when the rate increased from five to seven pounds. In 1971 the quality of turf on the seven-pounds plots was no better than on those receiving five pounds of fertilizer. By 1973 a reverse trend was noted, and by 1974 the quality had completely reversed, with the quality of turf on the three-pound plots significantly better than that on the five- or seven-pound plots.

There are two primary factors that contributed to this reversal in response to fertilization. First, it was noted during the first years of the study that copper spot *(Gloeocercospora sorgi)* incidence was positively correlated with nitroten rates increased. Injury resulting opened the turf to *Poa annua* invasion. Second, during the summer of 1973 extremely hot, humid weather occurred for a prolonged period. Turf on the plots receiving higher levels of nitrogen were actually scorched. This did not occur at the three-pound nitrogen rate. Again, *Poa annua* invasion was accelerated as a result. Photos taken in the spring of 1975 clearly illustrated the increase in *Poa annua* with increasing fertilizer rates. The percent of *Poa* present in December, 1974, as influenced by topdressing frequency and the amount of fertilizer used is shown in Table III.

For those who understand the management requirements of velvet bentgrass, these results might be predictable. The results also apply, however, to creeping bentgrasses. Although the fertility level might be at a higher level for creeping bentgrasses, probably fewer problems will occur if seasonal fertilizer rates are at lower levels than frequently used. Golfers may need to be reeducated to differentiate putting quality from color. It would be worth all the effort if a quality surface could be assured with the use of less fertilizer.

Table III. Percentage of *Poa annua* comprising turf cover, in December, 1974, as influenced by topdressing frequency and level of fertilization.

Topdressing frequency	% Poa annua	Fertilizer rate	% Poa annua
2 times	13.4	3 lbs.	2.7c*
3 times	15.7	5 lbs.	15.3b
4 times	15.4	7 lbs.	27.2a
7 times	15.8		

* Values followed by the same letter(s) are not significantly different at the 5% level using Duncans New Multiple Range Test.

A GREEN SECTION SUPPORTED RESEARCH PROJECT

Sulfur and Bentgrass Putting Green Turf

by DR. ROY L. GOSS,
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Adequate soil fertility is of great importance to the growth and development of turfgrasses. The major plant food elements nitrogen, phosphorous and potassium have received most of the attention in turfgrass fertility research and practice; however, lack of any one of the essential plant nutrients, N, P, K, Ca, Fe, S, Mn, B, Mg, Cu, Zn, Mo, and Cl will result in unsatisfactory growth. The information presented in this paper will deal mainly with sulfur, but will attempt to bring out the influence of N, P, and S on various factors related to putting green turfgrass quality.

THE SULFUR PICTURE HAS CHANGED

A number of factors are responsible for increased sulfur needs of turfgrasses. Coleman (2) indicated that the use of high-analysis fertilizers that contain little or no sulfur, increased growth, and decreased gain of atmospheric sulfur by soils and plants as a result of decreased combustion of coal and other high sulfur fuels are some of these factors.

It is common knowledge that nutrients leach from sand at a faster rate than from heavier textured soils. Due to current emphasis on the use of sand for building putting greens and tees, we should be aware of the continual need to regularly supply all nutrients including sulfur in a reasonable ratio. In general, the higher the application of nitrogren, the greater the stress for sulfur and other nutrients due to increased growth. Nitrogen applications for greens vary from less than five to over 20 pounds per 1,000 square feet per year with eight to 12 pounds being very normal for many areas in the U.S.

Volk and Horn (5) reported that yields and sulfur content of Tifway bermudagrass clippings from ammonium sulfate vs. ammonium nitrate treatments superimposed on various potassium sources was significantly higher from the ammonium sulfate treated plots grown on a loamy fine sand soil. Woodhouse (6) has reported increased yields seven out of eight years on Coastal bermudagrass fertilized with 62 to 123 pounds of sulfur and 0 to 1,478 pounds of N per acre when grown on a Eustis sand. These citations support the writer's belief that sulfur has often been neglected on turfgrasses growing on sand.

ROLE OF SULFUR AND DEFICIENCY SYMPTOMS

Sulfur deficiencies seriously retard the growth of turfgrasses because the element is needed for:

1. Synthesis of the amino acids cystine, cysteine, and methionine, all required for protein synthesis.
2. Synthesis of some vitamins (biotin and thiamin, glutathione, and coensyme A).
3. The formation of certain disulfide linkages which are associated with the structural characteristics of protoplasm. This is also associated with cold resistance.
4. The formation of ATP sulphurylase, an enzyme concerned with the metabolism of sulfur.

