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Newly Established Bermudagrass Response to Topramezone and Photosystem II-Inhibitor Herbicides

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Abstract

Bermudagrass is the most troublesome and difficult-to-control perennial grass weed in Florida sugarcane. Once established, it is only controlled effectively during the sugarcane fallow period using nonselective herbicides and tillage combinations. It is important to evaluate options for selective management of bermudagrass that escape sugarcane fallow period management programs to mitigate its progressive increase as the crop cycle increases from plant cane to ratoon crops. Greenhouse and field studies were conducted in Belle Glade, Florida, from 2017 to 2018 to determine the response of newly established bermudagrass from sprigs with stolons to two or three sequential applications of topramezone (25 and 50 g ha^{-1}) every 14 d and the combinations of topramezone (25 and 50 g ha^{-1}) with photosystem II (PS II)-inhibitor herbicides atrazine (2,240 g ha^{-1}), ametryn (440 g ha^{-1}), and metribuzin (2,240 g ha^{-1}). Two or three sequential applications of topramezone with a cumulative total of 75 to 100 g ha^{-1} provided >93% bermudagrass control 42 d after the first sequential application under greenhouse and field conditions. These treatments had 12% chance of survival 70 d after the first sequential application. There was an additive effect of PS-II inhibitor herbicides on bermudagrass control in mixtures with topramezone. The mixture of topramezone (50 g ha^{-1}) with metribuzin and atrazine provided more than 87% and 92% bermudagrass control under greenhouse and field conditions, respectively, 42 d after treatment. Bermudagrass treated with topramezone (50 g ha^{-1}) mixture with metribuzin had 23% chance of survival 70 d after treatment. The results show good efficacy of sequential topramezone applications every 14 d or mixtures with PS-II inhibitor herbicides atrazine and metribuzin for control of newly established bermudagrass which typically escape control measures during the sugarcane fallow management period.

Nomenclature: Ametryn; atrazine; metribuzin; topramezone; bermudagrass, *Cynodon dactylon* (L.) Pers. CYNDA; sugarcane, *Saccharum spp*. hybrid.

Key words: Perennial grass control, PS-II inhibitor herbicides, mixtures, plant cane.

Bermudagrass is one of the world's most serious perennial grassy weeds associated with many crops, including sugarcane (Holm et al. 1977; Mitich 1989). Sugarcane is an important crop in Florida grown on approximately 165,000 ha mainly on organic soils in the Everglades Agricultural Area in the southern part of the state (USDA-NASS 2024; VanWeelden et al. 2024). Bermudagrass is the most troublesome and difficult-to-control perennial grassy weed in Florida sugarcane (Webster 2012). Bermudagrass thrives in the hot and humid summers and cool to mild winters with infrequent frost in the subtropical climate of southern Florida where sugarcane is cultivated. Because bermudagrass is stoloniferous, it can rapidly spread laterally on the surface by an extensive network of strong flat stolons and subterraneously by deep scaly rhizomes (Mitich 1989), making it difficult to control once established in sugarcane. Bermudagrass mainly propagates vegetatively by rhizomes and stolons although limited spread by seeds can occur (Fernandez 2003; Holm et al. 1977).

Sugarcane is a 3- to 4-year perennial crop obtained from planting vegetative stalk pieces or setts from late August until early January in Florida. Florida sugarcane is harvested from mid-October to end of May. After harvest of the first crop in a year, referred to as plant cane, another crop of stalks, called a ratoon grows from the old plant stubble. There are usually one to three ratoon crops harvested approximately every year after the first plant cane harvest in Florida depending on cane and sugar yields, prevailing environmental conditions, and occurrences as well as type of pests. Interference from established perennial grasses such as bermudagrass can result in short longevity of the sugarcane crop by reducing the number of ratooning years. During the multi-year sugarcane cropping period, tillage is limited to the row middles thus allowing bermudagrass to establish over sugarcane rows and become difficult to selectively control (Richard and Dalley 2007). Reduction in sugarcane yield from bermudagrass infestation results in fallowing fields prior to replanting. The fallow period begins after the harvest of the final ratoon crop with mechanical destruction of the stubble crop and continues until the subsequent planting of the new crop. In Florida, fallow fields can also be planted with crops such as sweet corn (*Zea mays* spp. *saccharata*), snap bean (*Phaseolus vulgaris* L.), lettuce (*Lactuca sativa* L.), radish (*Raphanus sativus* L.), or rice (*Oryza sativa* L.) prior to sugarcane planting (Odero et al. 2023).

