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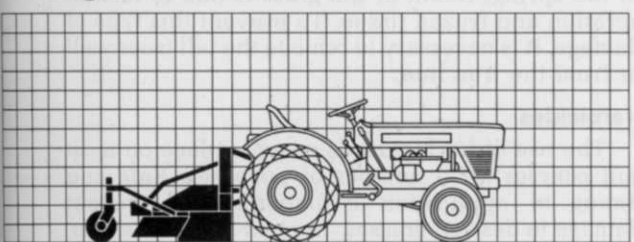

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Much has yet to be done in breeding better bermudagrasses in spite of the excellent work that is going on, especially in regard to winter hardiness. Present ones perform well in most years, if managed properly. Any bermudagrass should not, however, be grown at the outer edge of its range of adaptation. New grasses should be tested on location instead of arbitrarily deciding to use them.

For a number of years now, golf course superintendents in the Tennessee and north Georgia area have been critically examining Midiron (P-16) for its ability to overcome winter effects on their regular cultivars. Most seem to be pleased. Still they want more time to evaluate it. Some work at universities in the region shows this grass to perform well.

All bermudagrasses may suffer winter injury to some degree.

The same work indicates that all bermudagrasses may suffer winter injury to some degree. The best ones appear to be Tifway (419) and U-3 with Tifgreen (328). Tifdwarf and Tufcote are seemingly susceptible. Common bermudagrasses may suffer damage at times but, because of genetic diversity, performance in any one year is unpredictable. Commons selected within a region appear to tolerate winter injury a little better than other commons.

Choice of cultivars is especially important in the establishment of a turf. Spriggings and seedings that are able to withstand a severe first winter will have little difficulty in subsequent winters.

Drainage

Soils which retain water too long, especially in localized low spots, provide conditions which lead to loss of grass. The foremost condition is prevention of gaseous exchange of both oxygen and carbon dioxide, reducing transpiration and bringing about death of roots. Areas of little or no drainage are subject to prolonged freezing which brings about the same results. Too, these areas are prone to be compacted more easily by traffic. Providing drains for excess water to move out is essential to turfgrass survival in these areas.

Mowing

Turfgrasses are prevented from establishing as deep a root system as their counterparts used in forage and pasture by the kind of management applied. When a plant is fed it grows and produces leaves, stems and roots. Almost immediately, in turf management, the new top growth is removed by mowing which reduces the photosynthetic area needed for regrowth. When growth occurs again, it is primarily top growth. And again we cut it off!

Eventually, there is not much of a root system because its priority is below that of the leaves. With such a deficient root system the grass is in trouble in the winter. Raising the height of cut and reducing mowing frequency will do much to regenerate root growth. Generally, the higher the cutting height, the better the root system. The objective of mowing is not just to cut grass but to manage it in such a way as to strike a balance between roots and leaves and at the same time provide a suitable surface for a particular use.

Irrigation

Irrigation is both a boon and a detriment. When misused, it makes the work of the turf manager very difficult. Any system, that applies enough water to consistently run off the surface or to pass through the soil medium into drains, is applying too much water and courting trouble. Fertilizer is probably being leached and made unavailable to the turf. Secondly, roots are not stimulated to reach down into the soil and are usually situated within the top inch. Under these circumstances, loss of irrigation water would be catastrophic to the turf.

Thirdly, water-saturated soil is the same type of soil medium that compacted soil is. Such soil is also much more easily compacted. Atmospheric oxygen becomes unavailable and carbon dioxide becomes toxic. Lastly, this condition provides an excellent growing medium for water-loving fungi like the Pythiums which can further debilitate a root system.

Throughout the year, all factors considered, it is best to apply water only when it is needed by the plant almost to field capacity and then wait until the amount is depleted. Only then is the soil recharged. This type of application may be impractical to program into a system but shouldn't be any harder than syringing cycles.

