THATCH AND NITROGEN IMMOBILIZATION

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Introduction

The potential environmental impacts of nitrogen fertilizers applied to turfgrass have received a lot of attention in recent years. Considerable research has been conducted on the subject, dating back to the 1970's. Several factors that could contribute to leaching of nitrogen have been identified, including coarse textured soils, soluble fertilizer sources, high rates of application, and excessive rainfall or irrigation following fertilization. From this information, recommendations have been developed to promote the responsible use of fertilizer nitrogen that reduces the risk of groundwater contamination. Turfgrass managers now have the information and technology available to use fertilizer nitrogen with limited risk to the environment. When managed properly, the risk of nitrate leaching from turf is minimal. Additional research has shown that approximately 30 – 40% of the nitrogen applied can be harvested in grass clippings. Gaseous losses (volatilization, denitrification) may account for 0 – 20% of the N, based on a number of estimates. Where is the remainder of the nitrogen (40 – 70%) that was applied? It can usually be found in the thatch and soil.

Research utilizing ^{15}N has demonstrated the importance of thatch and soil in nitrogen fate. ^{15}N is a stable isotope of nitrogen that is slightly heavier than most of the N in the environment, including typical fertilizer N. This characteristic allows it to be distinguished. When ^{15}N is applied as a fertilizer and detected at a later time, its origin can be assumed to be from the fertilizer. This is a very powerful tool in investigating the impacts of fertilization). Starr and DeRoo (1981) recovered between 21% and 26% of the ^{15}N labeled fertilizer they applied to a Kentucky bluegrass / fine fescue lawn from the thatch. Eighteen days after applying ^{15}N labeled urea to Kentucky bluegrass in April, Miltner et al. (1996) recovered 31% of the applied fertilizer from the thatch. Following a November application, recovery in thatch was 62%. In both of these experiments, more fertilizer N was recovered in thatch than in the underlying soil. Knowing that a significant portion of fertilizer N can be found in thatch answers one question, but introduces others. Plant shoots and soil are components of the plant community that are easily defined and understood, but what is thatch? It is a complex and heterogeneous medium consisting of living plants (including shoots, crowns, rhizomes, and roots), dead plant parts, organic debris in various stages of decay, soil, and a variety of organisms associated with the plant-soil community. To state that N is tied up in thatch is simplifying the situation.

The immobilization of N in thatch and soil is not a one-time occurrence. It happens each time fertilizer is applied. It is also clear that thatch and organic debris accumulate with time, especially in new turf stands. What is the impact of this build-up of organic matter on nitrogen dynamics? Researchers in New York (Porter et al., 1980) sampled a wide variety of turf sites (lawns, golf courses, parks, etc.) of varying ages and found that soil nitrogen content increased with the age of the site. The mathematical model developed from this indicates that soil N content (and presumably organic matter) increase steadily during the first 15 to thirty years, then level off. Nitrogen inputs are accumulating in the turfgrass environment. Are there long-term implications associated with this?

Experimental procedures

Nitrogen Partitioning in Thatch

An experiment was conducted at Utah State University in Logan, Utah to determine the relative importance of the various components of thatch in nitrogen immobilization. Microplots were constructed of 8 inch (20 cm) diameter PVC pipe cut into 5 inch (12.5 cm) lengths, and were pushed into an existing stand of Kentucky bluegrass growing in a silt loam soil until the top edges of the plots were approximately on-half inch (1 cm) above the surface of the thatch. Plots were fertilized with a solution of ^{15}N labeled ammonium sulfate at a rate of 1 lb N per 1000 sq. ft. (49 kg N / ha). Fertilizer was immediately washed in with 0.2 inches (0.5 cm) of water. Fertilizer was applied to one-half of the plots on one of two dates: 14 November 1995 or 9 May 1996. Samples were collected on five different dates following fertilization by removing entire microplots. All fertilizer x sampling date treatments were replicated three times. Soil cores were transported to the lab. Leaf tissue (verdure) was removed by "scalping" the turf to the top of the thatch layer. The thatch layer was removed by cutting the core with a knife, and soil to a depth of 2 inches (5 cm) was then removed. All samples were dried at 65 C for 72 hours. The thatch was then dissected into various components: basal plant shoots (labeled as "crowns"); rhizomes; roots plus other organic debris (labelled as "roots+"); soil component of the thatch layer. All samples (verdure, thatch components, soil) were analyzed for total N and ^{15}N content on a mass spectrometer. The experiment was repeated during 1996-97.