Although bermudagrass is a short stature grass compared to taller grasses like johnsongrass (*Sorghum halepense* (L.) Pers.) and itchgrass (*Rottboellia cochinchinensis* (Lour.)

Claton) which infests sugarcane (Leon and Odero 2018), it can produce heavy ground cover capable of causing sugarcane yield losses. Bermudagrass interference in sugarcane in Louisiana reduced sugar yields by up to 32% each year in the plant cane crop and the second ratoon crop with greater yield loss occurring in the plant cane crop (Richard 1992, 1993; Richard and Dalley 2007). Even though there are no studies on bermudagrass interference effects on sugarcane yield in Florida, yield reduction is certainly higher because of the lack of hard winter seasons seen in Louisiana, where bermudagrass becomes dormant, thereby slowing its growth and development. This results in high bermudagrass infestations in Florida progressively as the crop cycle increases from plant cane into the ratoon crops. Because of lack of herbicides for selective control of bermudagrass in sugarcane, its vegetative propagules are usually only destroyed or reduced during the sugarcane fallow period primarily through multiple glyphosate applications and tillage (Ethredge et al. 2009; Miller et al. 1999; Richard 1997). Ethredge et al. (2009) reported that bermudagrass groundcover was reduced by 81% to 95% when treated with multiple glyphosate applications in combination with tillage. In Florida, where sugarcane is rotated with vegetable crops during the fallow period, bermudagrass vegetative propagules are reduced with graminicides used in these crops (Sandoya-Miranda et al. 2024). However, there still can be bermudagrass escapes in new plant cane, which are established from viable stolons and rhizomes despite the efficacy of fallow management programs (Ethridge et al. 2009). Also, bermudagrass escapes occur when sugarcane is successively replanted immediately after harvest of the final ratoon crop from viable stolons and rhizomes (Fernandez 2003). Approximately 30% of the Florida sugarcane acreage is plant cane with 66% and 34% from the fallow and successive planting systems, respectively (VanWeelden et al. 2024).

It is important to develop management programs that target bermudagrass which escape fallow management programs to mitigate any increases over time during the multi-year sugarcane cropping period. Topramezone is a postemergence herbicide with safety on sugarcane recently approved for control of broadleaf and grassy weeds in the crop (Anonymous 2018; Negrisoli et al. 2020). It belongs to the pyrazole family which inhibits 4-hydroxyphenylpyruvate dioxygenase (HPPD), a key enzyme in the biosynthesis of carotenoids (Grossmann and Ehrhardt 2007; Jhala et al. 2023; Shaner 2014). Topramezone elicits bleaching or whitening in susceptible plant species followed by death (Grossmann and Ehrhardt 2007; Jhala et al. 2023; Shaner 2014). It has been shown to significantly bleach bermudagrass leaf tissue and reduce total chlorophyll, lutein, and total xanthophyll cycle pigment concentrations (Brosnan et al. 2011; Elmore et al. 2011). Topramezone and mixtures with photosystem (PS) II-inhibiting herbicides provide more efficacious weed control compared with topramezone applied alone (Negrisoli et al. 2020; Fluttert et al. 2022). Photosystem II-inhibitor triazine herbicides including atrazine, ametryn, and metribuzin are widely used in Florida sugarcane for weed control (Odero and Dusky 2021). It is important to determine the efficacy of topramezone in mixtures with PS II-inhibitor herbicides used in Florida sugarcane for control of newly established bermudagrass that escape fallow management programs. The objective of this study was to evaluate the level of control of newly established bermudagrass from sprigs with stolons using 1) sequential applications of topramezone, and 2) topramezone applied alone or in combination with PS-II inhibitor herbicides atrazine, ametryn, and metribuzin.

