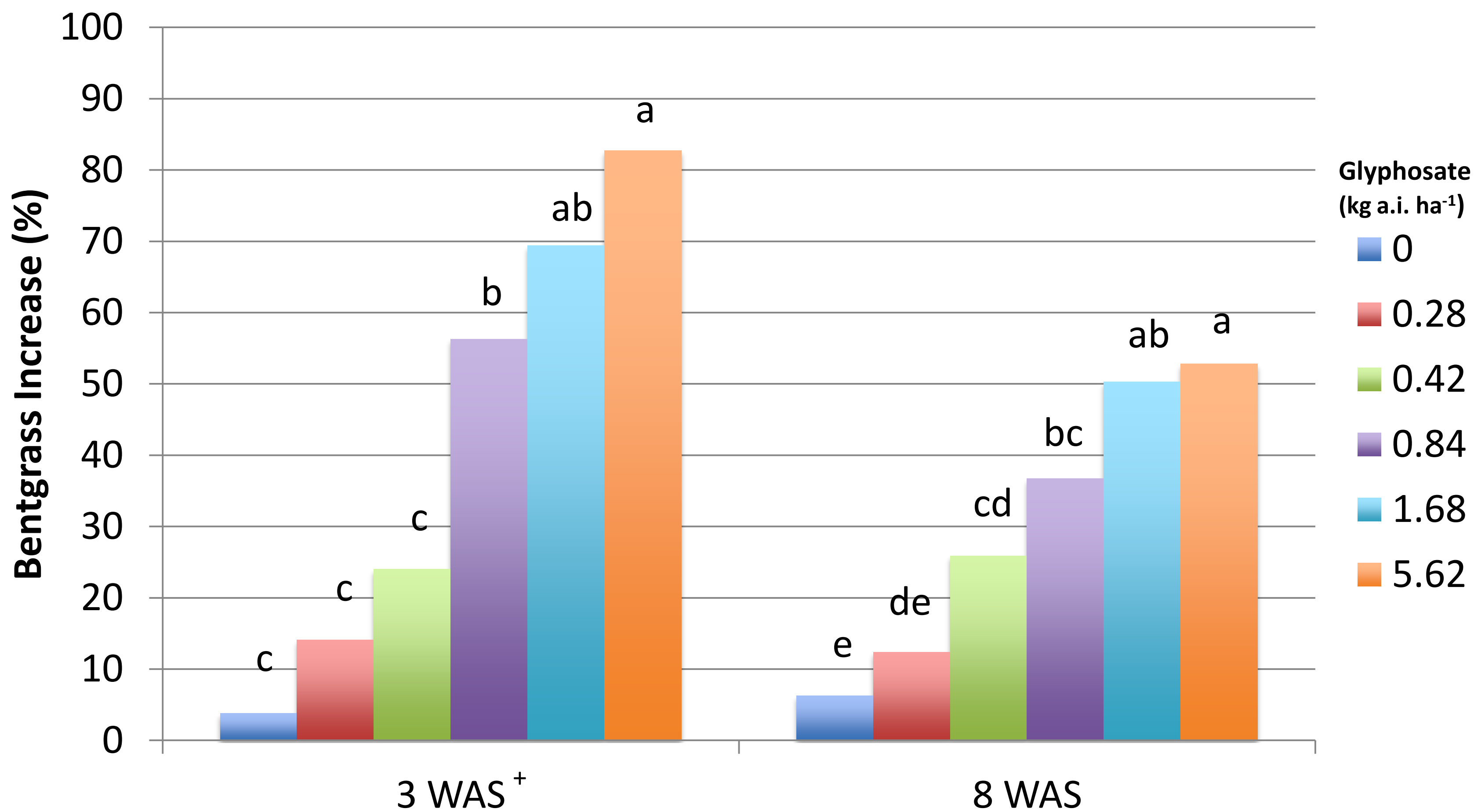
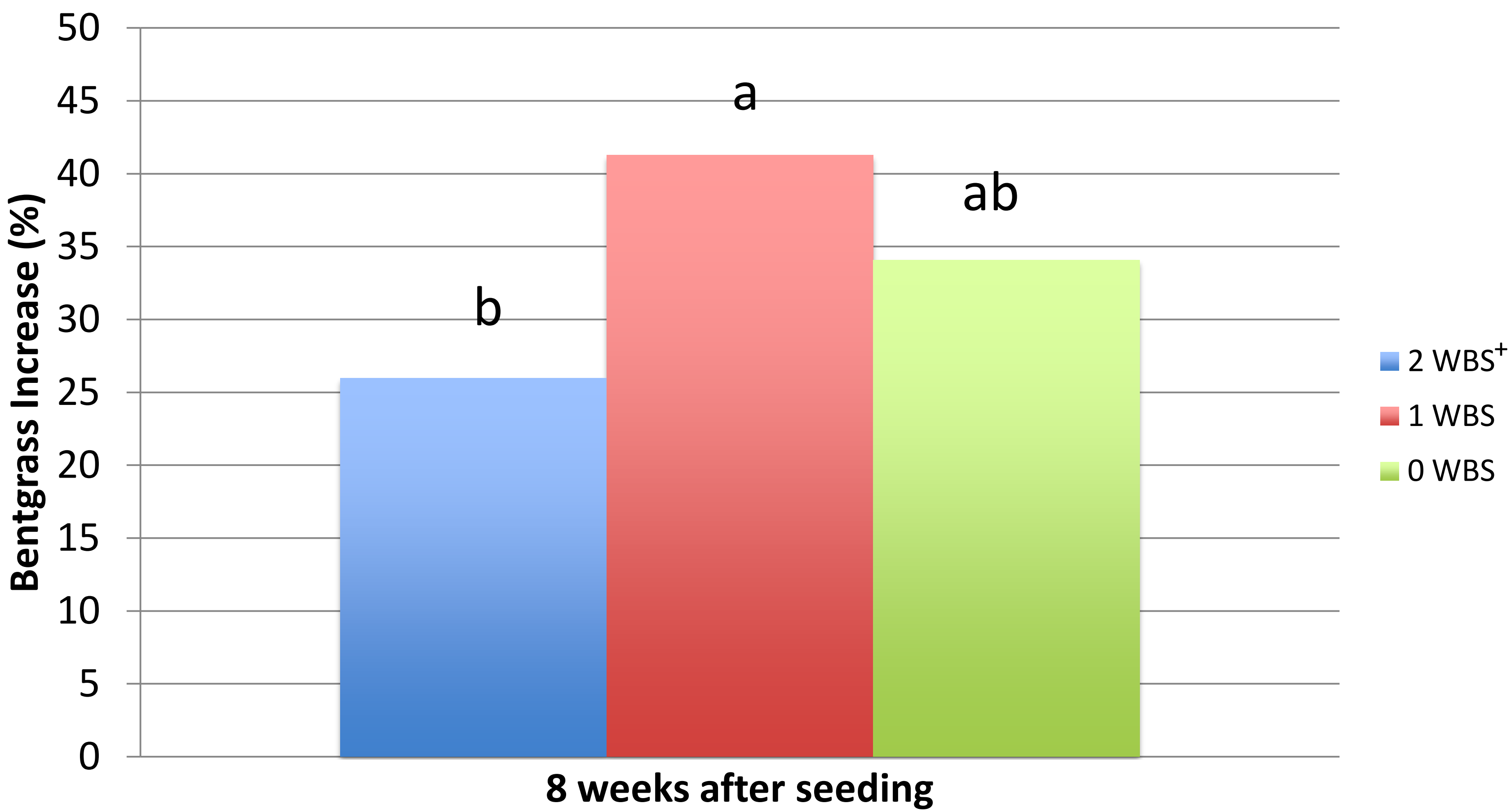
Bentgrass Increase as Affected by Application Rate



