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Effects of Mycorrhizal Fungi Inoculation on Landscape Turf Establishment under Arabian Gulf Region Conditions

تأثير التلقيح بفطر المايكورايزا على إقامة المسطحات الخضراء تحت ظروف منطقة الخليج العربي

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ABSTRACT: The development of technologies to hasten the establishment of grass lawn putting greens would be of a great advantage to landscape turf developers and renovators under dry regions conditions like Arabian Gulf region. A field experiment was conducted at Sultan Qaboos Center for Developed and Soilless Agriculture, Arabian Gulf University (Bahrain) to determine the effect of Arbuscular Mycorrhizal (AM) fungi inoculation (German BioMyc™ Vital inoculum) on water use efficiency and establishment of a lawn mixture of Kentucky bluegrass and perennial ryegrass grown on a sandy soil with low P fertilizer level (50% of commonly recommended rate). Root colonization with AM fungi occurred extensively in AM inoculated plants seven weeks after seeding (~88%). Inoculated plots with AM fungi had improved turf coverage, shoot and root growth, clipping yield, and water use efficiency in comparison with uninoculated plots. The results revealed that turfgrass inoculated with AM fungi established more quickly and had more biomass than uninoculated turf which indicate the potential of mycorrhiza in improving utilization of fertilizer and irrigation water to hasten and improve the establishment of grass lawn under Arabian Gulf region conditions.
Keywords: *Arbuscular mycorrhiza, Turf grass, Bahrain, Arabian Gulf region.*

المستخلص : إن تطوير تقنيات تؤدي إلى سرعة إنشاء ونمو حشائش المسطحات الخضراء له فوائد كبيرة وخصوصا في المناطق الجافة مثل منطقة الخليج العربي. تم إجراء التجارب في الحقل التابع لمركز السلطان قابوس للزراعة المتطورة وبدون تربة/ جامعة الخليج العربي (البحرين) لدراسة تأثير التلقيح بفطر المايكورايزا على كفاءة استخدام الماء ونمو و إنشاء المسطحات الخضراء (الحشائش). حيث تم زراعة بذور الحشائش في أحواض الزراعة قليلة التسميد الفسفوري (50% من المستوى الموصى به عادة) بعد تلقيحها أو عدم تلقيحها بفطر المايكورايزا المنتج German BioMyc™ Vital. تم ري النباتات بكمية محددة من المياه وبشكل يومي. بينت النتائج إصابة الجذور بشكل عالي بفطر المايكورايزا (80%) في التربة الملقحة بالفطر بعد 7 أسابيع من الزراعة. أدى التلقيح بالمايكورايزا إلى زيادة كبيرة في كفاءة استخدام المياه ونمو النباتات وبالتالي إلى زيادة سرعة غطاء الحشائش مقارنة مع تلك غير الملقحة بالفطر. إن زيادة نمو الحشائش وسرعة تغطيتها للتربة نتيجة التلقيح بفطر المايكورايزا يدل على أهمية هذا الفطر في تحسين قدرة النباتات على استخدام السماد ومياه الري بكفاءة عالية لزيادة سرعة غطاء الحشائش ونموها تحت ظروف منطقة الخليج العربي.
كلمات مدخلية : *فطر المايكورايزا، الحشائش، مملكة البحرين، منطقة الخليج العربي، المسطحات الخضراء.*

INTRODUCTION

The development of technologies to hasten the establishment of grass lawn putting greens would be of a great advantage to landscape turf developers and renovators under dry regions conditions like Arabian Gulf region. In these regions, water conservation is considered very important as water is a limited resource and environmentally sensitive component of landscape turf management. Therefore, conserving and incorporating fertility and water directly into the target turf grass is a goal of turf management professionals to maximize the utilization of water and fertilizer in enhancing establishment of grass lawns and reduce movement of fertilizer that is not utilized into groundwater

Arbuscular mycorrhizal (AM) fungi associated with plant roots confers numerous benefits to host plants, including improved plant growth and mineral nutrition (Al-Karaki and Clark 1998; Marschner and Dell, 1994), tolerance to disease (Trotta, *et al.* 1996; Matsubara, *et al.* 2001), improved water use (Al-Karaki and Clark,1998), and tolerance to abiotic stresses such as drought (Al-Karaki and Clark, 1998; Al-Karaki, *et al.* 2004), and salinity (Al-Karaki, 2000; Al-Karaki, 2006). AM fungi also enhances soil aggregation and water-holding capacity both by producing external hyphae and by exuding glomalin, a glycoprotein, from extraradical hyphae (Wright and Upadhyaya, 1998).

