A PRACTICAL RESEARCH DIGEST FOR TURF MANAGERS

TURFGRASS TRENDS

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AGRONOMY

Timing soil surfactant applications

Their effect on soil water repellency

By Chris Miller

The past seven years saw dramatic improvements in the diversity and quality of soil surfactant products offered to turfgrass managers. Many of today's surfactants are more effective than their earlier cousins for both treatment and management of localized dry spot symptoms, as well as enhancing penetration of water into the soil profile. With more and more golf course superintendents and athletic field managers using surfactants (wetting agents), demands have been made on manufacturers to provide flexible application regimes to fit into busy schedules.

Trials were conducted on a Penncross creeping bentgrass nursery green at Metedeconk National Golf Club in Jackson, NJ. The soil was a USGA-type sand with a history of soil water repellency related problems.

Due to the natural biodegradation of these surfactant materials in the soil profile over time (Swisher, 1986), surfactant applications have traditionally been made on a somewhat regular basis (ex. monthly) in order to maintain acceptable levels of product performance. Several manufacturers, however, have introduced surfactants that can be applied less frequently, with claims of extended periods of optimal performance between applications. For example, for golf course superintendents in the Northeast or the Midwest, extended performance from such products could translate into a single spring surfactant application resulting in management of soil water repellency that lasts the entire growing season.

Developed for application convenience and the option they give turf managers to treat on a less frequent basis, the marketplace has seen a proliferation of surfactant products available in recent years. However, little research has been conducted on these products to evaluate their effect on soil water repellency (the major cause of localized dry spot symptoms) from the time they are applied to the time when they ultimately biodegrade in the soil. While surfactants applied on a more frequent basis have been proven to maintain consistent performance over time in terms of soil water repellency reduction (Kostka et. al., 1997), questions have arisen as to how long these long-term products ultimately last once applied.

In an effort to answer some of these questions, research was performed that evaluated several different timing regimes for surfactant application, with investigation of application

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frequencies ranging from once per month to applications made one time only. It is hoped that this research will give a better understanding of the implications of surfactant application timing, leading turf managers to make more educated decisions on surfactant use for their operations.

Causes and significance of soil water repellency

Water repellent (hydrophobic) soils have been encountered in a variety of situations not exclusive to highly cultivated turfgrass. Water repellent conditions can occur in uncultivated sandy soils (Tucker, et.al. 1990), and have been reported in grassland soils in Australia (Bond, 1968), as well as burned over areas of forest soils (Osborn et al 1964). However, the most frequent occurrences are in turfgrass areas, particularly those areas situated in sand-based soils (York and Baldwin, 1992). Causes of soil water repellency are still not completely understood. However, there is evidence that microbial breakdown of organic substances (peat moss, roots, shoots), as well as fungal activity in the soil, leads to a wax-like coating of sand particles. Once these coatings dry out, they become extremely water repellent, and rewetting of the soil profile can be difficult. (Karnok and Tucker, 1999)

Drying out of the soil profile and the organic coatings on sand grains is a likely scenario in sand-based soils, due to their relatively poor water holding capacity and frequent wet-to-dry cycles. Wet-to-dry cycles may be triggered by turf managers intentionally (ex. promoting firmness or playability of a surface between irrigation cycles), or may be beyond their control (ex. insufficient irrigation or rainfall in times of excessive plant water use).

Water repellency typically develops in a turf stand 6 to 18 months after establishment, subsequently, it remains in the soil profile, to varying degrees (Karnok & Tucker, 1999). Because of these varying degrees of water repellency across the area of a turf stand, certain sections within the stand may be more prone to exhibit symptoms associated with it. If not managed properly in times of high stress and evaporative demand, sections of turf more severely affected by water repellency will begin to exhibit wilting symptoms and discoloration, primarily due to lack of infiltration and retention of water. These wilted, discolored patches of turf may lie directly adjacent to healthy areas of turf seemingly unaffected by this problem. Since these symptoms of water repellency are typically seen in a patchwork pattern, they are commonly referred to as localized or isolated dry spots.

Causes of soil water repellency are still not completely understood. There is evidence that microbial breakdown of organic substances, as well as fungal activity in the soil, leads to a wax-like coating of sand particles.

It is usually not until these localized dry spots develop, that turf managers begin to notice soil water repellency. A turf manager may not know the potential for a soil to develop water repellency related problems if irrigation practices or natural rainfall prevent the soil from drying to critical moisture levels that encourage its development. Measurement of the severity of the soil water repellency can give the turf manager an indication of the potential for problems associated with it to develop. Water repellent soils in turfgrass areas are most commonly found in the top 2 inches of the soil profile due to most of the root growth and microbial activity being situated in this area (Miller, 1998). Its severity can easily be measured by the water droplet penetration test. Once water repellency severity is assessed, management solutions can be implemented – with the most common being treatment with soil surfactants.

Measurement of severity of soil water repellency

A simple assessment to determine the severity of soil water repellency can be made using the water droplet penetration test. To conduct the test, extract a soil core

(2 cm/ 1 inch diameter is ideal) from a designated turf area to a depth of at least 10 cm. After allowing the core to air-dry for about a week, lie the soil core horizontally, then place small water droplets (about 0.5 cm in diameter) at 1 cm intervals (about 0.5 inches) along the length of the soil core surface, beginning at the thatch-air interface. With water repellent soils, water will bead up on the soil like rain on a freshly waxed car, and not penetrate into the soil. If the soil is minimally water-repellent, the drop should penetrate the soil within 25 seconds. Droplets that do not penetrate within 25 seconds signify soils that may have a tendency to develop water repellency related problems. The more water repellent the soil, the higher the amount of time needed for the drop to penetrate the soil. It should be noted that due to the inherent variability in the levels of soil water repellency inside a given turf area, several samples from different sections of a particular area should be taken to give an overall picture of the area's true water repellency potential.

