ture, may have a profound effect on turfgrass seed germination under saline conditions. Understanding the interaction of temperature and salinity on turfgrass germination, and its variation among species would aid in optimizing seeding time under salinity conditions.

We investigated the interactive effects of temperature and salinity on germination of NuStar Kentucky bluegrass in comparison with Rebel 3D tall fescue, a more salt-tolerant species.

Kentucky bluegrass and tall fescue were seeded under a gradient of salinity and under various temperature regimes in growth chambers. Seed germination was counted daily to calculate the germination speed. Total germination percentage was determined 28 days after treatments. Germination speed and percentage were compared to surface regression models to determine

Kentucky bluegrass seeds need to be seeded in a narrow temperature window to achieve acceptable germination under saline conditions.

the temperature window to achieve 50-percent germination for each salinity treatment.

As the salinity increased, the temperature window for germination narrowed. This trend was more pronounced in Kentucky bluegrass than tall fescue (Table 1). Kentucky bluegrass seeds, emerging slowly and exhibiting great sensitivity to salinity during germination, need to be seeded in a narrow temperature window to achieve acceptable germination under saline conditions.

For example, under a ratio of 16 hours of warm temperatures to 8 hours of cool temperatures (encompassing one full day) and in the absence of salinity, the temperature window to achieve 50-percent germination of Kentucky bluegrass was 57 degrees F to 84 degrees F (Table 1). As salinity increased to 4 mmho/cm, the window narrowed to 65 degrees F to 80 degrees F. At 6 mmho/cm, the window narrowed to 71 degrees F to 74 degrees F for Nustar Kentucky bluegrass.

For tall fescue, the temperature window to achieve 50 percent germination only narrowed from 52 degees F to 105 degrees F to 51 degrees F to 100 degrees F as salinity increased from .3 to 6 mmho/cm. Compared to tall fescue, Kentucky bluegrass has a much narrower window within which to achieve successful germination under saline conditions.

TABLE 1

Temperature window that resulted in 50 percent germination

Salinity level	Kentucky bluegrass	Tall fescue
0.3 mmho/cm	57-84 °F	52-105 °F
4.0 mmho/cm	65-80 °F	51-102 °F
6.0 mmho/cm	71-74 °F	51-100 °F

Predictive models, such as those generated in our study (Qian and Suplick, 2001), may be used in conjunction with long-term local climatic data to optimize germination. For example, assuming a soil salinity level of 3 to 4 mmho/cm and examining 50-year mean temperature data for this area of northern Colorado, the appropriate seeding times for Nustar Kentucky bluegrass would generally be the first week of June and the last two weeks of August.

Additionally, cultural practices such as irrigation and use of artificial cover may be used to keep soil-surface temperatures at optimum levels to maximize germination.

To confirm our lab results, we conducted a field experiment. Bluegrass and fescue were seeded in field plots with two different soil salinity levels [electrical conductivity of the saturated soil paste was 4 mmho/cm and .8 mmho/cm (control), respectively].

Kentucky bluegrass and tall fescue were seeded in September and May. Establishment was rated eight weeks after seeding. We observed that establishing Kentucky bluegrass in mid-September in northern Colorado, under saline field conditions, was 14 percent lower than late-May seeding. In contrast, tall fescue appeared unaffected by seeding date (Fig. 1)

Temperatures and stress

Environmental factors, including aeration, water present, soil type, temperature, relative humidity, nutrient balance and the length of exposure to salt stress all affect the salt tolerance of established bluegrass.

We conducted two identical experiments in a greenhouse using hydroponics. Fully established

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TABLE 2

Salinity levels that caused 25 percent shoot and root growth reduction and percent leaf firing (at 6 mmho/cm) of nine Kentucky bluegrasses in two greenhouse experiments with different temperatures

	Mean min temp. (°F)	Mean max temp. (°F)	$EC_{25\% root}$* (mmho/cm)	$EC_{25\% shoot}$** (mmho/cm)	Leaf firing***(%) (damage)
Experiment I	70.7	81.5a	7.4a	5.2	15.9a
Experiment II	72.5	92.2b	3.4b	6.7	33.8b

*$EC_{25\% root}$, electrical conductivity of 25% root growth reduction

**$EC_{25\% shoot}$, electrical conductivity of 25% shoot growth reduction

***Leaf firing percentage was determined by visually estimating the total percentage of chlorotic turf canopy area

Continued from page 61
Kentucky bluegrasses were subjected to constant salinity treatments at the control plot and at the other plots at 3, 5, 7, and 9 mmho/cm levels for 10 weeks to determine tolerance to salt stress (Suplick et al., 2002). Accumulated clippings were weighed, and total root weights were taken at the end of the experiment.

