CALIFORNIA TURFGRASS CULTURE
FORMERLY, SOUTHERN CALIFORNIA TURFGRASS CULTURE

VOLUME 19, NO. 1 JANUARY, 1969

EFFECT OF TEMPERATURE STRESS ON POA ANNUA*

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The actual temperature of a turfgrass plant or its individual parts is determined by the surrounding environment. Temperatures of the below ground portions of the plant are usually identical with the adjacent soil temperatures, while above ground plant parts tend to follow the surrounding air temperature. The greatest extremes in temperature commonly occur at the surface of the turf and are moderated with increasing distance above and below the surface. The air and soil temperatures will vary with (a) latitude, (b) altitude, (c) topography, (d) season of the year, and (e) time of day.

OPTIMUM TEMPERATURES

The temperature at which activity of a particular process occurs at the highest rate is referred to as the optimum temperature. The optimum temperature will vary depending upon the (a) age of the plant, (b) stage of development, (c) specific plant organ involved, (d) physiological condition of the plant, (e) duration of the temperature levels and (f) variation in other environmental factors. As a result, the temperature optimum is actually a range rather than a specific fixed temperature.

The optimum of temperature range for shoot growth of annual bluegrass is between 60 and 70 degrees Fahrenheit. In contrast the optimum temperature for root growth of annual bluegrass is between 55 and 65 degrees.

In general, it is more important to maintain an optimum temperature for root growth than for shoot growth. Turfgrass can maintain growth at relatively high air temperatures so long as the soil temperature remains in a favorable range. Turfgrass growing in the optimum temperature range will have increased nutrient and water requirements and will also require more frequent mowing.

As temperatures are increased or decreased from this optimum range the various metabolic processes within the plant are slowed. The net result is a general reduction in growth rate which continues until, at a certain point, growth actually ceases.

HIGH TEMPERATURE STRESS

Turfs are exposed to high temperature stress during summer periods when the degree of use is also the highest. This negative response where growth is slowly reduced and eventually ceases is termed indirect high temperature stress. Growth is impaired at superoptimum temperatures which are not necessarily fatal to the plant. Under these conditions the first visible effect of high temperature observed is a browning and die-back of the root system toward the soil surface. The roots will appear brown, spindly and weak.

High temperature stress actually causes increased maturation and death of the existing root system and also blocks the initiation of any new root system from the meristematic tissues. Loss of the root system is critical because it increases the susceptibility to injury from other adversities such as desiccation, diseases, insects, and nematodes .

The next significant effect of high temperature stress observed is a decline in shoot growth. Specifically, there is a reduction in leaf length, leaf width, leaf area, rate of new leaf appearance and succulence. Quite frequently the leaves will appear dark green to blue. The primary concern of the restricted shoot growth is that it limits the recuperative potential of the turf should injury from other adverse stresses occur.

The cause of high temperature stress is attributed to either (a) a destruction of certain heat sensitive enzymes involved in synthesis or (b) an imbalance between certain metabolic processes. Research at Michigan State University indicates that growth reduction is due to a blockage in either amino acid or protein synthesis.

Evidence supporting this phyothesis includes a decline in protein level an increase in free ammonia and a severe reduction in the amide level, especially glutamine. Michigan State University turfgrass researchers are attempting to describe the specific enzymes involved in high temperature growth stoppage. Once this is achieved it is hoped that the enzyme or enzymes involved can then be used as biochemical markers in a breeding program to select for heat tolerance. Such a technique would greatly accelerate the techniques of heat tolerance selection.

If temperatures are increased to quite high levels, direct high temperature injury may occur. This may be a more common problem than many individuals have previously thought. Direct high temperature kill involves denaturation of the proteins contained in the vital protoplasm of living cells. Studies at Michigan State University indicate that annual bluegrass can be killed at temperatures as low as 100 degrees. This is a surprisingly low temperature for kill to occur. Actually, temperatures of as high as 125 degrees have been measured at the surface of turfs.

Most turfgrasses have a built-in cooling system in the form of transpiration. During transpiration, energy is used to evaporate water from the leaf surface. In this process the leaf is actually cooled, therefore, so long as the leaf has open stomata which are actively transpiring, the temperature may not increase to a lethal level. However, should the stomata be closed due to a stress such as an internal plant water deficit, then transpiration will be impaired and lethal high temperatures may develop.

Detailed observations with annual bluegrass at Michigan State University show that the first signs of direct high temperature stress occur at the junction of the leaf sheaf and the leaf blade of the second and third youngest leaves. The lower portion of the crown, the youngest leaf and apical stem were more heat tolerant than the older tissues.

TECHNIQUES FOR PROTECTION AGAINST STRESS

The question which is frequently asked by the professional turfman is "How may I protect my turf against high temperature stress?" First of all, attempts shouud be made to maintain the plant tissues in a maximum state of hardiness. Specifically, heat hardiness is increased by decreasing the hydration level or water content of the tissue. In other words, judicious irrigation is important. A second factor is the nutrition level of the tissue. In general, excessive nitrogen fertilization should be avoided, because heat hardiness will be reduced, especially when the tissue is in a rapid state of growth.

