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A Three-year Study on the Leaf and Soil Nitrogen Contents Influenced by Irrigation Frequency, Clipping Return or Removal and Nitrogen Rate in a Creeping Bentgrass Fairway

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크리핑 벤트그라스 훼어웨이에서 관수회수 · 예지물과 질소시비수준이 엽조직 및 토양 질소함유량에 미치는 효과

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ABSTRACT

Responses of 'Penncross' creeping bentgrass turf to various fairway cultural practices are not well-established or supported by research results. This study was initiated to evaluate the effects of irrigation frequency, clipping return or removal, and nitrogen rate on leaf and soil nitrogen content in the 'Penncross' creeping bentgrass (*Agrostis palustris* Huds.) turf. A 'Penncross' creeping bentgrass turf was established in 1988 on a Sharpsburg silty-clay loam (Typic Argiudoll). The experiment was conducted from 1989 to 1991 under nontraffic conditions. A split-split-plot experimental design was used. Daily or biweekly irrigation, clipping return or removal, and 5, 15, or 25 g N m^{-2} yr^{-1} were the main-, sub-, and sub-sub-plot treatments, respectively. Treatments were replicated 3 times in a randomized complete block design. The turf was mowed 4 times weekly at a 13 mm height of cut.

Leaf tissue nitrogen content was analyzed twice in 1989 and three times in both 1990 and 1991. Leaf samples were collected from turfgrass plants in the treatment plots, dried immediately at 70℃ for 48 hours, and evaluated for total-N content, using the Kjeldahl method. Concurrently, six soil cores (18mm diam. by 200 mm depth) were collected, air dried, and analyzed for total-N content. Nitrogen analysis on the soil and leaf samples were made in the Soil and Plant Analytical Laboratory, at the University of Nebraska, Lincoln, USA. Data were analyzed as a split-split-plot with analysis of variance (ANOVA), using the General Linear Model procedures of the Statistical Analysis System.

The nitrogen content of the leaf tissue is variable in creeping bentgrass fairway turf with clipping recycles, nitrogen application rate and time after establishment. Leaf tissue nitrogen content increased with clipping return and nitrogen rate. Plots treated with clipping return had 8% and 5% more nitrogen content in the leaf tissue in 1989 and 1990, respectively, as compared to plots treated with clipping removal. Plots applied with high-N level (25g N m^{-2} yr^{-1}) had 10%, 17%, and 13% more nitrogen content in leaf tissue in 1989, 1990, and 1991, respectively, when compared with plots applied with low-N level (5g N m^{-2} yr^{-1}). Overall observations during the study indicated that leaf tissue nitrogen content increased at any nitrogen rate with time after establishment. At the low-N level treatment (5g N m^{-2} yr^{-1}), plots sampled in 1991 had 15% more leaf nitrogen content, as compared to plots sampled in 1989. Similar responses were also found from the high-N level treatment (25g N m^{-2} yr^{-1}). Plots analyzed in 1991 were 18% higher than that of plots analyzed in 1989. No significant treatment effects were observed for soil nitrogen content over the first 3 years after establishment.

Strategic management application is necessary for the golf course turf, depending on whether clippings return or not. Different approaches should be addressed to turf fertilization program from a standpoint of clipping recycles. It is recommended that regular analysis of the soil and leaf tissue of golf course turf must be made and fertilization program should be developed through the interpretation of its analytic data result. In golf courses where clippings are recycled, the fertilization program need to be adjusted, being 20% to 30% less nitrogen input over the clipping-removed areas.

Key words: *Agrostis palustris* Huds., 'Penncross' creeping bentgrass fairway, Irrigation frequency, Clipping return, Nitrogen rate, Leaf nitrogen content, Soil nitrogen content.

