Integrated vegetation management along roadsides in the south-eastern United States

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Summary Field research was conducted to evaluate the efficacy of plant growth regulators for tall fescue and bahiagrass growth and seedhead suppression along roadsides. These trials included conventional broadcast applications and in select cases were compared to specialised application placement equipment. Wet-blade mowers are specially designed equipment outfitted with fluid application systems allowing for low-volume plant growth regulator (PGR) application and mowing to be completed in a single pass. Other application placement equipment wipes chemicals directly on plant tissue, reducing opportunity for drift and visible application. Therefore, a wet-blade, rotary-wick and broadcast sprayer system were chosen to apply imazapic at three rates (8.8, 35.1 and 52.6 g a.i. ha^{-1}) and a mefluidide + chlorsulfuron tank mix at 6.6 + 140.2 g a.i. ha^{-1} for tall fescue roadsides and imazapic at 36, 53, 71, 110 and 140 g ha^{-1} for bahiagrass roadsides. Experiments were conducted during the spring and summer of 2003 and 2004 in central and western North Carolina (tall fescue) and 1995 and 1996 (bahiagrass) in North Carolina, Georgia and Florida. Tall fescue was slightly injured and discoloured by all treatments, but fully recovered by 2 months after treatment. In 2004, imazapic at 52.6 g a.i. ha^{-1} suppressed new vegetative growth 3 months after treatment compared to the non-treated (16.1 cm of growth) and mowed non-treated (21.1 cm) when applied with the rotary-wick applicator (5.1 cm) and broadcast sprayer (4.2 cm). However, differences in vegetative height primarily occurred when application placement equipment treatments were compared to non-treated as opposed to mowed non-treated. Although mowed non-treated and wet-blade treatments resulted in more new vegetative growth, non-treated plots still consistently had the greatest vegetative height. In 2003, seedheads were completely suppressed with all PGR and application placement equipment combinations throughout the study. With more favourable growing conditions in 2004, seedheads were not completely controlled. Seedhead suppression ranged from 76 to 100% when compared to non-treated, with the wet-blade treatments consistently providing the lowest seedhead suppression. Overall, application placement equipment did not improve PGR efficacy when compared to the foliar broadcast spray. Imazapic at 36, 53, 71, 110 and 140 g ha^{-1} reduced bahiagrass quality at some point in the growing season but bahiagrass recovered at 4 of 5 locations by 16 weeks after treatment (WAT). Imazapic at >71 g ha^{-1} reduced bahiagrass density 16 WAT at three of five locations. Bahiagrass quality and density were more severely affected by all imazapic rates at 8 WAT than at 4 or 16 WAT. Seedhead suppression was acceptable with all imazapic rates. Both North Carolina sites had imazapic treatments that resulted in no bahiagrass seedhead production. One North Carolina site showed enhanced imazapic activity with addition of a nonionic surfactant. The Georgia and Florida sites had sufficient season-long seedhead suppression to significantly reduce mowing. These results indicate imazapic can effectively be used to reduce mowing costs associated with bahiagrass management. However, rates >71 g ha^{-1} pose a risk of significant bahiagrass stand reduction.

Keywords: Chlorsulfuron, imazapic, mefluidide, sulfometuron, tall fescue, *Lolium arundinaceum* (Schreb.), bahiagrass, *Paspalum notatum*, seedhead suppression, foliar suppression, plant growth regulator, application placement equipment, low volume, wet-blade, rotary-wick, roadside, turfgrass.

INTRODUCTION

Turfgrass maintenance along highway roadsides requires the expenditure of millions of dollars in maintenance costs, primarily from multiple annual mowings. Roadside turfgrasses, such as tall fescue (*Lolium arundinaceum* (Schreb.) S.J.Darbyshire) and bahiagrass (*Paspalum notatum* Flugge), are typically mowed 4–6 times per year in North Carolina. This high mowing frequency results in increased equipment wear, fuel and labour costs as well as increased danger for transportation workers and motorists. Suppressing seedheads and reducing vegetative growth can decrease mowing frequency resulting in reduced expenditures for roadside vegetation management. Tall fescue and bahiagrass produce tall seedheads that are not only unsightly, but can obstruct the sightlines of motorists. Commercially available PGRs have the desirable ability to suppress seedheads and reduce vegetative growth when broadcast applied. Research has shown this can result in significant cost reductions. Recent introduction of application placement equipment has expanded options for turfgrass managers when maintaining roadside vegetation. If effective PGR treatments using application placement equipment were available, mowing and PGR application could be accomplished in one pass. This would not only complete one mowing cycle, but it would also reduce mowing frequency for the remainder of the growing season, diminish the potential for drift to non-target areas, eliminate visible pesticide applications, and reduce potential for worker exposure to chemicals.

Bahiagrass was introduced into the United States as a forage grass from Brazil in the early 1900s by the Florida Agricultural Experiment Station (Scott 1920, Emmons 1995). Following this introduction, unimproved bahiagrass ('Pensacola') has been widely used for roadside turf throughout the southeastern United States because it is easily established from seed and produces a complete cover on low fertility soils found throughout the region. Bahiagrass also performs better than Bermuda grass (*Cynodon dactylon* (L.) Pers.) on wet, poorly drained soils (Duble 1996) and is considered tolerant to drought (Emmons 1995). A lack of cold tolerance limits the range of bahiagrass to southern and midsouth states (Duble 1996).

Although bahiagrass is considered a low-maintenance turfgrass with respect to water and fertilisation, prolific seedhead production throughout the growing season results in high mowing requirements (Beard 1973, Duble 1996). Bahiagrass culms range from 40 to 80 cm tall (Radford *et al.* 1968) and can pose a hazard to motorists by reducing visibility on highway rights-of-way (Busey 1985). Due to its prolific, season-long seedhead production, bahiagrass is normally mowed between 4 and 8 times per year on roadsides in the southeastern United States.

Because mowing is the major maintenance requirement, bahiagrass is a good candidate for seedhead suppression with PGRs. Johnson (1990) suppressed bahiagrass seedheads in excess of 85% for 10 weeks with imazapic, glyphosate and glyphosate plus 2,4-D without permanently reducing turf density. Flanagan and Peacock (1986) suppressed bahiagrass growth on highway rights-of-way with EPTC, EPTC plus dicamba, sethoxydim and sethoxydim plus mefluidide without severe turfgrass damage. Goatley *et al.* (1996) evaluated PGR effects of imazaquin and imazapic on bahiagrass over 2 years in Mississippi. They reported greater than 80% suppression of seedheads for 8 weeks and only slight turfgrass discolouration with 420 g ha^{-1} imazaquin. Imazapic at 42 or 56 g ha^{-1} applied in late May or June provided 100% seedhead suppression for 8 weeks but when applied later in the summer in July or August, unacceptable discolouration was obtained. Lower rates of imazapic (14 or 28 g ha^{-1}) applied in July or August provided at least 90% seedhead suppression with acceptable bahiagrass injury.