Leaf firing percentage was determined for each cultivar under each salinity treatment by visually estimating the total percentage of chlorotic turf.

Experimental procedures in Experiment I and II were the same, but Experiment I was conducted during winter and spring. Experiment II was conducted throughout summer into fall when daily warm temperatures were higher. Their duration prolonged creating an environment less favorable to Kentucky bluegrass growth (Table 2). We found that the magnitude of salinity stress were significantly differerent between the two experiments. Compared to Experiment I, average leaf firing across cultivars was much higher in Experiment II. The salinity level that caused 25-percent root growth reduction was 7.4 in Experiment I and 3.4 in Experiment II, although the temperature that resulted in 25-percent shoot growth reduction did not follow the same trend.

To confirm the lab results, researchers conducted a field experiment comparing bluegrass and fescue.

The higher percentage of leaf firing and low salinity level that cause 25 percent root growth reduction indicated that bluegrass is more sensitive to salinity under summer temperatures. Summer conditions will increase Kentucky bluegrass susceptibility to salt stress.

Our findings with respect to the effect of high temperature conditions on the expression of salinity tolerance suggested the importance of temperature in evaluating the salt tolerance of bluegrass. Summer heat stress can escalate salinity damage to the root system of Kentucky bluegrass. Management strategies can be critical in reducing salt accumulation in the root-zone.

Water injection, which minimizes surface disturbance but boosts infiltration and reduces salt built up, would also likely mitigate salinity problems in cool-season turf.

Cultivar differences

Although Kentucky bluegrass is generally ranked as a salt-sensitive turfgrass, variability in salt tolerance has been shown to exist among cultivars (Qian et al., 2001).

Horst and Taylor (1983) examined germination and initial growth in saline solution culture, and reported significant differences in salt tolerance during germination and initial growth among 44 Kentucky bluegrass cultivars. Rose-Fricker and Wipff (2001) studied relative salinity tolerance of many bluegrass cultivars and also found significant differences.

We have conducted salinity screening studies. Cultivars of Kentucky bluegrass were sodded into shallow pots containing coarse sand. Pots were suspended over tanks containing 32 liters of con-

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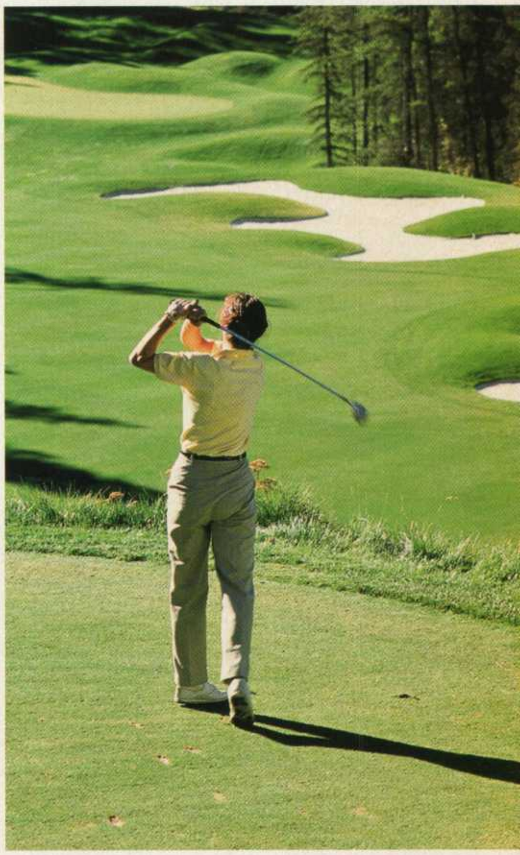
Granular Postemergent Broadleaf Herbicides