Addressing soil water repellency

Due to the constant root growth, decomposition of organic matter, and microbial activity in the soil profile that coincides with normal turf growth, materials with the potential to become water repellent are constantly being produced, therefore the eradication of soil water repellency is not realistic. For the turf manager, especially those with sand-based soils, management of the problem is the only alternative. Management options include incorporation of soil amendments, modification of irrigation practices, and cultivation. But, for many turf managers, use of soil surfactants provides the most practical option.

After applying soil surfactants to a turfgrass area, surfactant molecules are chemically attracted to soil particle surfaces where organic acid coatings produced by organic matter breakdown and microbial activity are present. Surfactant molecules then chemically bind to these organic coatings, leaving a portion of the soil surfactant molecule exposed that is hydrophilic, or attracted to water. After this, subsequent irrigation or rainfall, instead of running off or through the soil profile, is more easily maintained in the turf stand, and water repellency related symptoms can be addressed, or even prevented.

TABLE 1.

Treatment [x]	Treatment Application				
	0 Mos.		1 Mo.	2 Mos.	3 Mos.
	5/25	6/1	6/25	7/27	8/30
A. *Primer / 6 oz.*	*Yes* [y]	—	*Yes*	*Yes*	*Yes*
B. *Product B / 8 oz.*	*Yes*	*Yes*	—	—	—
C. *Product C / 8 oz.*	*Yes*	*Yes*	—	—	—

Short-term vs. long-term surfactants

Because of their proficiency in binding to water-repellent surfaces of soil particles, surfactants are effective for preventing the occurrence of water repellency related symptoms. Turf managers can apply soil surfactants to drastically reduce the amount of localized dry spot that is seen at their operation, often resulting in a reduction in hand watering or irrigation.

The trials demonstrate that monthly surfactant application at rates of 4 to 6 oz. per 1,000 sq. ft. can effectively maintain low levels of water repellency in the soil profile.

Today's turfgrass professionals have many soil surfactant products at their disposal. Due to the biodegradation of surfactant products applied to soils, many products have been designed to be applied on a regular basis (every 3 to 4 weeks). The basis of regular application of these materials is the maintenance of effective levels of the surfactant molecules in the soil profile. These products, 'short-term' surfactants, are typically applied to turf at rates ranging from 3 to 8 oz. of product per 1000 sq. ft.

Surfactant applications every three to four weeks may not be practical for some turf managers. Soil surfactant manufacturers have recently addressed this issue, and

have introduced products that can be applied on a less frequent basis. These "long-term" surfactants are typically applied at higher rates than their "short-term" counterparts. With application rates usually ranging from 8 to 16 oz. of product per 1000 sq. ft., long-term surfactant products come with label claims of management of water repellency related problems lasting from 3 months, to an entire season.

Timing surfactant application

In an effort to answer some of the questions on how long both long-term and short-term surfactant products last once they are applied, research was performed that evaluated several different timing regimes for surfactant application.

Two trials were conducted: the first involved application of both short-term and long-term surfactants and evaluated the effect of these treatments on soil water repellency over the course of a four-month period. The second trial involved regular application of short-term surfactants at varying time intervals, also with evaluation of the treatments' effect on soil water repellency over the course of a four-month period.

TABLE 2.

SURFACTANT TREATMENTS / DATES OF APPLICATION - TRIAL 2. METEDECONK NATIONAL GC, 1999

Treatment [x]	Treatment Application				
	0 Mos.	1 Mo.		2 Mos.	3 Mos.
	5/25	6/25	7/8	7/27	8/30
A. Primer / 6 oz.	*Yes*	*Yes*	—	*Yes*	*Yes*
D. Primer / 4 oz.	*Yes*	—	*Yes*	—	*Yes*
E. Primer / 6 oz.	*Yes*	—	—	*Yes*	—

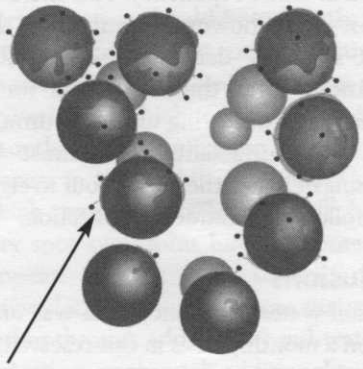
x = Rates for each treatment per 1000 sq. ft. Each treatment applied in a spray volume of 2 gal. per 1000 sq. ft. Letters preceding treatments are for reference only.

Both trials were conducted at the same site, a Penncross creeping bentgrass nursery green at Metedeconk National Golf Club in Jackson, NJ. The soil was a USGA-type sand with a history of soil water repellency related problems. Surfactant treatments were applied to 6-by-6-ft. plots (arranged in a randomized complete block design) using a backpack CO^2 sprayer calibrated to deliver two gallons of water per 1000 sq. ft. To measure water repellency, soil cores were taken from each plot area on a monthly basis. The first set of soil cores was taken immediately prior to initial treatment application and the final set of soil cores was taken one month after the final treatment applications. Soil cores were air-dried and subjected to the water droplet penetration test (Letey, 1969) at 1 cm intervals beginning at the thatch-air interface. Data was subjected to analysis of variance (ANOVA) and significant means among treatments were separated using Duncan's multiple range test.

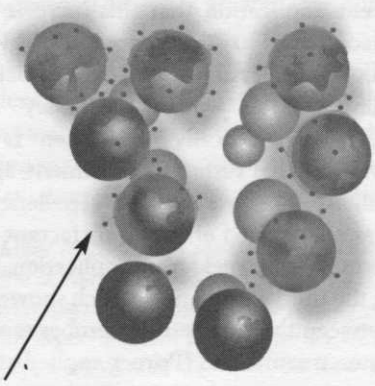
TRIAL 1 - SHORT TERM VS. LONG TERM

Treatments and their application frequencies are listed in Table 1. Primer treatments, representative of short-term surfactant chemistries, were applied on a monthly basis at a rate of 6 oz. per 1000 sq. ft. Both Product B and Product C, representative of long-term surfactant chemistries, were applied at the initiation of the trial in two separate applications of 8 oz. per 1000 sq. ft., each spaced one week apart (16 oz. total). No further applications of either Product B or Product C were made during the remainder of the trial.