Plant growth regulators have historically been effective in controlling the growth of numerous warm- and cool-season turfgrass species (Fagerness and Penner 1998a, 1998b, Johnson 1989a, 1989b, 1990, 1992, 1993, Johnson and Murphy 1991, Ruemmele *et al.* 1988). Additionally, other studies have specifically reported the effectiveness of PGRs on turfgrasses located along roadsides or in low maintenance utility areas (Foote and Himmelman 1971, Elkins 1974, Yelverton *et al.* 1997). Advantageous qualities provided by PGRs include suppression of seedheads and vegetative growth with little or no reduction in turfgrass quality.

Similar to herbicides, PGRs are placed into groups based on mode-of-action, or the way they inhibit growth of turfgrasses. Although classification schemes vary, three distinct groups of PGRs exist, including cell division inhibitors, herbicides and gibberellin biosynthesis inhibitors. Cell division inhibitors are primarily foliar absorbed and inhibit cell division and differentiation in meristematic regions. They inhibit both vegetative growth and seedhead development. Mefluidide and maleic hydrazide are examples of cell division inhibitors. Various herbicides are used at low rates to suppress growth or seedhead development of turfgrasses. Depending upon the chemical, herbicides inhibit turfgrass growth and development through interruption of amino acid synthesis (glyphosate, sulfometuron, chlorsulfuron, metsulfuron, imazapic, imazapic + imazapyr) or fatty acid biosynthesis (sethoxydim). Turfgrass tolerance to herbicides can be marginal and is highly rate dependent. Herbicides and cell division inhibitors are primarily used only on low and medium maintenance turfgrasses to reduce mowing and control weeds.

Concerns in the turfgrass industry over phytotoxicity and inconsistent performance linked with PGR applications have been the focus of much research (Christians 1985, Spokas and Cooper 1991, McCullough *et al.* 2004). Although slight discolouration is acceptable in low maintenance turfgrass situations, such as roadsides, inconsistent performance could result in increased need for multiple annual mowings and lost revenue. Because effects of PGRs on tall fescue can be unpredictable, application equipment that places chemical directly on cut or uncut plant surfaces could provide a viable solution to the problems of off-target movement and poor absorption encountered with conventional spray equipment. With wet-blade equipment, PGRs are placed in direct contact with internal plant tissues, thus circumventing passage through and dilution by the leaf cuticle (Wahlers *et al.* 1997a, 1997b). Estimations of total foliar-applied herbicide reaching the target site are very low indicating a high level of inefficiency in broadcast spray pesticide applications (Bohannan and Jordan 1995). Although wound-surface herbicide applications have been historically effective in forest situations (Johansson 1988), the development of mowing equipment that incorporates a fluid application system is relatively recent. The Burch Wet Blade™ (BWB) is the most recent technology developed to meet this goal (Henson 1996, Henson *et al.* 2003).

MATERIALS AND METHODS

The methods and results listed below include data from previously published research in Weed Technology and the International Turfgrass Society. Below is a discussion of results from several research projects.

TALL FESCUE

Experiments were initiated on 'Kentucky 31' tall fescue roadsides in the spring and summer of 2003 and 2004. Three separate experiments were conducted on established tall fescue roadside areas in the mountain and piedmont regions of North Carolina. Three types of application placement equipment were used to evaluate PGR efficacy, including a rotary wick-wiping mechanism (Weedbug™), a 1.5 m wet-blade rotary mower (BWB) (Henson 1996) and an all-terrain vehicle (ATV) mounted broadcast sprayer. PGR treatments evaluated were imazapic at three rates (8.8, 35.1 and 52.6 g a.i. ha^{-1}) and chlorsulfuron plus mefluidide at 6.6 + 140.2 g a.i. ha^{-1}. Experiments compared the efficacy of PGRs applied using two alternative application placement devices to a conventional broadcast spray.

The Weedbug and BWB are low volume systems of application whereby liquid can be placed directly onto vegetation. The Weedbug uses a rotary wick-type system to wipe pesticides directly on uncut stems and/or leaves of plants. The BWB pumps a pesticide solution from a reservoir through a closed delivery system to be released on the cutting surface of rotary mower blades, resulting in simultaneous mowing and pesticide application. Broadcast spray was applied using an ATV-mounted CO_2 sprayer at 187 L ha^{-1} (172.4 kPa with XR8003 Teejet nozzles). Weedbug and BWB treatments were applied at 9.35 L ha^{-1}.

Experimental sites were located on roadsides in Guilford and Madison County, North Carolina. Both sites had vegetation similar to highway rights-of-way in central and western North Carolina. Experimental plots were dominated by tall fescue, with very few weed species unevenly distributed. Weed species present included bahiagrass, broomsedge (*Andropogon virginicus* L.) and white clover (*Trifolium repens* L.). The soil type at the Guilford County site was a Cecil sandy clay loam and a Buladean-Chestnut sandy loam at the Madison County site. To simulate typical roadside conditions, supplemental fertility and irrigation were not applied to the experimental area throughout the duration of all experiments.

Treatments were initiated on 29 April 2003, 13 April 2004 and 19 April 2004 when tall fescue seedheads were at the 'boot stage' or just beginning to emerge. A factorial treatment design was employed with three types of application placement equipment and four PGR treatments. Experimental design was a randomised complete block with three replicates and a plot size of 12.2 × 21.3 m (2003) or 3.05 × 12.2 m (2004). Treatments were applied to different plots each year. All plots were mowed during the fall prior to experiment initiation and left unmowed until the experiments were completed. Tall fescue plant height averaged 15 cm at the start of all experiments. Plots treated with the BWB and mowed non-treated were mowed to 10.1 cm. Mowed non-treated and non-treated were included as a benchmark for reference. Treatments applied using broadcast spray and Weedbug were not mowed at treatment initiation.

Turfgrass phytotoxicity, quality, vegetative height, seedhead height and emerged seedheads were measured at 1, 2 and 3 months after treatment (MAT). Ratings of tall fescue phytotoxicity and quality were estimated visually, while plant and seedhead heights were measured from soil surface to tip of leaves or seedheads. Phytotoxicity was based on a 0 to 100% scale with 0 = no injury and 100 = complete kill. Tall fescue quality, based on a 1 to 9 scale with 1 = complete plant death and 7 = average and 9 = uniform grass cover, was measured for only 2 months after treatment. Three vegetation and seedhead heights were measured per plot and averaged. New vegetative growth values were determined by subtracting the initial tall fescue height (15 cm) from measurements taken at monthly intervals. Using 71 cm diameter plastic rings, three seedhead counts were measured per plot and averaged. These counts were converted to numbers of seedheads m^{-2}, and compared to the non-mowed non-treated to estimate percent seedhead suppression.

