THATCH BIOLOGY: BALANCING GROWTH WITH DECOMPOSTION

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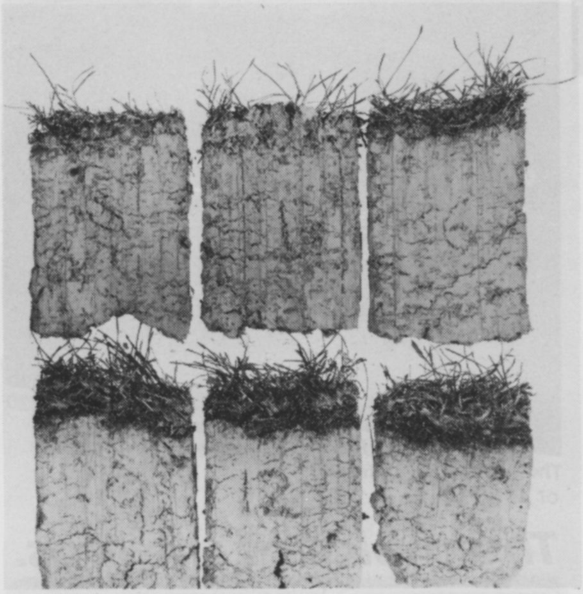
Thatch is an important property of turfgrasses. The causes of thatch are easily listed, but the manner in which these causal factors operate is not well known. This article will concentrate upon recent results of research on thatch accumulation.

Most definitions used to describe thatch agree that thatch is comprised of a layer of dead and living stems (tillers, stolons, and rhizomes) and roots that develop above the soil surface and below the leafy foliage. Leaf clippings are reported to contribute very little to the thatch layer. The leaf clippings generally form a pseudothatch, which is a less-densely packed layer above the thatch. A layer of intermixed soil, stems, and roots has been termed the mat.

Turfgrasses are not unique in possessing such layers; they are also found in grasslands, pastures, forests, and other ecosystems. In grasslands the layers are often designated at the A, Ao, and Aoo horizons, respectively, for the surface soil, mat, and thatch. Thatch is also synonomous with the terms surface litter, compressed litter or humid mulch. Pseudothatch is synonomous with loose litter or fresh mulch.

These comparisons set the stage for a discussion on the causes of thatch. It must be understood clearly that thatch is composed of organic litter, and that its management involves manipulations of biological process which do not differ from those occurring in other ecosystems.

Research conducted in other grasslands is therefore often directly applicable to our understanding of turfgrass thatch. Much of the following discussion is derived from studies of grassland ecology. The results seemingly explain many observed responses of turfgrass thatch to various environmental and management variables.



Fungicides can slow thatch decomposition in Kentucky bluegrass. Upper left sample was not treated with fungicide. Other samples show effect of five different fungicides on thatch accumulation.

Tissue Production vs. Decomposition

Plants produce tissues in cyclical patterns. Cool-season grasses, for instance, typically produce most leaf growth in the spring and autumn, and most root growth in the autumn and winter. The life of each leaf, tiller, rhizome, and root is relatively short, and a continuous cycle of tissue production and death occurs to perpetuate these perennial species. Decomposition of the tissues also depends upon seasonal cycles and the prevailing environmental conditions. Thatch results when the production of tissues proceeds at a rate more rapid than that for decomposition. This balance depends upon a multitude of interacting biological processes.

Factors Affecting the Balance

The tendency for thatch to accumulate or not depends mostly upon the plant growth rate, the composition of the plant tissues, the amounts and types of pesticides being used, and the fertility, aeration, temperature, and moisture *in* the thatch environment. Each of these factors can be expected to fluctuate widely and independently. The long-term overall balance is therefore more important than conditions at any specific time.

Plant Growth Rates

Plants which produce the most extensive root and stem systems are likely to become more thatched than those with limited amounts of these slow-to-decompose tissues. Varieties within a species can differ in both the composition and amount of these tissues. All of these variables can affect the tendency for thatch to accumulate. Likewise, all management procedures, including pesticides, which improve turfgrass growth will by definition increase the amount of tissue being produced. Some conditions will increase the rates of production and decomposition, but others will increase production and decrease decomposition. The most important of the factors are discussed below.

