Autonomous Compared with Conventional Mower Use on St. Augustinegrass Lawn Quality

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Abstract. Autonomous (i.e., robotic) mowers have recently garnered interest with the public and within the turfgrass industry. However, limited research has been conducted on their use for mowing warm-season turfgrasses. An experiment was conducted at the University of Florida's West Florida Research and Education Center (Jay, FL, USA) to investigate the performance of an autonomous mower using a lower than recommended height-of-cut on St. Augustinegrass (*Stenotaphrum secundatum*). Treatments included an autonomous mower with a height-of-cut of 2.5 inches set to mow daily and a conventional mulching mower with weekly mowing at recommended height-of-cut of 3.5 inches. Data collection included weekly digital images that were subjected to digital image analysis to determine overall turfgrass quality, percent green cover, and uniformity. The autonomous mower resulted in greater overall turfgrass quality from January to March and in November, and greater green cover from November to April compared with conventional mowing. Additionally, the autonomous mower produced greater turfgrass uniformity than conventional mowing. Results indicate that autonomous mowers can be successfully used to maintain St. Augustinegrass at a lower than recommended height-of-cut.

Mowing is one of the most important cultural practices for the maintenance of a healthy lawn. Proper mowing height and intervals increase turfgrass density, which leads to overall healthier turfgrass that is more competitive against weeds, diseases, and insects (Trenholm et al. 2018). Traditional mowing is generally performed with gasoline-powered engine lawn mowers. The use of battery-powered lawn mowers is increasing, as evidenced by their market growth, which was valued at $1.98 million in 2021 and is expected to reach $13.93 million by 2027 (ReportBuyer 2022).

Autonomous mowers have been gaining popularity due to various benefits, such as reduced labor, convenient mowing schedule, and lower operator injury risk, compared with traditional, gasoline-powered mowers. Additionally, autonomous mowers provide environmental benefits by reducing gas emissions, dust production, and noise emissions (Grossi et al. 2016; Pirchio et al. 2018). Autonomous mowers can also reduce energy consumption by up to 3 times compared with gasoline-powered mowers (Grossi et al. 2016). However, the work time of autonomous mowers can be 10 times greater than a gasoline-powered mower due to their slower operating speeds and narrow cutting swath (Grossi et al. 2016; Pirchio et al. 2018).

Mower performance typically considers working time, energy consumption, and overlapping. With autonomous mowers, systematic trajectories minimize overlapping, which can reduce working time and energy consumption (Sportelli et al. 2021). However, autonomous mowers can use a random trajectory setting, which is a better alternative for areas with obstacles, but this operating scheme generates frequent overlapping, decreasing overall efficiency, and increasing wheel marks (Sportelli et al. 2020, 2021). Newer autonomous mowers have improved their trajectories, and they "memorize" where fixed obstacles are located, thus improving their mowing efficiency.

Autonomous mowers typically use very small, two-edged, razor-type blades that are affixed to a spinning disk. These blades are small (<1.5 inches) compared with traditional mowers (∼20 inches). Autonomous mowers can run daily, and the small cutting edge of the razor blades on autonomous mowers can improve quality of cut (i.e., cleaner cut), decrease leaf chlorosis (i.e., yellowing), and reduce turfgrass stress from mowing (Pirchio et al. 2018; Shaddox et al. 2020). In tall fescue (*Festuca arundinacea*), autonomous mowers increased turfgrass density and decreased average leaf width resulting in higher turfgrass quality (Grossi et al. 2016; Pirchio et al. 2018). Autonomous mowers can also reduce spontaneous weed cover compared with conventional mowers, which may be due to increased shoot density (Grossi et al. 2016). However, creeping weeds can adapt to constant mowing and will grow prostrate below the mowing height-of-cut if not controlled (Pirchio et al. 2018).