Where appropriate, data were combined across tests and subjected to analysis of variance (ANOVA) using the Statistical Analysis System (General Linear Model procedure). Treatment means for application equipment within PGR treatments were separated by Fisher's protected LSD at the 0.05 significance level. Interactions between years were observed; therefore, data were separated for year and pooled for location in 2004. Regression analysis was then conducted on the data to determine if there was a linear relationship between the imazapic rates and quality, injury, vegetative growth and seedhead suppression. No rate effect was found for these four measurements; therefore, data will be presented for each rate of imazapic separately.

BAHIAGRASS

Five field experiments were established in 1995 and 1996 in Nash County, North Carolina; Tift County, Georgia; and Gainesville, Florida. Each trial was located on established unimproved 'Pensacola' bahiagrass stands that had received no prior herbicide or PGR treatment.

North Carolina Imazapic and sulfometuron were evaluated for bahiagrass seedhead suppression in 1995 and 1996. The soil type in both years was a Norfolk loamy sand (fine-loamy, siliceous, thermic Typic Paleudult) with a soil pH of 5.5 and 5.4 in 1995 and 1996, respectively. In 1995, imazapic was evaluated at 36, 53, 71, 110 and 140 g ha^{-1}, and sulfometuron was evaluated at 260 g ha^{-1}. All treatments included the addition of a nonionic surfactant at 0.25% (v/v) of the spray volume. Imazapic was also evaluated at 360 g ha^{-1} without surfactant. The same treatments were evaluated in 1996 except imazapic at 110 and 140 g ha^{-1} were omitted.

All treatments were applied after complete bahiagrass greenup on 31 May 1995 and 1 June 1996 with a $C0_2$ backpack sprayer set to deliver 305 L ha^{-1} at 190 kPa. Treatment timings were estimated at 3 weeks prior to bahiagrass seedhead emergence. Plot size was 1.5 × 3 m. Plots were not mowed prior to or following PGR applications. No fertiliser or supplemental irrigation was used in either year.

Treatments were evaluated at 2-week intervals beginning 2 weeks after PGR treatment with the last evaluation at 16 weeks following application. Bahiagrass quality was visually rated on a scale of 1 to 9 (1 = dead turf, 5 = minimal acceptable turf and 9 = perfect turf). Turf density was also visually rated as a percentage of turf ground cover. Seedhead counts were initiated at 4 weeks after PGR applications and continued through 16 weeks. Seedhead counts were taken by tossing a 30.5 cm^2 circular ring at three random locations into each plot.

Treatments were arranged in a randomised complete block design (RCBD) with four replicates. Data were analysed using analysis of variance and means were separated with Fisher's protected LSD at the 0.05 probability level.

Georgia PGRs were evaluated for bahiagrass seedhead suppression in 1995 and the same plots were treated with the same treatments in 1996. The soil type was a Rains loamy sand (fine-loamy, siliceous, thermic, Typic Paleaquults) with a soil pH of 5.6. Imazapic was evaluated at 36, 53, 71, 110 and 140 g ha^{-1} and sulfometuron was evaluated at 26 g ha^{-1}. All PGR treatments included a nonionic surfactant at 0.25% (v/v) of the spray volume.

Treatments were applied after complete bahiagrass greenup on 25 April 1995 and 6 May 1996 with a CO_2 backpack sprayer set to deliver 238 L ha^{-1} at 205 kPa. Plots were not mowed prior to PGR applications in 1995 but were mowed 10 days prior to treatment in 1996. No subsequent mowing occurred following PGR application. Plot size was 3.7 × l5 m in 1995 and 1.8 × 15 m in 1996. No fertiliser or supplemental irrigation was used in either year. Treatments were evaluated at 2, 4, 8, 12 and 16 WAT. Percent bahiagrass discolouration, stand reduction and seedhead suppression were visually rated on a 0 to 100 scale.

Treatments were arranged in a RCBD with three replicates. Data were analysed using analysis of variance and means were separated with Fisher's protected LSD at the 0.05 probability level.

Florida Imazapic was evaluated for bahiagrass seedhead suppression in 1995 on an Arredondo fine sand (loamy, siliceous, hyperthermic, Grossarenic Paleudult) with a soil pH of 6.0. Imazapic was evaluated at 36, 53, 71, 110 and 140 g ha^{-1}. All imazapic treatments included a nonionic surfactant at 0.25% (v/v) of the spray volume.

All treatments were applied on 25 May with a CO_2 backpack sprayer set to deliver 190 L ha^{-1} at 205 kPa. Plots were mowed 7 days prior to PGR treatments. No subsequent mowing occurred following PGR application. Plot size was 1.5 m × 4.6 m. Nitrogen was applied at 49 kg ha^{-1} to all plots on 30 April. Treatments were evaluated at 1, 2, 4, 8, 12 and 16 WAT. Bahiagrass quality was visually rated on a scale of 1 to 10 (1 = dead turf, 5 = minimal acceptable turf and 10 = perfect turf). Turf density was also visually rated as a percentage of ground cover. Seedheads were counted 1, 4, 8, 12 and 16 WAT.

Treatments were arranged in a RCBD with three replicates. Data were analysed using analysis of variance and means were separated with Fisher's protected LSD at the 0.05 probability level.

RESULTS AND DISCUSSION

TALL FESCUE

Phytotoxicity All treatment combinations resulted in ≤20% plant injury, and tall fescue completely recovered from injury by 2 MAT (data not shown). Plant injury was lowest (≤5%) when PGR treatments were applied with the broadcast sprayer. Phytotoxicity increased when PGRs were applied with the Weedbug and BWB. These results demonstrate that PGR phytotoxicity could be altered by the application method, possibly by circumventing a limiting factor, e.g. inadequate foliar absorption (BWB only) or higher PGR concentration on leaf surface (BWB and Weedbug). Generalisations from these results should be treated with caution because more research is needed. However, it is possible that plants currently resistant to spray applications may be sensitive to PGR applications that integrate mowing or tissue cutting with delivery of a phytotoxic pesticide.

Quality Quality evaluations were significantly higher than the non-treated and mowed non-treated for all broadcast spray applied PGR treatments. Plots received higher quality ratings, when the tall fescue was dense, relatively weed free, good colour and absent of seedheads. Non-treated and mowed non-treated tall fescue quality ranged from 3.5 to 4.7, while plots treated with PGRs ranged from 4.5 to 7.0 at 1 and 2 MAT in 2003 and 2004 (Table 1). Quality ratings were usually higher for all placement equipment when compared to non-treated plots (Table 1). In 2004, the highest imazapic rate and tank mix applied using the BWB did not improve turf quality when compared to non-treated plots. Alternatively, the same treatments applied through the Weedbug and as a broadcast spray did increase tall fescue quality. Some BWB and Weedbug treatments resulted in lower quality ratings possibly due to higher concentrations of chemical in direct contact with leaf tissue (Table 1).