+ weeks after seeding

Bentgrass Increase as Affected by Application Time



+weeks before seeding

Accepted for publication 7 November 2011. Published 27 January 2012.

Establishment of Creeping Bentgrass in Annual Bluegrass Fairways Using Glyphosate and Interseeding

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Bauer, S., Horgan, B. P., Watkins, E., Hathaway, A., Calhoun, R., and Frank, K. 2012. Establishment of creeping bentgrass in annual bluegrass fairways using glyphosate and interseeding. Online. Applied Turfgrass Science doi:10.1094/ATS-2012-0127-01-RS.

Abstract
Creeping bentgrass (*Agrostis stolonifera* L.) is a highly desirable cool-season turfgrass that produces a quality golf playing surface. Golf courses that are established with creeping bentgrass are often invaded by annual bluegrass (*Poa annua* L.) and other turfgrass species over a relatively short period of time. Interseeding and non-selective herbicides, like glyphosate, have often been used to increase creeping bentgrass on golf course fairways. The objective of this research was to determine the most effective glyphosate rate and application timing necessary to quickly increase creeping bentgrass populations through interseeding into predominantly annual bluegrass fairways, while keeping the golf course open for play. This study was conducted from July to October 2010 at the University of Minnesota Les Bolstad Golf Course (St. Paul, MN) and Michigan State University Hancock Turfgrass Research Center (East Lansing, MI). Glyphosate was applied to plots at 14, 7, or 0 days before seeding (DBS) at rates of 0, 0.28, 0.42, 0.84, 1.68, or 5.62 kg ai/ha (0, 0.25, 0.37, 0.75, 1.5, or 5.0 lb ai/acre). 'T-1' creeping bentgrass was slit-seeded into the entire plot area in two directions at a total rate of 73.2 kg/ha. Higher glyphosate rates provided the greatest increase in bentgrass abundance at both locations. The greatest bentgrass population increase (54%) was observed in Michigan for the 5.62 kg ai/ha (5.0 lb ai/acre) treated plots at 8 weeks after seeding (WAS). The glyphosate applications at 7 and 0 DBS had the longest duration of acceptable turf quality and the greatest increase in creeping bentgrass. Our results suggest optimal bentgrass conversion during mid-summer stress periods when interseeded at a rate of 73 kg/ha in combination with glyphosate applied between 0 and 7 DBS at 1.68 kg ai/ha (1.5 lb ai/acre) or greater.

Introduction
Fairways make up the largest portion of intensively maintained turfgrass areas on a golf course (18) and creeping bentgrass is a desirable species for use on fairways in the Midwest. Golf course fairways that are established with creeping bentgrass are often invaded by annual bluegrass, which may easily become the dominant species over time (5,7). Undesirable traits associated with annual bluegrass are a light green color, prodigious seed head production, poor environmental stress tolerance, high disease susceptibility, and lack of uniformity (14). Golf course superintendents have utilized interseeding in combination with herbicides or plant growth regulators as a means of establishing creeping bentgrass into a predominantly annual bluegrass stand. Researchers have demonstrated success with plant growth regulators for selective suppression of annual bluegrass in creeping bentgrass turf, including paclobutrazol (19,33), flurprimidol (3), ethofumesate (33), amicarbazone (21), and chlorsulfuron (12). Additionally, the herbicide bispyribac-sodium has been shown to selectively control annual bluegrass in creeping bentgrass, although

multiple applications are required (17,20). However, a gradual conversion to creeping bentgrass is only possible if creeping bentgrass populations are relatively abundant to begin with (29). If bentgrass populations are low, the use of interseeding and a non-selective herbicide may be necessary.

