GEORGIA DOT RESEARCH PROJECT 12-37
FINAL REPORT

ENHANCING EXTENSION EDUCATION AND RECOMMENDATIONS TO MINIMIZE SPREAD OF INVASIVE SPECIES AND ESTABLISH NEW GRASSES FOR GEORGIA ROADSIDES

GDOT
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GDOT Research Project No. RP 12-37

Enhancing Extension Education Recommendations to Minimize Spread of Invasive Species and Establish New Grasses for Georgia Roadsides

Final Report

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<tr><td colspan="5">16. Abstract: Current DOT management practices could be contributing to the release of invasive weeds, such as broomsedge and vaseygrass, on Georgia roadsides. The herbicide imazapic, used to reduce mowing requirements of roadside grasses, injured bermudagrass twice as much as broomsedge, an invasive species, in greenhouse experiments. Imazapic provided no control of broomsedge in the field. MSMA applied in fall provided good control of broomsedge for 1 year after initial treatment. However, imazapic tank-mixed with MSMA provided less control than MSMA alone, suggesting imazapic antagonizes efficacy of MSMA on broomsedge. The new herbicides Derigo and Pastora controlled or suppressed vaseygrass populations when applied in late spring. However, these herbicides did not control broomsedge. MSMA will need to be applied in sequential programs when ALS inhibitors are used for other controlling other weeds or for growth regulation of roadside grasses. Introducing new grasses for roadside vegetation could reduce the spread of invasive weeds and enhance management. Centipedegrass and zoysiagrass have potential to establish under roadside conditions as alternatives to bermudagrass and fescue in Georgia. These grasses effectively established when planted from sod or plugs. Centipedegrass was the quickest grass to establish from sod. Growth of centipedegrass was comparable to zoysiagrass from plugs, and both species were more competitive than bermudagrass under guardrails. None of the grasses established from seed under simulated roadside conditions. Significant differences in vaseygrass germination were detected by location. Vaseygrass seed germinated in June from collections in south Georgia. Seed germination was detected from July to November in Newnan, but other locations had minimal germination in fall. These results suggest that mowing operations could spread significant amounts of viable seed throughout the state from June to November.</td></tr>
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EXECUTIVE SUMMARY

Invasive weeds compromise the safety of Georgia roadsides and are difficult to manage. Broomsedge and vaseygrass are invasive species that are spreading throughout Georgia due to limitations of current management programs and minimal competition of the species maintained for roadside vegetation. Experiments were conducted to evaluate control programs of these weeds in bermudagrass roadsides, establishment of new turfgrass species under roadside conditions, and germination potential of vaseygrass seed throughout the state. In field, laboratory, and greenhouse research it was determined that imazapic (Plateau herbicide) suppressed bermudagrass growth twice as much than broomsedge. Broomsedge was effectively controlled by MSMA applied in fall, but imazapic provided no control. Imazapic applied with MSMA antagonized the efficacy of MSMA for broomsedge control. Results suggest that imazapic use by the DOT for growth regulation of roadside grasses is exacerbating the spread of broomsedge. Imazapic applications should be suspended when MSMA is applied to minimize potential antagonistic effects on broomsedge control. Imazapic should not be used in areas with heavy broomsedge populations unless MSMA will be applied for control programs. New herbicides, Derigo and Pastora, were evaluated for broomsedge and vaseygrass control in roadsides. Neither herbicide controlled broomsedge, and were similar to imazapic. Derigo showed better efficacy on vaseygrass in spring than imazapic, but control did not exceed 76% from any treatment evaluated.

Over a three-year period, centipedegrass and zoysiagrass sod established more consistently than bermudagrass under roadside conditions. These species did not establish when planted from seed due to competition with weeds. Mowing was also beneficial for enhancing turfgrass establishment from sod. The lateral growth of centipedegrass and zoysiagrass under guardrails was about 2-times greater than bermudagrass after planting from plugs. These results suggest centipedegrass and zoysiagrass sod have potential to establish under roadside conditions and spread laterally over time. In seed collection studies, vaseygrass seed germinated throughout the spring and fall, but varied across locations. Vaseygrass germination was noted in Tifton from June to September. Other locations had significant germination in late summer and fall. There was no trend in location or collection timing for vaseygrass germination. Results suggest that vaseygrass may produce viable seed early after seedhead development, which will significantly contribute to the spread and distribution of populations on roadsides.

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INTRODUCTION

The spread of invasive weeds throughout the Southern U.S. is increasing the costs of roadside maintenance. Chemical and cultural practices employed by the Georgia DOT are effective for managing desirable grassy species, but could exacerbate the spread and establishment of problem weeds such as broomsedge, Johnsongrass, and vaseygrass. Agronomists from the DOT are limited to two mowing per year on roadsides throughout Georgia and management limitations could promote competition of these invasive weeds over roadside grasses. With over 700,000 acres of roadside vegetation under management, limitations on mowing timings could result in the spread of seed throughout the state. Mowing roadside vegetation during periods of inflorescence could exacerbate seed dispersal and subsequent infestations throughout the state.

