A PRACTICAL RESEARCH DIGEST FOR TURF MANAGERS

TURFGRASS TRENDS

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TURFGRASS SEED RESEARCH

Major Developments
In Turfgrass Breeding

By Doug Brede, Ph.D.

Turfgrass breeding is a rapidly evolving technology, not unlike computers in how fast it's changing. Over the past ten years, plant breeders have been pumping out an array of advanced turfgrass varieties that make older varieties pale by comparison. Substantial improvements in endurance, playability, appearance, and stress and pest tolerance have been incorporated into each successive generation. Superintendents are confronted with the paradox of when to climb on board: "Do I invest in this year's best grasses or hold out for next year's model?"

In this article I'd like to update you on all the latest advancements in turfgrass breeding so you'll be an informed buyer, able to pick the right moment to take the plunge into the latest grasses. Secondly, I'll give you a glimpse of what the future holds, so you'll know whether it's better to buy now or hold out for something else.

Bentgrasses

Getting golf course superintendents to agree on the single most important feature in a creeping bentgrass variety is nearly impossible. Everybody has their own views of what traits are admirable to have in a bent.

Here ia a sampling of possibilities (4):

- **True putting** - It should produce a clean, smooth putting surface, free of bobbling as the ball rolls.
- **Uniformity** - The grass shouldn't segregate into patches over time.
- **Complete ground coverage** - Nothing fouls the game of golf faster than bare spots on a putting green.
- **Pest resistance** - No grass gets spared as pest pressures become heavy enough. What's

MAJOR DEVELOPMENTS IN TURFGRASS BREEDING

- Bentgrasses for greens
- *Poa annua* var. reptans for greens and fairways
- Kentucky bluegrasses below one inch for fairways
- Endophyte pest resistance
- Bioengineering

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important here, is the freedom from major "holes" in a variety's disease and insect spectrum.

- **Competitiveness with Poa** - A bent must stand up to Poa.
- **Close-cut tolerance** - Grasses with the ability to withstand close cutting heights have their own set of tradeoffs.
- **Summer stress tolerance** - In many areas, mid-summer is the make-or-break period for creeping bent. Varieties concocted out of southern strains tend to outperform northern varieties through this period.
- **Fairway adaptation** - More and more bentgrass seed is going into fairways. A good bentgrass should be able to handle the higher cut without becoming puffy and thatchy.

This discussion of desirable bentgrass attributes wouldn't have been possible 15 years ago, when all there was to choose from were 'Penncross' and 'Seaside' (7). Penncross was the hands-down favorite, save a few mavericks.

But today's superintendents are bombarded with over 20 different bentgrass varieties (11), all vying for a position on their putting greens. Each new bent has its own set of plusses and minuses. While these added varieties do satisfy our natural human desire for choice, it creates confusion about which one to select.

Judge for yourself. The avenue most superintendents follow when choosing a bentgrass is word of mouth. Grasses like fescue and ryegrass, on the other hand, are introduced to the trade by magazine ads alone. Not so with bentgrass. Superintendents need to hear about it from friends, they need to see it, touch it, bond with it - before they're ready to commit. After all, a lot is at stake in selecting a bentgrass, including your career.

In 1997, the golf industry took a giant step forward in selecting bentgrasses. The USGA, GCSAA, and the National Turfgrass Evaluation Program (NTEP) teamed up to create the world's first series of controlled, on-course variety trials (2). Unlike earlier bentgrass trials that were run under the rather cushy conditions of a college back lot, these trials will be maintained by actual superintendents, using real world chemicals, daily mowing, and wear and tear from golfers. Thirteen courses have been chosen from New York to California, spanning several climatic zones (Table 1). The greens were constructed in summer 1997 to USGA specs, with the entries planted in the fall.

NTEP will produce annual reports from these trials from the data collected by the university evaluators. But my advice to you is to travel to the course nearby and examine the grasses firsthand. Getting a personal impression is a far better way to pick a bentgrass than reading numbers from a list. Don't sell yourself short: Your impression of these grasses is every bit as important and relevant as the university profs who do the rating. Incidentally, the host superintendents at these courses have agreed to allow your visits to the sites, as long as you make an advanced appointment.

Poa annua and *Poa reptans*

When I was at Penn State University taking my first plant breeding course, the teacher had us write an essay proposing a new breeding project on some unusual species. For mine, I picked *Poa annua*. In the essay, I proposed to launch a breeding program on annual bluegrass for golf courses. As part of the class assignment, we were required to have the essay reviewed by someone in our specialty. I asked my major professor, Joe Duich, to look it over. Joe's reaction was, "This is the dumbest idea I've ever read, pal."

The irony is that 20 years later, David Huff, Joe's successor is doing just that: He's launched a breeding program on *Poa annua* for golf courses! (I wonder if Dave had Joe review his proposal?) "I haven't encountered much of a stigma in the industry as far as the superintendents are concerned," says Huff about his fledgling Poa breeding effort. "As a matter of fact, most of the resistance I've encountered has come from the scientists."

Huff's project was made easier this spring by the release of 'DW-184,' a new

TABLE 1. GOLF COURSES INVOLVED IN THE USGA/GCSAA/NTEP ON-COURSE BENTGRASS TESTING PROGRAM

Sites of the USGA/GCSAA/NTEP on-course bentgrass testing program launched last fall across the US (2). The USGA Green Section constructed an additional practice green at each course. NTEP is providing coordination for testing and reporting. GCSAA has offered sponsorship. These trials are open for your inspection, with appropriate notice given to the cooperating superintendent.