Water repellency data is illustrated in graphical form in Figure 1. This uppermost region of the soil profile, represented by this graph, was where the most severe water repellency was found in this trial. Throughout the first two months of the trial — May and July — all surfactant treatments maintained lower levels of water repellency than those found in the control plots. As the trial progressed through August and September, water repellency in the plots began to increase, as evidenced by the high water droplet penetration times seen in the control plots. Throughout the trial, the Primer treatment, applied monthly, maintained significantly lower levels of water repellency than in the control plots. However, during the months of August and September, significant increases in water repellency were observed in plots treated with Prod-



SURFACTANT MOLECULES ATTACH TO WATER REPELLENT SITES IN THE SOIL PROFILE



SUBSEQUENT RAINFALL OR IRRIGATION HYDRATES PREVIOUSLY WATER REPELLENT SOIL

Soil surfactant applications enable previously water repellent areas of the soil profile to retain moisture, resulting in the management of water repellency related symptoms such as localized dry spot.

ucts B and C. This is evidence that, despite the high rates applied in May, levels of Product B and Product C were not adequate to maintain a low level of soil water repellency during the months of August and September.

TRIAL 2 – APPLICATION OF SHORT-TERM SURFACTANTS AT VARYING TIME INTERVALS

Treatments and their application frequencies are listed in Table 2. In this second trial, Primer was applied at three different timing intervals, monthly (treatment A), every six weeks (treatment D) and every eight weeks (treatment E). Initial treatment applications coincided with initial treatments applied in Trial 1, applied May 25, with subsequent applications made over the course of a four-month period.

Water repellency data for Trial 2 is illustrated in in the graph in Figure 2. This graph represents the portion of the soil profile where the most severe water repellency was found. Throughout the first two months of the trial — May to July — all surfactant treatments were able to maintain lower levels of water repellency than those found in the control plots. Water repellency in the plots began to increase in August and September, as is evidenced by the high water droplet penetration times seen in the control plots during these two months. The monthly Primer treatment maintained a significantly lower level of water repellency than the control plots throughout the trial. However, during the months of August and September, plots treated with Primer on a less frequent basis showed inconsistent results.

Plots treated every six weeks with Primer (treatment D) showed a drastic increase in water repellency between the July and August sampling dates. This is evidence that between the period from two weeks to six weeks after treatment D application, the surfactant level in the soil was diminishing. At the rates in treatments D and E, it's likely that surfactant levels start to diminish in the soil and lose efficacy between four and eight weeks .

This hypothesis is based on three observations from Trial 2. First, data from the July sampling date for treatment D showed low water repellency levels, evidence the treatment is maintaining effective surfactant levels at least through two weeks after treatment application. Between the July and August sampling dates (two and six weeks after application of treatment D), water repellency levels greatly increase. It is

most likely at least four weeks after treatment application that this increase takes place, due to the second observation. Between the August and September sampling dates, water repellency levels decreased drastically in treatment D plots, evidence that surfactant treatment, applied August 30, lowered water repellency, and was maintained effective surfactant levels through four weeks after application. Finally, the third observation, which showed that between the July and September sampling dates, treatment E (Primer applied at eight week intervals) also showed a dramatic increase in water repellency. This increase was not seen, however, until after the August sampling date, four weeks after application With the increase in water repellency not occurring until this time, it shows that surfactant levels must be decreasing between the period four to eight weeks following treatment application.

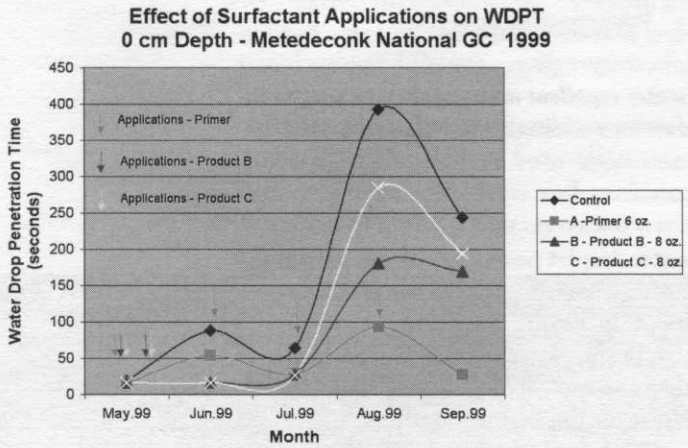


Figure 1. The effect of 'long term' surfactant applications (Products B and C) and primer soil surfactant on the time (in seconds) for water drop penetration into air-dried soil cores (Metedeconk National Golf Club, Jackson, NJ—1999)

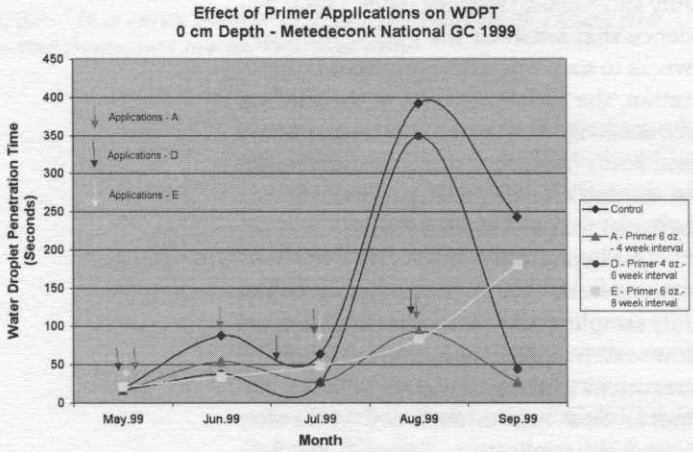


Figure 2. The effect of timing of Primer soil surfactant applications on the time (in seconds) for water droplet penetration into air-dried soil cores (Metedeconk National Golf Club, Jackson, NJ—1999)