Invasive weeds are managed with herbicide applications. Agronomists have limited options for controlling broomsedge, Johnsongrass, and vaseygrass. Recent federal restrictions on MSMA limit application programs necessary for controlling these species, and agronomists currently have no alternative chemistries for controlling broomsedge or vaseygrass. Additionally, growth regulator applications used to minimize mowing requirements could inhibit desirable grasses more than these weeds, thereby releasing populations of broomsedge and vaseygrass throughout the state. The spread of problem weeds is compromising the aesthetics, maintenance, and safety of Georgia roadsides and pose serious risks to farms, pastures, and residential areas in the state.

The management of invasive species and roadside vegetation could be improved through the introduction of new species for roadsides. Bahiagrass, bermudagrass, and tall fescue are the major grasses grown for roadsides in Georgia. These species have good drought and stress tolerances, but require multiple mowings and herbicide applications to manage growth and seedhead formation. Management limitations for roadside conditions limit the ability to effectively mange these species, which reduces competition of desirable grasses and predisposes roadsides to spread of invasive weeds. The introduction of other species with less intensive management requirements, such as centipedegrass or zoysiagrass, could reduce maintenance inputs and produce desirable vegetation. With over 18,000 miles of primary and secondary roads in Georgia, the potential introduction of new species that require less maintenance could be economically beneficial for long-term management programs.

Centipedegrass and zoysiagrass are major warm-season species used for lawns throughout Georgia. These grasses have shown to be successfully introduced as roadside vegetation in North Carolina. Compared to bermudagrass, centipedegrass has slower growth and requires less intensive maintenance. Zoysiagrass has desirable density, slow to moderate growth, and excellent cold hardiness. These two species are well adapted to growing conditions in Georgia and have potential to produce desirable roadsides that require fewer mowings and less intensive management for long-term culture. However, failure to establish new species in a timely manner could promote competition with weeds, especially after soil has been disturbed or prepared for planting. Agronomists need comprehensive research to evaluate establishment methods for new species to effectively introduce low maintenance species for roadsides n Georgia.

OBJECTIVE

The objective of the proposed research is to develop new recommendations for the Georgia DOT to minimize spread and establishment of invasive weeds in grassy areas. Additionally, recommendations will be developed through researching the potential of new turf species to establish and persist under roadside conditions in Georgia.

PROCEDURES

Evaluation of Bermudagrass and Broomsedge Growth Regulation with Herbicides

Greenhouse Experiments. Greenhouse experiments were conducted at the University of Georgia Griffin Campus to evaluate differential responses of bermudagrass and broomsedge to imazapic. 'Princess-77' hybrid bermudagrass (Pennington Seed Inc., Madison, GA 30650) and broomsedge (Roundstone Native Seed LLC, Raider Hollow Rd, Upton, KY 42784) were seeded in plastic pots with 3.8-cm diameters and 20-cm depths filled with sand:peat (80:20 v/v). Pots were irrigated to prevent moisture deficiencies and received fertigation weekly (LESCO® MacroN 28-7-14 Sprayable Fertilizer, LESCO Inc., Cleveland, OH) to promote growth. Pots were thinned to three plants during establishment and were at an ~15-cm height at treatment.

Treatments included seven rates of imazapic (Plateau 2L, BASF Corp., Research Triangle Park, NC 27709) ranging 0 to 64 oz/acre. Applications were made with a CO_2-pressured sprayer calibrated to deliver 40 gallons per acre with a single 9504E flat-fan nozzle (TeeJet Spraying Systems Co., Roswell, GA 30075). Injury was visually rated on a percent scale at 2 and 4 weeks after treatment (WAT) where 0 equaled no injury and 100 equaled complete desiccation. Shoots were harvested at 4 WAT, oven-dried at 60° C for 72 h, and then weighed. Shoot biomass reductions were calculated from the nontreated by replication. The average biomass for the nontreated was 90 (±18 se) mg cm^{-2} and 102 (±11) mg cm^{-2} for bermudagrass and broomsedge, respectively.

The experimental design was a randomized complete block with four replications and the experiment was repeated twice. Shoot biomass was harvested in two of the experiment repetitions, but injury was evaluated in all three. Data were subjected to analysis of variance to test for the interaction of treatment with experiment repetition. Data were then analyzed with the Nonlinear Regression Procedure in SAS (v. 9.0, SAS Institute, Cary, NC). Injury was regressed against imazapic rate using the Mitscherlich equation:

$$y = \beta_0 * (1- (P*(\exp(-\beta_1*(x - \beta_2)))))$$

where y is the 90% of the maximum response to imazapic dose *x*, β_0 the asymptote, β_1 the slope, and β_2 the value of x when $P = 0.10$. P was set at 0.10 for the Mitscherlich equation in order to determine the 90% response. For this data, the point on the curve where 90% of the maximum response occurred was calculated for comparison between species. Shoot biomass reductions from the nontreated were regressed against the following two-parameter exponential equation:

$$y = \beta_0 * (1- (P*(\exp(-\beta_1*x))))$$

where Y is percent dry weight reduction from the nontreated, β_o is the intercept, β_1 the slope, and x is the rate (g ai ha^{-1}). Estimates of regression parameters were separated using 95% confidence intervals.