Golf course	University evaluator
Boon Links GC, Florence, KY	A.J. Powell, Univ. of Kentucky
Crystal Springs GC, Burlingame, CA	Ali Harivandi, Univ. of California
Fox Hollow at Lakewood, Lakewood, CO	Tony Koski, Colorado State Univ.
Golf Club at Newcastle, Bellevue, WA	Gwen Stahnke, Washington State Univ.
North Shore CC, Glenview, IL	Tom Voigt, Univ. of Illinois
Purdue Univ. North Course, W. Lafayette, IN	Clark Throssell, Purdue Univ.
Westchester CC, Rye, NY	Jim Murphy, Rutgers Univ.
Westwood GC, Vienna, VA	Dave Chalmers, Virginia Tech
Bent Tree CC, Dallas, TX	Milt Engelke, Texas A&M Univ.
SCGA Members Club, Murietta, CA	Robert Green, Univ. of California-Riverside
CC of Birmingham, Birmingham, AL	Elizabeth Guertal, Jeffrey Higgins, Auburn Univ.
CC of Green Valley, Green Valley, AZ	Dave Kopec, Univ. of Arizona
The Missouri Bluffs, St. Charles, MO	John Dunn, Univ. of Missouri

variety from Donald White at the University of Minnesota (17). DW-184 has broken down a lot of barriers in peoples' minds about the concept of an intentionally planted Poa.

Peterson Seed, the producer of this new variety, is calling DW-184 a "creeping bluegrass," or *Poa reptans*. From a true botanical standpoint, DW-184 is actually *Poa annua var. reptans* (Hausskn.) Timm. - the perennial subform of annual Poa (14,17). But promoting it as *Poa reptans* has helped overcome some political barriers, since *Poa annua* is classed as a noxious weed by the seed laws of several states, making its sale prohibited.

Huff views DW-184 as a valuable fairway grass. He says, though, that it may be too tall growing for putting greens. "I view it, relative to what I'm working on, as a bigger, taller grass," he says. Huff's work has centered on what he calls "greens type" Poa's - shorter, denser plant forms.

Of course, the tradeoff toward a smaller plant has been an even scantier seed yield. Reportedly, DW-184 is no tiger when it comes to yield (14). Seed supplies are expected to be tight, with demand far outstripping supply. Huff's diminutive putting green types are skimpier still on seed. "We're focused right now on seed production. Quality doesn't seem to be a hard thing to get. We've got a lot of good types. So we're really looking hard at seed production," he says.

Future trends. Huff's groundbreaking work has opened new avenues in *Poa annua* research and breeding. "It seems we're learning something totally new about *Poa annua* every month or two - things we never knew before," he says. In addition to seed production, Huff is studying Poa's cold tolerance and resistance to two primary pests, annual bluegrass weevil and anthracnose.

A recent discovery of a truly blue-gray Poa strain has sent his research into a brand new vein. "In the past we were thinking of pure Poa greens. But we've recently gotten a selection that has an identical color match to bent. So, now we're thinking of the possibility of mixing Poa with bent when seeding a green. It would add the strength of *Poa annua* to the green, and it wouldn't stick out like a sore thumb," says Huff.

Don't expect to purchase seed of Huff's new invention next year, or for a few years to come. Plant breeding takes time, especially when you're dealing with a species that has never been commercially exploited before.

Fairway Kentucky bluegrasses

Fairway adaptation for early turf breeders was truly an afterthought. Varieties were bred and developed with home lawns in mind. Breeding plots received the same weekly tending your average homeowner might give his yard. Later, after a variety was released, if it showed a particular aptitude toward close mowing, it would be selectively marketed in that direction.

As time passed, golf courses turned their backs on Kentucky bluegrass for fairways. Ryegrass and bentgrass became the favored species - not because they were easier to manage, but because they could handle the sub-inch mowing. Bluegrasses prospered at 2 to 3 inches. As the cutting height of early bluegrasses was lowered below 1 inch, they quickly faded from disease and stress.

When I began breeding bluegrasses 12 years ago, I took a different path from my predecessors. Having been a golf superintendent, I decided to make the golf course a prime consideration in my breeding. Rather than make close mowing an afterthought, I made it a primary screening tool. Instead of waiting until a variety was released before testing it for fairway adaptation, I screened tens of thousands of early-generation hybrids using a cutting height below one inch. Under these grueling conditions, most hybrids quickly gave way to moss or bare ground. Only a handful of varieties out of thousands prospered under this intensity of mowing. I selected these for release (6).

By 1995, just as my new generation of fairway bluegrasses were making their debut, the NTEP initiated bluegrass testing at under an inch (12). Earlier NTEP bluegrass trials screened varieties at 1 to 3 inches, home lawn height. The latest trial evaluates sub-inch mowing at several locations, including in the tough, transition-zone cor-

ORIGINS OF MODERN BENTGRASSES

Experiment station selections - Back in the 1960's, nearly every state university worth its salt had its own bentgrass variety in the works. Many of these bents never got off the farm and into the industry. As early turf specialists - Bill Kneebone, Wayne Huffine, and others - traveled their state visiting golf courses, they'd extract a plug or two from attractive patches they observed. These plants would end up on the experiment station's putting green, where they would be compared endlessly against Penncross and Seaside. The University of Arizona experiment station was one of the few to actually release their selections to the public. 'SR 1020,' released in 1987, consists of 5 clones selected from attractive spots on golf courses (1).

University germplasm exchanges - Back in the late 1960's and early '70's, in an effort orchestrated by the US Golf Association, numerous colleges across the country agreed to an informal swap of their collected bentgrasses. This provided two opportunities for researchers: (a) Small colleges could share their collections with bigger programs in hopes that at least something good would become of their valued finds, and (b) colleges that wished to augment their breeding programs could do so without added cost. 'Putter' bentgrass, bred by Stan Brauen of Washington State University, traces its parentage in part to this early exchange of bent germplasm (5).

Composites from golf courses - One recent trend in bentgrasses has been toward varieties concocted from mass collections of plugs from golf courses. In some cases, 100 or more plugs have been grouped together from courses in several states to produce a new variety. The advantage of this strategy is a broader genetic base and fewer concerns with quirky disease susceptibilities, resulting from too narrow a germplasm. Some skeptics question whether the genetic base of these composite varieties is really that broad, since most plugs undoubtedly trace from old Penncross greens. Nonetheless, the performance of these broad-based varieties has been unmistakable. Varieties such as 'Southshore,' and 'L-93' which was selected from within Southshore, have been advancements in the state of the art (10,11).

ridor, long a nemesis of Kentucky bluegrass. Without a doubt, this new generation of Kentucky bluegrass has opened the eyes of many skeptics.

