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Evaluating Various Nitrogen Sources for Divot Recovery on Creeping bentgrass

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ABSTRACT. Creeping bentgrass (*Agrostis stolonifera*) is one of the most popular turfgrasses for high-quality playing surface such as putting green on golf courses and athletic fields. Continues damage such as divot injury on creeping bentgrass is major issue to maintain golf course properly. Although plentiful researches to maximize divot resistance have been reported, minimal research has focused on relation between nitrogen (N) sources and divot resistance. The study was conducted to determine the effect of N source for turfgrass divot recovery and overall tee performance. Eleven fertilizer treatments as N sources were applied to creeping bentgrass 'Penncross'. Before the first application, divot injuries were simulated by removing a core of soil and turfgrass from established plots and backfilling with native soil. Data collection included turfgrass color and quality. N release speed did not influenced divot recovery. Frequency of urea application had no effects on divot recovery. Urea with split application had no difference with no treatment for divot recovery. Polyon product especially polyon mini (41-0-0) had the best performance for divot recovery and for maintaining better turfgrass quality. Overall, small particle size of slow-release N form would influence creeping bentgrasss to recover divot damage.

***Key words*:** Creeping bentgrass, Divot injury, Nitrogen, Slow-release N form

Creeping bentgrass (*Agrostis stolonifera* L.) is one of the most popular turfgrasses for high-quality playing surface such as putting green on golf courses and athletic fields (McCarty, 2001). Because their aggressive lateral growth which allows them to recover partially from continues damage like wear stress, creeping bentgrass is mainly used for putting green in golf courses (Christians, 2011). It also has excellent tolerance to low mowing, adaptation to various conditions of climates, and good recovering ability damaged from traffic and environmental stress (Cuddeback and Petrovic, 1985; Rosenberg, 1964). However, creeping bentgrass putting green is vulnerable especially under high temperature in summer. The decline of creeping bentgrasss in summer is commonly problematic in golf courses due to environmental and mechanical stress (Dernoeden, 2002; Fry and Huang 2004). Creeping bentgrass is less tolerant for wear and traffic stress resulted from soil compaction than other cool and warm season grasses (Carrow and Petrovic, 1992). Among weakness of creeping bentgrass, continues damage such as divot injury is major issue to maintain golf course properly. Divot injury which is the area damaged by the impact of a golf club especially an iron leading the displacement of an area of turf and soil is one of the most serious difficulties on golf courses (Fry et al., 2008). Managing divot damage is important in order to maintain maximum turfgrass cover and uniform playing condition. The amount, size, and length of time divots exist on a tee or fairway can be influenced by turf species and cultivar (Beard, 1973). Karcher et al. (2005) investigated the divot recovery of numerous bermudagrass (*Cynodon* spp.) and zosiagrass (*Zoysia* spp.) cultivars. He reported that zoysiagrass 'Palisades' required 4.2 days to reach 50% recovery, and bermudagrass 'Riviera' required 4.6 days to reach 50% recovery. The previous researches regarding to increase divot resistance have been reported. Beard and Sifers (1990) reported that the presence of mesh materials in a rootzone reduced divot size and improved recovery of areas damaged by devoting. They found that divot length was 63.0 mm where no mesh materials were used and 57.5 mm where mesh materials were incorporated. Waldron (1977) had similar results with divot length where the unamended plots had average divot width of 37.7 mm and plots containing mesh materials had average divot width of 34.8 mm.

In addition to soil amendments like mesh materials, numerous factors may contribute to the divot injury including turfgrass rooting, traffic, athlete weight, soil physical characteristics, and soil moisture content (McNitt and Landschoot, 2005). While abundant researches to maximize divot resistance have been reported, minimal

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Table 1. List of treatments.

