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Application Placement Equipment for Bahiagrass (*Paspalum notatum*) Suppression along Roadsides

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Experiments were initiated during 2003 and 2004 to evaluate application placement equipment for plant growth regulator (PGR) applications along bahiagrass roadsides. Recently designed equipment combine low-volume application and pesticide placement technology. Application placement equipment conceal the image of a traditional spray application. Evaluated application placement equipment included a wet-blade mower (Burch Wet Blade) and rotary-wick applicator (Weedbug™) compared with a traditional broadcast spray. Wet-blade mowers are designed to mow and simultaneously apply a pesticide solution to a cut stem or leaf in a single pass, whereas rotary-wick applicators are designed to wick a solution onto foliage. Evaluated PGRs included imazapic (9, 35, or 53 g ha^{-1}) and sulfometuron-methyl (26 g ha^{-1}). Bahiagrass injury varied with application placement equipment and was greater with rotary-wick applications in 2003, compared with foliar broadcast applications and the wet-blade mower. Bahiagrass seedhead suppression ranged from 31 to 60% with application placement equipment in July 2003 compared with 93% for a broadcast spray. In 2004, rotary wick- or broadcast-applied PGRs provided excellent (> 90%) seedhead suppression. Although application placement equipment may have advantages to broadcast-spray applications, evaluated equipment did not enhance bahiagrass suppression along roadsides in North Carolina compared with a foliar broadcast spray. Additional research is needed to determine if this type of application may provide consistent results with other species and compounds.
Nomenclature: Imazapic; sulfometuron-methyl; bahiagrass, *Paspalum notatum* (Flueggé), 'Pensacola'.
Key words: Seedhead suppression, plant growth regulator, low-volume application, wet blade, rotary wick, roadside turf.

Los experimentos se iniciaron durante 2003 y 2004 para evaluar equipos de aplicación directa de reguladores de crecimiento de las plantas en*Paspalum notatum* creciendo en los bordes de los caminos. Dicho equipo, de diseño reciente, combina tecnología de aplicación de bajo volumen con la de aplicación directa de pesticidas. El equipo de aplicación directa oculta la imagen de una aplicación tradicional. El equipo evaluado incluyó una segadora de cuchilla húmeda (Burch Wet Blade) y un rotoaplicador de mecha (Weedbug TM), los cuales se compararon con la aplicación asperjada tradicional. Las segadoras de cuchilla húmeda están diseñadas para cortar y aplicar simultáneamente una solución de pesticida al tallo o al follaje en una sola pasada, mientras que los rotoaplicadores de mecha se diseñaron para saturar el follaje con la solución del pesticida. Los reguladores de crecimiento de las plantas evaluados incluyeron imazapic (9, 35, ó 53 g ha−1) y sulfometuron-methyl (26 g ha−1). El daño a *Paspalum notatum* varió con el tipo de equipo de aplicación utilizado y fue mayor en las aplicaciones con rotoaplicador de mecha en 2003, comparados con las aplicaciones tradicionales al follaje y con las de cuchilla húmeda. La supresión de la formación de semillas de *Paspalum notatum* varió de 31 a 60% con el equipo de aplicación directa en julio de 2003, en comparación con 93% para una aplicación tradicional. En 2004, el rotoaplicador de mecha o la aplicación tradicional de los reguladores de crecimiento de las plantas lograron una supresión excelente de la semilla. Aunque los equipos de aplicación directa podrían tener ventajas sobre las aplicaciones tradicionales, el equipo evaluado no mejoró la supresión de *Paspalum notatum* en los bordes de los caminos de Carolina del Norte, en comparación con una aspersión foliar. Se requiere investigación adicional para determinar si este tipo de aplicación podría proporcionar resultados consistentes con otras especies y compuestos.

Turfgrass management along roadsides requires expenditure of millions of dollars, much of which is spent on routine mowing. Bahiagrass is well adapted for use along roadsides in the southeastern United States because of its adaptation to a wide range of soil conditions including infertility (Turgeon 1996); however, bahiagrass is a prolific seedhead producer that requires routine mowing. According to the 1999 North Carolina Turfgrass Survey, bahiagrass comprises one-fourth of the managed turfgrass along North Carolina roadsides (Anonymous 1999). Bahiagrass requires routine mowing because emerged seedheads may impede motorist vision. Mowing of roadside turf is expensive because it involves specialized equipment as well as fuel and labor. Additionally, mowing along roadsides poses danger for motorists and transportation personnel (D.C. Smith, personal communication).