Conclusions

Since soil water repellency data was only taken on a monthly basis in this research, it is difficult to pinpoint the exact time when soil surfactant levels, either short-term or long-term, diminish to the point of decreased performance. At application rates of 4 to 6 oz. per 1000 sq. ft., evidence points to this time as being between four to eight weeks after application. At application rates higher than this, which were investigated in Trial 1 with Products B and C, it would naturally be expected that the time to decreased performance would be greater. While this is true, at this test site, data from trial 1 suggest that effective levels of these 'long-term' surfactants are only sustained in the soil from two to three months after application.

What does this research mean to the turf manager? With the advent of long-term surfactants in the marketplace, today's turf managers have a number of options at their disposal to help with the management of soil water repellency and the problems associated with it. Turf managers should be aware of the pros and cons associated with each of these options, the two most common being regular monthly surfactant application and less frequent or 'one-time' application of long-term surfactants.

The research from these trials demonstrates that monthly surfactant application at rates of 4 to 6 oz. per 1000 sq. ft. can effectively maintain low levels of water repellency in the soil profile. Through regular monthly applications, turf managers can be confident that adequate surfactant levels in the soil will be maintained that will manage the symptoms associated with this water repellency such as localized dry spot.

While applications of surfactants on a

less frequent or 'one-time' basis may be attractive from a convenience standpoint, turf managers should be aware that use of this type of surfactant could potentially lead to problems. If the biodegradation of these materials — which took place two to three months after application at this site — occurs in the middle of stressful weather (high temperatures, low rainfall) localized dry spot symptoms have the potential to appear. At that point, the turf manager must decide how to manage the problem, either through additional hand-watering or irrigation, or through additional surfactant applications.

Soil water repellency and the problems that go with it will always be present, a consequence of growing healthy turfgrass. If application of long-term surfactants at high rates is the method of choice to help manage this problem, the turf manager should be aware that additional applications might ultimately be necessary to maintain acceptable levels of performance, especially if the growing season is greater than three months long.

To maintain low levels of soil water repellency and manage the associated symptoms, regardless of the length of the growing season monthly surfactant applications at lower rates may be the best option.

Chris Miller holds a BS in plant and soil science from the University of Delaware and a MS from Michigan State University. He was an assistant superintendent at Franklin Hills CC in Michigan, then worked for Aquatrols for five years, until the end of 2000, as senior research agronomist, responsible for overseeing and organizing turfgrass related research involving the company's product line as well as new products. He now teaches computer programming at Computer Learning Centers, Inc. in Cherry Hill, NJ.

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New bluegrass species for turf

By David R. Huff
Pennsylvania State University

Commonly known as bluegrasses in North America and as meadowgrasses in Europe, the grass genus Poa contains many economically important grass species that are components of pastures, meadows and turf in both northern and southern temperate climates.

The grass genus Poa is a diverse collection of widely adapted, cool-season grasses containing 300 species. Many species of Poa have worldwide distribution, ranging from tropical mountainous regions to the most northern limit tolerated by any plant species.

Canada bluegrass shows potential for use as a low maintenance turfgrass.

Kentucky bluegrass (*Poa pratensis L.*), which produces some of the finest quality turf in the Green Industry, is the representative species of Poa, both agronomically and botanically.

This article's objective is to introduce several economically-important species of bluegrass that are not normally thought of as amenity turfgrasses, but nonetheless possess qualities that make them interesting and potentially useful as turf.

Identifying and distinguishing species within Poa is difficult because morphological variation often overlaps, and many species have an inherent ability to adapt to a range of environmental conditions. Furthermore, the retention of pollen recognition systems between species enables a variety of interspecific hybridization to occur in nature. Interspecific hybridization results in many species being introgressed with each other to such an extent that species classification is also often difficult.

Poa contains a variety of breeding systems including apomixis and dioecy (Table 1). Species may be annual or perennial, with simple culms, and have narrow, flat leaf blades with a pair of bulliform cell lines along either side of the midrib and a boat-shaped tip.

The retention of pollen recognition systems and the asexual nature of apomixis present many possibilities for interspecific hybridization within Poa.

The potential of integrating wider adaptation and transferring valuable agronomic traits through interspecific hybridization is attractive. The long-term commitment of such breeding objectives, however, has generally resulted in lack of substantial progress. Examples of interspecific hybridization include P. pratensis x P. compressa; P. pratensis x P. alpina; P. ampla x P. pratensis; P. scabrella x P. pratensis; P. longifolia x P. pratensis; P. arachnifera x P. pratensis; and P. caespitosa x P. arachnifera.

Annual bluegrass

Annual bluegrass (*P. annua L.*) is described as being an annual cosmopolitan bunchgrass with light-green foliage and sometimes rooting from lower nodes.

It is often considered a serious weed problem for fine-sports turf. However, annual bluegrass exhibits a range of variability in traits like color, shoot density and life history. As such, there are annual bluegrasses that exist as long-lived perennials [*P. annua f. reptans (Hausskn) Timm*] with dark forest-green color and a shoot density that is higher than any other recorded turfgrass.

