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# Clipping Management and Nitrogen Fertilization of Turfgrass: Growth, Nitrogen Utilization, and Quality

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# TURFGRASS SCIENCE

## Clipping Management and Nitrogen Fertilization of Turfgrass: Growth, Nitrogen Utilization, and Quality

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### ABSTRACT

**The effect of returning grass clippings on turfgrass growth and quality has not been thoroughly examined. The objective of this research was to determine the effects of returning grass clippings in combination with varying N rates on growth, N utilization, and quality of turfgrass managed as a residential lawn. Two field experiments using a cool-season turfgrass mixture were arranged as a 2 × 4 factorial in a randomized complete block design with three replicates. Treatments included two clipping management practices (returned or removed) and four N rates (equivalent to 0, 98, 196, and 392 kg N ha$^{-1}$). Soils at the two sites were a Paxton fine sandy loam (coarse-loamy, mixed, active, mesic Oxyaquic Dystrudepts) and a variant of a Hinckley gravelly sandy loam (sandy-skeletal, mixed, mesic Typic Udorthents). Returning clippings was found to increase clipping dry matter yields (DMYs) from 30 to 72%, total N uptake (NUP) from 48 to 60%, N recovery by 62%, and N use efficiency (NUE) from 52 to 71%. Returning grass clippings did not decrease turfgrass quality, and improved it in some plots. We found that N fertilization rates could be reduced 50% or more without decreasing turfgrass quality when clippings were returned. Overall, returning grass clippings was found to improve growth and quality of turfgrass while reducing N fertilization needs.**

Grass clippings traditionally have been removed from residential lawns and managed turfgrass areas. Oftentimes, grass clippings are bagged and deposited in landfills. During the summer months, from 15 to 20% of residential waste may be composed of grass clippings (Graper and Munk, 1994). As more landfills across the United States close, however, the efficient use of their space becomes essential. Many landfills in the U.S. no longer accept grass clippings at all (Shanoff, 1989; Young, 1992). In Connecticut, Public Act No. 98-99 (Substitute Senate Bill No. 439) mandates that resource recovery and solid waste facilities in the state may no longer accept significant quantities of grass clippings for disposal.

The simplest method of disposing of grass clippings is to leave them onsite. By leaving grass clippings onsite, a source of organic N is provided to the turfgrass/soil system. Considering the potential environmental impacts of overusing N fertilizers, research in this area could provide homeowners and other turfgrass managers with a scientific basis for optimizing their N management strategies for turfgrass.

Petrovic (1990) presented an excellent review of the fate of nitrogenous fertilizers applied to turfgrass. Part of this review included the examination of turfgrass uptake of fertilizer N. The research reviewed by Petrovic (1990) concerning grass uptake of fertilizer N included the use of quick-release nitrogenous fertilizers such as urea (Sheard et al., 1985; Halevy, 1987; Watson, 1987; Wesely et al., 1988), $NH_4NO_3$ (Hummel and Waddington, 1984; Mosdell and Schmidt, 1985), and $(NH_4)_2SO_4$ (Starr and DeRoo, 1981). Miltner et al. (1996) also used $^{15}N$-labeled urea in a mass balance study of Kentucky bluegrass (*Poa pratensis* L.).

Slow-release fertilizers used in the research that Petrovic (1990) reviewed included ureaformaldehyde, sulfur-coated urea, isobutyldine diurea (Hummel and Waddington, 1984), methylene urea, activated sewage sludge (Hummel and Waddington, 1981), melamine, and ammeline (Mosdell et al., 1987). The review illustrated that quick-release sources of N had generally higher N recovery in clippings (Petrovic, 1990).

Very few studies have examined the effects of returning clippings on turfgrass growth, N utilization, and quality. Heckman et al. (2000) returned clippings to a Kentucky bluegrass lawn by mulching mower. Results suggested that returning grass clippings improved the color of turfgrass compared with removing clippings and that reducing N fertilization by 50% did not decrease turfgrass color when clippings were returned. In addition, Heckman et al. (2000) found that potential turfgrass quality problems related to surge growth and unsightly clippings were lessened by the use of slow-release fertilizers. Starr and DeRoo (1981) also found that returning clippings clearly influenced N uptake of turfgrass from the system.