Many transportation departments use plant growth regulators (PGR) along roadsides. PGRs have been used in highly managed turfgrass to reduce mowing requirements, grass clippings, evapotranspiration rates, and thatch production while enhancing green color and playing conditions (Beard 2002). Roadside personnel are primarily concerned with reducing mowing requirements, whereas enhancing turf quality is a secondary objective. Select PGRs are able to suppress vegetative growth and seedhead production of cool- and warm-season turfgrass species (Fagerness and Penner 1998; Hixson et al. 2007; McCarty et al. 1990; McCullough et al. 2004; Spak et al. 1993). Bahiagrass seedheads are suppressed with a single broadcast application of imazapic, reducing the number of required mowing cycles along

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roadsides (Baker et al. 1994; Baker et al. 1999; Moreno et al. 1992; Yelverton et al. 1997). Not only does suppressing bahiagrass seedheads increase safety, it also results in fiscal savings. According to North Carolina Department of Transportation personnel, a PGR can be broadcast-applied along roadsides for approximately 80% of the cost of one mowing cycle (D.C. Smith, personal communication).

Commercially available PGRs include mitotic inhibitors (type I PGRs), sublethal rates of herbicides, and gibberellin biosynthesis inhibitors (type II PGRs) (Christians 1998; Murphy et al. 2005). Mitotic, or cell-division, inhibitors act in meristematic regions and inhibit vegetative growth and seedhead development (Murphy et al. 2005).

Sublethal rates of herbicides have been used most extensively in low-maintenance turf areas, including roadsides, where some injury is tolerable. Sublethal herbicide rates inhibit turfgrass growth by interrupting amino acid or fatty acid biosynthesis; examples include glyphosate, sulfometuron-methyl, chlorsulfuron, metsulfuron, and imazapic (Murphy et al. 2005). Yelverton et al. (2007) concluded that bahiagrass tolerance to imazapic was rate dependent, with rates ≥ 71 g ha^{-1} resulting in persistent bahiagrass injury. Similarly, Gover et al. (2004) concluded that tolerance of tall fescue to imazapic was rate dependent.

PGRs that target gibberellin biosynthesis are applied to reduce longitudinal shoot growth without negatively affecting plant productivity (Rademacher 2000). These PGRs function by reducing cell elongation or the rate of cell division and are commonly applied to highly managed turfgrass where reductions in turf quality are objectionable. Gover et al. (1995a) concluded that gibberellin biosynthesis inhibitors flurprimidol and paclobutrazol effectively suppress tall fescue growth but induced slight tall fescue injury. Fagerness and Penner (1998) concluded that trinexapac-ethyl effects on cool-season turf dissipated 4 wk after treatment (WAT), indicating that trinexapac-ethyl is not suited for use along cool-season roadsides because repeat applications would be required for season-long suppression. Gover et al. (1995b) evaluated fall-applied mefluidide and various tank mixes to increase the window of PGR application but concluded that fall applications were not effective compared with spring applications. Regarding turfgrass management along roadsides, repeat applications may not be a viable option as they require the expenditure of additional funds and pose danger to motorists and roadside personnel. Hence, it is desirable to decrease the number of herbicide or PGR applications while maintaining a safe and desirable turfgrass stand.

Recently, types of application placement equipment have been developed that combine the technology of low-volume applications with specific placement of a pesticide solution. It has been hypothesized this type of application equipment may be beneficial for several reasons. Application placement equipment may circumvent foliar absorption, a critical component of broadcast applications of foliar-absorbed herbicides or PGRs (Wahlers et al. 1997a,b). For example, wet-blade mowers allow for a small amount of pesticide solution to be sorbed into the vascular system of a plant at the moment the plant is cut by a mower blade (Skroch et al. 1998). Although pesticide solution is not applied to a cut stem or leaf, wet-blade mowers may provide enhanced coverage compared with a broadcast application; past research has reported that broadcast applications deliver as little as 3% of foliar-applied herbicide to the intended target (Bohannan and Jordan 1995).

