BIOSTIMULANTS AND MYCORRHIZAS DO NOT INCREASE *POA PRATENSIS* ESTABLISHMENT ON A SAND-BASED ROOTZONE

R.M. Goss* and R.E. Gaussoin

ABSTRACT

Many products are available to athletic field managers designed to increase the rate of turfgrass establishment. In addition, the environmental concerns to minimize synthetic fertilizer sources have encouraged turfgrass managers to seek alternatives to synthetic fertilizers. The objectives were to determine the establishment rate on a sand-based rootzone of *Poa pratensis* L. receiving commercial products that include synthetic or organic/slow-release fertilizers along with mycorrhizas and biostimulants as compared to a fertilizer control and to determine the effects of individual components from these protocols on *P. pratensis* establishment. Research was conducted in 2003 and 2004 near Mead, Nebraska USA to a newly-constructed 30.5 cm depth of 90:10 (v:v) USGA specification sand: Dakota reed-sedge peat rootzone. Establishment protocols were solicited from domestic commercial companies containing combinations of synthetic fertilizers, organic fertilizers, slow-release fertilizers, biostimulants, and vesicular arbuscular mycorrhizal fungi. Each protocol was conducted as recommended by manufacturer. A modified factorial arrangement was used to determine which of the components or combination from each protocol may reduce time to establishment of a *P. pratensis* three-seed blend. Turfgrass cover was increased by 28-33% in plots receiving fertilizer control as compared to organic and slow-release fertilizers at 30 day after seeding (DAS), 60 DAS and 90 DAS. The inclusion of both mycorrhizas and biostimulants to the fertilizer control did increase *P. pratensis* cover at 30 DAS by 6%, but reduced cover by 6% at 60 DAS and 3% at 90 DAS. The synthetic fertilizer program provided rapid establishment of *P. pratensis* with little long-term benefit observed from mycorrhizas or biostimulants.

INTRODUCTION

Athletic field turfgrass management is one of the largest growing sectors of the industry (Puhalla et al., 1999). These facilities receive high levels of traffic with minimal time between events for turfgrass recovery, overseeding, or complete reestablishment. Numerous products are sold to aid the management of this unique system promising shorter establishment and reestablishment periods. Previous research has determined fertilizer programs with relatively large amounts of synthetic or organic fertilizers will decrease time to turfgrass establishment compared to programs with lower N and P rates (Christians et al., 1981; Geron et al., 1993; Hathcock et al., 1984; Hummel, 1980; Juska et al., 1965; McVey, 1967; Turner, 1980; Turner and Waddington, 1983; Westfall and Simmons, 1971). However, the availability of nutrients will determine the effectiveness of the fertilizer application (Hummel, 1980; McVey, 1967). Kaminski et al. (2004) found synthetic fertilizers provided higher turfgrass cover ratings than a soil-incorporated poultry meal fertilizer for the first 49 DAS. In subsequent cover ratings, turfgrass receiving both fertilizer types had similar ratings. Surface applied poultry meal fertilizer provided lower turfgrass cover ratings than the synthetic fertilizer for most of the experiment.

Due to environmental concerns and community pressures to minimize synthetic fertilizer sources, turfgrass managers are seeking alternatives to synthetic fertilizers. Organic fertilizers, mycorrhiza inoculums, and biostimulants designed to reduce time to turfgrass establishment are available to the industry. However, few comparisons have been made with the various products for rapid establishment on sand-based rootzones commonly found in athletic fields.