INTRODUCTION

Fairways are the turfed area between the tee and the putting green, constituting the largest playable acreage on golf courses(Turgeon, 1996). Fairway turf conditions influence the golf course aesthetic appearance more than any part of the other turfs in golf courses. Perry(1989) indicated that golfer expectations for course aesthetics and playability will continue to grow in response to increased golfing pressure. Beard(1982) reported desirable fairway characteristics are not very different from those of putting greens. Most fairways are intensively maintained to produce verdure density, uniformity, smoothness, firmness, and resiliency for proper shot control. Mowing, fertilizing, and irrigation are the most fundamental and important cultural practices(Beard, 1973; Turgeon, 1996). These cultural practices influence turfgrass quality and playing conditions and are highly interactive. Cultural practices were interrelated and a combination of management practices was needed to maintain quality turf(Christians *et al.*, 1981; Erusha, 1990; Gaussoin and Branham, 1989; Kim *et al.*, 1991; Madison, 1969). Therefore, interactions among these practices need to be considered in a turfgrass management program to maintain acceptable quality and playability. Most of turfgrass culture researches have been on a single factor, such as a response to irrigation, mowing, and fertility and so on(Bogart and Beard, 1973; Carrow, 1980; Cuddeback and Petrovic, 1985; Dipaola and Lewis, 1989; Juska and Hanson; 1969; Pellett and Roberts, 1963; Schmidt and Breuninger, 1981; Shearman, 1986). Factors which have limited interaction studies have been the large number of experimental units required and the resources necessary to execute the experiments. Development of innovative statistical designs and analysis has improved the feasibility of multiple component researches. Consequently, research investigating individual and interactive effects of cultural practices on several characteristics such as turf quality, playability, thatch accumulation, soil and leaf tissue nutrients is feasible to obtain greater accuracy for interpretation.

Kentucky bluegrass(*Poa pratensis* L.) has been used as the primary fairway species across a wide range of conditions and cultural practices in northern regions(Beard, 1982; Christians, 1990; Turgeon, 1996; Wilson and Latham, 1969). Kentucky bluegrass, however, is intolerant of the mowing height perceived as needed by the golfer. A trend has been toward fairway conversion to creeping bentgrass because it tolerates lower mowing heights than Kentucky bluegrass and also provides an excellent playing surface (Christians, 1990). Information is readily available on the effects of cultural practices on Kentucky bluegrass fairway turf (Christians *et al.*, 1981; Erusha, 1990; Funk *et al.*, 1966; Monroe *et al.*, 1969; O'Neil and Carrow, 1982; Pellett and Roberts, 1963; Schmidt and Breuninger, 1981). However, responses of 'Penncross' creeping bentgrass turf to various fairway cultural practices are not well-established or supported by research results, since 'Penncross' creeping bentgrass has been used most commonly on putting greens in the cool and transitional climatic regions (Beard, 1982; Hanson *et. al.*, 1969). This study was initiated to evaluate individual and interactive effects of irrigation frequency, clipping return or removal, and nitrogen rate on the leaf and soil nitrogen content of 'Penncross' creeping bentgrass turf maintained under fairway conditions.

MATERIALS AND METHODS

Research was conducted at the John Seaton Anderson Turfgrass Research Facility located near Mead, Nebraska, USA. A creeping bentgrass fairway turf was established from 'Penncross' seed in May, 1988. The soils were classified as a Sharpsburg silty-clay loam(Typic Argiudoll). This investigation was accomplished under nontraffic conditions. A split-split-plot experimental design was used for the treatment arrangement. Irrigation frequency treatments were assigned to the main-plot(9m by 13.5m). Irrigation rate was based on 80% potential evapotranspiration(ETp) applied daily or once every 3 to 4 days on a weekly basis. The 80% ETp rate was determined by the Nebraska modified Penman equation(Rosenberg *et al.*, 1983). Rainfall was subtracted from the required replacement amount prior to irrigation. Weather data for the calculation of ETp were collected from an automated weather station located at the site of research(Fig. 1). Clipping return or removal constituted the sub-plot treatments(4.5m × 13.5m). The turf was mowed 4 times

Fig. 1. An Automated Weather Station located at the site of research, Mead, Nebraska, USA from which weather data for the calculation of ETp were collected.

weekly at a 13mm(0.5″) height of cut(bench setting), using a Jacobsen Park 30 mower (Jacobsen Manufacturing Co., Racine, WI). Three nitrogen levels of 5 (low-N), 15 (medium-N), and 25(high-N)g N m^{-2} yr^{-1} comprised the sub-sub-plot treatments(4.5m by 4.5m). Urea (46-0-0) was used as the nitrogen carrier. Nitrogen rate treatments were applied in 6 equal applications from May to October. A total of 12 treatment combinations were replicated 3 times in a randomized complete block design.

