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Effect of clippings management on turfgrass sward productivity and nitrogen content in the clippings and soil

K. Kauer[1], H. Raave[2], R. Viiralt[2], T. Köster[3], M. Noormets-Shansky[2], T. Laidna[2], I. Keres[2], A. Parol[2] and A. Selge[2]

[1]Estonian University of Life Sciences, Institute of Agricultural and Environmental Sciences, Kreutzwaldi 1, 51014 Tartu, Estonia; e-mail: karin.kauer@emu.ee
[2]Estonian University of Life Sciences, Institute of Agricultural and Environmental Sciences, Kreutzwaldi 1, 51014 Tartu, Estonia
[3]Agricultural Research Centre, Teaduse 4/6, 75501 Saku, Estonia

Abstract. The maintenance of turfgrass sward includes mowing and fertilization. Every year turfgrass sward produces a sizeable amount of clippings containing large amounts of nutrients which will be available for plants during the decomposition process. The aim of this research was to study clippings decomposition speed, the effect of returned clippings to the turfgrass sward's clippings yield and total nitrogen content in clippings and soil. The study was carried out on turfgrass sward (seed mixture composition *Festuca rubra rubra* 50% and *Poa pratensis* 50%). The turfgrass clippings were either removed after cutting or returned to the plots. The clippings yield and nitrogen content in the clippings were measured after every cutting. The soil samples from different plots were analyzed for total nitrogen at the beginning and the end of the growing season. The decomposition dynamics of clippings was studied using the litterbag technique. Also the nitrogen mineralization from decaying material and the concentration changes of cellulose and lignin were studied during 12 weeks.

The results showed that the turfgrass clippings mass and the content of nitrogen decreased during the decomposition process very quickly. The degradation of cellulose takes place after about 30% of initial weight decomposition. During the 12 week study period we did not fix the beginning of lignin decomposition. Higher productivity was obtained in treatments where clippings were removed. N content did not differ in plant from plots where clippings returned or removed but N content in soil of plots with clippings returned decreased compared to N content in soil of plots where clippings were removed.

Key words: clippings, turfgrass, decomposition, N mineralization, cellulose, lignin

INTRODUCTION

Environmentally friendly agriculture should move towards to a more closed nutrient cycle. This would mean the decreasing use of mineral fertilizers which have been dominant so far. Organic fertilizers as well as nutrients released from plant remains will be as a good replacement for plant nutrition and elevating soil fertility. The decomposition of organic matter has been investigated mainly in soil, and organic matter left above-ground for decomposition has not received so much attention. In amenity grasslands and set-aside fields, the returning of clippings to the site would be economically the cheapest possibility of management of those areas. On one hand the soil will be enriched with humus substances and on the other, the nutrients released during the mineralization process are ready for usage by plants.

Several investigations have shown that organic matter returned as mulch, will start to accumulate in grasslands (Meinhold et al., 1973; Murry & Juska, 1977). The reason could be the lack of micro-organisms which could decompose the organic matter above ground. At the same time opposite results can be found. The trials of Kopp & Guillard (2002) have shown that from returned clippings a remarkable amount of nitrogen (N) will be released, which would considerably lessen the need for mineral fertilizers. In their trial the returning of clippings did not cause the decomposition of thatch layer which was noticed in aforementioned investigations.

The goal of our work was to explain the decomposition dynamics of clippings left on the sward, the release of N from the clippings and its effect on sward productivity and N content of clippings and soil. Also the changes in concentrations of cellulose and lignin studied during decomposition.

MATERIALS AND METHODS

The experiment was carried out at the Estonian University of Life Sciences in the experimental station Eerika (58°23'32" N latitude, 26°41'31" E longitude) in 2007. The site had been seeded in 2003 with a turfgrass mixture (*Festuca rubra rubra* 50% and *Poa pratensis* 50%).

The soil of the experimental field was *Stagnic Luvisol* according WRB classification (FAO, 1998) and the humus horizon contained 1.6% organic carbon and 1.63 mg N g^{-1}.

The experiment was conducted on unfertilized sward in four replications with plot size 1x7 m. The swards were cut 14 times at a height of 5 cm during the growing season. For the cutting a lawn mower with a bag attachment was used. After every cutting the material was removed from the bag and weighed. After the weighing procedure the clippings of the turfgrass were either returned (hereafter CRT) to the plots or removed (hereafter CRM). The returned and removed clippings were analysed by total N and the amount of N (nitrogen uptake) removed or returned by clippings was calculated using the yields of the plots multiplied by N concentration.

After the first cutting, the decomposition dynamics of clippings was investigated using the litterbag technique. A total of 20 g of fresh biomass equivalent to about 5 g dry biomass was put into 20×20 cm polyester litterbags with a 1.5 mm mesh size. At certain time intervals the bags were collected and the material was removed from bags, dried (105°C, 4 hours), weighed and the weight loss was calculated. The biomass residue remaining in the litterbags was expressed as a percentage of the initial dry weight. The remaining percentage of mass (RPM) for each period was determined using this formula:

$$RPM\ (\%) = (100 \times M_t)/M_0,$$

where M_0 is the initial plant material dry matter mass in the litterbag and M_t is plant material dry matter mass in bag in time t, when litterbags removed from field. The litterbags material was analyzed for N and carbon:nitrogen ratio (C:N).