Some of these products promising quicker establishment include mycorrhiza and/or biostimulants. Previous research using vesicular arbuscular mycorrhizal (VAM) fungi often show quicker turfgrass establishment, especially with reduced phosphorus or irrigation inputs and with sand-based rootzones (Al-Karaki et al., 2007; Gemma et al., 1997; Koske and Gemma, 2005; Pelletier and Dionne, 2004; Podeszfinski et al., 2002). When a VAM product was included, a mixture of *Poa pratensis* L. ('Nustar' and 'Rugby II') and *Lolium perenne* L. ('Accent', 'Caddieshack', and 'Goal Keeper') had 91% turfgrass cover at seven weeks after seeding as compared with an uninoculated control at 42% (Al-Karaki et al., 2007). However, the product contains a mushroom substrate that may contain additional nutrients. A Quebec, Canada field-grown mixture of unfertilized and unirrigated *P. pratensis*, *Festuca rubra* L., and *L. perenne* inoculated with one of three *Glomus intraradices* Schenck and Smith mycorrhizas increased turfgrass cover compared to the control at 3 and 4 weeks after seeding, but not by 5 weeks after seeding (Pelletier and Dionne, 2004). The remaining mycorrhizas inoculations were not different than the control. In addition, mycorrhizal colonization rates did not differ between inoculums and uninoculated control. The results of this experiment indicate VAM can provide initial benefit to turfgrass establishment as compared to the uninoculated control, but these benefits may not be discernible at a given plant growth stage for each species. In addition, the field soil may contain enough VAM to self-colonize during establishment. Gemma et al. (1997) found inoculation with three mycorrhizal fungi increased shoot dry weight of *Agrostis stolonifera* L. 'Penncross' and *A. canina* 'Kingstown' during establishment when low phosphorus fertility rates were applied in a greenhouse or growth chamber

Ryan M. Goss, Dept. of Plant and Environmental Sciences, New Mexico State University, Las Cruces, NM, 88003 USA; Roch E. Gaussoin, Dept. of Agronomy and Horticulture, University of Nebraska, Lincoln, NE 68583 USA.
*Corresponding author: (ryangoss@nmsu.edu).

Keywords: organic fertilizer, slow-release fertilizer, synthetic fertilizer, vesicular mycorrhizal fungi

setting. One of the three mycorrhizal fungi, *G. intraradices*, also increased *A. stolonifera* shoot dry weight at a higher phosphorus application rate. Percent groundcover was not estimated and plant growth was estimated at 25 to 76 days after seeding. Podeszfinski et al. (2002) evaluated the impact of organic and chemical fertilizer programs on VAM colonization of *A. stolonifera* and *P. pratensis*. They found mycorrhizal colonization was dependent on both the type and rate of fertilization, but shoot growth rate was not affected by either fertilization or mycorrhizal treatments. Generally, higher fertilization rates had lower VAM colonization than lower fertilization rates. Twice the animal recycled products had higher VAM colonization than the slow-release, chemical fertilizer control. Not all VAM appear to provide equally desirable responses. Tarbell and Koske (2007) found that only three of eight unidentified, commercially available VAM inoculated onto a USGA sand:peat rootzone formed mycorrhizal colonies when applied at the recommended inoculums rates. The authors hypothesized that application rates should be higher than current recommended label rates when used in a sand-based rootzone to increase colonization success.

Although the definition of biostimulant varies, Karnok (2000) defined biostimulants as various natural chemicals and compounds including seaweed extracts and microorganisms that allegedly improve turfgrass health and quality. Some previous research has supported claims to improve turfgrass quality. Zhang et al. (2003) found mature *A. stolonifera* ‘Penncross’ stands had higher visual turfgrass quality when seaweed extracts, humic acid and fertilizer was applied as compared to fertilizer only treatments in the first year of study. In the second year of the study, humic acid only, seaweed extract only and the humic acid plus seaweed extract treatments had higher turfgrass quality ratings than the fertilizer control. However, no interaction between seaweed extract plus humic acid treatments and fertilizer rate treatments was found for either year. Tucker et al.(2006) found one seaweed extract increased root length density of *Cynodon dactylon* (L.) Pers x *C. transvaalensis* Burtt-Davy ‘TifEagle’ after two years of applications, but did not influence turfgrass quality. No interaction between fertilizer rate and biostimulant was documented. When grown on a sand-based rootzone in Wisconsin USA, *A. stolonifera* ‘SR 1119’ had higher 10 July to 1 Aug turfgrass quality ratings when receiving any of the biostimulants evaluated as compared to the control (Mueller and Kussow, 2005). Differences were not observed May or after 29 Aug.

