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THE POTENTIALS OF BERMUDAGRASS ADAPTATION

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The genus Cynodon Rich., is world-wide in distribution primarily because of the one species C. dactylon (L.) Pers., which is truly cosmopolitan. This species has perhaps the widest distribution of any perennial grass in the world. It is found throughout much of the warm regions of both hemispheres and well into the cool-temperate areas of Europe (Great Britain, Holland and Germany) and North America (Michigan). It grows under practically desert conditions in the waddis of the Negev and thrives in areas of rainfall which exceeds 100 inches annually. This species can be found at elevations below sea level to more than 10,000 feet, growing in extremely alkaline to acid soils, and sometimes inundated for lengthy periods of time. The enormous variability and range of adaptation of C. dactylon is even more remarkable when contrasted with the restricted distribution of the other nine species to which it is related. The most narrowly endemic Cynodon species is C. barberi Rang. et Tad., which is confined to wet places of tropical South India.

Only three species, C. dactylon, C. transvaalensis and the hybrid C. magennisii, are strictly rhizomatous. The other seven recognized species are non-rhizomatous. The stolons of a possible new species from Afghanistan have extended out radially from the parent plant a distance of 20 to 30 feet in a single season at Oklahoma State University.

The species vary in appearance from low-growing, fine-textured types with leaves about 1/16 inch in width, to tall, robust forms with leaves six to eight times as wide. The variation in shade tolerance is of such a narrow range that the possibility of getting a shade-tolerant bermuda seems rather remote. Seemingly there is considerable variation in salt tolerance between and within Cynodon species which makes the chances of getting a variety that is well adapted to saline soils more likely. In addition, the possibility of getting more cold and drought resistant bermudagrasses for the Southwest is increased, we hope, with collections made from the desert regions near the equator to the higher elevations and the colder climates of the temperate zones.

SOME PRINCIPLES IN THE DEVELOPMENT OF WEED POPULATIONS

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This is a truly thought-provoking topic, since all turf areas are continually plagued by weed invasion; yet, we have only two weeds that cannot be selectively controlled with success--Poa annua and nutgrass. Why, then, the invasions? Perhaps we need a closer look at our management programs in the light of modern turf usage.

Perhaps weeds are the end result of our misunderstanding nature and/or the mismanagement of tools of the trade. After all, we can consider weeds to be nature's way of protecting bare, erodable soil. With dense turf, weeds are negligible; therefore, consider weed populations as a measure of our problems.

Natural problems contribute greatly, of course. The soil is primary since it is the medium on which we grow turf and is usually the carrier for weed seed. Hard, crusty, poorly drained soils are difficult for plants to properly root into. Very loose sands move too easily and roots are often dislodged. These can be stabilized with heavier soils and organic matter, and heavy soils can be loosened mechanically. These are added operations to those necessary in granulated, friable loam soils.

Weather plays a great and largely uncontrollable part. Everyone is particular and vociferous about this--it's either too hot or too cold; too still or too windy; too wet or too dry. Managers, though, can choose adapted species, provide for maximum air movement by proper architecture or layouts and can establish drainage and irrigation systems.

Other environmental factors that contrive to grow weeds include tree root invasion (another weed?), poor air movement, and shade. Regarding the latter, Reid and later Madison have found that shade in the morning is as bad as shade all day, and sun in the morning is almost as good as sun all day. Air movement, root invasion, and shade problems can be largely reduced by cutting all or parts of offending trees. Of course, some people had rather have trees than grass.

In all these things, man exhibits some but not full control. In others, however, he does. For instance, turf users are generally color blind--if it's not pure green, it's no good. Many times a turf manager must do things contrary to good management simply to appease the ocular demands of his employers. Often, too, he does the opposite to prove his superiority over his weedy adversary. Why kill knotweed or crabgrass when he has made no provision to correct compaction, replant turf or fertilize what little turf is in the area to encourage its growth. Why will a golf course spend $1,500 to control goosegrass, then spend the rest of their funds for water--yet haven't fertilized for four years? Weeds are bad, but they're green.

Turf users must bear the blame in many instances. Golf players and golf cars are culprits, but only on too small, poorly built greens or tees, or where player movement is restricted. Heavily used athletic fields come into this also; after all, semi-dormant or dormant turf can stand only so

much attrition. But these are necessary evils that produce revenue that pays for the whole package. Let's not forget misuse of management equipment, such as following the same mowing pattern every time, service roads across fairways. These big, new machines are wonderful, but must be used with discretion and planning.

Management is truly the key to today's turfgrass management. A man was recently asked to apply for a job in an unfamiliar area. He first studied the climatic conditions and general soil characteristics. He then asked about the current equipment setup and its condition; then, about the memebership and the type course they wanted to pay for. At this point, salary was finally discussed. He knew what he was up against and could state his salary request on a firm basis.

Turf growers do not intentionally mismanage these things. Usually, the little things crowd in until they become a swarm. Turf loss and subsequent weed invasion is then blamed on the most apparent cause, when in reality, the culprit was some insignificant occurrence that was completely forgotten. We have heard talks about the little things that mean a lot and about turf management as a big picture. Every now and then, it will do us all good to re-read these and consider the ruts we may be getting into.

MODE OF ACTION, MOVEMENT, AND HAZARDS OF PREEMERGENCE HERBICIDES

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During the last ten years there has been extensive research on preemergence herbicides, and investigation on preemergence crabgrass materials has been studied in all areas where crabgrass was a pest. Comparison of products and formulations for their effectiveness in reducing the crabgrass plants has been one of the main phases of turf investigations. There have been some studies completed and others in progress to study why, how, and when the materials kill crabgrass seeds, seedlings, or plants. The majority of the references will be to preemergence herbicides for crabgrass control.

Safety of pesticides is one of the biggest publicity items today. The term "pesticides" in its broad meaning includes insecticides, herbicides, and fungicides. The last part of the title "Hazards of Preemergence Herbicides" emphasizes the fact that safety is of prime concern. Discussion of the hazards that may be encountered in the use of herbicides will help us to more safely use the herbicides on our turf. Hazards, according to Webster and to many of us, means peril, danger, or risk. Pesticides and fertilizers are necessary for satisfactory turf growth and maintenance; and by proper handling and use, the beneficial value of the products can be obtained safely.

Turf in this paper refers to the grasses on the golf courses, in the parks and playgrounds, lawns, sod farms, and along the highways.

Some of the recent basic work indicates that some of the materials used for crabgrass control have their activity in the liquid phase; others, in the vapor phase; and some in both liquid and vapor phases. Dr. Fults, Colorado State University, has reported on his plastic box test in which he used the growth of the primary roots of crabgrass to obtain quantitative data. An agar was placed on the bottom of the plastic box. A red line drawn at the center on the outside served as a guide line for the placement of the crabgrass seeds. The seeds germinate and after a period of days, the root growth was measured to determine the activity of the test material.

To determine if the material had activity, dosage levels of 1,000, 500, 250, and 125 ppm were impregnated on paper discs. In this initial exploration for activity, four paper discs per box were placed directly on the agar two inches below the planted crabgrass seed and the discs were left uncovered. Activity from this test was for both the liquid and vapor phases. To determine if the material was active in the vapor phase, the paper discs were fastened to the top of the plastic box. In this test, it was only the vapor that circulated and affected the seed or seedlings. Toxicity in the liquid phase was determined by placing the paper disc containing the herbicide on the agar below the crabgrass seed, and the discs were covered with Saran wrap. This technique eliminated the vapor action, and the amount of liquid phase activity was determined.

Calcium arsenate, according to Dr. Fults' evaluation, showed all of the activity for crabgrass control in the liquid phase. Bandane and chlordane were about equally toxic in both the liquid and vapor phases. Dacthal and Zytron showed their toxicity in the vapor phase. The above studies were conducted in plastic boxes under laboratory conditions.

In the various greenhouse tests, root growth responses and foliage effects were observed. From my observations, the action of crabgrass preemergence materials has been evident on the root development. In young seedling crabgrass plants, root development was often very short or clubbed and stunted from treatments of Betasan, Tupersan, Dacthal, Zytron, chlordane, and Bandane.

This fall, I saw some annual bluegrass plants (Poa annua) from Betasan treatment, and the roots were clubbed and very stunted. One interesting thing was that under western Washington conditions with high humidity, considerable rainfall and low temperatures, Poa annua plants with only clubbed or deformed roots were growing satisfactorily and producing seed.

Crabgrass seedlings in chlordane-treated greenhouse plots became yellow and dried up, but this may have been caused primarily by the effect of chlordane on the crabgrass roots. Some work indicated that chlordane affects the young foliage shoots as well as the young roots as they emerge from a sheath-like covering.

In most cases crabgrass seed germinates, but by the action of preemergence materials, does not develop. On the other hand, there is little post-emergence activity with most of the materials now used for preemergence crabgrass control. Most crabgrass materials must be applied before the first emergence. The movement of the preemergence crabgrass materials under field conditions is somewhat limited. In some cases, there is some surface movement caused by rains. Materials, such as chlordane that shows good reduction of crabgrass a year after treatment, indicate practically no movement down into the soil. Crabgrass germination occurs on or near the soil surface, and if chlordane moved down into the soil, fall treatments would not be effective. From insecticidal studies, chlordane and DDT move very little in the soil.

At the recent American Society of Agronomy meeting, Dr. Ralph Engel, Rutgers University, presented a paper on soil residues of preemergence crabgrass materials. This paper gave information on movement in the soil and the possible caution (hazard) aspects. Treatments were made in April of 1963 and soil taken in December of 1963. There had been 23 inches of rainfall from the application date to the taking of the soil for greenhouse studies. Materials applied at their recommended rates were Azak, Bandane, Betasan, calcium arsenate, chlordane, Dacthal, and Zytron. Samples of soil for the test were at 0 to 2 inches, and 2 to 4 inches. Merion bluegrass plugs were planted in the soil from the respective preemergence crabgrass materials and grown for 18 days in the greenhouse.

Root growth in the soil of the 0 to 2 inch layer was seriously reduced from plots treated with Azak and Betasan. Reductions in top growth (clippings) from chemical residues were rather frequent. In this test, soils from the 2 to 4 inch level did not show the effects as noted from the 0 to 2 inch soil level. This study indicates little movement in the soil. We must realize that this is a greenhouse test, and responses may differ in the field. The important factor is that this test gives a clue for possible

research with bermudagrass and other warm-season grasses. In the soil analysis for chlordane and Bandane, there is definitely more residue in the upper 0- to 2-inch soil than below. One word of caution is that soil samples show great variation from the same treatment. More research is needed for satisfactory interpretation of the analysis of soils.

The importance and necessity of crabgrass control is known, but consideration of the possible hazards of preemergence materials is of definite concern. In discussing the possible hazards of preemergence materials, I do not intend to alarm you, but we do desire to inform you. In referring back to the discussion of Dr. Engel's work on movement of preemergence crabgrass materials, there was some indication of the possible hazards. There are two phases of hazards that need more evaluation--those that result in obvious injury, and those that may be delayed or not detectable by observing the turf. In delayed action, information on the effects to root and foliage growth are important. Gaskin has reported on his work in Illinois on effects of Zytron, Dacthal, and Bandane to bluegrass root development.

Dr. Engel stated that the investigations conducted in the greenhouse using soil from different treatments indicated the need for more basic research studies on the responses of bermudas and other grasses to determine the beneficial and possible adverse effects of preemergence crabgrass materials.

Burning and killing of turfgrass from the usage of too high rates, formulations, or other factors, have been observed; but usually this injury has occured in the initial investigations or early field use. In some cases, there has been no injury observed throughout extensive testing, and then under some localized conditions or factors, injury has occurred. It is always advisable to "check test" on a small area a product used for the first time before the material is applied to the total area.

In one case of initial research, the same formulation was applied at the same rate on two dates, two weeks apart, and there were obvious differences in plant response. There was no detectable injury from the first application, but 25 to 30 percent of the grass was killed from the second or later application. This later application was made when the new root growth was at its maximum.

Studies over the years have shown that calcium arsenate treatments cause thinning of the turf although crabgrass control has been satisfactory for two or more years from one treatment. It is this delayed adverse action (hazard) that is of real concern in the evaluation of preemergence materials. Sometimes the injury occurs in one area and not in another.

Plots at Rutgers University are arranged so there is a check area adjoining all treatments. In these investigations, the materials were applied in 1962 and apparent injury was detected in 1963. The test area was one of low maintenance and there was an extreme drought in 1963. Differences could be observed between the checks and treatments for a number of the preemergence materials. Some of the treatments were chlordane, Zytron, Dacthal, Bandane, and calcium arsenate. These were critical observations, and the grasses were under extreme stress. Chlordane in another test and under the

above conditions resulted in a reduction of stand. It should be emphasized that numerous areas have been treated with very satisfactory results.

Everyone using pesticides should keep a record on the date of application, amount of material used, the exact formulations, and a chart of where the materials were applied. Information of all management practices, such as fertilizing, watering, renovation, verticutting, top dressing, and any other special practices should be recorded. This information can be of extreme importance in evaluating or determining the beneficial or adverse conditions that occur. There are some conditions which seem to defy all present knowledge in giving a satisfactory answer.

In conclusion, I would like to indicate that we know the value and necessity of crabgrass control in maintaining or growing a good turf. It is a critical requirement for a material to control one grass species (crabgrass) and not injure the desirable turf when they are growing together. Results on the control of crabgrass with preemergence materials have been outstanding. Extensive and continued research is required to keep us informed on the benefits and possible injury to the desirable grasses by the use of preemergence materials.

Investigations have shown that the mode of action is in the liquid phase, in the vapor phase, and in both the liquid and vapor phases. Very limited movement in the soil occurs with preemergence crabgrass materials according to our present knowledge. Some hazards to turf by preemergence materials have occurred, but in the vast majority of areas treated, the results have been satisfactory.

FROST - ITS EFFECTS AND PREVENTION

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Frost is formed when air containing moisture in the form of water vapor is cooled to below freezing temperature. The moisture condenses and collects as frost or lacy ice crystals on solid objects.

Frost is usually formed at night and in much the same way as dew. The earth is heated during the day by the sun. When the sun sets, the earth radiates heat into the air and cools off. The ground cools rapidly, and the moisture, held in the air near the ground as water vapor, condenses and collects in droplets or solid objects. When the temperature drops below freezing, frost is formed. Hoar frost is formed when air is cooled to freezing temperatures, and the moisture in it condenses on solid objects such as plants. It differs from ordinary frost in that the ice crystals are long and needle shaped. More frost is formed on a clear night than on a cloudy night because the ground cools faster on a clear night, resulting in more condensation.

The temperature at the soil surface may differ greatly from that a few inches above ground. In southern England, surface temperatures of 111°F. have been recorded on a closely cropped lawn. Twelve inches above the surface of the lawn the temperature was 93°F., a difference of 18 degrees. Night (clear) time temperatures showed about the same difference except in the opposite direction--75 degrees at twelve inches and 55 degrees at the surface.

Plants

Plants vary in their ability to resist or tolerate frost injury. Many plants native to tropical or sub-tropical regions are killed or seriously injured by temperatures above their freezing points. Bananas are a good example--the fruit may be damaged at 40 to 50 degrees F. This type of injury is referred to as a chilling injury. Plants subject to chilling injury are usually killed by the first touch of frost.

The more common form of low temperature injury (and the kind with which we are most concerned) is "Frost Injury." Frost injury may occur in all plants. Some may be frozen solid without damage; others may be killed at or slightly above freezing. Differences in tolerance among bermuda, bent, bluegrass, rye on golf courses are readily apparent.

More important perhaps than the species differences is the fact that for a single plant the range of frost killing temperatures may be large, depending on its physiological state. Soft, succulent grass is easier killed than that which has been permitted to "harden." This is one reason why late fall applications of nitrogen should be avoided.

Causes of Freezing Injury in Plants

A number of suggestions have been made regarding the possible causes of freezing injury to plant cells, the principal ones being the following:

(1) Ice formation in the intercellular spaces results in withdrawal of water from the cells. As ice forms, the moisture is pulled from the cell. The consequent dehydration results in disorganization and death of the protoplasm (Molisch, 1897). The black, water-soaked appearance sometimes observed when plants freeze is due to the inability of the cells to reabsorb this water when the ice melts.

(2) The ice formed in the intercellular spaces results in mechanical compression of the cells which in turn causes deformation and death of the protoplasm (Maximov, 1914).

(3) Withdrawal of water from the cells due to the formation of ice crystals in the intercellular spaces results in an increase in the concentration of electrolytes in the cell sap which may have a "salting out" or other destructive effect on the protoplasmic proteins (Harvey, 1918, and others).

(4) Ice crystals may form within the cell, resulting in compression or laceration of the protoplasm or other destructive effects (Stiles, 1930, and others).

(5) Death occurs, not at the time of ice formation, but as a result of the subsequent thawing of the tissue. This idea, originally sponsored by Sachs in 1860, largely dropped into disrepute but has been revived by the findings of Iljin (1933) and others that some plant tissues which can withstand freezing are killed by rapid thawing. Death is apparently due to various types of mechanical disturbances attendant upon the entry of water into the cells upon thawing. Black, water-soaked appearance, often observed in frost-killed plants, may be due to this inability of the cell to reabsorb water.

Most modern workers seem to favor the concept that injury to protoplasm during freezing is fundamentally due to mechanical effects of ice formation, either within or between the cells, rather than to dehydration per se or to chemical effects. The ultimate effect of such mechanical disturbances is presumably the disruption of the delicate organization of the protoplasm.

Effects

In any given condition of growth, the frost-killing temperature still depends on:

(1) Rate freezing--killing will occur at higher temperatures if freezing is rapid rather than if it is gradual.

(2) Rate of thawing--greater injury may occur if thawing is rapid rather than if it is gradual. Of course, this is a factor only if:

(a) the plants were already killed by rapid freezing, or

(b) the plants are so frost hardy that no injury occurs at any rate of thawing.