Organic Matter Accumulation

The work of Porter et al. (1980) was indicative of organic matter accumulation, but the many variables introduced by sampling different sites (soil type, grass species, weather, management) make it difficult to accurately model changes in the soil system. An experiment was designed to measure organic matter and nitrogen accumulation under more controlled conditions. The site was the Greenville Farm at Utah State University in Logan, Utah. The soil was a Millville silt loam, and had been fallow for two years prior to this experiment. Prior to that, an annual barley crop had been grown on the site for many years. Three turfgrass establishment systems were compared: Kentucky bluegrass sod ('Newport'); Kentucky bluegrass seed ['Newport', 2 lbs. PLS per 1000 sq. ft. (98 kg/ha)]; tall fescue seed (blend of 'Coyote' and 'Gazelle, 7 lbs. PLS per 1000 sq. ft. (343 kg/ha)]. Plots were established in September of 1995 with four replications of each treatment. Prior to establishment, soil organic matter was measured in the top 4 inches (10 cm) of soil. Organic matter content has been measure on approximately 6 month intervals since establishment in depth increments of 0 – 0.8, 0.8 – 2, and 2 – 4 inches (0 – 2, 2 – 5, 5 – 10 cm). Annually in the fall PVC microplots are installed and are fertilized with ^{15}N labeled ammonium sulfate at a rate of 1 lb N per 1000 sq. ft. (49 kg n / ha) as described in the previous experiment. ^{15}N is quantified in the same depth increments as organic matter.

Results and Discussion

Nitrogen Partitioning in Thatch

Results did not differ significantly between years. Only data from Year 1 is presented. Following November fertilization, 29% of labeled fertilizer nitrogen (LFN) was recovered in verdure at both 4 and 18 days after treatment (DAT) (Table 1). Verdure LFN decreased thereafter because clippings were removed but ^{15}N was not quantified, due to the fact that thatch was our primary interest. Thatch LFN was highest at 4 DAT, and was comparable to that measured previously (Miltner, 1996). Subsequent values for thatch LFN were lower, but not statistically different. Soil LFN was 5% at 4 DAT, and increased to 10% over the following summer. Still, very little LFN moved through the thatch. The results were similar following May fertilization, although verdure LFN recovery was higher (Table 2).

Thatch dissection revealed that the crown and soil portions contained the most LFN (Tables 3 and 4). Rhizomes and roots contained relatively minor amounts. In these tables, numbers in parentheses represent the percentage of LFN in inorganic forms, as determined by KCl extraction of the root+ and soil portions. The numbers representing total LFN (not in parentheses) include the inorganic LFN. These numbers indicate that very little of the LFN in the root+ portion is in inorganic forms. It was our hypothesis that inorganic LFN might be bound to exchange sites on decaying organic matter, and this would be extracted with KCl. The data indicates that this did not occur to a large extent. The LFN in the root+ fraction is largely in the organic form, probably in the form of plant tissue, meaning that most of the root+ LFN was immobilized through plant uptake. Thatch soil was a significant sink for LFN. The proprtion of soil LFN in the inorganic form decreased over time, either through vertical movement or through plant uptake.