Vegetative growth suppression All PGRs applied using the broadcast sprayer and Weedbug suppressed new vegetative growth for 1 MAT when compared to the mowed non-treated (Table 2). The two higher rates of imazapic (35.1 and 52.6 g a.i. ha^{-1}) applied with the broadcast sprayer and Weedbug in 2004 reduced vegetative growth throughout the growing season when compared to the non-mowed non-treated. Regardless of the type of application equipment, 8.8 g a.i. ha^{-1} imazapic and chlorsulfuron + mefluidide tank mix failed to suppress vegetative growth throughout the experiment compared to the non-mowed non-treated. Mowed non-treated and lowest imazapic rate applied with the BWB resulted in the most vegetative growth with 29.7 and 21.1 cm of new growth during the 2003 and 2004 experiments, respectively. In 2004, the high imazapic rate (52.6 g a.i. ha^{-1}) held new tall fescue growth to 5.1 cm or less for 3 MAT when applied with the broadcast spray or Weedbug (Table 2).

PGR treatments applied using the BWB suppressed new vegetative growth for only one PGR treatment at one sampling date. This lack of vegetative growth suppression indicates mowing may actually stimulate growth, even in the presence of PGRs. Because of this stimulatory effect, comparing vegetative heights allows for an alternative comparison of treatments. Even though mowed non-treated and wet-blade treatments resulted in more new vegetative

Table 1. Visual quality (score of 1–9) of tall fescue after plant growth regulator treatments applied by broadcast spray, rotary-wick or wet-blade systems.

Application method	Imazapic (8.8 g a.i. ha^{-1})[D]		Imazapic (35.1 g a.i. ha^{-1})[D]		Imazapic (52.6 g a.i. ha^{-1})[D]		Mefluidide + chlorsulfuron (6.6 + 140.2 g a.i. ha^{-1})[D]	
	2003[B]	2004[C]	2003[B]	2004[C]	2003[B]	2004[C]	2003[B]	2004[C]
1 month after treatment								
Non-treated	4.0 b	3.5 b	4.0 b	3.5 b	4.0 b	3.5 b	4.0 b	3.5 b
Mowed	4.7 b	3.6 b	4.7 b	3.6 b	4.7 b	3.6 b	4.7 b	3.6 b
Spray	6.7 a	5.9 a	6.3 a	5.9 a	5.7 a	6.4 a	6.7 a	6.0 a
Weedbug	6.8 a	6.0 a	6.3 a	5.9 a	5.8 a	6.4 a	6.3 a	6.2 a
BWB[A]	–	4.9 ab	–	5.8 a	–	6.58 ab	–	5.8 ab
2 months after treatment								
Non-treated	3.5 c	3.7 a	3.5 b	3.7 a	3.5 b	3.7 c	3.5 b	3.7 a
Mowed	3.5 c	3.8 a	3.5 b	3.8 a	3.5 b	3.8 c	3.5 b	3.8 b
Spray	6.5 b	5.9 a	6.5 a	5.7 a	6.7 a	6.5 a	6.7 a	6.0 a
Weedbug	7.0 a	5.2 ab	6.8 a	5.2 a	6.7 a	4.5 bc	6.8 a	5.9 a
BWB[A]	–	5.2 ab	–	5.9 a	–	6.2 ab	–	6.0 a

[A] In 2003, Plots treated using the Burch Wet-Blade (BWB) were abandoned due to equipment malfunctioning.
[B] Values are means of three replicates from one location.
[C] Values are means of six replicates from two locations.
[D] Means within a column followed by the same letter are not different, according to Fisher's Protected LSD at P = 0.05.

growth, non-treated plots still consistently had the greatest vegetative height throughout all experiments. The two higher imazapic rates often resulted in lower plant heights when compared to non-treated regardless of placement application equipment used (Table 3).

Overall, treatments applied using the broadcast sprayer and Weedbug suppressed new vegetative growth more than PGR treatments applied using the BWB. Even though some vegetative growth measurements appeared visually different from non-treated checks, variability prevented statistical differences. Vegetative growth suppression was inconsistent and no treatment was superior.

Seedhead suppression While vegetative growth suppression is the most advantageous result of PGR applications in fine turfgrass, seedhead suppression becomes most important in low maintenance areas such as roadsides where seedhead height and density can obstruct sightlines thereby reducing motorist safety. All plots treated with PGRs had very few seedheads present. Seedhead suppression was 76% or greater for all treatments throughout all experiments when compared to the non-treated (Table 4). In the rare case that seedheads were present, they were no taller than those in the non-treated plots (Table 5). Seedhead counts were very low for all application equipment, never exceeding 6 seedheads m^{-2} (data not shown). The low rate of imazapic and tank mix applied using the BWB provided the lowest level of seedhead suppression 1 MAT (76% and 87%). Although application with the BWB did not provide complete seedhead suppression throughout the growing season, suppression was significantly higher than the mowed-only plots at all rating dates. The broadcast sprayer and Weedbug provided greater than 96% seedhead suppression with all PGRs tested throughout the growing season when compared to non-mowed non-treated (Table 4).

Results from these studies illustrate that the type of application equipment does affect the efficacy of the PGR treatments evaluated. Presently, the most significant limiting factors are the design and construction of equipment that cuts vegetation while applying an effective dose of active ingredient. Henson (1996) explained these alternative application techniques must use commercial PGR/herbicide formulations designed for spray application. These formulations are chemical mixtures designed to effectively move the PGR/herbicide across the plant leaf cuticle and into the living tissue. The BWB applies the PGR/herbicide to the cut surface of a plant, and thus the composition of the formulation that would provide optimum efficacy

Table 2. Vegetative growth (cm of new growth) of tall fescue after plant growth regulator treatments applied by broadcast spray, rotary–wick or wet–blade systems.