The two main components of mowing are cutting height and frequency, both of which are related to the one-third rule, turfgrass species, cultivar, and the level of lawn quality desired (Christians et al. 2017; Trenholm et al. 2018). Most autonomous mowers were developed for the European market where cool-season grasses are dominant. These cool-season turfgrasses are generally mowed at heights <3.5 inches, and most models of autonomous mowers do not exceed this height-of-cut. St. Augustinegrass (*Stenotaphrum secundatum*), a common turfgrass in the southeastern United States, is mowed relatively high (i.e., 3–4 inches) because it has coarse-textured leaf blades (Trenholm et al. 2018). Therefore, the objective of this study was to evaluate the performance (i.e., overall turfgrass quality, green cover, and uniformity) of autonomous

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
48.8243	lb/1000 ft^2	$kg{\cdot}ha^{-1}$	0.0205

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Table 1. Analysis of variance for overall quality, percent green cover, and uniformity of 'Floratam' St. Augustinegrass subjected to different mowing regimes.

Source	Overall quality	Percent green cover	Uniformity
Treatment	***	***	***
Month	***	***	***
Treatment × mo.	***	***	NS

*, **, *** Significant at $P \leq 0.05$, 0.01, or 0.001, respectively. NS, nonsignitifcant at $P \leq 0.05$.

mowers at a suboptimal height-of-cut on St. Augustinegrass compared with conventional mowing practices at the recommended height-of-cut to determine if autonomous mowers can be used in the management of St. Augustinegrass lawns.

Materials and methods

A study was conducted at the University of Florida's West Florida Research and Education Center (Jay, FL, USA) to determine whether 'Floratam' St. Augustinegrass could be maintained using an autonomous mower with a nonadjustable fixed 2.5-inch height-of-cut. The experiment was conducted from 2018 to 2020 using an autonomous mower (Miimo; Honda Motor Co., Ltd., Minato City, Tokyo, Japan) set to mow daily between 9:00 AM and 3:00 PM. To prevent mechanical stress (i.e., notable wear patterns that develop because of excess tracking or turning), the total run time (2 h) was adjusted seasonally. Season running times were adjusted as follows relative to the regular mowing program: February 20%, March 30%, April to September 100%, October 70%, November 60%, and December 20%. The autonomous mowers were turned off in Jan 2019 due to freezing temperatures. Cutting blades were replaced every 2 months in the growing season (three times per year) following manufacturer recommendations. The autonomous mowers did not detect rain and operated regardless of the weather conditions. In Nov 2018, a lightning strike damaged the charging stations, which had to be replaced. The mowers themselves were unaffected by this event. The area surrounding the charging stations was treated with fipronil (TopChoice; Bayer Environmental Science, Cary, NC, USA) to prevent red imported fire ant (*Solenopsis invicta* Buren) mounding. For comparison, a conventional mulching mower (Honda Self-Propelled Lawn Mower; American Honda Motor Co., Alpharetta, GA, USA) set at 3.5 inches was used to mow plots on a weekly basis simulating standard maintenance practices. The conventional mower was exclusively used for this experiment. Therefore, the mower blade was sharpened once at the beginning of each growing season. The mowing pattern was alternated weekly, and turfgrass clippings were returned to the plots. The experiment was arranged as a randomized complete block design with three replicates. Each replicate of the autonomous mowed plots had its own mower, whereas the conventionally mowed plots used the same mower. The plot size was 24 ft by 40 ft.

Turfgrass plots were fertilized with 1 lb/1000 ft^2 of nitrogen (20N–0P–8.3K) in April and June. Pesticides were applied as needed for weed control [prodiamine (Stonewall® 65 WDG; Lesco, Cleveland, OH, USA) and dimethenamid-P (Tower®; BASF Corp., Research Triangle Park, NC, USA)] and disease control [chlorothalonil + acibenzolar-S-methyl (Daconil Action™; Syngenta Crop Protection, Greensboro, NC, USA), trifloxystrobin (Compass®, Bayer Environmental Science), and azoxystrobin (Heritage®, Syngenta Crop Protection)]. Irrigation frequency was every other day, and it was adjusted each week to deliver ∼100% of the previous week's reference evapotranspiration.

