnerable to insecticides, which are selected for their toxicity to arthropods. A point worthy of note is that insecticides are often applied to soil at appreciably higher rates than the herbicides.

Chemicals which seriously reduce earthworm populations are of special concern. As noted in the previous section, the repeated application of some insecticides, such as chloradane, dieldrin, and heptachlor, may adversely affect earthworm activity in turf, with build-up of thatch. The copper fungicides are particularly toxic to earthworms.

A serious problem arises when natural predators of soil pests are affected by pesticides. Alteration in the delicate balance between the various species of predators, parasites, and their hosts can upset the natural equilibrium of the animal community. It is well known that the elimination of one type of soil animal can seriously affect numbers of other species and numerous examples can be cited where a second pest problem was artificially created by application of a chemical which modified the faunal population as a result of activity against a non-target species.

Other items regarding the effect of pesticides on soil faunal organisms are as follows:

1. Several factors determine how severely soil faunal organisms are affected by pesticides. Some pesticides are more toxic than others.
2. The longer the pesticide remains in the soil, the greater will be the number of soil animals that will consume a lethal dose.

3. The more active the soil animal, the greater the probability that it will come in contact with the pesticide. Saprophagous species are usually less active than predatory ones; thus, the latter are usually more seriously affected. Surface dwellers are affected to a greater extent than animals living deeper in the soil.

4. Transport of pesticides through the food chain can be initiated by soil organisms. For example, earthworms can accumulate lipid-type compounds in their fatty tissues, hence to birds, and subsequently to other higher forms of animal life.

SOIL-BORNE DISEASES OF TURF

W.A.Meyer

There is no doubt that turf diseases caused by fungal parasites are important limiting factors in the production and maintenance of good quality turf. The incidence and severity of these diseases can vary greatly from year to year and location to location with age of plantings having little effect in many cases *(8)*.

In order to understand the effect of the soil environment on the occurrence of turfgrass diseases, we must consider its effect on three separate biological groups in the soil and how they interact. The three groups are: the fungal parasites; the organisms that are either competitive, antagonistic, or complimentary to the activities of the fungal parasite; and the host plant.

GROUP I: FUNGAL PARASITES

The fungi which make up the first group can be classified as obligate parasites or facultative parasites. Obligate parasites live only on the living parts of plants and therefore have evolved life cycles that tend to isolate them from competition *(8)*. The fungus *Ustilago striiformis*, which causes stripe smut on several cool season grasses, is an example of an obligate parasite. This fungus survives as mycelium in the crowns of infected plants or as spores which remain inactive in the soil or thatch until they germinate to cause new infections *(2,11)*.

Fungi which have the ability to live on both live and dead tissues are called facultative parasites. Most of the fungal parasites of turf grasses would fall into this classification. The ability of different facultative parasites to colonize dead tissues as saprophytes in competition with other microorganisms varies greatly *(8,9)*. The turfgrass pathogens *Fusarium roseum* causing Fusarium blight *(17)*, *Rhizoctonia solani* causing brown patch *(1)*, and *Pythium ultimum* causing Pythium blight *(9)* are examples of fungi which are vigorous competitive saprophytes of dead tissues. *Helminthosporium sativum*, causing leaf spot on many cool-season grasses, is an example of a facultative parasite having weak competitive saprophytic ability (CSA) *(3)*.

The fungi which have good CSA can survive in the soil both in the form of active mycelium in plant debris or as inactive spores or resting bodies in the thatch or soil. Facultative parasites having low CSA would survive periods unfavorable for active disease development, mostly as dormant propagules. Since inoculum concentration of a specific pathogen is an important factor determining the amount of disease, it is important to understand the survival and growth potential for each pathogen.