Shade

Bermudagrasses react adversely to the slightest bit of shade. The deeper the shade, the poorer the bermudagrass with potential natural replacement by shade-tolerant grasses. Winter shade becomes of importance in turf survival because of the long shadows cast by trees, especially tall pine species. Turf shaded in this way may remain frozen much too long.

Many golf fairways situated along streams are shaded in this manner and have to be renovated each spring. It is not uncommon in the South for this condition to last from late November to late February. The result is no bermudagrass emerging in the spring. Death of the grass is due to lack of aeration and frozen tissue. To prevent this type of damage, it is necessary to remove the tall trees well in from the tree line.

Herbicides

The use of herbicides is commonplace on most golf courses for a number of purposes. Rate and timing of application is important to prevent damage to desired grasses. In regards to transition, perhaps the most critical time is in late winter or very early spring when paraquat and glyphosate are used to eliminate broadleaves, *Poa annua*, and other green species from fairways and tees and other turfs. If bermudagrass has been aroused and is growing in the slightest degree, the application of these non-selective herbicides will retard it and prevent a normal transition. The bermudagrass

Winter-kill can lose a good customer if the phenomena is not carefully explained.

must remain completely dormant in this instance. The application of herbicides to turf that is making some growth is flirting with a replanting job. In spring renovation due to winter kill, it has been found that application of herbicides may delay the establishment of a satisfactory turf. This may predispose the turf to damage in the next winter.

The use of preemergence herbicides on golf greens is a similar situation. Post-emergents should never be used at higher rates in early spring as the bermudagrass is emerging from dormancy. Know the state and condition of your summer grass and apply herbicides only when it is safe to do so and the time and dose is right!

NATURAL PHENOMENA

There is nothing that man can do about what Mother Nature does. He can however, anticipate and prepare for what she does.

Dessication

At times, under low humidity, high velocity winds may occur during the dormant season. Dessication of this nature is more serious on green grasses, but there is an effect on dormant grass as well, even though indirect. Excessive transpiration depletes the soil of water and it must be replaced, especially on overseeded greens. Dry spots are damaging to dormant turf if allowed to remain.

Temperature

The effect of temperature on dormant grasses lies in the sharp contrasts that occasionally occur between these. A sharp drop to very low temperatures after a period of warmth which has stimulated dormant grass will result in retardation, at best. The earlier in the fall and later in the spring these contrasts occur, the more damaging to the grass. The damage is first invisible but becomes manifest in the spring because damaged cells cannot function.

Play or traffic on frozen turf must not be allowed! Frosts, and temperatures which fall below 32° F (0° C), cause ice crystals to form within the cells of all grass tisssues. When pressure by any form of traffic is applied to these cells, they are injured and will die. Where the soil water is frozen in a turf it must be allowed to thaw **completely** before traffic is permitted on it. Otherwise, devastating damage to roots by shearing occurs at the interface between frozen and unfrozen soil.

Snow/Ice

Winter precipitation which lingers too long as a cover is rare in the bermudagrass region. Its effect, if it persists, is the prevention of gaseous exchange in the soil and the enhancement of disease (snow molds) with resultant loss of both dormant and green grasses. The condition, if and when it occurs and persists, must be alleviated.

Diseases

Generally, diseases are not problems on dormant bermudagrass. They do, however, affect this grass prior to and after dormancy.

The Helminthosporiums, which affect leaves, crowns and roots and are perpetual inhabitants of soil and thatch, are especially active in late summer and fall and have a direct effect on entrance of grass into dormancy. Their control should be by a year-round preventive fungicidal-cultural program.

The snow molds are rarely a problem in bermudagrass even though the causal agents (especially of pink snow mold) are omnipresent in our soils and thatch and are seen growing saprophytically on dormant turf. There is not a snow cover of enough duration.

Perhaps the most important disease of dormant bermudagrass if the root rot named spring dead spot of bermudagrass(SDS). The disease is so named because straw-colored spots ranging from a few inches to a foot in diameter remain as the grass becomes green in the spring. These spots remain dead throughout the growing season and become green only because of encroachment by stolons from the periphery of the spot. The disease usually appears the third year after establishment on turf that has been fertilized heavily and which has heavy thatch. It affects all cultivars to some degree and has been investigated since 1954. To date no causal agent has been identified.