The majority of grasses form an AM symbiosis and can greatly benefit from mycorrhizal colonization in terms of growth and nutrient acquisition (Gemma and Koske, 1989; Sylvia and Burks, 1988; Hall, *et al.*, 1984; Newman and Reddel, 1987). Mycorrhizae are especially important for uptake of nutrients that do not readily move through the soil such as phosphorous and many of the micro-nutrients (Al-Karaki, 2006; Marshner and Dell, 1994). The mycorrhizal fungi once are established on the host plant root system it radiates out from the roots to form a dense network of filaments. These filaments form an extensive system of hyphae that grow into the surrounding soil and provide a variety of benefits for the host plant (Marschner and Dell, 1994). This network of filaments obtains water and nutrients and transport these materials back to the host root system.

Few studies have been conducted on mycorrhization of turfgrass species, as it was generally believed that because turfgrass grow under high maintenance conditions, are less dependent on mycorrhizae. However, research studies have shown that these specialized fungi can improve plant growth, fertilizer utilization, rooting depth, the speed of establishment, disease and drought and salinity resistance of turf (Gemma, *et al.* 1997a,b; Charest, *et al.* 1997; Auge, *et al.* 1995; Koske, *et al.* 1995). Warm-season grasses such as bermuda grass with coarse root systems are very dependent upon mycorrhiza for sustained growth (Hetrick, *et al.* 1988; 1990). Some other studies indicate that cool-season, finer rooted bentgrass species also form abundant mycorrhiza and benefit from the relationship, especially where the phosphorous levels are not too high (Gemma, *et al.* 1997; Koske, *et al.* 1997). It is also well documented that inoculation of grasses with mycorrhizal fungi in soil with low phosphorous concentrations can produce greater shoot and root biomass (Hall, *et al.* 1984; Hetrick, *et al.* 1988). Charest, *et al.* (1997) and Gemma, *et al.* (1997a) reported that Kentucky bluegrass and creeping and velvet bentgrasses produced more aboveground biomasses over time when inoculated with mycorrhizae compared with the uninoculated control. Moreover, Gemma, *et al.* (1997b) showed that creeping bentgrass inoculated with the AM fungus *G. intraradices* tolerated drought conditions for longer periods and recovered more quickly from wilting than did nonmycorrhizal turf.

The objective of the present study was to determine the effect of arbuscular mycorrhizal (AM) fungi inoculation (German BioMyc™ Vital inoculum) on water use efficiency and establishment of a lawn mixture of Kentucky bluegrass and perennial ryegrass grown under low P fertilizer on a sandy soil under Arabian Gulf conditions (Bahrain).

MATERIALS AND METHODS

A field experiment was established on a sandy soil at Sultan Qaboos Center for Developed and Soilless Agriculture, Arabian Gulf University, Manama, Bahrain. Experimental plots (2 x 1 m each) were seeded with a standard commercial lawn seed mixture composed of 30% Kentucky bluegrass (*Poa pratensis* L. Nustar and Rugby II) and 70% perennial ryegrass (*Lolium perenne* L. Accent, Caddiesheck and Goal Keeper) on 18 March 2007 at 65 g m^{-2}. There were two experimental treatments: AM inoculated with German BioMyc™ Vital inoculum at a rate 200 mL m^{-2} and an uninoculated control with three replicates for each treatment. The AM fungi inoculum was supplied as spores on expanded clay produced by BioMyc International Corporation, Germany. Both mycorrhizal inoculum and seeds were uniformly sprinkled by hand over the surface plots and mixed with a rake into the top 1 cm of the soil. The turf plots were watered daily with 5 L m^{-2} for the first month after seeding and 10 L m^{-2} thereafter. Prior to establishing plots, a soil amendment (compost) which is based on selected sphagnum peats (Growmer, UK) was applied at 5 L m^{-2} and inorganic fertilizers (KNO_3, KH_2PO_4 and urea) were applied to plots at the rates 40 nitrogen (N), 3.3 phosphorus (P) and 27 potassium (K) in gram per m^2 and all were incorporated into the upper 20 cm of soil.