Broomsedge control with imazapic and MSMA programs. Two experiments were conducted at the University of Georgia Westbrook Farm in Griffin, GA from October 2012 to 2014. Plots in 2013 were adjacent to plots in 2012. Soil was a Cecil sandy loam (Fine, kaolinitic, thermic Typic Kanhapludults) with 3.4% organic matter and a 7.3 pH. The field was a simulated roadside that was mowed twice per year at 15-cm height with a tractor-mounted rotary mower. Broomsedge populations averaged 75% and 70% ground cover on the day of initial treatments in 2012 and 2013, respectively. The field was mowed three weeks before treatments in both years, and debris was removed with blowers.

Treatments included imazapic (Plateau 2L) at 6 oz/acre, MSMA (Target Plus 6L, Luxembourg-Pamol, Inc., Memphis, TN 38137) at 2 lb ai/acre, nicosulfuron at 2 oz/acre (Accent 75%, E.I. du Pont de Nemours and Co., Wilmington, DE 19898), imazapic + MSMA, and nicosulfuron + MSMA. The application rate of imazapic was chosen because it delivers the highest label rate recommended for perennial weed control in bermudagrass turf (Anonymous, 2008). Nicosulfuron was chosen as a comparison to imazapic because it is an ALS inhibitor from a different chemical family. The MSMA rate was chosen from label recommendations and with compliance by current EPA regulations for roadside turfgrass. Initial application dates in Experiment 1 and 2 were October 15, 2012 and October 15, 2013, respectively. Sequential treatments were applied on November 5, 2012 and November 4, 2013 in Experiment 1 and 2, respectively. Treatments were made with a CO_2 pressured sprayer calibrated to deliver 25 gallons per acre using three 8004 flat-fan nozzles.

The experimental design was a randomized complete block with four replications of 1.5 x 3-m plots. Broomsedge control was visually rated on a percent scale where 0 equaled no injury from the nontreated and 100 equaled complete desiccation. Data were subjected to the analysis of variance with the General Linear Model Procedure in SAS. Means were separated with Fisher’s Protected LSD test at $\alpha = 0.05$. Year by treatment interactions were not detected, and thus results were pooled over years.

Evaluation of New Herbicides for Broomsedge and Vaseygrass Control

Broomsedge. A field experiment was conducted at the University of Georgia Griffin Campus to evaluate the influence of application timing on the efficacy of Derigo and Pastora for broomsedge control, compared to Plateau and MSMA. Soil was a Cecil sandy loam (Fine, kaolinitic, thermic Typic Kanhapludults) with 3.4% organic matter and a 7.3 pH. The field was a simulated roadside that was mowed twice per year at 15-cm height with a tractor-mounted rotary mower. The field was mowed approximately three weeks before treatments in summer and fall.

Herbicides were applied on June 14, 2013 or September 10, 2013. Herbicides evaluated included Derigo 36.4WG (foramsulfuron + iodosulfuron + thiencarbazone-methyl) at 3, 4, or 5 oz/acre with a non-ionic surfactant or methylated seed oil at 0.25% and 1% v/v, respectively. Pastora 71DF (nicosulfuron + metsulfuron) was applied at 1.5 oz/acre with a non-ionic surfactant. The standard comparison herbicides included Plateau at 4 oz/acre and MSMA (Target 6) at 2 lb ai/acre. Treatments were applied with a CO_2 pressured backpack sprayer calibrated to deliver 25 gallons per acre with three 8004 flat-fan nozzles. Broomsedge control was visually evaluated every four weeks after applications. The experimental design was a randomized complete block with four replications of 5 x 10-ft plots. Data were subjected to the analysis of variance with the General Linear Model Procedure in SAS. Means were separated with Fisher's Protected LSD test at $\alpha = 0.05$.

Vaseygrass. A field experiment was conducted on a roadside off I-85 in Newnan. The area had bermudagrass present with significant populations of vaseygrass. The area was mowed in August and September at 20-cm height. Treatments evaluated in the broomsedge study were applied on June 25, 2013. Vaseygrass cover and control were visually evaluated as previously described in the broomsedge experiment. The experimental design was a randomized complete block with four replications of 5 x 10-ft plots. Data were subjected to the analysis of variance with the General Linear Model Procedure in SAS. Means were separated with Fisher's Protected LSD test at $\alpha = 0.05$.

