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Cultivation and Fertility Practices Influence Hybrid Bermudagrass Recovery from Spring Dead Spot Damage

Wendell J. Hutchens, Jordan C. Booth, J. Michael Goatley, and David S. McCall
School of Plant and Environmental Sciences, Virginia Polytechnic Institute, 675 Old Glade Road, Blacksburg, VA 24060

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***Abstract.* Spring dead spot (SDS), caused by *Ophiosphaerella* spp., is among the most damaging diseases to hybrid bermudagrass (*Cynodon dactylon* × *transvaalensis*) in areas where winter dormancy occurs. Management strategies that aid in turfgrass recovery from SDS damage have not been widely studied. An experiment was conducted in Blacksburg, VA, in 2019 and 2020, to determine the influence of various cultural practices on bermudagrass recovery from SDS damage. Fertility and cultivation were applied in the late spring/early summer, which is earlier than normal for cultivation practices for bermudagrass, to test their effectiveness in aiding bermudagrass recovery from SDS damage. The main effects of fertility and cultivation were arranged in a 2 × 3 factorial design with vertical mowing, solid-tine aerification, and no cultivation applied with urea (48.8 kg·ha^{-1} N) sprayed at trial initiation and 2 weeks later or without urea. Plots were assessed for the percent of SDS throughout the study. Data were analyzed as the percent change relative to the initial assessment to measure bermudagrass recovery. The main effect of fertility increased bermudagrass recovery from SDS damage in both 2019 and 2020. The main effects of vertical mowing and solid-tine aerification reduced bermudagrass recovery from SDS damage in 2020. These data suggest that two properly timed nitrogen fertilization applications at 48.8 kg·ha^{-1} optimized bermudagrass recovery from SDS damage, whereas late spring/early summer cultivation without fertility may inhibit bermudagrass recovery.**

Spring dead spot (SDS), caused primarily by *Ophiosphaerella herpotricha* J. Walker, *O. korrae* (J. Walker & A.M. Smith), Shoemaker & C.E. Babcock (=*Leptosphaeria korrae* J. Walker & A.M. Smith), and *O. narmari* (J. Walker & A.M. Smith) Wetzel, Hulbert, & Tisserat (=*L. narmari* J. Walker & A.M. Smith) in the United States, is a common and detrimental patch disease of hybrid bermudagrass [*Cynodon dactylon* (L.) Pers. × *transvaalensis* Burtt Davy] home lawns, athletic fields, and golf courses in areas where winter dormancy occurs. Patches appear sunken, necrotic, and straw-colored (Wadsworth and Young, 1960). The sunken nature of the patches decreases not only the aesthetics but also the surface playability and player safety of hybrid bermudagrass for golf and other sport uses (Martin et al., 2001). Many preventative chemical and cultural practices are used to mitigate this disease.

Fungicide treatment is one of the primary management strategies for SDS prevention. Fungicides targeted at SDS are typically applied in the fall, when soil temperatures are between 15.5 and 26.7 °C (Butler and Tredway, 2006). Fungicide efficacy against SDS has been sporadic, and efforts to increase fungicide efficacy through various application methods have produced mixed results (Beck et al., 2012; Butler and Tredway, 2006; Earlywine and Miller, 2015; Tredway et al., 2009b; Walker, 2013). New chemistries, particularly within the demethylase inhibitor and succinate dehydrogenase inhibitor fungicide classes, are effective at inhibiting *Ophiosphaerella* spp. growth (Hutchens et al., 2019). However, the cost of these newer fungicides may be a limiting factor for some turfgrass managers.