To avoid high temperature and drought pressures of the summer months, creeping bentgrass seed is typically sown in late summer or early fall; however, this timing might not be best when seeding into an existing stand of annual bluegrass due to competition from germination of this winter annual (26). Annual bluegrass seed germination increases in the late summer when soil temperatures fall below 21°C (10), putting tremendous pressure on newly-seeded bentgrass fairways. Bentgrass seed is able to germinate at higher temperatures than annual bluegrass (10) and annual bluegrass becomes physiologically stressed at these high temperatures after producing seed heads in the late spring (32). Murphy et al. (26) conducted a field experiment in New Jersey to determine the effect of seeding time while overseeding into a mixed annual bluegrass and creeping bentgrass putting green previously treated with glyphosate. They determined that competition from annual bluegrass (one year after seeding) is significantly reduced when seeding creeping bentgrass in June or August (80% establishment) versus September or October (50% establishment). Similarly, Henry et al. (15) attempted conversion of existing creeping bluegrass [*Poa annua* L. spp. *reptans* (Hauskins) Timm.] in a golf green situation by overseeding three varieties of creeping bentgrass and 'SR7200' velvet bentgrass (*Agrostis canina* L.) on three dates over two years without the use of non-selective herbicides. They found that conversion from creeping bluegrass to creeping bentgrass was increased when using summer seeding dates and higher density creeping bentgrass cultivars. A maximum of 72% creeping bentgrass coverage was achieved 24 months after seeding from a July seeding date, though factors such as a large bluegrass seed bank and golfer or maintenance traffic were not present in this study.

Researchers have evaluated numerous methods for opening up the turfgrass canopy to allow for seed-to-soil contact, including vertical mowing and core aeration (15,26,29), spiking (4), scalping (34) and slit-seeding (16). Dant and Christians (8) evaluated five methods for introducing glyphosate-resistant creeping bentgrass seed into a stand of 'Penncross' creeping bentgrass. Results from this study showed that surface preparation method had little to no effect on the establishment of glyphosate-resistant creeping bentgrass, indicating that the method employed is of minor importance. However, a successful establishment of bentgrass depends on the existing annual bluegrass being non-competitive, and glyphosate has been the product of choice for annual bluegrass suppression and control (28). Glyphosate is a systemic, non-selective, post-emergent herbicide that is readily phloem translocated (30). It is inactivated by soil adsorption (25) and has a low leaching and volatilization potential (11).

The objective of this study was to determine the most effective glyphosate application rate and timing necessary to increase creeping bentgrass populations while keeping predominantly annual bluegrass golf course fairways in play.

Evaluation of Glyphosate Application Timing and Rate

Research was conducted from July to October 2010 at the University of Minnesota Les Bolstad Golf Course (St. Paul, MN) and Michigan State University Hancock Turfgrass Research Facility (East Lansing, MI). The Minnesota location was established in 1929 and has since transitioned to annual bluegrass. The plots in Michigan were established in 2006 from annual bluegrass seed heads collected during mowing of an annual bluegrass stand. Minnesota was subjected to normal golf traffic and received routine fairway maintenance (12.5 mm height of cut, mowing three times per week) throughout the duration of the study, while the Michigan site was not subject to golf traffic, but did receive the same routine fairway maintenance. Soil types in Minnesota and Michigan were a Cathro Muck (organic material over loamy sediment) and Colwood-Brookston loam, respectively.

Initial turfgrass species composition was evaluated prior to initiation of the study using the grid intersect method described by Tinney et al. (31) and modified by Gaussoin and Branham (13). A 1.2 by 1.8-m PVC frame with an internal monofilament grid of 240 intersections was placed over individual plots. The turf species present under each intersection was recorded and converted to a percentage by dividing individual species counts by 240. Species compositions as averaged over the study areas at each location were: Minnesota, 99% annual bluegrass and 1% perennial ryegrass (*Lolium perenne* L.); Michigan, 96% annual bluegrass and 4% creeping bentgrass. Kentucky bluegrass (*Poa pratensis* L.) abundance was less than 1% at both locations.

Treatment factors included glyphosate rate and application timing relative to date of seeding. The glyphosate product used was Razor Pro (Nufarm Americas Inc., Burr Ridge, IL), containing 41% glyphosate in the form of isopropylamine salt. Glyphosate applications were applied with a CO_2 pressurized sprayer calibrated to deliver 7.5 liters/100 m^2. Application rates were 0, 0.28, 0.42, 0.84, 1.68, and 5.62 kg ai/ha (0, 0.25, 0.37, 0.75, 1.5, or 5.0 lb ai/acre), applied either 14, 7, or 0 days before seeding (DBS). Seeding dates were 15 and 20 July 2010 for Minnesota and Michigan, respectively. Seeding was conducted using a Turfco Triwave (Turfo Manufacturing Co., Minneapolis, MN) slit-seeder calibrated to deliver a total of 73 kg/ha 'T-1' creeping bentgrass seed to the study area by seeding in two directions on 45° angles from a fixed line. Seeder depth was set to penetrate the surface to the thatch-soil interface, not exceeding 12.5 mm. Subdue GR (Syngenta Crop Protection Inc, Greensboro, NC), 1% mefanoxam, was applied and watered in with 4 mm of water on the day of seeding and 2 weeks after seeding (WAS) to prevent *Pythium*. A starter fertilizer was applied at a rate of 24.5 kg N/ha, 49 kg P_2O_5ha, and 24.5 kg K_2O/ha on the day of seeding and 3 WAS. Subsequent fertilizer applications of 24.5 kg N/ha and 24.5 kg K_2O/ha were applied at 6 WAS and 9 WAS; additional phosphorus was not required based on a soil test. Irrigation during establishment was applied daily at 600 h, 1200 h, and 1800 h and delivered in uniform applications of no more than 12.5 mm water per day. Following establishment, irrigation schedules were adjusted to apply water at 80 to 100% of evapotranspiration as dictated by onsite or local weather station data.