Some turf scientists like Bill Torello, University of Massachusetts, are once again promoting bluegrass for fairways as a lower maintenance alternative to ryegrass and bentgrass.

Endophyte

Endophytes are those microscopic fungal creatures that live inside the veins of grass leaves, giving off protective insecticides in exchange for their cozy homes. Endophytes are an inexpensive insurance policy that guards many of today's top ryegrass and fescue varieties from pests. Insects are repelled or killed by these natural pesticides, reducing the turf managers' need for artificial insecticides.

Endophytes have been protecting turf varieties long before their presence was even detected. Turf historians speculate that even the earliest ryegrasses, Manhattan and Pennfine, contained 20 to 30 percent endophyte. Although, curious as it may sound, the breeders never intentionally put it there in the first place (9). The parents of Pennfine and Manhattan were selected for their relative fitness - a trait that may have been induced partly by the endophyte.

Today, pioneering turf breeders are taking the concept of endophytes several steps further. "We're developing populations of tall fescue and perennial ryegrass that utilize diverse sources of endophyte. We don't want to rely on one particular biotype of endophyte," says Don Floyd, turf breeder for Pickseed West in Tangent, OR. Incorporating multiple strains of endophytes into one variety reduces the possibility of failure of a given fungal strain, while broadening its insect and stress spectrum.

A common concern in pest management is chemical pest resistance (16). Over time, insects and fungi have mutated into forms resistant to many of today's popular ag chemicals. Benomyl fungicide, for example, has become nearly useless as more and more dollar spot-resistant strains have emerged. Although this has never happened with the chemicals in endophytes, it never hurts to be too careful.

Another modern innovation in endophyte technology involves breeding the endophyte itself. Some adventuresome scientists are breeding and selecting endophyte strains just as they would breed and select grass varieties.

There might even come a day when a sticker on your turf seed bag identifies the strain of a popular endophyte inside - just as many of today's computers come with a sticker promoting "Intel Inside."

Some turf scientists are again promoting bluegrass for fairways as a lower maintenance alternative to ryegrass and bentgrass.

NOTES ON MANAGING A NEW BENTGRASS

Paul Jett, superintendent at Pinehurst Resort, Pinehurst, NC, recently presented a seminar on his experience maintaining Penn G-2, a new creeping bentgrass, during the 1998 GCSAA conference, Anaheim, CA. Pinehurst No. 2 puts an incredible amount of maintenance into their greens. In the past, they spent a lot of money on their old bentgrasses, but they have doubled their maintenance input after planting 'Penn G-2.'

G-2 has a number of unique management requirements. Jett says it must be topdressed regularly with a very fine sand. The grass was so dense that regular topdressing sand will not work through the turf canopy. Consequently, very fine "sugar" sand must be applied on a regular basis.

Pinehurst topdresses 40 times a year. Of course, all that sand wreaks havoc on the mowers. The mowers must be sharpened every day, in comparison to sharpening once every two weeks with normal bentgrass management. Ball marks must be filled every day. They use a green-dyed sand because it takes two to three weeks for a ball mark to heal on a G-2 green. This is compared to less than one week on a Penncross green.

In practice, superintendents may find that these modern ultra-dense bentgrasses have a place for only the top 5 percent of the golf courses in America - the ones who can afford to maintain this level of grass.

Kentucky bluegrass endophyte. Unlike ryegrass and fescue, which commonly contain an endophyte, Kentucky bluegrass varieties never do. This unfortunate quirk of nature could change, if Suichang Sun here at Jacklin has anything to say about it. Sun has undertaken an ambitious project to instill an endophyte into this previously endophyte-free species (3). If he's successful, the implications for turf management will be profound.

"Kentucky bluegrass is the major cool-season turf used around the world. Adding an endophyte would help cut pesticide use on a lot of turf acres worldwide," says Sun. To achieve his goal, Sun isolated an endophyte fungus from an obscure Kentucky bluegrass relative in a distant Asian country (15). Later he perfected a way to incorporate the fungus into bluegrass - a process he later patented. Today, Sun has obtained 57 endophyte-infected Kentucky bluegrass plants ready for field testing.

Tinkering with the actual genes of plants is the ultimate tool for making grasses do our bidding.

"We've even gotten the endophyte fungus to crawl along through the bluegrass rhizomes into new daughter plants. I know that sounds funny, but no one's ever seen endophyte propagate underground before," he says.

Bioengineering - the final frontier

Tinkering with the actual genes of plants is the ultimate tool for making grasses do our bidding. Plant breeders already do this, but on a much clumsier scale. Plant breeders move thousands of genes at a time by means of hybrid crosses. Bioengineers, on the other hand, can move a single gene from one plant to another - or even a gene from a bacteria into a grass.

Bioengineering opens up a whole realm of possibilities for turf breeders:

• **Varietal improvement** - Bioengineers in California have isolated a drought-tolerance gene from the ice plant and are transferring it into grasses, in hopes it will enhance the grasses' resistance to droughty soils.

• **Pest resistance** - Michigan scientists have cloned an antifungal gene found in an American elm tree that showed resistance to Dutch-elm disease. The gene codes for chitinase, a enzyme that degrades chitin, the backbone protein found in fungi. When inserted into grass, it appears to give resistance to common diseases such as dollar spot.

• **Weed control** - In recent years, herbicide-resistant plant varieties have set the corn and soybean seed markets on their ear (pun intended). New varieties are engineered with a gene that allows a full rate of non-selective herbicide (Roundup® or Finale®) to be applied over-the-top without damage to the crop. Weeds are eliminated, leaving only resistant crop plants alive in the field. Biotechnology giant, Monsanto, estimates that by 2005, the global market for gene-altered plants will soar to an incredible $6.6 billion (8).