Due to the difficulty in VAM colonization in sand-based rootzones, some research has focused on adding biostimulants to improve mycorrhiza success. *A. stolonifera* establishment at 19 days after seeding on a sand:peat rootzone was increased 20% when inoculated with a VAM, 16% when fertilized with a biostimulant and by 58% when receiving both treatments (Koske and Gemma, 2005). The authors hypothesized the growth-enhancing effects of the mycorrhizas were likely due to increased rooting and nutrient uptake. Butler and Hunter (2008) evaluated two commercially available biostimulants to increase VAM activity in a USGA golf course putting green. Arbuscular mycorrhizal activity was not found in the greens which suggests newly-constructed sand-based rootzones are difficult to root colonize by these microorganisms, regardless of biostimulant treatment.

The objectives of this research were to determine the establishment rate on a sand-based rootzone of *P. pratensis* receiving commercial products that include synthetic or organic/slow-release fertilizers along with mycorrhizas and biostimulants as compared to a fertilizer control and to determine the effects of individual components from these protocols on *P. pratensis* establishment.

MATERIALS AND METHODS

Research was conducted in 2003 and 2004 at the University of Nebraska-Lincoln John Seaton Anderson Turf Research Center near Mead, NE. The experimental area was established on a newly constructed 90:10 (v:v) sand meeting United States Golf Association specification (U.S. Golf Association, 1993) and Dakota reed-sedge peat in a 30.5-cm depth rootzone.

Turfgrass establishment protocols from multiple manufacturers were solicited (Table 1). These protocols contained various combinations of synthetic fertilizers, organic fertilizers, slow-release fertilizers, biostimulants, or mycorrhizas. SymBios contains three VAM inoculums: *G. intraradices*, *G. etunicatum* Becker and Gerd., and *G. clarum* Nicol. and Schenck. Vaminoc-G could include various unspecified VAM from *Glomus*, *Acaulospora*, *Entrophosphora*, *Gigaspora*, *Scutellospora* and *Scierocytis* species. Fertilizer control program was developed from recommended turfgrass establishment protocols of several eastern Nebraska turfgrass managers and commercial company representatives. Each protocol was conducted as recommended by the manufacturer. Treatments in addition to the company protocol included individual components (fertilizer, mycorrhiza and/or biostimulant) of recommended protocols to help determine the effect of components or combination of components on *P. pratensis* establishment (Tables 2 and 3). Protocol-specific biostimulants and mycorrhizas for specific organic and slow-release fertilizer protocols were applied as recommended by the manufacturer. Amount of N and P for each component is found in Table 2. The last fertilizer application was made 84 DAS, or 6 d before last rating. No efforts were made to equilibrate nutrient rates between treatments.

The study was initiated on two dates (9 July 2003 and 22 September 2003). These dates were selected to represent non-ideal and ideal planting dates, respectively, for the central plains of the United States. Plots were 0.91 m by 0.91 m and arranged in a completely randomized design with three replicates. Placement of treatments, as seed coating, shallow incorporation or surface applied, is described in Table 1. Seed-applied treatments were coated on seed prior to seeding by shaking seeds with product in paper bag for 30 seconds. Granular treatments were applied with a hand-held shaker can in two directions. Shallow incorporation of pre-plant fertilizers included hand-raking to an approximate 2-cm depth. Granular applications not requiring incorporation remained on the rootzone surface. Liquid treatments were applied with a CO_2-driven backpack sprayer equipped with an

Table 1. A description of fertilizers, mycorrhiza, biostimulants and their combinations evaluated for effect on establishment speed of *P. pratensis* on a USGA sand-based rootzone