Mowing direction was changed with each mowing practice to encourage an upright growth pattern and minimize differential soil compaction. Vertical mowing was done in October to control thatch. Core cultivation was done in May and October to reduce soil compaction and to improve turfgrass growth. Potassium sulfate (0-0-41.5K) was applied in 3 equal applications (May, June and September) for a total of 15g K m^{-2} yr^{-1}. A single application of superphosphate (0-19.8P-0) was applied in late September at 5g P m^{-2} yr^{-1}. Pesticides were applied on a curative basis. Metalaxyl [N-(2,6-dimethylphenyl)-N-(methoxyacetyl) alanine methyl ester] and Fosetyl Al [Aluminum tris (O-ethyl phosphorate)] fungicides were used to control pythium blight(*Pythium aphanidermatum* and *Pythium graminicola*) and brown patch(*Rhizoctonia solani*). Chlorpyrifos [O,O-diethyl O-(3,5,6-trichloro-2-pyridyl) phosphorothioate] was applied to control sod webworm (*Crambus* spp.).

Leaf tissue nitrogen content was evaluated twice(July and September) in 1989 and three times(May, July, and September) in both 1990 and 1991. Leaf samples were collected from turfgrass plants in the treatment plots, dried immediately at 70℃ for 48 hours, and analyzed for total-N content, using the Kjeldahl method(Bremner and Mulvaney, 1982). Concurrently, six soil cores(18mm diam. by 200mm depth) were collected, air dried, and analyzed for total-N content. Nitrogen analyses on the soil and leaf samples were made in the Soil and Plant Analytical Laboratory, at the University of Nebraska, Lincoln, USA.

Data were analyzed as a split-split-plot with analysis of variance(ANOVA), using the General Linear Model procedures of the Statistical Analysis System(SAS Institute, 1990). The level of significance selected for treatment effects was $P \leq 0.05$. ANOVA results for all treatment effects are listed in Tables 1 and 2. The split-split-plot design used in the study allowed assessment of individual and interactive responses(Steel and Torrie, 1980). Interpretations were focused on the interactive effects rather than main effects, when interactions were significant among treatments. Irrigation frequency and clipping treatment means were separated by Fisher's protected least significant differences at $P \leq 0.05$, when interactive effects were not significant. Planned comparisons on nitrogen treatment means were performed by orthogonal polynomial contrasts to test for significant linear or quadratic responses and an appropriate regression model was generated.

RESULTS AND DISCUSSION

Irrigation frequency treatments were not a significant factor in leaf tissue nitrogen content during the study(Table 1). Daily or biweekly irrigation did not influence the nitrogen content of leaf samples for the first 3 years after establishment. Clipping treatments significantly affected leaf tissue nitrogen content in both 1989 and 1990(Table 1). In 1989

Table 1. Significance levels (PR>F) of split-split-plot for leaf tissue nitrogen content on 'Penncross' creeping bentgrass fairway turf under nontrafficked conditions during the study. Treatments were arranged in a split-split-plot experimental design with irrigation frequency as the main-plot, clipping return or removal as the sub-plot, and nitrogen rate as the sub-sub-plot

Source	1989	1990	1991
Irrigation frequency (I)	0.57	0.14	0.33
Clippings (C)	0.01	0.01	0.14
I × C	0.62	0.60	0.45
Nitrogen rate (N)			
N linear	0.00	0.00	0.00
N quadratic	0.38	0.00	0.84
I × N linear	0.89	0.24	0.84
I × N quadratic	0.73	0.47	0.71
C × N linear	0.63	0.11	0.60
C × N quadratic	0.99	0.36	0.32
I × C × N linear	0.34	0.16	0.24
I × C × N quadratic	0.10	0.30	0.38