Dollar spot (*Sclerotinia homoecarpa*, F.T. Bennett) occurred at both locations throughout the study and was controlled with clorothalonil (Daconil Weather Stik, Syngenta Crop Protection Inc, Greensboro, NC). An infection of *Pythium* occurred in Minnesota on 12 August 2010 and was controlled with propamocarb hydrochloride (Banol, Bayer Environmental Science, Research Triangle Park, NC); this was beyond the 14-day mefenoxam re-application interval and was attributed to excessively wet, hot, and humid weather. Additional fungicide applications were not required for the remainder of the study.

Data collection and experimental design. Increase in bentgrass abundance was evaluated using the previously described grid-intersect method at 3 WAS and again when all plots received 100% cover ratings. Visual turfgrass quality was evaluated weekly following the initial glyphosate application and continued until all plots gained 100% cover. Following guidelines from the National Turfgrass Evaluation Program (NTEP), visual turfgrass quality was assessed on a 1 to 9 scale (9 = best turf quality) based on color, density, uniformity, texture, and biotic or abiotic stresses. A 6 or above was considered to be acceptable (24).

The experimental design was a 5 by 3 factorial with a control (no glyphosate) in a randomized complete block with four replicates. Plot size was 1.2 by 1.8 m with a 0.3-m border around each plot. Data were separated by location due to significant differences and subjected to analysis of variance (ANOVA) using software from The R Project For Statistical Computing (2009, R Development Core Team, Vienna, Austria). Means were separated using Fisher's least significant difference at a 95% confidence level.

Bentgrass Increase with Glyphosate Applications

In Michigan, bentgrass abundance was significantly affected by glyphosate rate at 3 WAS and on the final rating date (8 WAS, when all plots reached 100% cover). A significant effect of application timing on bentgrass abundance was present on the final rating date only. Neither the rate by time interaction nor the effect of blocking was significant on either rating date (Table 1). On both rating dates, bentgrass abundance was greatest with increasing glyphosate rates. The 5.62 kg ai/ha (5.0 lb ai/acre) rate provided the greatest bentgrass abundance, with 83% and 53% bentgrass at 3 WAS and 8 WAS, respectively; although this rate was not statistically different from the 1.68 kg ai/ha (1.5 lb ai/acre) rate (Fig. 1). Glyphosate treatments at 7 DBS provided the greatest bentgrass abundance (41%) at 8 WAS, versus 14 DBS (26%) and 0 DBS (34%) (Fig. 2).

Table 1. Analysis of variance for bentgrass abundance in Michigan and Minnesota.

Source of variation	df	Michigan		Minnesota	
		3 WAS[x]	8 WAS	3 WAS	12 WAS
Glyphosate rate (Rate)	5	***[y]	***	**	**
Application time (Time)	2	NS[z]	***	NS	NS
Block	3	NS	NS	*	NS
Rate*Time	8	NS	NS	NS	NS
Error	45	–	–	–	–

[x] weeks after seeding.

[y] *, **, *** indicates significance according to ANOVA at $P \leq 0.05$, 0.01, and 0.001, respectively.

[z] NS indicates non significance.