(3) Length of time frozen--greater injury occurs after long continued freezing than after short freezing periods at the same temperature. Dr. Jim Beard shows that cool season grasses may remain frozen for long periods--up to 90 days.

(4) Number of times frozen--generally the more times, the more the injury because the plant may be weakened a little each time.

Frost Prevention or Protection

Four techniques will be discussed briefly: smudge, sprinkler irrigation, polyethylene covers, and soil warming.

(1) Smudge - This is an established technique used in citrus orchards. Air that is heated will rise and be replaced with cold air. Smudging is a technique used to overcome this and takes advantage of incomplete combustion of oil to provide hot carbon particles that will hang close to the surface and give up their heat slowly. This technique would work on golf greens, but it is not practical.

(2) Sprinkler Irrigation - This technique is used to protect many vegetable and truck crops against freezes. It also may be used to protect turfgrass.

The principle involved is similar to smudging in that heat is added to the surface you are trying to protect.

The heat comes from that contained within the water itself from the ground because the moisture forms a seal which prevents loss of soil heat, and from the heat of fusion (heat required to convert liquid to solid). Heat is required in one form or another to turn ice into water. In a like manner, when water turns to ice, heat is given up or released. This is known as heat of fusion. Heat of fusion is by far the more important factor involved in protecting against frost. By the time the water droplets reach the plant, they have been chilled to the atmospheric temperature thus adding relatively little heat. The heat absorbed by the plant surfaces from the added water is enough to keep the plant above its freezing temperature except when air temperature is very low or when heat is rapidly removed by a cold wind. Ice may not form if the frost is light. However ice usually starts building up when temperatures are around 30°F. and may accumulate from 1/16 to 1/2 inch depending on length and severity of the cold snap.

When ice does build up water application should continue until the air temperature is above 32 degrees and all the ice has melted from the plants. Most of the experimental work in this area (sprinkler) has been conducted on truck crops. Many

crops have been protected against temperatures as low as 20°F. Gladiolus have protected to 27°F. At lower temperatures, the ice builds up to a point where the stems and flowers are damaged, but this is not the case with turfgrass.

Obviously, for successful use on turfgrass, the soil must be well drained, both surface and internal, as irrigation may have to continue for 2 to 3 days. Water application procedure is different to regular irrigation. Sprinkler spacings may be greater, application rates low and droplet size small.

(3) Covers - tarps, polyethylene

Covers work effectively in preventing frost but considerable effort is necessary in installing covers to keep them in place and frequent removal is necessary to avoid excessive growth or shading.

(4) Soil Warming - Tests have been conducted at Lethbridge, Alberta; Tucson, Arizona; and Lafayette, Indiana (Purdue University). Studies are underway this year at Texas A&M and Toro Research and Development.

This technique may have considerable merit in some areas, especially on greens, tees, and other specialized areas. In combination with sprinkling, the system may permit keeping bermuda green all winter.

Preventing Damage After Frost

(1) Keep traffic of all kinds off the area; pressures apparently cause the ice crystals to penetrate or puncture cells, causing mechanical damage.

(2) If traffic must be permitted, wash frost off with sprinklers before sun rise.

EQUIPPING A GOLF COURSE FOR MAINTENANCE

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When Dr. Holt assigned the subject of equipping a golf course for maintenance to me, I was very pleased. I have made many lists of equipment and supplies for new golf courses, in fact, these lists have been made for some of you present. In looking back over the past 15 years, I see that many of the things recommended then have no place in modern golf course maintenance, and several new machines and materials have emerged to replace them.

In looking through my files, I found a Stumpp and Walters catalog printed in 1940 which illustrates the point made above. They compiled a list of equipment they thought necessary to maintain an 18 hole course then, and I will read from this list:

Traction and Transportation

	Cost - 1940	Cost - 1964
1 tractor w/5' sickle	$ 920.00	$ 3000.00
1 tractor w/dump	795.00	2850.00
2 wheelbarrows	25.00	50.00
1 medium wt. truck	1000.00	3000.00
	$ 2740.00	$ 8900.00

Soil Working Implements

1 soil shredder	195.00	350.00
1 soil screen	125.00	250.00
6 shovels, spades, rakes, etc.	70.20	130.00
Disc plow, axe, crow bar, brush hooks	120.00	200.00
	$ 510.20	$ 930.00

Distributing Apparatus

1 power drawn spreader	135.00	350.00
1 hand topdressing spreader	62.50	140.00
1 wheelbarrow seeder	32.00	20.00 (cyclone)
1 200 gallon power sprayer	295.00	850.00
1 flexible drag mat	8.00	15.00
12 bamboo poles	5.50	15.00
	$ 538.00	$ 1090.00

Rollers (Aerators)

	Cost - 1940	Cost - 1964
1 power drawn 5-unit roller	$ 230.00	
1 self-powered roller w/turf conditioner	125.00	
1 spike roller	169.50	
1 greens aerator		850.00
1 fairway aerator		1000.00
1 power roller		400.00
	$ 524.50	$ 2250.00

Grass Cutters

1 5-gang on steel wheels	$ 750.00	$ 1750.00
2 power putting green mowers	405.00	920.00
6 hand putting green mowers	330.00	
2 power putting green mowers		920.00
1 30" park-type mower for tees	305.00	650.00
3 scythes and grass hooks	19.50	30.00
1 mower grinder	225.00	350.00
	$ 2029.50	$ 4620.00

Irrigation Supplies

3000' of 1" rubber hose @ 22¢	$ 660.00	$ 2400.00
9 1" greens sprinklers @ $28.50	256.50	370.00
6 tee sprinklers @ $7.50	45.00	90.00
Shower heads, pipe dies, vise, etc.	100.00	200.00
	$ 1061.50	$ 3060.00

Turf Repair and Sodding Tools

1 tractor drawn sod cutter	$ 60.00	$ 140.00
2 sod lifters	6.00	14.00
4 turf repairers--various sizes	44.00	60.00
2 hollow tined forks	21.00	44.00
1 spike tamp	4.50	10.00
2 turf edgers--half moon	6.00	9.00
Rakes, hoes, spading forks, etc.	50.00	100.00
	$ 191.00	$ 377.00

Requisites for Play

	Cost - 1940	Cost - 1964
1 hole cutter	$ 10.00	$ 18.50
18 aluminum cups	29.00	63.00
18 aluminum poles	58.50	99.00
18 numbered flags	10.50	19.50
18 tee markers--mushroom	45.00	90.00
9 Lewis ball washers @ $10.50	94.50	148.50
Distance markers, sand rakes, mole traps, etc.	150.00	300.00
	$ 397.50	$ 738.50
Total	$ 8038.60	$22037.50

With the addition of items to this list to modernize the maintenance, some $52,000.00 will be added--$40,000.00 of which is for a sprinkler system.

At the time this check list was compiled, the average laborer working on a golf course was making 25¢ to 30¢ an hour. It is interesting to note that, while our labor costs are four to five times higher today, the cost of equipment is only 2½ to 3 times higher than it was 25 years ago.

As our labor costs increased and our knowledge and techniques improved, we found that we had to mechanize more to better utilize our man-hours. This means more equipment--equipment that was unheard of 25 years ago. At this point, it might be interesting to list equipment in common use today on golf courses that was not used extensively and, in many cases, not even manufactured in 1940:

1. Power putting green mowers
2. Hollow-tined aerating machines
3. Power sod cutters
4. Power edgers
5. Rotary mowers
6. Quick coupling valves
7. Rotary pop-up sprinklers
8. Automatic sprinkler controls
9. Electric hedge shears
10. Power chain saws
11. Hydraulic controlled mowers
12. Broadcaster fertilizer distributors
13. Leaf blowers or vacumns
14. Motor scooters
15. Power topdressing machines

At the same time we might reflect a moment, and list some materials that we commonly use today that we did not have in 1940:

1. Chlorinated hydrocarbons
2. Pre-emergence weed killers
3. Hormone weed killers
4. Highly selective arsenicals (DSMA)
5. Broad spectrum fungicides
6. Urea-form fertilizers
7. Systemic insecticides
8. Calcined clays
9. Wetting agents
10. Hybrid bermudas and others

We have compared costs of 1940 with those of today on the lists just read. Now, let's see what we would add to this list to modernize it to efficiently maintain an 18 hole golf course today. I realize that our operating budgets vary, so the following is aimed at the upper middle class or lower high class club with a budget in the $60,000 to $70,000 a year range. How many will this cover? How many lower? How many higher?

Under transportation, we would certainly want to add a minimum of two Cushman motor scooters--one for the night water man and one for the superintendent. We use five at Brook Hollow. Each of the green cutters has one complete with a low boy trailer in which they haul their mowers, edgers, hose and other small equipment. They also dump their clippings into the trailer as well as paper from the waste receptacles around their route. We have found that this greatly increases the efficiency of each man and saves some repair work on the transport mechanism of the greensmowers.

Another item needed under this category is an agricultural tractor with a loader and grader box. This is invaluable in accomplishing small construction jobs, in loading soil for various uses and in furnishing the power for sprayers, spreaders and rotary mowers.

Under distributing apparatus we might supercede a tractor-drawn gravity-flow spreader with a broadcaster type. This type will cut your fairway fertilization time by two-thirds and do a more uniform job without streaks. I would suggest getting the type that has an independent engine that drives the spreading fans instead of the PTO type. Some of the courses having bermuda greens can probably use a power topdressing machine.

We would also want to add a weed boom to our power sprayer for the uniform application of weed killers.

Under soil working implements we would add the aerating machines. We should have one or two of the vertical core machines on bent greens and either the open spoon or vertical core on bermuda greens. Bent greens will heal faster following aeration with the vertical core type machine, especially in the fall when the roots are shallow.

A fairway aerator should also be included in this category.

The grass cutting section needs to be supplemented somewhat. In keeping any large turfed area, the mowing of grass consumes more time than all the other operations put together, so we must pay close attention to this category. As you know, it is very difficult to get each separate area mowed and trimmed at the same time unless you have several mowers for each job. At our course, during the summer we mow at five different heights. We mow the greens at 9/32 inches, the fringe of the greens and tees at 1/2 inches, the fairways at 3/4 inches, the roughs at 1 1/4 inches and the lawn area around the club house at 1 inch. During the course of a year there is less than a half dozen times when everything is mowed and trimmed at the same time and nothing needs cutting. The number of mowers you own is directly proportional to the degree of maintenance your members demand. The ideal set-up would be to have a seven gang and a five gang to mow fairways and around the greens, another five gang to mow the roughs, two 30 inch park type mowers for tees, two 76 inch self powered reel mowers for banks around the greens and tees, six power putting green mowers, one heavy duty rotary mower and ten small trimmer type rotaries. With this collection of mowers, and a crew of 20 men, you could mow every blade of

grass on the course every two days, and there are a few courses in the state that do just that. Most of us, however, have to be content with somewhat less. I would say that the following would give us an adequate supply of mowing equipment. The first thing I would do with Mr. Stumpp's list is to scratch the six hand green mowers and add three power green mowers, which will make a total of five. We should also have a 76 inch self-powered reel mower, two 19 to 20 inch rotary mowers for trimming, one 32 inch rotary for rough work and leaf mulching. These units, along with the ones already on the list, will give you an efficient mower operation. How much mowing equipment you own is like comparing the merits of flying to California or driving. Both methods will get you there, but flying is much faster, so if your membership wants a faster mowing job with less player interference, get more mowers and men.

We know that we cannot obtain the type of irrigation we want on our golf course today with 3000 feet of hose and 15 sprinklers. Time will not permit a discourse on the merits of different type systems. One of the newer courses in our area has spent $140,000.00 on a completely automatic system; however, a tee to green quick coupling system can be installed for under $50,000.00, and this is adequate for most of us at this time. I think that we will all live long enough to see automatic irrigation systems as common as quick coupling systems are today.

Our turf rennovating tools are now much the same as they were in 1940, except we now use a self-powered sod cutter instead of the tractor drawn model and instead of two half moon edgers, we use two power edgers to keep the walks and traps edged and to help keep the bermuda out of our bent greens. If you do not use this tool at the present, I strongly urge you to consider it, because the edging of traps can do a world of good in making your course appear well groomed.

The requisites for play today are the same as they were in 1940. We might want to go to a more attractive tee marker such as an enamelled aluminum sphere or the ceramics.

Before closing, I would like to say a few words about a very important part of your maintenance inventory--a building to house all of this equipment. One of my pet peeves with the farmer is the fact that not one out of 100 has enough storage space to keep his equipment under a roof and out of the weather when not in use. How many farms have you seen that had tractors, combines, plows, hay balers, seeders, etc., setting in the yard gathering dust? I would wager that among us there is not five people who have seen one farm operation where adequate machinery storage was in use. While we are on that subject, how many of you have enough space to park all of your equipment under a roof each night? We built a new maintenance building three years ago, and before drawing the plans, we visited some 20 golf courses and talked to the superintendents at each of these. He was asked: 1. How he liked his building? 2. What he would change if he could rebuild? From this survey I arrived at a floor plan that represented my thoughts and the composite of 20 other superintendents in this area. Below are the ten major prerequisites I think are important in planning a maintenance building.

1. Completely floored inside.
2. Enough space to accommodate all equipment.
3. Located close to the center of the property.
4. Painted and built to be unobtrusive.
5. A drive-thru feature for loading and unloading.
6. Adequate lighting, ventilation, heat, etc.
7. Comfortable office.
8. Spacious work shop.
9. Locker room and lounge.
10. Landscaped and maintained.

If these steps are followed, maybe people will stop calling it "the barn".

OVERSEEDING BERMUDAGRASS GREENS - THE SEED MIXTURES

J. M. Latham, Jr., Agronomist
Milorganite Turf Service

Early reports in USGA Bulletins mention several grasses used in the South for overseeding Bermudagrass greens. Redtop, red fescue, and until 1959, ryegrass were used extensively. B. P. Robinson initiated bent-ryegrass comparisons in Tifton, Georgia in 1954-55, hoping to find a finer textured wintergrass over fine textured Tifton hybrids. Plantings of Seaside bent alone and in combination with redtop at the Athens, Georgia, Country Club in 1957 and 1958 were poorly received because the overseeded grasses did not develop useable coverage until March. Herb Green at Dublin, Georgia, successfully used a mixture of ryegrass and bent in 1955 or 1956.

In 1959, the Milorganite Turf Service, under O. J. Noer, initiated a set of overseeding tests in Atlanta and Sea Island, Georgia. Results that year showed Pennlawn fescue and Poa trivialis to be excellent all year, but subsequent tests showed the fescue to be erratic in action.

Agrostis species were all late in developing. In order of excellence, these grasses are Seaside, Astoria, redtop and Highland. The last two were very poor all season. Compared to Poa trivialis, they were as poor as the check plots.

Later tests showed mixtures of grasses to be the best approach to the problem. Putting tests showed the Poa trivialis to be of slow putting quality, while red fescues were very fast. As play picks up in the spring, more growth is needed, so bent is included to provide a "finished" appearance and to increase density. A combination of the three was ideal all season.

Florida tests showed Kentucky bluegrass to be helpful in maintaining color and density during warm periods in the winter.

From these tests (13 locations in 1963-64) our current recommendations are:

1. In Northern regions--

   4 lbs. Poa trivialis per 1,000 square feet

   6 lbs. Pennlawn fescue per 1,000 square feet

   2 lbs. Seaside bent per 1,000 square feet

2. In Florida and coastal regions--

   4 lbs. Poa trivialis per 1,000 square feet

   8 lbs. Pennlawn fescue per 1,000 square feet

   2 lbs. Kentucky bluegrass per 1,000 square feet

   1 lb. Seaside bent per 1,000 square feet

Current seed prices indicate 1 to cost about $9.00 per 1,000 square feet, supplying 25,600,000 seed, while 2 costs about $9.20 per 1,000 square feet, supplying 25,300,000 seed. Fescue has been reduced from earlier rates because of cost of such large seed. It might be mentioned here that because of increased use of Poa trivialis, its price may be expected to double in the next year or two. So, I guess, overseeding evaluations must continue for quite a while, keeping an eye on turf quality all season and price per 1,000 square feet.

DISEASES OF OVERSEEDED GRASSES

Robert T. Miller, Turf Specialist
Industrial and Biochemicals Department
E. I. du Pont de Nemours and Company

Diseases of turfgrass are always a problem for golf course superintendents, but with overseeding of grasses, the problems may be more serious. When disease occurs in turf, it can be eradicated and the turf fills in, but with overseeded grasses, there can be no recovery unless the area is reseeded.

Many would like to think that disease control is nothing more than regular applications of a fungicide. Fungicides are important, but their use must be coupled with an over-all disease control program.

There are several problems that can occur with overseeded grasses and a good fungicide program is only a part of the answer. Let's consider the whole problem.

Bermudagrass is the most popular turfgrass, but because of its nature, during a period of cold weather, it ceases to grow and loses its color--or goes dormant. But the golfer wants a green turf, and because he pays the bills, it is our job to supply a growing green turf. So there are actually two main problems--protect the Bermuda for the next season's play and provide a growing green cover for the cold months.

One of the big problems about overseeding appears to be proper timing. If you seed too early and weather conditions are warm enough for Bermudagrass growth, there usually is too much competition for the seedling grasses. On the other hand, if you seed too late, germination is slowed and complete coverage is delayed. Seed according to temperatures, not according to calendar dates. Some of the growth regulators have been used with excellent results. It is suggested that they be tested for use under your conditions.

The first disease problem will probably be damping-off or seedling blights. This can be controlled easily by seed treatments and fungicide applications as the seeds are emerging. Many will argue about the need for a spray or sprays at this time, but disease organisms are always present and become active during periods conducive to their activity. At the time of overseeding, you have reasonably warm soil temperatures, plenty of organic matter in the top inch of soil, good soil moisture--everything necessary for disease organism activity. Also, Bermudagrass is subject to attacks of Helminthosporium in the fall and because the organism is carried over on infected plants and debris in the spring, this increases the possibility of attack on new seedings.