In Table 5, the data is presented in a way to highlight the importance of plant uptake. Any recovered LFN that can be attributed to plant tissue with a high level of assurance is represented. The fact that verdure, crown, and rhizome LFN are included is obvious. The organic portion of root+ LFN is also included, using the logic that if the LFN is in either roots or dead plant material, it probably got there through plant uptake. The data shows that 60 to 70% of the applied LFN was taken up by the plant. This is significant for two reasons. First, it shows that using clipping N content as a measure of fertilizer N utilization greatly underestimates plant N use. Secondly, it shows that the living plant portion of the thatch is highly active and is significant in its nutrient utilization. N immobilized in thatch is not tied up and bound in some form that makes it unavailable to the plant. The perception that thatch binds N, making it unavailable for plant use, is largely incorrect according to the results of this study.

When this study was conceived and initiated, it was thought to be primarily a more detailed investigation into the environmental fate of fertilizer nitrogen. As it turns out, the results may be more applicable to the subjects of plant nutrition and fertilizer use efficiency. This experiment is also further evidence that the thatch is a living, thriving, active component of the turf community, not just a mat of decaying plant material.

Organic Matter Accumulation

Organic matter accumulation in the upper 4 inches (10 cm) has been rapid during the first two years of this study (Table 6). Increases have been most dramatic in the 0 – 0.8 inch (0 – 2 cm) depth (data not shown). Immobilization of applied ^{15}N has been occurred proportionately by depth with accumulation of organic matter.

Table 1. Percent recovery of labeled fertilizer nitrogen in various components of the plant community following November fertilization.

	18 Nov.	2 Dec.	27 May	2 July	31 Aug.	LSD (0.05)*
Verdure	29	29	18	13	8	3
Thatch	57	38	17	38	27	NS**
Soil	5	4	6	2	10	2
Total	91	71	41	53	45	NS

* Significantly different at P=0.05 according to Fisher's Protected LSD.
** NS = not significant

Table 2. Percent recovery of labeled fertilizer nitrogen in various components of the plant community following May fertilization.

	13 May	27 May	2 July	31 Aug.	LSD (0.05)*
Verdure	43	53	23	10	6
Thatch	37	32	31	27	NS**
Soil	2	3	1	6	1
Total	82	88	55	43	NS

* Significantly different at P=0.05 according to Fisher's Protected LSD.
** NS = not significant

Table 3. Percent recovery of labeled fertilizer nitrogen in various components of the thatch following November fertilization.

	18 Nov.	2 Dec.	27 May	2 July	31 Aug.	LSD (0.05)*
Crown	23	18	9	12	8	NS**
Rhizome	4	6	2	5	3	NS
Root+	4 (0.2)	2 (0.1)	3 (0.2)	5 (<0.1)	5 (<0.1)	NS
Thatch soil	26 (4)	13 (1.8)	8 (0.7)	18 (0.5)	12 (0.1)	NS

* Significantly different at P=0.05 according to Fisher's Protected LSD.
** NS = not significant

Table 4. Percent recovery of labeled fertilizer nitrogen in various components of the thatch following May fertilization.

	13 May	27 May	2 July	31 Aug.	LSD (0.05)*
Crown	14	11	10	11	NS
Rhizome	4	3	6	4	NS
Root+	9 (1.0)	5 (0.2)	5 (0.1)	3 (<0.1)	NS
Thatch soil	10 (3.7)	13 (1.0)	11 (0.3)	9 (0.2)	NS

* Significantly different at P=0.05 according to Fisher's Protected LSD.
** NS = not significant

Table 5. Percent recovery of labeled fertilizer nitrogen in plant tissue four days after fertilization in Novemeber or May.

	November	May
Verdure	29	43
Crown	23	14
Rhizome	4	4
Root+	4	8
Total	60	69

Table 6. Percentage organic matter by weight in the upper 4 inches (10 cm) of the profile under three turf establishment regimes.

Date	Ky blue sod	Ky blue seed	Tall fescue seed	Mean
Sep 95	2.6	2.5	2.5	2.5
May 96	2.6	2.5	2.5	2.5
Oct 96	3.0	2.8	2.9	2.9
May 97	3.6	3.9	3.6	3.7
Oct 97	4.2	4.1	4.9	4.4

References

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