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Reduced leaching of nitrogen and phosphorus using nutrient coated perennial ryegrass seed (iSeed[®])

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Research technician Trond Pettersen measures turf traction in grow-in trial, Landvik, Norway, 2010. Photo Gedime Kusliene



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Keywords:

fertilizer, grow-in, leaching, *Lolium perenne*, nitrogen, perennial ryegrass, phosphorus, seed coating, turfgrass

Field of work:

Turfgrass and Seed Production

Summary:

This report presents results from a field trial evaluating the effect of iSeed® coating on turf quality and nitrogen and phosphorus leaching during the grow-in of athletic fields on sand-based rootzones.

Sammendrag:

Rapporten presenterer resultater fra et forsøk i lysimeteranlegget på Landvik der vi undersøkte virkningen av iSeed® på graskvalitet og utlekking av nitrogen og fosfor ved etablering av fotballbaner på sandbaserte underlag.

Approved

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1. Abstract

High fertilizers rates, especially of nitrogen (N) and phosphorus (P), are commonly used for turfgrass grow-in on sand-based soils. The United States Golf Association recommends preplant applications of up to 1.0 kg P and 0.5 kg N per 100 m² followed by applications of up to 0.3 kg N/100 m² every fifth day until plant cover is complete. Such high rates of N and P, given before roots have developed, incur a great risk for nutrient leaching. Irrigation several times per day to keep the seedbed constantly moist also contributes to this leaching potential.

iSeed[®] is a seed coat patented by Yara International ASA and used for grass seed marketed by DLF Trifolium. The coat contains both fast-acting and slow-release fertilizers, in total 10% N and 2% P of coated seed weight.

The objective of this research was to determine the effect of iSeed[®] on turf quality and nitrogen and phosphorus leaching during turfgrass grow-in on two sand-based rootzones. A two-factorial experiment was carried out in the field lysimeter facility at Bioforsk Øst Landvik, South East Norway (58°34'N, 8°52'E) from 22 June to 26 July 2010. The rootzone was made up of either straight sand, SS, or Green Mix[®], GM, (Høst AS, Grimstad Norway), the latter being SS amended with 20% (v/v) mature garden compost. The 2 m² lysimeter plots were seeded with either iSeed[®] or uncoated seed of the same seed lot of perennial ryegrass (*Lolium perenne* L.) 'Berlioz 1', the sowing rate in both cases corresponding to 20 g/m² pure seed. Use of uncoated seed was combined with preplant applications of 4 g N (as calcium ammonium nitrate, 27% N) and 0.8 g P (as superphosphate, 8% P) per m², i.e. the same amount of total nitrogen and phosphorus as in the iSeed[®] coating. One treatment included additional applications of 5 g N (as calcium nitrate, 15.5% N) and 1.0 g P (as superphosphate, 8% P) on day no. 10 and 21 after sowing. The experiment was irrigated heavily, especially during the first ten days after sowing. Observations were made over the 35 day period.

The results revealed significant effects of rootzone composition (SS vs. GM) and/or seed type/additional fertilizer application on turfgrass ground cover, overall impression, colour, surface traction and root development. For all these characters, the GM rootzone showed significant benefits compared with the SS rootzone; however, total nitrogen leaching was 21 % higher and total phosphorus leaching 11 times higher from the GM than from the SS rootzone. Plots seeded with iSeed[®] usually performed slightly better than plots seeded with uncoated seed, but the visual effects were mostly insignificant and small compared to those of additional fertilizer applications on day no 10 and 21 after sowing. Use of iSeed[®] reduced nitrate and total nitrogen leaching by approximately 50% during the first 10 days after sowing, but caused no significant reduction during the following 25 days; these effects probably reflect the slow-release properties of 82% of the nitrogen contained in iSeed[®]. Leaching of phosphorus was not affected by either seed type or additional fertilizer application. Interactions between rootzone and seed type/additional fertilizer applications were mostly not significant.

We conclude that iSeed[®] has the potential to reduce nitrogen leaching during turfgrass establishment on sand-based rootzones. However, as iSeed[®] does not eliminate the need for additional fertilizer inputs about two weeks after sowing, the environmental benefit seems to be of relatively short duration when growing in perennial ryegrass on athletic fields. The advantages of iSeed[®] may perhaps be more significant when growing in forage or amenity grasslands over a longer period and with less fertilizer inputs.

Key words: fertilizer, grow-in, leaching, *Lolium perenne*, nitrogen, perennial ryegrass, phosphorus, seed coating, turfgrass

2. Introduction

Turfgrass areas often border lakes, streams, and other water features. Nitrogen (N) and phosphorus (P) are two of the most important nutrients used for the establishment and maintenance of turf. In USA, when establishing golf course putting greens, it is usually recommended to incorporate up to 10 g P and 5 g N/m² into the seedbed before sowing, followed by up to 3 g N/m² every fifth day until plant cover is complete (White, 2003; Christians, 2004; McCarty, 2009). Such high rates of N and P, given before roots have developed, incur a great risk for nutrient leaching (Brauen & Stahnke, 1995). Nitrogen and phosphorus transported in water as runoff or leakage from turfgrass areas may contribute to eutrophication at concentrations as low as 1 mg N/l and 25 µg P/l, respectively (Walker & Branham, 1992).

Fertilizers can be applied in several ways: broadcast, in bands, in the seed row, or as seed coating. iSeed[®] for grasses has been patented by Yara International / DLF Trifolium and is used for both forage and lawn/amenity grass seed mixtures (H. Nijenstein, personal communication). iSeed[®] is a nutrient coating that is placed around the seed. The coated seeds contain 10 % N and 2 % P on a dry weight basis. Of the total nitrogen content, 82 % is in slow-release form (urea formaldehyde), 8 % is in the form of amides, and 10% is in the form of ammonium (NH₄⁺) (Yara International ASA). The direct attachment of the nutrients to the seed / seedling, and the fact that most of the nitrogen is in a slow-release form, will both likely contribute to less nutrients, particularly nitrogen, being lost to the environment by leaching.

