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RESEARCH

Evaluation of an Amino-Acid-Based Fertilizer for Grow-In of Creeping Bentgrass Putting Greens

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ABSTRACT

Turfgrass grow-in on sand-based putting greens usually incurs a high risk for nitrogen (N) leakage. Our objective was to evaluate how substitution of a standard mineral fertilizer with an amino-acid-based fertilizer affects creeping bentgrass (*Agrostis stolonifera* L.) establishment rate and the concentration of nitrate and total N in drainage water. The experiment was conducted from 19 May to 26 July 2016 in the United States Golf Association green field lysimeter facility at Landvik, Norway. The liquid fertilizers arGrow Turf (70% of N as arginine and 30% as lysine) and Wallco (60% of N as nitrate and 40% as ammonium) were applied at ~2-wk intervals at the two rates of 1.5 or 3.0 g N m^{-2} application^{-1}. Results showed significantly faster grow-in on plots receiving amino-acid-based fertilizer than on plots receiving mineral fertilizers; the average turfgrass coverage 26 d after the first fertilization was 75 and 36%, respectively. In parallel with this, the average concentration of nitrate and total N in drainage water, as well as the total N loss, were all reduced by 40 to 45%. Arginine and lysine at 1.5 g N m^{-2} gave faster grow-in than Wallco at 3.0 g N m^{-2} and was the only treatment in which the drainage water complied with EU's requirements for maximum concentration of nitrate in drinking water.

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Abbreviations: USGA, United States Golf Association.

High nitrogen (N) rates are often used for turfgrass grow-in on sand-based putting greens. For creeping bentgrass (*Agrostis stolonifera* L.), the United States Golf Association (USGA) suggests applications of 1.5 to 3.0 g N m^{-2} in KNO_3 every fifth day until the plant cover is complete (White, 2003). Such frequent and high N inputs before roots have developed incur a high risk for N losses. Nitrogen concentrations in leakage from turfgrass areas may contribute to eutrophication at concentrations as low as 1.0 mg N L^{-1} (Walker and Branham, 1992). For drinking water, the United States and EU have maximum contaminant guidelines of 10 mg NO_3–N L^{-1} and 50 mg NO_3 L^{-1} (corresponding to 11.3 NO_3–N L^{-1}), respectively.

Nitrogen is primarily taken up by plants as ammonium (NH_4^+) and nitrate (NO_3^-) (Carrow et al., 2001; Marschner, 2012). Foliar absorption of urea and amino acids may, however, be equally effective as foliar uptake of NH_4^+ or NO_3^- (Stiegler et al., 2013; Kim et al., 2014). For root uptake, Näsholm et al. (1998, 2000) documented 20 to 60% uptake of intact amino acids after application of glycine.

The amino acids arginine and lysine are both cations and therefore adsorb to negatively charged soil particles. This reduces the risk for N losses in drainage water. Studies in tree nurseries showed that 80% of N applied in arginine was recovered by the cultivated plants, as opposed to only 50% for mineral fertilizers containing NO_3^- and NH_4^+ (Öhlund and Näsholm, 2002).

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The objective of this research was compare the effect of an amino-acid-based fertilizer and a mineral fertilizer containing NO_3^- and NH_4^+ on turfgrass grow-in and N leaching during establishment of a creeping bentgrass putting green.

MATERIALS AND METHODS

A field experiment was performed from 19 May to 26 July 2016 in the USGA green field lysimeter facility at NIBIO Landvik Turfgrass Research Center, Grimstad, Norway. The facility consists of 16 lysimeters arranged in four blocks. Each lysimeter has a 2.0-m^2 surface area and contains a 30-cm rootzone layer underlain by a 10- to 15-cm gravel layer. For this experiment, the rootzone consisted of sand that met the particle size recommendations of the USGA (USGA, 2004), amended with 10% (v/v) peat. The soil pH (H_2O) was 5.9, the cation exchange capacity was ~6 cmol c+ kg^{-1}, and the ignition loss was 0.8% as determined by combustion at 450°C for 3 h. The soil's content of plant available phosphorus (P) was 13 mg P kg^{-1} as determined spectrophotometrically after extraction with ammonium lactate (Murphy and Riley, 1962). According to Bechmann et al. (2005), this corresponds with a Mehlich-3 value of 19 mg P kg^{-1}. The leakage from each lysimeter was collected in 200-L containers made with stainless steel and placed in a central collection unit.