Although wet-blade mowers have been proven successful for woody vegetation management (Johansson 1988), little published research is available regarding the use of this technology for herbaceous vegetation management utilizing commercial equipment. Hixson et al. (2007) concluded that application placement equipment including the wet blade did not enhance tall fescue seedhead suppression when compared with a conventional broadcast application of select PGRs. Greenhouse and field experiments have demonstrated the effectiveness of wet-blade applications with select species. Past research indicates that simulated wet-blade applications of triclopyr or clopyralid control annual lespedeza [*Kummerowia striata* (Thunb.) Schindl.], red clover (*Trifolium pratense* L.), white clover (*Trifolium repens* L.), dogfennel [*Eupatorium capillifolium* (Lam.) Small], multiflora rose (*Rosa multiflora* Thunb. ex Murr.), and purple loosestrife (*Lythrum salicaria* L.) (Henson et al. 2003; Wahlers et al. 1997a). Sellers and Mullahey (2008) reported that broadcast applications of triclopyr were more effective for southern wax myrtle (*Myrica cerifera* L.) control compared with wet blade applications. Additionally, Mullahey and Williams (2001) reported that tropical soda apple (*Solanum viarum* Dunal) control with broadcast applications was similar to or less than wet-blade applications with pasture herbicides.

Henson et al. (2003) reported that the most significant limiting factor of wet-blade applications is the design and construction of equipment that effectively cuts vegetation and simultaneously applies a pesticide solution. Henson et al. (2003) also warned that most commercial POST herbicide formulations are designed to move the formulated product across the leaf cuticle and into plant tissue, whereas wet-blade equipment applies the pesticide solution to a cut surface, raising the question, will a herbicide that is formulated to move across a leaf cuticle be effective when applied to a cut stem or leaf surface?

Rotary-wick applicators are a second type of application equipment that combines low-volume application with specific placement of a pesticide solution. Rotary-wick applicators such as the Weedbug™ wipe a pesticide solution onto uncut foliage where a height differential is present between undesirable and desirable species. Little published research is available evaluating the use of rotary-wick applicators, although Lee (2000) concluded that the Weedbug was an improvement over past wick technologies because the distribution was consistent as the wicks did not become clogged during operation.

Application placement equipment conceal the image of a conventional broadcast pesticide application. The public may perceive broadcast pesticide applications as harmful; however, in the case of application placement equipment, many individuals may not realize a pesticide is being applied and it may not attract unwarranted attention. Other advantages of application placement equipment include reduced drift potential and worker exposure during application (Burch

2000). Additionally, applications with wet-blade mowers combine mowing and pesticide application in a single pass, which may reduce roadside maintenance budgets. The objectives of this research were to evaluate two types of application placement equipment for PGR application along bahiagrass roadsides.

Materials and Methods

Research trials were established to compare application placement equipment with conventional broadcast sprays for PGR applications along bahiagrass roadsides in Montgomery County, NC in 2003 and on a practice airfield located on Fort Bragg Army Base, NC in 2004. Each site was comprised of unimproved 'Pensacola' bahiagrass and was representative of roadside turf in central and eastern North Carolina.

Soil types were Georgeville silty clay loam (fine, kaolinitic, thermic Typic Kanhapludults) and Candor sand (sandy, kaolinitic, thermic Grossarenic Kandiudults) in 2003 and 2004, respectively. In 2003, trial areas were mown four times in the previous season but were not mown in 2003 before trial initiation; canopy height at trial initiation averaged 15 cm. In 2004, trial areas were mown (7 cm) biweekly in the previous season and once during early May before trial initiation; canopy height at trial initiation averaged 12.5 cm. After treatment initiation, mowing was discontinued until the end of the trial each year.

Two types of application placement equipment were evaluated for PGR applications: a rotary-wick applicator (Weedbug)[1] and a 1.5-m wet-blade mower (BWB).[2] Each was compared with an all-terrain-vehicle (ATV)-mounted broadcast sprayer. The Weedbug is a low-volume application system that uses a series of discs comprised of wicks arranged radially from the center. The discs rotate at a speed such that the pesticide solution does not leave wicks but rotation may allow more uniform coverage of the pesticide solution onto uncut plant foliage. The Weedbug does not mow in the process of PGR application. Additionally, the Weedbug is equipped with adjustable-gauge wheels to adjust height such that discs are prevented from contacting desirable vegetation or soil.

The BWB is also a low-volume application system that utilizes a rotary cutter with a ported shaft that allows solution to be metered through the gearbox. After passing through the gearbox, solution is delivered to the cutting blades, resulting in simultaneous mowing and pesticide application to a cut stem or leaf. The BWB uses a versatile application control unit and ground speed sensor to assist in metering pesticide solution. The Weedbug and BWB were calibrated to deliver 9 L ha^{-1}, whereas the ATV-mounted broadcast sprayer was calibrated to deliver 187 L ha^{-1} (172 kPa with XR8003 Teejet nozzles[3]).