Cultural practices are frequently used by turfgrass managers to prevent SDS, and an abundance of research has been conducted with mixed results (Tredway et al., 2009b). Miller et al. (2017) showed that nitrogen and manganese sources had no effect on SDS severity the following year, whereas other studies demonstrated that the nitrogen source differentially affected *O. herpotricha* and *O. korrae* (Tredway et al., 2009a, 2020). Dernoeden et al. (1991) found that potassium chloride can increase the survivability of bermudagrass inoculated with *O. korrae*; however, McCarty et al. (1992) determined that potassium sulfate actually increased SDS severity. Moreover, lowering pH with fertilizers such as ammonium sulfate has been shown to reduce SDS symptoms in the field and suppress mycelial growth in vitro (Cottrill et al., 2016; Dernoeden et al., 1991; Tredway et al., 2020). Furthermore, there is documented evidence of a positive correlation between pH and SDS severity, particularly with *O. herpotricha* (Dernoeden et al., 1991; Tredway et al., 2020). Cold tolerance of bermudagrass cultivars was positively correlated with reduced SDS in certain studies, yet cold-tolerant cultivars are not entirely immune from damage (Baird et al., 1998; Iriarte et al., 2005a, 2005b; Martinez et al., 2014). Cultivation practices that remove thatch such as fraze mowing, sod stripping, and aerification plus vertical mowing during the summer can reduce SDS development the following spring (Miller et al., 2017; Tisserat and Fry, 1997). In contrast, vertical mowing or core aerifying was also demonstrated to increase SDS severity the following spring compared with a nontreated control (Perry et al., 2010). The results regarding the effect of cultivation practices on SDS prevention are unclear.

Research of curative and recuperative management strategies for symptomatic bermudagrass is limited. Studies have focused on which fertilizers most effectively increase bermudagrass recovery from SDS. Dernoeden et al. (1991) found that ammonium-based fertilizers generally provided the greatest SDS recovery. The authors reported one rating date at the Denton, MD, location: a fertilizer treatment of $(NH_4)_2SO_4$ provided greater bermudagrass recovery from SDS damage than $NaNO_3$, NH_4Cl, $CO(NH_2)_2$, $NaNO_3$ plus KCl, and $CO(NH_2)_2$ plus KCl, and no fertility while the $NaNO_3$ plus KCl treatment provided the least recovery. However, the authors reported conflicting results at the Silver Spring, MD location, with all fertility treatments similarly increasing bermudagrass recovery compared with the nontreated control, with the exception of KCl. Ascocarps of *O. korrae* were observed at the Silver Spring location, but no attempt at identifying the *Ophiosphaerella* species at the Denton location was performed (Dernoeden et al., 1991). Polymerase chain reaction methods for identifying *Ophiosphaerella* species were not available during the time of the Dernoeden et al. (1991) study; therefore, identification of the species was more difficult. Recent data from our laboratory that were gathered using species-specific primers developed by Tisserat et al. (1994) and Martinez et al. (2019) suggested that *O. korrae* is predominantly isolated from the Silver Spring area, whereas *O. herpotricha* is predominant on the eastern shore of Maryland, where Denton is located, with 62% of the 42 samples collected from the eastern shore of Maryland amplifying

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W.J.H. is the corresponding author. E-mail: wendelljh@vt.edu.

O. herpotricha (Hutchens et al., 2021). Potential differences in the *Ophiosphaerella* species may be the cause of the discrepancies in bermudagrass recovery between the two locations in this study.

There has been research of the effects of preventative applications of fertility and cultivation on SDS caused by *O. herpotricha*, but there is no documented research of the influence of therapeutic cultivation and fertility applications on bermudagrass recovery during the growing season from SDS caused by *O. herpotricha* (Dernoeden et al., 1991; Miller et al., 2017; Tisserat and Fry, 1997; Tredway et al., 2009a, 2020). Most research efforts addressing the influence of cultivation practices on SDS have been aimed at the prevention of SDS the following spring (Miller et al., 2017; Tisserat and Fry, 1997). Based on a review of the literature, there have been no studies of how cultivation practices such as vertical mowing and solid-tine aerification affect bermudagrass recovery from SDS within the same growing season. Moreover, SDS patches can be slow to recover because of the use of certain preemergence herbicides or metabolites produced by the pathogen that can inhibit shoot regrowth (Beck et al., 2013; Fermanian et al., 1981; Venkatasubbaiah et al., 1994). Therefore, methods to aid in bermudagrass recovery from SDS damage are needed. The objective of our studies was to determine how implementation of late spring/early summer vertical mowing, solid-tine aerification, and urea (46–0–0) applications influence bermudagrass recovery from SDS within the same growing season.