Granular postemergent herbicides from The Andersons incorporate all the latest chemistries that have been developed for postemergent weed control. Granular postemergent products are excellent for areas that are difficult to spray along with windy or wet conditions. In addition granulars are excellent for spot treating or when spraying is environmentally risky. The granular postemergent products offered by the Andersons are featured in the chart below

The Andersons ability to formulate small particle products as noted in the chart, deliver up to four times the particles per square inch compared to larger particle-size formulations (SGN240) with the same percentage of active ingredient. This in turn will provide better efficacy and a wider spectrum of weed control. Fertilizers with postemergent combination products allows turf managers to more efficiently utilize key labor resources by taking care of turf nutrition and weed pests in one operation.



Product	Active Ingredient	Key Feature & Benefits
18-5-9 with Millennium Ultra Herbicide	2,4-D Clopyralid Dicamba	■ Both foliar & root absorbed ■ Effective on wet and dry turf ■ Excellent against hard to control weeds like clover ■ Low usage rates ■ SGN150 — excellent coverage ■ Contains NS-52 slow release nitrogen
16-4-8 with Millennium Ultra Herbicide	2,4-D Clopyralid Dicamba	■ Both foliar & root absorbed ■ Effective on wet and dry turf ■ Excellent against hard to control weeds like clover ■ Low usage rates ■ SGN150 — excellent coverage ■ Contains NS-52 slow release nitrogen
21-3-20 Fertilizer Plus Dicot Weed Control III	2,4-D Mecoprop Dicamba	■ Homogenous product ■ Apply to wet turf for best results ■ Fine granules for excellent coverage and weed control ■ Contains methylene urea slow release nitrogen
20-4-10 with Trimec 20-3-3 with Trimec 22-2-4 with Trimec	2,4-D MCPP Dicamba	■ Excellent broad spectrum weed control ■ Both foliar and root absorbed ■ SGN145 for excellent weed coverage ■ Contains NS-52 slow release nitrogen
20-2-6 with 2,4-D & MCPP	2,4-D MCPP	■ Sugar grade consistency to provide maximum foliar contact ■ SGN145 for excellent weed coverage ■ Contains NS-52 slow release nitrogen
K-O-G Weed Control	Dicamba	■ Highly effective against resistant weeds like knotweed, wild onion and wild garlic ■ Label for use on bentgrass greens ■ SNG100 for excellent coverage
29-3-4 with St. Augustine Weed Control	Atrazine	■ Only combination homogenous fertilizer plus post and preemergent herbicide ■ Use on newly sprigged or established St. Augustine; Zoysiagrass; centipedegrass and carpetgrass ■ Contains methylene urea slow release fertilizer ■ SNG125 for excellent coverage

Article contributed by Darrin Johnson, Territory Manager, The Andersons Inc.

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TABLE 3

Relative salinity tolerance of Kentucky bluegrass cultivars

Good	Fair	Poor
Moonlight	Nuglade	Kenblue
Northstar	Midnight	Park
SR-2000	Blacksburg	Huntsville
Limousine	Abbey	Challenge
Eclipse	Award	Livingston

Continued from page 62

stantly aerated and balanced nutrient solution. The pots had coarse nylon-screen bottoms, allowing root systems to grow into the nutrient solutions.

Different Kentucky bluegrass cultivars were subjected to constant salinity treatment to determine tolerance to salt stress. Table 3 lists the cultivars tested and their relative salinity tolerance. We have found few newly released cultivars exhibited greater salinity tolerance.

If saline conditions are expected in the soil or irrigation water, use of a more salt-tolerant Kentucky bluegrass may mean the difference between success and failure. Nevertheless, Kentucky bluegrass is still salt-sensitive compared with other species such as tall fescue and creeping bentgrass (Carrow and Duncan, 1998). Selecting salt-tolerant Kentucky bluegrass cultivars is beneficial for sites where salinity level is marginally high.

