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present in fractures in coal, in siderite nodules, and in other ways in the overburden. This mineral is soluble in acids, and can also be oxidized by ferric ions in reactions similar to the oxidation of pyrite by ferric ions. Sphalerite frequently contains appreciable quantities of cadmium; thus oxidation and acid leaching of the sphalerite can release appreciable quantities of zinc and cadmium to aqueous solutions.

Nutrients found in minute or trace quantities in plants in addition to iron and manganese include boron, zinc, copper, molybdenum, cobalt (required for symbiotic nitrogen-fixing plants), and chlorine. In the past deficiencies and toxic levels of these and other trace elements were found on mines; however, these are not likely to be found under the regulations promulgated by the new federal Office of Surface Mining.

Plant Growth on Mined Lands — Successful plant growth results from placing each species in a suitable environment. Pasture and forest species have been widely used in reclamation and have given excellent growth. Success with these plantings has resulted from the use of species which were not highly bred for a local environment. Success with a variety genetically tailored for a previous soil condition, such as hybrid corn, cannot be expected on a newly created mine soil, just as corn tailored for northern Illinois soils does not excel in southern Illinois.

Fertilization recommendations for reclaimed stripmines need to be tentative.

Fertilization recommendations for reclaimed stripmines need to be tentative, irrespective of whether the surface rooting medium consists of mixed overburden materials or of replaced soil. Recognition should be accorded and advantage taken of the mineral- and ion-rich environments which can be created from overburden materials underlying geologically impoverished soils on unmined land in many areas (Smith *et al.* 1976). Plant growth, or bioassay, will probably be a better means for assessing fertility relationships than chemical tests on selected nutrients.

Grandt and Lang (1958) analyzed 1,800 soil samples from 15 mining counties in Illinois. They found most of the samples to be very high in phosphorus and high in potassium. Test plots supported excellent growth of pasture.

Plots with 17 tree species each were established in 1947 by the USDA Forest Service on mined and unmined land in Randolph County, Illinois (Ashby *et al.* 1978). In 1976 the unmined plots were at pH 5.0 with extractable phosphorus (P) levels of 4 pounds and extractable potassium (K) of 144 pounds per acre. In contrast one set of mined plots with no previous management was at pH 7.2 with 9 pounds P and 354 pounds K and a