After a stand of grass has been established, there must be adequate fertilizer available to the plant. The fertility levels can be maintained by small, regular applications of solubles or organics, or some of the long lasting nitrogen carriers applied well in advance of seeding. All of them will do the job if applied and used properly.

Also, after the stand is established, we would suggest regular

applications of a good preventive fungicide and with it a little iron for color and the general health of the grass. Keep the soil moisture at a level to prevent wilt or desiccation, but do not over-water or over-fertilize.

Toward spring when the soil temperatures get higher and the Bermuda starts to show some color, apply a good application of nitrogen and reduce the height of cut of the overseeded grasses. This will reduce the transition period and force the Bermudagrass through faster for better turf and happier golfers.

TRANSITION

Gene Bockholt, Watson Distributing Company
Houston, Texas

The most acute problem in managing the Bermuda-cool season turf is the transition of Bermudagrass to cool season grass in the fall and back to Bermuda in the spring.

Spring transition is especially critical in that the high seeding rates that are essential to give satisfactory winter turf, delay the development of Bermuda in the spring and also the cool season grasses may die in the spring before the Bermuda has developed.

Too often we think in terms of transition as being strictly a spring problem. Actually, most of the groundwork for a smooth transition is made in the fall. Poa annua encroachment is a major problem tied very closely to the transition problem.

Essentially all of the factors involved in the transition problem are in the control of the golf course superintendent. The most uncontrollable factor is the same one that makes overseeding necessary--temperature. Temperature not only makes it essential to overseed, but also determines time of fall and spring transition.

What important factors influence transition?

1. Fall Preparation

   Bermuda must go into the cool season of the year in a good, strong condition. Severe verticutting or chemical injury (example--misapplication of maleic hydrazide) could both cause a poor spring changeover to Bermuda and severe Poa annua infestation.

2. Selection of Grass to Use in Overseeding

   Ryegrass has lost popularity to mixtures of Poa trivialis, Bentgrass, Bluegrasses, Fescues, etc.

3. Rate of Seeding

   Excessively dense stand causes shading, crowding and competition for food, light, moisture, etc.

4. Preventative Fungicidal Program

   Loss of wintergrass in spots requires reseeding plus exposing dormant Bermuda to damage by traffic. Disease damage to Bermuda could go almost undetected causing near to complete loss of same.

5. Watering

Excessive or heavy watering in spring to hold winter grass will be deteriorating to Bermuda, increase disease problems and encourages growth of Poa annua and crabgrass.

6. Fertilizing

Manipulation of the NPK ratio. Fall fertilizing requires added P and K with low nitrogen to promote good seedling growth and discourage rapid Bermuda growth. In the spring increasing the amount of nitrogen will encourage Bermuda growth.

7. Thinning

Spiking, aerifying, brushing and light verti-cutting will thin the wintergrass as required to encourage transition to Bermuda.

8. Mowing

Manipulation of cutting height is important in allowing proper wintergrass development and growth. Lowering cutting height in spring and brushing is helpful in opening the turf to permit room for rooting of stolons, greater light penetration, etc.

9. Changing Cups

Daily change of cup location on greens with medium to heavy traffic is essential to protect overseeded grass and dormant sod below. Loss of wintergrass cover or Bermuda sod will result in encroachment of Poa annua, crabgrass and other weeds.

10. Scheduling Tournaments

Improper scheduling of tournaments too frequently cause a superintendent to overseed at a time not of his choosing--could be too late or too early. Problems in spring scheduling of tournaments may cause having to hold the wintergrass too long, resulting in poor transition.

In summary, we see that temperature is the uncontrollable factor, making overseeding of greens a necessity. Essentially all the other factors discussed influence and encourage wintergrass or Bermuda growth and are under the direct influence and control of the superintendent. Their proper manipulation is the key to success and failure in both fall and spring transition.

CARE OF BENT GREENS - WINTER MAINTENANCE

James M. Latham, Jr., Agronomist
Milorganite Turf Service

Winter, to bentgrass growers in the North, is a time for rest, relaxation and worry about desiccation or snowmold diseases. In these more moderate climes, worry about desiccation may also be a problem in January or February cold waves.

As a general rule, however, with good water management, winter is a time for work. Your winters are usually like our spring and fall periods when most of the important cultural practices are accomplished. These include aeration, topdressing and vertical mowing. Drainage work, sodding, reseeding, etc., are other operations that can be accomplished at this time.

The most sadly neglected cultural practice that is best accomplished in late fall and early spring is topdressing. At one time, this was considered the most important cultural practice, not practiced in day-to-day maintenance. As labor costs rose, soil availability declined and aerating tools came into the picture the practice was reduced greatly.

Recent research work in thatch control at Rutgers and Mississippi State, however, shows this to be much more valuable to turf excellence than thinning or distribution of aeration plugs. Topdressing machines are now available that do a rapid, efficient and uniform job.

Topsoil mixing has been quite laborious, but new machinery has mechanized this operation considerably. Composting is again being used in many parts of the country to get rid of weedseed in preference to sterilization. In Texas, where Bermudagrass invasion is always a hazard, sterilization is still a must. But this can be accomplished rather easily with the kiln-type machines that use heat as the sterilant.

This doesn't mean that aeration and vertical mowing are no longer essential. It does mean, though, that aeration can again be considered only as an operation to reduce compaction and the vertical mowers as thinning devices, not as thatch removers. This, naturally, will keep many golfers happier and permit better putting quality for more days.

Water management in winter is still of prime consideration in the more arid, windy areas. Midwesterners had much rather combat snowmold and ice than to haul water to exposed greens during the winter to prevent drying out. Those who assure good soil moisture before cold windy weather avoid a great deal of winterkill due to "midwinter drought."

Frost is also something to consider in daily management. Traffic on frosted turf causes leaves to break off or be injured. This often disfigures greens significantly. Leaving frost on the green also causes the upper leaves to discolor. Such damage is often avoided by syringing early in the morning, even if thin ice sheets form. The freezing of water helps warm the turf and discoloration and footprinting are avoided to a great degree during many light frosts.

Wet winter weather can mean snowmold without snow. This has happened to Zoysia nurseries in Mobile, resulting in considerable turf losses. This is much easier on waterlogged bent greens. The good point is, though, that snowmold is easily controlled by Thiram or any mercurial fungicide. Prevention programs are easy and comparably inexpensive and should be used as necessary through the winter.

The better greens are cared for in the winter, as well as worked properly, when weather and growth permit. This even includes irrigating during cool rainy periods to leach as much accumulated salts from the root zone as possible. All these things help the golf course superintendent provide the best possible turf for the golfers for the longest period of time during the year.

TURFGRASS DISEASE CONTROL

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Since disease can be caused or influenced by natural environment as well as living organisms, control of disease is much more than just the application of a good fungicide. It takes good cultural practices, as well.

Naturally, every manufacturer would like to think of his product as being perfect, but how efficient is any fertilizer at a pH of 4.8? What kind of a job with a dull lawn mower do? How can a fungicide be expected to control diseases effectively when the plant is grown under adverse conditions?

Under all conditions fungicides will help, but often when a fungicide is used, disease is expected to be completely controlled--not just reduced. When the story is told about the course superintendent using fungicide to control cutworm after aerification, we have a tendency to laugh, but fungicides have been criticized because they have failed to control cutworm and other turf problems unrelated to disease.

The more we study diseases, the more we become aware of the interrelationship between environmental factors and cultural practices. Cultural practices alone will not control disease, but good cultural practices, coupled with regular preventive fungicide applications, will keep diseases under control.

You, as a golf course superintendent, are in as competitive a field as anyone. You have a selling and service job to do. All of your members, or all of those paying greens fees, are buying pleasure. They are constantly comparing your course with every other course they play, and to them there is no average over a season. They picture your course as always being in the condition as the day they see it. To make yourself more valuable to your course or available to another course, it is essential to have your course in the best possible condition every day of the playing season.

NITROGEN NUTRITION AND FERTILIZATION

Cecil R. Brooks
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Functions of Nitrogen in Plants

Nitrogen was among the first of the elements to be recognized as an essential plant nutrient. The characteristic yellowing of plants suffering from a deficiency of nitrogen is to be expected, since it is an essential unit of the chlorophyll molecule. Chlorophyll is the green pigment which absorbs light energy essential to the process of photosynthesis taking place in plants. From the photosynthetic process are derived the simple sugars that yield the energy and carbohydrate compounds necessary for the development of all plant tissues.

As a necessary constituent, nitrogen makes up 12 to 19 percent of all plant proteins. Proteins are formed through a systematically controlled condensation of amino acid molecules. The necessary amino acids (of various kinds) are produced by combining reduced nitrogen with carbohydrates produced in the plant through photosynthesis. In addition to the proteins that become a permanent part of the structure of plants, other proteins or protein-like compounds containing nitrogen make up enzymes, hormones and the complex molecules responsible for carrying and directing genetic inheritance from generation to generation. Thus, it may be said that all "living" substances contain nitrogen as an essential constituent.

Relationship to Other Nutrients

Since nitrogen is involved in so many plant processes and substances, there exists an inevitable relationship between nitrogen and other nutrient elements and compounds. Some general rules are as follows: (a) where the soil is deficient in nitrogen and all other nutrients are in adequate supply, the result is usually an abnormally high level of phosphorous in plant tissues; (b) when phosphorous is the only deficient element, plant tissues will usually contain an abnormally high level of nitrogen; (c) if potassium is the deficient element, the tissues of some plants will contain abnormally high levels of nitrogen (especially as soluble nitrate nitrogen); (d) where magnesium is deficient many plants will accumulate abnormally large amounts of potassium and low amounts of nitrogen, especially if the nitrogen is supplied as nitrates.

Because of the many complex reactions necessary for the metabolism of nitrogen in plants, the absence or deficiency of one or more of the necessary factors may lead to an accumulation of unassimilated nitrate nitrogen in plant tissues. This condition is unfavorable to plant growth and health if the nitrate content of the plant exceeds certain critical levels. This condition is incompletely understood; however, drought, phosphorous deficiency and potassium deficiency have been found to be contributing factors.

Nitrogen in Relation to Plant Growth and Health

Nitrogen promotes vegetative growth, which is the desired end product for all plants except those plants grown for their flowers and fruits. For a good grass turf probably no other consideration should be placed ahead of vigorous vegetative growth. This does not mean that maximum accumulation of leaves and

stems is most desirable. However, the cultural practices used should favor vegetative growth over reproductive growth. For this end nitrogen nutrition, and especially the balance between nitrogen and other elements, is of major importance. The balance between nitrogen, phosphorous and potassium has often been found to affect such plant factors as tolerance to droughth, cold and diseases. For the latter two of these, an overly abundant supply of nitrogen is detrimental because the too-succlent t iss ues are more readily damaged by freezing and more readily attacked by disease-producing organisms. This damage is associated with both the physical and chemical condition of plant tissues that is brought about by an over-abundant supply of nitrogen.

Although nitrogen is absolutely essential for seed formation, the rate and time at which seeds are produced can often be changed by regulating the balance between nitrogen and other nutrients (and cultural practices such as mowing and watering). The general rule for grasses is that seed production rates and total amounts produced can be reduced if the nitrogen supply is slightly overbalanced with respect to phosphorous.

With respect to general quality of turf, excess supply of nitrogen may produce turf that if flaccid and subject to easy damage by traffic. On the other hand, an inadequate supply will retard rate of recovery from damage caused by traffic, diseases, insects or weeds.

Forms of Nitrogen in Soils and Forms Absorbed by Plants

Nitrogen may be absorbed by plants in the form of ammonium, NH_4^+, and nitrate, NO_3^-, ions; and these are the forms usually found in soils. Other complex nitrogen compounds, such as urea and amino acids, may occasionally be absorbed but these are unimportant sources. The bulk of the nitrogen absorbed from well-aerated soils is in the nitrate form, but the ammonium form may be most important for certain plant species and soil conditions. In any case, the nitrogen must be in the reduced (ammonium or amine) form before it can be used in the synthesis of compounds in plants. The reduction process can take place in the soil or in various parts of plants. It is worth noting that the reduction of nitrate is accelerated by increasing temperatures within the range favorable to plant growth.

The ammonium ion, NH_4^+, may be held (against leaching in drainage water) by clay particles and soil humus as an exchangeable ion that is available for plant use. However, certain types of clays have the ability to fix the ammonium so that it is unavailable to plants. Because of its high solubility and negative charge, the nitrate ion, NO_3^-, is not held to an appreciable extent by soil particles and may be readily lost in drainage water. Slowly-broken-down sources of nitrogen, such as some natural organic materials and urea-formaldehyde, partially offset the effects of leaching and fixation by having a rate of conversion to nitrate that is approximately equal to the rate of absorption by plants.

Organic matter plays a dominant role in the nitrogen economy of soils. Regardless of the form in which it is applied, much of the nitrogen will very soon be converted to organic forms by higher plants, fungi or bacteria. All of the organic forms may (and eventually do) undergo transformations that make the nitrogen available to crop plants. Most of the

nitrogen in a soil at any given time is in organic form; hence, the conclusion that attention should be given to organic matter as a storehouse of nitrogen as well as the physical conditioning benefits to be derived from the organic matter in soils.

Loss of Nitrogen from Soils

In addition to the large amounts removed in harvested plants and the loss in drainage water already mentioned, considerable nitrogen may be lost from soils in various gaseous forms. The gaseous form lost will depend on the particular soil and climatic conditions. Under conditions of denitrification, nitrogen may be lost as NO, N_2O, or N_2 gases. The process of denitrification (transformation of nitrates to other forms) involves complex microbiological processes and is difficult to measure quantitatively in the field.

In some instances large losses of ammonia from soils occur. This is especially true where anhydrous ammonia or ammonium salts have been applied in too large amounts or too near the surface of alkaline soils or soils of low exchange capacity. In the case of alkaline soils, ammonium salts undergo a double decomposition reaction to release ammonia and carbon dioxide.

Properties of Nitrogen Fertilizers

A. Readily available inorganics (soluble salts)

1. Sodium nitrate, $NaNO_3$--relatively low in N content and expensive per pound of N; the sodium content may be objectionable in some cases.

2. Calcium nitrate, $Ca(NO_3)_2$--low in N content but popular on acid soils of Europe because of its alkaline nature.

3. Potassium nitrate, KNO_3--fair content of available N and good content of K, but high cost of manufacture has limited its use.

4. Ammonium nitrate, NH_4NO_3--high content of available N and low cost have made it the principal source of nitrogen for agriculture.

5. Ammonium sulfate, $(NH_4)_2SO_4$--intermediate in N content and cost; the $SO_4^=$ contained in it may cause excess acidity, but $SO_4^=$ is a plant nutrient and the added acidity may be desirable on some soils.

6. Urea, $CO(NH_2)_2$--high content of N and low cost make this salt popular for mixed fertilizers; also used to make urea-formaldehyde fertilizer.

7. Multiple salts--the principal of these are ammonium phosphates, potassium-ammonium phosphates and urea-phosphates; some of these are in common use and are expected to gain in popularity because of their high total concentration of more than one plant nutrient.

B. Natural organics:

This group includes such diverse materials as sewerage sludge, crop residues and farm animal manures. Their chief advantage is not low cost per unit of plant food, but rather their low content of soluble salts (non-burning), slow availability and contribution to soil organic matter.

C. Anhydrous and aqua-ammonia:

These materials are relatively cheap and are widely used for field crops but not for ornamental plants or turf bacause of problems of application.

D. Synthetic organics:

These materials are relatively high in N content and slowly available. Their principal advantage is that they may be applied infreguently in large amounts without damaging plants.

The principal material now being marketed is urea-formaldehyde, a mixture of methelene ureas, some of which are readily available and others much less so. This mixture of differentially soluble plastic polymers gives good initial effect as well as uniform availability over extended periods.

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POTASSIUM, THE NEGLECTED NUTRIENT

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Potassium is one of the several chemical elements which are essential for plant growth and potassium is needed in rather large amounts by plants, especially by the grasses.

All growing portions of plants, both tops and roots, are rich in the element. Potassium seems especially abundant in the cells of new roots and young leaves. Potassium is one of the more mobile nutrient elements and is apparently withdrawn from older tissues of the plant and transferred to regions of new growth. As plant approach maturity, it has been found that potassium can be translocated into the soil.

Of all the major nutrients, potassium seems to be the only one that does not become a constituent of plant compounds. Its primary role seems to be that of a catalist--a substance which accelerates a chemical reaction or enables it to go on but does not enter into the products of the reaction. An Australian researcher working with perennial ryegrass found that potassium occurs entirely as soluble, ionic potassium in cell sap and protoplasm. Other workers have found the potassium contained in plants to be readily soluble in water. It appears that if the potassium in plants is combined at all with the protoplasm, it is easily dissociated from it.

The loss of the plant's power to synthesize carbohydrate in the absence of potassium has been reported in several papers. It seems that potassium is essential for the process of photosynthesis in which sugars are manufactured. Potassium has also been found essential for the condensation of the simple sugars into more complex carbohydrates such as starches and the celluloses and for the formation of lignin, the principal compound of woody plants. Several workers have reported evidence that potassium is necessary for the translocation of the carbohydrates from one part of the plant to another.

The lignin contained in plants contributes to the strength of stems and also the leaves. It has been reported that potassium significantly affects the lignin content of plant parts. The highest lignin content was found in plants of the grass family when the plants were supplied with medium amounts of potassium. Both deficient and excessive supplies resulted in lower lignin contents.