Treatment	Manufacturer†	Product	% WIN‡	Product Rate		Application Description
Untreated control	-	-		-		
Fertilizer control	Andersons Golf Products	21-3-20	0§	232	kg/ha	Preplant shallow incorporation
	Andersons Golf Products	16-25-12	11§	439	kg/ha	Preplant shallow incorporation
	Andersons Golf Products	A-TEP Hi-Mag 0-0-0	NA	586	kg/ha	Preplant shallow incorporation
	Andersons Golf Products	17-3-17	16	146	kg/ha	Weekly after germination
Biostimulant #1	Becker Underwood Inc.	VigaRoot 0-0-2	NA	3	kg/ha	Prior to seeding, surface apply
Biostimulant #2	Sustane	Bolster	NA	13	L/ha	After seeding, surface apply
	Sustane	Bolster	NA	13	L/ha	Every 30 d after seeding
Biostimulant #3	Bio-Green	CPR	NA	488	kg/ha	After seeding, surface apply
Mycorrhizas #1	Becker Underwood Inc.	Vaminoc-G	NA	195	kg/ha	Preplant shallow incorporation
Mycorrhizas #2	ReForestation Technologies International	SymBios Seed Coating	NA	0.5	kg/100,000 seeds	Seed coating
Organic/slow-release fertilizer #1	Nu-Gro Technologies, Inc.	Nitroform 38-0-0	27	488	kg/ha	Preplant shallow incorporation
	Nu-Gro Technologies, Inc.	Nutralene 40-0-0	35	293	kg/ha	Preplant shallow incorporation
	Nu-Gro Technologies, Inc.	16-25-12	11	390	kg/ha	Preplant shallow incorporation
Organic/slow-release fertilizer #2	Sustane	4-6-4	3	1220	kg/ha	Preplant shallow incorporation
	Sustane	4-6-4	3	1220	kg/ha	30 d after seeding
	Sustane	4-6-4	3	976	kg/ha	60 d after seeding
Organic/slow-release fertilizer #3	Bio-Green	Turf Master 8-1-1	5	488	kg/ha	Preplant shallow incorporation
	Bio-Green	Turf Master 8-1-1	5	488	kg/ha	Every 8 wk after germination

† Andersons Golf Products, Maumee, OH 43537; Bio-Green Wauconda, IL 60084; Becker Underwood Inc, Ames, IA 50010; Nu-Gro Technologies, Inc., Grand Rapids, MI 49546; ReForestation Technologies International, Salinas, CA 93901; Sustane, Cannon Falls, MN 55009

‡ Percent slow-release based on percent WIN in product, as listed on label. NA = not applicable due to lack of N listed on product label.

§Product does contain sulfur coated urea or sulfur coated, polymer coated urea.

Table 2. Cumulative amount of N and P applied for each treatment† identified in Table 1 as estimated from product labels.

	Days after Seeding							
	0	30	60	90	0	30	60	90
	------------- kg N/ha ------------				------------- kg P/ha -------------			
Untreated control	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fertilizer control‡	117	283	459	625	52	65	79	92
Organic/slow-release fertilizer #1	382	382	382	382	43	43	43	43
Organic/slow-release fertilizer #2	49	98	148	148	33	65	74	74
Organic/slow-release fertilizer #3	40	80	80	119	4	9	9	13

†None of the biostimulant or mycorrhiza product labels included active ingredient or nutrient information.
‡ See Table 1 for additional details for each fertilizer, biostimulant and mycorrhiza.

TeeJet 8002V flat-fan nozzle applied at 448 L/ha. Treatments requiring watering following application received irrigation as recommended. Each plot was individually seeded via hand-held shaker can with a *P. pratensis* blend (61 kg seed/ha; 34.5% 'Blackstone', 34.3% 'Langara', 23.8% 'P-105', and 5.0% 'Midnight' by wt.). The entire experimental area was irrigated to maintain surface wetness during the establishment period and then irrigated to prevent drought stress once approximately half of the treatments reached 95% cover.

Visual percent cover ratings were taken 30, 60 and 90 DAS. The variances were homogenous according to Harley's F-max test (P=0.05; Hartley, 1950). Therefore, the percent cover ratings will be combined for both seeding dates. These data were subjected to an analysis of variance and a Fisher's protected least significant difference means separation test (alpha = 0.05). To further delineate treatment effects, number of DAS to reach 95% cover for each planting date and treatment was determined using probit analysis of the untransformed percent cover ratings (Finney, 1971). The time period of 25 Nov. to 25 Feb., or 92 d, was not used in any calculations due to limited growing conditions of winter. Treatments were combined over fertilizer type, biostimulant or mycorrhiza to compare main effects of management strategy (Table 4). Probit analysis indicates relative trends in the data, but does not allow for direct comparison between treatments or treatment groupings. For contrast comparisons, the two seeding dates were combined to ease understanding based on visual percent cover ratings taken at 30, 60 and 90 DAS. Contrasts were made between treatment comparisons of interest as listed in Table 5. Contrasts were selected to describe the various groups represented in this experiment. These groups included the type of fertilizer, presence of a biostimulant and/or presence of mycorrhiza.