Materials and Methods

Sequential topramezone application study

Greenhouse experiment. Two greenhouse experiments were conducted at the University of Florida Everglades Research and Education Center (EREC) in Belle Glade, Florida, from 2017 to 2018. Bermudagrass was established using sprigs collected from sugarcane fields at the EREC. Sprigs with stolons averaging 15-cm long with two to four rooting nodes were planted into round 7.6-L (16-cm top diameter and 17-cm height) pots filled with a commercial potting medium (Fafard®; Sun Gro Horticulture, Agawam, MA) on September 18, 2017, and December 13, 2017, for the first and second experimental runs, respectively. The basal part of sprigs with stolons having rooting nodes were planted approximately 8 cm below the potting medium surface. A slow-release 14-14-14 fertilizer (Osmocote®; The Scotts Company, Marysville, OH) was mixed with the potting medium, and the plants were kept in a greenhouse with a maximum temperature of 30 C under natural light for the entire study. The plants were watered as needed to ensure that moisture was not a limiting factor. Plants averaged 16 cm in length, ascending to decumbent stems 21 d after establishment. Herbicide treatments were applied on October 9, 2017, for the first experimental run and on January 3, 2018, for the second experimental run after plant sizes were recorded 21 d after establishment.

The experiment was a completely randomized design with five replications of each treatment. Topramezone (Armezon®, BASF Corporation, Research Triangle Park, NC) was

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applied at 25 and 50 g ha^{-1} once or sequentially every 14 d for up to three applications for a total of nine treatments (Table 1). All herbicide treatments included methylated seed oil (99% ai; Dyne-Amic®; Helena Chemical Co.) at 1% v/v. A nontreated control was included for comparison. Herbicide treatments were applied using a moving-nozzle spray chamber (Generation II Spray Booth, Devries Manufacturing Hollandale, MN) equipped with a TeeJet® 8002E nozzle tip (Spraying Systems, Wheaton, IL) calibrated to deliver 187 L ha^{-1} at 172 kPa. Plants were returned to the greenhouse immediately after herbicide application in the spray chamber.

Bermudagrass control was visually estimated using a scale of 0 to 100, with 0 being no control and 100 being complete plant death 14 d after the final or third sequential topramezone treatment application (equivalent to 42 d after the first sequential or single application). Plants were harvested at the soil surface level 42 d after the first sequential or single application and dried in an oven for 48 h at 60 C to determine aboveground dry weight.

Field experiment. Two field experiments were conducted at the EREC in Belle Glade, Florida (26.6583°N, 80.6260°W) in 2018 and 2019. The soil type was Dania muck (Euic, hyperthermic, shallow Lithic Haplosaprists) with pH of 7.3 and 85% organic matter. Soil pH and organic matter content were determined using the method described by Fernandez et al. (2019). Bermudagrass was established from sprigs with stolons as described in the greenhouse experiment but using muck soil as the potting medium. The plants were kept in the greenhouse for 14 d before transplanting in the field when plants averaged 12 cm in length with ascending to decumbent stems. The fields were conventionally prepared and treated with preemergence applied atrazine (4.5 kg ha^{-1}) and pendimethalin at (4.3 kg ha^{-1}) prior to transplanting bermudagrass to control other weed species. Plots were subsequently kept free of any other weeds by hand pulling. The first experimental run was transplanted in the field on March 6, 2018, and the second experimental run was transplanted on April 2, 2019. The field was sprinkler irrigated as needed to ensure establishment of the transplanted bermudagrass. The experiment was set up as described to simulate the occurrence of bermudagrass escapes in a plant cane field because it was difficult to get a homogenous infestation of new escapes in a field large enough to set up the experiment. Once established, herbicide treatments were applied 21 d after transplanting on April 10, 2018, for the first experimental run, and on May 7, 2019, for the

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second experimental run. Plants averaged 36 cm in length from the longest ends with spreading mat forming stolons.