According to the iSeed[®] homepage (http://www.dlf.com/Turf/Technical_info/iSeed.aspx, accessed 1 July 2010), the advantages of this type of seed are: a) Faster and more uniform emergence; b) Quick release of phosphorus for root growth enhancement; c) Quick release of nitrogen for leaf growth enhancement; d) Slow release of nitrogen, prolonging these effects; e) Better competition against weeds; and f) Improved stress tolerance. It has been assumed that the nitrogen and phosphorus content in iSeed[®] is sufficient to secure the nutrient supply to the seedling during the first month after sowing (H. Nijenstein, personal communication).

Several studies have been conducted to investigate possible advantages of iSeed[®]. Comparisons of root development, clipping yield and seedling nutrient uptake of iSeed[®] versus uncoated seeds were undertaken by Jokinen and Ylikojola (2006) and Ylikojola (2006), both referenced by Nijenstein (2008). Crossley & Newell (2007) investigated the impact of iSeed[®] on turfgrass germination rate, ground cover, sward height, colour and rooting. These studies mostly showed positive results for iSeed[®] compared with untreated seed. However, as the experiments were conducted on ordinary soils, Crossley & Newell (2007) called for further studies into the benefits of iSeed[®] on sand-based rootzones, which are commonly used for athletic fields and golf course putting greens. Sand-based rootzones are liable to nutrient leaching during turfgrass grow-in (e.g. Aamlid, 2005), and it may be hypothesized that incorporation of N and P into the seed coat will reduce such losses compared to standard fertilization practices. Thus, the objective of the present research was to determine the effect of iSeed[®] on turfgrass quality and nitrogen and phosphorus leaching during establishment of perennial ryegrass (*Lolium perenne* L.) on sand-based rootzones varying in organic matter content.

3. Methods

3.1. Experimental site and soil analyses

A field experiment was established in the lysimeter facility at Bioforsk Landvik Research Station (58°34'N, 8°52'E), South East Norway. The facility consists of 16 stainless steel lysimetres, each with a surface area of 2.0 m x 1.0 m. Each lysimeter contained a 30 cm rootzone underlain by a 10-15 cm gravel layer. The root zone was made up of either straight sand, SS, or Green Mix[®], GM, (Høst AS, Grimstad, Norway), the latter being SS amended with 20% (v/v) mature garden compost.

The lysimeter facility had been used for an irrigation experiment with velvet bentgrass (*Agrostis canina* L.) until 1 October 2009. In early June 2010, the 3 cm thick sod layer was removed and a similar layer of new growing media added on top of the respective plots. Soil analyses indicated that GM contained 2-4 times more mineral N, plant-available P and plant-available K than SS (Table 1). Both media had a pH of 6.4 and a textural analysis showing (0.2 % fine gravel (>2.0 mm) 10.2% very coarse sand (1.0-2.0 mm), 32.9% coarse sand (0.5-1.0 mm), 37.6% medium sand (0.25-0.5 mm) 16.2% fine sand (0.125-0.25 mm) , 2.6% very fine sand (0.063-0.125 mm) and 0.3% silt and clay (<0.063 mm).

Before sowing, all plots were hollow-tine cored to avoid layering and irrigated thoroughly.

Table 1. Chemical analyses of the two growing media.

Rootzone	Ignition loss, %	pH (H ₂ O)	Plant available nutrients, mg per 100 g dry soil						
			Total-N	Mineral-N	P-AL	K-AL	Mg-AL	Ca-AL	Na-AL
Straight sand (SS)	0.4	6.4	<10	0.19	1	2	<1	<7	<3
Green Mix (GM)	1.7	6.4	20	0.62	4	4	3	51	<4

3.2. Experimental plan and implementation

The experiment was laid out as a two-way factorial with the following treatments:

Factor 1: Rootzone

- A. Straight sand (SS)
- B. Green Mix (GM, 20 vol% garden compost)

Factor 2: Type of ryegrass seed and fertilizer inputs

1. iSeed[®], 40 g/m² (20 g bare seed + 4 g N + 0.8 g P pr m²). No additional fertilizer. Three replicates.
2. Uncoated seed of the same seed lot as used in 1, 20 g per m². Preplant application of the same amount of N and P as included in iSeed[®] in treatment 1. Two replicates.
3. Uncoated seed of the same seed lot as used in 1, 20 g per m². Preplant application of the same amount of N and P as included in iSeed[®] in treatment 1. Additional inputs of 5 g N and 1.0 g P per m² on day no. 10 (2 July) and day no. 21 (13 July) after sowing (Two applications, totalling 10 g N and 2 g P per m²). Three replicates.

Due to lack of lysimeters, the experimental plan was not balanced (Fig 1, Photo 1).

In treatments 2 and 3 (uncoated seed), preplant fertilizer applications were given in the form of calcium ammonium nitrate (OPTI-KAS 27-0-0, (Yara, Norway) and superphosphate (Opti P, 0-8-0, Yara, Norway). In treatment 3, additional P on day no. 10 and 21 after sowing was also given in the form of Opti P (0-8-0), but additional N was given as liquid calcium nitrate (CalciNit 15.5% N, Yara, Norway) in order to avoid uneven coverage and spots resulting from the big granules in OPTI-KAS 27-0-0. In addition to N and P, all plots received potassium 10 g of potassium sulfate (41% K, 45 % S) per 100 m² on day no. 10 and 21 after sowing.