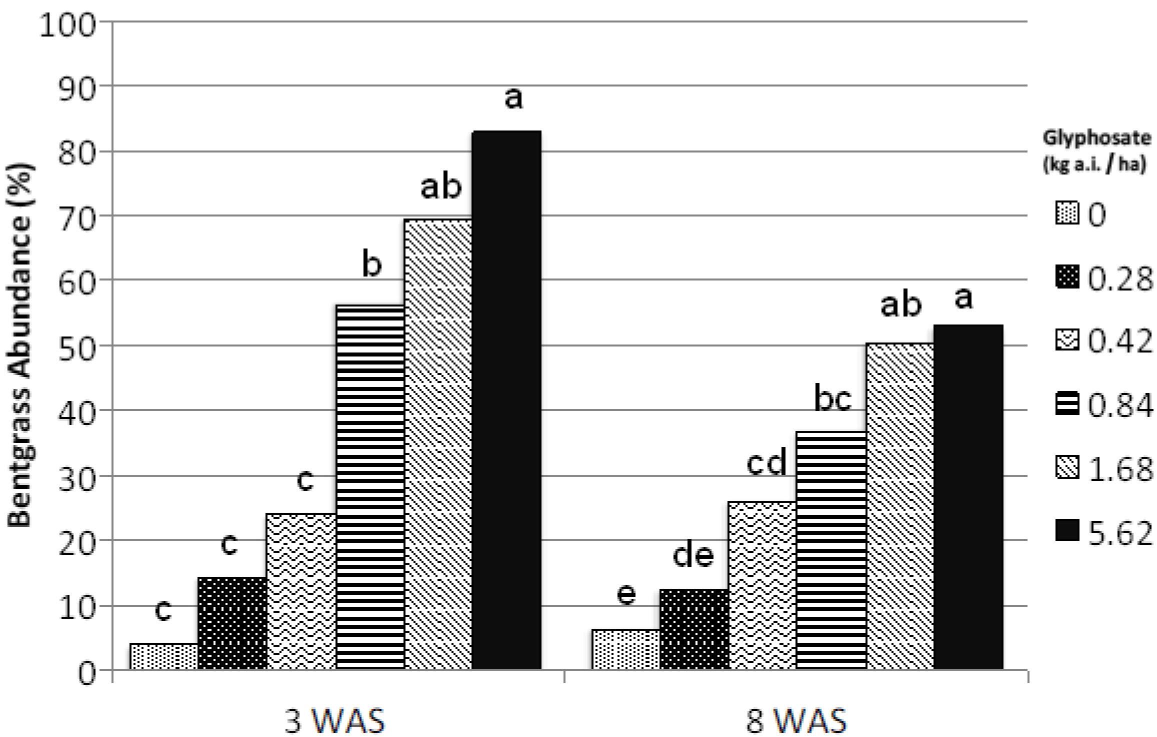

Fig. 1. Percent bentgrass abundance in Michigan as affected by glyphosate application rate. Bars sharing the same letter are not significantly different based on Fisher's protected LSD t-test (α = 0.05). WAS = weeks after seeding.

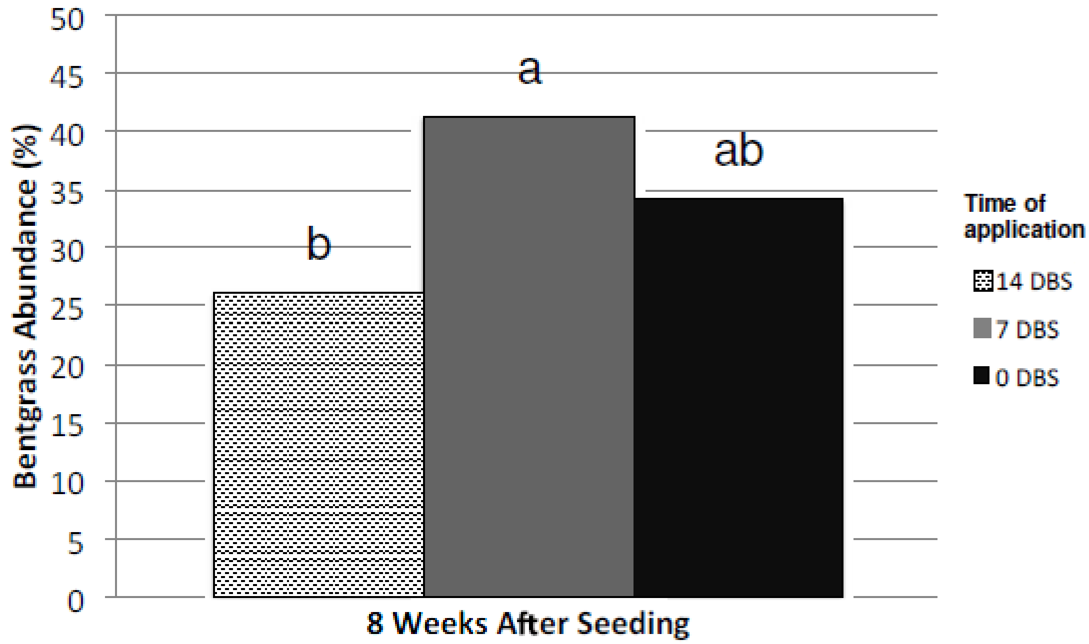

Fig. 2. Percent bentgrass abundance in Michigan as affected by glyphosate application time. Bars sharing the same letter are not significantly different based on Fisher's protected LSD t-test (α = 0.05). WAS = weeks after seeding.

Glyposate rates also resulted in significant differences in bentgrass abundance in Minnesota. Again, higher rates provided for the greatest bentgrass abundance at 3 WAS as well as 12 WAS, when all plots reached 100% cover. Maximum bentgrass abundance was 30% at 3 WAS and 24% on the final rating date (Fig. 3). This is approximately half of the increase as reported in Michigan, which is likely a result of additional golfing traffic and a large annual bluegrass seed bank at the Minnesota site. Timing of application was not statistically significant in Minnesota on either rating date.