Percentage of plot area covered by turfgrass was evaluated by visually estimating the surface covered by turfgrass 7 weeks after seeding. These evaluations were made by the same person. To assess shoot and root growth and mycorrhizal colonization of roots, ten plants were collected randomly and very carefully with their intact roots from each plot 7 weeks after seeding. After that, plants left on plots were clipped to the height of about 5 cm from soil level, and clippings were collected to determine clipping yield. Roots of sampled plants were washed with water to remove all soil. Five of sampled plants were used for determination of shoot and root growth parameters (shoot and longest root lengths, shoot and root fresh and dry weights). Root samples from the other sampled five plants were cleared with 10% (w/v) KOH solution and stained with 0.05% trypan blue in lactophenol as described by Phillips and Hayman (1970), and microscopically examined for colonization using a gridline intercept method (Giovannetti and Mosse, 1980).

Water use efficiency was computed according to the formula:

Water use effecincy (g/liter) = Clipping yield (g/m^2) / total applied water (liter/m^2)

Experimental design and statistical analysis

The experiment was arranged in a randomized complete block design with three replicates. Data were statistically analyzed using analyses of variance (ANOVA). Probabilities of significance among treatments were used to compare means between treatments.

RESULTS AND DISCUSSION

After 7 weeks of seeding, turfgrass roots in the mycorrhized plots had been colonized extensively with AM fungi (~88%), while no root colonization with AM fungi has been noted in the control plots (Table 1). Extensive network of filaments (hyphae) and other mycorrhizal structures (arbuscles and vesicles) has been also noted on colonized roots (Figure 1). It has been reported that extensive system of hypha that are growing out of colonized roots into the surrounding soil can provide a variety of benefits to the host plant (Pelletier and Dionne, 2004). The distributed network of hyphae beneath soil surface greatly increase the capacity of root system to absorb water and uptake of nutrients (especially low mobile nutrients in soil). The network of fungal filaments also helps in improving soil structure, porosity and aeration by binding soil particles (Pelletier and Dionne, 2004).

Table 1. Root Colonization, Grass Coverage, Shoot, Root Fresh, and Dry Weights of Turf Grass as Affected by Inoculation with Mycorrhizal Fungi after 7 Weeks of Seeding. (Different letters denote significant differences between means of treatments).

Treatment	Root colonization	Grass coverage	Shoot fresh weight	Root fresh weight	Shoot dry weight	Root dry weight
	%	%	mg $plant^{-1}$	mg $plant^{-1}$	mg $plant^{-1}$	mg $plant^{-1}$
Control	0 b	42 b	125 b	81 b	15 b	4.2 b
Inoculated	88 a	91 a	288 a	222 a	35 a	23.5 a

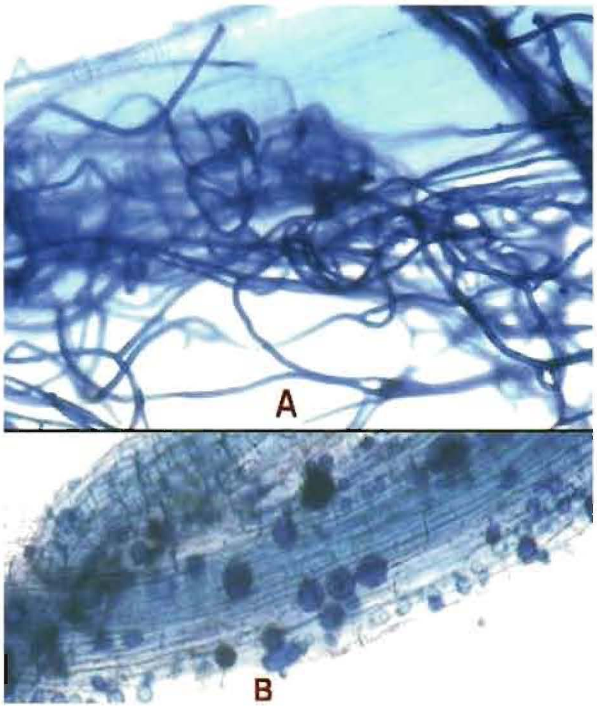

Fig. 1. Root Sections of Turfgrass in which AM Fungi Association Structures Appeared. (A: Network of fungi filaments (hyphae), B: arbuscles and vesicles.)