Plant Composition

An appreciation of thatch must include an understanding of the chemistry of plants. Numerous chemicals in plants occur in only small quantities, are easily decomposed by microorganisms, or both. These components contribute little to thatch. Constituents that are very resistant to decomposition processes and are also abundant in plants are the primary compounds found in thatch. Most of these compounds are necessary to provide strength to the grass plant, e.g., they give the plant its superstructure.

Waite and Gorrod (1959) analyzed the compounds of immature and mature ryegrass plants (Table 1). The most persistent components are ash, fats, waxes, phenolic compounds, lignin, hemicelluloses, and cellulose. Ash is the term designating the mineral elements (calcium, potassium, etc.) that are in the tissue. In this example the resistant components (excluding ash) comprised 42% of the young ryegrass plant, and 74% of the older plant. Beard (1976) provided a clearer per-

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spective of the resistant components in several turfgrass species (Table 2). The table reports the composition of leaves, stems and roots of a bentgrass, a bluegrass, and a fescue. The bentgrass leaves had more hemicellulose than the bluegrass and fescue leaves, and the total of the three components was 11% higher in bentgrass leaves than in bluegrass leaves. In contrast, bentgrass stems contained about 15% less resistant materials than stems of bluegrass and fescue. Bluegrass stems had more hemicellulose than the other grasses, whereas fescue stems had twice as much lignin as the other grasses. No major differences in the compositions of root tissue were reported.

The compositional differences become important when the rates of decomposition of these compounds are compared. Clark and Paul (1970) and Whitehead et al. (1979) have each reported that, under ideal conditions, the time required for a 50% loss (e.g., the 1/2-life) of ryegrass leaf or root weight (excluding water) in soil was 20 weeks (Fig. 1A). At this rate, only about 80% of the original leaf weight will be mineralized (decomposed) to carbon dioxide, mineral elements, and other primary compounds during the first year. Decomposition rates differ for each of the resistant compounds. The half-life period is about two weeks for hemicellulose and cellulose, one year for lignin, 2.5 years for waxes, and 6.5 years for phenolic compounds (Clark and Paul, 1970). These rates are essentially the same in all plant litter (e.g., grass leaves or roots, oak leaves, etc.) in which they occur.

Table 1. Compositions of young and mature ryegrass foliage (from Waite and Gorrod, 1959).

Component	Percent of Dry Water	
	Young	Mature
Fats and Waxes	3.9	1.9
Organic Acids	3.6	2.0
Water Soluble Carbohydrates	29.5	4.6
Phenolic Compounds	0.4	1.1
Pectins	3.1	4.1
Crude Protein	7.5	3.4
Lignin	3.5	11.3
Hemicelluloses	14.0	25.7
Cellulose	20.2	33.8
Acetyl	0.9	2.0
Ash	7.5	4.9
Unidentified	3.3	3.0
Unaccounted for	3.0	2.3

Table 2. Partial compositions (%) of tissues in creeping bentgrass, Kentucky bluegrass, and red fescue (from Beard, 1976).

Plant Structure	Plant Species	Hemi-cellulose	Cellulose	Lignin	Cell Wall
Leaves	Bentgrass	34	19	4	56
	Bluegrass	26	18	2	46
	Fescue	27	21	3	51
Stems	Bentgrass	30	23	4	57
	Bluegrass	39	28	5	72
	Fescue	29	35	11	75
Roots	Bentgrass	36	27	14	76
	Bluegrass	34	27	10	71
	Fescue	34	33	13	80

Since most of the major constituents of plants decompose more rapidly than lignin, it is not surprising that lignin is a major component of thatch. It therefore becomes apparent that leaves should decompose much more rapidly than roots, that fescue stems should decompose as slowly as roots, and that stems of bentgrass should decompose almost as rapidly as leaves. The modifying effects of cellulose and hemicellulose presumably reduce the decomposition rate for bluegrass stems (including rhizomes) much more than for bentgrass stems (including stolons).

Causes of Tissue Decomposition

The decomposition of plant tissue is performed by the microorganisms, microfauna (small animals, including insects), and macrofauna (larger animals) in the soil. The numbers and types of organisms involved are very large, and their interactions are complex. Precise sequences of events apparently differ from one habitat to another.