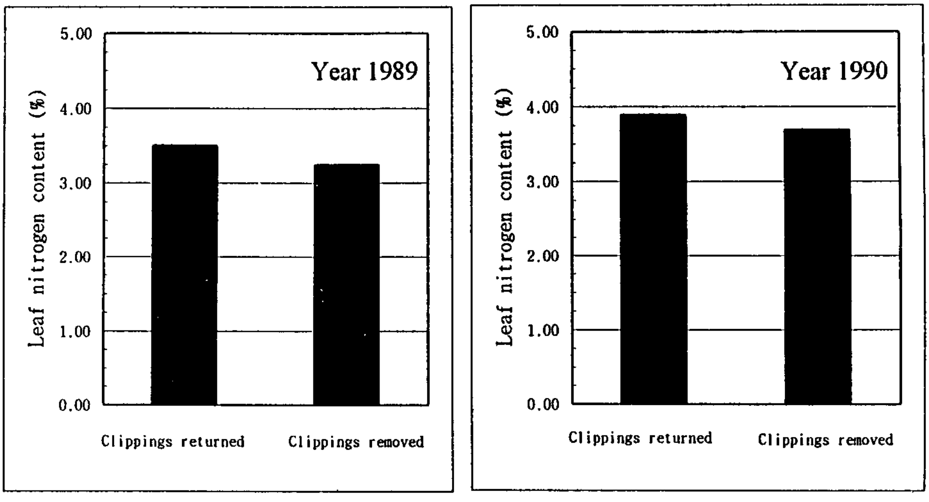

Fig. 2. Leaf tissue nitrogen content of 'Penncross' creeping bentgrass fairway turf under nontraffic conditions as influenced by clipping treatments.

clipping return treatment increased leaf tissue nitrogen content to 3.51%, while clipping removal treatment resulted in 3.25%(Fig. 2). Sicant contribution to leaf tissue nitrogen content by returning clippings was also observed in 1990. Leaf nitrogen content in the clipping-returned plots was 3.90%, being higher than 3.70% in the clipping-removed plots. Our data indicate that plots treated with clipping return had 8% and 5% more nitrogen content in the leaf tissue in 1989 and 1990, respectively, as compared to plots treated with clipping removal.

Grass clippings are a source of plant nutrients, including large amounts of nitrogen. In the dried grass clippings, nitrogen can comprise up to 5% of the total weight of a turfgrass(Shurtleff *et al.*, 1987; Turgeon, 1996). Thus, nutrients may be released from the decomposition of clippings. Starr and DeRoo(1981) reported increased leaf tissue nitrogen content from returning clippings in a mixture of Kentucky bluegrass and red fescue (*Festuca rubra* L.). These results suggest that different approaches should be addressed to turf fertilization program from a standpoint of clipping recycles. Where clippings are returned, the total application amount of nitrogen nutrients must be lowered, compared with that of clipping-removed areas. In areas of regularly removing clippings, the application of additional nitrogen fertilizer should be made to compensate for nutrients that have been removed by clippings.

Nitrogen rate treatments were very effective in leaf tissue nitrogen content. Significant differences by nitrogen rates were observed over 3 years (Table 1). High-N nutrition treatment(25g N m^{-2} yr^{-1}) was a significant factor for leaf tissue nitrogen content. This response agreed with the turfgrass color data(not presented in this study). Goss and Law (1967) observed high nitrogen rate(38g N m^{-2} yr^{-1}) resulted in increased leaf tissue nitro-