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TURFGRASS TRENDS

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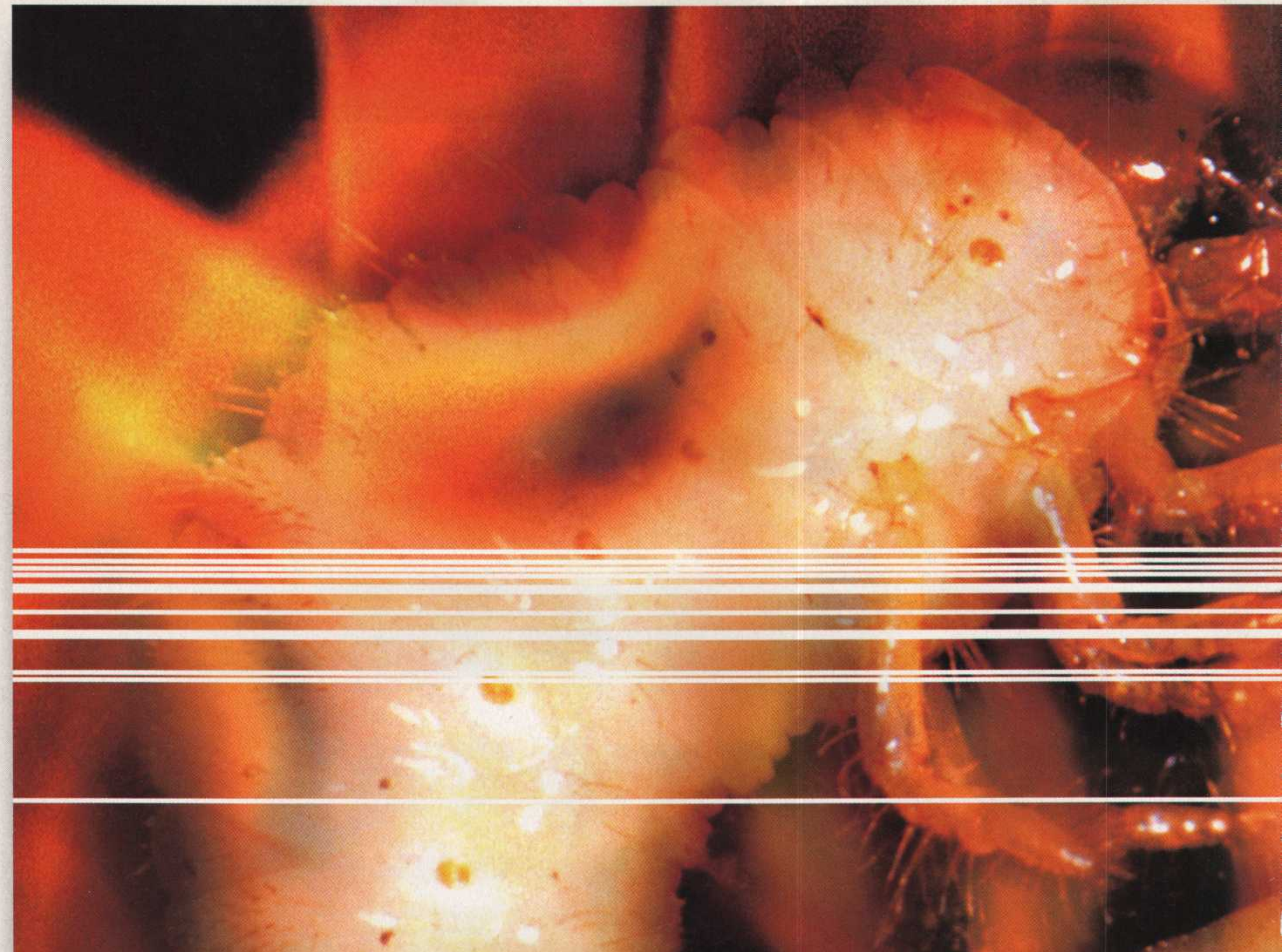