The effect of returning grass clippings to turfgrass in combination with N fertilization on N utilization by turfgrass has received little attention. Therefore, it was the objective of this research to explore the effects of returning grass clippings and varying N fertilization rates on growth, N use, and quality of turfgrass for conditions specific to residential lawn management.

### MATERIALS AND METHODS

In 1998 and 1999, field experiments were conducted at the University of Connecticut's Plant Science Research and Teach-

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**Abbreviations:** CRM, clippings removed; CRT, clippings returned; DM, dry matter; DMY, dry matter yield; NREC, apparent N recovery; NUE, N use efficiency; NUP, total N uptake; RF, Plant Science Research and Teaching Farm; SM, Spring Manor Farm.

ing Farm (RF) and Spring Manor Farm (SM) in Storrs, CT. At each site, the experiments were arranged as a 2 × 4 factorial and set out in a randomized complete block design with three replicates. Three split, equal applications of N fertilizer were made (0, 98, 196, or 392 kg N $ha^{-1}$ $yr^{-1}$) and clippings were either returned (CRT) or removed (CRM). The N source was a mixture of 65% 30-4-4 (urea, methylene urea, ammonium phosphate, and ammonium sulfate; 5.2% water insoluble N) and 35% 33-0-0 ($NH_4NO_3$) fertilizer.

During the summer of 1995, the existing sod was removed from both field sites. Dolomitic limestone was applied (5021 kg $ha^{-1}$) at the RF site, which had been an established lawn, as per soil test recommendations. Additional amendments were not recommended for the SM site, which had been an established hay field. During late fall of 1995, both sites were seeded with a bluegrass–ryegrass–fescue mixture [35% common Kentucky bluegrass, 35% common creeping red fescue (*Festuca rubra* L.), 15% 'Cutter' perennial ryegrass (*Lolium perenne* L.), and 15% 'Express' perennial ryegrass] at a rate of 244 kg $ha^{-1}$ and were overseeded at a rate of 49 kg $ha^{-1}$ during the spring of 1996. In 1997, experimental treatments were applied, but data were not collected. The plots were maintained at a height of 3.8 cm following establishment, and irrigation was not applied during the experiment.

In 1998 and 1999, clipping samples were collected from all plots to obtain a measure of DMY. While all clippings were removed from the CRM plots, clipping subsamples were collected from the CRT plots (from 1 to 5 g) and the remaining clippings were returned to and spread evenly over the plots from which they had been removed. The clipping samples from each plot were combined into five harvest periods that typically included grass clippings from a 4-wk period. There were five harvest periods each year, although the exact length of the harvest periods varied depending on year. Samples were dried in a forced-draft oven (70°C) until a constant weight was reached, and then ground in an UDY Mill (UDY Corp., Ft. Collins, CO) to pass through a 0.5-mm screen.

Clipping samples were analyzed using a LECO FP-2000 C/N Analyzer (LECO Corp., St. Joseph, MI) for the determination of total N concentration. The uptake of N (NUP) was calculated as clipping dry weight N concentration. Apparent N recovery (NREC) was calculated as:

$$\text{NREC} = [(\text{N uptake at } N_x - \text{N uptake at } N_0)/(\text{applied N at } N_x)] \times 100\%.$$

Nitrogen use efficiency was calculated as:

$$\text{NUE} = (\text{yield at } N_x - \text{yield at } N_0)/\text{applied N at } N_x$$

in units of kg dry matter produced $kg^{-1}$ N applied.

Quality ratings were made of all plots on a monthly basis. An overall quality rating for each month (ranging from 1 to 9, where 1 = lowest quality and 9 = highest quality) was determined as a function of color and density (Skogley and Sawyer, 1992).

Clipping DMY, NUP, NUE, and NREC data were analyzed using analysis of variance for a mixed model. Block and year were treated as random effects. Quality and total N concentration data were analyzed using analysis of variance with repeated measures for a mixed model. Analyses were performed on individual site–year data because the length of the harvest periods varied from year to year. Time of observation was the repeated measure. Blocks were considered random effects, and N fertilization rate and clipping management fixed effects. The SAS procedure MIXED was used for all data analyses (SAS Institute, 1999).