The other aspect to consider when minimizing the

Reprinted from the USGA Green Section Record chance of high temperature injury involves various means of cooling the turf or especially minimizing heat build-ups in the soil. Michigan State University research in this area has demonstrated the importance of good air movement in minimizing high temperature stress. Plantings, screens, or buildings which completely surround a turfgrass area and restrict air movement should be avoided. Investigations show that an air movement of only four miles per hour will cool a turf from 12-14 degrees during mid-day periods when air temperatures exceed 85 degrees.

The second factor to consider is the use of syringing as a technique to moderate peak mid-day temperatures. Although the light application of water may not necessarily lower the temperature, it will restrict heat accumulation for several. hours during the mid-day period and, therefore, moderate the extreme soil temperatures which might have occurred had syringing not been practiced.

One further point to be made is that syringing should only be used as needed to avoid high temperature stress, and should not be considered a practice to be used day in and day out as a part of the routine maintenance program. This is particularly important on poorly drained turfgrass areas where over-watering can lead to saturated soil conditions, a low oxygen level, and, therefore, a restricted root system and a less vigorous turf.

LOW TEMPERATURE STRESS

As temperatures are decreased below the optimum, there will eventually be a point at which growth will cease. However, respiration and photosynthesis have been found to occur in roots and shoots of turfgrass at temperatures near 32 degrees F. If temperatures continue to decrease, a point is reached where direct low temperature kill will occur. Research at Michigan State University shows that annual bluegrass is a turfgrass species which is relatively susceptible to low temperature kill compared to others, such as creeping bentgrass and Kentucky bluegrass.

The mechanism of direct low temperature kill involves mechanical disruption of the protoplasm caused by ice crystals. In general, the killing temperature increases with the hydration level or water content of the tissue. The relative low temperature tolerance of annual bluegrass will vary during the winter season. Maximum winter hardiness is achieved in late December, followed by a slight decrease in hardiness in late January, with a continued decrease in hardiness to a minimum level at the time of spring thaw. Therefore, low temperature kill is most likely to occur during the late winter, early spring freeze and thaw period when the crown tissues are at a higher hydration level.

It should be pointed out in relation to direct low temperature kill that the primary concern is the actual soil temperature rather than the air temperature. The critical tissues which must survive are the crown meristematic tissues. Leaf and root kill is of no concern since these tissues can be readily replaced by new growth from the crown. Thus, as long as temperatures in the crown area remain above the lethal level, no critical kill of the turf will occur.

Direct low temperature kill appears to be most common in an intermediate belt across Wisconsin, Michigan, New York, northern Illinois, and in certain areas of New England. This is an area that is subjected to extended periods of freezing and thawing and also has a higher potential for hydration of the crown tissues.

Of more immediate concern to the professional turfman are methods to elimate direct low temperature kill problems. Actually, there are no guaranteed methods of avoiding low temperature kill, but practices are available which will minimize the chance of injury. Detailed studies at Michigan State University show that excessive late fall nitrogen fertilization should be avoided because this will stimulate growth and increase the hydration level of the crown tissue. One should also be sure that adequate levels of potassium are present. It appears that a relationship of three to four units of nitrogen to one unit of potassium will provide the proper nutritional balance to insure maximum low temperature survival.

Other factors of concern are proper surface and internal soil drainage in order that free water can be drained from the vicinity of the crown tissue as rapidly as possible. If the annual bluegrass plants are permitted to stand in water for an extended period of time, the hydration level of the tissue will increase. If this is then followed by a very sharp freeze to temperatures of below 20 degrees F., the potential for direct low temperature kill is quite high. Thatch should also be avoided as it will contribute to increased low temperature kill. One final consideration is avoiding traffic over the turfgrass area during wet, slushy periods. If a sharp freeze occurs, this condition can result in severe turfgrass injury.

ICE AND SNOW COVERS

Extended periods of ice and snow coverage sometime occur during winter period. The possibility exists that an extended period of high density ice coverage could impair gaseous diffusion to the point that the turf could be injured through either (a) suffocation caused by a lack of oxygen for respiration, or (b) toxic gases which have accumulated adjacent to the living tissues.

Both field and controlled climate studies have been conducted at Michigan State University to clarify this type of injury. Based on these studies, one must conclude that injury caused by the ice cover itself is a rare occurrence.

In general, most turfgrass species are relatively tolerant to extended periods of ice coverage. Annual bluegrass is less tolerant than many others. For example, injury to annual bluegrass may occur under ice sheets which have been in place in excess of 60-70 days. In contrast, bentgrass has survived as long as 120 days under an ice cover.

This question frequently arises, "Should I remove the ice and snow cover from my greens and tees?" Basically, this is a good practice, although the reason for which you may be removing it may not be the correct one. By removing a majority of the ice and snow from a green, you are essentially mechanically removing the water from the green in a frozen state. Thus, during the thawing period, this water will not accumulate in the vicinity of the grass crown tissue, cause an increase in the water content of the tissue, and result in a greater chance of injury due to low temperature kill. In general, one should not completely remove the ice and snow cover. It is best to leave between one-half and one-quarter inch of snow cover to avoid winter atmospheric desiccation problems which may occur if the turf is exposed to drying winds for extended periods of time

In summary, annual bluegrass is relatively susceptible to both high temperature and low temperature stress, compared to many of the other permanent, perennial cool season turfgrasses being used. These are two reasons why annual bluegrass is objectionable in quality turfs. However, the prolific seed production and the presence of large quantities of Poa annua seed in the soil insures rapid reestablishment of a turfgrass stand following any temperature kill. Studies are continuing at Michigan State University in order better to understand high and low temperature stress mechanisms of turfgrass, with the ultimate hope of developing turfgrass species which have greater heat and cold tolerance.