There are several other cited needs for sulfur including its effect on chlorophyll content which affects photosynthesis.

SULFUR REQUIREMENTS FOR TURFGRASSES

There is little information available regarding the requirements and tissue sulfur levels for turfgrasses. Martin *et al* (4) stated that many field fertilizer experiments with S have been carried out, but only in a few has plant content of S been determined over a range of S rates or for an entire season. Love (3) reported higher levels of S in seaside bentgrass tissue than in Merion bluegrass or Pennlawn red fescue. He showed levels of 0.19, 0.15, and 0.12 per cent, respectively for the three grasses when receiving adequate fertilizer; and levels of 0.08, 0.06, and 0.04 per cent, respectively when deficient. Beaton (1) has stated that about 0.20 per cent S in turfgrass tissue would seemingly be about normal for good growth. Data presented by Love (3) also showed that tissue phosphorus levels were lower than tissue sulfur. It can be assumed from the little data available that S and P levels should be approximately equal.

SULFUR RESEARCH AT WASHINGTON STATE

The research reported in this paper was conducted at the Western Washington Research and Extension Center at Puyallup, Washington. Sulfur applications were started in 1967 on Astoria bentgrass putting green turf that was established in 1959 on a sandy loam soil. Fertilizer treatments from 1959 through 1967 were made up of all combinations of 20, 12 and 6 pounds of N, O and 4 pounds P_2O_5 phosphorus, and 0, 4 and 8 pounds of K_2O potassium per 1,000 square feet per year. In 1967, sulfur was applied to all plots that previously received potassium at rates of 0, 1.15, and 3.45 pounds of elemental wettable S per 1,000 square feet. Subsequently all potash was applied uniformly to all plots except the check at 8 pounds K_20 per 1,000 square feet per year. All sulfur was applied in March and April of each year in three equal applications.

EFFECTS OF S ON COLOR AND YIELD

All plots receiving 20 or 12 pounds N appeared significantly darker green when treated with 1.15 or 3.45 pounds S, regardless of P or K levels. The same treatments without S were pale, showing little response to N and had less turf density. Only slight color differences were observed at the 6 pound N level with any S treatment, but were slightly favored by 1.15 pounds S.

Although yield is not considered a highly desirable feature on putting greens, it still is a measure of vigor. Plots receiving 20 pounds N, 4 pounds P_2O_5 and 8 pounds K_2O per 1,000 square feet at both S levels produced 71 per cent more clippings than plots receiving N only. S applied at 1.15 pounds produced slightly more clippings than 3.45 pounds S. This indicates that 1.15 pounds S is adequate for good growth and color response and 3.45 pounds may be slightly above optimum.

X-ray spectographic analyses have shown significantly higher levels of tissue S from plots receiving S than those without S at the same N-P-K treatment. Tissue S increased also with increasing S levels.

The significance of the above discussion is that continual removal of clippings stimulated by high levels of N can result in S deficiency unless fertilizers contain adequate amounts. These plots received N from urea, P from phosphoric acid, and K from muriate of potash, hence, essentially no S is applied as fertilizer impurity.

EFFECTS OF S ON POA ANNUA

A significant reduction in *Poa annua* populations was observed in all plots that received 3.45 pounds S regardless of N and K levels. The most significant *Poa annua* decrease was noted in plots receiving 6 pounds N as compared to 12 and 20 pounds N.

Phosphorus is an important element for the development of *Poa annua*. All plots receiving P, regardless of N, K and S levels, had higher populations of *Poa annua* than those without P. Plots that received

A section of the turf plots showing no S on the left and application of S on the right.

1.15 pounds S had higher populations of *Poa annua* than those receiving 3.45 pounds at all levels of N, P, and K. It appears that 1.15 pounds S provides the greatest stimulus to growth and color of both bentgrass and *Poa annua*. The highest populations of *Poa annua* were recorded from all N and P treatments. Plots receiving 1.15 pounds S without P at all N levels had less *Poa annua* than those receiving P.