On 19 May 2016, the green was seeded with creeping bentgrass 'Independence' with a sowing rate of 8 g m^{-2}. No fertilizer was applied before sowing. After sowing, the seedbed was raked, rolled, and covered with a white permeable tarp until 15 June. The irrigation system was set to four irrigations per day, each providing 2 mm of water. On windy days, the plots were irrigated manually to ensure uniformity. Irrigation was cancelled on days with natural rainfall.

The green received liquid fertilizers on 3 June, 15 June, 29 June, 12 July, and 19 July. The fertilizer types were arGrow Turf with 70% of the N as arginine and 30% as lysine (Swe-Tree Nutrition AB) and Wallco 5-1-4 with 60% of the N as NO_3^- and 40% as NH_4^+ (Cederroth AB). arGrow Turf did not contain calcium and had a higher concentration of sulfur and iron than Wallco; otherwise, both fertilizers contained the essential nutrients in appropriate amounts (Table 1). Except for N in arGrow Turf, all nutrients were in inorganic form in both fertilizer types. The fertilizers were applied at two rates: 1.5 or 3.0 g N m^{-2} application^{-1}.

Registrations included visual assessments of turfgrass coverage (percentage of plot area) immediately before each fertilizer application. On 3 June, 15 June, 29 June, 12 July, and 26 July, the amount of drainage water coming from each lysimeter was measured, and samples were taken for analyses of total N and NO_3–N. Total N was analyzed using Shimadzu's Total Nitrogen Module (i.e., combustion oxidation and chemiluminescence detection), whereas NO_3–N was determined using method G-384-08 of an Omniprocess AA3 Autoanalyser.

The experimental data were analyzed by ANOVA for a randomized complete block experiment with four replicates, two fertilizer types, and two fertilizer rates in factorial combination. Data from repeated measurements were analyzed independently for each observation date. Means were separated by LSD ($P \leq 0.05$).

Weather Data, Irrigation, and Drainage

The average daily maximum and minimum air temperatures during the experimental period were 20.0 and 10.7°C, which are close to the 30-yr normal values for the experimental site (Table 2). The highest precipitation and drainage volumes were recorded between 19 May and 2 June and between 15 and 28 June. There was no rainfall from 3 to 14 June.

RESULTS

Turfgrass Coverage

On average, for the two fertilizer rates, turfgrass grow-in was faster on plots fertilized with arginine + lysine than with NO_3^- + NH_4^+ (Fig. 1). The largest difference was observed on 29 June, 6 wk after sowing. After that, the difference decreased, and both fertilizer types gave 94% coverage by the last observation on 27 July. Turfgrass coverage was not significantly affected by fertilizer rate on any of the observation dates, and there was no interaction.

Nitrogen Losses in Drainage Water

In total, for the experimental period, 92 and 94% of the N losses in drainage water were in the form of NO_3^- on plots fertilized with amino acids and mineral N, respectively. Substitution of NO_3^- and NH_4^+ with arginine and lysine reduced the concentrations of NO_3–N and total N in drainage water, as well as the total N leakage, by 40 to 45% (Table 3). On average, for all samples, a doubling of the N rate led to a significant increase in the NO_3^- concentration on plots fertilized with amino acids but had no effect on plots fertilized with mineral N. The interaction ($P = 0.047$) is illustrated in Fig. 2, which also shows that the drainage water reached a maximum NO_3–N concentration in the period with the highest rainfall from 15 to 28 June.