Potassium is considered to play a role in the synthesis of plant proteins. It is believed by a number of authors to be essential for the manufacture of the protein in plant cells. A deficiency of potassium has been found to result in significantly higher amounts of both amino nitrogen and nitrate nitrogen in the cell sap at the expense of protein.

The results of several studies have shown rather conclusively that an adequate potassium supply is necessary for normal development of the growing apexes of plants, especially the grasses. Not only will the above-ground parts show abnormal growth but root growth and extension is curtailed as well.

In one of the above paragraphs the essential nature of potassium on the formation of complex carbohydrates and lignins was pointed out and it was

stated further that these compounds, especially lignin, contributes the strength to stems and leaves. Turf plants deficient in potassium are soft and lush, the leaves are lacking in turgor, and the blades are neither erect enough nor stiff enough to present a desirable putting surface. The leaves are easily bruised by traffic. The correct ratio of potassium to other nutrients, particularly nitrogen, will do much to harden and stiffen the turf.

Potassium has been referred to as the "health nutrient." It is generally accepted that potassium-deficient plants are more subject to certain diseases. The regular clipping of turf, especially on putting greens of golf courses, prevents the plant from maturing and thereby it increases the susceptibility of the plants to disease. Several studies have indicated that leaf spot diseases of turf grasses, Helminthosporium especially, are more prevalent when the supply of potassium is limited. Other diseases of turf may be similarly affected by potassium. The influence is due in part to the soft, easily-crushed leaves of potassium-deficient plants which enable the pathogens to gain entrance and in part to the concentration of sugars and nitrates in the leaves which makes more favorable media for the development of the organisms. This does not mean that applications of potassium constitute a specific cure for diseases. If it is found, however, that a disease persists in spite of regular use of fungicides, it would be wise to check the potassium status of the soil. Any practice which will promote the vigor of the plants will help combat disease.

Both phosphorus and potassium fertilization have been reported to increase the winter-hardiness of turf grasses. The effect has been attributed to the increased concentration of dissolved substances, largely soluble carbohydrates, in the cell sap. The fact that potassium increases the reserve of stored carbohydrates in the roots is thought also to make perennials more cold tolerant.

In an experiment conducted at Iowa State, it was found that Kentucky bluegrass which was supplied relatively low nitrogen and phosphorus and high potassium withstood hot weather better than bluegrass supplied with either high nitrogen, phosphorus, and potassium or high nitrogen and phosphorus and low potassium.

The practice of applying nitrogen along during the summer months is likely to induce a nitrogen to potassium imbalance resulting in greater heat damage to the turf. Many green superintendents wisely make a practice of reducing the amount of nitrogen which they apply during the hot months to about half the amount they apply during the same period of time in the cooler spring months. Some withhold nitrogen entirely during the hot months, especially on bent greens. If adequate potassium has been applied in the fall and spring, a summer application of potassium fertilizer may not be needed. In case a shortage of potassium becomes apparent, however, it might be wise to apply a light application of potassium fertilizer in the hot months. What has been said about management of turf on golf courses applies also on lawns and other grassed areas.

A common problem in the management of turf grasses is the maintenance of a good stand, often referred to as turf density. Although much of the loss in density is due to winterkilling, injuries associated with high temperatures and the weakening of turf by disease also cause many plants

to die. Potassium deficiencies aggrevate all of the above. The growth and extension of roots which are promoted by potassium are particularly important in keeping a cover of healthy, vigorous turf. The importance of potassium in helping to maintain the density of turf should be emphasized, but the need for potassium fertilization is often overlooked.

Potassium occurs in several forms in the soil. By far the greatest portion of it is present as a constituent of the minerals and the organic matter composing the solid portion of the soil. Only a relatively small portion of the potassium occurs in soluble, available forms. Potassium is taken up through the roots of plants as the potassium ion which occurs in the soil solution and also attracted to the clay particles. Either of these can be absorbed by plants.

Plant species vary considerably in their potassium needs. A review of the literature seems to indicate that the potassium requirements of turf grasses are intermediate to high as compared to plants as a whole. At least the turf grasses are generally benefited by potassium fertilization.

Some soils are well supplied with natural potassium whereas many others are deficient. Sands and sandy loams are nearly all naturally lacking in potassium. The finer-textured soils usually, but not always, contain a good supply of the nutrient. It has been said that all Texas soils are deficient in nitrogen, most are deficient in phosphorus, and some are deficient in potassium. This statement applies equally well to the soils of nearby states.

Inasmuch as the grass on fairways and tees as well as lawns and parks is usually grown on the soil occuring locally, potassium may be lacking or in adequate supply depending upon the nature of the soil. The soil mixture used to construct putting greens of golf courses usually contains more sand and potassium deficiencies commonly occur. This is especially true if the putting greens have been constructed according to Green Section specifications. The potassium problem under turf is aggrevated by the practice of frequent mowing and removing the grass clippings. The removal results in accelerated exhaustion of several plant nutrients including potassium unless the nutrients are regularly replaced. It has been shown that the removal of large amounts of herbage can reduce potassium from an apparently high to a low level in one season bringing about problems associated with potassium deficiency.

Much has been written about "nutrient balance," which is to say that an over-supply of one nutrient will bring about deficiencies of one or more other nutrients. Large applications of lime, for example, have been known for a long time to induce shortages of phosphorus and potassium and often magnesium also. The trend toward the use of nitrogen fertilizers alone, or nitrogen and phosphorus fertilizers, has resulted in deficiencies of potassium. On the other hand, too much potassium amy induce deficiencies of calcium and magnesium.

Deficiencies of potassium may be indicated in several ways. The specific symptom depends upon the species or possibly the group of plant and, to an extent, upon the available supply of other nutrient elements. Signs of potassium starvation are often seen as premature dying of the leaves when nitrogen and phosphorus fertilizers are applied in high amounts relative to the potassium. When nitrogen and potassium are simultaneously in short supply, the plants tend to be stunted, their leaves small and somewhat ash-gray in color. Premature death often occurs, starting at the tips and along the

margins of the leaves. Large supplies of nitrogen relative to potassium, on the other hand, results in the development of large leaves which are watery and lush. Actually clear-cut visible symptoms of potassium deficiency in turf grasses are not common. The growth and health of turf grasses are not common. The growth and health of turf grasses may be impaired due to a potassium shortage although there are no visible signs. The insiduous nature of "hidden hunger," especially that induced by a shortage of potassium, has been mentioned by several writers. The result is an overall loss of vigor in the plants.

Soil and tissue tests are helpful tools in the diagnosis of plant needs. By chemical techniques we hope to ascertain the "hidden hunger" that is not visibly evident. Recommended procedures for soil and tissue analyses are not entirely infallible, however, and interpretations of test results are not easy. This is particularly true in the case of potassium. For example, many people have full confidence in plant tissue tests for potassium although it is known that in nitrogen deficient plants, potassium may accumulate whereas with adequate nitrogen, potassium may be utilized so rapidly that it appears deficient.

By the foregoing statements, it is not intended to imply that soil or tissue testing are not helpful tools. They must be conducted and interpreted by a well-trained, experienced person, however, who knows or has been informed of past treatments and plant behavior. At several of the Land-Grant Universities the personnel concerned with soil and tissue testing are cooperating closely with the turf specialists. Such is the case here at Texas A&M.

Most growers of turf use liberal amounts of nitrogen fertilizer. Many make applications of phosphorus and potassium along or with nitrogen once or perhaps twice a year. In some cases, only nitrogen and phosphorus are applied. There is evidence that enough phosphorus fertilizers are being used on most areas of turf to satisfy the needs of the plants. There is about as much evidence to indicate that the amount of potassium which is being applied does not adequately supply the grass plants throughout the year. Either an insufficient amount of potassium fertilizer is being put on or the amount being applied could be better distributed through the year. Such a statement may be made because plants are known to take up more potassium than they need if the soil supply of potassium is high and a fall or winter application of potassium can be exhausted before summer.

The variations in soil characteristics and the differences in plant species mean that there is no such thing as a balanced fertilizer. Amounts of N, P, and K which seem adequate or "balanced" for a certain turf grass on one soil are likely to prove inadequate on another soil or for the desirable growth of another turf grass.

The need for better balance between nitrogen and potassium is currently receiving more attention. Relative amounts of nitrogen and potassium which appear to result in the production of desirable turf in the cooler spring months usually do not work out so well in the hot months. This is not to say that nitrogen is not needed during the summer; it does appear, however, that more potassium in relation to the nitrogen is needed during summer, especially on bermudagrass.

Potassium is most commonly applied as muriate of potash. In areas such as Florida or the Pacific Northwest where sulfur is often deficient, sulfate of potash is recommended. There has been little evidence of a shortage of sulfur in the soils of the Southwest. A few other potassium materials are used in parts of the country where such materials are cheaper than muriate of potash. At the present time, nearly all of the muriate of potash fertilizer used in the Southwest is mined near Carlsbad, New Mexico.

Most of the mixed fertilizers on the market contain potassium as well as nitrogen and phosphorus although a few contain only nitrogen and phosphorus. All of fertilizer having ratios of 1-1-1, 2-1-1, 3-1-2 and the like contain potassium. They are called complete fertilizers.

The amount of potassium in a fertilizer is expressed as percent potassium oxide usually referred to as potash. None of our potassium fertilizer materials or mixed goods actually contain potassium oxide. Any potassium compound in the fertilizer which is soluble in water is determined chemically and calculated as percent K_2O (potassium oxide). It is not necessary that any potassium oxide be present in the fertilizer. In muriate of potash, the most common potassium material, most of the potassium occurs as the chloride but there may be a very small amount of potassium sulfate present. Both the chloride or the sulfate forms of potassium are suitable as sources of potassium.

Fertilizer recommendations are usually given in pounds of plant food per acre although recommendations for lawns, golf courses and other small sized areas are often given in pounds per 1000 square feet. A recommendation of 120-80-80, for example, calls for sufficient fertilizer to supply to each acre nitrogen equivalent to 120 pounds of N, phosphorus equivalent to 80 pounds of P_2O_5, and potassium equivalent to 80 pounds of K_2O. The fertilizer recommendation is taken to mean the annual amount unless otherwise stated and all of the plant food may not be put out in one application.

In order to convert a recommendation in pounds per acre to pounds per 1000 square feet, one simply needs to divide each number of the former by 43. To the nearest whole number then, the recommendation of 120-80-80 would become 3-2-2 pounds of N, P_2O_5, and K_2O respectively per 1000 square feet. This means that an amount of fertilizer equivalent to 3 pounds of N, 2 pounds of P_2O_5, and 2 pounds of K_2O should be applied to each 1000 square feet.

The amount of potassium which will produce healthy, vigorous turf depends upon several factors or conditions. It is not possible to give a specific amount which will fit all soils and all turf grasses. Recommendations have ranged from one to as much as four pounds of equivalent K_2O per 1000 square feet annually. Frequently all of the potassium is applied in the fall or sometimes all is applied in the spring. Some people apply part of the potassium in the fall and the remainder in the spring. Most commonly all of the phosphorus and a part of the nitrogen are applied with the potassium.

Although recommendations based on sound soil tests are more reliable, the following may be helpful in arriving at the amounts of potassium to apply:

1. Pounds of equivalent K_2O annually per 1000 square feet on natural soils (lawns or golf courses)

   a. Clay or clay loam soils ..... 1 pound
   b. Loams or silt loams ..... 1 pound
   c. Sands and sandy loams ..... 2 pounds

2. Pounds of equivalent K_2O annually per 1000 square feet on putting greens

   a. Sands and sandy loams ..... 3 pounds
   b. Putting green mixture* ..... 3 pounds

For best results it appears that the annual amount should be split into fall and spring applications. The fall and spring applications should include all of the phosphorus and a part of the nitrogen in addition to the potassium. In other words, a fertilizer having a ratio 1-1-1, 2-1-1, or 3-1-2 is a good choice. Inasmuch as nitrogen fertilizer is usually applied regularly on lawns and golf courses throughout the year, a high nitrogen to low potassium balance may develop resulting in greater heat damage to the turf. In this connection, it is wise to consider reducing nitrogen slightly and increasing potassium a bit during the summer months if frequent applications of fertilizers are made. Applications of about 1/2 pound of equivalent K_2O per 1000 square feet should be ample even on putting greens.

Inasmuch as recommendations are nearly always given in pounds of equivalent K_2O, it is necessary to be able to calculate the amount of potassium fertilizer or mixed fertilizer needed to attain the recommendation. Suppose it is desired to apply one pound of equivalent K_2O per 1000 square feet, using a 12-4-8 fertilizer. The amount of the 12-4-8 fertilizer needed would be calculated as follows:

*According to the specifications recommended by the Green Section of the USGA.

The equivalent percentage of K_2O in the mixed fertilizer is 8%, therefore each 100 pounds of the fertilizer contains 8 pounds of equivalent K_2O. Since one pound is 1/8 of 8 pounds, 1/8 of 100 pounds is 12.5 pounds, the amount of the 12-4-8 fertilizer which should be applied to 1000 square feet. Such an amount 12-4-8 would supply also 1 1/2 pounds of equivalent N and 1/2 pound of equivalent P_2O_5.

Soluble salt crystals which cling to the foliage cause the injury called burning. Pelleted fertilizers are less likely to cause burning then crystalline or powdered materials. It is well to keep in mind that potassium fertilizer materials like nitrogen materials have a salt effect and will burn the turf if not applied properly. Potassium materials can be applied dry but to prevent burning the turf must be sprinkled immediately to wash the fertilizer off the tops. Muriate of potash can be dissolved in water and applied as a solution. It should be borne in mind also that uniform distribution of fertilizers is essential.

Potassium has been aptly called the neglected nutrient. Its effect on the growth and appearance of grass is not as pronounced as that of nitrogen, therefore a deficiency of potassium is not so evident and is often overlooked. From experimental evidence, we are certain that proper attention to potassium fertilization is essential for a healthy, vigorous turf.

TRACE ELEMENTS

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Trace element or micronutrient fertilization has become of major interest in the fertilizer field in the past two or three years.

The trace elements frequently are of major importance in efficient crop production. This is true also of turf production and of maintaining normal green color in healthy flowers, shrubs and trees.

Trace elements are required in measurable proportions rather than in true trace quantities. Therefore, the accepted term has become micronutrient, implying that the required amounts of these nutrients are generally small in comparison with plant demand for macronutrients.

Micronutrient elements considered to be essential for plant growth are: iron, zinc, manganese, copper, boron, molybdenum, and chlorine.

Research has been an invaluable aid in dealing with micronutrient problems in many regions of the world. Certain of these nutrients have been applied regularly to specific areas of soil and to particular plants for a long time. The use of micronutrients is increasing, as direct additions to the soil, as foliage sprays, and as constituents of mixed fertilizers. New data on their chemistry, manufacture, and use are continually being revealed by able scientists in research and development.

The history of micronutrient research has interesting parallels with other advances in contemporary science in making energy sources available for human use. We are all familiar with the tremendous quantity of energy which a small amount of uranium can release in an atomic blast. But how many of us realize the potential magnitude of a small quantity of micronutrient fertilizer? Practical field demonstrations with molybdenum fertilizer applications have revealed that a gram of molybdenum may harness more energy through greater conversion of sunlight into plant materials than can be obtained from a gram of uranium as converted to TNT equivalents. Thus micronutrients, though needed in only small amounts can have a very large effect.

One possible reason for more micronutrient deficiencies may be the trend toward the use of higher analysis fertilizers such as synthetic ammonium phosphates, ammonium nitrate, ammonium sulfate, urea, etc. This use of high analysis fertilizers also reduces the need for fillers. Some of the older type fertilizers such as superphosphates, chilean nitrate, filler materials, and barnyard manure have supplied significant quanities of trace elements as impurities which may have prevented the development of deficiencies. More vigorous growing turf resulting from better management and improved fertilization is placing a greater demand on the soil for micronutrients. Better liming practices may also cause the micronutrients to become less available as the pH is raised. Total areas where micronutrients are needed is not well known; however, it is safe to say that we may expect more micronutrient deficient areas to be located in the future.

As far as is known at present, the total number of areas where trace elements are needed is very small compared to areas where nitrogen, phosphorus and potassium are needed.

The knowledge of the need for micronutrients is of comparatively recent origin. Therefore not as much research work has been done on micronutrients as has been done on the major plant nutrients.

Only a small percentage of the total amount of any of the micronutrients found in the soil is released for plant growth. In this respect micronutrients are like the major plant food elements. The main supply of the elements is locked up in soil minerals and in the soil organic matter. This supply is realeased slowly over a period of time. When the elements become soluble or available, plants use them. As the plants withdraw them from the soil, more become soluble. It is about like drawing water from a well. As water is drawn out, the water level in the well drops below the level of the water table of the surrounding soil. If the water is pumped out faster than the soil can supply it, the well goes dry temporarily.

The amount of any one of the micronutrients needed by a particular species of plant varies from other species in the same way as does the need for nitrogen, phosphorus and potassium. For example, azaleas and roses have a much higher requirement for iron than does bermudagrass. St. Augustinegrass is also rather susceptible to iron chlorosis.

Iron deficiency symptoms usually appear as light yellow chlorotic stripes on the youngest leaves between the green veins. Most soils contain a great deal of iron but under highly alkaline conditions this iron is not available to plants. Iron deficiencies can be corrected by spraying of iron sulfate (about 0.5 percent solution), or iron chelates on the plant leaves according to the manufacturer's directions. However, this may have to be repeated frequently throughout the season because iron is not stored up. Other micronutrient deficiencies are more difficult to diagnose but are found less frequently in Texas.

There are no really good soil tests for determining the amount of available micronutrients in the soil. Probably one of the best tests is to try a small amount on an area where a deficiency of one of the micronutrients is suspected. A test strip across an area will tell you whether or not it is needed.