The ryegrass seed used in all treatments was of the variety ‘Berlioz 1’, seed lot no 284504. The iSeed[®] coating had been added specifically for this treatment by DLF Trifolium.



Photo 1. Research technician Atle Beisland prepares lysimeter plots trial for sowing, 22 June, 2010. Note that Green Mix rootzones had a darker colour than straight sand rootzones. Photo: G. Kusliene.

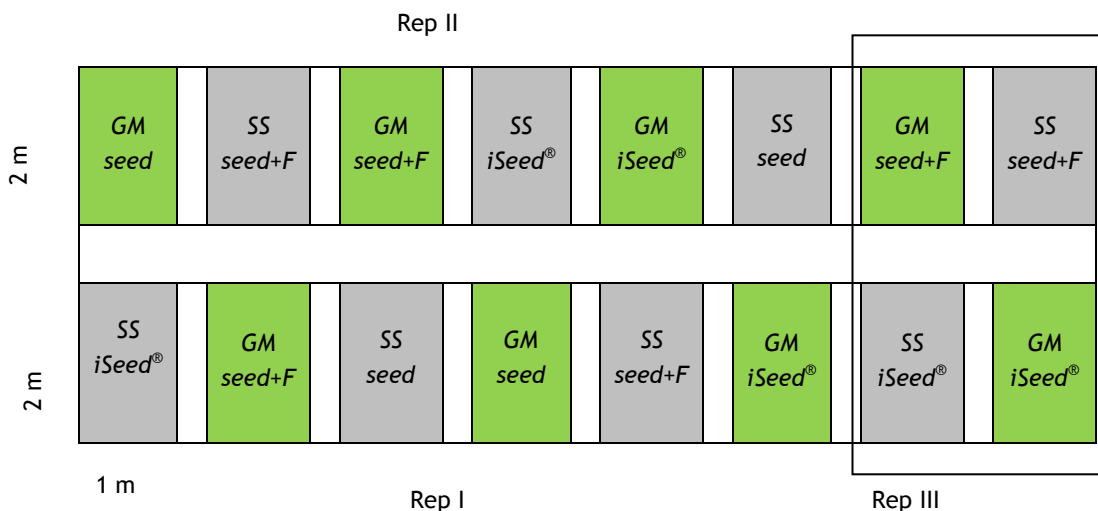


Figure 1. Schematic plan of the lysimeter facility. (SS=Straight Sand rootzone; GM=Green Mix rootzone; iSeed[®]=coated seed (treatment 1); seed=uncoated control seed (treatment 2 and 3); F=additional fertilizer given in treatment 3).

After sowing on 22 June 2010, all lysimeters were covered with a permeable white tarp for one week. The irrigation system supplied 6 mm of irrigation water (15 minutes sprinkler irrigation) every second hour from 7:00 to 19:00 every day (42 mm/day) during the first week and 2 mm of irrigation water (5 minutes sprinkler irrigation) every second hour from 7:00 to 17:00 every day (12 mm/day) during the second week after sowing. The very heavy irrigation during the first week after sowing was due to improper adjustment of the irrigation timer; unfortunately, this was not corrected until 29 June. During the last three weeks of the experiment, all plots were irrigated 4 mm/day, i.e. a little more than the daily evaporation values (Fig. 2, Photo 2).

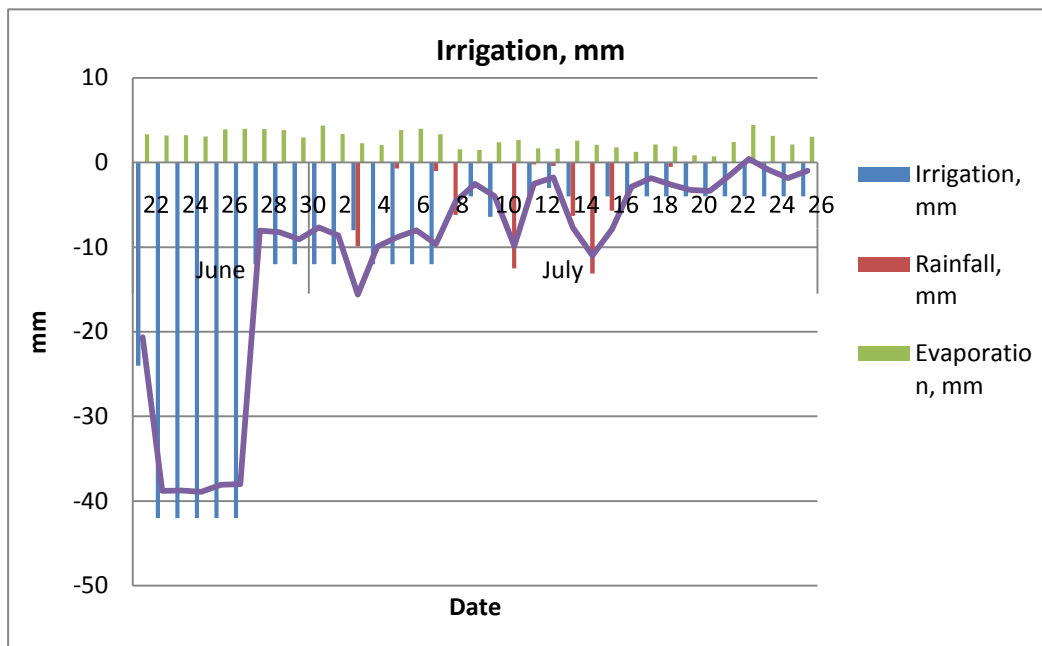


Figure 2. Daily values for irrigation, rainfall and pan evaporation during the experimental period 22 June - 26 July. Data on rainfall and pan evaporation are from Landvik meteorological station, about 200 m from the experimental site.