Materials and Methods

Site description. A field study of SDS symptomatic ‘Latitude 36’ hybrid bermudagrass at the Virginia Tech Practice Football Field (VTPFF), Blacksburg, VA, and SDS symptomatic ‘NorthBridge’ hybrid bermudagrass at Blacksburg Country Club (BCC), Blacksburg, VA, growing in urban soils was conducted. Based on a recently conducted *Ophiosphaerella* species geographic distribution study, *O. herpotricha* is primarily isolated in the Blacksburg area, where both of our study sites are located (Hutchens et al., 2021). Studies were conducted at the VTPFF from 24 May 2019 to 2 Aug. 2019, and repeated the following year from 25 June 2020 to 6 Aug. 2020. Studies at BCC were conducted from 30 May 2019 to 12 Aug. 2019, and repeated the following year from 25 June 2020 to 6 Aug. 2020. The Latitude 36 hybrid bermudagrass at the VTPFF was maintained at 1.3 cm with an irrigation regiment sufficient to maintain turf vigor and prevent wilt, whereas the NorthBridge hybrid bermudagrass at BCC was maintained at 1.3 cm with no supplemental irrigation. No preventative SDS fungicide applications were made at either study site.

Study design and treatments. In both studies, the main effects of fertility and cultivation were arranged in a 2 × 3 factorial design in complete blocks with vertical mowing at a 1-cm depth from the soil surface, solid-tine aerification with 16-mm diameter tines at a 5.7-cm depth, and no cultivation applied with urea (48.8 $kg{\cdot}ha^{-1}$ N) sprayed at trial initiation and 2 weeks later or without urea. There were four replications, and treatments were applied to 1.8-m × 1.8-m plots with a CO_2-pressurized sprayer delivering solution at 276 kPa of pressure at a carrier volume of 842 $L{\cdot}ha^{-1}$. Urea treatments were irrigated within 1 h after application in an attempt to prevent severe foliar burn from the fertilizer. Individual treatments are listed in Table 1. The same plots for each treatment were used in both study years.

Data collection and analysis. Plots were visually assessed every 1 to 2 weeks throughout the duration of the study to determine the percent SDS. The percent SDS was measured as the percent area of the plot expressing sunken and/or necrotic patches with at least a 7.6-cm diameter area of necrosis. All data were transformed to percent change relative to the initial assessment within the plot. The additive inverse of the percent change relative to the initial assessment is equal to the percent bermudagrass recovery. The

Table 1. Treatments for spring dead spot recovery trials at Blacksburg Country Club and the Virginia Tech Practice Football Field.

Cultivation[z]	Fertility[y]	Treatment name
None	None	Nontreated control
Vertical mowing	None	Vertical mowing
Solid-tine aerification	None	Solid-tine aerification
None	96.7 $kg{\cdot}ha^{-1}$ N	Urea
Vertical mowing	96.7 $kg{\cdot}ha^{-1}$ N	Urea + vertical mowing
Solid-tine aerification	96.7 $kg{\cdot}ha^{-1}$ N	Urea + solid-tine aerification

[z]Vertical mowing was applied at trial initiation at a 1-cm depth and solid-tine aerification was applied at a 5.7-cm depth at trial initiation with 16-mm diameter tines.

[y]All fertility applications were made with urea at a rate of 48.8 $kg{\cdot}ha^{-1}$ N applied at trial initiation and 2 weeks later.

Table 2. Analysis of variance for main effects of fertilization, main effects of cultivation, and interaction effects on bermudagrass recovery from spring dead spot at Blacksburg Country Club in 2019 and 2020.

Yr	Source	df	Sum of squares	Mean square	F-value	*P* value
2019	Cultivation	2	2,439,014	1,219,507	1.7810	0.2023
	Fertility	1	3,396,236	3,396,236	4.9599	0.0417
	Cultivation × fertility	2	2,567,146	1,283,573	1.8745	0.1876
	Block	3	11,523,729	3,841,243	5.6098	0.0088
	Error	15	10,271,151	684,743		
	Total	23	30,197,275			
2020	Cultivation	2	8,874,224.4	4,437,112.2	7.0148	0.0071
	Fertility	1	3,453,958.5	3,453,958.5	5.4605	0.0337
	Cultivation × fertility	2	1,615,208.4	807,604.2	1.2768	0.3076
	Block	3	1,775,241.1	591,747.0333	0.9355	0.4479
	Error	15	9,487,992	632,533		
	Total	23	25,206,624			