The process of this transformation from a annual weedy type to a high shoot density perennial-type is an interesting one. Initially, golf greens planted to creeping bentgrass eventually become infested with the wild

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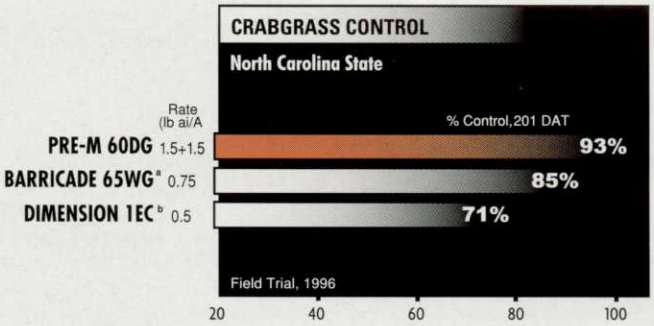

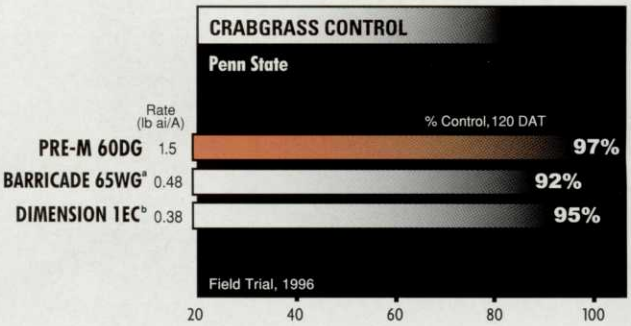

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TEAM[c]	H	M	M	M	M	M	NR	NR
RONSTAR[d]	M	H	NR	M	M	NR	NR	NR
SURFLAN[c]	H	H	H	M	MH	M	H	H
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*Source: Kline & Company Report, US Acre Treatments by Turf Management.

and weedy annual types of annual bluegrass. Because of the ability of annual bluegrass to flower and set seed under close mowing heights, those annual bluegrass plants that become established on the green sire progeny that are more adapted to the green's environment than the original colonizers.

TABLE 1.

AGRONOMICALLY IMPORTANT POA SPECIES AND SOME SELECTED CHARACTERISTICS

Common name	Scientific name	Chromosome number	Method of Reproduction
Canada bluegrass	*P. compressa L.*	35-36, 42, 56	Apospory apomixis
Bulbous bluegrass	*P. bulbosa L.*	14, 21, 28, 35, 42, 45	Bulbiferous apospory
Annual bluegrass	*P. annua L.*	14 (sterile), 28	Self-compatible, gynomonecy
Texas bluegrass	*P. arachnifera Torr.*	56	Dioecious

Over time, each generation becomes more tolerant of the close mowing heights by investing more of their photosynthesis energy into vegetative growth and less into seed production. Over decades, the annual bluegrass types that exist on golf greens have evolved stoloniferous-like shoots, a short-stature and a high shoot density.

These perennial forms of annual bluegrass have become an important turfgrass for the golf industry in regions like the Pacific Northwest and coast and the U.S. Northeast. Because such greens-type annual bluegrasses evolve on-site and cannot survive in environments other than golf greens, they are considered cultivars. Presently, no commercial sources of such cultivars are available. Therefore, prospects for developing improved cultivars are good.

One commercially available cultivar source of perennial annual bluegrass, known as Peterson's Creeping bluegrass, has had some limited success in the semi-arid regions of California as turf. However, there still are no commercially available cultivars for use on golf greens.

Canada bluegrass

Canada bluegrass (*P. compressa L.*) is a rhizomatous perennial with a distinctive bluish-green color of its leaves. Its flowering culms are stiff and flattened and the lemma of its seed has only two nerves and either lacks or has sparse basal webbing.

Canada bluegrass resembles Kentucky bluegrass but is distinguishable by its flatter culms, its obscure lemma nerves, and typically does not have as high a shoot density. Despite its name, Canada bluegrass is native to Europe and southwest Asia and was introduced and naturalized throughout much of North America. It's primarily used for pastures and for erosion control on nutrient-poor or thin soils in parts of Ontario, Canada, and in humid northern United States.

It is best adapted to open, poor, dry soils and under these conditions may be better than Kentucky bluegrass for lawns. Some strains of Canada bluegrass show greater shoot density than others suggesting that variability exists within the species for turfgrass quality characteristics. Thus, Canada bluegrass shows potential for use as a low maintenance turfgrass.

Future prospects for developing improved cultivars are good. Current cultivars include: Canon, released in 1944 by the Ontario Agricultural College, University of Guelph, Guelph, Ontario. (Canadian Seed Growers' Association, P.O. Box 8455, Ottawa, Ontario, K1G 3T1). Another cultivar is Reubens developed and marketed by Jacklin Seed Company (W. 5300 Riverbend Ave., Post Falls, ID 83854, 208-773-7581). The intended use of Reubens is for low-maintenance turf and erosion control cover in areas of low fertility, irregular moisture supply and where mowing is difficult.

Bulbous bluegrass

Bulbous bluegrass (*P. bulbosa L.*) is a dense, perennial bunchgrass that possesses swollen, fleshy basal sheaths at the bases of its tillers and culms that resemble bulbs. In addition, its flowers do not produce seed but contain vegetative bulblets having purple bases and slender bracts 5 to 15 mm long.

Bulbous bluegrass growth usually begins about October 1 and ceases early to mid-May.

Bulbous bluegrass is a native of southern Asia, Europe, and North Africa. Its growth usually begins October 1 and ceases early to mid-May soon after the bulblets are set in the inflorescences. This growth period of bulbous bluegrass makes it an interesting grass for use in regions where dormant warm-season grasses are normally overseeded to provide a green turf during the winter months.

Given its active winter growth and perennial nature, bulbous bluegrass offers potential as a permanent overseeding grass in areas where warm-season grasses go dormant.

