soil mixes in putting greens is an example of an area where minor nutrients are required because of the possible leaching and heavier irrigation. As with magnesium, high concentrations of manganese, boron, zinc and copper can be toxic to the turfgrass plant.

Iron and Manganese—Both iron and manganese are important to the color of the turf and both are required for chlorophyll synthesis. Therefore, when either one or both of these elements are deficient there is a discoloration in the turf. Iron is most likely to be deficient in waterlogged, poorly drained soils, or soils with a high content of organic matter. Areas that have heavy thatch layers are likely to be low in iron. Manganese is likely to be deficient in alkaline conditions or heavily leached areas. As noted before, manganese can become toxic with high concentrations. The manganese concentration is highest on poorly aerated soils, compacted soils and acid soils.

Molybdenum—Molybdenum is required in extremely small amounts by the plant. The primary function in plants is associated with nitrate reduction. A deficiency results in poor protein synthesis and nitrate accumulation.

Zinc and Boron—Zinc and boron functions are not well understood. Even though at high concentrations they are toxic, they are essential to the plant. High concentrations have been found only on rare occasions by researchers.

Chlorine—Chlorine is the last of the micronutrients. It is thought to be associated with osmotic pressure and cation balance in the plant. Again, deficiencies have rarely been observed. Research shows no specific role in the plant's metabolism by chlorine.

In these few paragraphs I have tried to explain an update of thoughts behind nutrient application. When we fully understand the complete functions of all the nutrients, then we will be able to fertilize and truly make a nutrient application.

Physiological Responses of Cool and Warm Season Grasses

by **THOMAS L. WATSCHKE**, Assistant Professor, Pennsylvania State University

Over the past 50 years the golf course superintendent has made tremendous advances in improving his status and, particularly during the past decade, has gained the recognition he has long deserved. With this recognition has come rapidly increasing salaries and improved social prominence. But, also with it has come an awareness by the public of the earning power and educational training today's superintendent possesses. Consequently, today's superintendent is going to have considerably more expected of him; both from his club membership and society.

As a result, presentations at conferences of material which do not always directly apply to practical situations will increase. This material is presented to improve and increase the overall knowledge of the turf superintendent about his commodity; turfgrass.

Most superintendents recognize symptoms of physiological breakdown; slowing of growth and wilt from drought and temperature stresses, lesions and chlorosis from diseases, nutrient deficiencies and insect damage. The time has come for superintendents to increase their knowledge of why these symptoms occur beyond knowing that the soil is dry or the temperature is high. Being acquainted with physiological processes and how they are affected by environment and management should be a part of the arsenal of knowledge that today's successful superintendent possesses. For example, a superintendent in the transition zone may be asked by someone why bermudagrass does so well compared to bluegrass in the summer months. If the superintendent merely points out that bermuda is a warm season grass and bluegrass is cool season, he undoubtedly will not be revealing anything the person does not already know. Golf superintendents are considered, and rightfully so, to be the turf experts in their community. People asking questions about turf have the right to expect a knowledgeable answer. Therefore, it is the responsibility of golf course superintendents to attend conferences and meetings to improve and increase their knowledge of how grass grows, and keep abreast of research developments and new extension publications.

Many physiological phenomena occur in plants. The two most important are photosynthesis and respiration. Different environmental conditions and management greatly influence the rate and efficiency of these two processes. Changes in the rates of these two processes ultimately affect the growth and performance of turfgrasses.

Variations in environmental conditions such as light, temperature, and moisture influence the rate of photosynthesis. Photosynthesis of cool season grasses like bluegrasses, fescues, ryegrasses, and bents is affected differently by temperature from that of warm season grasses like bermudas and zoysias. The mechanism for fixing CO_2 in warm season species is more efficient than the mechanism of cool season grasses. Because of this difference, warm season grasses have a higher temperature optimum for photosynthesis than cool season species (Figure 1).