Photo 2. Covered lysimeters were irrigated automatically. Photo: G. Kusliene

The turf was mowed for the first time when seedlings were 40 mm high on 5 July. Then the trial was mowed two times per week for the rest of the experiment. Mowing height was always 30 mm. We used a rotary mower with collection of clippings.

3.3. Registrations

Visual assessments. Visual assessments of turfgrass coverage started on 28 June and were carried out twice per week using percentage evaluation (Photo 3). Turfgrass overall impression (1-9, 9 is best turf) was evaluated on 23 and 26 July, and turfgrass colour (1-9, 9 is darkest turf) by the end of the experiment on 26 July.

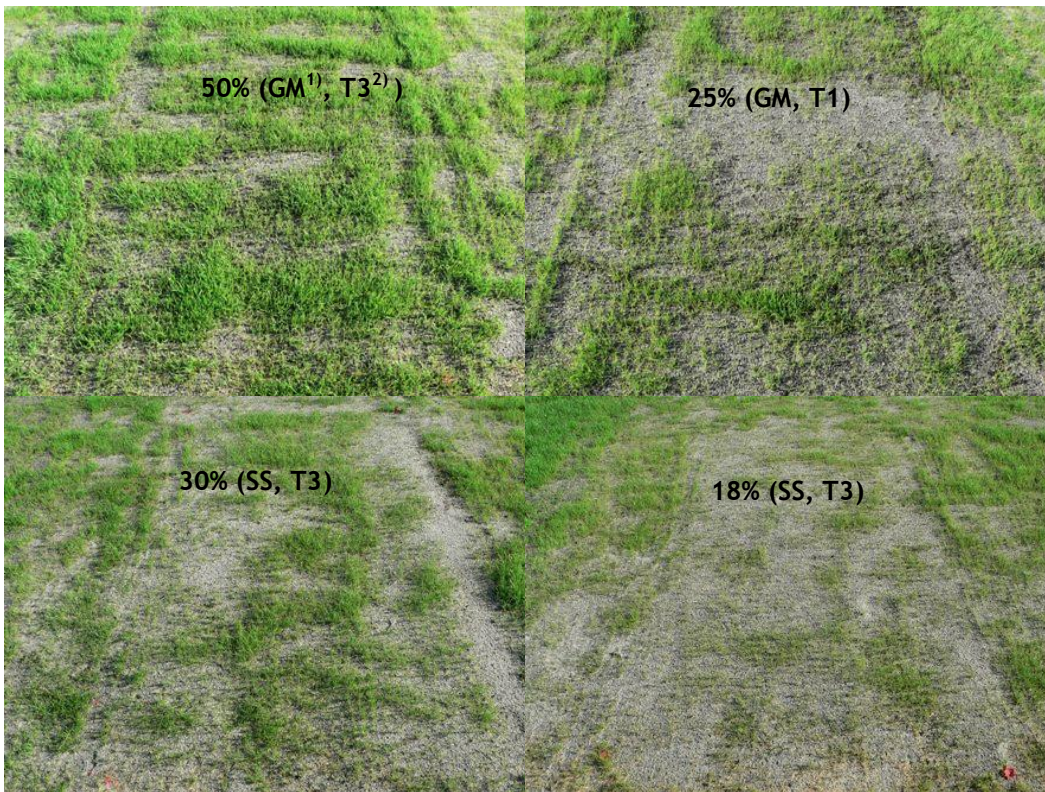


Photo 3. Ground coverage on 9 July, 2010 (17 days after sowing). ¹⁾ GM=Green Mix, SS=Straight Sand, ²⁾ T2=treatment 2, T3=treatment 3.

Traction. For determination of traction, a disc, equipped with studs on the bottom side and with a total weight of 40 kg, was dropped onto the playing surface and the momentum (Nm) required to tear the turf measured with a torque wrench. Two measurements per plot were conducted on 22 July (Photo 4).



Photo 4. Research technician Trond Pettersen measures turf traction, 22 July. Photo: G. Kusliene

Root development. Core samples were taken from each plot by the end of the trial on 26 July. Each core was 5.8 cm in diameter and 25 cm deep (Photo 5). For measuring the maximum depth of roots, soil cores were laid down on a flat surface. Working from the bottom of the core, rootzone material was carefully inspected for the presence of roots. The depth of roots was measured using a ruler. Due to old roots from previous experiments in deeper layers, root weight was only determined in the 0-3 cm top layer. Roots were washed and air dried for 36 hours at 105°C before weighing.



Photo 5. Research technician Trond Pettersen takes core samples, 26 July, 2010. Photo: G. Kusliene

Leakage. The total amount of leakage water was measured and representative samples taken on 2 July (representing day no. 0-10 after sowing) and 26 July (representing day no. 11-35, Photo 6). The samples were analysed for nitrate-N ($\text{NO}_3\text{-N}$), total N and total P.



Photo 6. Leakage water was collected for N and P analyses. Photo: G. Kusliene.

3.4. Weather data

With an average of 16.8 °C the temperature during the 35 day experimental period was slightly higher than the 30 year normal value (Fig. 3). During the same period, natural rainfall and pan evaporation totalled 57 and 95 mm, respectively (See also Fig. 2). The first natural rainfall was 10 mm on 3 July.