GROUP II: ANTAGONISTIC, COMPETITIVE, AND COMPLIMENTARY ORGANISMS

It is a well-known fact that in every gram of soil there are millions of microscopic organisms present, including bacteria, actinomycetes, fungi, algae, nematodes, and

W.A. Meyer is director of research and plant pathologist, Warren's Turf Nursery, Palos Park, Illinois.

protozoa. The microbial activity in the thatch of turfgrasses is very high because of the high organic matter content. In studies on the fungal ecology of creeping bentgrass turf, over 28 genera of fungi were found to be prevalent in thatch and upper soil layers, treated or untreated with fungicides *(14)*. Only a small percentage of the fungi isolated were known pathogens of creeping bentgrass. Many of the others isolated are known to be antagonistic or competitive with the facultative parasites which attack creeping bentgrass. Inoculations with fungal pathogens on plants grown in sterile soil cause more damage than when plants are grown in normal field soil *(7,8)*. This suggests that saprophytic microorganisms, such as bacteria and fungi, may play a role in the suppression of facultative fungal parasites. Blair *(1)* has shown that the parasitic activities of *R. solani* can be suppressed by saprophytic microorganisms.

Nematodes have been shown to be pathogenic to cool-season grasses *(12,18)*. They may also increase the severity of diseases caused by fungal parasites by damaging root systems which would then be more susceptible to attack *(19)*.

GROUP III: HOST PLANTS

Cool-season grasses have a temperature optimum for growth of 65 to 70° F. When grasses such as Kentucky bluegrass and creeping bentgrass are exposed for long periods of time to temperatures much lower or higher than the optimum temperatures, their growth is retarded, and these plants are then more subject to attack by fungal parasites.

Other factors such as variety, light intensity, plant age, and cultural practices can have a drastic influence on host susceptibility.

SPECIFIC DISEASES RESULTING FROM THE INTERACTION OF THE THREE BIOLOGICAL GROUPS

Helminthosporium sativum is a major pathogen of Kentucky bluegrass and creeping bentgrass in many areas of the U.S., especially in the summer months *(2)*. This fungus causes some leaf spotting at 77° F. and extensive necrosis on Kentucky bluegrass at temperatures above 86° F. *(10)*. The growth and development of this fungus is favored at higher temperatures. The growth of most cool-season grasses such as bluegrass and bentgrasses is not favored by high temperatures of 86° F. or above. This may explain why the serious disease caused by *H. sativum* occurs at the higher temperatures.

Recently some excellent evidence was reported which described a relationship between *H. sativum* and other saprophytic organisms in the soil. Colbaugh and Endo *(4)* found that moist thatch does not allow spores of *H. sativum* to germinate and thus infect a plant. If the thatch layer is dried the spores will germinate, but seven hours after rewetting the dried thatch, its inhibitory properties are restored. Drying and moistening also resulted in an increase in nutrients available for the growth of the pathogen. Bacterial isolates from the thatch were isolated and found to give off volatile inhibitors to *H. sativum* germination. Since bacteria require a lot of moisture for growth, the drying of thatch greatly reduces their activities and favors the pathogen upon rewetting. They were also able to correlate the initiation of *H. sativum* epidemics in the field with a previous drouth stress and then moistening of an area. This is the first good evidence to show that a factor such as drouth stress could be a trigger to free facultative parasites from the restraining influence of the thatch microflora.

Leaf spot and crown rot by *Helminthsporium vagans* on Kentucky bluegrass are usually most prevalent in the cool months of late fall or spring *(6,10)*. It is most serious with extended periods of cloudy, wet weather. Possibly the cool temperatures (40 to 50° F.) which favor the sporulation and infection by *H. vagans* have a negative effect on the many bacteria in the soil which are known to favor high temperatures.

Lukens *(13)* has also reported that shading (such as cloudy weather) can increase the amount of disease caused by *H. vagans*.

The Kentucky bluegrass varieties Merion, Pennstar, A-20, Anheuser Dwarf, and Nugget are some varieties which have a high degree of resistance to both of the previously mentioned leaf spots *(10,16)*. Newport, Delta, Park, and Common are varieties very susceptible to leaf spot. It should be noted that at times even the variety Merion can be severely damaged when ideal disease conditions exist. A good example would be the severe damage caused by *H. vagans* in the spring of 1973 on Merion in southeastern New York during an extended period of cloudy wet weather *(16)*.

Fusarium blight caused by *Fusarium roseum* and *Fusarium tricinctum* is a serious disease on most cool-season grasses, especially Kentucky bluegrass and creeping bentgrass *(5)*. Most severe disease outbreaks occur when high temperatures are associated with some degree of drouth stress and high nitrogen fertilization. Most of the isolates of these two species are favored by high temperatures. Most of the cool-season grasses are not favored by high temperatures, even though some varieties may have better high-temperature tolerance than others. Whether drouth stress is having a restraining influence on other competitive organisms or whether it is adversely affecting the physiology of the host is still not known.