SANDS USED IN SOIL MIXES

JOHN H. MADISON. University *of California, Davis*

The USGA has long supported research on soils for turf. In retrospect we can see the work they supported as leading in a steady and almost directly unfolding path to the USGA specification green. The final result however would not have been guessed from results of the first study. After two years of study at the Arlington Turf gardens, Fitts concluded that each addition of sand to soil resulted in a decrease in turf quality — the more sand the poorer the turf — therefore the best soil to use was the soil in place without amendments. In 1925 this was probably a good conclusion. The missing factor in Fitt's work was compaction. With later work it was found that 'when there is no compaction a loam soil is best for growing grass. With compaction however, growth on a loam rapidly deteriorates while that on sand holds up. I believe we are all aware of the reasons. With compaction, pores in a loam change size and shape and supplies of air and water to the root are changed. With sand, compaction produces little change in size or shape of pores or in rooting. In effect, when we choose a sand based soil we are planning to raise 2nd quality grass instead of 3rd quality. Compaction from foot traffic keeps us from growing first quality.

In 1954 when Lunt introduced the idea of a four inch layer of sand on top of trafficked soil, he was using an engineering approach to the problem of compaction. The purpose of the sand was to dissipate the compacting forces and protect the soil beneath. He modified the engineering approach with an agricultural approach, and also used the sand as a growing medium.

Meanwhile 35 years steady work by the USGA culminated in 1960 in the publication of "Specifications for a method of putting green construction." The final approach of this method is empirical. Do it this way, it works. It has worked. It will work.

But the American character is peculiar. I'm willing to make a wager. I'll wager 90% of you readers would, if given the USGA specs for a green and told to build it, 90% would feel they could make changes and improve on it.

We have this characteristic that won't let us be satisfied with even a good recipe. We always want it better, to improve the methods; to question existing ways.

We use much sand for topdressing, much for soil modification. As we look around we see many different kinds of sand. They look different, they feel different. Some form a loose pile, some a stable pile. The plasterer wants one grade, the concrete company another. The railroad engineer is fussy about the kind of sand he uses to sand the tracks. Which sand do we want? Or are the differences important?

Many persons are studying these questions. Let's explore sand and some of the things they are finding out about sand.

We are all familiar with the cycle of rain, as ocean water is evaporated into the air, forms into clouds, falls as rain, makes its way to the rivers and ends again in the ocean. There are some similar cycles with sand. In California, beach sand moves back and forth between the ocean and the shore gradually working its way south. At river mouths it is often washed out to sea, but is carried back during big storms. Some is picked up by the wind and blown inland where it forms deposits. Deposits may lie for years then be washed into rivers and carried back to the sea.

Sand is part of California's gold. It is a valuable mineral and many large fortunes have been made from sand;

In the US there are two official size classifications for "sand." The international standard recognizes two sizes, coarse (2.0-0.2mm) and fine (0.2-0.02mm). We will use the USDA standard: This system recognizes verv coarse sand, 1-2 mm; coarse sand, 1/2-l mm; medium sand, 1/4-1/2 mm; fine sand, l/l0th to l/4 mm, and very fine sand, l/lOth-1/20th mm. These are all sand, though the largest grains have 100 times the diameter of the smallest, and l,OOO,OOO times the volume. A size difference of a million times is a big difference and we can expect this to result in a difference in behavior of different sand sizes.

There are also important chemical differences in sand. Sand can come from granite, from limestone, from serpentines, or from other minerals.

Granite is a mixture of minerals and so is sand that comes from the weathering of granite. Granite has a large amount of quartz and quartz is relatively inert in soil. Of the feldspars, orthoclase is a potassium bearing mineral from which bentgrass can extract a fair amount of potassium. Bluegrass can't get potassium from orthoclase, however. Some feldspars are also a source of calcium mineral. Granite also contains micas and micas can supply potassium, magnesium, and iron. In addition micas can provide cation exchange capacity.

Many California sands are rich in such iron-magnesium minerals as serpentines and olivines. Other iron bearing minerals are frequent, and vermiculite is often present.

The various minerals break down at different rates. Silica is very resistant to breakdown, calcium minerals are readily broken down. As a result finer grades of sand have more silica, and less of the calcium, feldspar, and magnesium minerals. Breakdown of iron and aluminum minerals results in formation of hydroxides which contribute to cation exchange capacity.

So we find chemical differences in sand depending on the source, and depending on the size.

Another difference in sands is among shapes. Sands produced by glaciers result from grinding action and have sharp angular edges, and many fracture planes. Sands produced by normal weathering are often cystaline and have 'sharp edges but are simple in shape.. Sands washed by streams and by the ocean are smooth and rounded. But a few thousand years buried in the soil and processes of crystalization and cementing may reform the grains and add back corners and edges.

