of the green. This seems to be as efficient as the herringbone. By this time we had become convinced that the most important thing in building a green is to provide for surface drainage without channelling and to provide for drainage away from the green so as to not have any low spots or flat areas close to the putting surface. Our last twelve greens were built to provide ample surface drainage off and away from the greens. I am happy to say that none of these greens has ever given us any trouble.

### Used Concrete Mixer

From our experience with soils, we think that any mixture with high sand content, soil and peat will be good if they are thoroughly mixed. At Richland we used a concrete mixer.

The answer to keeping bent grass greens through Southern summer months is water management. The green should be built to provide for subsurface drainage with tile lines sloped at the bottom. A blanket of gravel, well mixed topsoil and good surface drainage are very important. Water will not move through any soil very fast and the best way to take care of excess water is through surface drainage. If ample surface drainage is not provided for, or if low spots exist, or if excess water is channelled off, disease very likely will result.

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# *Temperature and Light in Growth of Turf*

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Some factors affecting grass growth are almost completely outside the range of the supt's influence. The most obvious of these are the climatic factors, temperature and light. Directly or indirectly they are related to every aspect of turfgrass management.

From the moment the grass seed is placed in the soil, it comes under the influence of weather and other environmental factors. For example if the soil temperature is too high or too low, germination will be poor and many seedlings will be deformed. And, so, throughout the life of the turf, every phase of grass growth and development is being primarily controlled by weather and climate.

The activities of the supt., particularly in timing of operations, can work with nature to develop better turf. But if incorrectly done or improperly timed, these same activities may work with nature to weaken or destroy the turf.

### Controlled Environment Observations

The recent development of new techniques for the study of environment and plant growth has opened a future full of promise for greatly increasing this knowledge. Such a new technique is the creation of the "phytotron," controlled environment

growing rooms, like the one recently constructed for the UCLA Dept. of Floriculture. With the phytotron we can regulate accurately the temperature, day length, light intensity, etc. at which the plants are grown to study the effects of specific conditions on growth of the grass plant.

Research work of recent years indicates that with many of our cool season grasses root and top growth are opposing growth phases. That is, conditions which promote top growth are not the same as those that promote maximum root development. This is especially true when we superimpose mowing, as we do in turf culture, over all other conditions.

If we recognize three temperature points in respect to growth; minimum, optimum, and maximum, we find that the three points for root growth are several degs. lower than for top growth for many cool season grasses. This is confirmed by field studies which have shown that maximum root development occurs during the late winter and early spring in temperate climates before much top growth is evident and again in late fall when top growth is slow. In late spring and early summer, the period of maximum top growth, root development has practically ceased.

### Food Reserve Depletion

Food reserves, carbohydrates stored in roots and other plant parts, increase during the period when top growth is very slow. On the other hand, during periods

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of rapid foliage growth, these food reserves are rapidly used. As temperatures increase above a certain optimum, the rate of food storage decreases until eventually there is a utilization of previously stored food materials. To further complicate this picture, it has been demonstrated that clipping retards both root development and rate of food storage. This is because the plant, in order to renew its top growth following clippings, must have additional food in the form of carbohydrates (sugars, starches, etc.)

High nitrogen feeding which stimulates top growth, when coupled with clipping has a further restrictive effect on root development. When temperatures are high, activity of soil micro-organisms which convert unavailable nitrogen to a form available for plant growth is increased.

Now, where does this information lead us in turf management? First, it is an accepted premise that in order to have a good durable turf there must be a healthy well developed root system below, and in order to have a good root system we must have a vigorous top. On the surface, it would appear that we are fighting a battle against ourselves when we feed and mow. This indeed may be true if good judgment is not used. We see that as warm summer temperatures arrive, natural root development slows and top growth increases. However, we continue to fertilize and mow further retarding root growth and perhaps actually damaging the root system. At the same time, organic nitrogen in the soil is being converted to available forms to stimulate more top growth which must be removed.

### Disease Organisms Multiply

While all this is occurring disease organisms in the soil and organic mat are multiplying as the soil becomes warmer. The result is familiar to nearly everyone with turfgrasses. The time comes when the turf has a shallow weak root system, a soft succulent top and little food reserve. Then, if weather conditions are favorable for disease infection, practically nothing can stop it.

What can be done to prevent this from occurring?

There is no satisfactory solution at present but there are a few things which will help to some degree. First, time fertilizer applications so as to have only enough nitrogen available during the hot

weather to keep satisfactory color. Second, if possible, raise the mowing height during this season but retain the same mowing frequency. Third, do not apply herbicides or other chemicals (fungicides excepted) which may damage either top or root system at this time. Finally, control water as much as possible to avoid having a saturated soil but at the same time prevent wilting. It should be quite obvious that turf disaster may result at this time from anything which will damage the root or crown of the plant.

### Warm Season Grasses

Warm season grasses, particularly Bermudas, do not exhibit the differential response to temperature such as cool season grasses. Minimum, optimum, and maximum temperatures for root development closely parallel those for top growth. Similarly, food reserves continue to be built up during periods of high temperature. Both food reserves and rot development appear to be affected less by mowing than in the case of cool season grasses.

We have some interesting temperature problems with these grasses, however. These are in respect to low temperatures. It is a common observation that as temper-

atures drop in the fall, growth of Bermudas ceases and eventually the turf discolors even though freezing weather has not been experienced. We have found that the minimum temperature for growth of Bermuda is approximately 50 degs. F. But growth will continue at even much lower night temperatures provided day temperatures are sufficiently high — 70 or above. Some improved strains, Ormond and Tifgreen, for example, appear to have a somewhat lower minimum growing temperature.

Zoysiagrasses have an even higher minimum — approximately 60 degs. for Meyer and around 55 for Emerald and Matrella.

**Light Intensity Factor**

Discoloration or winter dormancy of these grasses is an interesting reaction to climatic factors. It is generally assumed that this is caused by temperatures between 30 and 40. However, this is only partly true as we have kept U-3 Bermuda alive and green at a constant 34 for over a month. This would indicate that another factor is involved in discoloration. We have found that this factor is light intensity. The plants held at 34 without discoloration were under artificial lights of low intensity. When plants are exposed to high intensity, light comparable to natural sunlight in conjunction with temperatures of approximately 45 or less, typical winter discoloration develops. Low temperature and high light intensity interact to destroy the chlorophyll (the green coloring material in plants) and at the same time to prevent the synthesis of new chlorophyll. However, if day temperatures are approximately 70 or above, discoloration will not develop even though night temperatures are just above freezing. Of course, freezing temperatures will stop all growth and bring about discoloration because of tissue destruction and disruption of physiological processes.

Discoloration of Meyer Zoysia occurs at slightly higher temperatures and lower light intensities than for Bermuda. Emerald and Matrella Zoysia are more comparable to Bermuda.

Application of soluble nitrate, ammonia, or urea nitrogen in the fall will prolong the period of green color and will cause earlier greening in the spring. How nitrogen functions in relationship to temperature and light to do this is not known.