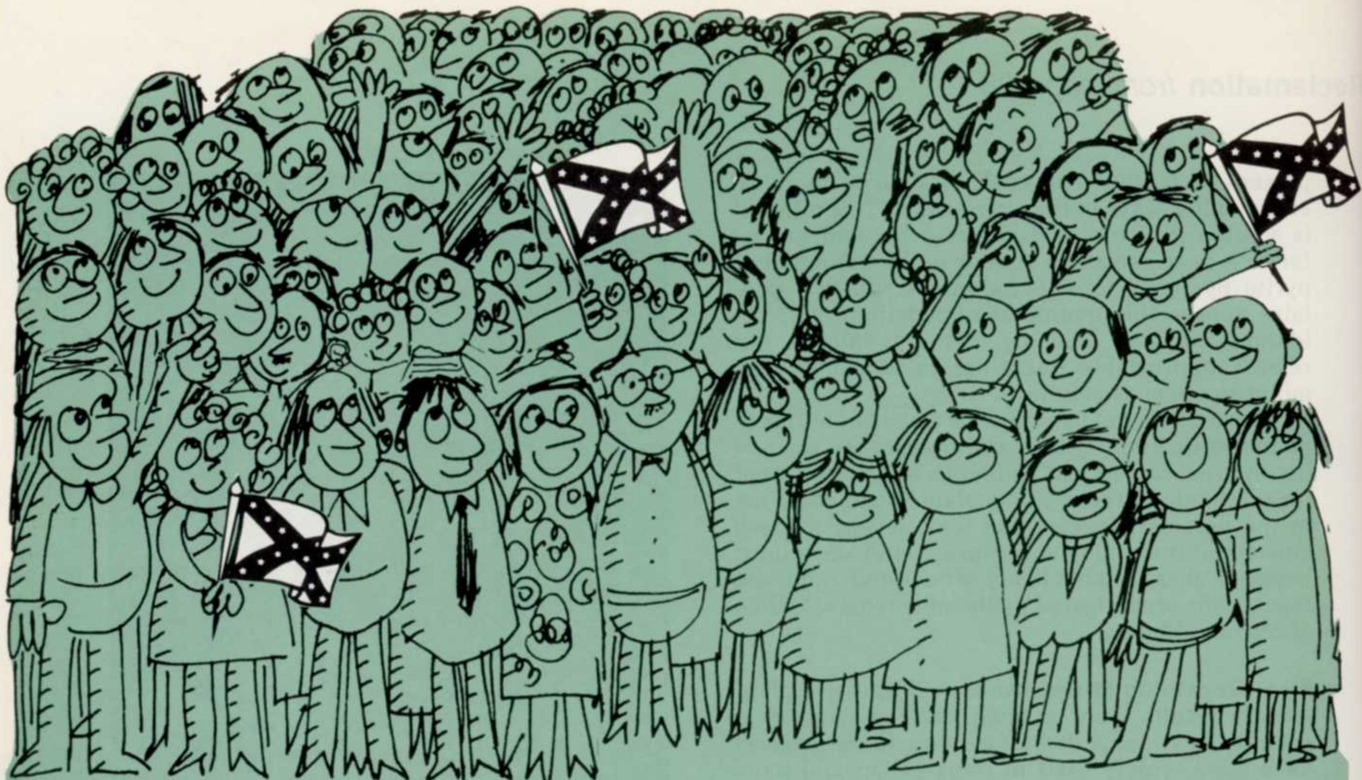
Grass grows in earthmover's tracks indicating the compacted earth was a better growing medium than the uncompacted on this site.

second set at pH 7.7 with 10 pounds P and 224 pounds K using the Bray acidified ammonium fluoride soil extraction method. Differences in P and K levels of the unmined and mined lands were even more marked using the Olsen sodium bicarbonate soil extraction method. Loblolly and shortleaf pine grew best on the unmined plots. These species are common on abandoned fields in the southeastern states. In contrast, black walnut grew much better on the mined plots. Soil which supports good black walnut growth is considered desirable for corn.

Until the properties of a newly-restored field are known, some nutritional requirements may go unrecognized. *A good way to find out the nutritional status of reclaimed land is to grow a select group of indicator plants which differ in their nutritional requirements.* An initial planting of mixed species for bioassay of the chemical environment on a mine site also serves to build organic matter, create root channels, and condition graded spoils for growth of later plantings.

Total Dissolved Solids — Stripmine soils and drainage waters commonly have high concentrations of total dissolved solids (TDS) resulting from direct and indirect effects of pyrite oxidation. Further TDS may be formed from neutralization of acidity with lime, fly ash, or other soil amendments.

Continues on page 61



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Experts Discuss Latest On Thatch at Nebraska

Latest Thatch Information Is Helpful But Controversial

R. C. Shearman, Turfgrass Specialist, Department of Horticulture, University of Nebraska, Lincoln, Nebraska.

Thatch is a management problem on many turfgrass sites. The turfgrass manager is faced with maintaining turf on these areas under difficult and sometimes impossible conditions. In many cases, the turf manager is unaware of the integrated and complicated factors that are related to thatch accumulation and its influence on turfgrass stress and culture.

Considerable advances have been made in our knowledge about thatch during the past few years. We have learned new aspects about thatch, and its chemical and physical nature, causes, problems, benefits and prevention. Although considerable knowledge about thatch has been gained, more is needed and controversy exists over the knowledge we have gained so far. This is substantiated in the following articles included in this Symposium.