DEVELOPMENT OF PARK USE AREAS ON SANITARY LANDFILLS

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The sanitary fill is the only practical alternative to incineration for refuse disposal in the United States. No one should ever consider the open dump. The open dump has a record as a carrier of disease, potential fire hazard, generator of odors, pest and bad aesthetic appearance.

Climate should have little effect on the operation of a landfill for the equipment available today will meet practically any condition. The appearance of the disposal site, whether it be a burning, rat-infested dump or a clean sanitary operation, depends upon the will of the people and not upon the physical obstruction.

Under most conditions one of three basic techniques are available for the construction of a sanitary landfill: the trench method, the area method and the ramp method.

Certain basic principles apply to the sanitary landfill, regardless of the method employed. One advantage of the fill is its flexibility. No city should rely on a sanitary landfill unless plenty of land is available--enough to continue the work for more than 20 years.

Controlling factors for sanitary landfills include method of operation, composition of refuse, degree of compaction and amount of cover material used each day. Seven acre feet per 10,000 persons per year at one time served as a guide to spatial requirements. This figure is close to the median of the most recent data as reported in the American Cities Magazine.

Methods of Operation

The Trench Method

The trench method provides for the most orderly sanitary fill operation. It is probably the oldest method and is particularly suited to flat or gently rolling ground. In this method, the refuse is placed in the trench and covered with the material removed during the excavation. Local conditions dictate the manner in which the operation is conducted. Where sufficient equipment is available, excavation may proceed on a day-to-day basis, with freshly excavated earth used to cover the refuse as it is brought to the landfill.

Trench depth normally runs between six and twelve feet but may be considerably deeper. The trench should be wide enough to provide operation room for the equipment working in the trench, but not so wide that the tractor operator loses control of the working face. Trenches can be as close together as three feet, depending on the soil characteristics.

The Ramp Method

The ramp method is sometimes called the progressive slope or moving trench. It embodies some of the techniques of the trench and area methods. One basic difference is the technique of obtaining cover material just ahead of the operating face. In most ramp-type operations the refuse trucks and the equipment working the fill approach the working face from opposite directions.

The Area Method

The area method, while it does not provide as orderly an operation as the trench method, does permit the filling of gullies, ravines, abandoned gravel pits and similar depressed areas.

Cover material is obtained at the site or hauled in from some nearby point. Where cover material is scarce, it is often hauled to the site and stockpiled when available. Some cities specify that excavated material from public works projects, such as street paving, must be hauled to the sanitary fill site.

Practical Uses of Sanitary Landfills

The general public has a different concept of sanitary landfill than that of the sanitary engineer. Usually associated with refuse disposal are the factors of potential fire, flood, health and traffic hazards. These concepts are based on the old-time smoldering dumps.

With the sanitary method of refuse disposal, stringent provisions can be worked out acceptable to all parties and protection for the residents in areas adjacent to the landfill site. Regulations can provide for fire and flood protection as well as for working hours. Salvage activities can be eliminated. Heavy-duty mufflers and silencers on all equipment can regulate exhaust noises. Fencing the area confines any loose paper and debris to the site. Each day's deposit of refuse can be covered with earth before the day's work ends.

Several cities have realized the potential value of the sanitary landfill area. They have either developed recreational facilities, or have plans for future development, over sanitary landfills. A few examples will be given.

The Maryland National Capital Park and Planning Commission of Silver Spring, Maryland, has successfully developed park land on sanitary landfill. It is located on property adjacent to the Anacostia River. In considering future developments, the Washington Suburban Sanitary Commission was given permission to fill an area of approximately 45 acres, subject to a predetermined grading, a covering of top soil is required on the site of two feet. The total estimated cost of time with regard to this fill is six years. After the landfill is completed, the ground covering provided, the Park Commission will assume all responsibility for stabilizing of the top soil and detailed revision of the grades to meet the requirement for a golf course.

Glendale, California, planned extensive developments on sanitary landfills. Glendale was faced with a problem of a shortage of land for needed expansion of park facilities. In 1960, Glendale was almost completely developed, with virtually the only undeveloped land being hilly or mountainous terrain unsuited for park purposes. As the city continued to grow, primarily through vertical expansion in multiple-dwelling units and development of hillside lots, the increasing leisure of its population created a demand for more parks and recreation programs. With the need for new level land, the use of sanitary landfill was proposed for the development of a park site. This involved filling a canyon of over 30 million cubic yards to an extreme depth of as much as 430 feet. This volume provides low-cost refuse disposal facilities for 700,000 for 15 to 17 years.

Four stages for the development of the park were proposed. Facilities included an 18-hole golf course, a clubhouse, driving range and other active recreation areas.

The Economic Aspects

The estimated value of the reclaimed land is $1,900,000. A $1.25 per ton dumping fee was established and a provision was made for a 25¢ per ton royalty to be pledged for park construction. The royalties would mount to $2,000,000 during the life of the project. Upon completion of the project, the income of the county will be sufficient to permit commencement of other similar projects elsewhere, thus making possible continuation of the program of reclaiming unusable land and erecting parks on the filled sites.

In Charlottesville, Virginia, the sanitary landfills of the area type were opened to push the old fill toward a creek to make room for more fill. After six years, all garbage was decomposed but some paper and rags were still in good condition. Ferrous metals without galvanizing were pretty well rusted away. The disturbed material packed solidly and the only odor was a musty one. The city of Topeka, Kansas, also uses a sanitary landfill in order to push back the banks of the Kansas River. The water has been moved back about 200 feet at the particular site of the landfill.

A bit of American Revolution history has been restored and perpetuated in Mount Holly, New Jersey, through the township's sanitary landfill. The Iron Works Park commemorates the tract of land on which stood a revolutionary war iron works that manufactured connon balls used by General George Washington in battle in and around Mount Holly and Trenton. Most of the park was a 22-acre swamp. It has been reclaimed by the sanitary fill method, has been successfully landscaped and has some improvements.

Recommendations

Based upon the report of Mertz, UCLA, and from personal correspondence with directors of parks in numerous cities employing sanitary landfills for recreational areas, the following factors should be considered in the construction of sanitary landfills for recreational use:

1. Dumping should be controlled to keep the working area as small as possible, for the size of the operation. The working surface should be no larger than is necessary to accomodate all the collection equipment without delay at the site. This helps to control the blowing of papers and other light materials and provides for a better appearing fill site.

2. Good housekeeping is mandatory to keep complaints to a minimum and to make it easier to locate new sites. The working area should be fenced to prevent papers from blowing around. Quick compaction and covering of the refuse is the key to clean operation.

3. The depth of the fill should be no more than 12 to 15 feet for the various methods of operation. Deeper fills should use alternate layers of earth and refuse to increase the compaction ratio.

4. The covering of the fill should be top soil with a minimum depth of

two feet. Three to four feet would be a better recommendation. Some cities have used up to twenty feet of clay. The growth of grass on less fill than two feet has been met with difficulty.

5. Whether the trench, area or ramp method of construction is employed, the greatest shrinkage usually occurs in the first six months after its completion. After six months the rates of settlement are negligible. The area should be regraded to the desired level; and, at this time, plant material can best be planted. Trees can be planted in areas between cells.

6. The rate of settling for any specific method varies with the type of refuse employed to make the fill. The exact amount of settlement cannot be predicted. If differential settling does occur, additional soil should be used to bring the area up to the desired grade.

7. Material used in the landfill process should be limited to normal refuse which will have a uniform rate of decomposition. That is, materials can be classified and deposited at different sites. Concrete slabs, rubber tires, large rocks, tree trunks, car bodies should not be mixed with normal refuse acquired from residential areas.

8. Gass production is a major problem of the sanitary landfill. Gasses have caused some fires; workers have been asphyxiated during the excavation of landfill areas. In general, the thicker the soil covering, the less problems with gasses.

9. No permanent structures should be built on a landfill after its completion. If structures are necessary, predetermined grades should be established; foundations and piers should be poured prior to the fill operation. Pre-planning is extremely important for drainage, installation and location of roads and permanent structures. Depending on depth of fill, underground water mains can be installed prior to fill.

10. If good topsoil is not available, sewage sludge may be successfully employed to improve the structure of the soil. Due to bacterial action, additional fertilizer will be required for the first few years, depending upon the rate of decomposition of the sludge.

11. The water and fertilizer requirements of grass and other plant material is generally higher the first few years after the construction of the fill. This is generally due to the structure and composition of the fill material, and leaching of nutrients through the fill.

In summary, the best use of a sanitary landfill seems to be for the development of parks, golf courses and play grounds because of the flexibility of design and the need for a minimum number of structures over a wide area. The sanitary landfill offers a large potential for the development of future recreation areas. In many cases land used for a landfill had little or no value. In practically all cases, the reclaimed land has a higher value than the original purchase price. Developing of the areas require preplanning and special techniques. In preplanned fills, after the first two years of the development of the area, normal maintenance practices are generally the only requirements.

WEED CONTROL IN TURFGRASSES

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In discussing the weed problems in bent greens, bermudagrass greens, and turf for parks and playgrounds, we should take into account a number of factors common to all. Conditions that are specific for each of the above types of turf will be discussed under specific headings. Weeds compete with the different turfs for plan nutrients, moisture, and light; often increasing the mowing problems, affecting the playability, and spoiling the appearance of our desirable grass areas.

The use of pesticides and fertilizers is essential for producing and maintaining acceptable greens, tees, fairways, lawns, parks, and playgrounds--but the handling and treatments vary for each use of the grass. Care in treating the various turfs should be our slogan in the use of pesticides and fertilizers so that injury rarely, if ever, occurs, and the beneficial grass responses are obtained. This is a big problem.

First, we should review some of the problems caused by weeds. Heavy stands of weeds remove a considerable amount of nitrogen, phosphorus and potash applied for the grass needs. Research in Texas indicates that heavy stands of weeds use as much as 30, 8 and 16 pounds per acre per year for N, P and K respectively.

Weed heads and vegetative growth on the greens and fairways present problems in the golf courses' playability. In the Northwest, the heads (flowering parts) of the English daisy growing in the fairways result in deflecting the roll of the golf ball and often makes it difficult for the player to see the ball.

Mowing practices are affected by the growth of weeds in the turf. Weeds and grass grow at different rates. Weeds tend to grow faster during the cool season, requiring additional mowing. The cutting texture and varying plant sizes require adjustment of the mower to obtain even and uniform cutting. Weed control is necessary to keep the turf suitable and acceptable for play.

Each year we hear more and more about the appearance of the greens, fairways, lawns, parks and playgrounds. Weeds growing in grass areas spoil their appearance. In the winter, weeds in bermudagrass stand out like a "sore thumb" although we may like their bright green color.

In the hot seasons, there are special problems in maintenance and management of turf. Dr. Ferguson stresses the point of minimum treatments of fertilizers, herbicides, insecticides, and fungicides during hot weather because the grass is already taxed to the maximum to maintain life. The plant processes for life are growth, respiration, transpiration, moisture, and nutrients. During hot weather, transpiration is extremely high. The plants require a lot of water; and, as the functions are maintained, any change due to too much fertilizer, possibly herbicide injury, or adverse watering practices, may upset the balance necessary for proper plant functioning.

In the August, 1962, issue of The Golf Course Reporter, there was an excellent article by Dr. John A. Long on "Weed Control in Southern Turf."

Information is presented on the seasonal weed problems, effects of weed infestation, management limitations, and the advances in herbicide control up to 1962.

We have cool-season weeds, which are growing now, and warm-season weeds which are bothersome during the summer. Dr. Long gave us a list of these seasonal weeds with data on responses of the broadleaf weeds to the treatment of 2,4-D and Silvex.

Bent Greens

Weed control in bent greens often presents some special problems due to the fact that many of the herbicides cause injury to the bents. In general, there is a greater possibility of injury to the bent green during the summer, so weed control during the cool season is suggested whenever possible. Under any condition, spot check bent grass before making a treatment to all the greens.

I have also heard that it is also wise to test treat a green that is not in full view of the club house window, porches or patio.

Winter weeds should be controlled so the bent grass can fill in the weed areas when the weather is most suitable for growth and increased plant vigor.

Bents are sensitive to any herbicides that would be effective for weed control. 2,4-D often causes injury to bents and should not be used although it gives excellent control of dandelions and plantains; but its control of chickweeds, knotweed, henbit and burclover is not satisfactory. Silvex, which became available a few years ago, gives good control of mouseear chickweed, common chickweed, burclover and clover; but its control of dock, knotweed, henbit and spurges was only fair to good. Silvex causes more injury to bent greens than is generally acceptable.

Recently two materials have been evaluated for control of weeds in bent greens. The products are MCPP and BANVEL D (dicamba). Some of the first tests using MCPP on bent greens were conducted in 1961 and followed by tests of BANVEL D in 1962. These products are to be handled with care on bent greens, but have greater safety than the previous tested materials.

Dr. Duich of Pennsylvania State University has tested MCPP and reported his findings in the 18th Annual Meeting, Northeastern Weed Control Conference, January, 1964. MCPP was applied at the rate of one pound per acre to 14 bent strains. Treatments were made on June 13, August 30 and October 17. Chickweed control was excellent for the June and August applications, but poor from the October treatment. C-1, C-19 and Seaside showed the most injury of the strains tested.

In 1963, MCPP, MCPP plus 2,4-D, 2,4-D, 2,4,5-T, and dicamba (BANVEL D) were applied at different rates on September 6. Injury ratings were on the scale of 0 to 10 with 0 being no injury. Readings were taken on September 15 and September 30. All rates for the above products showed traces of injury on September 15, but "0" injury ratings were recorded on September 30 for MCPP and 1.0 and 1.5 pounds per acre and for dicamba at 0.25 and 0.5 pounds per acre. All rates of dicamba and

MCPP gave 100 percent control of chickweed. In 1964, dicamba at 0.25, 0.5 and 0.75 pounds per acre gave excellent control of Dutch white clover (99 to 100 percent) and knotweed (80 to 99 percent). MCPP at 1.0 and 1.5 pounds per acre gave good to excellent control of white clover (85 to 97 percent), but poor knotweed control (0 to 53 percent).

Dr. S. W. Bingham of Virginia Polytechnic Institute has evaluated herbicides for Dutch white clover control in bent greens and turf. White clover has been a very serious weed in the greens of Virginia. Materials tested for white clover control were various salts of Silvex, 2,4-D and 2,4,5-T and the dimethylamine salt of dicamba. Weeds, other than white clover, were buckhorn plantain, curly dock and chickory. Dicamba at 0.5 pounds per acre gave 100 percent control of white clover, curly dock and chickory but poor control of buckhorn plantain. The other materials gave up to 90 percent control of the various weeds. Dicamba was tested at a number of locations for white clover control in bent greens at rates as low as 0.25 pounds per acre and gave complete control. "Dicamba at 1/2 pound per acre was effective for control of white clover with little or no phytotoxic effect to bent grass turf."

Two new products, dicamba and MCPP, have been used on a number of bent greens with promising results for weed control of white clover and chickweeds. The control of knotweed with the dicamba treatment has been excellent. There has been some temporary discoloration in various research tests, but in other tests there has been no discoloration of the bents. Some golf course superintendents have detected no discoloration and some only temporary discoloration in the use of these products.

For bent grasses, especially greens, care should be taken in the application and the dosage rates of the herbicides. With greater safety, dicamba and MCPP showed definite promise in giving control of some of the weeds which previously has not been satisfactorily controlled by available materials.

Bermudagrass Greens

Many of the general points given on grass and weed management are applicable to the handling of Bermudagrass greens. During the winter the Bermudagrass turns a brownish color and the cool-season weeds make a serious contrast of colors. In overseeded areas, or on bent greens, the contrast between weeds and grass, from the color standpoint, is not so important.

Dr. Long listed eleven weeds of importance in the Southern Turf. Of these weeds, spurges and Aster were resistant to 2,4-D or Silvex treatment. Other weeds of the eleven which were resistant or intermediate in response to the 2,4-D treatment were mouseear chickweed, common chickweed, true clovers, carpet burweed, henbit, mattchafflower and prostrate knotweed. The response to Silvex is somewhat different, but weeds of the eleven not susceptible were: carpet burweed, mattchafflower, henbit, prostrate knotweed and dock.

We need additional information on the tolerance of various bermudagrasses to the new herbicides. Dr. E. O. Burt, University of Florida, presented a paper at the 17th Annual Meeting of the Southern Weed Conference, January, 1964, on the tolerances of six grasses to many herbicides. Tifgreen and Ormond bermudagrass were in the test. In general, the preemergence crabgrass materials at rates of 2 and 4 times the suggested rates appear safe. Of the materials used for broadleaf weed control, Simazine was safe on Ormond but at the 8 pound

rate showed considerable injury to Tifgreen. Dicamba at 4 pounds gave practically no injury to Ormond but definite injury to Tifgreen. Tordon at 1/2 pound rates appeared safe but rates of 1 and 2 pounds per acre caused marked injury to Tifgreen and considerable injury to Ormond at the 2 pound rate.

Dr. Wayne Huffine, Oklahoma State University, has been evaluating materials for better control of henbit. From some preliminary work, Silvex and dicamba appear promising. In 1964, he conducted two tests, one applied on January 3 and the second on March 6. Dosages rates were 0.5, 0.75 and 1.0 pound per acre for both materials. Plots were scored for control on March 31 and April 28 with the method of scoring being 10 as complete kill and 0 as no effect. The March 31 scoring was too soon after the March 6 treatment to show results, so all results were based on the April 28 ratings.

When materials were applied on January 3, the ratings were 9.3, 9.5 and 9.9 for dicamba at rates of 0.5, 0.75 and 1.0 pounds per acre respectively. Ratings for Silvex were 7.5, 8.3 and 9.1 respectively for the different rates. When these products were applied in March, control in general was 7.9 and below, which is not satisfactory. The high rate of Silvex has a score of 8.9. Early application of BANVEL D in September and a spring application in March under Alabama conditions gave poor control of henbit. Dr. Campbell, Kansas State University, has obtained satisfactory control of henbit with BANVEL D at the 1 pound rate when applications were made in December. More tests are underway to check the optimum time of the application for the best control of henbit.