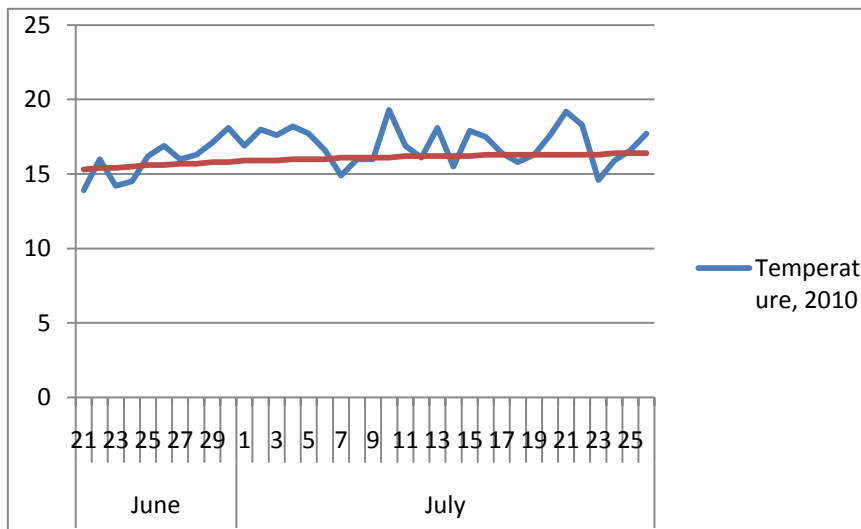


Figure 3. Temperature data from Landvik meteorological station for the project period 21 June-26 July, 2010, compared with the 30 year temperature normal (1961-1990).

3.5. Statistical calculations and presentation of results.

Due to the unbalanced design, the results were analyzed using the SAS procedure GLM (SAS, 2002). Exact probability levels up to $P=0.2$ have been indicated in the tables, but the term ‘significant’ always refers to $P<0.05$. Differences among rootzones, seed types/ fertilizers and the six treatment combinations were identified by $LSD_{0.05}$.

4. Results

Turfgrass ground coverage

Throughout the experiment, turfgrass ground coverage was significantly better on GM plots than on SS plots ($P=0.001$, Fig. 4, Photo 7). Plots receiving additional fertilizer on day no. 10 and 21 after sowing (treatment 3) showed significantly better coverage than treatment 1 and 2 from day no. 17 (9 July). From day no. 24 (16 July) plots that had been seeded with iSeed® (treatment 1) had slightly but not significantly better coverage than plot that had been seeded with uncoated seed and received the same amount of N and P (treatment 2). On average for rootzones, turfgrass coverage at the end of the trial was 59%, 50% and 81% in treatments 1, 2 and 3, respectively. The interactions between rootzone and seed type/additional fertilizer were not significant on any of the observation dates.



Photo 7. Ground coverage by the end of experiment, 26 July 2010. ¹⁾ GM=Green Mix; SS=Straight Sand, ²⁾ T1=treatment 1, T2=treatment 2; T3 =treatment 3. Photo: G.Kusliene.

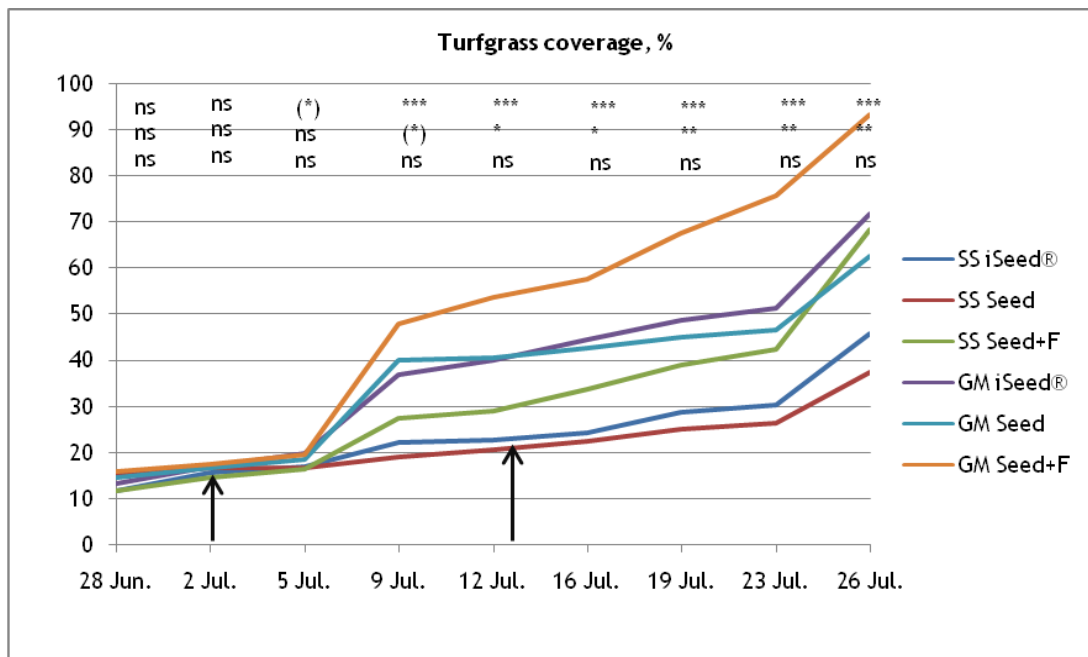


Figure 4. Turfgrass coverage as affected by rootzone and seed type/fertilization. Fertilizer application dates are indicated by arrows. The significance symbols ***, **, *, (*) and ns indicate the probability levels $P < 0.001$, $P < 0.01$, $P < 0.05$, $P < 0.1$ and $P > 0.1$, respectively. First row indicate main effect of root zone, second row main effect of seed type/additional fertilizer and third row interaction.

Turfgrass overall impression

On average for observations on 23 July and 26 July, turfgrass overall impression was significantly better on GM than on SS rootzones (Table 4). Additional fertilizer application (treatment 3) resulted in significantly better overall impression than treatment 1 and 2. On average for the two observation dates, plots seeded with iSeed® (treatment 1) had better overall impression than uncoated seed (treatment 2). The interaction between rootzone and seed type/fertilizer was not significant.