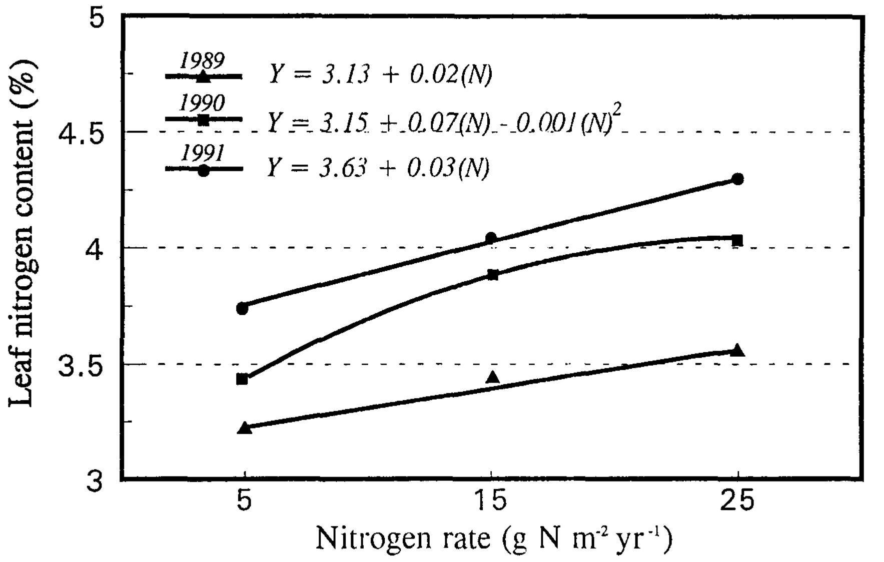

Fig. 3. Effects of nitrogen nutrition rate on leaf nitrogen content(1989-91) of 'Penncross' creeping bentgrass fairway turf under nontraffic conditions.

gen content, compared to low nitrogen rate (12g N m^{-2} yr^{-1}). As nitrogen rates increased from 5 to 25g N m^{-2} yr^{-1}, leaf tissue nitrogen content increased from 3.25 to 3.60% in 1989, from 3.45 to 4.05% in 1990 and from 3.75 to 4.25% in 1991(Fig. 3). These results demonstrate that plots applied with high-N level (25g N m^{-2} yr^{-1}) had 10%, 17%, and 13% more nitrogen content in leaf tissue in 1989, 1990, and 1991, respectively, when compared with plots applied with low-N level (5g N m^{-2} yr^{-1}).

Overall observations during the study indicated that leaf tissue nitrogen content increased at any nitrogen rate with time after establishment. At the low-N level treatment(5g N m^{-2} yr^{-1}), plots sampled in 1991 had 15% more leaf nitrogen content, as compared to plots sampled in 1989 (Fig. 3). Similar responses were also found from the high-N level treatment (25g N m^{-2} yr^{-1}). Plots analyzed in 1991 were 18% higher than that of plots analyzed in 1989. Nitrogen content in leaf tissue would accumulate over years. In other words, plant nutrients of golf course turf increase with the time, depending upon edaphic environments and cultural systems employed after establishment. These observations suggest annual amout of nitrogen application in turfgrass management can be reduced with time after establishment. Therefore, regular analysis of leaf tissue of golf course turf must be made and fertilization program should be developed through the incorporation of its analytic data interpretation. No significant treatment effects were observed for soil nitrogen content over the first 3 years after establishment (Table 2). Several factors would be associated with this response, such as the heterogeneous characteristics of soil medium, the soil sampling depth, and early stage of creeping bentgrass turf stand of being 3 years after establishment.

In conclusion, cultural practices influenced the leaf tissue nitrogen content in a creeping

Table 2. Significance levels (PR>F) of split-split-plot for soil nitrogen content on 'Penncross' creeping bentgrass fairway turf under nontraffic conditions during the study. Treatments were arranged in a split-split-plot experimental design with irrigation frequency as the main-plot, clipping return or removal as the sub-plot, and nitrogen rate as the sub-sub-plot

Source	1989	1990	1991
Irrigation frequency (I)	0.69	0.70	0.80
Clippings (C)	0.52	0.20	0.32
I×C	0.74	0.79	0.93
Nitrogen rate (N)			
N linear	0.22	0.88	0.55
N quadratic	0.73	0.55	0.36
I × N linear	0.76	0.78	0.76
I × N quadratic	0.21	0.36	0.57
C × N linear	0.36	0.59	0.76
C × N quadratic	0.63	0.37	0.57
I × C × N linear	0.82	0.93	0.26
I × C × N quadratic	0.61	0.66	0.40