The experiment was a randomized complete block design with four replications. Plots were 2 m by 2 m. One pot was transplanted at the center of each plot. Topramezone was applied at 25 and 50 g ha^{-1} once or sequentially every 14 d for up to three applications for nine treatments (Table 1). All treatments included methylated seed oil at 1% v/v. A nontreated control was included for comparison. Herbicide treatments were applied using a CO_2-pressurized backpack sprayer with a swath width of 1.8 m calibrated to deliver 187 L ha^{-1} at 276 kPa using TeeJet® XR11002VS nozzle tips at a walking speed of 4.8 km hr^{-1}.

Visual estimation of bermudagrass control was made using a scale of 0 to 100, with 0 being no control and 100 being complete plant death at 14 d after the final or third sequential topramezone application (equivalent to 42 d after the first sequential or single topramezone application). The binomial response of the presence or absence of bermudagrass green tissue was recorded 28 d after the final control rating from each plot (equivalent to 70 d after the first sequential or single topramezone application) as 1 or 0, respectively, to determine chances of bermudagrass surviving topramezone sequential treatments.

Topramezone and mixtures with PS II-inhibitor herbicides study

Greenhouse experiment. Two greenhouse experiments were conducted at the EREC in Belle Glade, Florida in 2017 to 2018. Bermudagrass was established from sprigs with stolons as described in the sequential greenhouse experiment using the same potting medium on September 18, 2017, and December 13, 2017, for the first and second experimental runs, respectively. Plants of the same size as in the sequential greenhouse experiment were treated with herbicides 21 d after planting on October 9, 2017, for the first experimental run, and on January 3, 2018, for the second experimental run.

The experiment was a completely randomized design with five replications of each treatment. Topramezone was applied at 25 and 50 g ha^{-1} or in mixtures with PS II-inhibitor herbicides atrazine at 2,240 g ha^{-1}, ametryn at 440 g ha^{-1}, or metribuzin at 2,240 g ha^{-1} for a total of eight treatments (Table 2). These are rates of the PS II-inhibitor herbicides commonly used for weed control in Florida sugarcane (Odero and Dusky 2021). Methylated seed oil at 1% v/v was included in all treatments. A nontreated control was included for comparison. Herbicide treatments were applied as described in the sequential greenhouse experiment.

Visual estimation of bermudagrass control was made using a scale of 0 to 100, with 0 being no control and 100 being complete plant death at 42 d after treatment. Plants were harvested at the soil surface level 42 d after treatment and aboveground dry weight determined as described in the sequential greenhouse experiment.

Field experiment. Two field experiments were conducted at the EREC in Belle Glade, FL in 2018 and 2019 at the same location as the sequential field experiment. Bermudagrass was established from sprigs with stolons, transplanted, and maintained in the field as described in the sequential field experiment. The first and second experimental runs were transplanted in the field on March 6, 2018, and April 2, 2019, respectively. Herbicide treatments were applied on plants of similar sizes like for the sequential field experiment 21 d after transplanting on April 10, 2018, for the first experimental run and on May 7, 2019, for the second experimental run.

The experiment was a randomized complete block design with four replications. Plots were 2 m by 2 m with one pot transplanted at the center of each plot. Topramezone was applied alone and in mixtures at rates like for the greenhouse experiment (Table 2). A nontreated control was included for comparison. Herbicide treatments were applied as described in the sequential field experiment.

Bermudagrass control was visually estimated using a scale of 0 to 100, with 0 being no control and 100 being complete plant death at 42 d after treatment application. The binomial response of presence or absence of bermudagrass green tissue was recorded as 1 or 0, respectively from each plot 70 d after treatment to determine chances of bermudagrass surviving topramezone and mixture treatments.