Application method	Imazapic (8.8 g a.i. ha^{-1})[D] 2003[B]	Imazapic (8.8 g a.i. ha^{-1})[D] 2004[C]	Imazapic (35.1 g a.i. ha^{-1})[D] 2003[B]	Imazapic (35.1 g a.i. ha^{-1})[D] 2004[C]	Imazapic (52.6 g a.i. ha^{-1})[D] 2003[B]	Imazapic (52.6 g a.i. ha^{-1})[D] 2004[C]	Mefluidide + chlorsulfuron (6.6 + 140.2 g a.i. ha^{-1})[D] 2003[B]	Mefluidide + chlorsulfuron (6.6 + 140.2 g a.i. ha^{-1})[D] 2004[C]
1 month after treatment								
Non-treated	5.1 a	3.4 b	5.1 a	3.4 b	5.1 a	3.4 b	5.1 a	3.4 ab
Mowed	5.1 a	10.2 a	5.1 a	10.2 a	5.1 a	10.2 a	5.1 a	10.2 a
Spray	0.8 a	1.7 b	0 b	2.5 b	0.8 a	0.8 c	0 b	1.3 b
Weedbug	0.8 a	0.4 b	0 b	2.5 b	0.8 a	0.4 c	0 b	1.7 b
BWB[A]	–	7.6 a	–	6.8 ab	–	4.6 b	–	5.9 ab
2 months after treatment								
Non-treated	11.8 a	6.8 ab	11.8 ab	6.8 ab	11.8 a	6.8 ab	11.8 a	6.8 a
Mowed	16.1 a	12.7 a	16.1 a	12.7 a	16.1 a	12.7 a	16.1 a	12.7 a
Spray	16.9 a	5.5 ab	12.7 a	3.0 b	9.3 a	4.2 ab	10.2 a	5.1 a
Weedbug	12.7 a	0.8 b	7.6 b	2.5 b	12.7 a	0 b	11.0 a	5.1 a
BWB[A]	–	14.8 a	–	12.3 a	–	11.4 a	–	11.0 a
3 months after treatment								
Non-treated	17.8 b	16.1 ab	17.8 ab	16.1 a	17.8 b	16.1 a	17.8 b	16.1 ab
Mowed	29.7 a	21.1 ab	29.7 a	21.1 a	29.7 a	21.1 a	29.7 a	21.1 a
Spray	23.1 ab	13.5 ab	16.9 b	3.1 c	16.9 b	4.2 b	14.4 b	7.6 b
Weedbug	21.2 ab	11.9 b	19.5 ab	8.5 bc	20.3 ab	5.1 b	17.7 b	6.8 b
BWB[A]	–	22.9 a	–	17.8 ab	–	16.9 a	–	17.8 a

[A] In 2003, Plots treated using the Burch Wet–Blade (BWB) were abandoned due to equipment malfunctioning.
[B] Values are means of three replicates from one location.
[C] Values are means of six replicates from two locations.
[D] Means within a column followed by the same letter are not different, according to Fisher's Protected LSD at P = 0.05.

Table 3. Vegetative height (cm from soil surface) of tall fescue after plant growth regulator treatments applied by broadcast spray, rotary-wick or wet-blade systems.

Application method	Imazapic (8.8 g a.i. ha^{-1})[D]		Imazapic (35.1 g a.i. ha^{-1})[D]		Imazapic (52.6 g a.i. ha^{-1})[D]		Mefluidide + chlorsulfuron (6.6 + 140.2 g a.i. ha^{-1})[D]	
	2003[B]	2004[C]	2003[B]	2004[C]	2003[B]	2004[C]	2003[B]	2004[C]
1 month after treatment								
Non-treated	20.3 a	22.9 a	20.3 a	22.9 a	20.3 a	22.9 a	20.3 a	22.9 a
Mowed	15.2 a	19.9 a	15.2 b	19.9 ab	15.2 a	19.9 ab	15.2 a	19.9 a
Spray	13.6 a	19.5 a	12.7 b	18.6 ab	14.4 a	17.8 ab	14.4 a	18.6 a
Weedbug	15.2 a	16.9 a	15.2 b	20.8 ab	13.6 a	16.9 b	14.4 a	19.9 a
BWB[A]	–	17.8 a	–	16.9 b	–	14.8 b	–	16.1 a
2 months after treatment								
Non-treated	27.1 a	26.3 a	27.1 ab	26.3 a	27.1 a	26.3 a	27.1 a	26.3 a
Mowed	26.3 a	22.9 a	26.3 ab	22.9 a	26.3 a	22.9 a	26.3 a	22.9 a
Spray	32.2 a	24.6 a	28.0 a	21.2 a	24.6 a	24.1 a	25.4 a	23.7 a
Weedbug	28.0 a	19.9 a	22.9 b	21.6 a	28.0 a	18.2 a	26.2 a	23.7 a
BWB[A]	–	25.0 a	–	22.4 a	–	21.6 a		21.2 a
3 months after treatment								
Non-treated	33.0 ab	36.4 a	33.0 a	36.4 a	33.0 a	36.4 a	33.0 a	36.4 a
Mowed	39.8 a	31.3 a	39.8 a	31.3 ab	39.8 a	31.3 ab	39.8 a	31.3 a
Spray	28.0 b	33.9 a	32.2 a	21.2 b	32.2 a	24.5 b	29.6 a	27.9 a
Weedbug	36.4 ab	32.2 a	34.7 a	28.8 ab	35.6 a	25.4 b	33.0 a	27.1 a
BWB[A]	–	33.0 a	–	27.0 ab	–	27.1 b	–	27.9 a

[A] In 2003, plots treated using the Burch Wet-Blade (BWB) were abandoned due to equipment malfunctioning.
[B] Values are means of three replicates from one location.
[C] Values are means of six replicates from two locations.
[D] Means within a column followed by the same letter are not different, according to Fisher's Protected LSD at $P = 0.05$.

Table 4. Seedhead suppression (percent suppression compared to non-treated non-mowed plots) after plant growth regulator treatments applied by broadcast spray, rotary-wick or wet-blade systems.

Application method	Imazapic (8.8 g a.i. ha^{-1})[D]		Imazapic (35.1 g a.i. ha^{-1})[D]		Imazapic (52.6 g a.i. ha^{-1})[D]		Mefluidide + chlorsulfuron (6.6 + 140.2 g a.i. ha^{-1})[D]	
	2003[B]	2004[C]	2003[B]	2004[C]	2003[B]	2004[C]	2003[B]	2004[C]
1 month after treatment								
Mowed	19.3 b	27.2 c	19.3 b	27.2 b	19.3 b	27.2 b	19.3 b	27.2 b
Spray	100 a	97.8 a	100 a	100 a	100 a	100 a	96.2 a	100 a
Weedbug	100 a	100 a	100 a	99.7 a	100 a	100 a	100 a	100 a
BWB[A]	–	76.0 b	–	99.3 a	–	99.7 a	–	87.2 a
2 months after treatment								
Mowed	43 b	29 b	43 b	29 b	43 b	29 b	43 b	29 b
Spray	100 a	99.3 a	100 a	100 a	100 a	100 a	100 a	98.5 a
Weedbug	100 a	100 a	100 a	99.3 a	100 a	100 a	100 a	100 a
BWB[A]	–	92.8 a	–	98.3 a	–	100 a	–	91.3 a
3 months after treatment								
Mowed	22.3 b	0.7 b	22.3 b	0.7 b	22.3 b	0.7 b	22.3 b	0.7 b
Spray	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a
Weedbug	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a
BWB[A]	–	100 a	–	100 a	–	100 a	–	100 a

[A] In 2003, plots treated using the Burch Wet-Blade (BWB) were abandoned due to equipment malfunctioning.
[B] Values are means of three replicates from one location.
[C] Values are means of six replicates from two locations.
[D] Means within a column followed by the same letter are not different, according to Fisher's Protected LSD at $P = 0.05$.