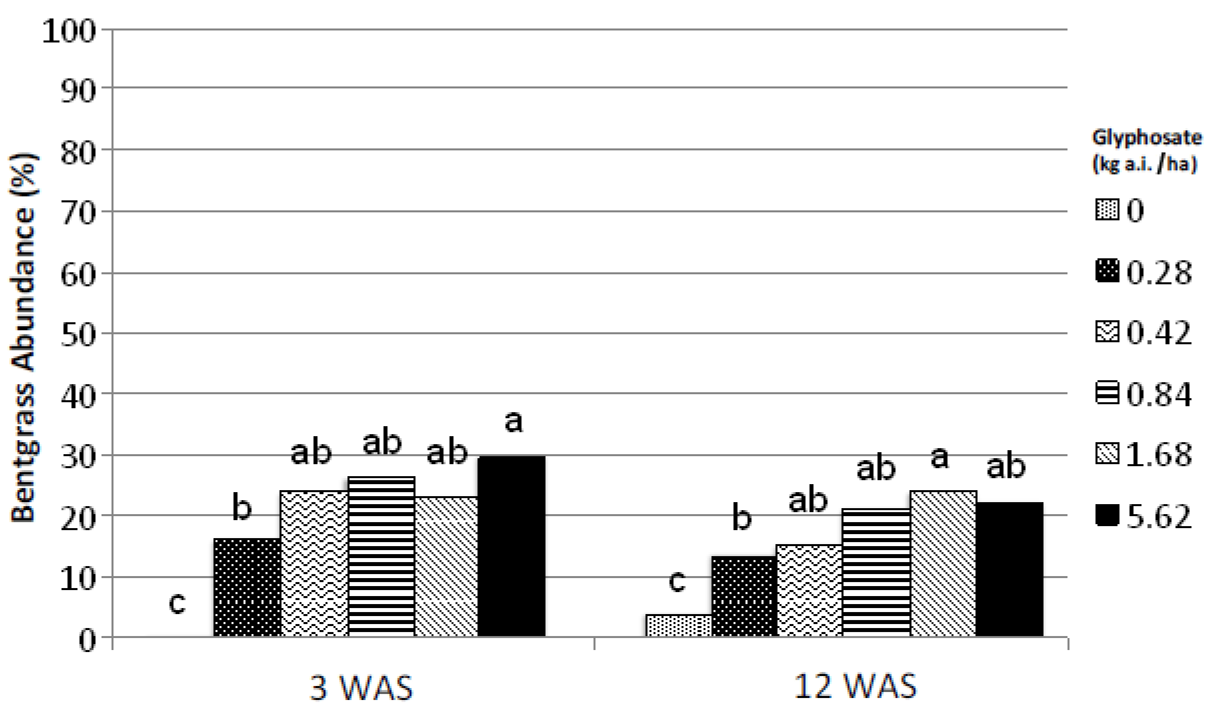

Fig. 3. Percent bentgrass abundance in Minnesota as affected by glyphosate application rate. Bars sharing the same letter are not significantly different based on Fisher's protected LSD t-test (α = 0.05). WAS = weeks after seeding.

Overall, greatest bentgrass abundance was associated with increasing glyphosate rates, with the assumption that higher glyphosate rates suppressed the existing turf enough to allow adequate germination of new bentgrass seedlings. Annual bluegrass regrowth and competition was likely the main factor inhibiting bentgrass germination and spread in the lower rate glyphosate treated plots. Due to this competition, both locations showed a reduction in creeping bentgrass populations from 3 WAS to the final rating date.

Although not consistently significant, glyphosate application timing at 7 DBS produced greater bentgrass abundance on the final rating date at both locations. This was expected, as the 14 DBS application allowed for annual bluegrass regrowth before seeding was conducted. Additionally, the 0 DBS application took approximately 5 to 7 days to suppress the existing annual bluegrass, while creeping bentgrass germination occurred as soon as 3 days after seeding and was therefore competing with the annual bluegrass.

Turfgrass Quality Reflects Glyphosate Application and Abundance of Bentgrass

Turfgrass quality was preserved with lower glyphosate rates more so in Michigan (Fig. 4) than Minnesota (Fig. 5); the Minnesota applications were made earlier in the morning to avoid golfer traffic and it is hypothesized that more glyphosate was taken up by the plant during this time period. Foliar uptake of glyphosate is enhanced in more humid environments (11) and weather data for St. Paul, MN, demonstrates that the relative humidity is historically 27% higher in the morning than in the afternoon during the month of July (27). At the beginning of the study, all glyphosate-treated plots showed a reduction in turfgrass quality compared to the control plots. At approximately 3 WAS in both locations, the control plots, comprised primarily of annual bluegrass, showed a significant reduction in turfgrass quality. This is consistent with observations in New Jersey by Henry et al. (15) showing summer decline of annual bluegrass putting surfaces. In terms of resistance to heat stress, annual bluegrass is inferior to creeping bentgrass (1). In Minnesota, the annual bluegrass quality reduction continued beyond 5 WAS, at which time the control plots received lower turfgrass quality ratings than all of the glyphosate treated plots. In Michigan, control plots received lower turfgrass quality ratings beyond 4 WAS. Dollar spot disease played a role in the decline of the annual bluegrass control plots at both locations. Trends in turfgrass quality ratings beyond 5 WAS reflected the amount of bentgrass present; plots that had more bentgrass received higher turfgrass quality ratings. This turfgrass quality difference based on glyphosate rate was statistically significant in Michigan, but not in Minnesota.