Statistical analysis

Bermudagrass control and aboveground dry weight data for the topramezone sequential and mixtures with PS II-inhibitor herbicides studies were subjected to ANOVA using the LME4 package (Bates et al. 2024) of the R statistical language (version 4.2.2; R Core Team 2022). The control and aboveground dry weight data were analyzed using a mixed-effects model with the *lmer* function in the LME4 package for both greenhouse and field experiments. Treatment was considered a fixed effect, while experimental run and replication nested within experimental run were considered as random effects. Estimated marginal means were calculated where significant effects were detected, and the post hoc Tukey test was performed for all pairwise comparisons ($P < 0.05$) using the EMMEANS package of R (Lenth 2024). A generalized linear model was used to conduct analysis of deviance for the binomial response data of presence or absence of bermudagrass green tissue for the topramezone sequential and mixtures with PS II-inhibitor herbicides field experiments. Analysis of deviance, analogous to ANOVA, is appropriate for binomial data (Venables and Ripley 2002). The binary outcome of presence or absence of bermudagrass green tissue was analyzed using the *glmer* function with a binomial family in the LME4 package for both topramezone sequential and mixture field experiments. The probability of having green bermudagrass tissue 70 d after treatment was determined for each observation using the *predict* function in R followed by aggregation of the predicted probabilities by treatment and replication nested within run using the *aggregate* function in R. The mean probabilities of each treatment across replication nested within run was predicted using the *aggregate* function for both topramezone sequential and mixture field experiments.

Results and Discussion

Sequential topramezone application study

The main effect of herbicide treatment was significant for newly established bermudagrass control and aboveground dry weight accumulation in response to sequential topramezone applications for the greenhouse experiment ($P < 0.05$). Bermudagrass control ranged from 78% to complete control 42 d after the first sequential or single application of topramezone (equivalent to 14 d after the final sequential application) (Table 1). A single application of topramezone at 25 g ha^{-1} controlled bermudagrass less (78%) effectively than topramezone at 50 g ha^{-1} (89%) and the sequential applications of topramezone (>99%). All sequential applications of topramezone controlled bermudagrass by over 99% and were more effective than single applications. All topramezone applications reduced bermudagrass aboveground biomass accumulation 42 d after the first sequential or single application compared to the nontreated control even though there were no significant differences between the treatments (Table 1). Similar to the greenhouse experiment, the effect of herbicide treatment was important for controlling newly established bermudagrass in the field ($P < 0.05$). Single or sequential topramezone applications controlled bermudagrass 61% to 100% 42 d after the first sequential or

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single application in the field (Table 1). Single application of topramezone at 25 g ha^{-1} controlled bermudagrass less effectively compared to the single topramezone application at 50 g ha^{-1} and the sequential applications in the field. Sequential applications of topramezone in the field controlled bermudagrass 87% to 100% with no differences between the treatments. Sequential applications with a cumulative total of 75 to 100 g ha^{-1} controlled bermudagrass by >93% in the field. Brewer et al. (2017) predicted that a single application of topramezone at 36.8 g ha^{-1} would cause a maximum bermudagrass injury of 81%. In comparison, a sequential application of the same rate, applied at a 21-d interval, resulted in a higher injury level of 93%. Topramezone can be applied at 25 to 50 g ha^{-1} on sugarcane with not more than 50 g ha^{-1} per application and not more than a cumulative total of 100 g ha^{-1} per year (Anonymous 2018). These results indicate that sequential applications of topramezone at 14 d intervals provided greater control of newly established bermudagrass than single applications in greenhouse and field experiments. Topramezone injury on bermudagrass was manifested as bleaching of leaf tissue with most of the bleaching observed 14 d after treatment. Brosnan et al. (2011) reported that sequential application of topramezone for bermudagrass control should be made at 14 to 21 d intervals because the stress imposed by the herbicide was greatest at 14 and 21 d after treatment when peak visual bleaching occurred. These intervals were ideal because bermudagrass increased its photoprotective xanthophyll cycle pigments, a mechanism which allows it to recover from HPPD-inhibiting herbicide injury 14 and 21 d after treatment, allowing it to recover by 35 d after treatment (Brosnan et al. 2011). Similarly, Elmore at al. (2011) suggested that sequential applications of topramezone on hybrid bermudagrass should occur at 14 to 21 d intervals based on occurrence of peak visual bleaching and maximum pigment reductions at these intervals.