The remaining percentage of N (RPN) at the time t was calculated:

$$RPN\ (\%) = (100 \times N_t)/N_0,$$

where N_0 is initial N amount in sample and N_t is N amount in sample at time t, when the litterbag was removed from the plot. Van Soest's method used to measure the changes of lignin and cellulose concentration in decomposing clippings (Van Soest, 1963).

At the beginning of the vegetation period (May 2007) and at the end (September 2007) of the vegetation period, the total N content of soil samples (0-5 cm) of both management variants (CRM and CRT) was determined according to Kjeldahl.

The statistical package Statistica version 7.0 (StatSoft.Inc) was used for all the statistical analyses. Factorial ANOVA was applied to test the effect of the treatments on the yield and N content in the clippings and the soil.

RESULTS AND DISCUSSION

The turfgrass clippings decomposition and N mineralization

The decomposition of clippings on the sward was rapid in the first weeks. Already by the first 2 weeks, 27.4% of initial material was decomposed (Fig. 1).

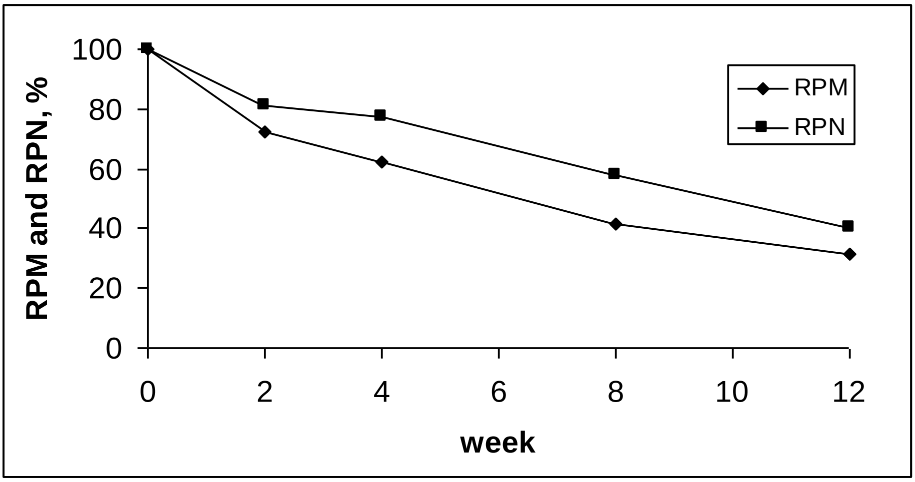

Fig. 1. The remaining percentage of mass (RPM) and nitrogen (RPN) (%) in turfgrass clippings during decomposition process.

After 12 weeks of decomposition, 31.2% of clippings initial mass remained. The initial concentration of cellulose in the clippings was 178.2 mg g^{-1}. During first two weeks the concentration of cellulose increased to 249.0 mg g^{-1} but by the end of week 8 had decreased down to 103.3 mg g^{-1}. The cellulose started to decompose after week 4 and approximately 30% of the initial material had decayed. Analyzing the decomposition process of clippings indicated that approximately 60% of the turfgrass clippings consisted of easily soluble compounds and the remaining 40% was the material needed for that year's decomposition. Such a long-term degradation is caused by the increased lignin concentration. The clippings initial lignin concentration was 12.6 mg g^{-1}. During the studied decomposition period the lignin decomposition did not occur and the lignin concentration increased after week 8 to 150.0 mg g^{-1}.

Living organisms using the plant residue's carbon as a source of energy and the nitrogen for building cell structure cause the decomposition and mineralization of organic matter. The plant cell is mainly composed of different water soluble carbohydrates, cellulose and lignin. Plant material chemical composition determines the availability of plant carbon to the soil decomposers, and will therefore have a crucial influence on the dynamics of N mineralization during decomposition (Gunnarsson, 2003; Trinsoutrot et al., 2000). The most easily decomposable compounds are water-soluble carbohydrates, and then cellulose and the most difficultly decomposable compounds is lignin.

At the beginning of the decomposition process, the content of N in the clippings was 31.5 mg g^{-1} and after 12 week 59.5% of that was mineralized. Nitrogen released from the clippings did not affect the content of total N in either the soil or the clippings. At the same time the variants where the clippings were removed the soil total N content was increasing during the growing season (Table 1).

Table 1. Total N (mg g^{-1}) content in soil (0-5 cm) from plots with clippings were returned (CRT) or removed (CRM) plots in spring and autumn.

	CRT		CRM	
	spring	autumn	spring	autumn
N, mg g^{-1}	1.37a	1.34a	1.43b	1.61c

Different letters within line indicate significant difference of the mean values at $p<0.05$.