It is known that these two *Fusarium* pathogens have good competitive saprophytic ability and that high inoculum concentrations are required to produce infections. The high inoculum concentrations are important because these fungi would be classified as weak pathogens. When mycelial pieces are placed into wounds in the crown area of Kentucky bluegrass tillers, complete death of susceptible varieties occurs in 7 to 10 days *(15)*. This high concentration of inoculum in the crown area of the more resistant varieties resulted in small spots on the emerging leaves but very little crown rot or death as seen with the susceptible varieties. Possibly the more resistant varieties have the ability to outgrow infections at the high temperatures.

Recently the role of nematodes in the development of *Fusarium* blight was described *(19)*. These studies suggest an interaction between the fungus *Fusarium roseum* and the stunt nematode *Tylenchorhynchus dubius* in development of symptoms associated with *Fusarium* blight. Merion Kentucky bluegrass plants growing in blight areas were found to have poorly developed root systems and high populations of *T. dubius* in the root regions.

In greenhouse studies the nematode was found to be the dominant pathogen in this relationship. In the original description of *Fusarium* blight by Couch and Bedford *(5)*, high nematode populations were found to be associated with this disease in some cases but not consistently. Pathogenic nematodes in moderate to high populations were also found to be associated with *Fusarium*-blighted lawns in the Chicago area, but again this relationship was not found in all diseased lawns. It is also interesting to note that the nematode *T. dubius* described in the Michigan studies has not been isolated from blighted lawns in Illinois so far *(16)*.

It is reasonable to assume that damage done to the root systems of turfgrass plants by any of the pathogenic nematodes could influence the incidence and severity of *Fusarium* blight. Shallow root systems result in stunting of top growth and increased tendency for the occurrence of drouth stress.

The previously discussed diseases are good examples of the complex interactions of the three biological groups which can occur in the soil environment. In an effort to understand the effect of the soil environment on the occurrence of turfgrass diseases, we must always consider its effect on the three separate biological groups.

By understanding how the biological groups interact, unique and effective disease controls can be found. Since bacterial activity of *Helminthosporium sativum*, it is suggested that the thatch layer be maintained in a moistened condition *(4)*. With the discovery that the nematode *Tylenchorhynchus dubius* can play a dominant role in the development of *Fusarium* blight, it was suggested that nematicides be used to control this disease *(19)*. These are both excellent examples of why a thorogh understanding of the interactions of biological groups is so important.

LITERATURE CITED

1. Blair, I. D. 1943. Behavior of the fungus *Rhizoctonia solani* Kiihn in the soil. Ann. Appl. Biol. 30:118-127.

2. Britton, M. P. 1969. Turfgrass diseases. In "Turfgrass Science" (A. A. Hanson and F. V. Juska, eds.), pp. 288-335. American Society Agronomy, Madison, Wisconsin.

3. Butler, F. C. 1953. Saprophytic behavior of some cereal root-rot fungi. I. Saprophytic colonization of wheat straw. Ann. Appl. Biol. 40:284-297.

4. Colbaugh, P. F., and R. M. Endo. 1972. Drouth stress as a factor stimulating the saprophytic activity of *Helminthosporium sativum* on bluegrass debris. Phytopathology 62:751 (Abstr.).

5. Couch, H. B., and E. R. Bedford. 1966 *Fusarium* blight of turfgrasses. Phytopathology 56:781-786.

6. Couch, H. B., and H. Cole, Jr. 1957. Chemical control of melting out of Kentucky bluegrass. Plant Dis. Reptr. 41:205-208.

7. Endo, R. M. 1961. Turfgrass diseases in southern California. Plant Dis. Reptr. 45:869-873

8. Endo, R. M. 1972. The turfgrass community as an enviornment for the development of facultative fungal parasites. In "The Biology and Utilization of Grasses" (V. B. Younger and C. M. McKell, eds.) pp. 171-202. Academic Press, New York and London.