The effect of single or sequential topramezone applications with respect to bermudagrass probability of survival in the field based on the presence of green tissue 28 d after the final control rating (equivalent to 70 d after the first sequential or single topramezone application) was significant ($P < 0.05$). The probability of bermudagrass survival was higher for single topramezone application treatments compared to sequential application treatments (Table 1). Bermudagrass treated with single topramezone application at 25 g ha^{-1} was estimated to have 100% chance of survival 70 d after the first sequential or single application compared to 88% for topramezone at 50 g ha^{-1} and 12% to 75% for sequential applications. Bermudagrass treated with two and three sequential applications of topramezone with a cumulative total of 100 g ha^{-1} had

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12% chance of survival compared to two applications with a cumulative total of 75 g ha^{-1} that had 37% chance of survival. The results show that topramezone sequential applications every 14 d with cumulative total of 100 g ha^{-1} is necessary to reduce chances of newly established bermudagrass surviving topramezone treatment application as the crop season progresses. The present study was conducted under full sunlight with no shading on bermudagrass which is atypical in a sugarcane field. Sugarcane canopy closure can be slow, intermediate, or fast depending on the sugarcane cultivar. For example, sugarcane ‘CP 80-1762’ and ‘CP 88-1743’ have intermediate and fast canopy closures, respectively (Sandhu et al. 2022a, 2022b). Weed growth and development are influenced by the speed of sugarcane canopy closure. Bermudagrass foliar growth and ground cover are negatively impacted by shading (Bittencourt 2009; Jurami et al. 2004). Because shading reduces bermudagrass growth and development, it is likely that the effect of topramezone in combination with shading as sugarcane canopy closes can be important for its long-term control. For fields likely to have bermudagrass escaping fallow management programs, planting sugarcane cultivars which emerge early, generate high stalk population with less upright leaves, and produce shading can be important in ensuring increased efficacy of topramezone for management of bermudagrass.

Topramezone and mixtures with PS II-inhibitor herbicides study

The main effect of herbicide treatment was significant for newly established bermudagrass control and aboveground dry weight accumulation in response to application of topramezone and mixtures with PS II-inhibitor herbicides for the greenhouse experiment ($P < 0.05$). Bermudagrass control ranged from 72% to 100% at 42 d after treatment (Table 2). Topramezone applied alone at 25 g ha^{-1} provided 72% control at 42 d after treatment compared to 86% control with the highest rate although they were not significantly different. Mixtures of topramezone at 25 g ha^{-1} with atrazine, metribuzin, and ametryn provided 87%, 90%, and 89% control, respectively compared to 97%, 100%, and 87% control with topramezone at 50 g ha^{-1} in mixtures with atrazine, metribuzin, and ametryn, respectively. Bermudagrass control was improved 15% to 18% with mixtures of topramezone at the lower rate with the PS II-inhibitor herbicides compared to 1% to 14% improvement with mixtures of topramezone at the highest rate. The combination of topramezone (50 g ai ha^{-1}) with metribuzin provided the highest bermudagrass control (100%) whereas topramezone (25 g ha^{-1}) plus ametryn had the least control (87%) although they were not significantly different. All treatments significantly reduced bermudagrass aboveground biomass compared to the nontreated control (Table 2). However, topramezone at 25 g ai ha^{-1} had significantly higher aboveground biomass accumulation compared to the higher rate and all mixtures. The effect of herbicide treatment was significant for control of newly established bermudagrass in the field ($P < 0.05$). Bermudagrass control ranged from 63% to 79% with topramezone only treatments compared with 84% to 95% control provided by topramezone mixtures with PS II-inhibitor herbicides 42 d after treatment in the field (Table 2). Mixtures of topramezone at 25 g ha^{-1} with PS II-inhibitor herbicides controlled bermudagrass 79% to 84% compared with 88% to 95% control provided by mixtures with topramezone at 50 g ha^{-1}. Bermudagrass control was improved 16% to 21% with mixtures of topramezone at the lower rate with the triazine herbicides compared to 7% to 13% improvement with mixtures of topramezone at the highest rate in the field. Similar to the greenhouse experiment, improvement on bermudagrass control with PS II-inhibitor herbicides was much more profound for mixtures with topramezone at 25 g ha^{-1} compared to 50 g ha^{-1}. The mixture of topramezone (50 g ai ha^{-1}) plus metribuzin provided the highest bermudagrass control (95%), whereas topramezone (25 g ha^{-1}) plus ametryn had the least control (79%) even though they were not significantly different. Results from this study indicate that the level of bermudagrass control improved with combinations of topramezone with atrazine, ametryn, and metribuzin. Enhancement of control of several weed species by combining HPPD and PS II-inhibitor herbicides has been reported (Armel et al. 2007; Negrisoli et al. 2020; Fluttert et al. 2022). The interactive effects of HPPD and PS II-inhibitor herbicides have mainly been reported to involve atrazine (Fluttert et al. 2022). In this study, bermudagrass control improved with the combination of topramezone with metribuzin and ametryn with the highest level of control occurring with the combination with metribuzin. Similarly, Negrisoli et al. (2020) reported improved control of fall panicum (*Panicum dichotomiflorum* Michx.) in sugarcane with the mixture of topramezone with metribuzin.