The research work in Texas indicated that late November application (November 21) of BANVEL D, Paraquat, cacadylic acid, and Endothal gave better control of cool season weeds than either mid-winter (January 21) or spring applications (April 9). "BANVEL D, Paraquat, and Endothal effectively reduced weed competition and allowed the development of good bermudagrass cover where only thin stands had previously existed." BANVEL D is slow in killing weeds, but it did not discolor bermudagrass and can be used during the growing season. BANVEL D is a selective material and did not affect the established grass but but did not control the grassy weeds in the Texas test. BANVEL D and Paraquat showed residual burclover control from the November application, but cacadylic acid and the 1 pound rate of Endothal were not effective. From the mid-winter application (January 21), BANVEL D at 0.5, 1.0 and 2.0 pounds per acre, Paraquat at 2 and 4 pounds per acre, and Endothal at 2 pounds per acre definitely reduced burclover stands according to the April 14 readings. Simazine has been effectively for weed control in bermudagrass, but spring applications may cause damage.

Parks and Playgrounds

Common bermudagrass and St. Augustinegrass are the most commonly used grasses in the parks and playgrounds. The information given for broadleaf weed control in bents and bermudagrass should be satisfactory for St. Augustinegrass. Simazine and Atrazine wettable powders are suggested as a preemergence control of broadleaf weeds in St. Augustinegrass. The suggested rate of active ingredient is 2 to 4 pounds per acre. As mentioned before, Simazine used in the growing season may cause injury to bermudagrass. It is suggested on the BANVEL D label not to treat inside of the drip line

of trees or shrubs.

Caution should be used in the application of herbicides, and the directions on the label should be followed.

Grassy weeds are a problem and recently considerable research has been conducted on the methylarsonates and related compounds. Texas Leaflet L-425 presents information on treatment, and Dr. Holt and his group are doing special work on the control of nutgrass. Annual bluegrass is a serious grassy weed in many areas. Some extensive work has been conducted by Dr. Goetze of Oregon State, and Betasan is one product which has shown effective control as a preemergence material, but more research is needed.

In summary, new herbicides are being found to handle special weed problems that the phenoxy materials do not control satsifactorily. Better control of Dutch white clover, chickweeds, knotweed, henbit, chickory, dock, and red sorrel in bent greens, bermudagrass greens, and turf can be obtained with the proper application of BANVEL D (dicamba) and/or MCPP. Always spot test the pesticides to check their effectiveness and safety to grass or other plants under local conditions. Extensive tests are conducted before label acceptance can be obtained, but each operator should handle the pesticides carefully and properly. As mentioned in the beginning, pesticides and fertilizers are essential for the production and maintenance of the best turf, and with the research and the newer products, better turf can be obtained for use on the golf courses, parks, playgrounds and for home lawns.

Outside living in the warm areas has increased the need for good turf. With the new technology and increased research, better turf and maintenance methods are and will be obtained for outside living and pleasure.

INSECTS AND INSECTICIDES

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There are some insects which have caused damage for the first time in parts of Texas and others that have caused more damage than usual and will possibly continue to do so. I would like to discuss some of these and their control at this time.

First of all, let's talk about the bermuda mite which belongs to the group normally called the aeirophyid mites. These mites are extremely small and cannot be seen without the aid of a microscope. Since the mites are so difficult to see, it is necessary to be familiar with the type of damage they do in order to detect them before they have caused serious damage. Heavily infested bermudagrass will fail to begin normal growth in the spring despite adequate moisture and fertilizer. Grass that does appear will display typical rosetting and tufting of growth caused by shortening of the internodes and apparent stimulation of abnormal leaf growth and will eventually cause grass to turn brown and die. This, of course, thins the bermuda considerably and allows noxious weeds and grasses to invade the turf area. Areas that develop heavy infestations during the season will usually start showing this damage in July and August in Texas. The mites like hot, dry conditions; therefore, the first damage will usually appear on dry ridges, along margins of the turf area or in shaded spots where the moisture stress is normally first apparent. The mites will be found beneath the leaf sheaths.

Lawns which are mowed close and irregularly seem to show the most injury. This is not necessarily true on golf courses which receive regular close mowing. Shorter plants may be subjected to conditions of lower humidity when cut infrequently.

Summer blight fungus, a Helminthosporium species, is nearly always present where bermuda mites are found. It is very likely that the killing of the grass is actually caused by the fungus rather than the mites. Damaged or unthrifty grass is much more susceptible to fungus attack than good healthy grass.

The variety of bermudagrass is apparently a very significant factor in susceptibility of bermuda mite attack. Arizona common, Ormon, and Tifgreen seem to be very susceptible while Sunturf, Uganda and Tifway seem to be quite resistant to mite damage. Of 218 bermuda selections tested for susceptibility to bermuda mite damage, 115 showed no symptoms whatsoever, while 25 showed severe symptoms. The other 78 showed intermediate degrees of susceptibility. This indicates that selections could be very useful in developing mite resistant strains of bermudagrass.

Well-fertilized grass seems to be much more attractive to mites than poorly or non-fertilized grass. However, fertilizing damaged areas with nitrogen fertilizers is effective in making the grass grow out of the damage.

Flood-irrigated turf areas are less likely to have bermuda mites than sprinkler-irrigated areas or where rainfall alone is the water supply.

Trithion, diazinon and dimethoate are chemicals that have shown good results when properly used. Dusting sulphur at one pound per 100 square feet has also been effective, however it has a disagreeable odor and should children play on the lawn, it is possible that they will get sulphur in their eyes and cause severe irritation. This can be prevented by using flowable sulphur which is in a liquid and adheres to the plant very good. The use of a surfactant would be helpful as it will cause the material to get further down in the leaf sheath by breaking down the surface tension of the droplets. The application of an effective insecticide plus a nitrogen fertilizer or follow closely after application with the fertilizer application will help the grass grow out of the damage faster.

Lawn chinchbugs continue to spread throughout the St. Augustine-growing areas of the state. Their typical damage is a brown dead spot in the middle with yellow marginal area around it. These spots will increase rapidly in size and new ones will appear if the area is not treated. These spots usually show up first in the edges of the lawn, along sidewalks, curbs, flowerbeds, etc. St. Augustinegrass that is well-fertilized with adequate moisture may host as many as 350 to 500 chinchbugs per square foot with no visible damage. When fertility or moisture is lacking, damage will show with fewer chinchbugs present. Usually the heaviest concentration of the chinchbugs can be found in the yellow marginal area around the dead spot of the affected area.

Adults of the lawn chinchbug are approximately 1/5 inch long, black in color with white marks on the wings. The immature stages, or nymphs, are pink to red in color with a white band around the middle and are about 1/20 of an inch long when they first hatch from the egg. The nymphs shed their skin five times in the growth process before developing into winged adults. Female chinchbugs will lay 15 to 20 yellowish eggs a day until they have laid from 300 to 500 eggs on the lower stems and roots of the grass plants. These eggs hatch in about 7 to 10 days and the nymphs start immediately to feed on the roots and lower stems. Both nymphs and adults have piercing and sucking mouth parts and suck the nutrients from the plants by inserting their needle-like snout. The life cycle is complete in 45 to 60 days; therefore, it is possible for them to have four to five generations a year in Texas. Adults hibernate in thatch or grass clumps in the winter months and become active again in the spring when the temperature gets up to about 70 degrees. At first in the spring, this will be for only a few hours a day at which time they come out to mate and/or feed and prepare themselves for the warm weather that is ahead. The chemicals that have been most widely used and most effective are trithion and ethion, and aspon. Other materials that are recommended are diazinon, sevin, and VC-13. For best results, chemicals should be used properly. It is advisable to soak the lawn thoroughly before treatment. The soil should be wet at least two to three inches deep as this helps the insecticide penetrate the thatch. Surfactants will help penetration, but do not depend on them entirely. The proper dosage of the chemical used should be distributed uniformly over the area treated. When power sprayers are used, twenty to thirty gallons of water at 100 pounds pressure per square inch should be used per 1,000 square feet. For best results, a Teejet nozzle should be used as it will give you larger droplet size and less drip. With the hose-on type sprayer, 30 to 40 gallons of water per 1,000 square feet should be used. Pay special attention to the edges and treat the entire area as spot treatment is not recommended. Do not water the treated area for at least 48 hours.

Granules of the recommended insecticides are effective if properly applied. These granules should be put on dry and thoroughly watered in.

Fertilizer-insecticide combinations are effective when properly applied; however, it is not too often that a fertilizer application is needed when chinchbugs should be controlled. Preventive applications of the recommended insecticides in April or early May will often delay or entirely prevent damaging infestations from occuring. These areas should be watched closely and additional applications made as necessary.

Fall army worms caused considerable damage over many areas of the state this year after we received early fall rains. Wet seasons are favorable for the development of this pest. These worms are the larvae stage of a moth.

The larvae are greenish or brownish in color and grow to 1 1/2 inches in length. They live for 12 days or a month depending upon food supply and weather conditions. They feed primarily on grain and grass crops and are voracious feeders. After the food supply is exhausted in one area, they move as an army to new areas; thus, the name "army worm."

This pest is very easy to control with chemicals. Nearly any of the chlorinated hydrocarbons such DDT, toxaphene, chlordane, heptachlor, or dieldrin are effective. Sevin and malithion are also effective and safe to use. Chemical application should be made as needed.

Sod webworms have also been more plentiful this year. These worms are the larvae of a Lepidoptrous moth and feed primarily at night. In the day time they stay in silk-lined tunnels just under the soil surface. They have chewing mouth parts and feed on the grass blades, often cutting the blades off and taking them into the tunnel to eat them. They overwinter as partly grown larvae in the silken tunnels. Their size will range from 1/2 to 1 inch.

The first visible sign of the sod webworm will be irregular brown areas. By taking a section of the sod and breaking it apart the worms and their silken tunnels are found. Another way is to sprinkle one square yard of the suspected area with one gallon of water plus one tablespoon of pyrethrum extract or oil of evergreen. This will cause the worms to come to the surface.

Most of the chlorinated hydrocarbons such as chlordane, heptachlor, dieldrin, toxaphene and DDT have been effective in controlling this pest. However, several people have reported difficulty in controlling sod webworms with some of these materials this year, and there is a possibility that they are developing a tolerance for the chlorinated hydrocarbons. Should you experience such difficulty, I would suggest that you use malathion or sevin, either of which will do a good job.

For the rates of application recommended for the control of the insects discussed, please read your insecticide label or consult your county agent or other informed persons of your area.

THATCH - ITS DEVELOPMENT, EFFECTS AND CONTROL

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Thatch is a natural development in all good turfgrasses. Thatch is the surface accumulation of dead stems, clippings and old dead leaves of the grass plant.

Grass blades grow in all directions from the base of the plant. Conventional mowers (reel types, rotaries, sickle bars, and flail types) can cut only those grass blades that are standing upright. They cut horizontally only the grass blades that are in line with their cutting elements, and it has been demonstrated that conventional mowers used for regular cutting of turfgrasses clip only 20 percent or less of the grass at each cutting.

The basal uncut blades of the grass slough off and die. These accumulate as undecayed organic matter and become part of the thatch. Grass clippings fall back into the turf to become part of the thatch. Surface stems die off to add to the accumulating undecayed surface material.

To retard the accumulation of thatch, grass catchers are used on the mowers to collect clippings. However, it is impossible to collect all of them with present-day equipment. The accumulation of clippings that are missed, along with dead surface stems and the basal uncut blades, have their effect in thatch accumulation.

Thatch, therefore, is an inevitable condition on intensely managed turfgrass areas.

To further hasten thatch accumulation are the increased use of fertilizers, the better management practices and the development of hybrid strains of turfgrasses. These all contribute to increased growth, which is what we are striving for on the golf course. It does, however, result in the more rapid accumulation of thatch. Unless thatch is controlled, it can lead to disastrous loss of turf.

Deleterious Effects of Thatch on Turfgrass Areas

Accumulated thatch on turfgrass areas is undesirable for many reasons. Apart from the total loss of grass, we can list its bad effects as follows:

1. Thatch interferes with the performance of the game. In golf, a thatched green is a "grainy" green and such a green seriously interferes with the putt of the ball. On golf tees, turf is too deep. To anchor the wooden tee properly in the ground reduces the clearance between the ball and the turf. On fairways, the ball nestles down into the turf, requiring the player to slice out more turf to get to the ball. Grass between the club head and the ball makes it extremely difficult to control the shot. Carry of the ball is not as great because much of the force applied to the club head is lost before it reaches the ball.

   In games where the ball is made to roll, lawn bowling and sometimes baseball, the roll of the ball is deflected.

In running games, such as baseball, soccer, football, and lawn tennis, the graininess and sponginess of the turf lessens much needed foot traction. Sponginess of turf, which is synonymous with thatch, causes "footprinting" and results in uneven playing surfaces.

2. Thatch is the cause of many turfgrass problems. Thatch holds too much water resulting in turf areas that are too wet for too long. (Thatch will hold as much as 500 times its weight in water.) Irrigation or natural water is held at the surface and does not get down to the root bed of the grass plants. This brings about a shallow root system since roots will grow only in the presence of moisture.

   When accumulated thatch is packed down by men and machinery, it is reduced to a felt-like layer which is extremely hard to wet; and, when it is wet, it does not dry out normally. It becomes a perfect thatch roof over the soil, effectively shedding water. Water run-off on such areas can be as high as 80 percent. In an age when water conservation is of concern to all of us, this is a serious matter.

   Disease is always more devastating on heavily thatched areas. Many of the turfgrass diseases depend upon partially decomposed organic matter in which to multiply and grow. Thatch is a perfect host for turfgrass diseases. Fungicides, which normally do a good job of controlling turfgrass diseases, become relatively ineffective when applied to turfgrass areas that are heavily thatched.

3. Thatch screens out vital nutrients and contributes to shallow root growth. Fertilizers that are applied to the surface are simply filtered or screened out and never reach the soil below. The results of this filtering action is that roots will come to the surface to feed, resulting in shallow root systems. Lime, phosphates and potash are similarly affected. It has been well established, both experimantally and in practice, that these materials do not move rapidly through the soil and tend to become fixed rather rapidly. Thatch can prevent these materials from reaching the soil. As will be described later, lime is beneficial in controlling thatch. But if lime is applied because soil needs it, the thatch layer will prevent it reaching the soil.

   There are indications that even soluble nitrogen, when applied to heavily thatched turfgrass areas, is held in the surface thatch because of the highly absorptive quality of the undecomposed material. All these effects of thatch unquestionably restrict root growth of the turfgrasses.

4. Last and most serious is the spontaneous combustion that can occur in heavily thatched areas. Under certain conditions, when temperature and moisture are in balance to favor rapid decomposition, bacterial action is accelerated. Accelerated bacterial action generates heat. Heat drives off moisture and kills the grass plant. (Proof of this is to note the rapid decomposition

and heat generated in a pile of grass clippings.)

In view of all these deleterious effects of thatch, we know that the control of thatch is of vital importance to the survival and use of intensely managed turfgrass areas.

Control of Thatch on Turfgrass Areas

In agriculture, one of two things, or a combination of the two, is done to the crop that is produced. One is to harvest the crop and remove it from the land on which it was grown. The other is to plow the crop under to enrich the soil and add valuable organic matter for other crops to use. Also a combination of these two things may be done--part of the crop may be harvested and removed and part of it may be plowed under (for instance, when corn is cut and removed and the stubble is plowed under).

These same principles apply to turfgrasses, for they too are an agricultural crop. However, the methods used are different. The objective with turfgrasses is to perform these removal and decomposing operations and still keep the area in use. As a result, various methods and types of operations have been developed. Most of these practices keep one objective in mind--to do as complete a job as possible of thatch removal and decomposition with the least disturbance to the use of the area.

These methods of thatch control and removal can be divided into three categories. They are:

1. Temporary Cultural Methods
2. Cultural Management Practices
3. Renovation

Let's examine each one of these categories.

Temporary Cultural Methods

These are operations and practices which cause little or no disturbance to the use of the turfgrass areas. The methods and practices produce a temporary relief from a basic problem, but do little or nothing to permanently correct a bad situation. These methods and practices can be likened to taking aspirin for a headache. You still have the headache, but it doesn't hurt anymore. Aspirin does nothing to get rid of the basic problem that caused the headache. Temporary cultural methods have this same effect. They alleviate the headache. They help us "get by." They carry us through the trying periods until conditions are better to get rid of the basic problem.

Temporary Cultural Practices include:

1. Light Syringing: Light syringing of turfgrasses under stress "puts the fire out" (using O. J. Noer's famous words). It reduces the temperature and adds small amounts of water. Oxygen, adsorbed to the fine particles, is carried to the suffering root system to sustain life.

2. Application of Lime: Very light dusting with hydrated lime gives turfgrasses under stress relief. This should be done with much

care. The mechanics of using lime in this manner is not well understood. It is thought that the lime absorbs some of the moisture. (Mold will not grow on dry bread.) Drying the turf will help check disease. It has an effect on the pH in the micro zone of the turfgrasses.

3. Use of Iron: When turfgrasses are under stress, they sometimes become chlorotic (indicated by the yellowing of the grass blades). Light applications of iron applied to the leaf surface produces an immediate response.

4. Height of Cut: The height of cut is sometimes increased when turfgrasses are under stress. Increased leaf surface helps the grass plant through these trying periods.