9. Garret, S. D. 1956. "Biology of Root-Infecting Fungi," Cambridge Univ. Press, London and New York.

10. Halisky, P. M., C. R. Funk, and R. E. Engel. 1966. Melting out of Kentucky bluegrass varieties by *Helminthosporium vagans* as influenced by turf management practices. Plant Dis. Reptr. 50:703-706.

11. Hodges, C. F. 1967. Etiology of stripe smut, *Ustilago striiformis* (West.) Niessl, on Merion bluegrass, *Poa pratensis*. Ph.D. thesis, University of Illinois.

12. Laughlin, C. W., and J.M. Vargas, Jr. 1972. Pathogenic of *Tylenchorhynchus dubius* on selected turfgrass. Journal of Nematology 4:277-280.

13. Lukens, R. J. 1970, Melting out of Kentucky bluegrass, a low-sugar disease. Phytopathology 60:1276-1278.

14. Meyer, W. A., M. P. Britton, L. E. Gray, and J. B. Sinclair. 1971. Fungicide effects on fungal ecology in creeping bentgrass turf. Mycopathologia and Mycologia Applicata 43:309-315.

15. Meyer, W. A. 1973. Tiller-puncture technique to artificially screen Kentucky bluegrass cultivars to *Fusarium* blight. Proceedings of the 2nd International Congress of Plant Pathology, 1075.

16. Meyer, W. A. 1973. Unpublished studies.

17. Sadasivan, T. S. 1939. Succession of fungi decomposing wheat straw in different soils, with special reference to *Fusarium culmorum*. Appl. Biol. 26:497-508.

18. Sikora, R. A., D. P. Taylor, R. M. Malek, and D. I. Edwards. 1972. Interaction of *Meloidogyne nassi*, *Pratylenchus penetrans*, and *Tylenchoryhynchus agri* on creeping bentgrass. Journal of Nematology 4:162-165.

19. Vargas, J. M., Jr. and C. W. Laughlin. 1972. The role of *Tylenchorynchus dubius* in the development of *Fusarium* blight of Merion Kentucky bluegrass. Phytopathology 62:1311-1314.

20. Weihing, J. L., S. G. Jensen, and R. I. Hamilton. 1957. *Helminthosporium sativum*, a destruction pathogen of bluegrass. Phytopathology 47:744-746.

SOIL FERTILITY CONSIDERATIONS

T.D.Hughes

Scientific investigation of nutritional requirements for plants began about 100 years ago. Prior to that time, the lack of laboratory techniques and knowledge of chemistry had caused many experimenters to draw erroneous conclusions and the subject of plant nutrition was extremely confusing. Currently, there are many unanswered questions, particularly with respect to the details of specific functions for all of the elements which have been shown to be essential. Much of the information about essentiality of various elements for turfgrass species has been borrowed. That is, it is information that is thought to be applicable to most plant species and it has not been obtained by using turfgrass species as test plants. It seems that turfgrasses are generally not as sensitive to minute amounts of nutrient elements and thus are not usually used in basic or pioneering studies of plant nutrition. This fact has some rather far-reaching implications in the practical turfgrass management situation.

16 ESSENTIAL ELEMENTS

There are 16 elements which are essential for turfgrasses and these are the same 16 elements that are essential for plants in general. In the absence of any of these elements the plant cannot complete its life cycle and no other element can completely substitute for or replace the missing element.

Three essential elements--carbon, hydrogen, and oxygen--are present in turfgrasses and other plants in extremely large amounts. These three elements are seldom a problem in turfgrass management because they are obtained primarily from the air and thus deficiencies do not occur. Also, there is no practical way to alter the amounts present.

The remaining 13 essential elements come primarily from the soil, and turfgrass managers have much more opportunity to alter the amounts that are available. Of particular interest and concern are the three major elements--nitrogen, phosphorus, and potassium. These elements are called major elements because larger amounts of them are required than any of the others which are obtained from the soil. They are of major importance in turfgrass management because responses to fertilization are usually fairly dramatic.

The other essential elements--calcium, magnesium, sulfur, iron, manganese, copper, zinc, boron, molybdenum, and chlorine--are required in extremely small quantities and, with the exception of iron, are seldom of any consequence to turfgrass managers. Most turfgrass species tolerate sufficiently broad ranges of amounts of these elements for there to be no problem, and fertilization is seldom necessary.