So we have differences in size, shape, and composition among different sands. There is another difference associated with size that concerns us. That is the particle size distribution, the relative amounts of fine or coarse particle in the sand mixture.

From the standpoint of soil physics we are most interested in the spaces between sand particles. When you compact loam soils, they lose the larger spaces; the surface becomes impermeable to air and water; and small capillary spaces hold water too tightly for plants to use it.. When you compact sand it quickly becomes firm with the pores stabilized. If we grow turf on coarse sand, pores are large, water runs through, grass soon wilts, the sand is droughty. If we use fine sand there are still enough large pores to drain well but we may have to use a layer of sand 12-15" deep to get enough pull to cause larger pores to drain. With a mixture of all sizes of sand, there is dovetailing. Middle size grains fit in the pores between large particles. Small grains fit in the pores between medium size grains, and very fine sand grains fit in the remaining pores. As a result a sand of mixed sizes may set up hard, be slow to accept water, and drain poorly. Hence a sand with a narrow range of sizes performs better than one with a wide range of particle size.

At Kansas, Ray Keen grew putting green bents on sands. He used a 1 mm mason sand and a medium sand, l/4-1/2 mm size. Dr. Keen found the 1 mm sand too droughty. Medium sand had more roots, provided a better playing surface, and had more latitude for management.

Joe Duich has had a program on soil modification at Pennsylvania for several years. Unfortunately he has not used fine sands. His good performing sands contain about 8% fines. He used a coarse sand which has a very high infiltration rate but which only holds 1 l/2 inches of available water per foot of depth. It is droughty. A medium sand holds 3 l/4" of water per foot which is more than twice as much. Duich notes that we can use different combinations of particle sizes to achieve the same result. But we must have that gap of voids with no particle that fits and plugs them.

At Purdue, a student David Bingaman is studying sands. He is doing an excellent job. Of the many differences in sands, he finds three important, and has worked out methods to characterize these three characteristics. He has a roundness index to characterize particle shape. Size is characterized by a weighted particle diameter. This is a little different from a average but like an average lets us use a single figure to represent a collection. For particle size distribution, Bingaman uses a gradation index. The sand is seived. The hole size retaining 5 % is divided by the size hole in the seive retaining 95% of the sand. This provides the gradation index. If a sand is uniform the gradation index will be 1. A sand about equally divided among coarse, medium, and fine sand would have a gradation index of about 5. Divided among, coarse, medium fine, and very fine, the gradation index would be about 20. The higher the gradation index, the more pores are blocked by fine particles which fit into the pores between larger grains.

Bingaman looked at a lot of other characteristics of sand particles, but he found performance could be related to these three; size, distribution, and shape. Of these three he found that if the gradation index were larger than four it overshadowed size and shape in field performance. Bingaman hasn't published his work yet. From the information I have, his work shows a good usable soil medium when the sand falls mostly between two particle size groups, most of the sand is in the fine or very fine group, and the sand is more round than angular.

We have always considered a narrow particle size distribution a most important characteristic. For a suitable rooting medium for grass, Bingaman specifies a gradation index between 2 and 6.

When I apply Bingaman's gradation index to our California sands, I find a few of the better ones have a gradation index of 5-6. Most sands have a higher gradation index. In other words benefits we might get from size and shape are overshadowed by too much of a spread in particle size.

Many sands being used contain a fair amount of small gravel; as much as 25% for example. This gravel fraction is undesirable. It dulls the mowers, dirties the green, and occupies space without contributing any benefits. Fortunately we don't have to use sand with all this coarse material in it. Our good fortune extends to cost. We want the finer grades of sand for which there is less demand and so prices are usually lower. We prefer rounded smooth sand while the building trades want sharp sand. So again we are not competing for high demand uses. We should like to have sand that has mica and vermiculite in it and perhaps some serpentine. These are soft minerals that can reduce the value of sand for concrete, but which provide us with usable minerals and cation exchange capacity to buffer our fertility. So in every respect except one we can preferentially use the cheaper sands. That one exception is particle size distribution. At present, most sands need to be more closely graded to give us optimum results.

Before going on to my illustrations let me summarize the above: Sand is made up of particles that differ a million times in volume between the largest and smallest. Of many physical characteristics, the one most important for us is that most of the particles lie in a narrow range of sizes. In addition finer sizes are less droughty and easier