Currently, bulbous bluegrass is used for pastures and erosion control in parts of the western United States., including southwestern Idaho, Oregon and northern California. It is increased from its bulblets that form in its panicles, and these bulblets are planted as though they were seed. There is extensive variation among naturally occurring strains of bulbous bluegrass, particularly for traits like shoot density, leaf texture and stature. So, our ability to select for fine textured, dense, short-statured types makes the prospects for developing improved cultivars appear good.

Currently, there are no named varieties available in the United States., however, "seed" (i.e. bulblets) is available in limited supply from Seeds Inc., Box 866, Tekoa, WA, 99033, 509-291-5411.

Texas bluegrass

Texas bluegrass (*P. arachnifera Torr.*) is a creeping, rhizomatous perennial grass that is also dioecious (the sexes are separated onto different individual plants).

The spikelets of its female plants are webbed near bases of the lemmas, resembling fuzzy balls of cotton, while the spikelets of male plants are only sparsely webbed. Texas bluegrass is native to the plains and prairies of south central U.S., and is sometimes cultivated as winter pasture and as turf in Texas.

The characteristics that make Texas bluegrass a potentially useful turfgrass species are good winter growth and good summer heat stress survival. Thus, Texas bluegrass is already a valuable species within its native habitat, however, seed production and seeding is often difficult due to the cottony-webbing of its seed. Consequently, the production and establishment of stands for turf use is limited.

However, Texas bluegrass is known to hybridize with Kentucky bluegrass which radically improves its potential for eventual commercial seed production and turf use in areas of the hot, humid south. Thus, prospects for developing improved cultivars are good. Although no commercially available cultivars are currently available, interested parties should contact Dr. James Read, Texas A&M University, Agricultural Experiment Station, Dallas, TX.

Wood bluegrass

Wood bluegrass (*P. nemoralis L.*) was introduced from Europe and has naturalized in many areas across Canada and south into the northern tier of states.

Wood bluegrass is suitable for lawns in the shade, or low-maintenance lawns under trees. It produces good turf under low maintenance conditions and has a fine leaf texture.

Prospects for developing improved cultivars are good. Current cultivars include: Barnemo, which was developed from European material and has shown to produce a good turf under low maintenance conditions and has a fine leaf texture. For further information interested parties may contact Barenbrug USA, P.O. Box 239, Tangent, OR 97389, 503-926-5801.

Sandberg bluegrass

Sandberg bluegrass (*Poa secunda Presl*) is a native bluegrass occurring throughout the Northern Plains and Western States. It is a bunchgrass reaching to 24 in. under optimum conditions. Leaves are sparse.

The grass starts growth early in spring and matures and dries in midsummer. While green, and even after drying, the foliage is palatable, so it is a valuable range grass. Seed germination is low. Sandberg is usually seeded in combination with later growing grasses for maximum pasturage over a long season. Its potential for turf is only now being explored.

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OTHER BLUEGRASS SPECIES OF INTEREST

Not every species of bluegrass is ready for prime time. However, there are several species which are of interest to breeders and may have some impact on the genus down the road. Here is the outlook on several such species:

- **Big bluegrass** *(Poa ampla Merr.)* is a strong-growing perennial bunchgrass native in Western United States. Plants are up to 4 ft. tall, with numerous basal leaves 8 to 16 in. long by 0.375 in. wide and a deep, fibrous root system. Stands are generally not dense.
- **Mutton bluegrass** *[Poa fendleriana (Steud.) Vasey]* is native from the Great Lakes westward to the Cascade Mountains and south into Mexico. It is a perennial bunchgrass with erect stems up to 24 in. tall. It develops tillers at the base and rarely produces short rhizomes. Leaves are mainly basal, are rather firm and stiff. They are folded or inrolled, rarely flat. The species grows under a wide range of conditions including elevations to near the top of the Rocky Mountains. It is also found among sagebrush and in open timber stands.

  Mutton bluegrass is well adapted to dry slopes and is found on clay loam as well as sandy or gravelly soils. It is drought resistant, palatable and nutritious, and starts growth very early. Even the dry growth is grazed well. These characteristics make it a valuable range grass. The name reflects the value sheepmen place on the grass for sheep feed.
- **Alpine bluegrass** *(Poa alpina L.)* is a low-growing, non-rhizomatous, perennial bunchgrass that is erect, with culms arising from a tight crown, 10-30 cm tall, and has short leaf blades that are 2-5 mm wide. It naturally grows in mountain meadows, arctic regions of the Northern Hemisphere, extending south to Quebec, northern Michigan, and the alpine summits of Colorado, Utah, Washington, and Oregon.

  Alpine bluegrass has extremely early seed maturation and superb winter-hardiness. It also forms a noticeable thatch with persistent leaves from previous year's growth. Gruening is the first named cultivar of this species. Gruening is tended for use in erosion control, reclamation, and restoration in arctic, sub-arctic, and boreal regions. It has been observed to out-compete other bluegrass cultivars on gravelly, alpine slopes. For more information contact: Stoney J. Wright, Manager, Alaska Plant Materials Center, State of Alaska, HC 02, Box 7440, Palmer, AK 99645, 907-745-4469.
- **Plains bluegrass** *(Poa arida Vasey)* is a native bluegrass that grows in prairies, plains, and alkali meadows, up to 3,000 m elevation in Manitoba to Alberta, south to western Iowa, Texas, and New Mexico. It has erect culms, 20-60 cm tall with leaf blades that are mostly basal, firm, folded. It is mildly rhizomatous, and has ability to establish excellent stands in saline-alkaline affected soils.