Turfgrass colour

By the end of the experiment, analysis of turfgrass colour demonstrated significantly better results on the GM rootzone than on the SS rootzone (Table 4). A significant interaction between rootzone and seed type/additional fertilizer reflected that iSeed® (treatment 1) gave significantly better colour than uncoated seed (treatment 2) only on the SS rootzone. On the GM rootzone, additional fertilizer (treatment 3) significantly enhanced turfgrass colour while no significant difference could be identified between iSeed® (treatment 1) and control seed (treatment 2).

Turfgrass traction

Turfgrass traction values show significantly better results for the GM than for the SS rootzone (Table 4). Additional fertilizer (treatment 3) significantly improved traction when compared to both iSeed® (treatment 1) and the control treatment with uncoated seed and no additional fertilizer (treatment 2). No significant difference was identified when comparing iSeed® to uncoated seed (treatments 1 vs 2). The interaction was also not significant.

Turfgrass root development

Roots were significantly deeper in the GM than in the SS rootzone (Table 4). Seed type/additional fertilizer had no effect on turfgrass root depth, and there was no interaction between the two factors (Table 4, Photo 8).

Root dry weight in the 0-3 cm topsoil layer was significantly greater on GM than on SS plots. Root weights from plots receiving additional fertilizer (treatment 3) were significantly higher than those determined on other plots. There was no significant difference in root weight between iSeed[®] (treatment 1) and uncoated seed (treatment 2). The interaction between rootzones and seed type/additional fertilizer was also not significant.



Photo 8. Soil cores and washed roots (0-3 cm) from GM and SS rootzones. Photo: G. Kusliene.

Table 4. Main effects of rootzone, seed type/additional fertilizer and their interaction on turfgrass overall impression and colour (1-9, 9 is highest overall impression and darkest green colour, respectively), root length, root weight in the 0-3 cm topsoil layer, and traction by the end of the experiment. SS=straight sand root zone, GM=compost-amended root zone, iSeed[®]=coated seed, Seed=uncoated seed, Seed+F=uncoated seed with additional fertilizer application.

	Overall visual impression (1-9)	Turf colour (1-9)	Root depth, cm	Root dry weight, 0-3 cm, g/m ²	Traction, Nm
SS	1.8	3.0	18	59	30
GM	3.2	5.3	22	75	33
<i>P-value</i>	<0.001	<0.001	0.04	0.04	0.01
iSeed [®]	2.0 b ¹⁾	4.1 b	20	60 b	31 b
Seed	1.6 b	2.4 c	20	54 b	28 b
Seed+F	3.7 a	6.0 a	19	84 a	34 a
<i>P-value</i>	<0.001	<0.001	>0.2	0.02	0.02
iSeed [®] x SS	1.3	3.7 b	19	45	29
Seed x SS	1.1	1.0 c	17	47	26
Seed+F x SS	2.9	4.3 b	17	81	33
iSeed [®] x GM	2.7	4.5 b	22	74	33
Seed x GM	2.1	3.8 b	23	60	31
Seed+F x GM	4.4	7.7 a	21	86	36
<i>P-value</i>	>0.2	0.004	>0.2	>0.2	>0.2

¹⁾ The same letter shows no difference according to LSD_{0,05}.

Leakage

Leakage water. No significant difference was detected in the amount of leakage water depending on rootzone, seed type/additional fertilizer or their interaction in any of the two collection periods (data not

shown in table). The amount of leakage water averaged 144 l/m² during the first collection period (22 June - 2 July) and 101 l/m² during the second collection period (2 - 26 July).

Nutrient concentration. The nitrate (NO₃-N) and total phosphorus (TP) concentrations were significantly lower in leakage water from the SS rootzone than from the GM rootzone during both collection periods. The total nitrogen (TN) concentration was also lower in water from the SS than from the GM rootzone, but this difference was significant only during the first collection period.

According to factor 2, nitrate and TN concentrations were significantly lower in leakage water from plots seeded with iSeed[®] (treatment 1) than from plots seeded with uncoated seed (treatments 2 and 3) during the first collection period. No significant difference in nitrate or TN concentrations in leakage water from iSeed[®] plots (treatment 1) vs. control plots (treatment 2) were detected during the second collection period, but additional fertilizer (treatment 3) increased the average nitrate and TN concentration by a factor of approximately four. During the second period, there were also interactions as the effects of additional fertilizer on nitrate and TN concentration were larger on the SS than on the GM rootzone. Significant differences in TP concentration depending on seed type / additional fertilizer were not detected during any of the periods, and there was also no interaction for this element.

Table 5. Main effects of rootzone, seed type/fertilizer and their interaction on concentrations of nitrate (NO₃-N), total N (TN) and total P (TP) in leakage water. SS=straight sand root zone, GM=compost-amended root zone, iSeed[®]=coated seed, Seed=uncoated seed, Seed+F=uncoated seed with additional fertilizer application.