Table 5. Height of tall fescue seedheads (cm from soil surface) after plant growth regulator treatments applied by broadcast spray, rotary-wick or wet-blade systems.

Application method	Imazapic (8.8 g a.i. ha^{-1})[E]		Imazapic (35.1 g a.i. ha^{-1})[E]		Imazapic (52.6 g a.i. ha^{-1})[E]		Mefluidide + chlorsulfuron (6.6 + 140.2 g a.i. ha^{-1})[E]	
	2003[B]	2004[C]	2003[B]	2004[C]	2003[B]	2004[C]	2003[B]	2004[C]
1 month after treatment								
Non-treated	71.1 a	83.0 a	71.1 a	83.0 a	71.1 a	83.0 a	71.1 a	83.0 a
Mowed	54.2 a	72.0 a	54.2 a	72.0 a	54.2 a	72.0 a	54.2 a	72.0 a
Spray	0 b	71.1 a (2)[D]	0 b	0 b	0 b	0 b	30.4 a (1)	0 b
Weedbug	0 b	0 b	0 b	61.0 a (1)	0 b	0 b	0 b	0 b
BWB[A]	–	57.6 a	–	43.2 a (2)	–	45.7 a (1)	–	59.3 a (3)
2 months after treatment								
Non-treated	103.3 a	86.8 a	103.3 a	86.8 a	103.3 a	86.8 a	103.3 a	86.8 a
Mowed	94.8 a	75.8 a	94.8 a	75.8 a	94.8 a	75.8 a	94.8 a	75.8 a
Spray	0 b	63.5 a (2)	0 b	0 b	0 b	0 b	0 b	71.1 a (2)
Weedbug	0 b	0 b	0 b	61.0 a (1)	0 b	0 b	0 b	0 b
BWB[A]	–	60.5 a (5)	–	71.1 a (1)	–	0 b	–	69.4 a (3)
3 months after treatment								
Non-treated	88.1 a	77.1 a	88.1 a	77.1 a	88.1 a	77.1 a	88.1 a	77.1 a
Mowed	84.7 a	63.5 a	84.7 a	63.5 a	84.7 a	63.5 a	84.7 a	63.5 a
Spray	0 b	0 b	0 b	0 b	0 b	0 b	0 b	0 b
Weedbug	0 b	0 b	0 b	0 b	0 b	0 b	0 b	0 b
BWB[A]	–	0 b	–	0 b	–	0 b	–	0 b

[A] In 2003, plots treated using the Burch Wet-Blade (BWB) were abandoned due to equipment malfunctioning.
[B] Values are means of three replicates from one location.
[C] Values are means of six replicates from two locations.
[D] Values in parentheses are the number of plots with seedheads present.
[E] Means within a column followed by the same letter are not different, according to Fisher's Protected LSD at P = 0.05.

is likely to be different. From our data, mowing elicits a stimulatory response and causes rapid growth to a height similar to non-mowed areas. Although the BWB reduces new vegetative growth compared to the mowed only treatment, when compared to the non-treated non-mowed treatment there are no differences throughout the growing season.

Greenhouse and field studies involving herbicides have demonstrated the concept of wound-surface application by effectively controlling growth of dogfennel (*Eupatorium capillifolium* (Lam.) Small.), multiflora rose (*Rosa multiflora* Thunb. ex Murr.) and purple loosestrife (*Lythrum salicaria* L.) (Wahlers *et al.* 1997a, Henson *et al.* 2003). Wahlers *et al.* (1997a) used pruning shears to simulate herbicide application with a mowing blade and demonstrated that long-term control was provided by low volumes and concentrations of triclopyr and clopyralid. Complimentary laboratory studies with dogfennel demonstrated the applied herbicide was rapidly absorbed by the freshly cut stem and translocated to the roots (Wahlers *et al.* 1997b). More recently, two different biological control agents, a bacterial and viral agent, were used for effective control of tropical soda apple (*Solanum viarum* Dunal) by using the wet-blade technology (Charudattan *et al.* 2001). Inconsistency associated with our data indicates more field research is needed focusing on uniformity of pesticide distribution and improved matching of pesticide formulation to the type of application equipment used.

Theoretically, the concept of wound-surface PGR application to mowed vegetation is both practical and cost-effective, but consistent, reliable equipment will be necessary for this to become a viable vegetation management tool. Placement equipment evaluated was unable to provide enhanced seedhead or vegetative growth suppression when compared to a broadcast spray application, but advantages such as drift control, mowing and chemical application in a single pass, no visible chemical application and reduced applicator exposure to toxic chemicals may outweigh disadvantages. Elucidating reasons for inconsistent results should be the focus of future research. Answers to these questions may allow wet-blade and rotary-wick application equipment to be incorporated into reduced-cost vegetation management programs.

BAHIAGRASS

Because of several treatment by location interactions, data could not be combined over years or locations. Therefore, results are presented separately. Data are shown from 4, 8 and 16 WAT evaluation dates.

North Carolina Imazapic and sulfometuron had a significant effect on bahiagrass quality, density and seedhead suppression in both years of the study (Table 6). In 1995, all PGR treatments reduced turf quality at 4 WAT. Imazapic at 110 and 14 g ha^{-1} severely reduced turf quality 16 WAT. Turf quality reductions were attributed primarily to discolouration caused by treatments. Discolouration by imazapic was similar to that described by Goatley *et al.* (1996). By 8 WAT, no reduction in turf quality occurred from the lowest rate of imazapic and sulfometuron, whereas all other treatments reduced quality to an unacceptable level. However, by 16 WAT, all treatments except the two highest imazapic rates had acceptable turf quality. Because unacceptable bahiagrass injury resulted from imazapic at 110 and 140 g ha^{-1}, these treatments were not included in 1996 North Carolina trials. In 1996, no treatment reduced quality to an unacceptable level at 16 WAT, although quality was reduced for all treatments at 4 WAT when compared to non-treated

Table 6. The effects of imazapic and sulfometuron on bahiagrass quality, density and seedhead number at 4, 8 and 16 weeks after treatment. Trials carried out in Nash County, NC, USA, over 2 years (1995 and 1996).