Thatch has been defined as "An intermingled organic layer of dead and living shoots, stems, and roots that develops between the zone of green vegetation and the soil surface." Careful examination of this definition indicates that emphasis is placed upon the intermingled layer of dead and living organic matter comprised of shoots, stems, and roots. In thinking this over, soil on a thatch-free, turfgrass site consists of living and dead organic matter comprised of shoots, and roots. The above definition of thatch therefore, is not entirely satisfactory. Thatch is a media located above the soil surface and is comprised of undecomposed and decomposed organic matter that is capable of supporting turfgrass plant growth. Mat is an additional term that adds confusion to the situation. Mat is not synonymous with thatch. Mat consists of a tightly intermingled layer of soil and decomposing organic matter. The added soil factor makes mat a more desirable growing media than thatch alone.

The chemical composition of thatch is mostly cellulose, hemicellulose, and lignin. Lignin is particularly prominent in the lower thatch where decomposition is more advanced. Turfgrass clippings contain very little lignin and decompose rapidly. As long as an adequate mowing frequency is maintained, clippings do not contribute significantly to thatch accumulation. Thatch may accumulate in intensively managed turfs such as creeping bentgrass or bermudagrass or it may accumulate in low maintenance turfs such as creeping red fescue or zoysiagrass. The cause of thatch accumulation, therefore, is not just the production of organic matter versus the rate of decomposition, but also the chemical composition of the plant materials comprising thatch.

The causes of thatch accumulation are equally as controversial as the definition of thatch. One can readily accept that if organic matter production exceeds the rate of decomposition then the net effect should be thatch accumulation. Factors that encourage organic matter production and discourage organic matter decomposition favor this accumulation. Cultural practices must be adjusted to avoid excessive organic matter production, and to provide an environment conducive to thatch decomposition. Earthworms and some insects are known to digest portions of the organic matter. They are important in relocating organic matter throughout the soil profile with their movement up and down in the soil. Certain pesticides reduce earthworm populations and induce thatch accumulation.

TABLE 1. Advantages and disadvantages of thatch in a turfgrass community.

Advantages (When present in moderate amounts):
1. Insulates the soil surface beneath the thatch layer
2. Reduces soil compaction
3. Increases the resiliency or cushioning effect of the turf
4. Increases turfgrass wear tolerance*

Disadvantages (When present in excessive amounts):
1. Increases turfgrass environmental stress
2. Reduces turfgrass tolerance to heat, cold, and drought
3. Increases disease incidence
4. Increases insect activity
5. Increases puffiness, scalping, footprinting, and spiking
6. Increases proneness to localized dry spots
7. Increases susceptibility to iron chlorosis
8. Reduces activity of certain pesticides
9. Increases phytotoxicity of certain pesticides

**Research at the University of Nebraska indicates that wear tolerance increases with thatch accumulation until a critical point is reached, when wear tolerance decreases.*

Contradictions also exist concerning the role of turfgrass cultivars, nitrogen, and mowing height in the accumulation of thatch. The turfgrass cultivar and mowing height may play a more important role in thatch accumulation then excessive nitrogen fertilization. Regardless of the cause of accumulation thatch is involved in beneficial and detrimental aspects in the turfgrass community (Table 1.). These factors are covered in detail in the subsequent articles.

In the past ten years we have gained considerably in our knowledge about thatch and its interaction with turfgrass culture and stress. As turfgrass managers we need to become more aware of the causes of thatch; its detrimental and beneficial aspects; its prevention; and perhaps most importantly, its modification to a more desirable growing media. The articles included in this Symposium will inform the reader of the present state of knowledge about thatch and will give the reader a better background for coping with this maintenance problem.

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Influence of Thatch on Soil Is Both Positive and Negative

A. J. Turgeon, Associate Professor of Turfgrass Science, University of Illinois, Urbana, Ill.

Thatch is a frequently observed phenomenon in turf. It is generated by the plant community and, in turn, influences turfgrass response to environmental conditions and cultural practices. Its presence in a turf is considered to contribute both positive and negative influences toward turfgrass persistence and quality. Much confusion exists over factors contributing to thatch formation and the impact of thatch in turf; therefore, this paper will attempt to provide insights into the significance of thatch and its derivatives as edaphic features in turfgrass ecosystems.