Establishment of New Species for Reducing Inputs in Georgia Roadsides

Preliminary experiments. Experiments were initiated on May 30, 2012 and May 29, 2013 to evaluate the establishment of bermudagrass, centipedegrass, and zoysiagrass from seed and sod at the University of Georgia Dempsey Farm in Griffin, GA. The areas were killed out with glyphosate (Roundup Pro 4L) at 3 qt/acre applied three weeks before planting. One week before, the area was scalped with a mower, and then sliced in two directions. 'TifBlair' centipedegrass and 'Zenith' zoysiagrass were established from seed or sod. 'Princess-77' and 'Tifway' were used for bermudagrass seed and sod, respectively.

Bermudagrass, centipedegrass, and zoysiagrass were planted in a randomized complete block with four replications of 8 x 20-ft plots. Immediately after planting grasses were rolled and seeded plots were covered with wheat straw (Pictures 1 and 2). Irrigation was applied immediately after planting. Half of the plot area was mowed in July while the other half was left unmowed. Mowing was done with a tractor-mounted unit that cut the vegetation to a 4" height. Cover of the species was evaluated monthly and quantified with a sampling grid. At one year after planting, the entire area was mowed and final stand establishment was quantified to determine turf establishment.

Picture 1. Sod and seed planting May 30, 2012 in an experiment at the UGA Griffin Campus.

Picture 2. Rolling the sod after planting on May 30, 2012 at the University of Georgia Griffin Campus.

Evaluation of Sod Establishment Under Guardrails. An experiment was conducted to evaluate establishment of 'Tifway' bermudagrass, 'TifBlair' centipedegrass, and 'Zenith' zoysiagrass sod under a guardrail in Griffin, GA. Local soil was a Cecil sandy clay loam with 6.2 pH and about 2.5% organic matter. The vegetation under the guardrail was killed with glyphosate, scalped, and sliced as previously described in preliminary experiments. Rolls of sod measuring 1.5 x 8-ft were planted individually on both sides of the guardrail on May 30, 2014. Sod was immediately rolled and irrigated with 150 gallons of water from a portable tank. The area was cut with a rotary mower in July and October. Sod was planted in a randomized complete block with four replications. Green cover of each species was rated on a percent scale monthly, where 0 equaled brown turf and 100 equaled complete cover per plot.

Evaluation of Vaseygrass Seed Viability on Georgia Roadsides. Seed was collected from Johnsongrass and vaseygrass at four locations including Commerce, Griffin, Macon, Tifton, and Newnan. Seedheads were harvested from plants monthly from April to October. Plant height and growth stage was recorded on each sampling date (Table X). Seed was dried and removed from branches with sieves. One hundred seed of each species was planted in 4 x 4" plastic boxes on a filter paper that was moistened with 5-mL of tap water. Seed was placed on the paper and then a clear lid was placed over the box. Germination boxes were then placed in a growth chamber set for 32/25° C for four weeks. Germination was monitored weekly. Plants that germinated were removed from the boxes and recorded.

FINDINGS

Evaluation of Bermudagrass and Broomsedge Growth Regulation with Herbicides

Bermudagrass and broomsedge response to imazapic. Grasses exhibited significantly different asymptotic (β_o) levels for injury and biomass reductions from imazapic (Figure 1). At 2 WAT, broomsedge required ~10x higher imazapic rates than bermudagrass to reach 20% injury and species exhibited a 7-fold difference imazapic rate values. At 4 WAT, bermudagrass and broomsedge reached 90% of the maximum injury at 355 and 979 g ha^{-1} of imazapic, respectively. Susceptibility of bermudagrass to growth inhibition from imazapic has been reported in forages, hayfields, and roadside turfgrass. Researchers have also noted that imazapic enhances the competition of various *Andropogon* species similar to broomsedge in polyculture with other species during establishment and land restoration. Imazapic is more injurious to bermudagrass than broomsedge and differential levels of growth regulation could render applications ineffective for reducing mowing requirements in polyculture stands. Results support the supposition that imazapic enhances broomsedge competition with bermudagrass and contributes to the release of populations in roadside turf.

Regular use of imazapic for turfgrass growth regulation could exacerbate the spread of broomsedge biotypes with enhanced tolerance levels to ALS inhibitors. In North Carolina, researchers have identified a biotype of vaseygrass (*Paspalum urvillei* Steud.) with enhanced tolerance levels to ALS inhibitors compared to susceptible biotypes. The differential tolerance levels of other *Andropogon* species to imazapic could also vary and warrant further investigation.

Figure 1. Bermudagrass and broomsedge injury from imazapic in greenhouse experiments, Griffin, GA. Results were pooled over experimental runs.