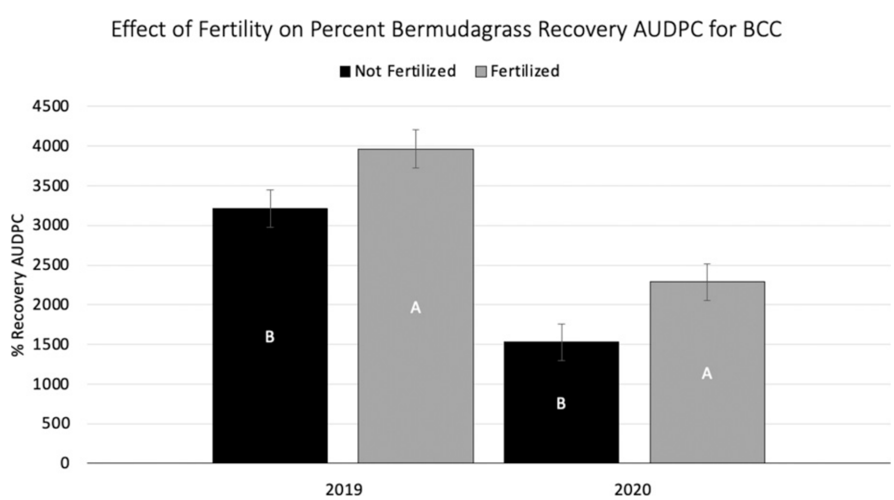

Fig. 1. Main effect of fertility on the percent bermudagrass recovery area under the disease progress curve (AUDPC) at Blacksburg Country Club in 2019 and 2020. Different color bars represent different fertility practices. Means are compared within the year. Bars with different letters are significantly different ($P < 0.05$).

equation was as follows (n is equal to any given assessment date): Percent recovery = [(Assessment$_{Initial}$ − Assessment$_n$)/Assessment$_{Initial}$] × 100. Initial assessments were performed on the day of study initiation. The range of the initial percent SDS within each plot at each location was as follows: VTPFF in 2019 (1% to 18%), VTPFF in 2020 (0.6% to 20%), BCC in 2019 (2% to 35%), and BCC in 2020 (1.5% to 20%). Final assessments were performed on 2 Aug. 2019 and 6 Aug. 2020 at VTPFF, and on 12 Aug. 2019 and 6 Aug. 2020 at BCC. The relative percent SDS compared with the initial SDS (i.e., percent recovery) was converted to the area under the disease progress curve to encompass the factor of time and bermudagrass recovery from SDS damage. The main effects were separated by year for each location. Data were subjected to an analysis of variance and means were separated using Student's t test. Means were separated with a significance level of $P \leq 0.1$ in JMP Pro 15 (SAS Institute, Cary, NC).

Results

The main effect of fertility increased bermudagrass recovery in both 2019 and 2020 ($P \leq 0.0417$) at BCC (Table 2). In 2019, fertility increased bermudagrass recovery by 19% compared with nonfertilized plots (Fig. 1). Similarly, in 2020, fertility increased bermudagrass recovery by 33% compared with nonfertilized plots (Fig. 1). The main effect of fertility influenced bermudagrass recovery ($P = 0.0629$) at VTPFF in 2019, but fertility did not influence bermudagrass recovery in 2020 ($P = 0.4907$) (Table 3). Fertility increased bermudagrass recovery by 40% in 2019 at VTPFF (Fig. 2).

Although there were negative trends on bermudagrass recovery in both years at BCC, cultivation practice did not have a significant effect on bermudagrass recovery in 2019 ($P = 0.2023$), but it did negatively impact bermudagrass recovery in 2020 ($P = 0.0071$) (Table 2). Bermudagrass recovery for solid-tine aerification and vertical mowing were not significantly different, and both cultivation practices reduced bermudagrass recovery by >32% compared with no cultivation (Fig. 3). There was no significant main effect of cultivation at VTPFF in 2019 ($P = 0.6420$) or 2020 ($P = 0.5304$) (Table 3), but the trends were similar to BCC with solid-tine aerification and vertical mowing numerically reducing bermudagrass recovery. There were no fertility × cultivation effects at BCC or VTPFF.