• **Varietal fingerprinting** - With 100 perennial ryegrass varieties in the latest NTEP trial alone, breeders are finding it increasingly difficult to identify their new products. As a result they're turning to biotechnology to pinpoint genes present in their variety alone. "We're moving into an era where the breeder has to protect his varieties - an era where biotechnology will become paramount," says Pickseed's Floyd. "There will be molecular techniques applied to protecting our proprietary varieties."

Turf bioengineering. According to *Business Week* magazine (8), last year U.S. farmers sowed more than 16-million acres of genetically-modified seed. Of those acres, how many of them were turf? The answer is zero.

What are the reasons turf is lagging behind its agronomic cousins in bioengineering? Size is one factor. Multinational chemical companies have invested hundreds of millions of dollars in bioengineering over the past decade. Larger crops such as wheat, cotton, and soybeans provide a stronger avenue for recouping their massive

R&D investments. Turf to them is a bit crop - to small to worry about right now.

Another problem with turf is that it's perennial. If you think about it, all of the current bioengineered crops are annuals. And there's a reason why: They all die after one season of use.

Biotech companies like annual crops because new seed must be purchased each spring. They also like the fact that after a set period of months, their products self-destruct, eliminating the possibility of the plants crawling away, as plants sometimes do. Alfalfa will become the world's first bio-engineered perennial crop, available beginning in 2005.

Last but not least, turf suffers from one huge complication that makes bioengineers cringe, it has natural relatives. Corn and rapeseed - two popular bioengineered crops - have no natural relatives near where they're grown. Turf on the other hand, has a slug of cousins along roadsides, in abandoned fields, and on virtually every square foot of ground across the land. Bioengineers' biggest fear is that the biotech bentgrass planted on your golf course will hybridize with the native bent plants along your streambank, spreading their valuable genes into the wilds. Though this may sound like a trivial concern, its very possibility has raised the ire of green groups the world over.

An actual case of gene escape occurred last October in France. Scientists reporting in Nature magazine, showed that herbicide-resistance genes from oilseed rape could transfer to wild radish weeds, conveying herbicide resistance into weed populations. Can you imagine: Weeds that you can't kill with herbicide. That's why the biotech giants are progressing slowly with turfgrass. They don't want a two-bit crop to jeopardize their global moneymakers.

REFERENCES

1. Alderson, J. and W.C. Sharp. 1994. Grass varieties in the United States. USDA SCS Ag. Handbook no. 170.
2. Anonymous. 1997. USGA, GCSAA, NTEP join forces. Golf Course Management 65(10):13.
3. Blais, Peter. 1994. Suichang bringing endophyte strains to bents and blues. Golf Course News 5[6]9:1, 32.
4. Bowley, S.R. and D. Hancock. 1994. Genetic improvement of turfgrass - 1994 progress. 1994 Annual Research Report, Guelph, Ontario, Canada, p. 8.
5. Brauen, S.E., R.L. Goss, and A.D. Brede. 1993. Registration of 'Putter' creeping bentgrass. Crop Science 33(5):1100.
6. Brede, Doug. 1996. Big changes in Kentucky bluegrass. Golf Course Management 64(6):61-66.
7. Duich, J.M. 1985. The bent grasses. Weeds Trees & Turf 24(1):72-78,104.
8. Flynn, Julia, John Carey, and William Echikson. 1998. Seeds of discontent. Business Week, Feb.
9. Halisky, P.M. and C.R. Funk. 1984. Prevalence of Lolium endophyte in seed lots and plants of Manhattan perennial ryegrass. Phytopathology 74(7):812.
10. Hurley, R.H., V.G. Lehman, J.A. Murphy, and C.R. Funk. 1994. Registration of 'Southshore' creeping bentgrass. Crop Science 34(4):1124-1125.
11. National Turfgrass Federation. 1994. National Bentgrass Test - 1989 (Native Soil - Green): Final Report 1990-93. USDA ARS, Beltsville Agricultural Research Center.
12. National Turfgrass Federation. 1997. 1995 National Kentucky bluegrass test. USDA ARS, Beltsville Agricultural Research Center.
13. Rose-Fricker, Crystal and Melodee Fraser. 1997. Bentgrass breeding. Field day 15, Turf Seed, Inc., Hubbard, OR, p. 86.
14. Ruemmele, B.A., D.B. White, and P.D. Ascher. 1987. Reproductive biology in Poa annua L. seed set analysis. Agron. Abstr. p. 138.
15. Sun, Suichang. 1996. Finding friendly fungi: Endophytes for creeping bentgrass and Kentucky bluegrass. Golf Course Management 64(9):49-52.
16. Vittum, Patricia J. 1997. Back to basics - Insecticide primer part two: Chemical classes of turfgrass insecticides. Turfgrass TRENDS 6(1):9-16.
17. White, Donald. 1994. Improvement of Poa annua var. reptans for golf turf. 1994 Turfgrass Research Summary [USGA]. p. 18-20.

Plots in this trial were seeded in the fall of 1996 and rated through spring 1997 at a mowing height of _ inch. Rating scale was 1 to 9, with 9 equal to best quality.

I'm not saying that all doors are closed in regard to turf bioengineering. Yes, the avenue of herbicide-resistant varieties has been derailed for five or 10 years. But advancements in drought, pest, and stress tolerance from bioengineering could begin appearing on the market as soon as 2005.

Doug Brede, Ph.D., is research director for Jacklin Seed and Medalist America, the turf seed branch of the J.R. Simplot Company in Idaho. His team of scientists and breeders have released over 40 popular turf cultivars in recent years. Brede has written over 100 articles on turfgrass and related subjects. His latest venture is a book on how to reduce your turf maintenance, due out in the fall. Turfgrass TRENDS subscribers can save $20 off the cover price by ordering early from Ann Arbor Press at (734) 475-8787.