bentgrass fairway turf maintained under nontraffic conditions. Results from this study suggest leaf tissue nitrogen content is variable with clipping recycles, nitrogen application rate and time after establishment. Particularly, clippings significantly contributed leaf tissue nitrogen content. Clippings are normally returned on fairways to reduce maintaince cost and thereby recycle nitrogen, phosporous, and potassium to the turf. Turfgrasses require nitrogen in the largest amount of any of the essentional nutrients (Beard, 1973; Turgeon, 1996; Turner and Hummel, Jr., 1992). In the golf course of a growing season, considerable amount of nitrogen and other nutrients returned to the turf in clippings. Gaussoin (1992) reported that recycled clippings can reduce the turfgrass nitrogen requirement for the growing season by as much as one third. In other words, strategic fertilization application is necessary for the golf course turf, depending on whether clippings are returned or not. In golf courses where clippings are recycled, the fertilization program, especially nitrogen application, need to be adjusted, being 20% to 30% less input over the clipping-removed areas. However, turf manager should consider the other aspects such as turf quality, turf color, and thatch accumulation and so on. Clippings can also lower turfgrass quality under moist conditions by remaining as objectionable clumps or damaging turf by light exclusion. Kim (1992) reported clipping return in combination with daily irrigation and high-N fertility (25g N m^{-2} yr^{-1}) stimulated thatch accumulation over clipping removal treatment.

적 요

본 연구는 크리핑 벤트그라스(*Agrostis palustris* Huds.) 훼어웨이에서 관수회수 · 예지물 및 질소시비 수준이 엽조직 및 토양 중 질소함유량에 미치는 효과를 규명하기 위해 시작되었다. 연

구포장은 펜크로스 ('Penncross') 크리핑 벤트그라스 잔디밭으로 1988년에 Sharpsburg silty-clay loam(Typic Argiudoll) 토양에 조성되었으며, 실험은 1989년부터 1991년까지 3년간 진행되었다. Split-split-plot 실험디자인을 사용하여 주구에 Daily or Biweekly irrigation, 세구에 Clipping return or removal, 세세구에 Low-N (5g), Moderate-N (15g), High-N (25g N m^{-2} yr^{-1}) 시비수준이 난괴법 3 반복으로 배치되었다. 생육기간 중 잔디예초는 13mm 예고로 일주일에 4번 실시하였다. 코링(Core cultivation)은 일년에 2번 실시했으며 코링 후 바로 배토(Topdressing)를 실시하였다. 엽조직 및 토양샘플은 1989년에는 7월과 8월 2회 채취했으며, 1990년과 1991년에는 5월, 7월, 9월 모두 3회 채취하였다. 채취한 샘플은 즉시 70℃ 온도조건의 오븐에 48시간 건조시켜 네브라스카 주립대 토양·식물분석실에 의뢰하였다. 데이터 통계분석은 SAS 프로그램을 이용하여 ANOVA 분석을 실시하였다.

엽조직의 질소함유량은 예지물·질소시비수준 및 잔디조성후 경과기간에 따라 다르게 나타났으며, 특히 예지물 순환 및 질소 시비량이 증가할수록 엽조직의 질소함유량도 증가하였다. Clipping return 처리구의 엽조직 질소함유량은 Clipping removal 처리구보다 1989년에 8%, 1990년 5% 더 많이 함유한 것으로 나타났다. High-N(25g N m^{-2} yr^{-1}) 처리구의 엽조직 질소함유량은 Low-N (5g N m^{-2} yr^{-1}) 처리구와 비교시 1989년 10%, 1990년 17%, 그리고 1991년에는 13% 더 많은 것으로 나타났다. 크리핑 벤트그라스 잔디조성후 경과기간에 따라 엽조직의 질소함유량도 증가함을 알 수 있었다. Low-N (5g N m^{-2} yr^{-1}) 수준에서 엽질소 함유량은 1989년보다 1991년에 15% 더 많았으며, High-N (25g N m^{-2} yr^{-1}) 수준에서는 1991년의 엽조직 질소함유량이 1989년보다 18% 더 많은 것으로 나타났다. 토양질소함유량에 대한 처리구간의 차이는 펜크로스 크리핑 벤트그라스 잔디밭 조성초기인 1990년부터 1991년까지 3년간 연구기간 중 통계적으로 유의성이 없는 것으로 나타났다.

잔디조성 후 경과기간 및 관리방법에 따라 엽조직의 영양분 상태가 달라지므로 골프장 잔디관리에서 정기적으로 토양 및 엽분석을 실시해서 시비프로그램에 활용하는 것이 필요하다. 또한 예지물이 재활용되는 지역과 그렇지 않은 지역의 잔디관리에 있어서 장기간 차별화된 접근이 필요하며 예지물이 순환되는 지역은 년간 20~30% 정도 질소 시비량을 감소시킬 수 있는 것으로 사료되었다.

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