RESULTS AND DISCUSSION

Percent turfgrass cover ranged from 11 to 57% at 30 DAS, 45 to 93% at 60 DAS and 52 to 95% at 90 DAS (Table 3). Protocols lacking N and P fertilizer were the poorest performing. When N and P fertilizer was not applied, all these treatments at 30 DAS, six of eight treatments at 60 DAS and seven of eight treatments at 90 DAS were in the lowest performing LSD grouping. None of the treatments with fertilizer control were in the lowest LSD grouping for 30, 60 and 90 DAS. Organic/slow-release fertilizer provided less turfgrass cover than the quick release fertilizer found in the fertilizer control. Two of ten treatments containing slow release fertilizer were in the lowest performing group at 30 DAS, one of ten treatments at 60 DAS, and no treatments at 90 DAS. Kaminski et al. (2004) also found synthetic fertilizers provided higher initial *A. stolonifera* cover ratings than a poultry meal, organic fertilizer. However after 35 DAS, *A. stolonifera* receiving synthetic fertilizer and receiving incorporated and surface applied poultry meal fertilizer had similar percent cover. Availability of nutrients likely determines the effectiveness of the fertilizer application (Hummel, 1980; McVey, 1967). Organic fertilizer sources nutrient availability to plants is dependent on soil microbial activity.

P. pratensis receiving fertilizer control or organic and slow-release fertilizers had 18-28% more ground cover than untreated control at 30, 60 and 90 DAS (Contrasts 1 and 2 in Table 4). This data supports previous research (Christians et al., 1981; Hathcock et al., 1984; Juska et al., 1965; McVey, 1967; Turner and Waddington, 1983; Westfall and Simmons, 1971). More turfgrass cover (8-10%), however, was found in plots receiving fertilizer control than organic and slow-release fertilizers at all rating dates likely due to fertilizer nutrient release rates (Contrast 3 in Table 4). Also at 30 DAS, turfgrass receiving fertilizer control with biostimulants and

Table 3. Treatment combinations of fertilizer, biostimulants, and/or mycorrhizas used in establishment experiment and their effect on percent cover at 30, 60 and 90 days after seeding (DAS). Treatments are sorted by 30 DAS rating.

Products								
Fertilizer	Biostimulant	Mycorrhiza	30 DAS		60 DAS		90 DAS	
			---------------------------- percent cover ---------------------------					
Fertilizer control	-	#1	57	a	92	a	95	a
Organic/slow-release #1	#1	-	57	a	91	ab	88	a
Organic/slow-release #1	-	-	52	ab	85	ab	87	ab
Fertilizer control	#1	#1	50	ab	82	ab	92	a
Fertilizer control	#2	-	50	ab	88	ab	94	a
Fertilizer control	#2	#2	50	ab	83	ab	88	a
Fertilizer control	#1	-	48	ab	88	ab	95	a
Fertilizer control	#3	-	45	abc	88	ab	94	a
Fertilizer control	-	-	44	abc	89	ab	93	a
Organic/slow-release #1	#1	#1	40	abcd	78	abc	83	abc
Organic/slow-release #1	-	#1	37	abcde	86	ab	87	ab
Organic/slow-release #2	-	-	36	bcdef	87	ab	92	a
Fertilizer control	-	#2	35	bcdef	78	abc	88	a
Organic/slow-release #2	#2	-	35	bcdef	93	a	92	a
Organic/slow-release #2	-	#2	32	bcdefg	84	ab	90	a
Organic/slow-release #2	#2	#2	32	bcdefg	83	ab	89	a
Untreated control	#3	-	25	cdefg	73	abcd	73	bcd
Untreated control	-	#1	23	defg	68	abcde	60	def
Organic/slow-release #3	#3	-	22	defg	67	bcde	82	abc
Untreated control	#1	#1	18	efg	70	abcd	63	def
Untreated control	#1	-	17	efg	52	de	58	ef
Untreated control	#2	#1	16	fg	47	e	52	f
Untreated control	-	#2	14	g	45	e	55	f
Untreated control	#2	-	14	g	55	cde	63	def
Organic/slow-release #3	-	-	14	g	70	abcd	69	cde
Untreated control	-	-	11	g	61	cde	65	def
LSD (0.05)			20.6		24.2		14.4	