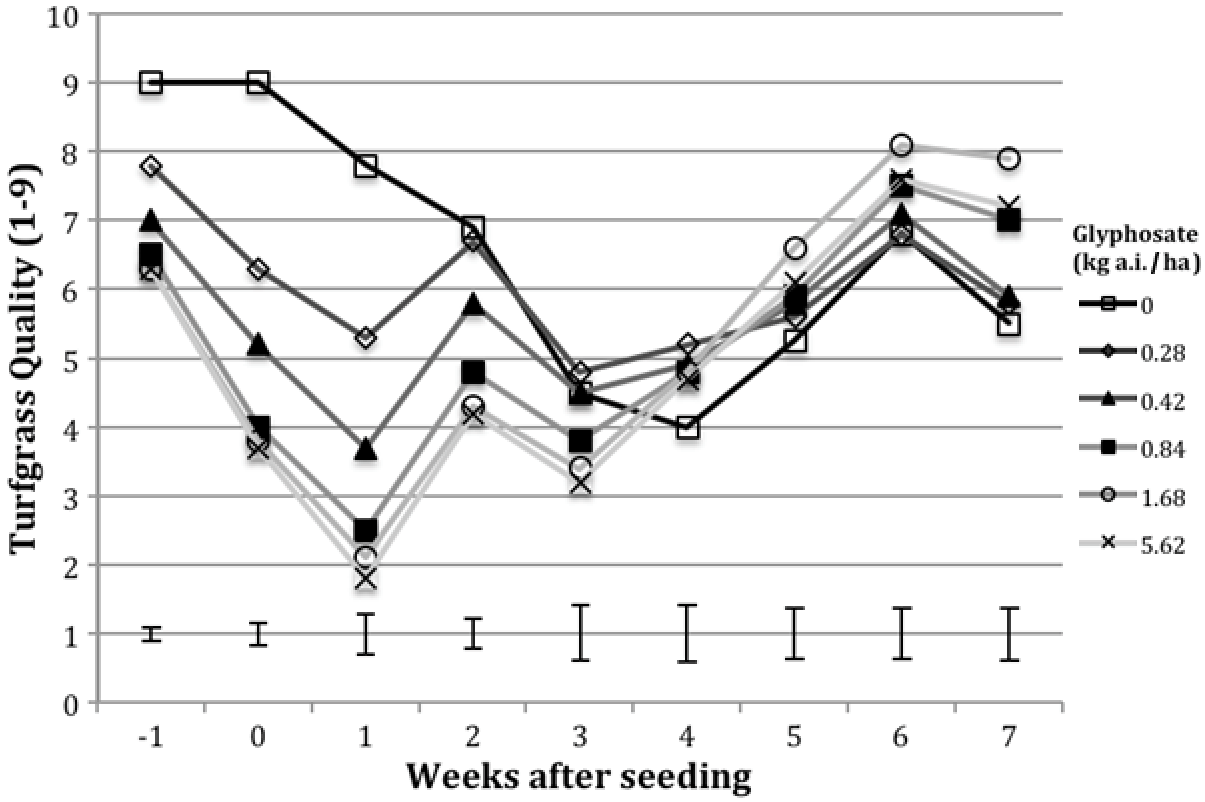

Fig. 4. Turfgrass quality ratings in Michigan as affected by glyphosate application rate. Error bar values were obtained from Fisher's protected t-test LSD (α = 0.05).

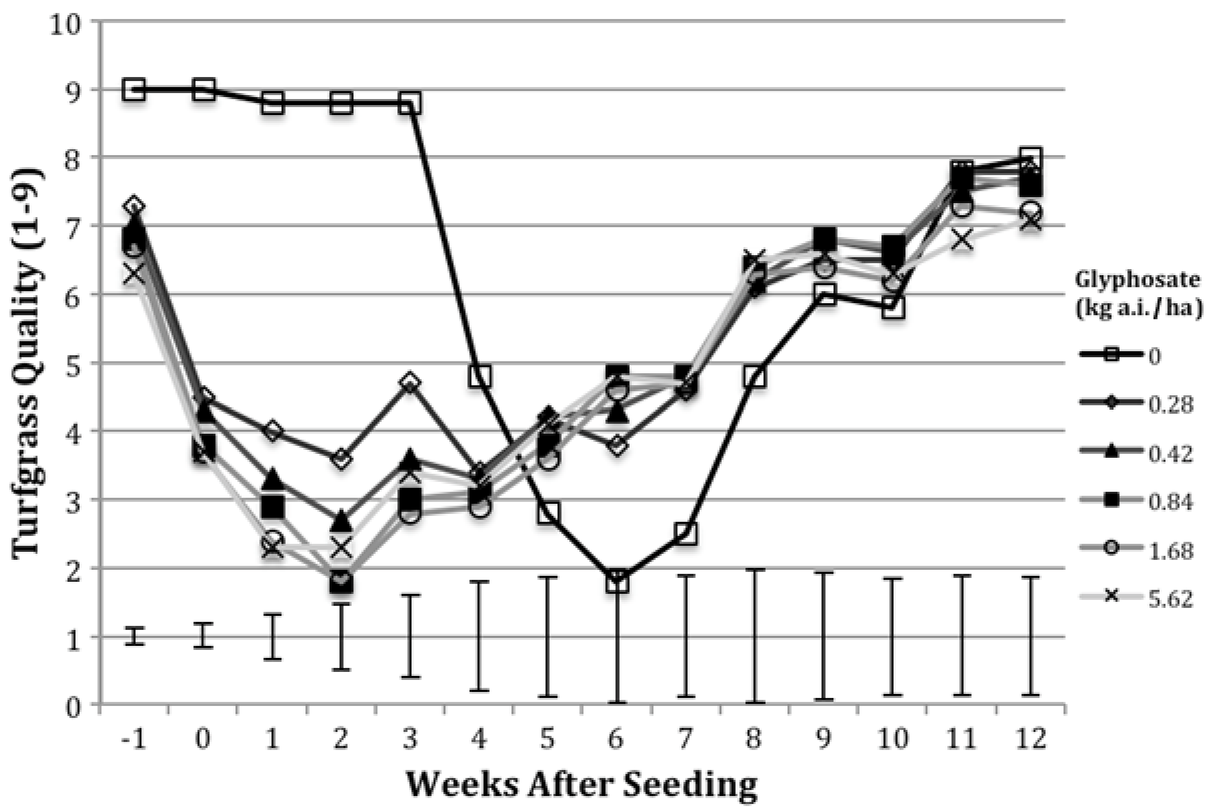

Fig. 5. Turfgrass quality ratings in Minnesota based on glyphosate application rate. Error bar values were obtained from Fisher's protected LSD t-test (α = 0.05).

Fig. 6. Image taken of a Minnesota control plot (no glyphosate) at 6 WAS. Annual bluegrass was the predominate species in this plot and is shown here suffering from summer stress and dollar spot. This plot received a TQ rating of 3.

Fig. 7. Glyphosate applied at 0.28 kg ai/ha at 7 DBS in Minnesota. This image was taken at 6 WAS and the plot received a TQ rating of 5.

Fig. 8. Glyphosate applied at 0.42 kg ai/ha at 0 DBS in Minnesota, also taken at 6 WAS. This plot received a TQ rating of 8.

