Can Arbuscular Mycorrhizal Fungi Inoculum Improve Conditions of Various Golf Greens?

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Objective: Determine if repeated inoculations of arbuscular mycorrhizal fungi would result in improved turfgrass quality, NDVI, and soil moisture of four different types of golf greens.

Materials & Methods

Experimental design and treatments

The experimental design was a split-plot design with 3 replications. The main plot was nitrogen treatment applied every 10 days, and the sub-plot was inoculum treatment applied at least once per month. The arbuscular mycorrhizal fungi (AMF) inoculum used was MycoApply® Injector Endo (**Figure** 1; Mycorrhizal Applications, Grants Pass, OR).

Main plot: Nitrogen treatment
- Low (0.15 g N m^{-2})
- Regular (0.49 g N m^{-2})

Sub-plot: Inoculum treatment
- AMF-inoculum (initial application rate of 2.6 mg inoculum m^{-2}, subsequent applications rate of 1.3 mg inoculum m^{-2})
- Water-treated

Figure 1. Bottles of AMF inoculum mixture. The inoculum contains propagules of *Glomus intraradices, Glomus mosseae, Glomus aggregatum, and Glomus etunicatum.*

Experiments

The study was implemented as four separate experiments, each on a different type of research green (**Table 1**). Each experiment was performed once throughout the 2020 growing season.

Table 1. Turfgrass species and rootzone type of each experiment

Experiment no.	Turfgrass species	Rootzone
1	Creeping bentgrass (*Agrostis stolonifera* L.)†	USGA sand-based
2	Creeping bentgrass	Push-up (silty loam)
3	Fine fescue mixture (*Festuca* spp.)‡	USGA sand-based
4	Fine fescue mixture	Push-up (silty loam)

† 'L-93' creeping bentgrass
‡ 'Radar' and 'Compass' Chewings fescue (*Festuca rubra* spp. *commutata* Gaudin), and 'Seabreeze GT' and 'Joppa' slender creeping red fescue [*Festuca rubra* spp. *litoralis* (G.F.W. Meyer) Auquier]

Data collection

The following data was collected 7 and 15 days after each inoculation:
- Turfgrass quality (1-9 scale; TQ)
- Normalized difference vegetation index (NDVI)
- Volumetric water content (VWC)

Statistical analysis

Each experiment was analyzed using a linear model representing a split-split-plot. The main plot was date, the sub-plot was nitrogen treatment, and the sub-sub-plot was inoculum treatment. Mean separation for any significant interactions was performed using estimated marginal means with Tukey's method at α=0.05.

Results

Experiment 1

Table 2. ANOVA results of Experiment 1

Source of variation	df	TQ	NDVI	VWC
Rep	2	ns	ns	ns
Inoculum	1	ns	0.055	ns
Nitrogen (Ntrt)	1	ns	*	ns
Date	8	***	***	***
Ntrt:Inoculum	1	ns	ns	ns
Date:Ntrt	8	***	***	*
Date:Inoculum	8	ns	ns	ns
Date:Ntrt:Inoculum	8	ns	ns	ns

* Significant at 0.05 probability level; ** significant at 0.01 level; *** significant at 0.001 level; ns, nonsignificant at 0.05 level

In this experiment, there was a moderately significant (*P*-value = 0.055) effect of inoculum treatment on NDVI **(Table 2)**. Averaged across date, the AMF-inoculated and water-treated plots had NDVI ratings of 0.782 and 0.778, respectively.

Experiment 2

Table 3. ANOVA results of Experiment 2

Source of variation	df	TQ	NDVI	VWC
Rep	2	ns	ns	ns
Inoculum	1	ns	ns	0.097
Nitrogen (Ntrt)	1	*	**	0.095
Date	8	***	***	***
Ntrt:Inoculum	1	ns	ns	ns
Date:Ntrt	8	*	ns	ns
Date:Inoculum	8	ns	ns	ns
Date:Ntrt:Inoculum	8	ns	ns	ns

* Significant at 0.05 probability level; ** significant at 0.01 level; *** significant at 0.001 level; ns, nonsignificant at 0.05 level

In this experiment, there was a moderately significant (*P*-value = 0.097) effect of inoculum treatment on VWC **(Table 3).** Averaged across date and nitrogen treatment, the AMF-inoculated plots and water-treated plots had VWC of 34.1% and 32.7%, respectively. This may be due to plot location.