DISCUSSION

The 10-wk period needed to reach >90% coverage was longer than usually encountered when establishing creeping bentgrass greens in Scandinavia. Reasons for this were that no slow-release fertilizer was mixed into the rootzone before sowing, and that fertilizers were only applied every 2 wk during the first 8 wk of the experiment. According to the recommendations by White (2003), it is likely that

Table 1. Nutrient content in the two liquid fertilizers arGrow Turf and Wallco 5-1-4.

Fertilizer	N	P	K	Mg	Ca	S	Fe	Mn	B	Zn	Cu	Mo
	%											
arGrow Turf	5.5	0.9	3.9	0.3	0.0	0.8	0.27	0.05	0.018	0.014	0.002	0.003
Wallco 5-1-4	5.1	1.0	4.3	0.4	0.4	0.4	0.02	0.02	0.010	0.003	0.002	0.00004

Table 2. Air temperature, rainfall, irrigation, and drainage during five consecutive periods and in total for the 68 d grow-in period. Temperature was measured at Landvik weather station, about 250 m from the experiment. Rainfall, irrigation, and drainage were measured on site.

Parameter	19 May–2 June	3 June–14 June	15 June–28 June	29 June–11 July	12 July–26 July	Total
Daily max. temperature, °C	18.3	20.2	19.4	19.7	22.6	20.0
Daily min. temperature, °C	10.2	9.5	11.0	10.0	12.8	10.7
Days with rainfall	6	0	8	8	5	27
Rainfall, mm†	75	0	104	51	39	269
Irrigation, mm†	88	86	35	48	51	278
Total water input, mm†	163	86	138	99	90	547
Drainage from lysimeters, mm‡	101	56	99	53	48	357

† Mean of six rain gauges.

‡ Mean of 16 lysimeters.

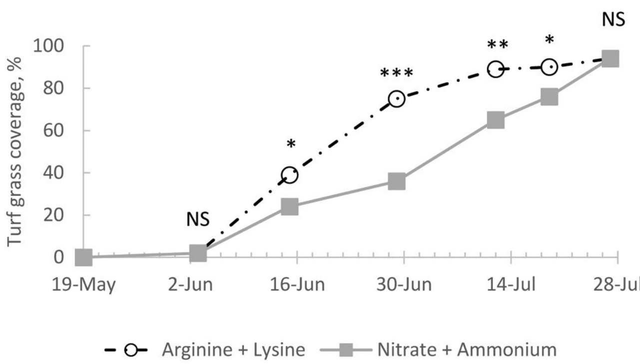

Fig. 1. Development of turfgrass coverage on plots fertilized with arginine + lysine (arGrow Turf) and with nitrate + ammonium (Wallco). Mean of two fertilizer rates. Significance: *** $P \leq 0.001$; ** $0.001 < P \leq 0.01$, * $0.001 < P \leq 0.01$; NS, not significant.

a presowing fertilization with 5 g N m^{-2} and postsowing application every 5 to 7 d, rather than every 12 to 15 d, would have sped up the establishment rate. The fact that turfgrass coverage did not develop any faster with 3.0 than with 1.5 g N m^{-2} application^{-1} suggests that the establishment rate was more limited by application frequency than by fertilizer rate per application.

Besides N, P is usually considered a critical element for turfgrass grow-in (Carrow et al., 2001). White (2003) recommended preplant application of 10 g P m^{-2} (i.e., twice as much as of N), but this is probably excessive, as Aamlid et al. (2013) found substantial leaching of P during turfgrass grow-in on sand-based substrates, especially after amendment with compost, but also after amendment with peat, as in the present experiment. The N:P ratio in Wallco and arGrow Turf was 100:20 and 100:18, respectively, which are both higher than the ideal ratio of 100:12 reflecting plant uptake (Ericsson et al., 2012). Besides N, leaching of P probably occurred for both fertilizer types, but the fact that coverage developed faster on plots receiving amino acids than on plots receiving mineral N clearly points to N as the most limiting element to turfgrass grow-in in this study.