The effect of topramezone and mixtures with PS II-inhibitor herbicides regarding probability of survival of newly established bermudagrass in the field based on the presence of green tissue at 70 d after treatment application was significant ($P < 0.05$). Like the topramezone sequential study, the probability of bermudagrass survival was higher with single topramezone applications compared to mixtures with PS II-inhibitor herbicides (Table 2). Bermudagrass treated with topramezone alone at 25 g ha^{-1} was estimated to have 100% chance of survival compared to 89% for topramezone at 50 g ha^{-1} and 23% to 76% for mixtures with PS II-inhibitor herbicides. For mixtures of the PS II-inhibitor herbicides with topramezone at 25 g ha^{-1}, bermudagrass had 63% to 76% chance of survival compared to 23% to 63% with the mixtures with topramezone at 50 g ha^{-1}. Bermudagrass treated with topramezone at 50 g ha^{-1} in mixtures with metribuzin and atrazine had the lowest chances of survival at 23% and 36%, respectively. Like the sequential study, the effect of topramezone and mixtures with PS II-inhibitor herbicides might probably have been more profound under shading because of the negative effect of shading on growth and development of bermudagrass (Bittencourt 2009; Jurami et al. 2004).

Results from this study indicated that topramezone applied sequentially or in mixtures with PS II-inhibitor herbicides atrazine, ametryn, and metribuzin provided acceptable control of newly established bermudagrass from sprigs with stolons. Sequential applications with a cumulative total of 75 to 100 g ha^{-1} provided acceptable bermudagrass control in the field, and applications with a cumulative total of 100 g ha^{-1} had a 12% chance of survival at 70 d after the first sequential treatment. The mixture of topramezone (50 g ai ha^{-1}) plus metribuzin provided the highest bermudagrass control with a 23% chance of survival 70 d after treatment. The use of sugarcane weed management programs involving sequential topramezone applications or mixtures with PS II-inhibiting herbicides in plant cane can provide growers with options to reduce progressive increment of newly established bermudagrass in the sugarcane crop cycle. Such bermudagrass infestations escape control programs during sugarcane fallow management period or in successively planted sugarcane.