T.D. Hughes is assistant professor, Department of Horticulture, University of Illinois.

THE MOST IMPORTANT ELEMENTS

Nitrogen is probably the most important of all essential elements in turfgrass management. Nitrogen is an indispensable component of many compounds within the turfgrass plant and is present in turfgrasses in relatively large quantities. Nitrogen tends to aid in maintaining vegetative growth and prevents dormancy in turfgrasses. Thus, turfgrasses are fertilized with relatively large amounts of nitrogen, and an available supply of nitrogen must be maintained over relatively long growth periods in comparison with many other crop plants. Problems with nitrogen deficiency are more likely to occur in sands of low organic matter, and under high rainfall or irrigated conditions. It is interesting to note that turfgrass management is one of the few fields of agricultural production where extensive use of slow-release and slowly soluble nitrogen fertilizer materials has been justifiable.

Phosphorus is a component of many essential compounds in the turfgrass plant, but the chemistry of phosphorus in the soil is distinctly different from nitrogen, and severe deficiencies are much less common. Inadequate phosphorus is much more likely to be a problem on seedling stands of turfgrasses or in any situation where there is poor root development. Mature stands of turfgrasses that are adequately supplied with other nutrient elements seldom show phosphorus deficiency. Cold temperatures and extremely high soil pH are two factors which may cause a problem. Problems may also be caused by use of extremely large amounts of arsenic due to an inability of the plant to distinguish between arsenic and phosphorus. When arsenic replaces phosphorus in plant compounds which are essential, these essential compounds are unable to function normally.

Potassium is definitely essential but, ironic as it may seem, its specific role in plant metabolism is not understood. It is not a component of essential compounds in the plant, but is present in all plant parts in relatively large quantities. Deficiencies are most likely in extremely sandy soils under high rainfall or irrigated conditions. Mature turfgrass stands seldom are deficient in potassium. However, it has been shown to influence disease resistance and winter hardiness of turfgrasses as well as of other plant species. In situations where clippings are removed from turfgrass areas, fertilization with potassium is more important than phosphorus fertilization because clipping removal results in removal of larger amounts of potassium.

IRON DEFICIENCIES

Iron is the only minor element that is commonly a problem on turfgrass areas. Iron is important in turfgrass management because if there is not enough iron, plant color is greatly affected. Iron is essential for chlorophyll formation and nitrate reduction. Iron chlorosis can be induced by excesses of most of the heavy metals. High soil phosphorus can aggravate problems with iron, but probably the most common cause of iron chlorosis is high soil pH. Thus, iron availability is closely related to the amounts of several other elements, and iron chlorosis is usually caused by improper balances or relationships between other elements rather than the absence or lack of iron. Iron is nearly always present in large quantities when chlorosis occurs and, therefore, soil applications seldom correct the problem. Foliar sprays of iron chelate or iron sulfate however, usually correct the chlorosis.

Other minor element deficiencies seldom occur and are very difficult to diagnose visually. On the other hand, toxicities can develop as a result of fertilizer applications of minor elements and if this does occur the situation is usually very difficult to correct. It is extremely important to remember that a suspected minor element deficiency should be positively identified prior to application of any minor element fertilizers and that guesswork in minor element fertilization can lead to disaster.