	22 June-2 July			2-26 July		
	NO ₃ -N mg/l	TN mg/l	TP mg/l	NO ₃ -N mg/l	TN mg/l	TP mg/l
SS	13.5	18.5	0.02	34.6	33.3	0.02
GM	23.7	26.4	0.18	38.6	36.0	0.19
<i>P-value</i>	<i>0.0002</i>	<i>0.003</i>	<i><0.0001</i>	<i>0.03</i>	<i>0.15</i>	<i><0.0001</i>
iSeed [®]	10.9 a	14.4 a	0.10	15.8 a	14.3 a	0.11
Seed	22.6 b	27.0 b	0.09	17.2 a	16.4 a	0.10
Seed+F	23.5 b	27.5 b	0.10	70.3 b	67.2 b	0.10
<i>P-value</i>	<i>0.0003</i>	<i>0.0006</i>	<i>>0.2</i>	<i><0.0001</i>	<i><0.0001</i>	<i>>0.2</i>
iSeed [®] x SS	5.7	10.1	0.02	10.7 a	10.0 a	0.01
Seed x SS	17.8	23.0	0.02	9.9 a	10.3 a	0.02
Seed+F x SS	18.5	24.0	0.01	75.0 d	72.0 d	0.02
iSeed [®] x GM	16.1	18.7	0.19	21.0 b	18.6 ab	0.20
Seed x GM	27.6	31.0	0.15	24.5 b	22.5 b	0.18
Seed+F x GM	28.6	31.0	0.19	65.6 c	62.3 c	0.18
<i>P-value</i>	<i>>0.2</i>	<i>>0.2</i>	<i>>0.2</i>	<i>0.002</i>	<i>0.01</i>	<i>>0.2</i>

¹⁾ The same letter shows no difference according to LSD_{0,05}.

Total nutrient leakage. Total nitrate leakage was significantly lower from the SS than from the GM rootzone during the first collection period and when added over both periods (Table 6). Total nitrogen (TN) leakage was significantly lower from the SS rootzone only during the first collection period. Total TP leakage was significantly lower from the SS rootzone during the whole experiment.

According to factor 2, nitrate and TN leakage from plots seeded with iSeed[®] (treatment 1) were significantly lower than from plots seeded with uncoated seed (treatments 2 and 3) during the first collection period. No significant difference due to seed coat could be detected during the second collection period, but additional fertilizer (treatment 3) caused the significantly highest nitrate and TN leakage both during this period and for

the experiment as a whole. The total leakage of phosphorus was not influenced by seed type/additional fertilizer treatments.

Interactions among rootzone and seed type / additional fertilizer were not significant for any of the nutrients or during any of the periods.

Table 6. Main effects of rootzone, seed type/ additional fertilizer and their interaction on leakage of nitrate (NO₃-N), total N (TN) and total P (TP). SS=straight sand root zone, GM=compost-amended root zone, iSeed[®]=coated seed, Seed=uncoated seed, Seed+F=uncoated seed with additional fertilizer application.

	22 June-2 July			2-26 July			Total		
	Leakage, g/m ²								
	NO ₃ -N ⁻	TN	TP	NO ₃ -N ⁻	TN	TP	NO ₃ -N ⁻	TN	TP
SS	2.0	2.7	0.002	3.4	3.3	0.002	5.4	6.1	0.004
GM	3.3	3.7	0.026	3.9	3.7	0.019	7.3	7.4	0.045
<i>P-value</i>	<0.0001	0.0003	0.001	>0.2	>0.2	0.0003	0.03	0.10	0.0006
iSeed [®]	1.6 a	2.0 a	0.015	1.6 a	1.4 a	0.011	3.1 a	3.4 a	0.026
Seed	3.2 b	3.8 b	0.012	1.7 a	1.6 a	0.010	4.9 a	5.4 a	0.022
Seed+F	3.4 b	4.0 b	0.015	7.1 b	6.9 b	0.010	10.6 b	10.9 b	0.025
<i>P-value</i>	<0.0001	<0.0001	>0.2	<0.0001	0.0002	>0.2	<0.0001	<0.0001	>0.2
iSeed [®] x SS	0.8	1.4	0.002	1.0	0.9	0.001	1.8	2.3	0.004
Seed x SS	2.8	3.6	0.004	1.0	1.0	0.002	3.8	4.6	0.006
Seed+F x SS	2.7	3.5	0.002	7.5	7.3	0.002	10.2	10.8	0.004
iSeed [®] x GM	2.4	2.7	0.027	2.1	1.9	0.021	4.5	4.6	0.049
Seed x GM	3.6	4.0	0.020	2.4	2.2	0.018	6.0	6.2	0.038
Seed+F x GM	4.2	4.5	0.029	6.7	6.4	0.018	10.9	10.9	0.047
<i>P-value</i>	>0.2	0.13	>0.2	>0.2	>0.2	>0.2	>0.2	>0.2	>0.2

¹⁾ The same letter shows no difference according to LSD_{0,05}.

5. Discussion

The results revealed significantly better ground coverage, overall impression, turfgrass colour, traction, root depth, and root weight on the GM than on the SS rootzone. Similar results were reported by Hannaford & Baker (2000), Murphy et al. (2005) and Aamlid et al. (2009a). The most likely explanations for these effects are that the SS rootzone was physically unstable (Aamlid, 2005), and had a very low nutrient content (Table 1) and cation exchange capacity (not analysed in this experiment, but see Aamlid et al. (2009a)). The nutrient concentrations in leakage water varied from 4.4 mg/l to 77 mg/l for NO₃-N, 6.1 to 77 mg/l for total N, and 4.1 to 250 µg/l for total P. In most cases, the concentrations were significantly higher in drainage water from GM than from SS rootzones. For nitrogen the results are contradictory to those of Aamlid (2005) and Gaines & Gaines (1994), who found that organic amendments retained nitrogen leaching from sand-based rootzones. Possible explanations for this discrepancy are that the compost in our experiment was more mature than the corresponding 'composted garden litter' used by Aamlid (2005), and that removal of old turf and hollow tine coring stimulated nitrogen mineralization and leaching in our experiment (Danneberger, 1993). Besides, the unintentionally heavy irrigation during the first week after sowing (42 mm/day) probably caused N leaching not only of the fertilizer contained in iSeed[®] (treatment 1) or the preplant fertilizer application (treatments 2 and 3), but also from the compost used in the GM rootzone (McCarty, 2009). Given the nitrogen losses of 1.4 g/m² in treatment 1 and 3.5-3.6 g/m² in treatments 2 and 3 (Table 6), and the fact that the SS rootzone contained only 0.86 g mineral nitrogen per m² (corresponding to 0.19 mg mineral N per 100 g dry soil; Table 1), it is reasonable to assume that, in turn, 25-35 % and 70-80 % of the initial nitrogen input of 4 g/m² in treatment 1 (iSeed[®]) and treatments 2 and 3 (untreated seed) was lost in leaching water during the first ten days after sowing. Of the additional 1.9 g/m² (corresponding to 0.62 minus 0.19 = 0.43 mg/100 g dry soil; Table 1) of mineral nitrogen contained in the GM rootzone, another 0.4-1.3 g N/m² (Table 6), or a rough average of 50 %, seems to have been lost during the same period. Due to wind and other factors causing nonuniform irrigation coverage, turfgrass managers usually apply high amounts of irrigation water during turfgrass grow-in (White, 2003), but in our experiment, 7 x 2 mm = 14 mm per day, as practiced during the second week after sowing, would probably have been more than sufficient also during the first week. A strong effect of irrigation volume on nitrogen leaching from turfgrass rootzones has earlier been documented by Starrett et al. (1995).