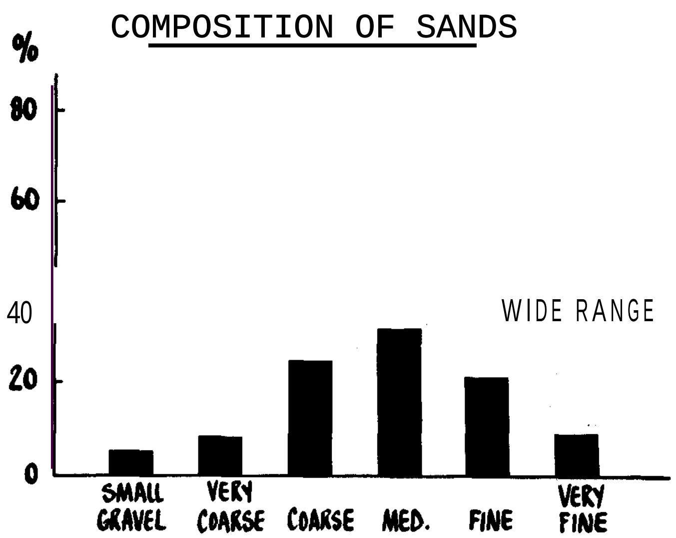

Fig. I-A

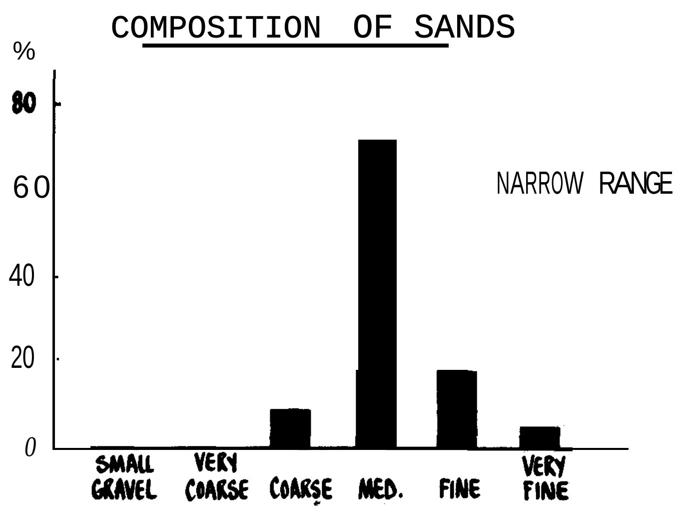

Fig. 1-B

to manage, roundness improves characteristics of sands, and some minerals provide a more favorable chemical environment as compared to others.

The illustrations are based on generalizations.

Figure one illustrates two sands, one of which (la) has a broad particle size distribution. The second (lb) has a narrow particle size distribution with most of the sand falling in a single particle size group. The second would be more desirable for either top dressing or to USC in greens mix.

The next two illustrations (see Figures 2 & 3) are based on water release curves. On the horizontal axis is the tension on the water in pores of the sand, After irrigation the tension depends on thickness of the sand layer. Later on tension is increased by water use by the grass. The vertical axis represents the pore space and goes from 0 to 100% of the pore space. To interpret these curves consider the space above and to the right of the curve to be air, that to the left and below the curve to be

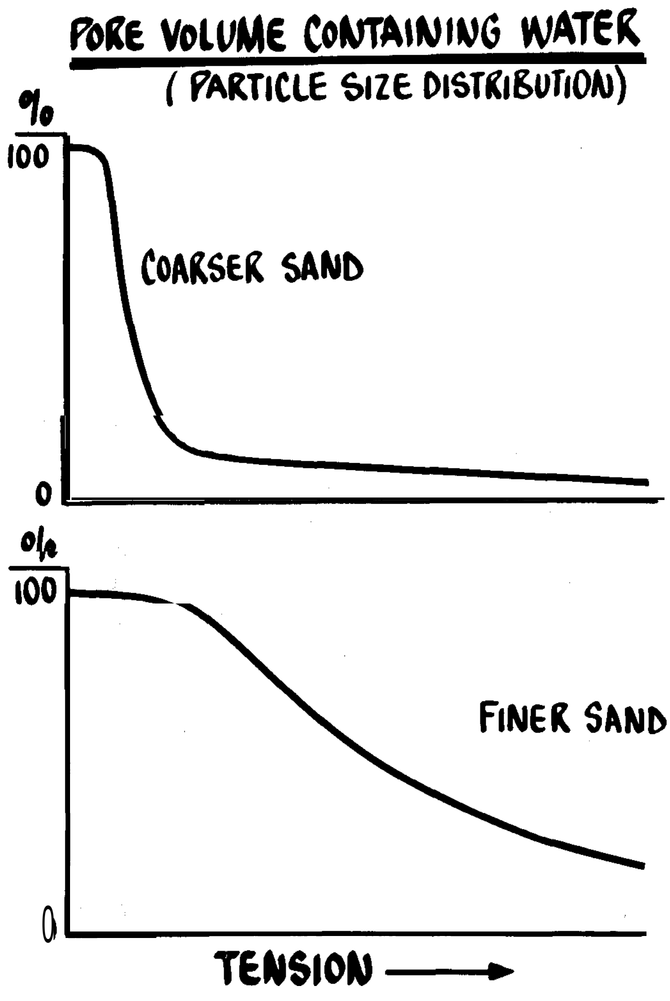

Fig. 2

water. Comparing curves for coarser sand with that of finer sand (Fig. 2), we note the curve for fine sand has a more gradual slope and releases more water more gradually. Water is released from a coarse sand quickly. Coarse sand is droughty, finer sand with a more gradual release is easier to manage. In a shallow layer neither has many air filled pores. With increasing depth air after irrigation increases, but with the coarser sand a small increase in depth can result in so much loss of water as drainage, that little is left to the plant.

Comparing sands with wide and narrow particle size distributions (Fig. 3) we find that release is more gradual with a wide particle size distribution. But we need a much greater depth of sand before drainage brings air into the root zone. Unless we have that depth we may have prob lems of wet wilt and limited root growth from lack of surface aeration.