1973 MEMBERSHIP ILLINOIS TURFGRASS FOUNDATION

A & J Landscaping, Inc.
American Sod Corp.
USS Agri-Chemicals
Arlington Country Club
The Athletic Assn. of the U of I
Aurora Public School Dist. #129
Joe D. Balsley
Barrington Hills Country Club
Beverly Country Club
Biltmore Country Club
Bloomington Country Club
Bob O'Link Golf Club
Briarwood Country Club
Bryant Nurseries
Bryn Mawr Country Club
Burdett's Inc.
Caterpillar Tractor Co.
Casey's Garden Shop
Calumet Country Club
Cedar Park Cemetery Assn.
Lake of the Wood Golf Course
Chanute AFB Golf Course
D.R. Church Landscaping
Highland Park Golf Club
City of Lake Forest
City of Springfield, Il.
W.A. Cleary, Corp.
Art Clesen Wholesale Fertilizer
Coal Creek Country Club
Country Club of Decatur
Country Club of Peoria
Countryside Golf Club
Paul R. Craig
Crestwicke Country Club
Crystal Lake Country Club
Cushman Sales & Service of Ill.
Otto Damgaard Landscape Contractor
Danville Country Club
Clarence Davids & Sons
George A. Davis Inc.
Dayton Development Corp.
Decatur Park District
Dodson Seed Store
Des Plaines Park District
Drake-Scruggs Equipment Co.
E.I. duPont de Nemours & Co.
Dundee Township Park District
Easy Aces Golf Club
Edgewood Valley Country Club
Elanco Products Co.
El Paso Golf Club
Evanston Landscaping Co.
Oliver G. Miles
Franklin Park Gardens
Freeport Park District
Geneva Golf Club
Glencoe Golf Club
Glen Flora Country Club
Harold W. Glissmann Inc.
Green Garden Landscaping Co.
Green View Nursery Inc.
Grieder Sod Farm
G.A. Grundstrom Co., Inc.
H & E Sod Nursery, Inc.
University of Chicago
Hinsdale Golf Club
D.A. Hoerr & Sons
Holy Sepulchre Cemetery
Hubbard Trail Country Club
Bacil B. Hurr Landscape Contr.
Illinois Lawn Equipment, Inc.
Illini Country Club
Illinois State University
Imperial Landscape & Supply Co.
Inverness Golf Club
Jacobsen Mfg. Co.
O'Hare Inn Golf Course
Joliet Jr. College District 525
Joliet Lawn Service
Keller-Heartt Co.
Kewanee Park District
Charles Klehm & Son
Knollwood Country Club
Lake Forest, Il.
La Croix Agency
La Grange Country Club
Lake Cook Farm Supply Co.
Lakeview Country Club
Lake View Memorial Gardens
Lake St. Memorial Park Cemetery
Lawn Medic of Peoria
Clarence R. Lawrence
Lockport Township Park District
Lockhaven Country Club
Lofts Chanderlin Seed Co.
Lombard Park District
McCann Lawn Sprinkling System
McGinty Bros. Ins. Spray Service
Mill Creek Country Club
Michael's Lawn & Landscape Service
Midlothian Country Club
Midwest Assn. of G.C.S.
Midwest Landscape Co.
City of Moline
Mott Corp.
Mount Emblem Cemetery Assn., Inc.
Mt. Prospect Park District
Mueller Farms Sod Nurseries
Daniel E. Wright
Northrup King Co.
Norridge Park District
North Shore Spray Service
Oak Hills Golf Club
Olympia Fields Country Club
Paul Owens Landscapers
Playboy Club Hotel
Park District of Oak Park
Pekin Park District
Pinecrest Golf & Country Club
The Rail Golf Club
Ravinia Green Country Club
Reliable Sod Nursery
The Roman Catholic Diocese of Joliet
Rhodia Inc. - Chipman Div.
Ridge Country Club
Ridgewood Comm. H.S. District 234
Rite Landscape Service Co.
Rolling Green Country Club
Scruggs-Drake Equipment Co.
Shamrock Turf Nurseries, Inc.
Short Hills Country Club
Leon Short & Sons, Inc.
Silver Lake Country Club
Skokie Country Club
Southern Ill. G.C.S. Assn.
Southside Country Club
Sportsman Country Club
Sprinkler Irrigation Corp.
Springfield Park District
St. Andrews Golf & Country Club
Sunnybrook Landscaping Co.
Ralph Synnestvedt & Associates
Thorngate Country Club
Thornton's Turf Nursery
Timber Trails Country Club
Botanic Garden
Toro Distributing-Chicago
Turf Products, Inc.
The Upjohn Co.
Vaughan's-Jacklin Seed Co.
Village Greens of Woodridge C.C.
The Village Links
The Wadsworth Company
Warren's Turf Nursery
Wee-Ma-Tuk Hills Inc.
Wilmette Park District
Wolf Creek Golf Club
Woodmar Country Club
Woodridge Golf Club
Clinton Hill Country Club
Glen Oak Country Club