**Table 1. Summary of analyses of variance indicating significant source effects on dry matter yield (DMY), N uptake (NUP), apparent N recovery (NREC), and N use efficiency (NUE).**

| Source | df | DMY | NUP | df | NREC | NUE |
|---|---|---|---|---|---|---|
| Clipping (C) | 1 | *** | *** | 1 | *** | *** |
| R Rate (N) | 3 | *** | *** | 2 | NS† | * |
| C × N | 3 | *** | *** | 2 | NS | NS |
| Site (S) | 1 | *** | NS | 1 | NS | *** |
| C × S | 1 | *** | *** | 1 | * | *** |
| N × S | 3 | *** | NS | 2 | NS | NS |
| C × S × N | 3 | ** | NS | 2 | NS | NS |

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
† NS = not significant.

# RESULTS

## Weather Conditions

For the growing seasons of 1998 and 1999, overall rainfall totals were comparable (735 mm in 1998 and 715 mm in 1999). However, rainfall in June and August of 1999 was very low (89 and 53 mm below normal, respectively), causing greater inconsistency across the growing season than in 1998.

## Dry Matter Yield

Significant effects on DMY were attributed to all treatments and interactions (Table 1). The practice of returning clippings was found to increase overall DMY at both sites, as did increasing N fertilization rates (Fig. 1). Removing clippings generated similar DMY for both sites. Of note was the finding that DMY for CRT at 0 kg N $ha^{-1}$ was comparable with the DMY for CRM at 392 kg N $ha^{-1}$ at the RF site (Fig. 1A). Also, DMY for 98 kg N $ha^{-1}$ CRT was comparable with the DMY for 392 kg N $ha^{-1}$ CRM at the SM site (Fig. 1B). On average, returning grass clippings to the RF site increased DMY by 221% across fertilization treatments. At the SM site, returning grass clippings increased DMY by 64% on average across fertilization treatments.

## Total Nitrogen Uptake in Clippings

Total N uptake increased when clippings were returned and with increased N fertilization (Table 1; Fig. 1C, D). In addition, the interactions of clipping × N rate and clipping × site were significant. While removing clippings generated similar NUP at both sites, returning clippings had a more pronounced effect at the RF site. Uptake of N for CRT at 0 kg N $ha^{-1}$ was comparable with the NUP for CRM at 392 kg N $ha^{-1}$ at the RF site (Fig. 1C). On average, returning grass clippings to the RF site increased NUP by 205% across fertilization treatments. At the SM site, returning grass clippings increased NUP by 70% on average across fertilization treatments.

## Apparent Nitrogen Recovery

Significant effects on NREC were attributed to clipping and clipping × site interaction (Table 1; Fig. 1E, F). While returning clippings increased NREC at both sites, the effect was less pronounced at the SM site. A