To return to the USGA specification green we may ask why, if- Variations in sand are important, they are ignored. In the USGA green we are solving problems of the physical movement of soil air, and water. These physical characteristics are related to other physical characteristics such as roundness of sand grains, particle size distribution etc. When the laboratory measures infiltration rate of a recommended mix, they indirectly evaluate all the other factors. But before you send materials in for laboratory testing, you may have a choice of a dozen sands. Your choice of sand at that time may affect the per cent used in the final mix, the latitude in managing the final green, and the attention to and effectiveness of fertilizers used in the nutrition of the green.

The USGA specs are a major step forward. They work. What I have shown is that in our search for perfection we do not stop with one problem solved but go on to ever finer levels of sophistication. Of two managers with USGA greens having similar infiltration rates, and about the same total and non-capillary porosity, one may have easier management because of a different choice of sand in the basic mix. I have indicated advantages from a finer sand of narrow particle size distribution containing a high percentage of vermiculite and other "soft" minerals.

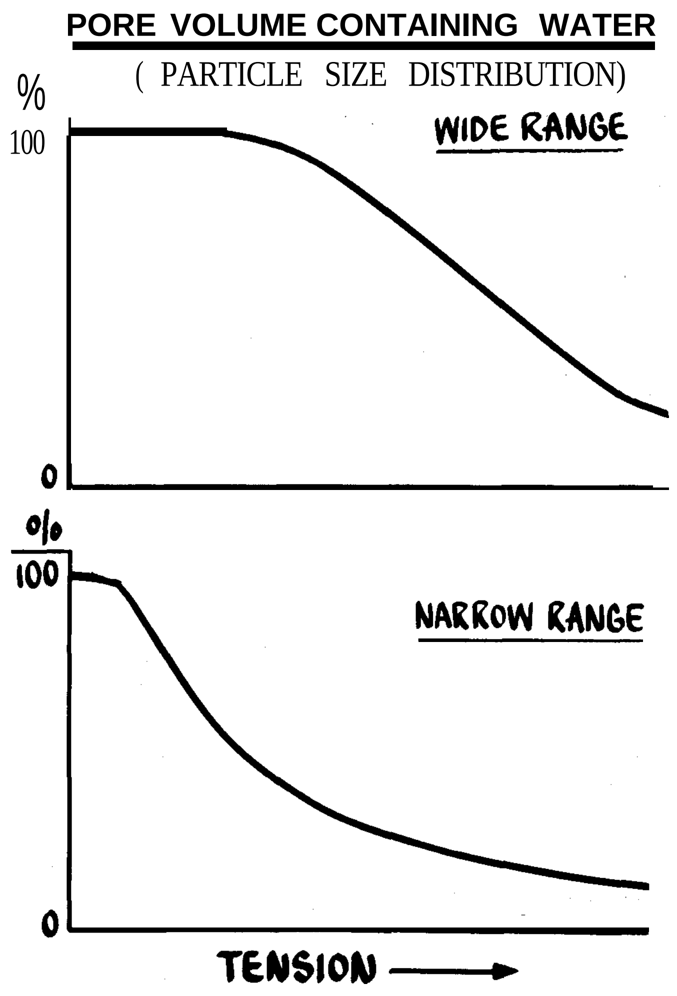

Fig. 3

A REVIEW OF RECENT TURFGRASS RESEARCH IN SOUTHERN CALIFORNIA

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Turfgrass research in Southern California began in 1948 at the Los Angeles campus of the University. In 1965 the program was transferred to the Riverside Campus.

Recognition of the essentially arid nature of the western climate directs the course of nearly all turfgrass research in California. In other respects the climate ranges from Mediterranean with mild winters and long dry summers to continental with winters characterized by intense cold and heavy snowfall. However, the population is concentrated in the areas of mild Mediterranean and marine climates, hence turf research concentrates on the problems of these regions.

Because of the diversity of climates nearly every turfgrass species is grown in this region. Centipede, carpet and buffalograss are the only turfgrasses of any importance not used in the West. Consequently, the scope of the research here is one of the most extensive in the United States. Greenhouse, growth chamber and laboratory investigations are carried out at Riverside. Field research is conducted at the University's South Coast Field Station, Santa Ana, and on the Riverside campus. A number of field studies are run cooperatively with golf courses, turf nurseries and other industry organizations.

Most turfs in the West require at least some irrigation every month of the year so naturally considerable research has been devoted to irrigation and water management problems. The use of tensiometers for measurement of soil moisture in turf was pioneered in California. Today many turf managers are using these instruments as a guide for their irrigation programs. Recent work by University of California personnel has shown that tensiometer control of the sprinkler system is feasible and efficient where soils are fairly uniform. Studies still underway demonstrate clearly that with the use of tensiometers water consumption can be reduced greatly while still maintaining as good or better quality turf. *Poa annua* populations in bermuda turf have been significantly reduced as a result of lower irrigation rates and less frequent applications.

Soil salinity is a western problem associated with the low rainfall and heavy use of irrigation water that has received considerable investigation. Through a series of greenhouse studies the relative salinity tolerance has been determined for many of the turgrasses. Results of this work are summarized in Table 1 and 2. There are no cures for saline soils except leaching periodically with large amounts of water to flush the excess salts out of the root zone. As this may be difficult to do under many conditions, selection of the more salt tolerant species and varieties is recommended.