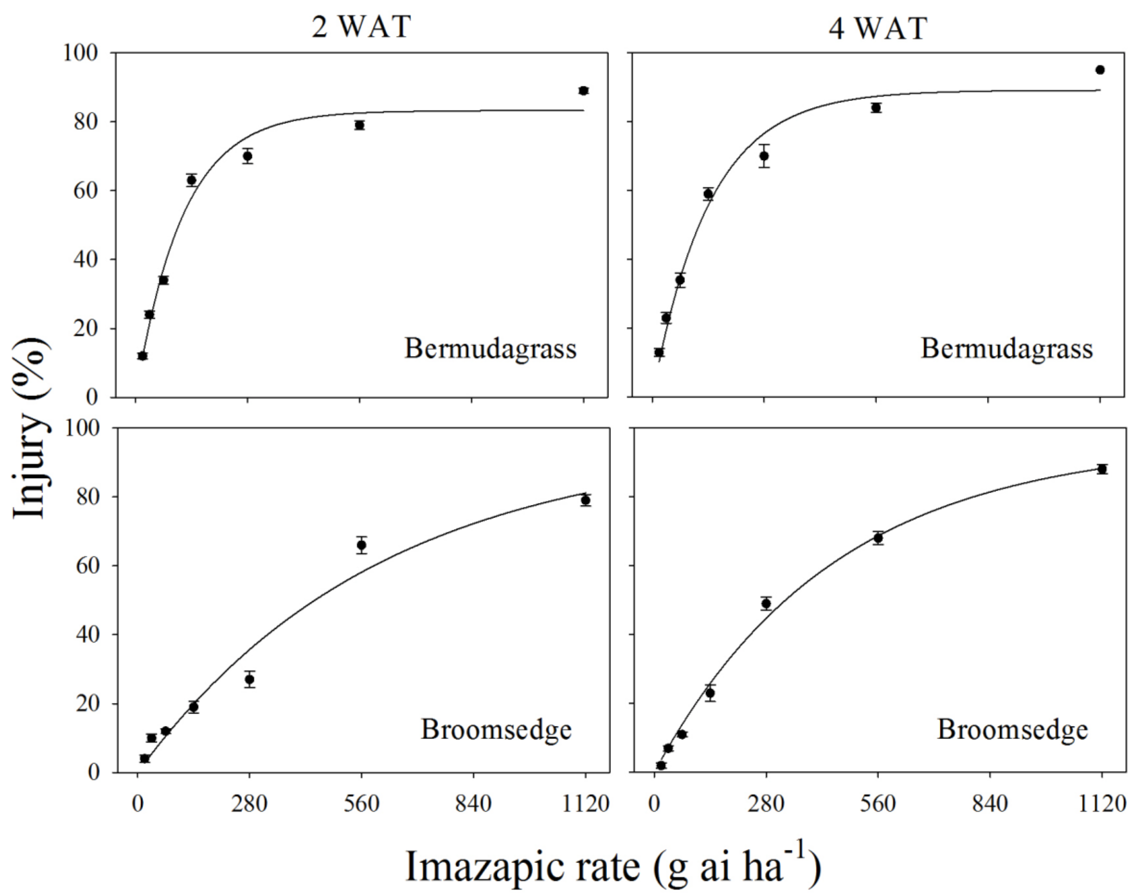


Table 1. Broomsedge control following two applications of imazapic, glyphosate, and MSMA in two field experiments, 2012-2014, Griffin, GA. Results were pooled over years.

Treatment[§]	Rate	Broomsedge Control (MAIT)[†]				
		1	3	6	9	12
		——— % ———				
Plateau	6 oz/acre	0	0	11	0	0
Plateau + MSMA	6 oz + 2 lb ai/acre	75	86	99	81	45
MSMA	2 lb ai/acre	78	87	100	93	81
Accent	2 oz/acre	0	11	17	0	0
Accent + MSMA	2 oz + 2 lb ai/acre	76	88	100	91	76
	$LSD_{0.05}$	3	8	11	4	9

[†]MAIT = months after initial treatment. Evaluation dates for the 2012 experiment were November 19, 2012; January 7, 2013; April 3, 2013; June 24, 2013; and October 15, 2013. Evaluation dates for the 2013 experiment were November 25, 2013; January 13, 2014; April 1, 2014; July 14, 2014; and October 15, 2014.

[§]Initial application dates were October 15, 2012 and October 15, 2013. Sequential treatments were applied on November 5, 2012 and November 4, 2013. Herbicides applied were Plateau 2L (imazapic), BASF Corp., Research Triangle Park, NC 27709; Target Plus 6L (MSMA), Luxembourg-Pamol, Inc., Memphis, TN 38137; Accent 75% (nicosulfuron), E.I. du Pont de Nemours and Co., Wilmington, DE 19898.