Table 3, continued

Organic/slow-release #2	#2	#2	32	bcdefg	83	ab	89	a
Untreated control	#3	-	25	cdefg	73	abcd	73	bcd
Untreated control	-	#1	23	defg	68	abcde	60	def
Organic/slow-release #3	#3	-	22	defg	67	bcde	82	abc
Untreated control	#1	#1	18	efg	70	abcd	63	def
Untreated control	#1	-	17	efg	52	de	58	ef
Untreated control	#2	#1	16	fg	47	e	52	f
Untreated control	-	#2	14	g	45	e	55	f
Untreated control	#2	-	14	g	55	cde	63	def
Organic/slow-release #3	-	-	14	g	70	abcd	69	cde
Untreated control	-	-	11	g	61	cde	65	def
LSD (0.05)			20.6		24.2		14.4	

mycorrhizas had 14% higher cover than organic and slow-release fertilizers with biostimulants and mycorrhizas (Contrast 9 in Table 4). When no fertilizer was applied, biostimulants or mycorrhizas did not increase turfgrass cover at any rating date (Contrast 5 and 6 in Table 4). The inclusion of both mycorrhizas and biostimulants with fertilizer control fertilizers did provide for 6% higher cover ratings than fertilizer control alone at 30 DAS, but showed a 3-6% reduction in cover at 60 and 90 DAS (Contrast 7 in Table 4). More research is needed to understand the reduction in turfgrass cover at 60 and 90 DAS. However, the increase in turfgrass cover at 30 DAS may be a result of the initial mycorrhizal benefits during the first few weeks after seeding. Pelletier and Dionne (2004) showed one mycorrhiza increased cover of a turfgrass mixture compared to the unfertilized control for the first four weeks after seeding, but not at five weeks. The addition of mycorrhiza, biostimulant or both did not increase establishment cover for any other contrast comparison (Contrasts 8, 10-13 in Table 4).

Although probit analysis does allow for direct treatment comparisons, the analysis does help identify trends in data. Similar to the cover data, protocols containing N and P produced the lowest number of days to 95% cover (Table 5). The addition of biostimulants and mycorrhizas did not provide substantial differences from fertilizer only treatments. Slow-release or organic fertilizers provided intermediate establishment rates which were slower than the fertilizer control but more rapid than treatments lacking fertilizer. The untreated control and treatments that did not contain any fertilizer required more time for *P. pratensis* establishment than treatments with fertilizer (Table 5). Fertilizer control program provided 95% cover in 45 DAS for July seeding and 116 DAS for September seeding. No other treatment obtained 95% cover in less time for July seeding. However, fertilizer control also receiving biostimulants, mycorrhizas or both biostimulants and mycorrhizas obtained 95% cover in as few as 91 DAS when seeded in September. In general, *P. pratensis* receiving organic and slow-release fertilizers required more time to establishment than *P. pratensis* receiving fertilizer control. No apparent trend existed for *P. pratensis* receiving organic and slow-release fertilizers with biostimulants, mycorrhizas or their combination compared to fertilizer control.

Table 4. Selective contrasts performed to evaluate important treatment comparisons associated with *P. pratensis* percent ground cover, 30, 60 and 90 Days after seeding (DAS).

Comparison		30 DAS	60 DAS	90 DAS
		--------% ground cover --------		
1	Fertilizer control (FC) vs.	44	89	93
	untreated (UTC)	11*†	61*	65*
2	Organic/slow-release fertilizer (OSR) vs.	34	81	83
	UTC	11*	61*	65*
3	FC vs.	44	89	93
	OSR	34*	81*	83*
4	Any treatment with FC vs.	44	83	91
	any treatment with OSR	36*	82	86*
5	Biostimulant (BIO) vs.	19	60	65
	UTC	11	61	65
6	Mycorrhiza (MYC) vs.	18	57	57
	UTC	11	61	65
7	FC + MYC + BIO vs.	50	83	90
	FC - MYC - BIO	44*	89*	93*
8	OSR + MYC + BIO vs.	36	81	86
	OSR - MYC - BIO	34	81	83
9	FC + MYC + BIO vs.	50	83	90
	OSR + MYC + BIO	36*	81	86
10	FC + MYC - BIO vs.	46	85	91
	FC - MYC - BIO	44	89	93
11	FC - MYC + BIO vs.	49	88	95
	FC - MYC - BIO	44	89	93
12	OSR + MYC - BIO vs.	34	85	88
	OSR - MYC - BIO	34	81	83
13	OSR - MYC + BIO vs.	38	83	87
	OSR - MYC - BIO	34	81	83