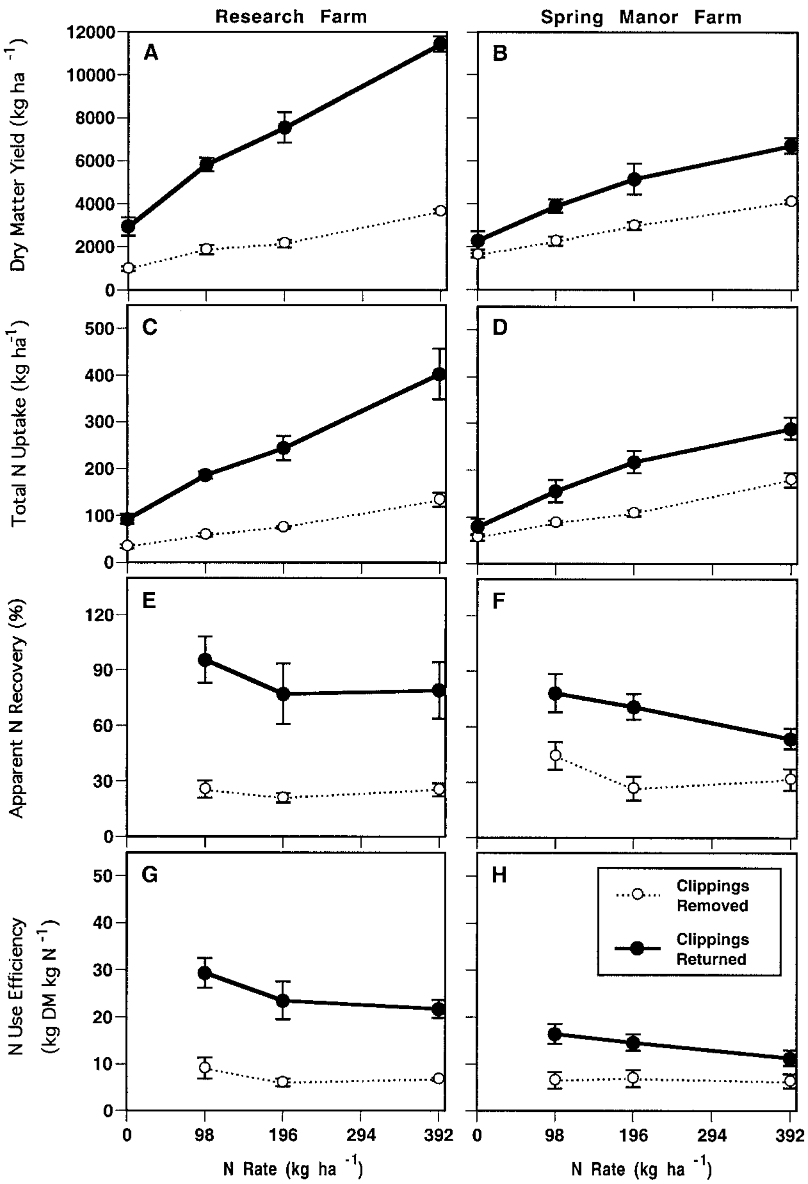


**Fig. 1. Dry matter yield (A, B), N uptake (C, D), apparent N recovery (E, F), and N use efficiency (G, H) responses across N rates at the Research Farm and Spring Manor Farm sites. Vertical bars represent standard errors of the means.**

general decrease in NREC was observed as N fertilization rate increased at both sites (Fig. 1E, F). At the RF site, NREC ranged from 21 to 26% CRM and from 77 to 96% CRT. At the SM site, NREC ranged from 27 to 32% CRM and from 54 to 78% CRT. On average, returning grass clippings increased NREC by 256% at the RF site and by 160% at the SM site.

## Nitrogen Use Efficiency

Nitrogen use efficiency increased when clippings were returned (Table 1; Fig. 1G, H). Significant effects on NUE were also attributed to N rate, site, and clipping × site interaction (Table 1). When grass clippings were returned, NUE ranged from 21.7 to 29.4 kg dry matter (DM) $kg^{-1}$ N at the RF site. At the SM site, NUE ranged from 11.3 to 16.4 kg DM $kg^{-1}$ N when clippings were returned. With the removal of clippings at the RF site, NUE ranged from 6.8 to 9.1 kg DM $kg^{-1}$ N and from 21.7 to 29.4 kg DM $kg^{-1}$ N when clippings were returned. At the SM site, NUE ranged from 6.4 to 6.9 kg DM $kg^{-1}$ N when clippings were removed. When clippings were returned, NUE ranged from 11.3 to 16.4 kg DM $kg^{-1}$ N. At the RF site, returning grass clippings increased NUE by 263% on average and NUE was higher than at the SM site. At the SM site, returning grass clippings increased NUE by 154% on average. When clippings were removed, NUE at both experimental sites were comparable (Fig. 1G, H).