  Although no cultivars exist, seed for limited field testing is available from: Plant Materials Center, SCS, RR 1 Box 1189, Bridger, MT 59014, 406-662-3579.
- **Glaucous or upland bluegrass** *[Poa glauca Vahl ssp. glaucantha (Gauldin) Lindm.]* is a perennial, loosely tufted bunchgrass that spreads by tillering; numerous compressed, fine, wiry culms, decumbent at the base; many flat, short, well-distributed, dark green leaf blades. Seed heads numerous, lax, becoming brownish, compact, and nodding at maturity. Seeds are small, lemmas lightly pubescent, and sparsely webbed at the base.

  Plants resemble Canada bluegrass but become sodbound less readily, lodge less, and produce more seed. Upland bluegrass is adapted to low-fertility soils and is used for ground cover.

  It was first introduced in 1935 by Westover and Enlow from Chorsum, Turkey. A cultivar known as Draylar has been selected soil erosion control on disturbed lands with a minimum annual precipitation of 45 cm. Draylar is apomictic (2n=50) and has been used by the Carnegie Institution of Washington for bluegrass hybrid studies. For more information contact: Plant Materials Center, SCS, Room 104, Hulbert Agricultural Sciences Bldg., WSU, Pullman, WA 99164-6211, 509-335-7376.

  The first cultivar of this species was released as Tundra with an intended use for revegetation purposes. Tundra originates from selected plant indigenous to Alaska along the Sagavanirktok River about 116 km south of the northern coast at Prudhoe Bay. It is adapted arctic regions to northern fringes of boreal forest in Alaska and neighboring areas of Canada. For more information contact: Palmer Research Center, Agricultural and Forestry Experiment Station, 533 E. Fireweed, Palmer, AK 99645, 907-745-3257.

Smooth cordgrass synthetic seeds:

Production, storage and potential use for coastal erosion controls

By Herry S. Utomo, Ida Wenefrida, and Timothy P. Croughan
Louisiana State University

An acre of coastal wetlands in Louisiana is lost to erosion every 20 minutes. Synthetic seeds of smooth cordgrass (*Spartina alterniflora Loisel (Poaceae)*) would be a useful adjunct approach to the hand-transplanting employed in coastal erosion control.

The synthetic seed production process can be automated, therefore synthetic seeds can expand the vegetative propagation of smooth cordgrass: an acre of land can be planted by airplane in eight seconds, compared to a minimum of 24 man-hours to plant the same area by hand transplanting.

Smooth cordgrass is a perennial warm-season grass found along shorelines. It grows vigorously at seawater salinity and has a extensive root system, but it can grow in both fresh and saltwater environments. It tolerates fluctuating water levels and is adapted to many soil types. Smooth cordgrass can provide an effective buffer that disperses wave energy, reduces shoreline scouring and entraps floating sediments and other solids.

Smooth cordgrass is sterile with little or no viable seed production. As a result, erosion control materials are produced through vegetative propagation. Divided plants can be placed in one-gallon containers to produce new stems before transplanting. Vegetative propagation and hand-transplanting is labor intensive and expensive.

Cordgrass synthetic seeds

Development and potential use of synthetic seeds, or artificial seeds, has been a hot topic since Murashige introduced the concept in 1977. The definition of synthetic seed refers to the encapsulation of somatic embryos that functionally mimic the behaviors of true seeds and sprout into seedlings under suitable conditions. Under a broader definition, synthetic seeds include encapsulated buds, bulbs or any form of meristem that can develop into a plant (Li, 1993).

Hydrogelling agents used for encapsulation include sodium pectate, Gel-rite, agar, guar gum, carrageenan, and sodium alginate.

Currently, plant regeneration through somatic embryogenesis has been achieved in more than 200 species and therefore the production of synthetic seeds from these species is theoretically possible. Efforts to produce synthetic seeds have involved a range of species, including papaya (Castillo et al. 1998), pistachio (Onay et al. 1996), white spruce (Fowke et al. 1994), celery and lettuce (Sanada et al. 1993), and alfalfa (Redenbaugh 1993, Fuji et al. 1992). Despite progress in this research area, synthetic seed germination rates remain a major problem.

Research in smooth cordgrass synthetic seeds has been directed towards improving seed viability. Synthetic seed technology developed for smooth cordgrass may serve also as a model for other grass species.

Tissue culture

Somatic embryogenesis can be a rapid propagation tool, since a large quantity of embryogenic callus capable of producing plants can be obtained quickly in either a semi-solid or liquid medium. The amount of callus tissue cultured in liquid medium triples within a one-week period of subculture. A tissue culture protocol has been developed for clonal propagation of smooth cordgrass in which a half gram of smooth cordgrass callus tissue can be induced to

regenerate into 25 or more plants.

The medium for producing somatic embryos and micro-plantlets contains R4 salts (Chaleff and Stolarz, 1981) supplemented with 0.5 g l-1 casein acid hydrolysate, 100 mg l-1 inositol, 1 mg l-1 biotin, 0.4 mg l-1 thiamine.HCl, 64 g l-1 maltose, and 6 g l-1 agarose, with the pH adjusted to 5.8 before autoclaving. Cultures are maintained at 25oC in a light regime of 16:8 light/dark with a light intensity of 15 mE.m-2.s-1. Resulting somatic embryos and micro-plantlets are then encapsulated to produce synthetic seeds.

Embryogenesis

Embryogenic tissues of smooth cordgrass are formed during callus initiation and proliferate to produce more embryogenic tissues. A part of the tissues develops into somatic embryos which further undergo a maturation process.

A maturation phase is the most critical period in which fully developed, germinable somatic embryos are formed. The mature embryos enter a phase that involves elongation of the hypocotyl-root axis and emergence of the radicle, resulting in a seedling-like somatic plantlet. The somatic plantlet (or "micro-plantlet") becomes the plant material of choice for developing high germinating synthetic seeds. Micro-plantlets are small in size, facilitating easy encapsulation, and they are already growing.

Encapsulation

Encapsulation protects both embryos and micro-plantlets. It provides favorable conditions for handling, storage and mechanical seeding. It also provides a suitable environment to support acclimatization of autotrophic micro-plantlets to field conditions.

