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Comparison of Cultivation Methods Impact on Playability of *Agrostis stolonifera* Greens

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ABSTRACT

Creeping bentrgrass putting greens require intense management due to stoloniferous growth (thatch accumulation) and excessive wear and traffic by equipment and golfers. Increases in thatch and soil compaction are often managed with cultivation practices, which lead to downtime for golfers. Field research was conducted in Knoxville, TN, and Elizabethtown, KY, to compare new and traditional cultivation methods for their impact on playability on creeping bentgrass putting greens. Treatments included air injection, dry sand injection, solid tine cultivation topdressed with sand, hollow tine cultivation topdressed with sand, and non-treated control. Treatments were arranged in a randomized complete block design replicated three times at two locations. As determined 15 minutes after treatments, air injection resulted in the least reduction of green turfgrass cover, no ball roll reduction from the control, and lower reductions in surface firmness compared to other methods tested. Hollow tine had the greatest reduction in green turfgrass cover, lowest ball roll distance, and greatest reductions in surface firmness. Air injection had a lower impact on surface characteristics than hollow or solid cultivation. Because turf cover, ball roll, and firmness can all affect putting green playability, these findings indicate that air injection cultivation has the smallest impact on golfers immediately after a cultivation event.

Keywords

hollow tine, solid tine, ball roll distance, surface firmness

Introduction

Creeping bentgrass (*Agrostis stolonifera* L.) is commonly used on putting greens due to its uniform surface characteristics and its ability to tolerate low mowing heights [1]. However, creeping bentgrass putting greens require intense management due to stoloniferous growth (thatch accumulation) and excessive wear and traffic by equipment and golfers [2,3]. Greater amounts of thatch can increase scalping, decrease ball roll distance, reduce infiltration, harbor disease, and increase root death [1–3]. The need to reduce thatch accumulation is often accomplished by cultivation and topdressing practices [4].

Although thatch is a serious concern on putting greens, soil compaction can also impede growth [5]. Soil compaction is known to cause the following issues: reduced soil aeration, poor root growth, poor water infiltration, and reduced percolation [6]. The most common use of cultivation practices are typically to reduce compaction, modify organic matter, and rejuvenate plant growth [3,5,7]. Cultivation practices, however, impact the playing surface and can stop or reduce the quality of play for a short period. Previous research found 8 mm diameter hollow tine aerification recovery at approximately 14 days, and about twice as long for 16 mm diameter tines [8].

Hollow tine cultivation is a common cultural practice applied to golf course putting greens to reduce thatch accumulation and alleviate soil compaction [9,10]. This practice removes a small soil core, which physically removes soil to aide in compaction reduction [3]. Solid tine cultivation is another method frequently used on golf putting greens. This cultivation technique does not remove a core but creates a void within the surface, allowing some of the benefits of hollow tine cultivation [5]. Previous research indicates that both solid and hollow tines are effective at decreasing surface compaction [5].

Dry material injection (Dryject) is a relatively new method of cultivation that uses a venturi effect (created by a short-time stream of water pressurized to 4000 psi) to inject dry granular material no more than 2 mm in diameter (typically sand) into the surface of a turf. Granules are injected on a 7.6 cm lateral spacing, with a 1.3 to 7.6 cm adjustable forward spacing at a rate of up to 34.1 kg ha^{-1}. The air injection machine known as Air2G2 is new to the cultivation equipment market. This machine uses a self-contained air compressor to build up pressure and injects air below the soil surface through tines. The machine has three tines that are simultaneously inserted into the ground via air pressure. Tines range in length from 18 to 31 cm and are spaced 31 cm apart. Once in the ground, bursts of compressed air are released at the desired depth. Air pressure can be adjusted from 0 to 1034 kPa for both the tine insertion into the ground, as well as the bursts of compressed air into the root zone.

Currently there is no published research comparing air or dry material injection cultivation machines to better studied methods of hollow tine and solid tine cultivation. The comparison of both of these newer methods to traditional cultivation techniques is needed to determine the potential benefits on managing creeping bentgrass putting greens. The objective of this study was to determine if air and dry-material injection cultivation units will have a greater impact on surface characteristics that impact playability compared to solid and hollow tine cultivation with sand topdressing.