Individual species of soil microorganisms do not possess all of the enzymes and other characteristics

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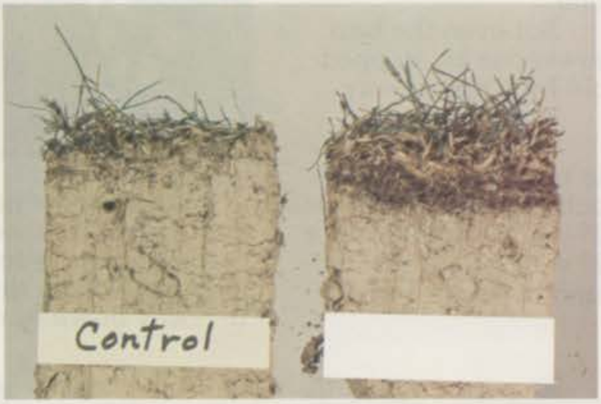

Three-year difference in thatch accumulation (top) in untreated and fungicide treated Kentucky bluegrass. **Two inches of thatch** in Kentucky bluegrass virtually separating turfgrass roots from the soil.

necessary to decompose more than a few of the components in higher plants. Mukhopadhyay and Nandi (1979) have shown that *Fusarium* and *Penicillium* species decompose lignin much more readily than cellulose, whereas the reverse was true for *Helminthosporium* and *Curvularia*. Successions of microorganisms are necessary to totally decompose plant tissues; each group feeds on the residues remaining from a previous group's activities. Most soil animals, including earthworms, do not produce the enzymes needed to decompose plant tissues (Waid, 1974). The fauna assist decomposition by physically tearing tissue apart to allow microbes access to larger amounts of surface area.

Turfgrass specialists sometimes feel that decomposition of thatch is initiated by faunal activity and concluded by microbial activity. The fauna are thought to digest portions of the thatch and to relocate some of it deeper into the soil. This view appears to be supported only by popular belief and by visual observations of thatch accumulation where earthworms are absent (Lofty, 1974). But this viewpoint is contrary to the results of detailed soil ecology research. Tribe (1960) studied successions of organisms on cellulose in soil and found that fungi initiated the decay. Bacteria became involved later, and then nematodes began feeding on the bacteria and fungi. Later stages of decay involved larger fauna, including mites, collembolans, and enchytraeid worms. Clark and Paul (1970) and Waid (1974) concur with this general sequence for decomposition of grass roots. Curry (1969) used nylon bags of various small meshes to screen out variously sized groups of soil fauna from bentgrass and fescue leaves and stems that were buried or were left on the surface of a grassland. He concluded that the fauna contributed almost nothing to the rate of decay and disappearance of the foliar litter on the soil surface, and did not accelerate its decay in the soil. Malone and Reichle (1973) used chemical toxicants to eradicate different faunal groups in a fescue meadow, and reached the same conclusions as Curry. However, in contrast to the results with foliar litter, these scientists also showed that the fauna slightly accelerated decomposition of buried roots. Thatch accumulation in our long-term fungicide plots (Smiley and Craven, 1978) was considered to be associated with inhibition of the microflora, and not earthworms, by some of the fungicides.

In my view, microorganisms have been demonstrated to be the most important organisms for decomposition of plant litter, and inhibition of the fauna in grassland ecosystems has been of only minor consequence. It is also my view that earthworms can be considered as indicators of overall soil faunal activity, and that their absence is an expression of imbalance in the ecosystem. Tissue decomposition rates may be reduced under these conditions, without the necessity for a cause and effect relationship with earthworms *per se*. More detailed research is needed on this topic.

Pesticides

Some pesticides can alter the rates of production for turfgrass tissues, and some can alter the rates of decomposition. Pesticides that reduce the activity of soil microorganisms are most inhibitory to litter decomposition. Many insecticides, herbicides and fungicides can alter the activity of microorganisms such as fungi, and may also inhibit the activity of fauna such as insects and earthworms. The overall effects of pesticides are very complex. Thatch accumulation on turf that is regularly treated with certain fungicides, herbicides, and insecticides is well documented (Beard, 1973; Beard, 1976; Smiley and Craven, 1978). Effects of these chemicals on the soil microflora and fauna are not as well known (Beard, 1973; King and Dale, 1977; Meyer et al., 1971; Smiley and Craven, 1979).