		1995			1996		
Treatment	Rate (g ha^{-1})	4 weeks	8 weeks	16 weeks	4 weeks	8 weeks	16 weeks
Turf quality[A]							
Non-treated	–	7.0	7.0	6.9	6.9	7.0	6.8
Imazapic	36	5.3	6.6	6.8	5.6	6.6	6.8
Imazapic + NIS[B]	36	5.0	4.8	6.6	5.3	6.4	7.1
Imazapic + NIS	53	5.0	4.6	6.5	5.3	5.8	6.8
Imazapic + NIS	71	5.0	4.1	6.6	5.6	5.1	6.8
Imazapic + NIS	110	4.8	3.5	2.1	–	–	–
Imazapic + NIS	140	4.8	4.0	3.0	–	–	–
Sulfometuron	26	4.5	7.8	6.5	5.4	6.8	6.9
LSD P = 0.05		0.5	0.7	1.1	0.5	0.5	NS
Density[C]							
Non-treated	–	53	74	69	60	73	76
Imazapic	36	36	54	61	55	64	76
Imazapic + NIS	36	33	35	48	56	60	74
Imazapic + NIS	53	26	33	48	56	55	73
Imazapic + NIS	71	34	30	39	56	51	73
Imazapic + NIS	110	30	24	9	–	–	–
Imazapic + NIS	140	35	26	19	–	–	–
Sulfometuron	26	33	68	66	58	66	78
LSD P = 0.05		7.5	6.7	10.2	NS	NS	5.8
Seedheads m^{-2}							
Non-treated	–	37.7	129.1	69.9	8.2	57.1	90.5
Imazapic	36	0	0	7.3	0	0	6.9
Imazapic + NIS	36	0	0	0	0	0	3.7
Imazapic + NIS	53	0	0	0	0	0	5.9
Imazapic + NIS	71	0	0	0	0	0	0
Imazapic + NIS	110	0	0	0	–	–	–
Imazapic + NIS	140	0	0	0	–	–	–
Sulfometuron	26	1.5	7.2	20.1	0	0	5.9
LSD P = 0.05		12.5	29.5	26.0	1.8	12.3	19.2

[A] Turf quality is a visual scale between 1 (dead turf), 5 (minimally acceptable) and 9 (perfect turf).
[B] NIS = nonionic surfactant at 0.25% (v/v).
[C] Density is a visual rating of percent ground cover.

checks. Only sulfometuron and imazapic at 36 g ha^{-1} with no surfactant failed to reduce quality at 8 WAT.

In 1995, bahiagrass density at 4 WAT was also reduced by PGR treatments and only sulfometuron did not reduce density by 8 WAT. At 16 WAT, 36 g ha^{-1} imazapic without surfactant was the only imazapic treatment that did not significantly reduce turf density. It was apparent from this study imazapic activity was enhanced with addition of a nonionic surfactant. However, this effect was not readily obvious in 1996. In 1996, all PGR treatments reduced bahiagrass density at 8 WAT but all had recovered by 16 WAT. PGR treatments did not affect turf density as much as the same treatments in 1995. The most likely explanation is that 1996 rainfall the following 4 weeks after treatment was greater than in 1995. This may have reduced some phytotoxicity from PGRs.

Seedhead suppression was excellent with all treatments in both years. By 16 WAT in 1995, only plots treated with the lowest rate of imazapic without surfactant and sulfometuron produced any seedheads and both produced less than the non-treated checks. In 1996, only 71 g ha^{-1} of imazapic with surfactant totally prevented seedhead production whereas other treatments produced only a small number of seedheads. With the exception of sulfometuron in 1995, none of the PGR-treated plots would have required mowing the entire 16-week growing season.

Georgia As observed in North Carolina, all PGR treatments had a significant effect on bahiagrass growth (Table 7). Only 36 g ha^{-1} of imazapic in 1995 did not significantly discolour bahiagrass. Discolouration was similar to that described in North Carolina. However, by 16 WAT, bahiagrass discolouration from all treatments was not evident in both years of study. Sulfometuron and imazapic at 36 g ha^{-1} tended to recover from discolouration earlier than other treatments. The level of discolouration was rate responsive, with increased discolouration at the higher rates of imazapic.

Imazapic at 110 and 140 g ha^{-1} reduced the bahiagrass stand at all evaluations in 1995 when compared to non-treated plots. In 1996, imazapic rates >71 g ha^{-1} significantly reduced bahiagrass density at 16 WAT. The difference in response between the two years may be explained by treating the same plots in 1996 with the same treatments in 1995. Imazapic at 71 g ha^{-1} resulted in a slight but non-significant stand reduction in 1995, but the use of the same rate in 1996 reduced bahiagrass density 35% at 16 WAT. This indicates that rates >71 g ha^{-1} of imazapic in successive years may be detrimental to bahiagrass growth.

Seedhead suppression was excellent in both years of study with all PGR treatments through 8 WAT. Goatley *et al*. (1996) also showed that imazapic effectively suppressed bahiagrass seedheads. By 16 WAT, the PGR effects on seedhead suppression had begun to dissipate. However, seedhead suppression was greater in 1996 than in 1995 with the same treatments. Again, this may be indicative of an additive effect when the same PGR is applied to bahiagrass in successive years.

Florida Similar to the results obtained in Georgia and North Carolina, imazapic had a significant effect on bahiagrass growth at the Florida site (Table 8). All imazapic rates reduced bahiagrass quality at 4 WAT and rates >71 g ha^{-1} had lower turf quality at 8 WAT. Discolouration was the same as described in previously discussed experiments. By 16 WAT, bahiagrass had recovered with respect to visual quality with all imazapic treatments. This is the same response obtained at the Georgia site in 1995 and 1996 and North Carolina in 1996. However, for Florida at 8 WAT, only the highest rate of imazapic reduced quality below the minimal acceptable level.

Bahiagrass density was not affected at 4 WAT but all imazapic rates >53 g ha^{-1} reduced turf density at 8 WAT. By 16 WAT, all rates in excess of 53 g ha^{-1} reduced bahiagrass density. Density reductions also occurred in 1996 in Georgia where rates >71 g ha^{-1} caused significant stand reduction. Current label recommendations allow for rates of 36 to 71 g ha^{-1} for bahiagrass seedhead suppression (Anon. 1996). These results indicate the high end of the recommended rate may be detrimental to bahiagrass stands.

CONCLUSIONS

These data indicate imazapic is effective in reducing bahiagrass and tall fescue seedhead emergence in the southeastern United States which may result in significant savings in mowing costs (Figure 1). Imazapic, or sulfometuron along bahiagrass roadsides only, may or may not completely eliminate the need for mowing but it would significantly reduce the frequency. Currently, four to eight mowing cycles are common along bahiagrass roadsides in the southeastern United States. In North Carolina, roadside managers have effectively reduced the number of mowing events to three per year when plant growth regulators are utilised. Based on current costs (plant growth regulator materials and application), North Carolina roadside vegetation managers are able to save 26% by utilising plant growth regulators and reducing mowing frequency. Additionally, motorist and worker safety is increased when plant growth regulators are employed and mowing frequency is reduced.