Treatment[z]	N sources	Particle size (mm)	Application rate of N (g/m^{-2})
NS-1	Nurea + 10% Nitamin (43-0-0)[y]	3-4	9.8
NS-2	Nurea + 30% Nitamin (42-0-0)	3-4	9.8
NS-3	Nitamin 30 L (30-0-0)	2-3	9.8
NS-4	Polyon mini (43-0-0)	< 1	9.8
NS-5	Polyon mini (41-0-0)	< 1	9.8
NS-6	Nitroform (38-0-0)	3-4	9.8
NS-7	Urea (46-0-0)	3-4	9.8
NS-8	Nurea (39-3-5)	3-4	9.8
NS-9	SCU (37-0-0)	3-4	9.8
NS-10	Urea (46-0-0)	3-4	2.5 Every 2 weeks (4 times)
NO-N	Untreated Control	3-4	0.0

[z] All products of N sources were slow release N except Urea. Urea with split applications was the simulation of slow release N using application frequency.
[y] Three numbers indicated after product name were the analysis of N, P_2O_5, and K_2O.

research has focused on relation between nitrogen (N) sources and divot resistance. Nitrogen is one of the most important nutrients among 17 essential nutrients for maintaining turfgrass color and quality. An intensive N fertilization program and high N fertilization rate are required for turfgrass optimal quality (Exner et al., 1991). If turfgrass is deficient in N, it will become chlorotic resulted in less carbohydrate production. If turfgrass has sufficient N, it increases carbohydrate production leading to shoot and root growth (Christians, 2011). In this situation, turfgrass can be recovered relatively faster than turfgrass with deficient N. Divot injury on creeping bentgrass damaged by various factors can be recovered from N applications because N promotes stolon growth to refill damaged area by divot. Calhoun (1996) reported that 250 kg ha^{-1} yr^{-1} increased divot recovery on creeping bentgrass than the N amount of 125 kg ha^{-1} yr^{-1}. However, Beard (2002) reported that N is not necessary for more root growth. Kruse and Kenworthy (2009) evaluated N rate effects on divot recovery of bermudagrass. They reported N rate ranged from 2.4 to 4.9 g m^{-2} had no effects for divot recovery. Guertal and Hicks (2009) evaluated N sources and rates to influence dry weight of turfgrass stolon. They found that dry weight of stolon was decreased as N rate increased. From the previous researches, N application to recover turfgrass damaged by divot is not enough to be clear The objective of the study was to determine the effect of N source for turfgrass divot recovery and creeping bentgrass growth.

Application of nitrogen sources

On June 30, 2004, eleven fertilizer treatments as N sources were applied to creeping bentgrass ‘Penncross’ at the Hancock Turfgrass Research Center on the campus of Michigan State University. Plot sizes were 1.2 × 1.8 m which mowed every other day at mowing heights of 1.6 cm. For the complete list, treatments were described in Table 1. Urea of 2.5 g N m^{-2} was applied 4 times every two weeks giving a total 10 g m^{-2}. Fertilizer treatments were applied with a hand shaker container. Thereafter, irrigation was applied at 1.9 cm water per week. Irrigation was scheduled to return 80% of potential evaportranspiration (PET) as estimated with the modified Penman method calculated by the on-site WS-200 Rainbird Maxi weather station (Rainbird, Glendora, CA). Creeping bentgrass was mowed at mowing height of 4 mm every day and clipping was removed when creeping bentgrass was mowed. On the date of application the high temperature was 23.9ºC and relative humidity was over 97% . Before the first application, divot injuries were simulated by removing a core of soil and turfgrass from established plots and backfilling with native soil. Data collection included turfgrass color and quality. Turfgrass color was visually rated on a scale of 1 to 9 (1 = straw brown, 6 = acceptable, and 9 = excellent). Turfgrass quality was visually rated on a scale of 1 to 9 (1 = poor, 6 = acceptable, and 9 = best). Rating of turf color and quality were taken at 9, 13, 19, 29, 34, 49, 57, and 66 day after treatment (DAT).

The experimental design was a randomized complete block design with 3 replications with 11 treatments. Data were analyzed using analysis of variance (PROC GLM). Mean separation was performed by Fischer’s protected least significant difference (LSD) at a 0.05 significance level. All statistical analyses were performed by SAS (SAS Inst., 2001).

Table 2. Mean creeping bentgrass color for nitrogen source main effect.