Broomsedge control with imazapic and MSMA. The interaction of MSMA with ALS inhibitors (imazapic and nicosulfuron) was not significant at 1, 3, or 6 MAIT (Table 1). Treatments that included MSMA controlled broomsedge ≥99% at 6 MAIT. Imazapic and nicosulfuron treatments without MSMA provided <20% control on all dates. At 9 MAIT, MSMA alone and nicosulfuron + MSMA controlled broomsedge >90% but the MSMA + imazapic treatment only controlled broomsedge 81%. By 12 MAIT, broomsedge control ranged between 76 to 81% from MSMA alone or tank-mixed with nicosulfuron. However, tank-mixing imazapic with MSMA reduced broomsedge control to 45%.

Imazapic does not provide short or long-term control of broomsedge at these rates and was comparable to another ALS inhibitor, nicosulfuron. Similar tolerance of *Andropogon* species to imazapic has been previously reported (Masters et al. 1996). Currently, alternative selective herbicides for broomsedge control in bermudagrass roadsides do not exist. While nonselective herbicides have the potential to control broomsedge, excessive injury to roadside turfgrasses would result in the infestation of new weed species after applications or soil erosion and roadbed deterioration.

MSMA is the only selective postemergence herbicide for broomsedge control in bermudagrass. Despite recent restrictions, applications rates and regimens that effectively control broomsedge are currently legal for use in roadside turfgrass (U. S. Environmental Protection Agency 2013). The antagonism of MSMA on broomsedge control by imazapic is concerning due to the heavy reliance on imazapic in Georgia roadsides. Imazapic has previously shown to antagonize efficacy of another graminicide, clethodim, for postemergence goosegrass control. The physiological effects of imazapic on MSMA absorption and translocation have not been elucidated and were therefore investigated in laboratory experiments.

Imazapic is an important herbicide for growth regulation of bermudagrass roadside in Georgia. Imazapic use is an economical option for inhibiting turfgrass growth and reducing mowing requirements of roadside turf. However, imazapic rates that suppress bermudagrass growth are less efficacious on broomsedge. Biochemical differences between species influences imazapic efficacy and broomsedge likely has competitive growth advantages in polyculture with bermudagrass. Agronomists should incorporate MSMA in spray programs while it is currently legal for use in bermudagrass roadsides. The potential loss of MSMA from future EPA regulations would remove an important mechanism of action and the only selective herbicide for broomsedge control in turfgrass. Imazapic applications should be suspended when MSMA is applied to minimize potential antagonistic effects on broomsedge control. Further research is needed to evaluate application regimens of imazapic when MSMA is applied and the physiological basis of antagonism on efficacy for broomsedge control.

Evaluation of new herbicides for broomsedge and vaseygrass control

Pastora and Derigo treatments controlled broomsedge less than 15% on all evaluation dates. At 111 days after the June application, MSMA provided 70% control of broomsedge (Table 2). Similar results were noted from the fall application where no treatments, except MSMA, controlled broomsedge (data not shown). A rate response was noted from Derigo treatments for vaseygrass control. Control increased with application rate from 3 to 5 oz/acre, but adjuvants did not have a meaningful effect on control at 86 days after treatment. MSMA initially injured vaseygrass, but the final control only measured 29%.

Table 2. Broomsedge and vaseygrass control from herbicides in field experiments. Treatments were applied June 14, 2013 and June 25, 2013 for the broomsedge and vaseygrass experiments, respectively.

Herbicide	Product Rate	Adjuvant	Broomsedge (111 DAT)	Vaseygrass (86 DAT)
	oz/acre		——— % control ———	
Derigo	3	NIS	0	41
	4	NIS	5	49
	5	NIS	0	64
	3	MSO	0	35
	4	MSO	0	58
	5	MSO	3	71
Plateau	4	NIS	0	44
Pastora	1.5	NIS	0	41
MSMA	2 (lb ai)	-	70	29
		$LSD_{0.05}$	13	32

Evaluation of Turfgrass Establishment on Roadsides

Preliminary experiments. In two separate studies, seeding the three turfgrasses resulted in little to no establishment due to the competition with weeds under simulated roadside conditions. Sod of all three grasses was able to establish, especially when the weeds were mowed at about two months after planting (Picture 3, 4). These preliminary experiments provided insight that vegetative establishment of these turfgrass species would be more effective under roadside conditions.

Picture 3. Plots from the preliminary evaluation of sod establishment under simulated roadside conditions at the University of Georgia Griffin Campus.

Picture 4. Centipedegrass on May 30, 2013 that was planted on May 30, 2012. The right side of the plot had been mowed in 2012 compared to the left that was not mowed in 2012.

Evaluation of sod establishment on guardrails. Grasses exhibited initial signs of dormancy after ~2 weeks after planting due to heat and drought stress associated with establishment under roadside conditions (Picture 5). Centipedegrass sod had faster establishment than bermudagrass and zoysiagrass at 1 and 2 months after planting (MAP, Table 3, Pictures 5, 6). By 2 MAP, centipedegrass had 44% green cover compared to bermudagrass and zoysiagrass that averaged 9%. Centipedegrass sod green cover increased until October (4 MAP) and reached 76% (Picture 8). Bermudagrass green cover continued to increase over time and reached 53 to 56% after 1 year. Zoysiagrass lagged the other two species, and had only 27 to 30% green cover after 1 year (Picture 9).