Digital images were acquired weekly after conventional mowing using a light box with a 14.1 megapixel digital camera (Cyber-Shot; Sony, Minato, Tokyo, Japan). A single digital image was collected at a random location within the plot avoiding the edges. Digital images were processed using a software program designed to analyze turfgrass images (Turf Analyzer; Green Research Services, LLC, Fayetteville, AR, USA), which analyzes images for overall quality (1–9, with 1 being the poorest, 9 being the best, and 6 minimally acceptable), coverage (percent green cover), and uniformity (Karcher and Richardson 2003; Morris and Shearman 1998; Richardson et al. 2001). Turf Analyzer low-high thresholds were set as 70–170, 10–100, and 0–100 for hue, saturation, and brightness, respectively. Quality ratings were calculated by converting each of the color, cover, density, and uniformity results in rating values, using the 1 to 9 scale. Those rating values were then used to calculate a weighted average representing an overall quality rating value. Data were analyzed using linear mixed models and subjected to analysis of variance in R (R Foundation for Statistical Computing, Vienna, Austria). An autocorrelation structure of order 1 was fitted using "nlme" to account for the correlation between the repeated measures (Pinheiro et al. 2022). The emmeans were compared using the "cld" function adjusted for Sidak's test (Lenth 2022). Differences were declared significant at $P \leq 0.05$.

Results and discussion

Treatment responses between months and years were similar. Therefore, data were averaged across years to facilitate the visualization of the results. Analysis of variance revealed a treatment by month interaction for

Table 2. Percent green cover averaged across years (2018–20) of 'Floratam' St. Augustinegrass subjected to different mowing regimes.

	Green cover (%)											
Treatment[i]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Autonomous	50.9 a[ii]	57.7 a	63.0 a	87.6 a	94.4 a	97.2 a	98.0 a	98.0 a	95.3 a	94.5 a	87.9 a	51.8 a
Conventional	33.7 b	34.0 b	40.4 b	78.0 b	93.5 a	96.0 a	97.9 a	97.1 a	95.0 a	93.4 a	82.9 b	45.2 b

[i] Treatments include autonomous mowers with a 2.5-inch height-of-cut and daily mowing and conventional mulching mower with a 3.5-inch height-of-cut and weekly mowing; 1 inch = 2.54 cm.

[ii] Means followed by the same letter in a column are not significantly different using Tukey's test at $P \leq 0.05$.

Table 3. Uniformity averaged across years (2018–20) of ‘Floratam’ St. Augustinegrass subjected to different mowing regimes.

	Uniformity											
Treatment[i]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Autonomous	0.70 a[ii]	0.70 a	0.64 a	0.75 a	0.81 a	0.84 a	0.85 a	0.87 a	0.87 a	0.84 a	0.79 a	0.67 a
Conventional	0.64 b	0.57 b	0.52 b	0.66 a	0.75 b	0.79 a	0.77 b	0.79 b	0.80 b	0.75 b	0.67 b	0.62 a

[i] Treatments include autonomous mowers with a 2.5-inch height-of-cut and daily mowing and conventional mulching mower with a 3.5-inch height-of-cut and weekly mowing; 1 inch = 2.54 cm.

[ii] Means followed by the same letter in a column are not significantly different using Tukey’s test at $P \leq 0.05$.

Table 4. Overall quality averaged across years (2018–20) of ‘Floratam’ St. Augustinegrass subjected to different mowing regimes.

	Overall quality (1–9 scale)[ii]											
Treatment[i]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Autonomous	5.8 a[iii]	5.5 a	5.1 a	5.9 a	6.5 a	7.2 a	7.3 a	7.5 a	7.4 a	7.3 a	7.3 a	5.3 a
Conventional	5.1 b	4.6 b	4.2 b	5.7 a	6.4 a	7.1 a	7.3 a	7.3 a	7.3 a	7.1 a	6.7 b	5.0 a

[i] Treatments include autonomous mowers with a 2.5-inch height-of-cut and daily mowing and conventional mulching mower with a 3.5-inch height-of-cut and weekly mowing; 1 inch = 2.54 cm.

[ii] 1 = poorest, 9 = best, 6 = minimally acceptable.

[iii] Means followed by the same letter in a column are not significantly different using Tukey’s test at $P \leq 0.05$.

overall quality and green cover (Table 1). Although the treatment by month interaction for uniformity was not significant ($P = 0.055$), data were also presented by month (Table 1).

St. Augustinegrass plots mowed with the autonomous mower had a greater green cover from November to April showing less loss of color and earlier spring green up (Table 2). Although canopy temperature was not recorded in this study, lower mowing heights tend to increase surface temperatures, which could explain these differences (Boeri et al. 2021). During the other months, the autonomous mower resulted in similar turfgrass quality and green cover relative to conventional mowing. St. Augustinegrass mowed with the autonomous mower also had a more uniform cover relative to conventional mowing due to the daily mowing frequency (Table 3). The autonomous mower resulted in significantly greater overall turfgrass quality during the winter months (November and January through March) with increased density, winter color retention, and an earlier spring green-up (Table 4).