† Indicates significant differences from contrasts at the given evaluation date (no stars = not significantly different, * = significantly different at p = 0.05)

Based on the results of these experiments, the fertilizer control for *P. pratensis* establishment on sand in the central plains of the United States of America and similar climates can be recommended as fulfilling the nutrient requirement. This protocol included 117 kg N and 54 kg P/ha applied at seeding and a total of 615 kg N and 103 kg P/ha

Table 5. Comparison of the number of days to reach 95% cover based on probit analysis combined treatments from July and Sept. seedings. Treatments are sorted by July ratings

	Days Until 95% Cover	
	July †	Sept.†
Fertilizer control (FC)	45	116
FC+Mycorrhiza (MYC)	46	91
FC+Biostimulant (BIO)+MYC	47	107
Organic/Slow-Release Fertilizer (OSR)	50	119
FC+BIO	51	95
OSR+BIO	54	113
OSR+MYC	73	124
OSR+BIO+MYC	73	129
Untreated control	188	229‡
MYC	202	148
BIO	217‡	224‡
BIO+MYC	227‡	152

† 25 Nov. to 25 Feb. (92 d period representing 139 to 231 d after July seeding and 64 to 156 d after Sept. seeding) were excluded from calculation due to winter conditions

‡ Estimated values extend beyond the evaluation period

applied within the first 90 DAS. In addition, using granular fertilizers both pre-plant and post-germination made the fertilizer control program effective, convenient and easy to use. Organic and slow-release fertilizers were generally slower to establish than fertilizer control program, but did decrease time to turfgrass establishment over untreated control. None of the mycorrhizas and biostimulants treatments increased *P. pratensis* establishment in a sand/peat rootzone by the end of our experiment. Organic fertilizer sources can also provide acceptable turfgrass establishment, but turfgrass managers should expect longer establishment times. Adding mycorrhizas and biostimulants to organic and slow release fertilizers did not improve establishment rates in the sand-based rootzone in this study.

ACKNOWLEDGMENT

A contribution by the New Mexico Agricultural Experiment Station, New Mexico State University, Las Cruces, NM 88003 and the University of Nebraska Agricultural Research Division, Lincoln, NE 68583 Supported by the Nebraska Turfgrass Foundation. Special thanks to Dakota Peat, Lyman-Richey Sand and Gravel Company, Andersons Golf Products and Grigg Brothers for partial support. Additional thanks to the Becker Underwood Inc., Nu-Gro Technologies, Inc., Sustane, and Bio-Green for products and technical support.

REFERENCES

Al-Karaki, G.N.O., Y. Othman and A. Al-Ajmi. 2007. Effects of mycorrhizal fungi inoculation on landscape turf establishment under Arabian Gulf region conditions. Arab Gulf J. of Sci. Res. 25(3): 147-152.

Butler, T. and Hunter, A. 2008. Soil microbial activity and rooting as influenced by biostimulant application under reduced nutrient inputs in the grow-in year of a USGA golf green. Acta Hort. (ISHS) 783:443-453.

Christians, N. E., D. P. Martin, and K. J. Karnok. 1981. The interactions among nitrogen, phosphorus, and potassium on the establishment, quality, and growth of Kentucky bluegrass (Poa pratensis L. 'Merion'). Int. Turfgrass Soc. Res. J. 4:p. 341-348.

Finney, D.J. 1971. *Probit Analysis.* 3rd ed. Cambridge University Press. Cambridge, England.