RESEARCH SUMMARIES

Controlling June Beetle Grubs, with surface-applied insecticides. *Research conducted by Dr. Rick Brandenburg, NC State University.*

Several different treatments were evaluated for control of green June beetle grubs (Cotinus nitida L.) on a bermudagrass fairway at the Quali Ridge Golf and Country Club in Sanford, NC.

Turfgrass on the site was mowed at 7/8-inch, with 1/4-inch of thatch present. The soil was classified as "sandy loam" with pH of 5.6 and 0.51 percent humic matter.

Plots 10ft. x 10 ft. were established in an area with a historyof green June beetle infestations and treatments (replicated four times) were randomly assigned to the plots. All liquid insecticides were applied using a CO_2 backpack sprayer delivering approximately 30 gpa, operating at 40 psi.

Granular insecticide formulations were applied using a hand-held Republic EZ Handscpreader. All treatments except for Orthene 75S received approximately 0. inches of water immediately after application of insecticides.

All plots were oversprayed on 29 September with a 5.0 lb. ai/acre rate of Sevin 80 -S, and were evaluated on September 30 by counting all the dead grubs on the surface within two $1m^2$ frames randomly placed in each plot. Dead grubs from the Sevin overspray are assumed to have survived the "initial test" treatment. The average number of grubs counted per lm^2 in each plot are reported in Table 1.

All data were transformed (square root of X+ 0.05) prior to ANOVA and DNMRT.

Actual means are presented in tables.

Results and discussion

Sampling showed treatments using Oftanol 5G provided greater control than both treatments using Orthene 75S and treatments using CGA-293343 2SC at the 10- and 20-ox. rates. Only the Oftanol and CGTA-293343 2SC at the 15-oz. rate provided a significant reduction in grubs.

TABLE 1.

Treatment	RATE (LB AI/A)	TARGET	—grubs per 2 m² per plot REP 1	REP 2	REP 3	REP 4	AVERAGE
Orthene 75S	3.0	1 st instar	22.00	20.00	18.00	31.00	22.75 bc
Orthene 75S	5.0	1 st instar	32.00	17.00	12.00	35.00	24.00bc
CGA-293343 2SC	10 fl. oz.	1 st instar	42.00	37.00	58.00	10.00	36.76 c
CGA-293343 2SC	15 fl. oz.	1 st instar	3.00	41.00	7.00	16.00	16.75 ab
CGA-293343 2SC	20 fl. oz.	1 st instar	14.00	16.00	26.00	22.00	19.50 bc
Oftanol 5G		1 st instar	6.00	9.00	3.00	2.00	5.00 a
Untreated	———	1 st instar	35.00	41.00	25.00	33.00	33.50 c

Means followed by the same letter are not significantly different (DNMRT, P=0.05)

Potassium Fertilization

By Dr. N. E. Christians
Iowa State University

The last 20 years have brought some major changes in how potassium (K) is used in turfgrass fertility programs. During that time, we've gone from programs that placed little emphasis on K, to modern programs that include fertilizer analyses high in this essential element. Supplemental applications of materials like potassium sulfate (0-0-50) during the growing season have also become popular. The objective of this article is to look at the functions of K in the grass plant, to discuss its role in soil chemistry, and to evaluate how our thinking about this important nutrient element has changed over the years.

Fertilizers

A complete turf fertilizer contains nitrogen (N), phosphorus (P), and potassium (K). These materials are expressed on the label with an analysis that lists the percentage by weight of N, P_2O_5 and K_2O. A 50 pound bag of 20-3-15 contains:

50 X .20 = 10 lbs. of N
50 X .03 = 1.5 lbs. P_2O_5, and
50 X .15 = 7.5 lbs. K_2O

The P_2O_5 is 44 percent by weight elemental P and K_20 is 83 percent by weight elemental K. Therefore this bag of fertilizer contains:

1.5 X .44 = .66 lbs. elemental P, and
7.5 X .83 = 6.2 lbs. elemental K.

The reason that P and K are listed on the fertilizer label as oxides and N as an individual element is due primarily to tradition. It was a convention adopted in the early days of commercial fertilizer production and it has never been changed. It would make a great deal of sense and would simplify fertilizer calculations if labels would be changed to list the three elements on an N-P-K basis. It appears unlikely that the fertilizer industry will change to this system any time in the near future, however. To do so would make it appear that that the bag contains less nutrients. A 10-10-10 (N- P_2O_5-K_2O) fertilizer, for instance, would become a 10-4.4-8.3 on an N-P-K basis. Even though these two analyses have the same meaning, it would appear to the public that the first analysis provides more for their money.

Potassium: Plant Activator

Potassium was often referred to in the past as the mystery element. While more is known about its function today than was known just a few years ago, there are still things about K that are not completely understood. One surprising fact about K is that it does not become a part of any of the plant biochemicals. The chlorophyll, proteins, nucleic acids, and other material in which N plays such an important role, contain no K. This doesn't mean that K is not found within the plant. Plants contain relatively large amounts of K and it is recognized to be the most abundant cation in the cytoplasm of many species (Marshner, 1995). Grasses are particularly heavy users of K and it is found in grass tissue at levels from 1.2 to 3.5 percent on a dry weight basis (Christians, 1977; Christians, 1979).

Plant scientists refer to K as a cofactor (enzyme activator). A cofactor is something that has to be present for certain plant constituents to be formed and for certain plant functions to occur, but it does not become part of the materials being formed. Among the many things that K becomes involved in are carbohydrate formation, meristematic growth, enzyme activation, the synthesis of proteins, and cell elongation (Marshner, 1995). Potassium plays a role in photosynthesis and carbohydrate production is reduced when K is deficient. Root development requires sufficient K levels (Christians, et al., 1979; DePaola, J. M. and J. B. Beard 1977). Potassium deficient plants are known to be less resistant to plant diseases (Goss and Gould, 1967; Salisbury and Ross, 1992; Tisdale and Nelson, 1975). The words that best summarize the role of K in the plant is **stress tolerance**.