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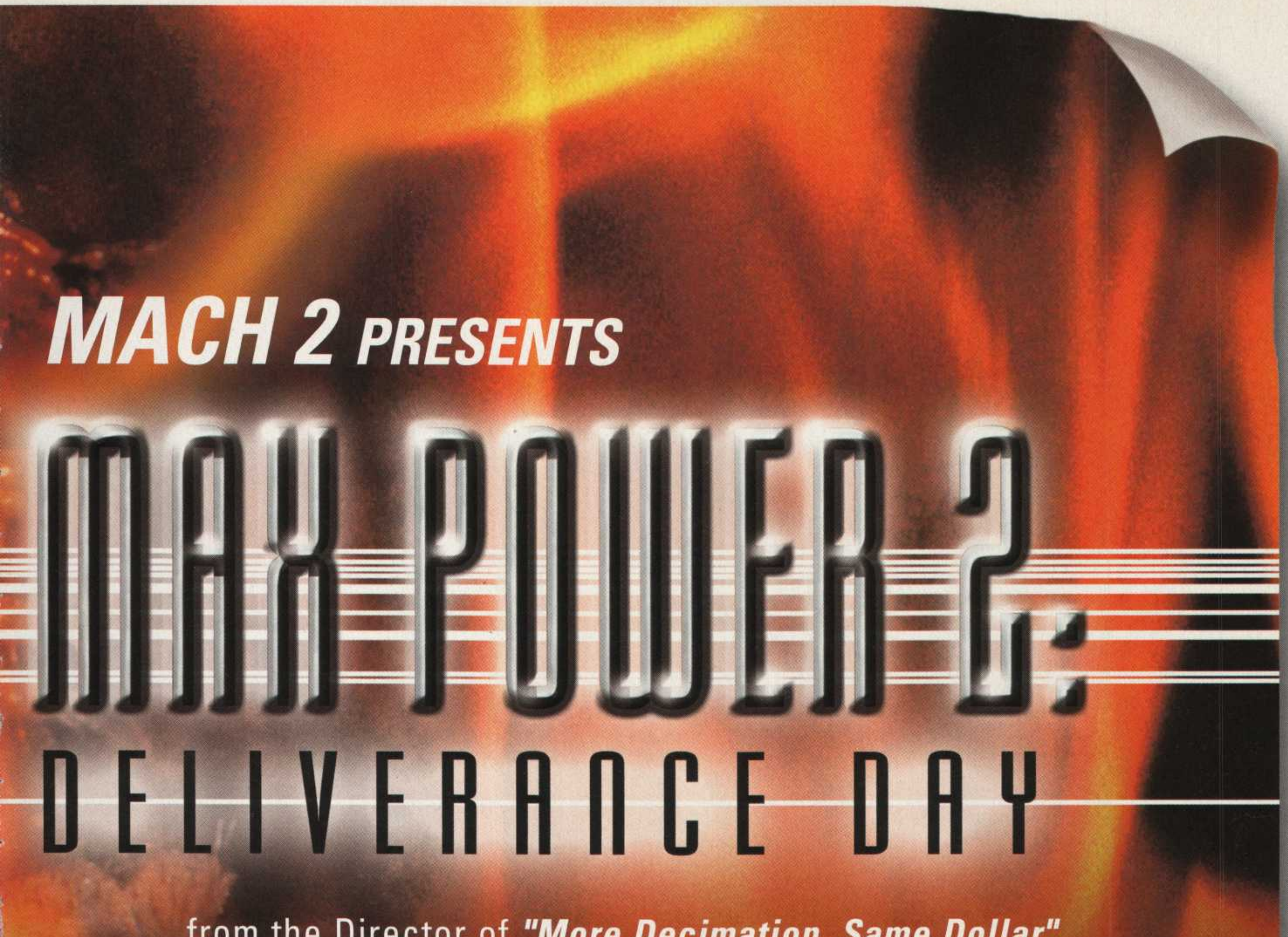
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INSIDE