Centipedegrass has potential to survive the initial dormancy period from heat stress after planting from sod under roadside conditions. Centipedegrass has stoloniferous growth that is attributed to the spread and competition with weeds. Our initial experiments showed that centipedegrass seed did not establish well under roadside conditions. Thus, vegetative establishment would likely be the most effective method to introduce centipedegrass to roadsides. Bermudagrass was much slower to establish and recover from dormancy after planting. The recovery of bermudagrass from the initial stresses of planting may enable agronomists to introduce improved varieties to roadsides. However, bermudagrass dormancy during the initial few months after planting may reduce the competition with weeds, which may be concerning after planting on roadsides.

Table 3. Establishment of 'Tifway' bermudagrass, 'TifBlair' centipedegrass, and 'Zenith' zoysiagrass sod planted on opposite sides of a guardrail on May 30, 2014 in Griffin, GA.

	Sod Establishment					
	6/26/14	7/24/14	9/18/14	10/16/14	5/28/15	6/24/15
	------------------ % green cover ------------------					
Bermudagrass	6	12	38	42	56	53
Centipedegrass	25	44	63	76	53	63
Zoysiagrass	4	5	11	20	21	18
$LSD_{0.05}$	19	32	34	40	30	27

Picture 5. Pictures of the plots at two weeks after sod planting in Griffin, GA.

Picture 6. Centipedegrass sod at two weeks after planting in a field experiment, Griffin, GA.

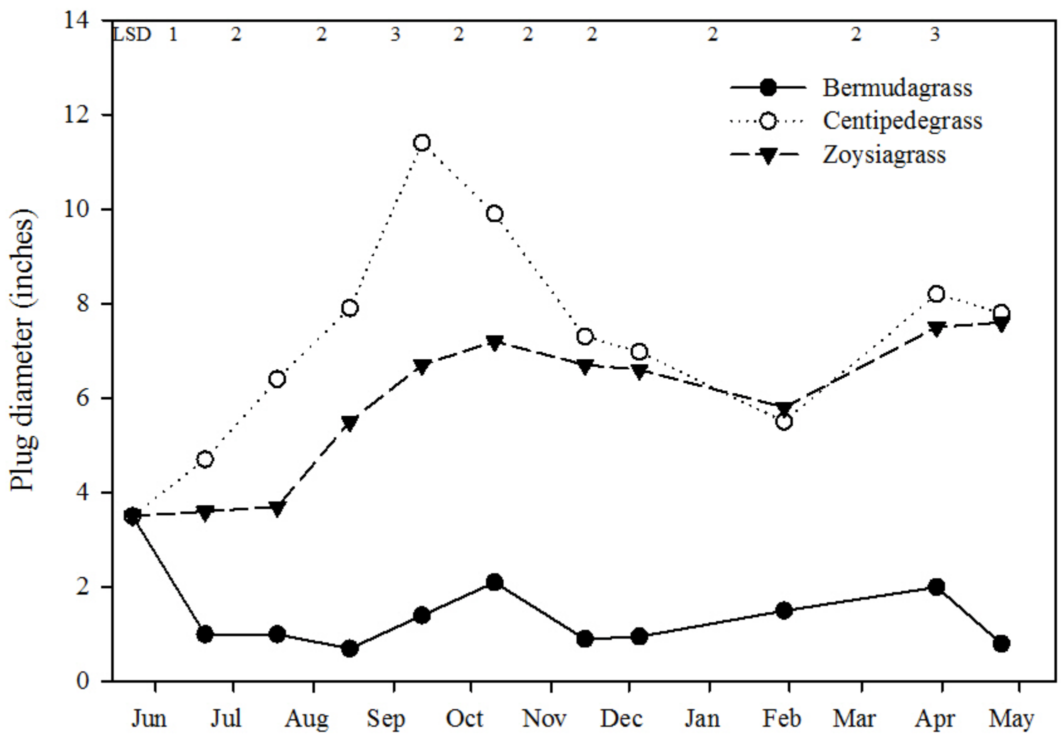
Picture 7. Bermudagrass establishment from sod planted May 30, 2014 in a field experiment, Griffin, GA. The picture was taken on October 2, 2014.

Picture 8. 'TifBlair' centipedegrass establishment from sod planted on May 30, 2014 in a field experiment, Griffin, GA. The picture was taken on October 2, 2014.

Picture 9. ‘Zenith’ zoysiagrass establishment from sod planted on May 30, 2014 in a field experiment, Griffin, GA. The picture was taken on October 2, 2014.