Turfgrass quality as affected by glyphosate application time showed similar trends for both locations, with the 14 DBS application having the longest duration of unacceptable turfgrass quality (*data not shown*). In Michigan, turfgrass quality levels based on the timing of glyphosate application were not significantly different by 5 WAS. Although, on the final rating date, both 0 and 7 DBS applications had significantly higher turfgrass quality values than the 14 DBS application, which is reflected in the higher level of bentgrass in these plots. In Minnesota, the timing of glyphosate application did not have a significant effect on turfgrass quality beyond 4 WAS.

Conclusions and Recommendations

Results from this study demonstrate that a summer glyphosate and slit-seeding approach has the potential increase bentgrass populations in annual bluegrass fairways, while keeping the golf course open for play. The control plots receiving no application of glyphosate showed a bentgrass increase of less than 5%, which indicates that interseeding without suppressing the existing turf is an ineffective technique. This result is similar to a fairway study performed by Reicher and Hardebeck (29) in which a 3% bentgrass increase was obtained after three years of interseeding into a stand of annual bluegrass without the use of non-selective herbicides. Other researchers have shown that creeping bentgrass has the potential to increase over time after the initial seeding (15,26), although our results showed a reduction over time, which may be due to competition with annual bluegrass. Aggressive bentgrass varieties, such as 'T-1', have been shown in other research to outcompete annual bluegrass (2,6,22,23); although this is probably dependent on altering management practices to favor creeping bentgrass over annual bluegrass, including collecting clippings, reducing irrigation frequency (13), alleviating soil compaction, improving drainage, using lightweight equipment, decreasing shade, and minimizing soil disturbance (9).

Annual bluegrass reduction programs have proven successful for selective control of annual bluegrass in creeping bentgrass fairways (3,12,13,19,20,33); however, implementation of a reduction program requires a moderate population of creeping bentgrass in order to maintain turfgrass quality and encourage bentgrass growth and development. The glyphosate and interseeding approach appears to be a good strategy to quickly increase bentgrass populations when initial populations are low. A specific recommendation based on this study would be glyphosate application of 1.68 kg ai/ha (1.5 lb ai/acre) or greater, applied at 0 to 7 DBS, while interseeding bentgrass at a rate of 73 kg/ha during mid-summer high stress periods. Lower rates of glyphosate will benefit turfgrass quality; however this will result in reduced bentgrass establishment Annual bluegrass fairways typically decline during the summer months in the Midwest, making this an optimum time to increase bentgrass populations. Timing glyphosate application from 0 to 7 DBS will maximize the duration of acceptable turfgrass quality and provide for a greater increase in bentgrass populations.

Acknowledgments

The authors would like to thank Turfco Manufacturing for financial support and the use of the Triwave. We also thank Brent Belanger and Carl Mielke from Les Bolstad Golf Course, and Paul Diegnau and Brett Wenzel from Keller Golf Course.

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TriWave™ 40-Inch Overseeder NEW

Go Green Anywhere on Your Course

Damaged turf on your #7 tee? Weak areas on your #2 and #12 greens? Want to improve the overall stand of grass on your high traffic areas? With the TriWave™ 40, greening up your course has never been easier or quicker. You can go green now—you don't have to wait for the grass to come back next season. Just hook it up to your turf vehicle and quickly seed all your trouble spots in one trip. No tools are required to quickly adjust seed rates and depths to match the conditions you need. Now's the time to take your course to the next level.

- Hooks up to your favorite turf vehicle and seeds while you turn so you can follow greens, collars and contours. No tractor of PTOs required.
- Dual 18-inch floating heads follow the contour of the ground while the patented seed delivery system works with the WaveBlade technology to optimize seed-to-soil contact with minimal turf disruption.
- Close, 1 ½-inch spacing increases germination with fewer passes.
- Easy to switch out green blades and fairway blades.

Patented floating heads follow the contour of the ground, optimizing seed-to-soil contact for better germination.

Proven 30 percent higher germination results vs traditional methods. Better germination with less seed.

Quickly and effectively seed fairways, intermediate cuts, roughs, greens, tees and driving ranges.

Specifications

Model	TriWave 40-Inch Overseeder w/ Fairway Blades (comes standard) (#85856) TriWave 40-Inch Overseeder w/ Green Blades (optional) (#85857)
Width	66.25" (1.68 m)
Height	56" (1.42 m)
Length	80.5" (2.05 m)
Capacity	2.38 ft^3 (0.07 m^3) Approx. 50 lb of grass seed
Application Pattern	Seed spacing 1 ½" (38.1 mm) apart
Application Width	40" (1.01 m)
Seed Gate	Automatic operation, adjustable variable opening
Ground Speed	Operating Speed: 3 MPH (4.8 Km/h)
Transport Speed	6 MPH (9.6 Km/h) (maximum)
Productivity	1.21 acres per hour at 3 MPH
Cutting Heads	2 heads, independently floating
Blade Assembly	2 WaveBlade sets, total 20 blades
Blade Assembly Operating Depth Range	0 to 1 3/8" (0 to 34.9 mm)
Engine	25 HP Briggs and Stratton Vanguard with electric start and 20 AMP charging system
Drive	Electric clutch with double groove V-belt
Hitch Type	Standard 5/8" pin, equipped with jackstand and safety chains
Weight	1,015 lb (460 kg) *hopper empty*
Optional	• Hydraulic Power Kit (HPU) (hose kit not needed when equipped with HPU) (#86185) • Hydraulic Hose Kit for use with Cushman Truck (#86186) • Hydraulic Hose Kit for use with Toro or John Deere Trucks (#86187)

Specifications subject to change without notice.