Table 7. The effects of imazapic and sulfometuron on bahiagrass discolouration, stand reduction and seed-head suppression at 4, 8 and 16 weeks after treatment. Trials carried out in Tifton, Georgia, USA, over 2 years (1995 and 1996).

Treatment	Rate ($g\ ha^{-1}$)	1995 4 weeks	1995 8 weeks	1995 16 weeks	1996 4 weeks	1996 8 weeks	1996 16 weeks
% bahiagrass discolouration[A]							
Non-treated	–	0	0	0	0	0	0
Imazapic[B]	36	13	12	0	30	8	0
Imazapic	53	18	17	0	40	28	0
Imazapic	71	30	32	0	38	48	0
Imazapic	110	40	38	0	42	70	0
Imazapic	140	45	68	0	43	73	0
Sulfometuron	26	45	8	0	47	18	0
LSD P=0.05		14	24	NS	6	15	NS
% bahiagrass stand reduction[C]							
Non-treated	–	0	0	0	0	0	0
Imazapic	36	0	10	0	10	7	0
Imazapic	53	3	12	0	17	23	13
Imazapic	71	2	23	10	17	47	35
Imazapic	110	10	37	18	18	60	68
Imazapic	140	12	55	42	18	68	83
Sulfometuron	26	23	7	0	27	12	2
LSD P=0.05		8	17	13	9	15	22
% seedhead suppression[D]							
Non-treated	–	0	0	0	0	0	0
Imazapic	36	100	87	27	100	100	50
Imazapic	53	100	98	38	100	100	58
Imazapic	71	100	100	53	100	100	77
Imazapic	110	100	100	68	100	100	92
Imazapic	140	100	100	87	100	100	99
Sulfometuron	26	100	93	17	100	98	57
LSD P=0.05		7	7	13	7	2	19

[A] Percent bahiagrass discolouration is on a 0 to 100 scale, where 0 = no discolouration and 100 = brown turf.
[B] All imazapic treatments contained a nonionic surfactant at 0.25% v/v.
[C] Percent bahiagrass stand reduction is a visual scale 0 to 100, where 0 = No stand reduction and 100 = elimination of turf.
[D] Percent seedhead suppression is a visual scale 0 to 100, where 0 = No seedhead suppression and 100 = total seedhead suppression.

Table 8. The effects of imazapic on bahiagrass quality, density and seedhead number at 4, 8 and 16 weeks after treatment in Gainesville, Florida, USA, in 1995.

Treatment	Rate ($g\ ha^{-1}$)	Bahiagrass quality[B] 4 weeks	Bahiagrass quality[B] 8 weeks	Bahiagrass quality[B] 16 weeks	Density[C] 4 weeks	Density[C] 8 weeks	Density[C] 16 weeks	Seedheads m^{-2} 4 weeks	Seedheads m^{-2} 8 weeks	Seedheads m^{-2} 16 weeks
Non-treated	–	8.7	8.0	8.0	75	73	77	38.5	24.5	0.3
Imazapic[A]	36	7.3	7.7	8.0	75	58	80	2.6	0.3	2.1
Imazapic	53	6.7	7.0	8.0	72	50	77	1.8	0.2	2.1
Imazapic	71	7.0	5.3	8.3	75	47	63	1.8	0.2	0.8
Imazapic	110	7.0	5.7	8.0	72	42	55	2.3	0.2	1.2
Imazapic	140	6.7	4.7	8.3	73	50	43	2.0	0.4	0.4
LSD P=0.05		0.9	1.4	NS	NS	19.3	11.7	7.2	4.6	1.8

[A] All imazapic treatments contained a nonionic surfactant at 0.25% v/v.
[B] Bahiagrass quality is a visual scale between 1 (dead turf), 5 (minimally acceptable) and 10 (perfect turf).
[C] Density is a visual rating of percent ground cover.

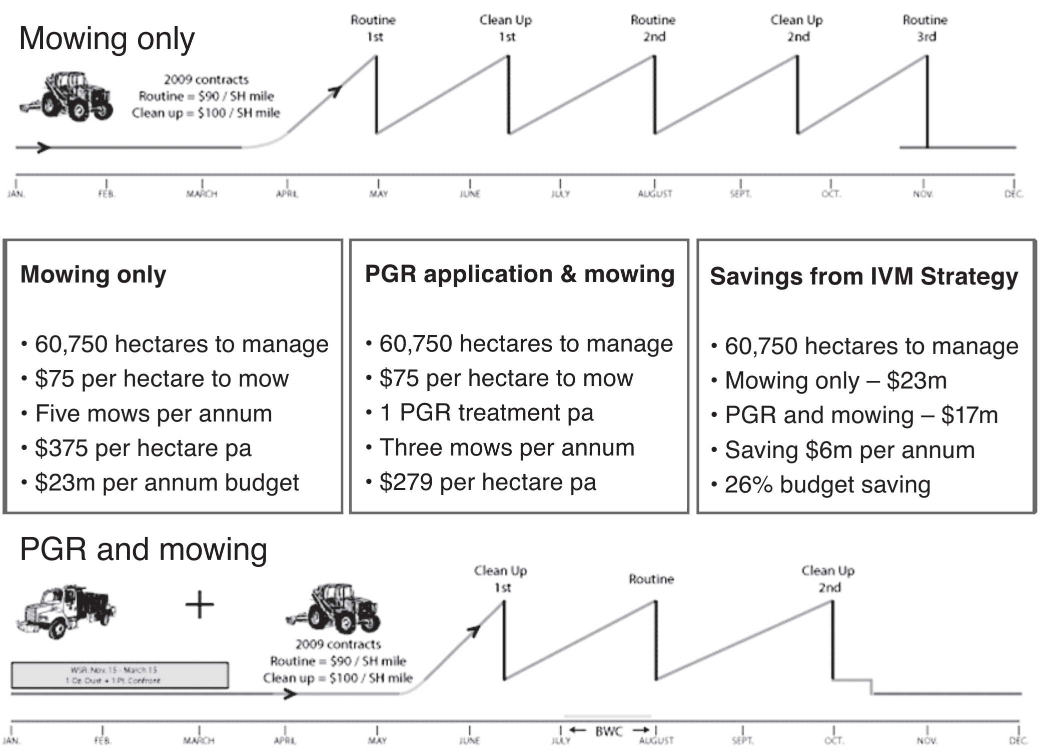

Figure 1. Schematic of potential cost savings utilising plant growth regulators along bahiagrass roadsides in North Carolina.

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