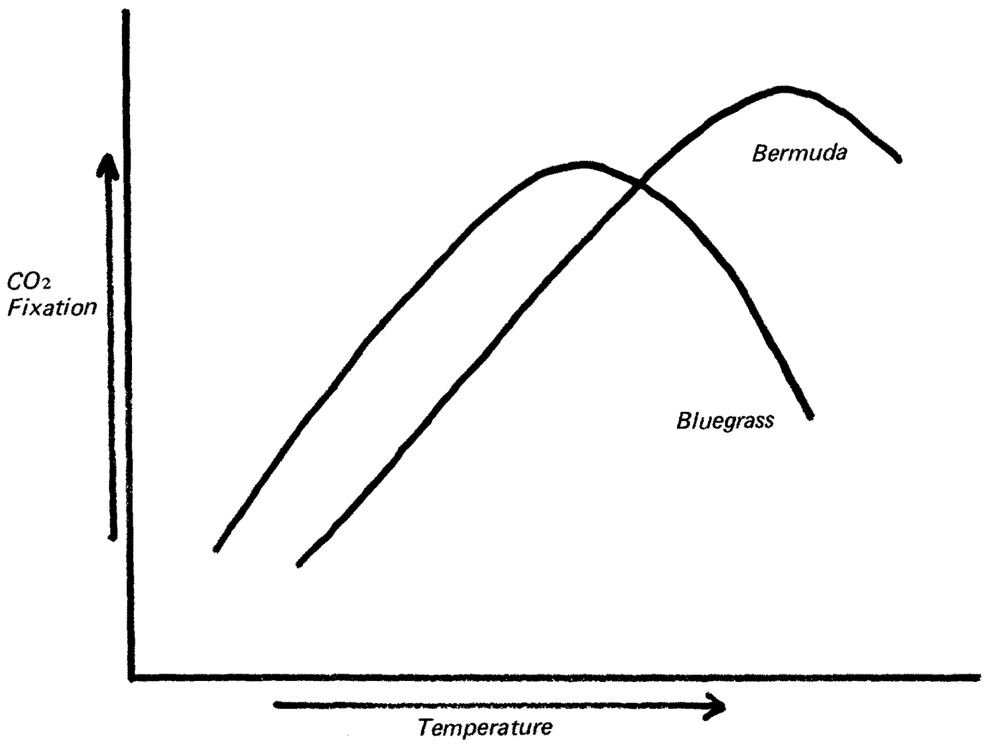
Occurring simultaneously with photosynthesis in cool season grasses is a process called photorespiration. This respiration liberates CO_2 from the leaf without supplying any usable energy to the plant. Consequently, they retain the carbon and incorporate it into useful materials. Subjecting temperate grasses to low oxygen atmosphere will inhibit photorespiration. When photorespiration is inhibited, the photosynthetic rate of bluegrasses will approach that of bermudagrass even at high temperatures (Figure 2).

Although no practical means of inhibiting photorespiration has been found, the implications of a practical solution are interesting to contemplate. It would be ideal if cool season grasses could maintain rapid photosynthesis at high temperatures and also retain the desirable characteristics they possess at cool temperatures. If germplasm of cool season grasses from southern regions can be found which show regulation of photorespiration, they should be included in breeding programs to enhance the possibility of increased high temperature tolerance of progeny.

Warm and cool season grasses also respond to different light intensity. In mid-summer, when light intensities are near or above 10,000 foot-candles, warm season grasses have increased fixation with increasing light intensities. However, cool season grasses, in general, do not appreciably increase fixation above 6,000-7,000 foot-candles (Figures 3). Consequently, warm season grasses utilize more of the available radiation than do cool season species.

Dark respiration rates are also strongly influenced by temperature; increasing when temperatures rise. This causes a reduction in

Figure 1. Effect of temperature on photosynthesis of bluegrass and bermudagrass.



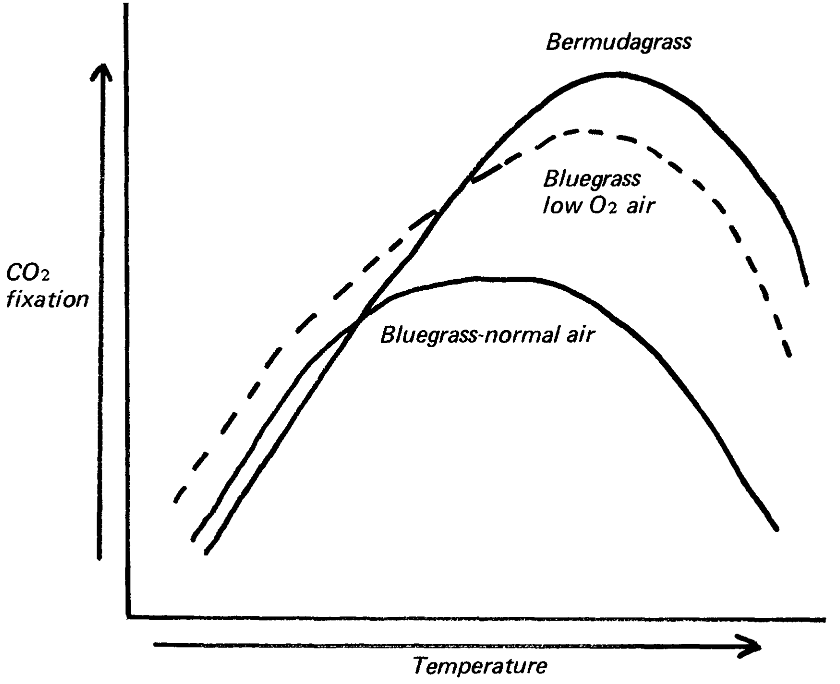


Figure 2. Effect of temperature on photosynthesis of bermudagrass and bluegrass in normal air and bluegrass in low O_2 air.

stored carbohydrates because CO_2 is being lost to the atmosphere, and as long as carbon is available, growth is accelerated. Therefore, high carbohydrate levels are desirable, particularly during the hot months of the year. Nitrogen fertilization should be frugal to minimize growth responses. Since the ability of temperate grasses to fix CO_2 is decreased at high temperatures and the utilization of previously fixed carbon is high, management must compensate for the plant's shortcomings.

When all is said and done, the successful golf course superintendent is the one who can predict plant responses to environmental and managerial influences because he knows something about how grass grows.

Figure 3. Effect of light intensity on photosynthesis of bluegrass and bermudagrass.