The Fringe

SPECIAL SECTION: THE PUTTING SURFACE

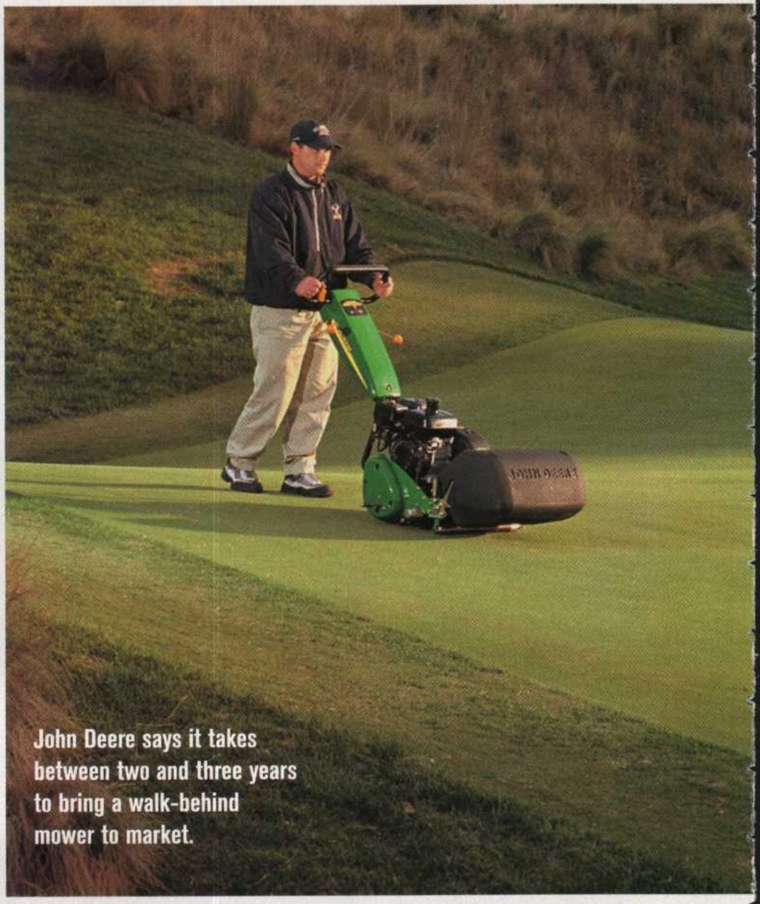
In this issue, *Golfdom* reports on the putting surface, from moss control to massaging greens.

MIKE KLEMME

Make Mine a (Walk-Behind)

The Big Three manufacturers discuss the time and effort (but not the dollars) they spend to bring new walk-behind machines to market

By Frank H. Andorka Jr., Managing Editor


John Deere says it takes between two and three years to bring a walk-behind mower to market.

An indication of how competitive the walk-behind greens mower market is that none of the Big Three manufacturers will reveal how much it costs them in research and development to bring one to market.

"I don't think I want to talk about those numbers," says Helmut Ullrich, senior marketing manager for The Toro Co.'s Greensmaster products. "The market's more competitive than ever."

"We're not at liberty to disclose specific numbers," says Jon Gorman, group product and brand marketing manager for John Deere Co.

"We hold those numbers very closely," says Shawn Daly, product manager for Jacobsen. "I'm sure you can understand why."

What is becoming increasingly clear is that the demand for high-quality turf maintenance has fueled a demand for walk-behind greens mowers. Superintendents like them because they offer a better quality of cut than the average triplex. In turn, there's mounting pressure on the manufacturers to put new products on the market as quickly as possible. But if manufacturers produce them too fast, they may contain mechanical defects, Those problems can alienate superintendents who value reliability above all else.

"You don't want to bring a product to market just to say you did it," Daly says. "You want to make sure you do it right. After all, the reputation of your company is at stake. If you lose that in this segment, you lose a lot."

What's driving the competition

While the mower business has always been competitive, it's become more intense in the past couple of years because the number of newly built courses has plummeted to 248 in 2002, according to a National Golf Foundation study. That's half of what it was just four years ago, and the slide is expected to continue.

"It requires you to take a look at your existing walk-behind products and whatever new ones you want to put in the pipeline," Daly says. "You need to meet your customers' needs exactly because you can't afford to miss in a tight market."

Ullrich says new grass cultivars have also fueled the growth in the walk-behind mower market. Some dwarf varieties allow superintendents to cut the greens at lower heights, and that's required a rethinking of the manufacturing approach to mowers.

"We've got a model that can go down to one-sixteenth of an inch," Ullrich says. "That was unheard of a few years ago. But the market demanded it, so we met its expectations."

Tracy Lanier, Deere's product manager for golf and turf, says newly designed golf courses also have more contoured greens than older courses, and those new contours require that mowers be lighter and smaller in footprint. Walk-behind mowers fit the bill for those conditions.

But in the end, nothing has driven superintendents to walk-behind mowers like the increased demands of