Good evidence indicates that this is a "management disease" which can be controlled by sensible turf management. Enough is not yet known to recommend fungicides for control; these have been tested but their general use would be overly expensive at the present time.

There is a mistaken notion that this disease is a form of winter-kill. Evidence shows that this is not so; it predominantly favors pathogenic action.

In summary, providing a suitable bermudagrass turf on all areas from one summer to the next lies in the best turf management procedures it is possible to apply, and requires knowlege and use of the basic principles of turfgrass science. **WTT**


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GEOCHEMICAL FACTORS AFFECTING PLANT GROWTH IN RECLAMATION

W. Clark Ashby, William C. Hood, and Mary L. Guerke

Reclamation under the strict requirements of the federal Surface Mining Control and Reclamation Act of 1977 requires a high level of knowledge of plant growth requirements in relation to geochemical factors on each mine site. A desirable reclamation goal would be to consider all feasible alternatives for creating productive soils and attractive landscapes. The raw materials for achieving such a goal are the rocks and unconsolidated overburden that are commonly termed spoil after mining. Misdirected reclamation tasks can introduce unnecessary costs, lessen success of revegetation, and deny opportunities for building a land better than before mining.

In this paper we focus on the geochemical processes, to which the various minerals contribute on an uneven scale. Sulphur-containing rocks and minerals dominate the geochemical processes. We do not evaluate the highly important role of soil physical conditions in reclamation.

In many respects the soil-plant relationships on mine spoils can be understood as an extension of knowledge from traditional agricultural studies. Agricultural soils are, however, composed for the most part of materials which have been exposed to weathering processes for thousands of years. They typically are leached and ion-poor. Mine spoils contain large amounts of minerals freshly exposed to weathering; these minerals may release large quantities of ions. Spoils underlying topsoil are subject to these same oxidative weathering processes, although probably at slower rates. Spoil thus differs from other midwestern soils in that it involves an ion-rich environment.

The Geological — Overburden is the general term that is applied to all the materials that lie between the earth's surface and a coal bed. A very large variety of materials can exist as overburden. These range from solid rocks such as shale, limestone and sandstone through various unconsolidated surficial materials of diverse origin, such as sediments deposited by streams, lakes, glaciers and wind. Soils can be developed on any of these materials.

Certain minerals or groups of minerals are common in all of these assorted earth materials. The clay minerals make up most of the fine-grained rocks such as shale and mudstone and are common in limestones, siltstones and some sandstones.

The authors are respectively Professor, Department of Botany; Professor, Department of Geology; and former Graduate Assistant, Department of Botany. This research was supported in part by funds provided by the USDA Forest Service Northeastern Forest Experiment Station, Research Work Unit NE-1605, and by the Southern Illinois University Coal Extraction and Utilization Research Center. We thank Clay A. Kolar for contributions.

Geochemical knowledge is vital to solving complex reclamation problems.

They are equally abundant in fine-grained unconsolidated sediments and are important constituents of soils.

Quartz is the most important mineral in the coarser sediments and rocks, such as sand and sandstone, and is very common in nearly all other types of overburden rocks. The mineral calcite is the chief constituent of limestone and is common in shales and as a cementing agent in sandstones and surficial materials. Lesser amounts of the minerals feldspar, mica, dolomite and siderite are frequently found. Manganese and iron oxide coatings frequently act as cements to hold grains together.