## Tissue N Concentration

Significant effects on tissue N concentration for each harvest period were attributed to clipping, N rate, and clipping × N rate (Table 2). At the RF site, increasing N rate was found to significantly increase tissue N con-

**Table 2. Summary of analyses of variance indicating significant source effects on tissue N concentration.**

| | | 1998 harvest period | | | | | 1999 harvest period | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Source | df | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| **Research Farm** | | | | | | | | | | | |
| Clipping (C) | 3 | NS† | * | NS | NS | NS | *** | NS | NS | NS | NS |
| N Rate (N) | 1 | * | *** | NS | * | ** | * | NS | NS | NS | *** |
| C × N | 3 | NS | NS | NS | NS | NS | NS | NS | NS | NS | * |
| **Spring Manor** | | | | | | | | | | | |
| Clipping (C) | 3 | * | NS | NS | NS | NS | NS | NS | NS | NS | *** |
| N Rate (N) | 1 | ** | *** | NS | *** | NS | NS | ** | *** | *** | *** |
| C × N | 3 | NS | NS | NS | NS | NS | NS | NS | NS | NS | * |

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
† NS = not significant.

centration for four harvest periods in 1998 and two harvest periods in 1999 (Table 2). At the SM site, N rate was found to have a significant effect on tissue N concentration for three harvest periods in 1998 and four harvest periods in 1999 (Table 2). The practice of returning clippings had a significant effect on tissue N concentration for one harvest period during each year at each site (Table 2). A trend toward increasing tissue N concentration was apparent across harvest periods (Fig. 2A–H). An overall increase in tissue N concentration was observed where the practice of returning clippings had a significant effect (Fig. 2A–H).

## Quality

Significant effects on turfgrass quality for each rating period were attributed to clipping, N rate, and clipping × N rate (Table 3). At the RF site, N rate was found to have a significant effect on quality for every rating period analyzed in both experimental years (Table 3). At

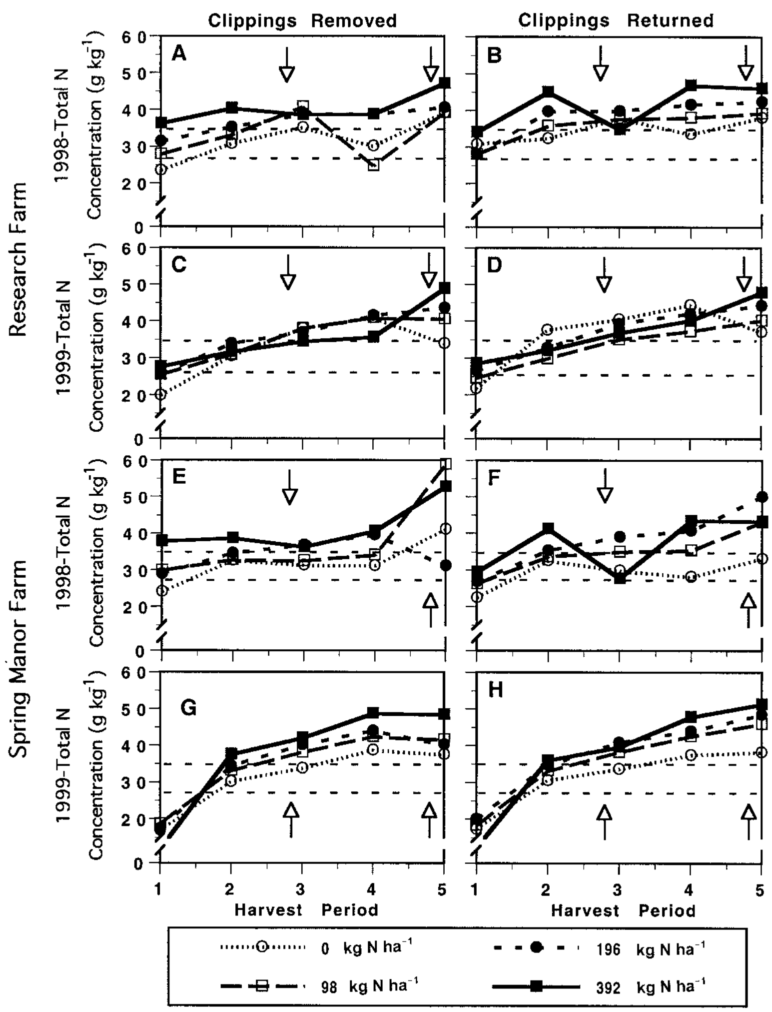


**Fig. 2. Tissue N concentration response of turfgrass during five harvest periods at the Research Farm 1998 (A, B) and 1999 (C, D), and Spring Manor Farm 1998 (E, F) and 1999 (G, H). Harvest periods correspond approximately to months (1 = May/June, 5 = Oct.). Arrows indicate dates of fertilization. The first fertilization occurred before the first harvest period.**