Treatments	Turfgrass color							
	7/9 (9 DAT[z])	7/13 (13 DAT)	7/19 (19 DAT)	7/29 (29 DAT)	8/3 (34 DAT)	8/16 (49 DAT)	8/24 (57 DAT)	9/2 (66 DAT)
NS-1	7.3[y] ab[x]	6.8 a	7.0 b	6.3 c	6.8 cde	5.0	6.3 bc	5.0 cd
NS-2	7.3 ab	6.7 a	6.7 b	6.2 cd	6.7 de	5.3	6.2 bc	5.0 cd
NS-3	7.0 ab	6.8 a	6.8 b	6.2 cd	6.8 cde	5.8	6.2 bc	5.5 c
NS-4	6.0 cd	6.5 ab	8.0 a	7.2 b	7.2 bc	5.7	6.5 b	5.7 bc
NS-5	5.7 d	6.0 bc	8.0 a	7.7 a	7.7 a	5.8	7.5 a	6.5 a
NS-6	6.0 cd	5.3 d	5.0 c	5.8 de	6.5 e	5.5	6.2 bc	5.7 bc
NS-7	7.5 ab	6.8 a	6.7 b	6.2 cd	6.7 de	5.8	6.0 bc	5.7 bc
NS-8	7.8 a	6.8 a	6.8 b	6.3 c	6.7 de	6.0	6.2 bc	4.7 d
NS-9	6.7 bc	6.8 a	7.0 b	6.3 c	7.0 bcd	6.3	6.2 bc	5.3 cd
NS-10	5.8 cd	5.5 cd	5.0 c	5.5 ef	7.3 ab	5.8	6.0 bc	6.3 ab
NO-N	5.7 d	4.5 e	4.3 d	5.2 f	5.7 f	5.8	5.8 c	4.7 d
LSD ($P = 0.05$)	0.9	0.6	0.6	0.4	0.5	NS[w]	0.5	0.8

[z] Days after treatment.
[y] Turfgrass color was rated visually on a scale of 1-9 (1 = straw brown, 6 = acceptable, and 9 = excellent).
[x] Means in a column followed by the same letter are not significantly different according to Fishers LSD (P =0.05).
[w] Not significant difference.

Effect of nitrogen sources

There was a significant N source main effect for turfgrass color (Table 2). NS-5 had the highest or equal to the highest color ratings on 5 of 8 rating dates. When significant differences were found, NS-5 had higher turfgrass color than acceptable color rating of 6 except July 9 rating date. As a fast release N sources, NS-10 had the unacceptable color ratings on 5 of 8 rating dates. NS-5 had no difference with NO-N which was treated by no N on 4 of 8 rating dates. While NS-6 had the unacceptable color ratings on 6 of 8 rating dates, it had no difference with NO-N on 3 of 8 rating dates. On August 16, NS-10 had higher color rating than NS-6 due to the 3rd application of urea. On September 2, NS-10 had higher color rating than NS-6 due to the 4th application of urea. NS-5 had the lowest color rating on July 9, but it maintained the highest or equal to the highest color rating after July 13. Although no differences were found between NS-4 and NS-5, NS-5 had higher turfgrass color than NS-4 after August 3. There were no differences for turfgrass color between NS-1 and NS-2 during the study. NS-7 which is urea treatment of single application had higher than NS-10 which is urea treatment of split application for the first 5 weeks. Urea as a fast release N form had no difference with NO-9 as a slow-release N form during the study.

Significant differences on N sources main effect were found for turfgrass quality (Table 3). NS-10 had no differences with NO-N except August 3 and September 2. No differences were found between NS-7 and NS-10 except July 29. There were no significant differences for turfgrass quality among treatments including Nurea which NS-1, NS-2, and NS-8 except July 13. NS-4 and NS-5 of polyon product had no differences during the study except August 3. NS-6 had the lowest or equal to the lowest turfgrass quality when significant differences were found. Regardless of frequency, treatment including urea had no differences with NS-9. NS-10 had lower quality than acceptable rating of 6 on 5 of 8 rating dates. NS-5 produced higher turfgrass quality than acceptable rating of 6 during the study.

Stein and Stier (2003) evaluated N source effects for divot recovery on creeping bentgrass. They reported that no differences were found between N sources and divot recovery on creeping bentgrass. However, N source effects for divot recovery were found based on the results of the study. N release speed did not influenced divot recovery. Frequency of urea application had no effects on divot recovery. Urea with split application had no difference with no N treatment for divot recovery. Among the products including Nurea, no differences were found for divot recovery. Although no effects for divot recovery were found on N release speeds, frequencies of urea applications, and Nurea products, polyon products, especially polyon mini (41-0-0), had the best performance for divot recovery and for maintaining better turfgrass quality. Overall, small particle size of slow-release N form would influence creeping bentgrasss to recover divot damage.