Potassium is also involved with the opening and closing of plant stomata. The stomata are small openings in the epidermis (outer cell layer) of the plant leaves. Like the pores in our skin, these stomata can open and close in response to environmental changes. Their function is to allow the entrance of gasses and to help control water release from the surface of the plant. The stomata play an important role in stress management and plants deficient in K are less tolerant of environmental stresses. The tolerance of creeping bentgrass to heat in midsummer, winter hardiness of bermudagrass (Gilbert and Davis, 1971), wear tolerance, and other related stress functions are all affected by K.

Potassium deficiency symptoms on plants can be very subtle and difficult to recognize. It is mobile within the plant and is easily redistributed from mature plant parts to younger tissue, so deficiency symptoms first appear on older leaves (Salisbury and Ross, 1992). The symptoms on K deficient plants generally differ on dicots (broadleaves) and monocots (grasses). Dicots deficient in K can become slightly chlorotic and can form discrete necrotic lesions near the margins of leaves, whereas monocots can show damage at the tip and margin of the leaf (Salisbury and Ross, 1992). For grain crops, the term 'hidden hunger' is often used because reductions in yield can occur without an outward expression of deficiency symptoms (Tisdale and Nelson, 1975). On turf, K deficiency symptoms are more difficult to identify. Likewise, the application of K to deficient turf will not generally show a visible response. The subtle responses of carbohydrate production, stress survival, and disease resistance are very difficult to discern visually.

Cation Exhange Capacity

To understand the role of K in the soil requires a knowledge of a phenomenon known as **Cation Exchange Capacity (CEC)**. The standard definition of CEC is 'the ability of the soil to exchange cations', a definition that usually requires further explanation. Cations are positively (+) charged elements that occur in the soil. Several of the cations that are important as plant nutrients or play other important roles in soil chemistry are listed in Table 1. The cations with single + charges are called monovalent cations and those with two + charges are known as divalent.

The fine particles of the soil, particularly the clays and the organic component (humus) are surrounded with negative (-) charges. These positive and negative charges function in ways similar to magnets. As like poles of magnets repel and opposite poles attract, like charges repel and opposite charges attract one another in the soil. This allows the negatively-charged soil and organic materials to hold the cations so that they can be exchanged with the root systems and be used by the plant .

The units of the CEC test are milliequivalents (meq.)/100 grams of soil. One millequivalent is equal to $6 \text{ X } 10^{20}$ (a 6 with 20 zeroes behind it). Even 1 meq/100 g of soil is a lot of negative charges, although a CEC of 1 would be considered to be very low. A knowledge of relative CEC numbers for various soil types can provide useful information on how soils should be managed (Table 2).

Sands are very low in CEC and have a much lower ability to hold and exchange cations, such as K+, than do clays. Clays, however, readily compact and do not provide a suitable media for the growth of turf on areas that receive heavy traffic such as golf course greens and athletic fields. In turf management, sands are generally used to construct the most heavily trafficked areas. To help increase the CEC, as well as the water-holding capacity, of the sand, organic matter is usually added to the media during construction. While this is an improvement, sandy media, such as a modern sand green or sand-based athletic field, is still likely to have a very low CEC.

The CEC has a major effect on how fer-

TABLE 1.

CATIONS THAT PLAY AN IMPORTANT ROLE IN SOIL CHEMISTRY.

ELEMENT	CATION
HYDROGEN	H^+
CALCIUM	Ca^{++}
MAGNESIUM	Mg^{++}
POTASSIUM	K^+
SODIUM	Na^+
AMMONIUM	NH_4^+

TABLE 2.

THE CATION EXCHANGE CAPACITY OF SOILS AND SOIL COMPONENTS.

SOIL TYPE OR COMPONENT	MEQ/100 G
SAND	>1 - 6
CLAY	80 - 120
ORGANIC MATTER	150 - 500
CLAY LOAM SOIL	25 - 30
SAND GREEN	>1 - 14

tilization is conducted. The CEC of a fertile clay loam soil, such as found in agricultural regions, will range from 25 to 30 meq/100 g. A soil such as this has sufficient CEC sites that cations like K+ can be applied in larger quantities to build-up available levels. Low CEC sands, however, present a different problem. They have far fewer CEC sites and are not capable of holding as much K as the clay loam soil. Soil tests on these sandy soils will often show very low levels of extractable K. Attempts to build up K levels on these soils are unlikely to be successful and may even result in other nutritional imbalances as will be discussed later.

The CEC is not a measure of soil fertility, but of "potential" soil fertility. It measures the number of negative charges only. Other soil testing procedures must be conducted to determine how much of each element is available in the soil.

Potassium Fertilization

Potassium recommendations for turf have changed considerably in the last two decades. A turf fertilizer analysis such as 20-3-3 was common only a few years ago. Modern fertilizer analyses are more in the range of 20-3-15, or even 30-0-30. Supplemental applications of potassium sulfate (0-0-50) are also quite common on many golf courses. What has changed during that time, is our understanding of turf response to K.

Soil test interpretations traditionally were borrowed from other crops where the primary goal of K fertilization is plant yield. Potassium plays an important role in plant growth, but it also plays very important roles in stress tolerance (Sandburg and Nus, 1990). As mentioned earlier, the ability of creeping bentgrass to survive high temperature stress, the ability of perennial ryegrass to survive cold winters, the ability of a bermudagrass green to tolerate wear stress, and many other things related to the plant's ability to tolerate stress are affected by K. Maximum tissue production is reached at lower levels of available K than are some of these stress related responses.

In turf management, the goal is not maximum tissue production, but the maintenance of a quality turf area that is capable of surviving stress conditions. Soil test laboratories that interpret tests on yield response data borrowed from other crops will generally underestimate the amount of K needed by turf.