**Table 3. Summary of analyses of variance indicating significant source effects on turfgrass quality.**

| | | 1998 rating period | | | | | | | 1999 rating period | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Source | df | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| **Research Farm** | | | | | | | | | | | | | | | |
| Clipping (C) | 3 | NS† | NS | * | NS | * | * | NS | NS | NS | NS | NS | NS | * | * |
| N Rate (N) | 1 | NS | *** | *** | ** | *** | *** | *** | NS | ** | ** | ** | ** | *** | *** |
| C × N | 3 | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | ** | NS |
| **Spring Manor** | | | | | | | | | | | | | | | |
| Clipping (C) | 3 | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| N Rate (N) | 1 | NS | ** | * | * | NS | ** | *** | NS | NS | NS | NS | NS | *** | *** |
| C × N | 3 | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
† NS = not significant.

the SM site, N rate was found to have a significant effect on quality during four of the rating periods tested in 1998 and two of the rating periods tested in 1999 (Table 3). In general, as N fertilization rate increased, turfgrass quality also increased (Fig. 3). The practice of returning clippings was found to have a significant effect on quality during three of the rating periods in 1998 and two of the rating periods in 1999 at the RF site (Table 3). When the clipping effect was significant at the RF site, returning clippings generally improved turfgrass quality (Fig. 3A–D). The practice of returning clippings did not have a significant effect on quality at the SM site during either experimental year (Fig. 3E–H).

## DISCUSSION

The results of this study suggest that the practice of returning clippings to turfgrass improves the growth response, N use, and quality of turfgrass. Dry matter yield increased significantly when clippings were returned at