Although generally minor in amount, sulfide minerals such as pyrite, marcasite and sphalerite are quite important in the geochemistry of weathering of overburden materials. Indeed iron sulfide, pyrite (or occasionally marcasite), is the main geochemically active mineral in overburden materials and any portion of the overburden that contains this mineral may give rise to conditions that affect plants. Because surficial materials have frequently been through one or more episodes of oxidative weathering, they are generally devoid of such minerals. On the other hand, the ancient sedimentary rocks may contain appreciable quantities of sulfide minerals and may cause major

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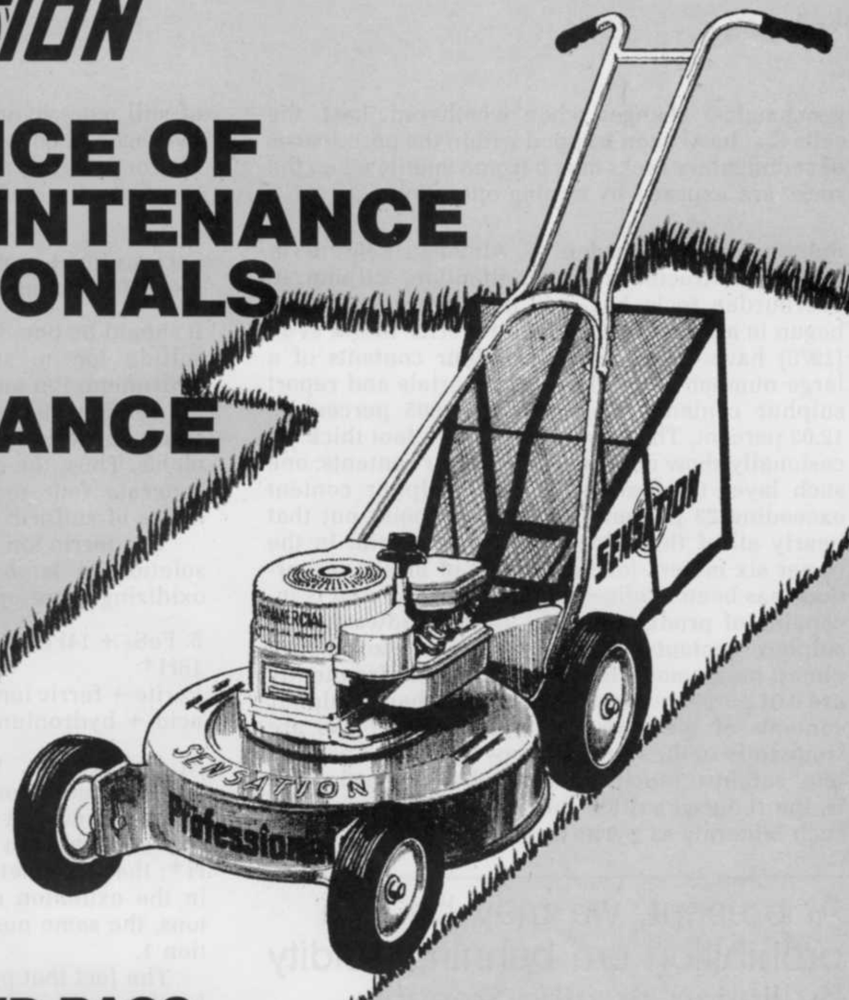

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THE SENSATION CORPORATION 3601 North 16th Street • Omaha, Nebraska 68110 geochemical changes when weathered. Last, the salts that have been trapped within the pore spaces of sedimentary rocks may become mobile when the rocks are exposed by mining operations.

Sulphur in Overburden — Although sulphur in coal has attracted a lot of attention, sulphur in overburden rocks has only in the past few years begun to attract the attention it merits. Smith *et al.* (1976) have examined the sulphur contents of a large number of overburden materials and report sulphur contents ranging from 0.005 percent to 12.03 percent. Thin layers less than a foot thick occasionally show much higher sulphur contents; one such layer 0.3 foot thick had a sulphur content exceeding 22 percent. Smith *et al.* point out that nearly all of the sulphur-bearing material in the upper six meters (about 20 feet) of most overburdens has been oxidized and neutralized, and is incapable of producing acids. In the Midwest, total sulphur contents of such weathered zones are almost never more than 0.1 percent and frequently are 0.01 percent or less. On the other hand, sulphur contents of unweathered sedimentary rocks are frequently in the range of a few tenths of a percent total sulphur. Much of this sulphur is pyritic, that is, the reduced sulfide form of sulphur present in such minerals as pyrite and marcasite.