Table 3 includes ranges of extractable K for turf. These are considerably higher than those used for many other crops (Christians, 1993). Exactly where these levels should be is somewhat controversial. While yield is easy to measure, stress-related responses are much more difficult to observe and to document. Some feel that the ranges should be higher, while others feel that they should be lower. These ranges are the opinion of this author. They are much closer to the needs of turf than are those currently used by many testing laboratories, but they may change with time as more data on turf response to K are collected.

Note that the K levels are listed in both ppm and pounds/acre (lb/A). The way of expressing K test levels may vary among laboratories. Some express the results in lb/A of available nutrients. Others use parts per million (ppm), where one ppm is equiv-

TABLE 3.

POTASSIUM TEST LEVELS RECOMMENDED FOR TURF.

PPM		LB/A
0-40	VERY LOW	0-80
41-175	LOW	81-350
175-250	ADEQUATE	350-500
250-	HIGH	500-

alent to one lb. of available nutrient per million pounds of soil. Soil tests in the U.S. are traditionally based on the 'acre furrow slice,' the soil in the upper six to seven inches of the profile. This term originated in the early days of soil test development. It relates to the depth of soil turned by a standard plow. This amount of soil is considered to weigh 2,000,000 pounds. Two pounds per acre is equivalent to two parts per two million or one ppm, and ppm will always be one-half of the lbs/A. A soil test of 20 ppm and 40 lbs/acre are equivalent. When interpreting soil tests, be sure to identify whether the values are in lbs/A or ppm.

There is a tendency among some turf managers to take this idea to extremes by applying very high levels of K and very low levels of N. Some turf managers now report applying N levels as low as 1 lb./1000 ft^2 and K levels as high as 8 lbs./1000 ft^2 per season. Remember that K is a cation. On soils with higher cation exchange capacities (25 to 30meq/100 g) increasing levels of K may be practical. On low CEC soils, such as sand greens on golf courses and sand-based athletic fields, excess levels of K have the potential of saturating CEC sites at the expense of other essential cations such as Ca^{++} and Mg^{++}. By default, any CEC site that has a K^+ attached to it does not have one of the other cations. On these sandy soils, **spoon feeding** K to the plant as it needs it is a better approach.

Spoon Feeding Programs for Turf

In a spoon feeding program, the fertilizer is applied in the liquid form. The amounts of materials applied in each treatment are so low that application in the dry form would not be possible on close mown turf. Attempts to do so generally result in a turf speckled with green dots. The advantage of a spoon feeding program is its flexibility. It can be adjusted to meet exactly the needs of the area being treated.

There are no effective soil tests for N and application rates are based on the color of the turf and the amount of clippings in the catch basket. Nitrogen rates in a spoon feeding program are usually in the range of 0.1 to 0.25 lbs. N/1000 ft^2/application. The amount will vary with rainfall, soil type, temperature, etc. and the amount should be adjusted to meet local conditions. Applications are made on 7 to 14 days intervals depending on the needs of the grass.

The other nutrients in the solution and their amounts will depend on a careful evaluation of the soil test and perhaps on turf tissue tests. If P is needed, available phosphoric acid (P_2O_5) should equal approximately one third the amount of N. If a liquid fertilizer base mix is 12 percent N, approximately 4 percent P_2O_5 should be applied. If 0.25 lbs N is applied per 1000 ft^2, 0.08 lbs P_2O_5 should be included. No P will be needed in many situations. In that case, none should be included in the solution.

The amount of K_2O included in the solution will again vary with soil test. Where K levels are sufficient, which will be rare on a sandy soils, no K should be included in the mix. A more likely situation will be that K soil test levels are very low. Liquid fertilizer solutions are limited by the solubility of K in the solution and liquids are often in the range of 3 to 4 percent K_2O. Where dry materials designed to be dissolved in water are used, K_2O levels can be higher. Soluble dry products with analyses like 23-0-23 or 23-8-16 are readily available. They generally must be applied with a recirculating sprayer to keep the materials in solution and suspension.

Other nutrients included in the solution will vary widely depending on soil conditions. This again is the advantage of a spoon feeding program. In a low pH and low

CEC soil where Mg++ may be deficient, Epsom salts or some other source of Mg^{++} may be included. The amount will vary with conditions but a target rate would be in the range of 0.02 to 0.1 lb Mg^{++}/1000 ft^2.

Iron will be the key material on high pH soils. There are several good Fe sources available. The label should be followed carefully with each product. Application rates are generally in the range of 2 to 3 oz/1000 ft^2.

Other elements like Mn, molybdenum (Mo), zinc (Zn), and copper (Cu) will rarely be deficient but situations may exist where they will be needed. These materials can usually be provided by micronutrient packages that can be added to the solution and provide trace amounts of these elements. They add very little to the cost of the application and they are usually included in small amounts as insurance against deficiencies. They should be used as directed on the label.

Supplemental K Applications

In situations where supplemental applications of K in addition to those provided by the spoon feeding program become necessary, there are more concentrated K containing fertilizers that can be used. Potassium sulfate (K_2SO_4) with an analysis of 0-0-50 is one of the most widely used. Potassium chloride (KCl) with analysis of 0-0-60 and potassium nitrate (KNO_3) with an analysis of 13-0-36 are also available.

Potassium sulfate has a lower burn potential than the other two materials. In cool weather, it can be applied at rates of 1 lb. K_2O/1000 ft^2 /application with little concern over burning. The other two materials can be applied at 0.5 to 1.0 lb. K_2O/1000 ft^2. They should be watered in shortly after application. Remember that the potassium nitrate will supply 0.36 lbs. of N for every lb. of K_2O. This should be taken into account when determining the N need of the turf.

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Literature Cited

Parts of the text are used with permission from a new text book titled 'Fundamentals of Turfgrass Management' by Nick Christians. The book will be available in April, 1998 from Ann Arbor Press, 121 South Main St., Chelseas, MI 48118. phone 313-475-8852. ISBN 1-57504-051-4.

Christians, N.E. 1977. The effect of nitrogen, phosphorus, and potassium on the quality and chemical composition of merion Kentucky bluegrass and penncross creeping bentgrass. MS thesis. Ohio State University. p. 97.