Faster establishment and less N leaching due to substitution of mineral N with arginine and lysine are in agreement with Öhlund and Näsholm (2002) and confirm our hypothesis that amino-acid-based fertilizer may have potential on sand-based golf greens. Of special interest was the high performance of plots receiving only 1.5 g N m^{-2} application^{-1}, as this was the only treatment in which the concentration of NO_3^- in leachate was in compliance with EU requirements for drinking water.

The observation that 92% of the N leakage from plots receiving arginine + lysine was in the form of NO_3^- confirms that the positively charged amino acids were bound to the soil particles before mineralization or direct uptake by creeping bentgrass roots. Our experiment was not set

Table 3. Main effects of fertilizer type and fertilizer rate on the concentration of NO_3–N and total N, and on the N loss in drainage water. Concentrations are weighed means, and losses are total for the 68 d grow-in period. *P*-values have been indicated for main effects and interaction.

	Concentration of NO_3–N	Concentration of total N	N loss in drainage water	Fertilizer lost in drainage
	mg L^{-1}		g m^{-2}	%
Fertilizer type				
Arginine + lysine (mean rate: 11.25 g N m^{-2})	10.7	11.6	4.0	36
Nitrate + ammonium (mean rate: 11.25 g N m^{-2})	18.6	19.8	7.2	64
P-value	0.0022	0.0023	0.0013	0.0013
Fertilizer rate				
1.5 g N m^{-2} × 5 applications = 7.5 g N m^{-2}	12.5	13.3	4.8	64
3.0 g N m^{-2} x 5 applications = 15.0 g N m^{-2}	16.8	18.0	6.5	43
P-value	0.032	0.028	0.027	0.027
P-value, interaction	0.047	0.041	0.10	0.10

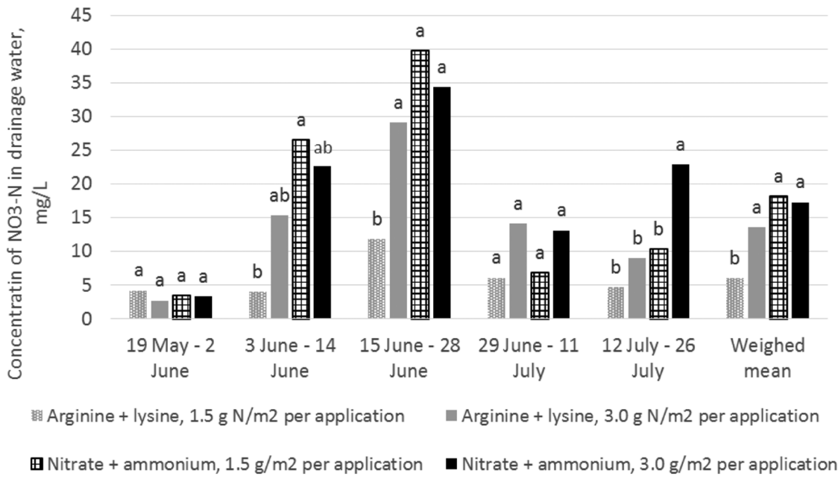

Fig. 2. Effect of fertilizer type and fertilizer rate on the concentration of NO_3–N in drainage water during various periods and on average for the entire grow-in phase. Within each period, bars with the same letter were not significantly different at $P \leq 0.05$.

up to determine to what extent mineralization occurred before root uptake, but the ratio on the immature, sand-based green may well have been between 20 and 60%, as determined for timothy (*Phleum pratense* L.) and wavy hairgrass [*Deschampsia flexuosa* (L.) Trin.] growing on agricultural soils and in boreal forests, respectively (Näsholm et al., 1998, 2000). Within this range, the metabolic savings of direct uptake of amino acids may well be significant, especially for turfgrasses exposed to stress. Further studies are therefore underway to elucidate the effect of amino-acid-based fertilization on the winter hardiness of creeping bentgrass greens.

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