Discussion

Our data suggest that late spring/early summer nitrogen applications are beneficial to turf recovery from SDS damage. Dernoeden et al. (1991) observed findings similar to those of our studies, with spring/summer applications of nitrogen increasing bermudagrass recovery from SDS damage. The authors showed that all sources of nitrogen evaluated enhanced turf recovery from SDS damage, yet the rate of recovery compared with a nontreated control differed among nitrogen sources. We found that late spring/early summer applications of urea were beneficial for turf recovery from SDS damage, suggesting that nitrogen is the key nutrient for turf recovery. Similarly, Dernoeden et al. (1991) showed that urea increased bermudagrass recovery from SDS. This has been documented for dead spot of creeping bentgrass (*Ophiosphaerella agrostis*) as well (Kaminski and Dernoeden, 2005).

We observed that plots treated with fertility in 2019 had less initial SDS in 2020 relative to the initial SDS in 2019 ($P = 0.0718$) at VTPFF (data not shown). This provides further support that nitrogen applications could be beneficial for SDS suppression; however, no significant reduction of SDS in 2020 from fertility applications in 2019 at BCC were observed (data not shown). Ammonium sulfate and calcium nitrate applications have also been shown to reduce SDS damage, depending on which *Ophiosphaerella* species is present (Dernoeden et al., 1991; Tredway et al., 2020). Our results are different from what McCarty et al. (1992) reported, with sulfur-coated urea increasing SDS up to 128%. Nitrogen applications in our study were made in late spring/early summer, whereas nitrogen applications used during the McCarty et al. (1992) study were made in the fall, offering a potential reason for the different results. Moreover, the addition of sulfur to the plant by using sulfur-coated urea in one study (McCarty et al., 1992) may have been the reason for the increased SDS, and this was also documented in another study (Perry et al., 2010).

Urea is a cost-effective fertilizer, but it only provides nitrogen to the plant; misapplications can cause phytotoxicity because of its high water solubility (Krogmeier et al., 1989). Less soluble fertilizers delivering nitrogen, as well as other required macronutrients or micronutrients, may be better options than urea on bermudagrass in the late spring/early summer to enhance overall bermudagrass health as well as recovery from SDS damage. Further research of the effects of the nitrogen source, other nutrients, and application timing on bermudagrass recovery and prevention from SDS damage needs to be conducted.

Our study showed that cultivation was inhibitory to bermudagrass recovery at BCC, but not at VTPFF. The VTPFF location was

Table 3. Analysis of variance for main effects of fertilization, main effects of cultivation, and interaction effects on bermudagrass recovery from spring dead spot at Virginia Tech Practice Football Field in 2019 and 2020.

Yr	Source	df	Sum of squares	Mean square	F-value	P value
2019	Cultivation	2	724,134	362,067	0.4565	0.6420
	Fertility	1	3,200,442	3,200,442	4.0355	0.0629
	Cultivation × fertility	2	2,330,997	1,165,498.5	1.4696	0.2613
	Block	3	14,354,870	4,784,956.7	6.0335	0.0066
	Error	15	11,895,949	793,063		
	Total	23	32,506,393			
2020	Cultivation	2	1,233,570.3	616,785.15	0.6617	0.5304
	Fertility	1	464,831.4	464,831.4	0.4991	0.4907
	Cultivation × fertility	2	831,117.9	415,558.95	0.4462	0.6483
	Block	3	3,782,162.8	1,260,720.93	1.3537	0.2948
	Error	15	13,969,938	788,835		
	Total	23	20,280,620			

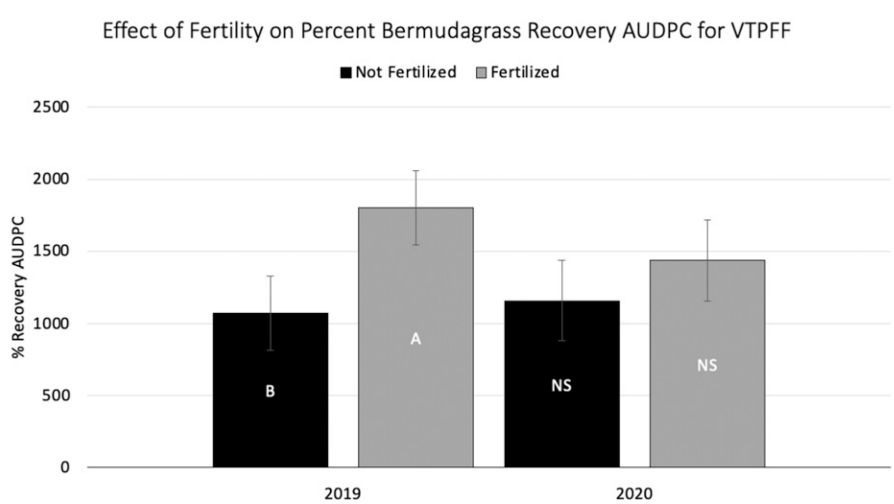

Fig. 2. Main effect of fertility on the percent bermudagrass recovery area under the disease progress curve (AUDPC) at Virginia Tech Practice Football Field in 2019 and 2020. Different color bars represent different fertility practices. Means are compared within the year. Bars with different letters are significantly different ($P < 0.1$).