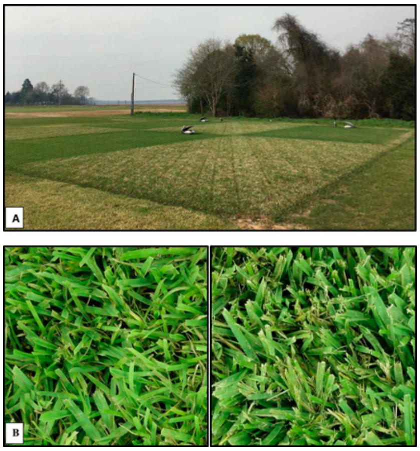

Fig. 1. Images showing St. Augustinegrass plots (A) exhibiting enhanced green color when mown with the autonomous mower in Mar 2019, and (B) quality of cut comparison between autonomous mower (left) vs conventional mulching mower (right) in Oct 2018.

Similar to studies conducted on tall fescue (Shaddox et al. 2021), the blades of the autonomous mower provided a better quality of cut, minimizing fraying and subsequent browning in St. Augustinegrass (Fig. 1). We observed wear patterns in the autonomous mower plots particularly where the mower approached the charging station. We also observed gray leaf spot (*Pyricularia grisea*) on the leaf blades of the stressed turfgrass in these areas. As described by Sportelli et al. (2021), elliptical wear patterns were noted because of excess tracking and turning in the corners (Fig. 2). Season running times for April and May to September could have been further adjusted to 60% and 80%, respectively, to reduce mechanical stress.

Fig. 2. Elliptical wear pattern that developed close to the charging station. Image was collected in Jul 2018.

In our research, when differences occurred, the autonomous mower resulted in higher overall turfgrass quality compared with the traditional gasoline-powered mower, demonstrating that autonomous mowers can be successfully used on St. Augustinegrass, even at a lower than typically recommended height-of-cut (Table 2). Although it was beyond the scope of this study, lower mowing heights generally result in lower root proliferation, resulting in increased water and fertilizer requirements (Wherley et al. 2011). Additionally, the influence autonomous mowers (i.e., lower height-of-cut and increased mowing frequency) on weed pressure, herbicide efficacy, and input requirements is unknown and should be explored. Moreover, published research on the use of autonomous mowers on warm-season turfgrasses including zoysiagrass (*Zoysia* sp.), Bermudagrass (*Cynodon* sp.), centipedegrass (*Eremochloa ophiuroides*), and bahiagrass (*Paspalum notatum*) does not currently exist. We observed a high level of red imported fire ant mounding in the charging stations. In regions known to have red imported fire ants, it is recommended to treat them preventively around the charging station. Although autonomous mowers are typically marketed to operate regardless of rain conditions, we did not observe any negative effects of the mowers operating during rainy conditions, even in a region where abundant precipitation occurs (sum of total precipitation during the trial period was 187 inches). However, mowing under saturated conditions (i.e., after irrigation or heavy rainfall) could increase soil compaction. Replacement of the autonomous mower cutting blades is recommended every 2 months, but the task of replacing the razor blades is simpler than sharpening a conventional rotatory mower's blade.

Conclusions

In summary, the autonomous mower resulted in greater turfgrass quality and green cover in the winter months and provided similar turfgrass quality and green cover during the rest of the growing season compared with conventional mowing. Moreover, the turfgrass canopy was more uniform when maintained with the autonomous mower. The effect of autonomous mowers on turfgrass management aspects such as pest pressure, fertilizer rates, soil compaction, and irrigation requirements in warm-season turfgrasses needs to be further investigated. Additionally, more research is needed to determine which component of the autonomous mower (i.e., height-of-cut, mowing frequency, and/or blade replacement) led to increased turfgrass quality. However, autonomous mowers are becoming more commonplace in southeast United States and have the potential to make turfgrass management more sustainable by reducing energy consumption, gas emissions, dust, and noise production.

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