Besides nitrogen, the highest concentration of phosphorus was also found in leakage water from the GM rootzone. This is in agreement with Aamlid (2005) and not surprising given the high content of phosphorus in the compost (Table 1). During grow-in there is no thatch layer to adsorb phosphorus (Atalay, 2001) and transport of this nutrient to deeper layers may therefore occur more readily than in a mature turfgrass profile. However, when compared to the total amount of plant available phosphorus in the GM rootzone (18 g P/m² corresponding to 4 mg/100 g dry soil; Table 1) phosphorus losses were altogether very small and they were not affected by the additional 2 g P/m² applied in treatment 3.

Not surprisingly, additional fertilizer application on day no. 10 and day no. 21 after sowing (treatment 3) had significant positive effects on ground coverage, overall impression, turfgrass colour, traction, and root dry weight. The quality scores for plots seeded with iSeed[®] were mostly better than those for plots seeded with uncoated seeds (Fig. 4, Table 4), but in agreement with Crossley & Newell (2007), the difference between iSeed[®] and uncoated seed was too small to eliminate the need for additional fertilizer application during the first month after sowing (Perris & Evans, 1996; White 2003; McCarty, 2009). A 50-75% reduction in the amount of irrigation water during the first week after sowing would obviously have reduced nitrogen leakage and thus the need for supplemental fertilizer, but as long as the nitrogen losses during the first ten days after sowing were two to three times higher in treatment 2 and 3 than in treatment 1, it is hard to argue that iSeed[®] would have been more advantageous compared to uncoated seed with less irrigation. Given that the time margins for turf managers on football stadiums are often narrow, and that the alternative to directly seeded ryegrass is often sod dominated by *Poa pratensis* (Aamlid et al., 2008), we would not recommend the total elimination of fertilizer applications until one month after sowing iSeed[®]. This conclusion may, of course, be different on pitches with more time available for grown-in.

As 82 % of the nitrogen in iSeed[®] was in the slow release form of urea-formaldehyde, the strongest advantage of using this type of seed occurred from about three weeks after sowing, which is when many groundsmen and greenkeepers will put on fertilizer anyway. The coating formulation may therefore, be better adapted to low management situations where the turf receives no or little additional fertilizers during establishment. This reasoning is also consistent with Crossley & Newell's (2007) observations that the advantage of using iSeed[®] was greater for slowly germinating turfgrasses, e.g. *Poa pratensis*, *Festuca rubra*, and *Agrostis* sp., than for perennial ryegrass.

During the first ten days after sowing, nitrogen concentration in leakage water was significantly lower when using iSeed[®] than when giving the same amount of fertilizer as preplant application (Table 5). Again, this was most likely a reflection of the slow-release properties of the nitrogen contained in iSeed[®], although it cannot be ruled out that initial root development and nutrient uptake was faster after sowing iSeed[®] than after sowing uncoated seed. As for the second collection period, there was no significant effect of iSeed[®] on either root development (Table 4) or nutrient leaching (Table 6). Enhanced lateral root formation of ryegrass seedlings after including nitrogen in the iSeed[®] coat has earlier been documented by Jokionen & Ylikojola (2006, ref. Nijenstein 2008), but in their work it is also noteworthy that inclusion of phosphorus in the seed coat reduced lateral root development compared to a seed coat containing nitrogen only. In turfgrass literature (e.g. Christians, 2004; McCarty, 2009) it is often argued that readily available phosphorus will enhance root development, but, from our judgement, it is more likely that limited access to phosphorus near the soil surface will trigger turfgrass roots to seek for this nutrient at deeper layers (Ericsson & Ingestad, 1988; T. Ericsson, Agricultural University of Sweden, personal communication). While significant effects of P-containing seed coats of grass establishment on P-deficient soils has been documented in New Zealand (Scott, 1975) and Australia (Scott & Blair, 1988 a,b), both our results and those collated by Nijenstein (2008) suggest that nitrogen is more important than phosphorus for the effect of iSeed[®] on turfgrass establishment in Northern Europe. This aspect may warrant further investigation, e.g. at different soil temperatures and under various competition levels from the phosphorus-demanding weed species *Poa annua* (Aamlid, 2006).

In conclusion, this research has documented reduced leakage of nitrogen from the use of iSeed[®] on sand-based rootzones. The reduction was mostly due to the slow release properties of the nitrogen in the seed coat, and it adds to the benefits of iSeed[®] reported earlier (Crossley & Newell, 2007; Nijenstein, 2008). For phosphorus, we were not able to document any difference in the leaching potential of fertilizer contained in iSeed[®] compared to conventional fertilizer practices.

6. References

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