Materials and Methods

Two field studies were conducted in Knoxville, TN and Elizabethtown, KY on seven-year-old "A-1" creeping bentgrass [*Agrostis stoloniferous* L. var. *palustris* (Huds.)] turfs established over a root zone meeting the USGA sand specification for putting greens [11]. Turf was maintained at a bench-setting of 3.8 mm with clippings removed after each mowing. Tennessee plots were mowed daily with a walk behind Jacobsen greens mower (Eclipse 2; Textron Inc., Charlotte, NC), while the Kentucky study was mowed daily with a walk behind Toro greens mower (Greensmaster Flex 2100; Toro Company, Bloomington, MN). Ammonium sulfate fertilizer was applied on May 17, prior to the study in both locations at 1.6 kg N ha^{-1}. No other fertility was applied prior to, or until after study completion. Irrigation was not applied during the study and no precipitation occurred within 5 day of treatment application at either location. Average air temperatures during the study were 22°C in Knoxville, TN and 21°C in Elizabethtown, KY.

Treatments included a non-treated control and four cultivation techniques: air injection (AI), dry (sand) material injection (DJ), solid tine cultivation topdressed with sand (ST), and hollow tine cultivation topdressed with sand (HT). Treatments were arranged in a randomized complete block design replicated three times at two locations. Plots measured 1.8 by 1.8 m. Treatments were applied on April 1, 2015. Air injection treatment utilized an injection-burst pressure of 414 kPa through 23 cm long tines and a tine-insertion pressure of 414 kPa on a 0.6 by 0.6 m spacing (Air2G2; GT Airinject Inc., Jacksonville, FL). Dry material injection incorporated sand at injection pressures of 14,479 kPa on a 5 cm spacing (DryJect; DryJect Inc., Hatboro, PA). Hollow tine cultivation utilized a 5 by 5 cm spacing with 1.3 cm o.d. tines (GA 24; Textron Inc., Charlotte, NC). Solid tine cultivation utilized a 5 by 5 cm spacing with 6.4 mm outside tine diameters (GA 24; Textron Inc., Charlotte, NC). Solid tine and HT plots were topdressed with sand within USGA size (0.125–0.5 mm) specifications at a rate of 19,768 kg ha^{-1}with a bulk density of 1.68 g/cm^3. Sand was brushed into the cultivation holes using a push broom. Initially all plots were mown then green turfgrass cover, surface firmness, and ball roll distance measurements were collected. All treatments were applied and response variables were collected again 15 min after application.

The green turfgrass cover (GTC) using digital image analysis (DIA) [12]. A 0.8 m^2 light box was used to provide consistent lighting. Images (12×10^6 mega pixels) were captured using as a Canon (G12; Canon Inc., Japan) camera. Sigma Scan Pro Software (v. 5.0, SPSS. Inc., Chicago, IL) was used to determine the number of green pixels in each image. Green pixels were defined as those having a hue between 35 and 140 and saturation of 0 to 100 %. The total number of green pixels in each image was divided by the total number of pixels (regardless of color) in each image (307,200) to calculate the percentage of GTC. Digital image analysis provides quantifiable measurements of GTC and removes observational inconsistency associated with visual ratings [12].

Surface firmness was determined using a Turf Firmness Meter (FieldScout TruFirm; Turf Firmness Meter Spectrum

Technologies Inc., Plainfield, IL). Firmness was measured as the depth of golf ball impact into the putting green surface [13]. Firmness was measured at seven random locations within the center of the plot with a 0.3 M border of each plot to avoid edge effects; seven measurements were collected and averaged.

Ball roll distance was measured using methods of Gaussoin et al. [14]. Similar to McCullough et al. [10], four balls (Pro V1, Titleist, Fairhaven, MA) were rolled in two directions and measured with a ruler (cm) on each plot.

Soil bulk density was measured 15 min after treatment. Due to surface disruption concerns of each golf course, soil core sampling was limited to three samples collected per plot. Samples had a volume of 98 cm^3 were collected from the 0 to 7.6 cm and 10 to 15 cm. Soil Samples were taken from the center of each plot, with grass material removed from the top 0–7.6 cm zone of each plot 15 min after treatment application. Methods for soil core extraction and analysis were the same as those used by Goddard et al. [15].