5. Spiking, Slicing and Slitting: This mechanical operation cuts through the thatch allowing water, air and nutrients to move down to the soil surface. It does nothing to eliminate thatch, which is the basic problem. The most beneficial effect of spiking or slicing is generally not too well known. This is the pruning effect on surface roots and runners. When roots are pruned, new growth is stimulated. This effect can be observed when noting the growth of new roots between sod that is cut thick and sod that is cut thin. Thickly cut sod does not send out many new roots because the root system of the grass plant is relatively intact. Thin cut sod, however, has lost most of its root system. In order to survive, new roots will quickly form. This same process is true when turf is cut vertically with a spiking or slicing implement. New roots will form where they have been pruned. True, they are surface roots, but when a sufficient number of them are formed, they can carry the grass plant through periods of stress.

These, therefore, are the most commonly practiced Temporary Cultural Methods to carry turfgrasses through adverse periods and cause little or no disturbance to the turfgrass areas.

Cultural Management Practices

Cultural management practices are all the operations known to science today for managing a turfgrass area to insure its healthy survival at all times. These practices sometimes temporarily interfere with the use of the turf. Most of these operations are done when the turf is actively growing, and this of course may also be the period when turf is most heavily used by the players. Because of the heavy use of the turf, and the fact that the players are unhappy when these operations are done, many times the turf manager will put off doing the things that he knows are right. Consequently, his turf suffers and then he must resort either to Temporary Cultural Methods or, at worst, Renovation, which will be discussed as the third method.

Cultural Management Practices include the following operations:

1. Aerification: Aerification relieves soil compaction. It removes soil cores. When soil thus removed is mixed with surface thatch, it helps to decompose the thatch. The openings made by aerifying forms channels through which decomposing thatch can reach the root bed to be re-used by the plants. Air, water and fertilizer can move deeply through the thatch, encouraging a deep root system. Aerification also creates a better environment for beneficial organisms to decompose thatch.

2. Verti-Cutting: Periodic vertical mowing physically removes surface thatch as it forms. This operation can be compared to the harvesting of the crop and removing it from the area. Vertical knives, revolving at high speed, cut prostrate leaves and surface runners and remove undecomposed thatch lying on the soil surface. The practice of verti-cutting, when part of a continuing management practice, controls thatch as it forms and is one of the operations that does not materially disturb the use of the turfgrass area.

3. Topdressing: Topdressing is a cultural management practice which can be practiced only on a limited scale, such as on golf greens, because of the expense in material and labor. However, it is one of the most beneficial operations for the control of thatch. Light dopdressings of a good soil mixture or compost, properly worked into the turf, does a good job of decomposing thatch on the soil surface. Aerification is substituted for topdressing on large turfgrass areas. A tractor-drawn aerifying machine will remove, on the average, twelve tons of soil to the acre and deposit it on the turf surface. When crumbled, this soil is good topdressing material that will help decompose the thatch.

4. Fertilizing: Fertilizer plays an important role in the control and decomposition of thatch. Nitrogen, along with lime, sustain the beneficial decomposing organisms that break down undecayed thatch. In a good management program, the intelligent use of fertilizer will do much to keep thatch under control as it forms.

5. Liming: Lime is a very necessary ingredient in good turfgrass management. It has many beneficial functions, not all of which are clearly understood by scientists. We do know its importance in regulating alkilinity and acidity of soils. We also know that thatch layers are predominantly acid, even though the underlying soil may be neutral or even alkaline in nature.

   The application of lime to thatched areas controls the alkalinity and acidity of the thatch. In so doing it creates a better environmental atmosphere for beneficial decomposing organisms. Also, it supplies needed calcium.

   Another important factor to consider, especially on golf course greens or other artificially irrigated turfgrass areas, is the tremendous amount of water applied that is constantly leaching out the thatch layer.

Lime is an essential part of any good turf management program and its importance in helping control thatch problems cannot be overlooked.

6. Mowing Frequency: Frequency of mowing has a pronounced effect on thatch. The more frequently a turfgrass area is mowed, the more the upright grass blades will be cut. The smaller the pieces of grass blades that fall to the surface, the more quickly they will be decomposed when followed with a good management program of aerification, verti-cutting, topdressing, liming and fertilizing.

Renovation

Renovation is necessary when the basic problems are so severe that even temporary measures cannot keep the turf. Thatch builds up slowly. If one wants to keep the turf playable, then thatch must be brought under control slowly. Many times the situation is so severe that the logical choice is renovation. After renovation, a management program of prevention and control of thatch can be initiated. Renovation means to renew. There are two approaches to renovation: partial renovation and complete renovation.

Partial renovation includes the deep removal of thatch, intensive aerification, liming and seeding if necessary.

Complete renovation includes complete kill of all existing vegetation, drastic aerification (10 to 12 passes over the area, or more if necessary), deep verti-grooving, removing the surface thatch, the application of lime and fertilizer, seeding or stolonizing, light rolling and watering.

To sum up this discussion, it is well to repeat the three categories of thatch control. They are:

1. Temporary Cultural Methods
2. Cultural Management Practices
3. Renovation

Proper cultural management practices will certainly reduce the need for the other two methods. However, the science of producing turfgrasses is one of man against nature. Unpredictable situations occur that demand the use of every known skill. There are times when we must resort to temporary cultural methods to keep the turf alive and playable. There are situations when nature throws a curved ball and we strike out. When this occurs, renovation is the only solution.

It is necessary, therefore, that every turfgrass manager become familiar with every known method of grass culture at his disposal. Then, he can deal logically with any problem that unpredictable Mother Nature may present to him.

BERMUDAGRASS VARIETIES

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More than 60 varieties of turf-type bermudagrasses are known to have been named while countless experimental selections and hybrids are each designated by a number at this time. Of the named varieties approximately 50 originated in the southern part of Africa while some 14 have been contributed from the U. S. The use of most varieties is limited to rather localized areas while a select few are widely utilized, particularly in the bermudagrass region of the United States.

A brief description of the more commonly used turf-type bermudagrass varieties in this country is given below. A more detailed description of many varieties, selections and introductions of bermudagrasses can be found in the USDA Agriculture Handbook No. 270* printed this year.

Bayshore (Gene Tift) was selected from the Bayshore Golf Club in Miami Beach, Florida, by Dr. Roy A. Bair in 1945. This grass reportedly originated from a natural cross of Florida turftype bermudagrass selections with selections of Cynodon species from South Africa. It is light green in color, fine textured putting green type grass which seems to be somewhat localized in its best areas of use. In Florida it seems to be better adapted for use in the southern than the northern part. It is more upright in growth than Everglades #1. It shows distinct resistance to certain leafspot diseases (Helminthosporum spp.) compared to Common bermudagrass.

Everglades #1 was selected in the vegetative state from the Bayshore Golf Club in Miami Beach, Florida, by Dr. Roy A. Bair in 1945. This is a dark green, fine textured, vigorous putting treen type of bermudagrass which apparently can be grown rather widely through the southeast. It exhibits resistance to certain leafspot (Helminthosporum spp.) diseases.

Ormond (C. dactylon) was selected from long-established fairway at Ellinor Village Country Club, Ormond Beach, Florida. It is arrtactive, blue-green, vigorous, has relatively prostrate growth havits, medium texture, some tolerance to leaf diseases, susceptible to dollar spot and lacks cold tolerance. It is well adapted in Florida for use on lawns, golf tees, fairways and recreational areas.

Sunturf is a sterile triploid hybrid of Cynodon dactylon and Cynodon transvaalensis. It was introduced into the United States in 1951 from Kimberly, South Africa, as P. I. 184339. Sunturf (Cynodon magennisii) produces a dark green, dense, fine textured turf of excellent quality. It ranks with U-3, Tiffine and Tiflawn in ability to withstand wear from foot traffic according to Oklahoma studies. It is one of the easiest bermudas to manage as it is slower to encroach on areas surrounding the lawn than most

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* Juska, F. V., and A. A. Hanson. Evaluation of Bermudagrass Varieties for General-Purpose Turf. USDA Agriculture Handbook No. 270. 1964.

other bermudas. In areas of high humidity, rust has been found on this grass. Dollar spot has occurred as a slight infestation on Sunturf.

Texturf IF (T-35A) is a fine textured strain selected in Texas. It is a very vigorous variety which will build up a thick mat in areas of high summer temperatures. It has a rather light green color when compared to some of the previously mentioned varieties. Perhaps its best area of use will be in the cooler or northern part of the bermudagrass region. This grass is suited for home lawns and playgrounds.

Texturf 10 (T-47) was selected at Texas Agricultural Experiment Station, College Station, and released in 1957. Medium textured, dark green, early-spring recovery. Slower growing than Common bermudagrass, but superior in fall color and in resistance to leaf diseases.

Tiffine (Tifton 127) is also an F_1 hybrid between Tiflawn (C. dactylon) and an African bermudagrass (C. transvaalensis) from the East Lakes Golf Course in Atlanta. Tiffine has a distinctive medium green color, is more disease resistant and finer in texture than Tiflawn bermudagrass. It is completely male sterile. At the time of its release (1952) it was the best bermudagrass for putting greens in the southeast. This grass is apparently well adapted to all the bermudagrass area and is now used mainly for lawns. Spreads by both above and below ground runners. Tiffine apparently isn't as cold tolerant as Tifgreen. Wearability studies conducted in Oklahoma showed this grass to be able to withstand considerable foot traffic.

Tifgreen (Tifton 328) bermudagrass, released in 1956, is an F_1 hybrid between a superior clone of bermudagrass from a golf green on the Charlotte County Club, Charlotte, North Carolina, selected by W. G. Thomas and Walter Harkey and an African bermuda (C. transvaalensis) from the East Lakes Golf Course in Atlanta. Tifgreen is darker green in color and produces a better putting surface than probably any other bermudagrass now available. In other respects it is similar to Tiffine. It is being used rather widely in the southeast for lawns and golf course putting greens. Most of the lateral growth is by above ground runners as there are very few rhizomes produced below ground as compared to many other bermudas. This grass has been found to be relatively disease free, with only an occassional slight infestation of dollar spot.

Tiflawn (Tifton 57) is an aggressive hybrid developed co-operatively by the USDA and the Georgia Coastal Plains Experiment Station that apparently has good disease resistance and was originally designed for use on lawns, athletic fields and parks. This grass will tolerate considerable punishment and wear from foot traffic.

Tifway (Tifton 37 and 419) was selected at the Georgia Coastal Plain Experimant Station, Tifton, and released in 1960 by Georgia Agricultural Experiment Station and Crops Research Division, Agricultural Research Service. F_1 hybrid between C. transvaalensis and C. dactylon. Found in seed lot of C. transvaalensis supplied by D. Meredith of Johannesburg, South Africa, in 1954. Dark green, stiff leaves, equal or superior to Tiffine and Tifgreen in disease resistance, density, weed resistance, seed-head production and rate of spread. Well suited for use on fairways, tees and home lawns.

Tufcote (C. dactylon) was selected at National Plant Materials Center, Beltsville, Maryland, and released as "Tuffy" in 1962 by Soil Conservation Service National Plant Materials Center, Maryland Agricultural Experiment Station, and Crops Research Division, Agricultural Research Service. Renamed "Tufcote" in 1963. Vegetative increase of surviving plant from one of three introductions--P. I. 142278, P. I. 142280 and P. I. 142281. Introductions received in 1942 from General Jan Smuts, Pretoria, South Africa. Stiff leaves, relatively rapid spread, few seed heads. Released on basis of winter hardiness and wear resistance for use in conservation plantings and on athletic fields.

U-3 was one of the first bermudagrass selections made in this country that was widely accepted. It is used to a large extent in the transition area between bermuda and bluegrass. This grass was found growing on the Savannah Golf Club, Savannah, Georgia, in 1938 and was selected by Mr. D. L. Hall, who was then superintendent. The U. S. Golf Association grew it for several years in their nursery at Beltsville, then it was released for general planting. Today it is perhaps the most widely used of all the Common bermudagrass varieties. It is finer textured than Common, with blades rarely wider than 1/8 inch when grown as turf. It is dark green in color with a slight gray cast. It too exhibited good wearability in the Oklahoma studies. It is rather slow in its growth habit and produces a dense turf which makes it well adapted for playgrounds, lawns and athletic fields.

The seed from stolons of U-3 that is now on the market is not the same as the vegetatively propagated U-3. The seed produces a number of off-type plants.

GRASSES (OTHER THAN BERMUDA) FOR USE ON PARKS, SCHOOLS, CEMETERIES, LAWNS, ETC. (OTHER THAN GOLF COURSES)

Albert W. Crain, Agronomist
Goldthwaites of Houston, Inc.

The title eliminates bermudagrass and its many strains and also golf courses. Since no grass approaches bermudagrass for use on athletic fields, they too are excluded.

To bring all of us together in our thinking and application, let us classify turfgrass areas for parks and add comparable uses in other fields so this will not be a "parks" talk, but I consider it easier to think direct than so general (over 80% of the audience are "parks" people). This classification placed on the blackboard will help keep our thinking in line.

Turfgrass Areas Classified

Class I	Administrative buildings, formal park areas, lawns, home lawns, dedicated cemeteries and other fertilized, irrigated lawns.
Class II	Parks on non-heavy used areas, non-dedicated cemetery acreage, most acreage of airports, highway right-of-way, broad expanse of school campuses. Areas kept mowed, good turf desired but seldom fertilized, never irrigated, mowed comparatively infrequently.
Class III	Scenic parks, seldom used except paths, never mowed areas, just protected.

Class III will be native vegetation so we can forget it in this discussion.

Class II areas in Texas will either be native vegetation with added bermudagrass in areas of 30-inch rainfalls or more or added St. Augustine in Coastal Bend area, Beaumont-Houston section, where rainfall is above 40 inches and natural fertility is high.

Class I areas thus become our subject area. These are by their nature areas on which $500 to $3,500 annually is expended per acre.

Areas in State Classified

St. Augustine is the dominant turfgrass used in and south of the Dallas-Fort Worth area. Looking at the population map one can see that St. Augustine will then cover 80% of the Class I turfgrass acreage of Texas. (Remember this discussion excludes bermudagrass.)

Kentucky bluegrass is used in the Amarillo section of the state. South of this section buffalograss finds some use.

Other Grasses and Where They are Used

Carpetgrass is a native grass and exists in some East Texas lawn areas but not in Class I areas. It grows well in poorly drained soils. Seed of the grass is available commercially. St. Augustine is erronously called and sold as "carpetgrass" in some parts of Texas. Carpetgrass is finding less and less use on turfgrass areas of Texas due to quality of turfgrass demanded, fertilizer and water.

Bahiagrass is another native turfgrass found in large acreages of Class II areas in East Texas and the Gulf Coast area. When Class I type lawns are desired, DSMA can be used to eradicate Bahia and, with water and fertilizer, bermuda and St. Augustine will grow. Bahia and carpet both provide satisfactory turf on Class II areas in areas where adapted.

Zoysiagrass for lawn use is confined to exotic, specialized "something-different" lawns. Matrella zoysia and Myers zoysia are two types finding limited use.

Centipedegrass, also called "Chinese Lawngrass" finds limited use in some southeastern states and in Texas for use as described for zoysia.

Grasses for Overseeding

Ryegrass has been used for many years for winter green color on established turfgrass areas. The major problem involved is not to overdo it by using heavy seeding rates.

Kentucky bluegrass on St. Augustine and bermuda lawn areas is coming into more prominent use. Again caution should be used in choosing seeding rate. Kentucky bluegrass may be used on St. Augustine to accomplish what is attained naturally on bermuda by Poa annua.

Poa Annua (annual bluegrass) is a native grass that naturally covers thousands of acres of primarily bermuda turfgrass areas in Texas. It serves an excellent purpose. It may be held to a minimum or encouraged by management practices, primarily time of fertilizer application.

Management of Grasses Used

Management was not the topic or implied in the subject to be discussed. Selecting the proper grass is only one step in growing turfgrass. When proper management is used on bermudagrass, St. Augustinegrass, buffalograss and Kentucky bluegrass there is little use in considering other grasses. On 95% of the turfgrass areas of Texas the first two grasses named will meet the demand better than any others.

ST. AUGUSTINEGRASS MANAGEMENT

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During the next few minutes let us consider some of the aspects of St. Augustinegrass management, after which color slides will be used to illustrate some of the points of our considerations.

This grass is widely used for lawns throughout the Gulf Coast Region of the U. S. It has also been reported as a lawn grass in East and West Africa, Australia and has been introduced into southern Franch and Italy.

St. Augustinegrass spreads only by its stolons because it is a non-rhizomatous species. While rhizomes and stolons are similar structures of the grass plant, they differ significantly in their position of growth. Stolons by definition grow on the soil surface. St. Augustinegrass stolons may occasionally be found below the actual soil surface, but one finds that soil has been placed over them, or is there by gradual accumulation, rather than their having penetrated and developed (grown) there. Rhizomes, by contrast (for example as in bermudagrass), actually grow and develop below the soil surface. In brief then, a stolon or stem becomes a rhizome when it grows below the soil surface--then should its end arise later and grow again on the soil surface, it is again called a stolon. Many of the cultural practices, as well as some of the limitations of St. Augustine-grass, can be attributed to the absence of rhizomes. Some examples of these will be mentioned later.

As with many other grasses, the desired effect to a great extent dictates its level of management. For example, roadside usage usually is not as demanding as a "showplace" lawn area such as that for which we strive in our home lawns, clubhouse lawns, municipal or industrial facility lawns or any other similar location. The example of an apparently poorly-kept St. Augustinegrass area is a space-planted nursery for use by a plant breeder. Of necessity he must obtain seed if he is using usual methods for line improvement and therefore must allow the plants to produce them. Also he is interested in the inherent growth habits in the absence of mowing--but, of course, also with mowing. This alone prohibits the mowing of at least part of each clone which produces an unkept appearance.