The C:N ratio of decomposing clippings at the beginning was 18 in our study and decreased down to 12 throughout the decomposition period. There is a wide assessment that plant materials with a C:N ratio less than 20 may result in net N mineralization and those with a C:N ratio greater than 20 tend to cause net immobilization (Quemada & Cabrera, 1995). Immobilization (i.e. increasing N amount in decaying sample) did not occur during the decomposition process in our trial (Fig.1). When the relationship of used C:N ratio of different week is calculated, it appears that during first two weeks, at the beginning of decomposition process, the used C and N ration is 27:1. This proves that there was insufficient N for microbial decomposition and the immobilization took place. After week 2 the consumed C:N ratio was 54:1 and after week 4, when the cellulose was degraded, the used C:N was in relation 19:1. The ratio was narrower, because the N which was earlier linked to cellulose was liberated during the mineralization and made available to bacteria. Thus, according also to Andersen & Jensen (2001) the C:N ratio in decomposable material does not influence the decomposing process but the C:N ratio in decomposing compounds is the crucial factor for explaining the decomposition process. The C:N ratio in easily decomposable compounds can be broader than in plant material total and therefore immobilization can occur eventhough the C:N ratio in decomposable organic matter in total is relatively narrow (Andersen & Jensen, 2001).

According to Swift et al. (1979) soluble substances and labile compounds, which form the biggest proportion in turfgrass clippings, are rapidly degraded in the early stages of decomposition by fast growing micro-organisms that require a high concentration of N which may cause its initial immobilization. To decompose the wide C:N ratio compounds the missing amount of N will be taken from soil. The soil total N did not increased, although during the vegetation period the big amount of N from clippings was returned to the sward after every cutting.

The impact of returned and removed clippings on sward productivity and N uptake

The total N content in the clippings was similar in most cuttings of CRT and CRM variants, a significant difference occurred in first cut where the yield of CRM variant contained much more N compared with CRT variant (Table 2). The average yield of clippings was 13.5% higher in CRM variant compared to the CRT variant but the difference was not statistically significant.

The average yield of the growing period was largely influenced by the yield of the first cutting, which was 42% larger in CRM variant compared to CRT variant. The following cuttings of these two variants were similar. N uptake was greater in CRM variant, referring to the larger amounts of N removed by clippings (34.8 kg N ha^{-1}), compared to the N returned by clippings in CRT variant (30.5 kg N ha^{-1}). If the data of first cutting is omitted from the data analysis, the results will be the opposite, but here the differences between two investigated variants will be statistically minor.

Table 2. The average total N content (mg g^{-1}) in clippings by different cuttings, dry matter yield (kg ha^{-1}) and N uptake (kg ha^{-1}) of turfgrass swards plots with clippings removed (CRM) and with clippings returned (CRT).

	Total N content in clippings, mg g^{-1}		DM yield of sward, kg ha^{-1}		N uptake by clippings, kg N ha^{-1}	
Cut	CRM	CRT	CRM	CRT	CRM	CRT
1st cutting	40.5b	31.5a	462.3a	268.7a	18.7a	8.46a
2-14 cuttings	29.6a	30.7a	681.9b	721.5b	20.2a	22.2b
All cuttings (1-14)	30.4a	30.8a	1144.2c	990.2c	34.8b	30.5c

Different letters within column indicate significant difference of the mean values at $P < 0.05$.

The results of our investigation differed remarkably from the findings of Kopp & Guillard (2002). According to their investigation the productivity of the unfertilized variant was in the context of returned clippings equal to the productivity of the variant receiving 392 kg N ha^{-1} where the clippings were removed. In our trial the amount of N returned by the clippings was 30.5 kg N ha^{-1} but did not have any significant influence on soil or plant N content. Earlier investigations have shown that by the decomposition of clippings a remarkable loss of N occurs by the volatilisation process in NH_3, which can reach up to 10-20% of total mineralizable N (Janzen & McGinn, 1991). Also N immobilization by microbe-decomposers is the reason for N decreasing in soil as we discussed earlier. According to the research of Kuzyakov et al. (2000) the so called *priming effect* will take place in plant-soil systems, which activates an extra decomposition of indigenous soil organic matter, and therefore the soil N content is decreasing. Immobilization took place in our trial because the total N content in CRT variant in upper 0-5 cm soil layer was stable in spring as well as in autumn. At the same time the total N in CRM variant was increasing during the growing season. The higher content of soil total N was presumably caused by the decomposition of plant roots and released N was combined to the soil organic matter, instead of being used by the microbes in decomposition of clippings as happened in CRT variant.

CONCLUSIONS

We can conclude that over 60% of the turfgrass clippings which stayed on site after mowing consisted of easily decomposable material, which is mostly influenced by the easily soluble compounds in the clippings. A large number of easily decomposable compounds in decaying material caused the nitrogen deficit and missing nitrogen will be taken from soil. The returning of clippings during the growing season did not have any effect on soil and clippings total N content, as the amount of N released from clippings was so small and most was used by the microbe-decomposers. The N content in soil was higher in plots where clippings were removed.

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