To find ways of improving soil, air, water and plant relationships, soil amendments and prepared soil mixtures for greens have been studied extensively in the West as elsewhere in the nation. Early work at UCLA showed the benefits *to* be derived from using sand and organic matter mixtures. The important criteria seemed to be to have medium fine sands of uniform particle size and organic materials that decomposed slowly in the soil. Redwood sawdust or lignified wood generally gave the best results for this purpose.

Many soil amendments, organic and inorganic, have been tested and studied. Most studies have shown that we cannot say that there is one best material or one better type. Use of soil amendments, and soil conditioners as well, must be considered in relationship to other soil physical characteristics and to management practices.

Studies devoted to problems of turfgrass nutrition and fertilization have been numerous. The development of plant tissue analyses as guidelines for fertilizer applications has been of particular interest. For Newport Kentucky bluegrass the optimum levels in leaf tissue of the three major nutrients are shown in Table 3. These percentages may be expected to vary to some extent for different species or perhaps even varieties of a species.

Field studies have indicated that optimum fertilizer ratios on a seasonal basis should approximate a 5:1:2 formula for turfs subjected to year around irrigation in the arid West.

The minor elements have also received some study. Boron in small amounts is essential for plant growth but becomes toxic at higher levels. In some cases as little as 2-3 ppm may be toxic. It has been shown, however, with the turfgrasses, clipped frequently, little or no injury will result from levels as high as 10 ppm. This is fortunate as western irrigation waters frequently may be high in boron.

Zinc deficiency has been demonstrated for many of the turfgrasses. This is difficult to distinguish from iron deficiency and often may occur simultaneously with iron deficiency. As with iron, zinc deficiency may be readily corrected with foliar sprays using zinc sulfate or applications of zinc chelate.

For many years a major research effort was directed towards improving the control of crabgrass. Today several excellent herbicides are available for crabgrass control. The preemergence materials recommended in the West are DCPA (Dacthal) for all turfgrasses but bentgrass greens, Benefin (Balan) for bermudagrass and bluegrass turfs, Bensulide (Betasan, Presan) for bentgrasses and general turf and Siduron (Tupersan) for bluegrasses and fescues in seedling stage *or* older. Postemergence control is readily achieved with the organic arsenicals (DSMA and related compounds).

Today attention in Southern California is focused on the control of kikuyugrass *(Pennisetum clandestinum)*. This aggressive weedy grass is familiar to most golf course superintendents in California. A few courses have been completely taken over by this grass except for the greens. Superintendents on these courses can do nothing but learn to live with it, which some have done quite well. Patches of kikuyu appear frequently on many courses and must be controlled immediately before they spread or serve as sources of infestation on other parts of the course.

Research to date has suggested the following as the best control methods: 1) methyl bromide fumigation under a tarp where infestations are isolated and relatively small 2) dalapon at 8 lbs active per acre repeated as new growth appears 3) SMDC (Vapam) at 10-20 lbs per 1000 sq. ft.

DSMA and MSMA show much promise in tests to date. However, results have not been consistent in all locations and the series of applications necessarily become costly. Current studies are attempting to improve translocation and increase toxicity of these materials.

Annual bluegrass, despite years of study, remains the number one weed problem for many golf superintendents. Effective preemergence herbicides are available but control is still not achieved because of a conflict between

Based on a talk presented at the 40th International Turfgrass Conference, Miami Beach, Florida.

cultural practices and weed control practices and because of the perennial nature of annual bluegrass strains which become dominant on greens (California Turfgrass Culture, 18(l) :6 and 18(3) :17-18).

Breeding and variety testing form a part of mose turf grass research programs. This work is necessary to obtain varieties with the best possible adaptation to the regional conditions. Santa Ana bermudagrass was a recent introduction for California. It has shown a high level of tolerance to salinity, the bermudagrass mite and smog. It has a short winter dormancy period and rapid recovery from injury or divots making it especially valuable for tees, athletic fields, and other heavy duty turf.

Dichondra improvement studies have led to the development of a new strain which will be released to certified seed growers within the next two years.

Wear resistance and recovery from wear is a requirement of turfgrasses for many uses. A number of years ago the UCLA research station developed a power driven machine for testing grasses for wear resistance. Many tests have been conducted since then and the machine is still used as a part of the variety testing work. Some of the results using this machine are shown in Table 4.

Basic research on grasses is essential to provide knowledge of grass growth and nutrition. Information from such investigations forms the basis for many applied studies and the development of better management practices. Some of the basic research projects of recent years involve the tillering of grasses, accumulation and utilization of carbohydrate reserves and the metabolism of growth regulators in the grass plant.

Research on the western disease and insect pests of turfgrasses seems never ending as new pests appear with great frequency. A few years ago the bermudagrass mite spread rapidly through the West. It was previouslv unknown here so studies on its control were initiated immediately. This work showed that it could be readily controlled with diazinon, but that a turf grower could live with moderate levels of infestation through good fertilization, irrigation and thatch control programs.