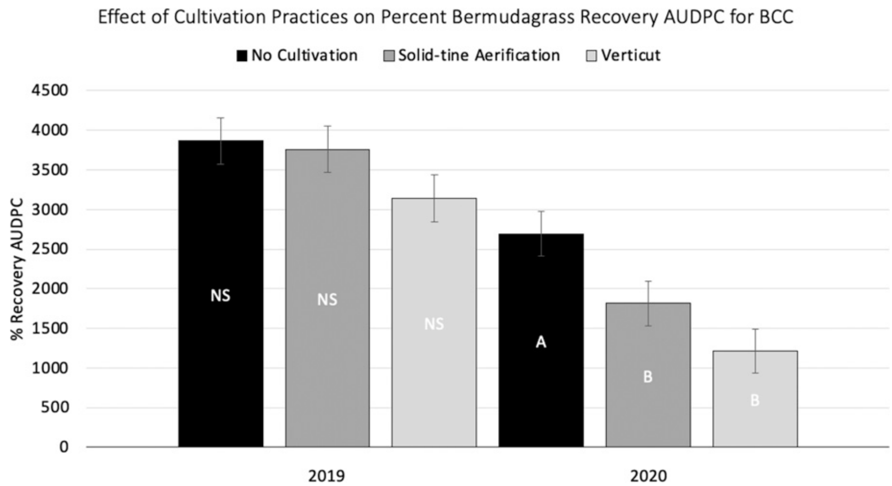

Fig. 3. Main effect of cultivation practice on the percent bermudagrass recovery area under the disease progress curve (AUDPC) at Blacksburg Country Club in 2019 and 2020. Different color bars represent different cultivation practices. Means are compared within the year. Bars with different letters are significantly different ($P < 0.05$).

more intensively managed than the BCC location, which may have reduced the inhibitory effects of cultivation on bermudagrass recovery from SDS. No research of the influence of cultivation practices on SDS recovery within the same season has been published, but research of the use of cultivation practices for the prevention of SDS is well-documented. Tisserat and Fry (1997) showed that vertical mowing or aerifying alone did not reduce SDS symptom expression the following spring, which is similar to what we observed (data not shown). However, they demonstrated that the combination of vertical mowing and aerifying did reduce SDS symptom expression the following spring. Miller et al. (2017) showed similar results with treatments using the highly disruptive fraze mower. In contrast, Perry et al. (2010) demonstrated that core aerifying or vertical mowing in the summer can increase SDS the following spring. However, the effects of increased SDS with cultivation practices were only observed during 1 year of a 3-year study (Perry et al., 2010). The Tisserat and Fry (1997) and Miller et al. (2017) studies suggested that highly disruptive cultivation practices are beneficial for preventing SDS the following season, which is likely because of thatch reduction and removal, increased oxygen to the root zone, and generation of new growing points on the plant. Our data suggest that early season cultivation, particularly in the absence of fertility, can decrease bermudagrass recovery from SDS within the same season. Although disruptive cultivation practices can be beneficial for the prevention of SDS, they do not aid in bermudagrass recovery from SDS damage within the same season, particularly in the absence of nitrogen fertility.

Our data indicate that up to 97.6 $kg \cdot ha^{-1}$ N from urea applied over a 2-week period in late spring/early summer greatly accelerated bermudagrass recovery from SDS. Cultivation practices should be implemented after bermudagrass has mostly recovered from SDS damage, which often occurs during midsummer. If 97.6 $kg \cdot ha^{-1}$ N is applied in late spring and cultivation is conducted in midsummer, then bermudagrass recovery from SDS damage should be optimized. However, more research needs to be conducted to determine the effects of various nitrogen sources and application timings on bermudagrass recovery from SDS damage.

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