Thatch has been defined in various ways depending upon the perspective of the observer. Ledeboer and Skogley (1967) simply referred to it as an "excessive accumulation of undecomposed surface organic matter." Beard (1973) defined thatch as "a tightly intermingled layer of dead and living stems and roots that develops between the zone of green vegetation and the soil surface."

The principal difference between these representative definitions is the role of living plant organs in the composition of thatch. Upon examining the thatch from a bentgrass turf profile, Ledeboer and Skogley (1967) reported that live roots, crowns, and stolons were found along with sclerified fibers from supporting tissues, and other undecayed organic residues. Others have interpreted this to mean that thatch is actually composed of living and dead plant material; thus, the contemporary definition offered by Beard (1973), and supported by the Crop Science Society of America, provides this perspective.

Examination of the surface soil layer of a thatch-free turf would show that it, too, is composed of live roots and stems from the plant community growing in it; yet, soil is usually not characterized the way thatch is. Soil analyses are typically conducted with the live plant community removed even though root and subsurface shoot growth undoubtedly influence soil physical and chemical properties.

Separation of live and dead components of a thatch layer is more difficult, so it usually is not attempted. In fact, the growth of plant organs within the thatch clearly shows that thatch is not simply a surface mulch; rather, it is a surface medium supporting the plant community and, as such, is analogous in function to the surface layer of soil from a thatch-free turf.

In the author's view, thatch is most appropriately defined as a layer of residual biomass generated by the turfgrass community, situated above the soil surface, and constituting an important portion of the edaphic medium supporting turfgrass growth.

Thatch Formation

The exact mechanism of thatch formation is not clear. Typical explanations of this phenomenon cite an imbalance between primary production (plant growth) and decomposition of organic residues. Thus, any factor which stimulates growth rates beyond decomposition rates, or which depresses the decomposition rate below that of plant production, leads to the formation of thatch. Of course, organic residues at the soil surface are not thatch.

A stable thatch layer must be stabilized by the plant community; otherwise, it can quickly become fragmented and decomposed, especially during winter in cold climates. Turfgrass-induced stabilization of thatch can occur in several ways: crowns can form from emerging rhizome terminals once light is intercepted near the thatch surface, existing crowns can continue to develop upwards into the thatch, and adventitious roots, rhizomes, and stolons emerging from these crowns can grow in the organic debris to form an interlocking network of live material.

Research at the University of Illinois has shown that certain pesticides, which inhibit earthworm and microbial activities, can induce thatch on sites where it otherwise would not form (Turgeon, Freeborg and Bruce, 1975; Cole and Turgeon, 1978). The amount of thatch which develops, however, is influenced by the turfgrass genotype and cultural practices. In field tests with over 50 cultivars of Kentucky bluegrass, the range in thatch depth, three years after establishment, was between 0.7 (Park) and 2.0 cm (Touchdown). In a cultural study comparing seven cultivars, two mowing heights (0.75 and 1.5 inches), and four fertilization programs (2, 4, 6, and 8 lb N/1000 sq ft/yr), only cultivar and mowing variables were found to influence thatch depth; higher mowing generally resulted in more thatch while increased use of nitrogen had no significant effect. Since the lack of any differential response to nitrogen in this study is inconsistent with many reports in the literature, it would seem that other conditions would have to exist in order to predispose the turf to nitrogen-induced thatch formation.

Edaphic Characteristics of Thatch

Since thatch constitutes an important growth medium for turfgrasses, attempts should be made to characterize it in much the same way as is done with soil media. Based upon work conducted at the University of Illinois, Hurto (1978) reported that "clean" thatch is a highly porous medium with a predominence of large (aeration) pores; therefore, its water-retention capacity is low compared to a well-structured Flanagan silt loam soil.