In 1957 a pest appeared that was common to the southeast but unknown in the West. This was the chinch bug on St. Augustinegrass. Although St. Augustinegrass is not a popular grass in California it is our best shade tolerant species so it is important that chinch bug control measures be devised. It is true that controls have been known for years in the Southeast but we cannot be certain that they will work as well in the West. Therefore, control tests are underway to develop the necessary control recommendation for this region.

Plant pathologists at the University of California, Riverside, have been investigating the causes of root tip degeneration as related to fungus diseases and environmental factors. The significance of this work is great as the condition of the root system is a major factor determining vigor and survival of a turf. Root tip degeneration has been shown to be caused by toxins produced by the dollar spot fungus and by certain sugars and sugar derivatives occurring naturally in many fungi and other plants.

We have discussed here only a few of the highlights of turfgrass research in Southern California. Each new development of new management idea is usually the result of numerous individual experiments. Major discoveries resulting from a single experiment are rare and progress is marked instead by a long series of small steps.

TABLE 1. Relative salinity tolerance of some major turfgrass Species.

Low	Medium	High
Kentucky bluegrass	Tall fescue (Alta)	Bermudagrass
Highland bentgrass	Perennial ryegrass	Zoysiagrass
Astoria bentgrass		Creeping bentgrass
Meadow fescue		St. Augustinegrass
Creeping red fescue		

TABLE 2. Relative salinity tolerance of several bermudagrass and creeping bentgrass varieties.

	Bermudagrass		Creeping bentgrasses
Highest	Tifway	Highest	Seaside
	Santa Ana		Arlington
	Sunturf		Pennlu
	Ormond		Old Orchard
	Tifgreen		Congressional
	Common		Cohansey
Lowest	u-3	Lowest	Penncross

TABLE 3. Optimum levels of N, P, and K in leaf tissue of Newport Kentucky bluegrass.

Nutrient	% of Dry Weight of Clippings
N	4.0 - 4.5
P	0.34 - 0.45
K	1.0 - 1.2

TABLE 4. Relative wear resistance and recovery rate of some common turfgrass species and varieties.

Wear Resistance		Recovery
Meyer zoysiagrass	Highest	Santa Ana bermudagrass
Zoysia matrella		Common bermudagrass
Santa Ana bermudagrass		U-3 bermudagrass
Tifway bermudagrass		Tifway bermudagrass
U-3 bermudagrass		Creeping bentgrass
Tall fescue		St. Augustinegrass
Common bermudagrass		Kentucky bluegrass
Perennial ryegrass		Creeping red fescue
Kentucky bluegrass		Tall fescue
Meadow fescue		Meadow fescue
Creeping red fescue		Perennial ryegrass
St. Augustinegrass		Zoysia matrella
Creeping bentgrass	Lowest	Meyer zoysiagrass

THE PREVENTIVE PROGRAM IN CONTROLLING TURFDISEASES

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You don't have to be an expert to grow good turf, but the adherence to basic principles of management and maintenance practices must be carefully observed. In attempting to control the various fungi which threaten turfgrasses, one has two alternatives (1) planned protection, which is a regular preventative schedule of fungicide application and (2) emergency curative measures, which are applied only after the disease has made its appearance. The reasons for a decided swing toward a preventive program does not allow destructive fungi to develop to the point where they are damaging. Moreover, it helps maintain healthy turf which can withstand heavy traffic, and in which weeds find it extremely difficult to compete.

Infection and decay of plant parts is constantly taking place even in an apparently healthy turf. In considering the preventive program one should keep in mind and understand that it is impractical to eliminate all fungi from turf. As research has advanced and more observations are recorded, one point is becoming clear; pathogenic fungi are always present to some degree on turf.

There are times of course when it is absolutely imperative that fungicidal materials be used. Much of the pioneer work on the use of fungicides for turf disease control was done in the United States. In 1917 trials were started on the use of Bordeaux mixture for the control of Brown patch (caused by *Rhizoctonia solani)* and in 1919 the material was in general use for that purpose. However, the continued use of Bordeaux led to accumulation of copper to toxic levels which caused more severe injury than the disease which it was intended to control. Mercuric chloride was first used in 1890 for the control of Brown patch in the Chicago area. Later, mercurous chloride was added to give the mixture a longer lasting action and soon became extensively used.

One of the first organic mercuries used against turf diseases was "chlorophenol-mercury". It was not conspicuously successful. During the period of mercury shortgage in the second world war, tetramethylthiuram disulphide (thiram or TMTD) was used in the U.S. for the control of turf diseases. Then came phenylamino cadmium dilactate, the first of many cadmium-containing fungicides. Several antibiotics have been used and actidione has had limited success as has griseofulvin. The dithiocarbamates and many others too numerous to mention in this article have also played a major role in preventing diseases of turf grass. The new systemics, "DuPont 1991", Vitavax and Plantvax are being eagerly watched and evaluated.

With California's total annual maintenance cost in excess of $500 million (based on Beutel and Roewkamp's 1961 figures when the population of California was 12.2 million) it is essential that we keep our turf grasses as healthy as possible.

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Riverside, California 92502
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CALIFORNIA TURFGRASS CULTURE is sponsored by the Federated Turfgrass Council of California and is financed by the regional councils and other turfgrass organizations of the state. The Federated Council consists of officers and directors of the regional councils. Subscription to this publication is through membership in one of the councils listed below.