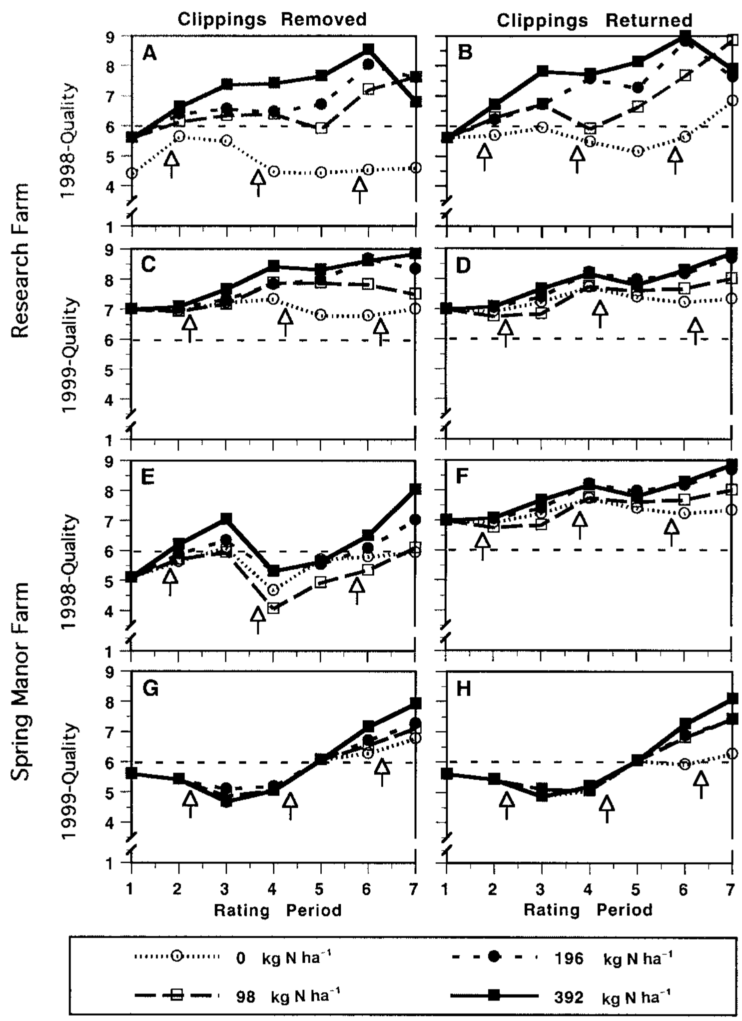


**Fig. 3. Quality response of turfgrass during seven different rating periods (monthly) at the Research Farm 1998 (A, B) and 1999 (C, D), and Spring Manor Farm 1998 (E, F) and 1999 (G, H). Rating periods correspond to months (1 = May, 7 = Nov.) and arrows indicate dates of fertilization. Dashed lines indicate the acceptable quality rating of 6.**

both experimental sites. In addition, clipping management combined with varying rates of N fertilization was found to greatly influence turfgrass yield. Starr and DeRoo (1981) also observed an increase in DMY (from 15 to 55%) when they returned clippings at N fertilization rates of 195 kg N $ha^{-1}$ (first 2 yr) and 180 kg N $ha^{-1}$ (final year) during their 3-yr study. This is much lower than the increase in DMY (79 to 254%, depending on site) that we observed at the comparable N rate of 196 kg N $ha^{-1}$ and may be related to soil moisture holding capacity.

Soil moisture holding capacity may also explain differences in experimental measurements that we observed between our experimental sites. The soil at the RF site is a Paxton fine sandy loam, and the soil at the SM site is a variant of a Hinckley gravelly sandy loam. The Paxton soil has an extremely hard and compact C horizon that tends to improve the soil moisture conditions in the overlaying horizons by impeding drainage. In fact, the RF site is known for its superior water holding capacity even during drought. The Hinckley variant at the SM site is known to be excessively well drained and droughty. Because irrigation was not applied during the course of our experiment, the contrasting soil types and their impact on soil moisture holding capacity were a likely reason for the differences we observed.

Another factor that may have impacted soil moisture holding capacity was the soil organic matter content at each site. Higher soil organic matter content allows more moisture to be retained in the soil, which improves mineralization of N and, therefore, turfgrass growth. Both sites had been established in turfgrass or forage for many years prior to the experiments and existed under the same climatic conditions. Coarser soil texture and its effect upon decomposition at the SM site are likely reasons for differences in organic matter content (89 and 73 g $kg^{-1}$ for the RF and SM sites, respectively) and, therefore, moisture holding capacity at the two sites.

At the RF site, we observed similar DMYs at 0 N CRT when compared with 392 kg N $ha^{-1}$ CRM (Fig. 1A). This result indicates that fertilization at the RF site could have been reduced drastically, or eliminated entirely, if clippings were returned, without an appreciable reduction in DMY. At the SM site, we found similar DMYs at 98 kg N $ha^{-1}$ CRT when compared with 392 kg N $ha^{-1}$ CRM indicating that fertilization could have been reduced by 75% without significantly reducing DMY (Fig. 1B). These findings illustrate that returning clippings without reducing N fertilization rates will increase clipping yield. In turn, more frequent mowing of turfgrass will be required, which increases labor and fuel costs.

For NUP, our results suggest that no appreciable change occurred when clippings were returned and fertilization was reduced by 75% at the RF site (Fig. 1C). Also, NUP for 98 kg N $ha^{-1}$ CRT was comparable with the NUP for 392 kg N $ha^{-1}$ CRM at the SM site, suggesting that no appreciable change occurred in NUP when fertilization was reduced by 50% and clippings were returned (Fig. 1D).