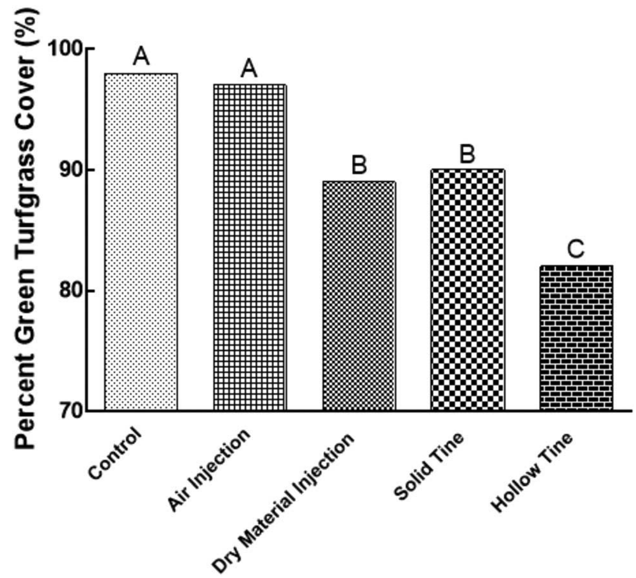
Green turfgrass cover, surface firmness, ball roll distance, and soil bulk density data were subjected to analysis of variance (proc ANOVA) in SAS (v. 9.3; SAS Institute Inc., Cary, NC). No significant location by treatment interaction was detected among treatments; therefore, data from each location were pooled in the analysis. All treatments were compared to the control to determine differences. Fisher's protected least significant difference (LSD) was used to separate GTC, surface firmness, ball roll distance, and soil bulk density means at $\alpha = 0.05$ level of significance. Correlations between surface firmness and GTC, as well as ball roll distance and surface firmness, were conducted in Prism 6 (GraphPad Software; San Diego, CA).

Results and Discussion

Green turfgrass cover values taken prior to treatment application indicated no differences after mowing among plots (data not shown). Green turfgrass cover collected 15 min after treatment applications showed AI did not reduce GTC compared to the non-treated control (**Fig. 1**). The HT treatment resulted in the largest reduction (16 %) in GTC compared to the control, whereas DJ (9 %) and ST (8 %) treatments resulted in an intermediate reduction in GTC compared to the control. These findings support previous research describing the initial loss of green turf by HT cultivation [16].

All cultivation methods reduced surface firmness at 15 min after treatment application compared to the control (**Fig. 2**). Hollow tine aerification produced the softest surface (−1.42 cm) among all treatments. The AI treated plots had the firmest surface (−1.30 cm) among all the cultivation plots; as expected, the non-treated plots had the greatest firmness (−1.25 cm). The firmness of the surface and GTC had a positive correlation 0.97 across both locations indicating that lower GTC (more surface disruption) after cultivation leads to a softer surface. Hollow tine cultivation

FIG. 1 Green turfgrass cover for various cultivation treatments 15 min after treatment applications on sand-based creeping bentgrass (Agrostis stolonifera L.) putting greens in Knoxville, TN and Elizabethtown, KY, April 1, 2015. Means pooled across locations. Letters represent significant differences between treatments.

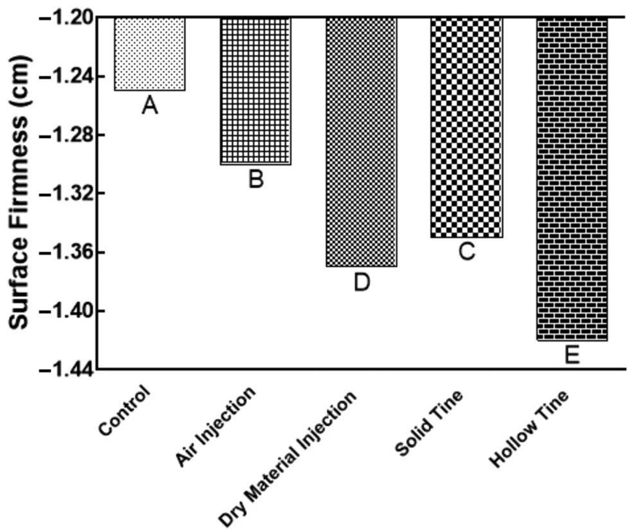


is known to immediately reduce surface firmness after application and becomes firmer over time [17]. A firm surface is desired for play, which would likely occur sooner after AI cultivation compared to other methods.