Plug establishment. Centipedegrass and zoysiagrass plugs doubled in size from June to October (Figure 1). The diameters for plugs of these two species were similar by the following spring, and averaged ~8 inches or twice the initial diameter at planting. Bermudagrass plugs did not exhibit lateral growth and declined to about half the diameter from the initial planting over time. This guardrail off of I-75 had broomsedge and other weeds present in the surrounding area. Perhaps, there was regrowth from the glyphosate application that was made before planting of certain weeds that were more competitive with bermudagrass than the other turfgrass species. Nevertheless, centipedegrass and zoysiagrass had the best lateral growth under guardrails of the species evaluated.

Figure 2. Establishment of 'Tifway' bermudagrass, 'TifBlair' centipedegrass, and 'Zeon' zoysiagrass plugs on a guardrail, 2014-2015.



Evaluation of vaseygrass seed viability on Georgia roadsides. Location by month interaction was detected for germination of vaseygrass seed collected from four roadside locations. There was no clear trend for seasonal timing in germination of the vaseygrass collected across locations (Table 4). However, vaseygrass seedheads were not present or did not produce viable seed until June at all locations. Vaseygrass in Tifton had 26% germination in June and July, while samples from other locations had less than 14%. By August, the vaseygrass in Tifton had 50% germination. Vaseygrass in Perry and Newnan had 14 and 19% germination in the August collection, respectively, but germination was not detected in Griffin. The vaseygrass in Newnan had more germination in fall than the other locations. The total germination ranged 32 to 45% in Newnan from September to November. The other locations had erratic germination levels that ranged 10% or less on these dates.

Differences in location maintenance or roadside conditions could contribute to the variability in germination of vaseygrass seed. Vaseygrass may have earlier seedhead development in south Georgia compared to northern areas, that may enhance seed viability earlier in spring compared to other locations. These plants were sampled from locations currently managed by the DOT. Plants may have been treated with imazapic or other herbicides that regulate growth of vaseygrass and influence seed production. Nevertheless, results demonstrate that vaseygrass produces viable seed from June to November, but these patterns may vary by location. Seed dormancy was not measured in this experiment, but may of the seeds that failed to germinate could have undergone dormancy. The results demonstrate ability for vaseygrass seed to immediately germinate after sampling from every seed present on the seedhead.

Table 4. Total germination of one hundred vasegrass seed at four weeks after seeding. Results were pooled over five replications per location and collection timing.

	Vaseygrass seed germination (%)			
	Griffin	Newnan	Perry	Tifton
April	0	0	0	0
May	0	0	0	0
June	13	6	0	26
July	0	0	0	26
August	0	19	14	50
September	10	40	5	3
October	0	32	0	0
November	0	45	0	0
$LSD_{0.05}$	5	26	15	13

CONCLUSIONS

The use of imazapic as a growth regulator is contributing to broomsedge release on Georgia roadsides. Bermudagrass growth was inhibited about twice as much as broomsedge in greenhouse experiments. We also found no control of broomsedge with imazapic in the field. These results suggest the repeated use of imazapic for mowing management is providing broomsedge a competitive growth advantage over bermudagrass. This supposition was supported by additional laboratory research that showed the target site (ALS) enzyme of bermudagrass was more susceptible to inhibition by imazapic than broomsedge.

MSMA applied in fall provided good control of broomsedge for 1 year after initial treatment. However, imazapic tank-mixed with MSMA provided less control than MSMA alone, suggesting imazapic antagonizes efficacy of MSMA on broomsedge. It is recommended that DOT agronomists cease using imazapic for growth regulation in areas with heavy broomsedge populations, or incorporate MSMA in management programs to control populations. The tank-mixture of MSMA with imazapic should be avoided.

New herbicides Derigo and Pastora have potential to control or suppress vaseygrass populations when applied in late spring. However, these herbicides do not control broomsedge. MSMA will need to be applied in sequential programs when ALS inhibitors are used for controlling other weeds or growth regulation of roadside grasses.

An alternative management strategy for invasive weed management is introducing new turfgrass species for roadside vegetation. Centipedegrass and zoysiagrass have potential to establish under roadside conditions as alternatives to bermudagrass and fescue in Georgia. These grasses need to be planted from sod or plugs in order to compete with weeds during establishment. Planting from seed may be effective in areas that receive irrigation and adequate mechanical or chemical control of weeds. Seed failed to establish after one year when irrigation was withheld and mowing operations were performed once or twice per year. Centipedegrass was the quickest grass to establish from sod. Growth of centipedegrass was comparable to zoysiagrass from plugs, and both species were more competitive than bermudagrass under guardrails.

Vaseygrass seed germination experiments revealed significant differences in locations throughout the state. Vaseygrass seed germinated in June from collections in south Georgia. Seed germination was detected from July to November in Newnan, but other locations had minimal germination in fall. These results suggest that mowing operations could spread significant amounts of viable seed throughout the state from June to November.