Gemma, J.N., R.E. Koske, E.M. Roberts and N. Jackson. 1997. Enhanced establishment of bentgrasses by arbuscular mycorrhizal fungi. J. of Turfgrass Sci. 73: 1997.

Geron, C.A., T.K. Danneberger, S.J. Traina, T.J. Logan, and J.R. Street. 1993. The effects of establishment methods and fertilization practices on nitrate leaching from turfgrass. J. Environmental Qual. 22: 119-125.

Hartley, H. O. 1950. The maximum F-ratio as a short-cut test for heterogeneity of variance. Biometrika. 37: 308-312.

Hathcock, A.L., P.H. Dernoeden, T.R. Turner, and M.S. McIntosh. 1984. Tall fescue and Kentucky bluegrass response to fertilizer and lime seed coatings. Agron. J. 76: 879-883.

Hummel, N.W., Jr. 1980. Evaluation of slow-release nitrogen sources for turfgrass fertilization. M.S. thesis. The Pennsylvania State Univ., University Park.

Juska, F.V., A.A. Hanson, and C.J. Erickson. 1965. Effects of phosphorus and other treatments on the development of red fescue, Merion, and common Kentucky bluegrass. Agron J. 57: 75-78.

Kaminski, J.E., P.H. Dernoeden, and C.A. Bigelow. 2004. Soil amendments and fertilizer source effects on creeping bentgrass establishment, soil microbial activity, thatch, and disease. HortScience. 39: 620-626.

Karnok, K.J. 2000. Promises, promises: Can biostimulants deliver? Golf Course Manage. 68: 67-71.

Koske, R.E. and J.N. Gemma. 2005. Mycorrhizae and an organic amendment with biostimulants improve growth and salinity tolerance of creeping bentgrass during establishment. J. of Turfgrass and Sports Surface Sci. 81: 10-25.

McVey, G.R. 1967. Response of seedlings to various phosphorus sources. P. 53. Agron. Abstr., Amer. Soc. Agron., Madison, Wis.

Mueller, S.R. and W.R. Kussow. 2005. Biostimulant influences on turfgrass microbial communities and creeping bentgrass green quality. HortScience. 40: 1904-1910.

Pelletier, S. and J. Dionne. 2004. Inoculation rate of arbuscular-mycorrhizal fungi *Glomus intraradices* and *Glomus etunicatum* affects establishment of landscape turf with no irrigation or fertilizer inputs. Crop Sci. 44: 335-338.

Podeszfinski, C., Y. Dalpe, and C. Charest. 2002. *In situ* turfgrass establishment: I. Responses to arbuscular mycorrhizae and fertilization. J. Sustainable Ag. 20: 57-74.

Puhalla, J, J. Krans and M Goatley. 1999. *Sports Fields: A Manual for Design, Construction and Maintenance*. Ann Arbor Press. Chelsea, MI.

Tarbell, T.J. and R.E. Koske. 2007. Evaluation of commercial arbuscular mycorrhizal inocula in a sand/peat medium. Mycorrhiza. 18: 51-56.

Tucker, B.J., L.B. McCarty, H. Liu, C.E. Wells and J.R. Rieck. 2006. Mowing height, nitrogen rate, and biostimulant influence root development of field-grown ‘TifEagle’ bermudagrass. HortScience: 41: 805-807.

Turner, T.R. 1980. Soil test calibration studies for turfgrasses. Ph.D. diss. The Pennsylvania State Univ., University Park (Diss. Abstr. 80-24499).

Turner, T.R. and D.V. Waddington. 1983. Soil test calibrations for establishment of turfgrass monostands. Soil Sci. Soc. Amer. J. 47: 1161-1166.

U.S. Golf Association. 1993. USGA recommendations for a method of putting green construction. USGA Green Section Record. 31(2): 1-33.

Westfall, R.T. and J.A. Simmons. 1971. Germination and seedling development of Windsor Kentucky bluegrass as influenced by phosphorus and other nutrients. P. 52. Agron. Abstr., Amer. Soc. Agron., Madison, Wis.

Zhang, X., E.H. Ervin, and R.E. Schmidt. 2003. Physiological effects of liquid applicants of a seaweed extract and a humic acid on creeping bentgrass. J. Amer. Soc. Hort. Sci. 128: 492-496.