Table 3. Mean creeping bentgrass quality for nitrogen source main effect.

Treatments	Turfgrass quality							
	7/9 (9 DAT[z])	7/13 (13 DAT)	7/19 (19 DAT)	7/29 (29 DAT)	8/3 (34 DAT)	8/16 (49 DAT)	8/24 (57 DAT)	9/2 (66 DAT)
NS-1	7.3[y]	7.8 a[x]	7.0	7.0 a	6.8 cd	5.7 cd	6.0	4.3 cde
NS-2	7.2	7.5 b	7.0	6.8 a	6.8 cd	6.2 bc	6.2	4.3 cde
NS-3	6.0	7.3 b	7.0	6.8 a	7.0 c	6.2 bc	6.5	5.2 bc
NS-4	6.0	6.8 b	7.0	7.0 a	7.5 b	6.8 ab	6.8	5.7 ab
NS-5	6.3	6.5 b	7.0	7.0 a	8.0 a	7.5 a	7.3	6.5 a
NS-6	6.0	6.0 b	5.7	6.2 bc	6.5 d	5.7 cd	6.5	5.2 bc
NS-7	7.3	7.7 b	7.0	6.7 ab	7.0 c	5.8 bc	6.2	4.8 bcd
NS-8	7.5	7.8 b	7.0	6.8 a	7.0 c	5.8 bc	5.8	4.0 de
NS-9	6.7	7.3 b	7.0	6.8 a	7.0 c	5.8 bc	6.5	4.8 bcd
NS-10	6.3	5.7 b	4.7	5.7 cd	7.0 c	5.7 cd	6.2	5.3 b
NO-N	5.7	5.3 b	4.7	5.2 d	5.7 e	4.7 d	5.7	3.7 e
LSD (P = 0.05)	NS[w]	0.7	NS	0.5	0.5	1.1	NS	0.9

[z] Days after treatment.
[y] Turfgrass quality was rated visually on a scale of 1-9 (1 = worst, 6 = acceptable, and 9 = best).
[x] Means in a column followed by the same letter are not significantly different according to Fishers LSD (P =0.05).
[w] Not significant difference.

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Creeping bentgrass 의 생육과 디봇피해 회복을 위한 질소의 유형별 효과

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Creeping bentgrass 는 골프장의 티나 퍼팅그린 그리고 경기장과 같이 집중관리가 요구되는 곳에 가장 많이 사용되는 잔디의 종류중 하나이다. 골프장에서 계속해서 발생하는 디봇과 같은 피해는 골프장을 관리하는데 있어서 가장 큰 장애요인중 하나이다. 디봇피해를 회복하기 위한 많은 연구결가가 선행 되었음에도 불구하고, 질소의 유형에 따른 디봇피해의 회복에 대해서는 그 연구결과가 제한적이다. 본 연구는 creeping bentgrass 에 발생한 디봇피해에 대한 질소의 유형별 효과에 대해 알아보기 위해서 수행되었다. 11가지 질소가 creeping bentgrass ‘Penncross’에 시비되었다. 첫번째 시비처리 이전에 일정한 단위규격당 디봇피해가 만들어 졌으며 피해가 생긴 빈자리에 원토양이 채워졌다. 실험기간동안 잔디의 색과 질이 평가되었다. 질소의 분해속도에 따른 효과는 디봇피해를 회복시키거나 creeping bentgrass 생육에 대해 영향을 미치지는 않았다. 총 4번에 걸쳐 시비한 urea 처리구는 질소가 시비되지 않은 대조구와 비교했을때 디봇의 회복이나 creeping bentgrass 생육에 대해 차이가 나타나지 않았다. 디봇피해에 대한 회복과 creeping bentgrass 생육에 대해 polyon 제품군, 특히 polyon mini (41-0-0)가 가장 좋은 효과를 보여 주었다. 본 실험결과 입자의 지름이 작은 완효성질소가 입자의 지름이 큰 완효성질소나 속효성질소 보다 creeping bentgrass 에 발생한 디봇피해의 회복에 좋은 효과를 나타냈다.

주요어: Creeping bentgrass, 디봇피해, 완효성질소, 질소