Alginate is an excellent encapsulating agent for smooth cordgrass synthetic seeds. Calcium alginate gel beads are produced by dropping alginate solution into calcium chloride solution. Sodium alginate will complex when mixed with calcium chloride to form calcium alginate. Ionic bonds will be formed between carboxylic acid groups on the glucoronic acid molecules of alginate. Solidified alginate will form after 20 minutes in 50 mM calcium chloride solution. Gel beads with an average diameter of 6 mm are produced.

An alginate concentration of 2 percent is adequate for smooth cordgrass encapsulation. The growth of non-encapsulated and encapsulated micro-plantlets under the same environment were similar, indicating that encapsulating material hardness did not affect the micro-plantlet's growth. The use of hollow encapsulations to encourage normal growth as suggested by Patel et al. (2000) may not be necessary.

Sugar and other constituents such as vitamins, myo-inositol and biotin can be incorporated into the capsule. Without such constituents, somatic embryos of smooth cordgrass will not always germinate. Incorporation of these chemicals into the capsule, however, provides favorable conditions for the growth of microorganisms.

The beads become rapidly contaminated with microbes when they are transferred into non-sterile environments. Preventive measures using a combination of biocides, bacteriocides and fungicides can provide complete control of microbial growth.

The use of a hydrated alginate gel for the encapsulation of natural seeds has also been reported to improve germination and survival in the soil. Encapsulating materials can carry a variety of pesticides, fungicides and fertilizers. Encapsulation also provides moisture and can be used to add weight to natural seeds that are relatively light.

Germination of synthetic seeds

Using micro-plantlets for producing synthetic seeds is more desirable than using somatic embryos for the following reasons.

First, synthetic seeds derived from micro-plantlets have about a two-week maturity advantage over embryo-derived synthetic seeds. Second, somatic embryos are more sensitive to growth environments and nutritional composition changes than micro-plantlets. Therefore, microplantlet-derived synthetic seeds perform better under the conditions of field planting.

Data from germination studies show that higher rates of viability were obtained when synthetic seeds were produced from micro-

Germination studies indicate that higher rates of viability were obtained when synthetic seeds were produced from micro-plantlets rather than somatic embryos.

plantlets rather than somatic embryos. A germination rate of 86 percent was produced with micro-plantlets, while only 6 percent of encapsulated somatic embryos germinated (Fig. 1). Seedling establishment was more rapid with micro-plantlet-derived synthetic seeds. Under controlled environments, encapsulated micro-plantlets grew to 6-cm shoot lengths with root lengths of 4 cm in ten days. This seedling establishment would be ideal for revegetating intertidal coastal marshes.

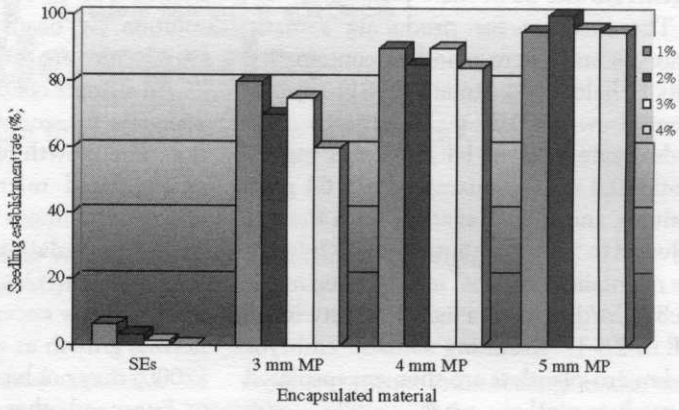

Figure 1. Seedling establishment rate for somatic embryos (SEs) and 3, 4, and 5 mm micro-plantlets (MPs) encapsulated with 1, 2, 3, and 4percent (w/v) alginate.

Storage

A storage method providing enough time for the accumulation of sufficient synthetic seeds for planting a large area is another important aspect in synthetic seed production. Preservation and storage methods include induction of slow growth using plant growth regulators (Ammirato, 1986), low temperatures (Molle et al., 1990; and Nadel et al., 1990) and hypoxia (Engelmann, 1990). Long-term preservation through freezing and desiccation that provides reversible arrest of embryo development to mimic true seed behavior has also been studied (Senaratna et al., 1989).

Despite significant progress in this research area, germination rates of synthetic seeds remain a major problem.

Encapsulated micro-plantlets can be stored at 1 to 5o C inside closed containers under a low light intensity of 5 mE.m-2.s-1 for 6 weeks without loss of viability (Fig. 2). With the potential for automating the production process of smooth cordgrass synthetic seeds, a six-week period should provide enough time for the accumulation of sufficient synthetic seeds to plant a large area.

Potential use for erosion control

Research progress involving in vitro clonal propagation of smooth cordgrass shows that this technique can mass-produce vegetative clones in a short period. Synthetic seeds can capture the benefits of this rapid plant multiplication. Individual plants possessing desirable characters can produce synthetic seeds.

Genetic diversity has been an issue related to the use of plants for coastal stabilization and wetlands reclamation. Populations with low genetic diversity may have greater vulnerability to sudden changes in macro/micro climate caused by disease, insects, drought, high salinity and fire. Resistance to these stresses favor long-term survival and need to be preserved. Genetic diversity among subpopulations of smooth cordgrass can be assessed using DNA fingerprinting techniques.

Besides possessing desirable characters, parental lines can be selected to represent the genetic diversity of the original populations in the target areas. The number of parental lines will not be a limiting factor in the synthetic seed production and as many as required can be included to keep the genetic diversity in the target regions. Parental line composition and the proportion of synthetic seeds derived from each parental line can be adjusted so that resulting synthetic seeds are tailored to provide the right degree of genetic diversity.

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