Christians, N.E. 1979. The interrelationships of nutrient elements and their effects on the growth and quality of turfgrasses. Ph.D. Dissertation. Ohio State University. p. 80-93.

Christians, N.E. 1993. The fundamentals of Soil Testing. Golf Course Management. June. p. 88.

Christians, N.E. 1996 a. Phosphorus nutrition of turfgrass. Golf Course Mgt. 64(2):54-57.

Christians, N. E. Martin, D. P., and J. F. Wilkinson. 1979. Nitrogen, phosphorus, and potassium effects on quality and growth of Kentucky bluegrass and creeping bentgrass. Agron. J. 71:564-567.

DiPaola, J. M. and J. B. Beard. 1977. The root growth of St. Augustinegrass <italic>(Stenotaphrum secudndatu</italic>m) during establishment from sod and subsequent drought as influenced by potassium. Agron. Abs. p. 110.

Gilbert, W. B. and D. L. Davis. 1971. Influence of fertility ratios on winter hardiness of bermudagrass. Agron. J. 63:591-593.

Goss, R. L. and C. J. Gould. 1967. Some interrelationships between fertility levels and Ophiobulus Patch disease in turfgrass. Agron. J. 59:149-151.

Marschner, H. 1995. Mineral nutrition of higher plants. 2n ed. Academic Press, Harcourt Brace & Co. p. 299-312.

Salisbury, F. B. and C. W. Ross. 1992. Plant Physiology, 4th edition. Wadsworth Publishing Co. p. 131.

Taiz, L. and E. Zeigler. 1991. Plant physiology. Benjamine/Cummings Publishing Co. p. 114.

Tisdale, S. L. and JW. L. Nelson. 1975. Soil fertility and fertilizers 3rd ed. Macmillan, New York. p. 66-80.

Tisdale, S.L., W.L. Nelson, J.D. Beaton, and J.L. Havlin. 1993. Soil fertility and fertilizers. Macmillan Publishing Co. p. 51-52.

Journal Abstracts

American Entomologist
Extension Entomology: A Personal Perspective; Past, Present and Future Challenges *Author: R. L. Bradenburg, Professor of Entomology, North Carolina State University, Raleigh, NC.*

AFTER 17 YEARS as an extension entomologist, Brandenburg reflects on the direction and focus of the Cooperative Extension Service. Extension personnel today have to deal with issues associated with integrated pest control, low-input sustainable agriculture, chemophobia, reductions in funding, downsizing, justifying their existence and expanding educational programs to urban audiences. Regardless, Brandenburg believes that existing opportunities exist for Extension and the book is far from closed.

Extension can help meet the needs of society through partnerships with other agencies and industries, requiring more linkages than before.

The author makes observations on four topics:

1) Extension's handling of controversial topics;
2) Extension's value in an increasingly urbanized world;
3) Extension's ability to align technological transfer with the needs of end users;
4) Extension's initiative to provide education about certain key issues to improve its leadership role and support its claim that it is an invaluable resource.

Handling of Controversy

Recently, the public has expressed concern about pesticide use in urban and agricultural environments. We, in Extension, have invested much time dealing with this issue. Unfortunately, much of our effort has focused upon minimizing the risks associated with pesticides by comparing the low number of pesticide-related deaths caused by other, more common risks. Increasing the public's awareness of other dangers does not necessarily lessen their concerns about pesticides. Several authors have discussed our general lack of appreciation for and understanding of the need for appropriate communication skills to enlighten the public about risks associated with the pesticide issue. Because extension specialists usually focus on technological transfer, our expertise in dealing with emotional issues, such as pesticide use, is often limited. We must improve out risk-communication skills if we expect to establish our credibility with the public.

Value in an Urbanized World

Extension's value is not evident to the general public because it addresses the public's needs indirectly toward producers, and our role is not clearly understood by most urban audiences. In fact, our role is not always evident to the agricultural community. Many readers of farm magazines do not realize that university specialists write or are the source for many articles in farm magazines.

Extension can help meet the needs of society through partnerships with other agencies and industries, requiring more linkages than ever before.

As a member of a team, Extension is challenged to maintain its visibility, particularly to appointed agricultural officials and legislators who have advocated severe cuts or elimination of Extension.

Currently we are putting more effort into communicating our relevance to the American public and increasing our grassroots support through greater emphasis on urban issues. Extension attempts to document its benefit to society. However, the impact of our educational efforts and the information we provide often is difficult and costly to evaluate. It is important for those of us in Extension to realize that we are in a country in which only a portion of our population has any connection to farming. As the percentage of the general public involved in agriculture decreases, the challenge becomes educating an unfamiliar urban public about the value of Extension.

Meeting End User Needs

My greatest challenge has been whether farmers will accept the content of teducational programs for IPM. Perhaps, I and other specialists do not understand completely the factors that compete for a grower's time, energy, and resources. I believe that IPM tactics would be embraced more completely under a different scenario.

Extension entomologists often are the facilitators between those who develop the concepts of IPM and the pragmatic individuals who apply them.

We structure educational programs that fit the concept of IPM but do not meet the client's needs. Such programs might not fit the farming situation and might be incompatible with profitable cultural practices We should deliver education about technologies to growers with a sound, logical, and open-minded approach

Key Issue Education

Extension must take the initiative to educate our clients about key agricultural issues. Extension entomologists must incorporate IPM with sustainable agriculture. New technologies, such as transgenic plants, insect growth regulators, and reduced risk pesticides, add a sense of excitement to our educational opportunities. We should establish guidelines and suggest rules rather than wait for individuals less familiar with agriculture to do so. No other group has the infrastructure, expertise, unbiased perspective, and trust to conduct this mission.

Extension specialists should voice their opinions about prescriptive pesticide use and determine how much visibility we want as this issue is debated. Extension assumed a similar responsibility in many states when we accepted leadersip for the pesticide certification training program.

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