EFFECTS OF S ON DISEASE AND WINTER HARDINESS

All plots receiving S had less *Fusarium* patch caused by *Fusarium nivale* than those without S, regardless of N, P, and K treatment. Plots that received the highest N levels, in general, had more disease than the lowest N plots. The mode of action of S in this case is not well understood, but may be related to a direct effect on the fungus itself or the increased formation of S containing substances which may make the plants more resistant. No *Ophiobolus* patch disease, caused by the fungus *Ophiobolus graminis* var. *avenae*, has been observed in any of the S treated plots, but does occur in some plots without S.

Increased resistance to low temperature injury was noted during one winter. The winters in western Washington are usually wet and mild, but occasionally temperatures fall below 15°F. accompanied with wind and no snow cover. After one such winter, all plots receiving S showed less scorching and greened up much faster than those without S. This is in agreement with statements made by Beaton (1) regarding the effects of S on structural characteristics of protoplasm.

THE EFFECTS OF S ON SOIL PH

Sulfur does increase soil acidity (lower pH) through reactions in the soil. Annual applications of 3.45 pound S per 1,000 square feet lowered the pH in some plots from 5.6 to 4.8 over a period of seven years. There was no noticeable effect from the lowered pH, and as pointed out previously, turfgrass quality was best in all plots receiving S. It should be pointed out that applications of 20 pounds of N per 1,000 square feet from urea without S reduced pH much lower than 12 or 6 pounds of N with the highest S rates. No lime has been applied to any of these plots since the research began; although calcium levels have fallen to as low as 1 meq. per 100 gm. of soil, there is no plant evidence of calcium deficiency.

CONCLUSIONS

Several important conclusions can be drawn with regard to sulfur applications to putting green turf as related to the conditions of this test.

1. Increased color, vigor and nitrogen utilization.
2. Highly reduced populations of *Poa annua* at the highest levels of S without regard to N, P, or K.
3. Low S levels (1.15 pounds per 1,000 square feet) caused an increase in *Poa annua* and general turf vigor.
4. Additions of P in excess of minimum maintenance requirements increased *Poa annua* in all treatments.
5. Decreased incidence of *Fusarium* patch disease and complete elimination of *Ophiobolus* patch disease.

6. Reduced earthworm activity.
7. Elimination of black algae.
8. Increased cold and dessication tolerance.

Sulfur investigations are continuing and it is hoped that more specific reasons for S activity can be clearly defined. Golf course superintendents have been advised to proceed with some caution since variable soil conditions, other chemical programs, and management practices may influence results.

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A GREEN SECTION SUPPORTED RESEARCH PROJECT

"TOUCHDOWN!" A New Bluegrass for Golf

by ALEXANDER M. RADKO, DR. C. REED FUNK, THOMAS F. REWINSKI and MARTIN C. PICK[1]

The release of a new turfgrass variety is always an exciting event. It is the culmination of years of testing, research, and rigid evaluation pitting the new experimental turfgrass against all others which include experimental as well as standard commercial varieties. When one particular grass stands out in this evaluation procedure, it has to be a plant worthy of note and potential release to the turf industry. Such an exceptional turfgrass is Touchdown, a new Kentucky bluegrass selection released jointly by Rutgers University and the United States Golf Association Green Section.

What sets this grass apart from others? According to Dr. Funk, Touchdown growing in New Jersey exhibits good resistance to the following major diseases that attack bluegrasses:

(1) Leaf spot *(Helminthosporim vagans)*
(2) Leaf rust *(Puccinia poae-nemoralis)*
(3) Powdery mildew *(Erysiphe graminis)*
(4) Stripe smut *(Ustilago striiformis)*

Although Touchdown is not resistant to *Fusarium* blight caused by *Fusarium roseum* and *F. tricinctum* (no bluegrasses are), it does appear to get less of this disease than average.

Touchdown is a medium-low turf-type Kentucky bluegrass having upright leaves. Its leaf width is slightly finer than Merion. Touchdown has a pleasing bright medium dark green, whose color greens-up earlier in the spring and stays longer in the fall than does Merion. Under moderate fertility, this new Kentucky bluegrass variety has excellent density and good aggressiveness.

The story of Touchdown started in 1908 in Southampton, N.Y. on Long Island, when the renown National Golf Links of America, a Charles Blair Macdonald creation, was built and seeded. In those days

Tom Rewinski, Superintendent of the National Golf Links of America, on the 9th fairway where Touchdown was discovered.