Practical Implications

Bermudagrass is a difficult-to-control perennial grass weed in Florida sugarcane. Sugarcane is a multi-year crop in which tillage is limited to the row middles thus allowing bermudagrass to establish over the rows and become difficult to control for the entire crop cycle because of lack of selective postemergence herbicides. Bermudagrass is only effectively managed in sugarcane after harvest of the final ratoon crop using a combination of multiple glyphosate applications and tillage during the fallow period. However, bermudagrass, which escapes fallow management programs or escapes that occur when sugarcane is successively replanted, can re-establish from viable stolons and rhizomes. Topramezone is a postemergence herbicide with safety on

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sugarcane for control of broadleaf and grass weeds in the crop. It can be used to manage newly established bermudagrass escapes in plant cane. Two or three sequential applications of topramezone every 14 d provide acceptable control of newly established bermudagrass. Mixtures of topramezone with PS II-inhibitor herbicides particularly metribuzin and atrazine commonly used in sugarcane improved control of newly established bermudagrass. These findings illustrate that sugarcane growers can mitigate adverse effects of newly established bermudagrass in plant cane using sequential applications of topramezone and its mixtures with metribuzin and atrazine. They can accomplish acceptable management of bermudagrass while also using topramezone and its mixtures to manage other problematic broadleaf and annual grass weeds in sugarcane.

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Competing Interests

The authors declare none.

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Table 1. Newly established bermudagrass control and aboveground dry weight in response to sequential applications of topramezone 42 d after the first sequential treatment (equivalent to 14 d after the final third sequential application) in greenhouse and field experiments combined over two experimental runs in 2017 to 2018 in Belle Glade, FL.[a, b]

		Greenhouse				Field		
Treatment program[c]	Rate	Control		Dry weight		Control		P(survival)[d]
	g ha^{-1}	%		g		%		%
Nontreated control[e]	--	--		9.19	b	--		100
Topramezone	25	78	c	1.21	a	61	b	100
Topramezone	50	89	b	1.34	a	84	a	88
Topramezone	25 fb 25	100	a	1.26	a	87	a	75
Topramezone	50 fb 50	100	a	0.95	a	99	a	12
Topramezone	25 fb 25 fb 25	100	a	0.94	a	98	a	25
Topramezone	50 fb 25	100	a	0.84	a	93	a	37
Topramezone	25 fb 50	99	a	1.10	a	93	a	37
Topramezone	50 fb 25 fb 25	100	a	1.24	a	98	a	12
Topramezone	25 fb 25 fb 50	100	c	0.93	a	100	b	12

[a]Abbreviation: fb, followed by.

[b]Means followed by the same letter within a column are not significantly different according to Tukey's test ($P < 0.05$).

[c]Sequential applications were made every 14 d.

[d]P(survival) is probability of bermudagrass survival (the presence or absence of bermudagrass green tissue) 70 d after the first sequential or single topramezone application (equivalent to 28 days after the final third sequential application).

[e]Nontreated control data were not included in the analysis because there was no variance.

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Table 2. Newly established bermudagrass control and aboveground dry weight in response to topramezone alone or in mixtures with photosystem-II inhibitor herbicides (atrazine, metribuzin, ametryn) 42 d after treatment in greenhouse and field experiments combined over two experimental runs in 2017 and 2018 in Belle Glade, FL.[a]

		Greenhouse experiment				Field experiment		
Treatment program	Rate	Control		Dry weight		Control		P(survival)[b]
	g ha^{-1}	%		g		%		%
Nontreated control[c]	--	--		7.00	c	--		100
Topramezone	25	72	b	2.60	b	63	b	100
Topramezone	50	86	ab	0.74	a	79	ab	89
Topramezone + atrazine	25 + 2,240	87	ab	0.89	a	84	a	76
Topramezone + metribuzin	25 + 2,240	90	ab	0.47	a	87	a	63
Topramezone + ametryn	25 + 440	89	ab	0.59	a	79	ab	76
Topramezone + atrazine	50 + 2,240	87	ab	0.57	a	92	a	36
Topramezone + metribuzin	50 + 2,240	100	a	0.18	a	95	a	23
Topramezone + ametryn	50 + 440	97	a	0.26	a	88	a	63

[a]Means followed by the same letter within a column are not significantly different according to Tukey's test ($P < 0.05$).

[b]P(survival) is probability of bermudagrass survival (the presence or absence of bermudagrass green tissue) 70 d after treatment.

[c]Nontreated control data were not included in the analysis because there was no variance.

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