The cation exchange capacity (CEC) of thatch samples has averaged approximately 50 milliequivalents per 100 grams (me/100g) which is substantially higher than that of a Flanagan silt loam. As long as different media have similar bulk densities, comparisons of CEC's provide indications of relative nutrient-retention capacities.

Lighter colored material just beneath grass is sometimes referred to as "pseudo-thatch".

Bulk density (BD) determinations with clean thatch samples have yielded very low values, usually less than 0.25 g/cc. Since plants grow in a given volume of a medium, rather than in a given weight, CEC comparisons should be made only after multiplying by BD as in the following example:

Thatch CEC @ 50 me/100g and BD @ 0.25 g/cc yields 12.5 me/100 cc

Soil CEC @ 30 me/100g and BD @ 1 g/cc yields 30 me/100 cc.

In this comparison, the volumetric CEC of soil is actually over twice as much as that of thatch. Given the low BD, the very porous nature of thatch and, consequently, the rapid percolation rate of water and dissolved nutrients through its profile, retention of cationic nutrients (NH_4^+, Ca^{++}, Mg^{++}, K^+, Fe^{++}, etc.) by thatch would be low compared to many soils.

Another notable feature of thatch is its resiliency. With the application of a downward force, thatch compresses. Once that force is removed, the thatch springs back to its original state. Therefore, unlike many fine-textured soils, thatch resists compaction.

In summary, a thatch medium is well aerated and resistant to compaction, but is also characterized by poor nutrient- and water- retention capacities. When comparing the relative advantages and disadvantages of thatch to those of many fine- and medium-textured soils, it would be logical to conclude that an integrated medium, in which soil and thatch are blended together, would incorporate the desirable features of each component while compensating for various undesirable features. Integrated thatch-soil media will be discussed further under Thatch Control.

Influence of Thatch on Turfgrass Quality

Turfgrass quality is a function of genotypic and environmental conditions. Thatch, although reflecting in part some features of the turfgrass genotype, is an environmental (specifically, edaphic environment) feature in the turfgrass ecosystem. If a pure, coarse sand was used as the growth medium, sustaining the turf would require more frequent irrigation and fertilization than where a finer-textured soil were used. Thatch is, in some ways, analogous to coarse sand.

Field studies have shown that thatchy Kentucky bluegrass was more wilt prone, and had a higher irrigation requirement, under mid-summer stress than thatch-free turf in Flanagan silt loam (Turgeon, Freeborg and Bruce, 1975). Laboratory studies by Falkenstrom (1978) have shown that nitrogen retention by thatch is much less than in soil following applications of urea. This was due to rapid leaching of the nitrogen under moist conditions, and substantial volatilization of nitrogen as ammonia (NH_3) under dry conditions.

Other influences of thatch include higher disease incidence, reduced rooting, and lower water-infiltration capacities (Turgeon, Freeborg and Bruce, 1975). Jansen and Turgeon (1977) found that where water infiltration was lower in Kentucky bluegrass turf with a pesticide-induced thatch, the reduction was not due to the thatch layer but, rather, was associated with an altered physical condition of the underlying soil. Restriction of root and rhizome growth to the thatch layer and absence of earthworms in the underlying soil were factors accounting for higher soil bulk density, lower hydraulic conductivity, and reduced infiltration capacity in thatchy turf.

In herbicide studies, Hurto (1978) found that some preemergence herbicides were more phytotoxic when applied to thatchy than to thatch-free Kentucky bluegrass. He attributed this to greater downward mobility of the herbicides in thatch than in soil, and the inherent susceptibility of Kentucky bluegrass to herbicide injury when the herbicide is allowed to come into direct contact with the root system.

In a similar field study with non-selective herbicides for turf renovation, he found that paraquat residues in thatch were highly phytotoxic to overseeded perennial ryegrass. However, where soil was incorporated into the thatch or where the study was performed on a thatch-free site, little or no inhibition of ryegrass germination occurred from prior paraquat applications.