At present, we may be in a prohibition era banning acidity by liming or other means because we do not have enough understanding of other indirect factors limiting plant growth.

It is well known that the oxidation of pyrite and related minerals generates acid mine drainage. Some of the oxidation reactions that have been proposed are:

1. $FeS_2 + 7/2\ O_2 + H_2O = Fe^{++} + 2SO_4^{=} + 2H^+$
Pyrite + oxygen gas + water = iron + sulfate + hydronium ions
2. $Fe^{++} + 1/4\ O_2 + H^+ = Fe^{+++} + 1/2\ H_2O$
Ferrous ion + oxygen gas + hydronium ions = ferric ion + water
3. $Fe^{+++} + 3H_2O = Fe(OH) + 3H^+$
Ferric ion + water = ferric hydroxide + hydronium ions

Equation 1 shows how one mole of pyrite can be oxidized in the presence of water and oxygen to liberate ferrous ions, sulfate and two moles of hydronium ion. Equation 2 illustrates the further oxidation of ferrous to ferric iron, and equation 3 shows how ferric ions hydrolyze to give a precipitate of ferric hydroxide with the liberation of still more hydronium ion. Equation 2, in which hydrogen is consumed, can be combined with the hydronium-liberating equation 3 to give the overall reaction:

4. $Fe^{++} + 5/2\ H_2O + 1/4\ O_2 = Fe(OH)_3 + 2H^+$
Ferrous ion + water + oxygen gas= ferric hydroxide + hydronium ions

It should be noted that the original oxidation of the sulfide ion to sulfate generates two moles of hydronium ion and the oxidation of ferrous ion to the ferric state, coupled with the precipitation of ferric hydroxide, generates an additional two moles. Thus, the complete oxidation of pyrite will generate four moles of hydronium ion, or two moles of sulfuric acid.

The ferric ion, although not usually present in solution in large amounts, can act as a strong oxidizing agent on pyrite. The equation is:

5. $FeS_2 + 14Fe^{+++} + 8H_2O = 15Fe^{++} + 2SO_4^{=} + 16H^+$
Pyrite + ferric ion + water = ferrous ion + sulfuric acid + hydronium ions

At first glance, this equation would appear to release much more acidity than the earlier equations. However, it must be realized that the generation of each mole of Fe^{+++} requires one mole of H^+; there is a net gain of two moles of hydronium in the oxidation of pyrite to ferrous and sulfate ions, the same number as were liberated in equation 1.

The fact that pyritic sulphur is present in overburden rocks is not in itself bad nor does it in itself mean the overburden will become acidic or toxic to plant life. The form of the pyrite is an important determinant in the rate at which the pyrite oxidizes and the rate at which acid is generated (Caruccio 1970, 1975). Smith *et al.* (1976) carefully point out that the balance between the acidity potential and the neutralization potential is an important factor in determining whether minespoil becomes acidic when weathered. Present regulations require the burial of rock which contains highly reactive forms of pyritic material in quantities exceeding the ability of the minespoil to neutralize the acid. Not quite so obvious is the situation where the upper portion of a minespoil contains reactive pyrite and an abundance of neutralization materials. This situation can create environments especially rich in ions and salts, which may be stressful to plants as discussed in a later section.

Effects of Acidity on Plant Growth — *Neither the best methods for the determination of soil acidity nor its interpretation in terms of soil chemistry and the effects of acidity on plant growth are agreed upon and well understood.* Most plants in the eastern United States probably grow best from pH 5.6 to 6.5, medium to slightly acid soils.

Plant physiologists agree that only below pH 3 (greater than 0.001 molar hydronium ion) are plants harmed directly by acidity itself (Arnon and Johnson 1942). Indirect effects, such as the liberation and mobilization of toxic elements, also may severely limit growth below pH 3. These indirect