Fertility

Nitrogen is essential for decomposition of organic litter. Microorganisms require a carbon-to-nitrogen ratio of at least 25:1 for effective decomposition (Beard, 1973). Organic litter is rich in carbon and lean in nitrogen. Furthermore, nitrogen is quickly and easily leached out of the thatch (Hunt, 1978), and the C:N ratio of thatch can therefore become rather high. Litter decomposition is independent of the nitrogen in soil below the thatch because this nitrogen is out of reach for the microbes in thatch (Hunt, 1978). Thatch decomposition is accelerated when soil is incorporated into the thatch layer (by coring and matting or by soil faunal activity) and when frequent, light applications of fertilizer are applied (Beard, 1973). The biological bases for such observations are provided in detail by Hunt (1978) and Smith (1979). Beard (1976) explained that the nitrogen application frequency and the type of carrier must be manipulated to keep nitrogen up in the thatch. Smith used eloquent mathematical models to predict that decomposition will be most efficient when split applications of water-soluble nitrogen are made, or when a single annual application of water-insoluble (slow release) nitrogen is made. Hunt (1978) illustrated how decomposition can be slowed whenever nitrogen concentrations in the thatch are reduced. Topsoil (but not sand) incorporated into thatch will help to elevate or prolong the available nitrogen supply (Beard, 1973). Care must also be taken to avoid excessive fertility levels which greatly increase tissue production rates, but not decomposition rates.

Acidity

Litter decomposition proceeds most rapidly at pH 6.0 (see Beard, 1976), and the rate decreases rapidly as either the acidity or the alkalinity is increased (Fig. 2B). If lime or neutral to alkaline soil are not added to turf, the alkaline components of litter may be leached downward, and the thatch will become acidic. Frequent, light applications of lime are necessary in many regions to maintain a proper pH balance in thatch (Beard, 1973). Infrequent heavy applications of lime appear to be capable of reducing the rate of thatch decomposition.

Temperature

All biological activities are temperature dependent. Production of tissues may be reduced or stopped during cold winters and hot summers. Shoot and leaf production are retarded earlier and more positively than root production (Beard, 1973). Tissue decomposition occurs at its maximum rate at 38°C (100°F) and is completely stopped at 0°C (32°F) and 45°C (113°F) (Hunt, 1978). The thatch temperature is quite responsive to air

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temperatures and to the cooling or heating that is governed by radiation and by evaporation of water. Temperatures presumably limit litter decomposition rates very commonly.

Moisture and Aeration

Poor aeration (excess water) and surface drying are associated with thatch accumulation (Beard, 1973). Ulehlova (1973) indicated that decomposition processes are essentially stopped in dry litter. She also indicated that the decomposition proceeds for a short time during overly wet conditions, but is soon halted by the accumulation of toxins produced when decomposition occurs under conditions of low oxygen. The toxins persist for some time even after aeration is re-established, and thus act to extend the time of inhibition. Hunt (1978) has described the moisture conditions which limit decomposition. Peak levels for decomposition are narrow (ca. -1 to -5 bars). These limits are stated in terms of water energy levels, and are therefore difficult to portray in readily understood terms. Suffice it to say that thatch that appears even slightly dry will probably be in the -15 to -100 bar range, and thatch which glistens with moisture when squeezed tightly will be in the 0 to -1 bar range. Turf is fully capable of growth when thatch is extremely dry, because the roots extract water from lower in the soil profile. Moisture can therefore limit thatch decomposition in turf during wet or dry periods.

Summary

Thatch is commonly associated with the use of intensive management practices on turfgrasses. But most of us have also had to address thatch accumulations on turfs that receive very low levels of management. These turf areas are seldom irrigated, limed or fertilized, and are therefore often inhospitable to the activities of microorganisms in the thatch layer.

Furthermore, low management turfs often have lower levels of leaf, stem and root production than found in high management turfs. Smith (1979) predicted that at tissue production rates below a certain broad minimum, the amounts of decomposer microorganisms will become restricted by a lack of available carbon, and that plant litter will begin to accumulate. At production levels above the minimum the amounts of tissues produced simply outstrips the ability of microorganisms to keep it decomposed. These principles indicate that a moderate level of management may be best adapted for control of turfgrass thatch. More research is obviously necessary, but there appears to be no reason to believe that thatch is only a high management problem.

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