Air injection (2.7 m) increased ball roll distance compared to control (2.5 m) 15 min after treatment application (**Fig. 3**). While a statistical increase was seen, research by Karcher et al. [18] found that differences of less than 31 cm were not detected by golfers when ball roll distance was greater than 2.3 m. This would indicate that AI was not different from the control. Ball roll on non-treated and DJ treated turf were similar, while ST and HT treated turf decreased ball roll distance compared to non-treated and DJ treated turf, but neither of these differences were over 31 cm. Decreased ball roll distance on HT and ST plot was attributed to the sand remaining on the turf surface after backfilling cultivation holes [19]. Ball roll data from this study also indicates that the injection of sand into the profile with the DJ method has less potential to interfere with ball roll distance. Moreover, a positive correlation of 0.63 existed between ball roll distance and surface firmness indicating that a firmer surface was associated with greater ball roll distance. Other research observed a similar relationship between ball roll distance and surface firmness [20].

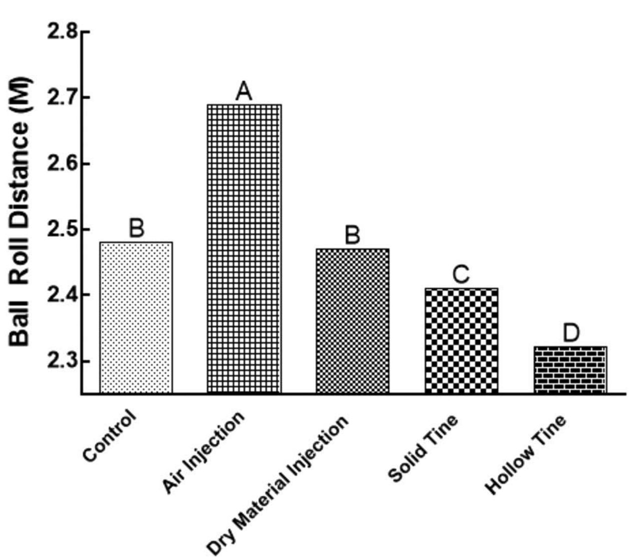
No soil bulk density differences were found among treatments at both depths collected. These findings suggest that more than one application of each cultivation treatment would likely be necessary to reduce the bulk density of a root zone. Previous studies have found reductions in soil bulk densities on sand root zones; however, these studies reported data from multiple

FIG. 2 Surface firmness as measured by the TrueFirm for various cultivation methods 15 min after treatment application on sand-based creeping bentgrass (Agrostis stolonifera L.) putting greens in Knoxville, TN, and Elizabethtown, KY, April 1, 2015. Means pooled across locations. Letters represent significant differences between treatments.



cultivation events [16,21]. Wiecko et al. [22] concluded that cultivation studies need a long-term program to determine the impact on soil physical properties. However, differences could have been missed due to sampling restrictions and volumes collected (98 cm^3) per sample. Both locations have sand-based greens and are intensely managed including annual aerification. The lack of compaction along with the high level of greens maintenance in the current study could explain why differences in bulk density were not observed.

FIG. 3 Ball roll distance for various cultivation methods 15 min after treatment application on sand-based creeping bentgrass (Agrostis stolonifera L.) putting greens in Knoxville, TN, and Elizabethtown, KY, April 1, 2015. Means pooled across locations. Letters represent significant differences between treatments.



Organic matter is managed by removal of organic matter from the surface through cultivation [3]. While the AI treatment improved playability, firmness and GTC, its impact on long term organic matter management were beyond the scope of this study. One of the limitations of this study is that it did not track the changes in organic matter over time. Future studies are warranted to address how these different cultivation methods impact organic matter management over time.

Conclusions

The results showed AI cultivation resulted in less surface disruption, which would allow a quicker return to high quality playing conditions compared to other cultivation methods. Positive correlations between GTC and surface firmness, as well as ball roll distance and surface firmness 15 min after treatment application indicate that cultivation practices with lower surface disruption will have a smaller impact on surface playability. The findings suggest that air and dry material injection have less of an impact on surface playability of putting greens than hollow and solid tine cultivation. Long-term changes in soil physical properties in combination with surface measurements would give the full scope of how AI and DJ methods impact the root zone which is beyond the scope of this study.

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