Highly significant differences in turf seedling size (shoot and root lengths and weights) were observed for the mycorrhized plots compared to the controls 7 weeks after seeding (Tables 1 and 2; Figure 2). Several studies have shown that grass species benefit greatly from mycorrhizal inoculation in terms of enhancement in the shoot and root growth (Gemma and Koske, 1989; Sylvia and Burks, 1988; Koske, *et al.* 1995). Enhanced mycorrhizal inoculated turf was related to improved plant nutrition (Gemma and Koske, 1989; Sylvia and Burks, 1988), higher chlorophyll concentrations which enhance photosynthate production (Gemma, *et al.* 1997b), improved rooting depth, speed of establishment, disease and drought and salinity resistance of turf (Gemma, *et al.* 1997a,b; Charest, *et al.* 1997; Auge, *et al.* 1995; Koske, *et al.* 1995).

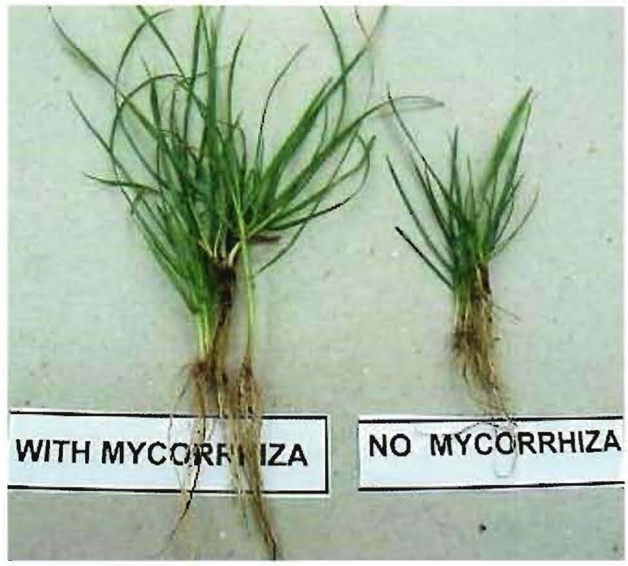

Fig. 2. Turfgrass Plants Inoculated with AM Fungi Inoculation using German BioMyc™ Vital Inoculum (Left) and Non Inoculated Control (Right) Grown In Sandy Soil with Low P. Fertility.

Plots inoculated with mycorrhiza had an average 88% turfgrass coverage 7 weeks after seeding while uninoculated plots had an average of 42% turfgrass coverage (Table 2; Figure3).

These results suggest that inoculation with AM fungi is very efficient in increasing the speed of establishment of turfgrass seedlings in comparison to the controls. The increase in establishment of turf grass is an important benefit to landscape owners as it improves the aesthetics of lawns, covering the surface and increasing the quality of grasses by reducing weed development. A dense cover that free from weeds may require less fertilizer due to high utilization of fertilizer directly into turf plants growth which reduces the fertilizer movement into ground water (Amaranthus, 2001).

Significant differences between mycorrhizal and control plots were noted for clipping yields and water use efficiency of applied irrigation water (Table 2). These results revealed that the

Table 2. Shoot and Root Lengths, Clipping Yield and Water use Efficiency of Turf Grass as Affected by Inoculation with Mycorrhizal Fungi after 7 Weeks of Seeding. (Different letters denote significant differences between means of treatments).

Treatment	Shoot length	Root length	Clipping yield	Water use efficiency
	cm	Cm	g m^{-2}	g L^{-1}
Control	8.5 b	7.1 b	22 b	0.065 b
Inoculated	18.6 a	11.4 a	387 a	1.138 a

Fig. 3. Turfgrass Cover with AM Fungi Inoculation using German BioMyc™ Vital Inoculum (Left) and Non-Inoculated Control (Right) Grown at Sultan Qaboos Center for Developed And Soilless Agriculture, AGU.

mycorrhizal plants produced more biomass (high clipping rate) per unit of water applied through irrigation than control plants. Early establishment of turfgrass might reduces the need for high water use which help growers to increase irrigation intervals (less number of irrigation times) due to improved water holding capacity and extended root system by mycorrhiza, so help the plants to utilize water more efficiently (Pelletier and Dionne, 2004).

It can be concluded from results of this study that inoculation of turfgrass at time of seeding with AM fungi is very efficient in increasing plant biomass, water use efficiency and the speed of establishment of a standard turfgrass lawn seed mixture in comparison to uninoculated turf grown with low Paper fertilizer inputs under Arabian Gulf region conditions.

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