Thatch Control

Traditionally, thatch control has been synonymous with either mechanical removal, or topdressing (primarily greens) to favor decomposition. Results from recent and continuing research suggest that an alternative method should be considered. This involves thatch modification. A particular operation, or sequence of operations, which effectively blends soil and thatch into an integrated medium would almost immediately reduce many of the problems associated with thatch.

Although experience with topdressing greens has shown that soil inclusion favors decomposition of organic residues in thatch, this result is not immediate while many of the benefits of topdressing are apparent soon after the operation has been performed. On fairways in which core cultivation is practiced routinely, presumably to alleviate the effects of soil compaction, thatch is usually not a serious problem.

Again, soil inclusion in the thatch layer reduces thatch-associated problems and, eventually, favors thatch decomposition. In this case, soil from the

Relationship of Thatch to Disease and Insect Stress

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Most turf will remain trouble-free the first few years after establishment. A few problems may occur, but diseases and insects are actually minimal those first few years, especially on home lawns. The length of time from establishment to the time when problems begin appearing varies depending on such factors as soils, turfgrass variety, maintenance and environmental conditions.

One factor generally associated with older established turfgrass is thatch, but this does not imply that turfgrass without a thatch problem is always disease and insect free. Thatch free turfgrass may also have disease and insect problems but not to the same extent. A turfgrass with a severe thatch accumulation will generally have more disease and insect associated problems.

The influence of thatch accumulation on disease and insect problems actually makes sense when the condition of turfgrass and factors involved with disease and insect problems are considered. Heavy thatch accumulation causes the turfgrass to grow under a stress situation most of the time.

Heavy thatch often results in many of the turfgrass crowns and roots growing in the thatch layer rather than in the soil. Because thatch does not have the moisture holding capacity that most soils do, turfgrasses growing in it are more prone to drought stress. Since the turfgrass crowns and roots are elevated in the thatch layer, the turfgrass also becomes less tolerant to temperature extremes and more prone to traffic stress. In addition, the turfgrass will have fewer roots into the soil to receive nutrients it requires to remain vigorous. Pesticides applied to a "thatchy" turf are generally rendered ineffective by the thatch.

Turfgrass in a weakened condition is more susceptible to disease and insect problems, while vigorously growing and healthy turf is better able to resist insect invasion or an attack by a disease causing organism. Healthy turfs can also tolerate higher populations of disease-causing organisms and insects without showing damage and recover from the damage more rapidly. Therefore, disease and insect problems occur when there is a susceptible host, a favorable environment, and a causal organism.

Host

The host, of course, would be the turfgrass. For an attack by a disease causing organism or insect to occur the host must be susceptible to that attack. Most turfgrasses are tolerant or resistant to a disease or insect problem to a certain extent but certain turfgrass species and varieties are more tolerant or resistant than others. This tolerance is minimized, if the turfgrass is in a stress condition, or if populations of the disease causing organisms or insects accumulate to damaging levels.

Thatch accumulations may be involved with both factors, of creating stress conditions and providing a place for disease causing organisms or insects to thrive.

Environmental Conditions

The resulting environmental conditions of heavy thatch is ideal for many disease causing organisms and insects. This thatch environment provides an excellent place for the turfgrass

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same system is cycled while, with topdressing, a foreign soil source is used. Core cultivation, then, can be regarded as a comparatively efficient procedure for cycling soil and converting thatch to an integrated medium which is no longer thatch, but a derivative similar to what Beard (1973) describes as mat.

Depending upon the thickness and density of the thatch layer, once over with a core cultivator may not be sufficient to convert thatch to a mat-like derivative. In some cases, it may be necessary to remove a portion of the thatch and open up the remainder via vertical mowing before proceeding with core cultivation. Each site will have to be examined and a suitable procedure determined. However, the objective is clear; only the method for accomplishing the objective is site dependent.

Evidence to date suggests that the results are highly beneficial. Reduced disease, improved water relations and aeration, reduced pesticide-induced phytotoxicity, and generally superior turf are obtainable where thatch modification, rather than removal, is practiced.

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