Experiment 3

Table 4. ANOVA results of Experiment 3

Source of variation	df	TQ	NDVI	VWC
Rep	2	ns	ns	ns
Inoculum	1	ns	ns	ns
Nitrogen (Ntrt)	1	ns	***	0.059
Date	8	***	***	***
Ntrt:Inoculum	1	ns	0.059	ns
Date:Ntrt	8	**	***	ns
Date:Inoculum	8	ns	ns	ns
Date:Ntrt:Inoculum	8	ns	ns	ns

* Significant at 0.05 probability level; ** significant at 0.01 level; *** significant at 0.001 level; ns, nonsignificant at 0.05 level

In this experiment, there was a moderately significant (*P*-value = 0.059) effect of nitrogen treatment - inoculum treatment interaction on NDVI **(Table 4)**. Averaged across date, the AMF-inoculated plots subjected to the low nitrogen treatment had the lowest NDVI and the AMF-inoculated plots subjected to the regular nitrogen treatment had the highest NDVI (**Figure 2, 3**).

Experiment 3 NDVI

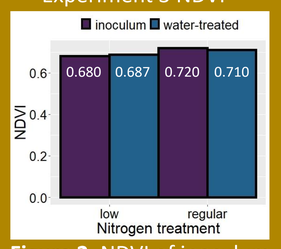

Figure 2. NDVI of inoculum treatment by nitrogen treatment, averaged across date.

Experiment 3 plots

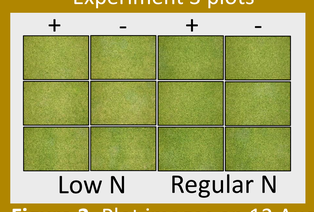

Figure 3. Plot images on 12 Aug 2020 of AMF-inoculated (+) and water-treated (-) plots by nitrogen treatment.

Experiment 4

Table 5. ANOVA results of Experiment 4

Source of variation	df	TQ	NDVI	VWC
Rep	2	ns	ns	ns
Inoculum	1	ns	ns	ns
Nitrogen (Ntrt)	1	*	**	0.086
Date	6	***	***	***
Ntrt:Inoculum	1	*	ns	ns
Date:Ntrt	6	*	***	ns
Date:Inoculum	6	ns	ns	ns
Date:Ntrt:Inoculum	6	ns	ns	ns

* Significant at 0.05 probability level; ** significant at 0.01 level; *** significant at 0.001 level; ns, nonsignificant at 0.05 level

In this experiment, there was a significant effect of nitrogen treatment - inoculum treatment interaction on NDVI **(Table 5).** Averaged across date, the AMF-inoculated plots subjected to low nitrogen had the lowest TQ **(Figure 4)**. This was likely due uniformity losses caused by the presence of weeds (**Figure 5).**

Experiment 4 TQ

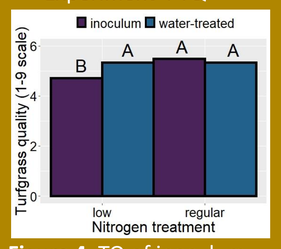

Figure 4. TQ of inoculum treatment by nitrogen treatment, averaged across date.

Experiment 4 plots

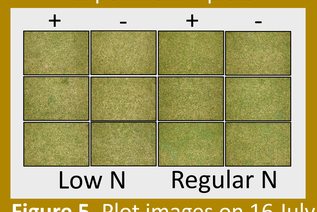

Figure 5. Plot images on 16 July 2020 of AMF-inoculated (+) and water-treated (-) plots by nitrogen treatment.

Conclusion: Additional research is needed on the use of arbuscular mycorrhizal fungi inoculations for established golf greens in northern climates.

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