Fertilization

Nitrogen, phosphorus and potassium nutrition and trace elements have been discussed separately and earlier during this conference. Consequently, we shall not delve into the basic aspects of the elements per se but offer only general comments regarding St. Augustinegrass fertilization. A ratio of 2:1:1 (nitrogen: phosphorus (P_2O_5): potassium (K_2O)) appears to be best under most conditions. This is based on an annual total. Therefore, the phosphorus and potassium may be applied in one or two applications if desired, but several light applications of nitrogen are usually more effective than fewer but heavier applications. In the period of one year, six to nine pounds of nitrogen and three to four pounds each of P_2O_5 and K_2O should be applied per 1000 square feet. When a complete fertilizer is applied and there is a choice, it should be made in the fall or late summer,

as applications of nitrogen alone may tend to produce a more succulent growth which would likely be more susceptible to cold damage during the winter.

Watering

As with other turf grasses, one should always strive to water as throughly and as infrequently as possible. Often irrigation every three or four days is required for reasonable growth in the turf plots here. Consider, for example, a situation in which adequate moisture is only available in the upper part of the root zone. Inasmuch as less soil volume is involved, there is less effective water holding area; and, consequently, irrigation must be more frequent. More important, however, is the problem of root penetration. Roots don't readily penetrate dry soil, and the above situation then inhibits the plants thriving for long periods due to the absence of a deeply penetrating root system. If, however, the water has been applied heavily from the start, the roots would be able to penetrate deeper and in turn would be able to draw water from a much larger soil volume.

Mowing

St. Augustinegrass can be maintained at 1 to 1½ inches without great difficulties. At heights less than 1 inch, some scalping will likely occur. The frequency of mowing should be governed by the growth rate. By removing no more than 1 inch of leaf at any one cutting no serious problems should result.

The most frequent source of much trouble from mowing is that of mower damage to the leaves being cut. Dull rotary mowers are probably the worst because they literally "beat" the leaves rather than cut them off. Least damaging is a sharp, properly adjusted reel-type mower.

Common Problems

Disease - Large Brown Patch is probably the most prevalent disease of St. Augustinegrass. Terraclor (PCNB) has shown to be the most effective preventative and curative treatment of the disease.

Insects - Army worms and chinch bugs are frequent pests of St. Augustinegrass. Army worms are usually easily controlled with DDT or chlordane or almost any other insecticide. Chinch bugs are usually controlled with diazinon or trithion.

Thatch - Thatch can build up to the point where its removal is warranted. When this occurs, removal should be planned as a spring time operation. As pointed out previously, St. Augustinegrass is non-rhozomatous; and, therefore, the thatch (and live stolons which inherently will be removed with it) will offer some added protection from cold damage. The degree of thatch removal should not be as great for this grass as is permissable for bermudagrass because of the absence of rhizomes in St. Augustinegrass.

Future Outlook

While it is important to evaluate existing problems, and methods or cultural practices which can be used to "live with them," it is also well to look ahead for some possible improvements either in our management or plant

material or both.

More desirable turf types are potentially possible inasmuch as a segregating population of St. Augustinegrass produces a wide array of characteristics. The incorporation of traits which will produce a more desirable turf type is conceivable, but will require much in time and effort. Such a trait as disease resistance alone could warrant releasing a strain if it compared fairly closely with common St. Augustinegrass in its other characteristics.

Induced polyploids, irradiation or some interspecific hybrid may produce a rhizomatous plant which closely resembles our present-day St. Augustinegrass. If so, it could likely be immediately adapted to more northern regions.

The breeding program underway here is a long way from such releases, but these are some of the ultimate objectives.

GROUND COVERS

Richard Thornton, Head
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The term ground cover is described by Mr. Donald Wyman in his book, Ground Cover Plants, as being principally low-growing, woody and herbaceous perennials and sprawling vines that have the ability to spread rapidly and keep close to the ground.

This description, in a sense, defines a long list of plants that have been used by gardeners and landscape people for ages to reduce the amount of maintenance in landscaped areas where lawn grasses are costly, troublesome or impossible to maintain. Over the years gardeners have searched and found many low-growing plants for use in their gardens, and today it is possible to obtain ground cover plants to fit almost any growing situation from dry slopes to low wet spots, from shady areas to bright sunny ones, and any number of other extreme growing conditions. With the wide selection of plants available, all one must do is survey the situation and pick the right plant for the problem at hand.

In addition to being adapted to many growing conditions and easy to maintain, ground covers also have characteristics of esthetic value which add materially to the beauty of a landscape. Plants can be selected for ornamental fruits, flowers, colored foliage, bright fall colors, interesting leaf patterns or evergreen foliage. When one plant possesses several of these characteristics it can be used in many attractive and interesting ways in the landscape.

The use of ground cover plantings to solve problem areas in the garden is still one of the most important uses of these plants; however, today plantings are being used in many other attractive and useful ways. The bases of buildings, for example, are no longer reserved for specimen shrub plantings as they were several years ago. Today ground cover plantings are being used in many instances to replace these plantings or in connection with specimen shrubs. These new plantings are very attractive when properly planned and present a more interesting foundation planting. The latest trends in architecture have influenced the use of ground cover plantings considerably in the last several years with the advent of low-profile buildings and the extensive use of floor length glass panels. These features have required the use of low-growing plants and have brought on a new trend in landscape planning and planting.

At Texas A&M University, the use of ground covers has been extensive for the last ten years, and today a wide assortment of these plants are proving their value in lowering maintenance and improving the appearance of the campus.

The following is a descriptive list of the ground cover plants in use on the A&M campus at the present time. In the future it is expected that this list of plants will be expanded considerably as other plants prove their value under local climate and soil conditions.

1. Hedera helix - English Ivy

   Height: 6 to 8 inches (clinging vine).

   Flowers: inconspicuous clusters of green flowers in September.

   Foliage: evergreen, attractive throughout the year, is at its best in early spring and summer when new growth presents a multi-color effect.

   Hardiness: will persist as far north as Boston with some protection in severe cold.

   Growing Conditions: prefers shade or semi-shade locations and a rich, moist, cool soil.

   Plant Spacing: for rapid cover 18 to 24 inches; maximum spacing 30 to 36 inches.

   Maintenance Requirements: requires frequent watering; occasional light pruning around bed edge; has no serious insect or disease problems.

2. Euonymus fortunei Radicans - Common Wintercreeper

   Height: 4 to 12 inches (vining shrub).

   Foliage: evergreen, tends to bronze during winter months which adds to its effectiveness in the fall and winter.

   Hardiness: hardy in all but the coldest areas of the northern United States.

   Growing Conditions: semi-shade to sunny locations and requires a moist, rich soil.

   Plant Spacing: space 18 to 24 inches for rapid cover, maximum spacing 30 to 36 inches.

   Maintenance Requirements: requires frequent watering in sunny locations, occasional fertilization and light pruning; must be watched closely for euonymus scale and other insects; requires frequent spraying to control mildew in humid climates.

3. Gelsemium sempervirens - Carolina Jessamine

   Height: 18 to 24 inches (twining vine).

   Flowers: yellow flowers in early spring with occasional blooming periods throughout the summer.

Foliage: evergreen lanceolate leaves that are very attractive, especially in early spring.

Hardiness: will withstand temperatures down to 5° to 10° F. without severe damage.

Growing Conditions: semi-shade to sunny locations; requires a moist, acid soil for best growth and flowering.

Plant Spacing: space 18 to 24 inches for rapid cover, maximum spacing 30 to 36 inches.

Maintenance Requirements: requires moderate watering and light pruning once or twice yearly, tends to contact leaf spot diseases but has no serious insect problems.

4. Liriope muscari - Lily-turf

Height: 8 to 12 inches.

Flowers: lilac color spikes in late spring and early summer.

Foliage: evergreen, leaves narrow and grass-like--about 1/4 inches wide.

Hardiness: will persist in most areas of the United States, -10° to -20° F.

Growing Conditions: requires a moist, rich soil for best growth and will tolerate dense shade, but prefers semi-shade areas; will survive in full sun with adequate water.

Plant Spacing: space 14 to 16 inches apart for rapid cover, maximum spacing 18 to 24 inches.

Maintenance Requirements: requires no pruning but flower spikes should be removed after flowering for best appearance; no serious insect or disease problems; moderate watering.

5. Ophiopogon japonicus - Monkey Grass

Height: 10 to 12 inches.

Flowers: not conspicuous; violet colored in July to August.

Foliage: evergreen, coarse and grass-like.

Hardiness: will persist in all but most northern regions of the United States, -5° to -10° F.

Growing Conditions: requires a moist, rich soil; will grow in shade or full sun with proper watering; tends to be more attractive in shade or semi-shade locations.

Plant Spacing: space 12 to 14 inches apart for rapid cover, maximum spacing 18 to 24 inches.

Maintenance Requirements: moderate watering in sunny locations; no pruning required; no serious insect and disease problems.

6. Lonicera japonica chinensis - Purple Japanese Honeysuckle

Height: 24 to 30 inches (vineing shrub).

Flowers: yellow-white, trumpet-shaped in clusters in late spring and throughout summer; very fragrant.

Foliage: semi-evergreen with purple underside and veins; very attractive in spring and early summer; bronze in fall

Hardiness: hardy in all but most northern areas of the United States, -10° to -58 F.

Growing Conditions: prefers sunny location and rich, moist soil--will persist in arid locations but is not as attractive.

Plant Spacing: space 24 to 30 inches apart for rapid cover, maximum spacing 36 to 48 inches.

Maintenance Requirements: requires moderate watering and occasional fertilization; light pruning once or twice in summer to control lateral spread; no serious insect or disease problems.

7. Plumbago capensis - Cape Plumbago

Height: 18 to 24 inches.

Flowers: baby-blue color from late spring until frost.

Foliage: light, mint-green that is very attractive, especially in early spring and summer

Hardiness: semi-tropical plant, tops die back to ground at frost but roots persist to 10° to 15° F.

Growing Conditions: prefers sunny location, moist, rich soil--will tolerate light shade.

Plant Spacing: space 14 to 16 inches apart for rapid cover, maximum spacing 24 to 30 inches.

Maintenance Requirements: requires moderate watering; occasional spraying to control aphids, caterpillars and other insects; in humid areas it is susceptible to mildew.

8. Tecomaria capensis - Cape Honeysuckle

Height: 24 to 30 inches.

Flowers: yellow-orange or scarlet-red funnel-form flowers throughout the summer.

Foliage: handsome pinnate foliage of dark green color, evergreen in subtropics.

Hardiness: tropical plant that will defoliate in freezing weather, roots will persist to 10° to 15° F. but tops die back.

Growing Conditions: prefers sunny location, moist, rich soil, will tolerate light shade.

Plant Spacing: space 18 to 24 inches apart for rapid cover, maximum spacing 30 to 36 inches.

Maintenance Requirements: has no insect or disease problems; requires only light pruning to keep in bounds; requires moderate watering for best appearance.

9. Vinca minor - Periwinkle

Height: 10 to 12 inches

Flowers: lilac-blue single flowers in early spring and few throughout summer. Other varieties available with white, purple or light blue flowers.

Foliage: evergreen--dark, lustrous green color

Hardiness: hardy to -10° or -20° F.

Growing Conditions: prefers moist, shady areas but will persist in sunny areas with proper watering.

Plant Spacing: space 14 to 18 inches apart for rapid cover, maximum spacing 30 to 36 inches.

Maintenance Requirements: requires moderate watering; light pruning to keep in bounds; must be watched for aphid, leaf rollers and other insects but has no serious insect or disease problem.

10. Ficus pumila Minima - Creeping Fig

Height: 2 to 4 inches.

Flowers: insignificant

Foliage: dark green color; small wavy round leaves; evergreen and very attractive at close distances.

Hardiness: will withstand short periods of 15° to 20° F. weather with only slight damage, colder temperatures kill top growth; roots persist to 5° to 10° F.

Growing Conditions: prefers shady, moist location but will persist in full sun with adequate water.

Plant Spacing: space 14 to 18 inches apart for rapid cover, maximum spacing 30 to 36 inches.

Maintenance Requirement: requires moderate watering; has no insect or disease problems; some light pruning needed to keep in bounds.

11. Ilex vomitoria Dwarf - Dwarf Yaupon

Height: 24 to 30 inches.

Fruit: small, scarlet globose fruit in fall and winter.

Foliage: evergreen, 1/2 to 1 inch leaves of medium green color; very attractive all year.

Hardiness: 0° to 5° F.

Growing Conditions: prefers moist, rich soil in sunny or or semi-shade location, will persist in full shade but less attractive.

Plant Spacing: space 24 to 30 inches apart for rapid cover, maximum spacing 36 to 48 inches.

Maintenance Requirements: requires moderate watering; has no serious insect or disease problems; an excellent low-maintenance plant.

12. Trachelospermum asiaticum - Japanese Star Jasmine

Height: 10 to 12 inches.

Flowers: small, insignificant white flowers in early spring.

Foliage: very attractive, glossy evergreen of dark green color.

Hardiness: will withstand cold to 5° to 10° F. for short periods; roots will persist to 0° or slightly lower.

Growing Conditions: prefers moist, semi-shade location but will grow equally well in shade or full sun.

Plant Spacing: for rapid cover space small rooted cuttings on 10 to 12 inch centers; two growing seasons are required for full development and thick cover.

Maintenance Requirements: requires moderate watering and light pruning around the edges; no insect or disease problem.

13. Trachelospermum jasminoides - Chinese Star Jasmine

Height: 18 to 24 inches.

Flowers: white, star-shaped flowers in early spring, very attractive and fragrant for approximately two weeks.

Foliage: glossy, evergreen foliage that is very attractive all year.

Hardiness: tops will persist to 10° to 15° F.; roots will withstand 0° to 5° F. for short periods.

Growing Conditions: prefers sunny or semi-shade location in moist, rich soil.

Plant Spacing: space 18 to 24 inches apart for rapid cover; maximum spacing 30 to 36 inches.

Maintenance Requirements: requires moderate watering and considerable pruning several times each season to keep in bounds; no serious insect or disease problems.

14. Juniperus sabina Tamariscifolia - Tamarix Juniper

Height: 18 to 24 inches.

Foliage: medium-green color, very attractive, evergreen; branches radiate from the center of the plant creating a very interesting pattern.

Hardiness: will withstand -5° to -10° F. temperatures.

Growing Conditions: for fast, active growth a rich, moist soil is desirable; will withstand drought conditions for long periods and many are used under these conditions; prefers sunny locations, will tolerate partial shade.

Plant Spacing: 24 to 36 inches for fast cover.

Maintenance Requirements: requires moderate watering for active growth; requires very little care other than occasional fertilization; must be watched carefully for red spider and bag worm, but has no serious disease problems.

15. Juniperus chinensis Sargenti - Sargent Juniper

Height: 12 to 14 inches.

Foliage: medium to light green color; spiny, scale-like leaves give an interesting texture that is very attractive.

Hardiness: will withstand -5° to -10° F.

Growing Conditions: prefers a rich, moist soil but will persist in arid locations; prefers full sun but will tolerate some shade.

Plant Spacing: space 24 to 30 inches for fast cover, maximum spacing 36 to 48 inches.

Maintenance Requirements: requires moderate watering for active growth but will grow under arid conditions; must be watched closely for red spider and bag worm; has no serious disease problems.

16. Juniperus horizontalis, Bar Harbor - Bar Harbor Juniper

Height: 12 to 14 inches.

Foliage: dark green foliage with slight plum tint, winter color is silvery-plum color that is very attractive.

Hardiness: will persist to -5° to -10° F.

Growing Conditions: prefers a rich, moist soil for rapid growth, will withstand arid situations but is not as attractive; prefers full sun but will grow in partial shade.

Plant Spacing: space 24 to 30 inches apart for rapid cover, maximum space 36 to 48 inches.

Maintenance Requirements: requires moderate watering; must be watched carefully for red spider and bag worm; has no disease problems.

17. Juniperus chinensis Pfitzeriana Compact - Compact Pfitzer Juniper

Height: 30 to 36 inches.

Foliage: medium green color and very attractive.

Hardiness: will persist to -5° to -10° F.

Growing Conditions: prefers a moist, rich soil for best growth but will grow in arid locations; prefers full sun but will tolerate light shade.

Plant Spacing: space 30 to 36 inches for fast cover, maximum spacing 48 to 54 inches.

Maintenance Requirements: requires moderate watering for best growth but will grow in arid areas; must be watched for red spider and bag worm; has no disease problem.

18. Juniperus chinensis Hetzi Glauca - Hetzi Juniper

Height: 30 to 36 inches.

Foliage: blue-green, attractive foliage that tends to be more feathery in appearance.

Hardiness: hardy to -5° to -10° F.

Growing Conditions: prefers a moist, rich soil but will grow in arid locations; prefers full sun but will tolerate partial shade.

Plant Spacing: space 30 to 36 inches apart for fast cover; maximum spacing 48 to 54 inches.

Maintenance Requirements: requires moderate watering for active growth but does well in arid areas; must be watched closely for red spider and bag worm but has no disease problem.

19. Juniperus chinensis Holbert - Holbert Juniper

Height: 18 to 24 inches.

Foliage: attractive blue-green foliage that appears silver-green in winter.

Hardiness: hardy to -5° to -10° F.

Growing Conditions: prefers a moist, rich soil for fast growth but will do well in arid areas; likes full sun but will tolerate light shade.

Plant Spacing: space 24 to 30 inches for fast cover, maximum spacing 36 to 42 inches.

Maintenance Requirements: requires moderate watering for best growth but will do well in arid spots; must be watched carefully for red spider and bag worm but has no disease problems.

All the plants described above are well adapted to the A&M University climate and soil conditions and are relatively maintenance free. At the present time various other ground cover plants--including sedums, Festuca ovina glauca, wild strawberry, potentilla verna, and several other plants--are being used on a trial basis until their usefulness under local conditions are determined. It is hoped that many new plants can be added to the above list of materials in the next few years.

Quality ground covers are a great asset to any landscaped area, and the use of these plant materials are heartily recommended to anyone interested in grounds beautification and maintenance work.