The uptake and recovery of fertilizer N by turfgrass leaf tissue as reported by Petrovic (1990) is comparable with the NREC values determined in this study. In those studies reviewed by Petrovic (1990), fertilizer N recovery ranged from 25 to 60% when quick-release sources of N were used and from 46 to 59% when slow-release forms of N were used. When $^{15}N$-labeled urea was used, Miltner et al. (1996) reported labeled-N recovery ranging from 3 to 55% in grass clippings. The vast majority of the studies reviewed by Petrovic (1990), as well as the study by Miltner et al. (1996), removed the grass clippings. Our NREC values ranged from 21 to 44% when clippings were removed, which is within the range of those values reviewed by Petrovic (1990) and Miltner et al. (1996). However, we also found that NREC increased dramatically when clippings were returned (1.6 to 2.6 times, depending on site; Fig. 1E, F). Starr and DeRoo (1981) also observed increased N recovery of turfgrass when clippings were returned and removed ranging from 19 to 74% during the course of their study. As with NREC, we observed increases in NUE when clippings were returned at both experimental sites (1.5 to 2.6 times, depending on site; Fig. 1G, H), but were unable to find studies with which to compare these results.

Our observations of tissue N concentration showed that with time and with increasing N rates, N concentration in grass tissue tended to increase (Fig. 2A–H). Tissue N concentrations reported for Kentucky bluegrass range from 36 to 56 g $kg^{-1}$ and from 40 to 54 g $kg^{-1}$ for perennial ryegrass (Hull, 1992). For tall fescue (*F. arundinacea* Schreb.), Hallock et al. (1965) reported a tissue N concentration of 30 g $kg^{-1}$. Although we utilized a mixed stand of Kentucky bluegrass, perennial ryegrass, and creeping red fescue, our tissue N concentrations fall within those ranges described by previous studies.

Many studies have considered the effects of varying N fertilization rates on quality, but very few have included the practice of returning grass clippings. Those studies that have considered the effect of returning clippings on turfgrass quality typically used single-species stands of turf. Murray and Juska (1977) reported that Kentucky bluegrass quality was higher when clippings were returned, and Johnson et al. (1987) found that turf quality was higher when clippings were returned to bermudagrass [*Cynodon dactylon* (L.) Pers.]. Hipp et al. (1992) found similar results for single-species stands of tall fescue and bermudagrass. Oftentimes, it may be assumed by home owners that returning grass clippings detracts from the appearance and overall quality of turfgrass and that this cannot be overcome. This is one reason many people bag their grass clippings (Shanoff, 1989). However, Heckman et al. (2000) observed that turfgrass color ratings at 98 kg N $ha^{-1}$ with CRT were generally better than those at 196 kg N $ha^{-1}$ with CRM. Heckman et al. (2000) concluded that reducing fertilization by 50% and returning grass clippings did not adversely impact turfgrass color. Our data also indicates that N fertilization may be reduced by 50% or more when clippings are returned without decreasing turfgrass quality.

Starr and DeRoo (1981) made casual observations of turfgrass quality in relation to clipping management and determined that returning clippings gave turfgrass a greener and "more luxuriant" appearance. When we observed clipping management to have a statistically significant impact on turfgrass quality, it generally took the form of improving quality when clippings were returned. Certainly, the return of clippings did not detract from turfgrass quality. When we returned clippings, the turfgrass in our study reached acceptable quality ratings more often than when clippings were removed (Fig. 3A–H). The most dramatic results that we observed were similar quality ratings at 0 kg N $ha^{-1}$ CRT when compared with 196 and 392 kg N $ha^{-1}$ CRM at both sites in 1998, indicating that quality was not impacted by completely eliminating fertilization, provided clippings were returned under the conditions of our experiment. During other rating periods, reductions in N fertilization of 50% did not adversely impact turfgrass quality when clippings were returned. These findings are consistent with those of Heckman et al. (2000).

## CONCLUSIONS

If the goal of environmentally sensitive N management is to optimize N uptake by plants (Petrovic, 1990), then the impact of conservation-minded N management strategies, such as the return of clippings, N use, and quality of turfgrass must be examined. By returning grass clippings to turfgrass managed as a residential lawn, significant increases in DMY, NUE, NREC, and NUP are made. In addition, returning clippings does not decrease turfgrass quality, and N fertilization may be reduced by 50% or more when clippings are returned without decreasing turfgrass quality. Therefore, if grass clippings are returned, N rates should be reduced.

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