Two experimental runs were conducted during 2003 and 2004. In 2003, treatments were initiated May 19 and June 12, whereas treatments were initiated May 24 and June 01 during 2004. Treatment timing coincided with bahiagrass in the boot stage, as no emerged seedheads were present at initiation. A randomized complete block design with factorial treatment arrangement was utilized with three application methods (Weedbug, BWB, or broadcast spray) and four PGR treatments. Evaluated PGR treatments included imazapic[4] (9, 35, or 53 g ha^{-1}) and sulfometuron-methyl[5] (26 g ha^{-1}). Evaluated application rates are representative of standard broadcast rates excluding 9 g ha^{-1} of imazapic. This rate was included for comparison since the BWB applies the PGR directly to a cut stem or leaf and may circumvent foliar absorption. All PGRs were applied with a nonionic surfactant[6] at 0.25% vol/vol.

A nontreated control was also included for comparison. Additionally, a mowed nontreated control was also included to discern the effect of mowing alone on bahiagrass growth and seedhead suppression. Three replications were included in each experiment. In 2003 and 2004, plots were 9 by 24 m and 5 by 17 m, respectively. Equipment was primed in an adjacent buffer area to ensure uniform application within experimental units. During treatment initiation, BWB and mowed nontreated plots were mown to 10 cm.

Bahiagrass phytotoxicity and vegetative height were determined mid-June, mid-July, and mid-August. Emerged seedheads were counted and seedhead height was measured mid-July and mid-August. Bahiagrass phytotoxicity was visually estimated on a 0 to 100% scale with 0 = no observed injury and 100 = complete plant death. Vegetative and seedhead heights were measured from the soil surface to the tip of the turfgrass canopy or seedhead. Using a 70-cm-diam (0.4 m^2) plastic ring, three seedhead counts were recorded and averaged to determine percentage seedhead suppression relative to the nontreated by the equation:

$$\%\text{Suppression} = [1 - (\text{seedhead count for each application method/seedhead count for nontreated})] \times 100$$

Data were subjected to ANOVA using SAS and are presented accordingly. Statistical results discouraged pooling over years; therefore, data from each year are presented separately. Effect of PGR was not significant regardless of measured response variable; therefore, data were pooled over PGRs. Treatment means for application equipment within year were separated according to Fisher's Protected LSD at $P = 0.05$.

Results and Discussion

Phytotoxicity. In 2003, averaged across PGRs, broadcast-spray applications induced the most bahiagrass phytotoxicity (31%) in June (Table 1). The Weedbug and BWB caused less (15 and 14%, respectively) phytotoxicity, although both exceeded the nontreated or mowed nontreated control. Regardless of application equipment, phytotoxicity did not persist in July and August. No reductions in bahiagrass cover were observed, regardless of application equipment as well (data not shown). In June 2004, applications with the Weedbug produced the most phytotoxicity (30%), whereas the broadcast spray and the BWB provided 21 and 19% phytotoxicity, respectively (Table 1). Unlike 2003, bahiagrass phytotoxicity persisted in 2004, and in the case of the Weedbug, phytotoxicity increased throughout the season.

Table 1. Bahiagrass phytotoxicity after plant growth regulator (PGR) treatments applied by broadcast-spray, rotary-wick, or Burch wet-blade systems.[a,b]

	2003			2004		
Application method	June	July	August	June	July	August
	%					
Nontreated	0 c	0 a	0 a	0 c	0 c	0 c
Mowed nontreated	0 c	0 a	0 a	0 c	0 c	0 c
Spray	31 a	2 a	0 a	21 b	18 b	13 b
Weedbug	15 b	0 a	0 a	30 a	53 a	57 a
Burch wet blade	14 b	1 a	0 a	19 b	13 b	13 b

[a] Phytotoxicity values were visually estimated on 0 to 100% scale.

[b] Data averaged over PGR and run. Means within a column followed by the same letter(s) are not different, according to Fisher's Protected LSD at $P = 0.05$.

During July and August 2004, the Weedbug resulted in 53 and 57% phytotoxicity, respectively (Table 1). Hixson et al. (2007) reported similar results with increased phytotoxicity along tall fescue roadsides when PGRs were applied with the Weedbug, indicating that this equipment may increase coverage or absorption, thereby increasing phytotoxicity. Although phytotoxicity in broadcast-spray- and BWB-treated plots persisted through July and August, it would not be objectionable for highway rights-of-way applications (≤ 20%) (D.C. Smith, personal communication).

Previous research demonstrated bahiagrass phytotoxicity with compounds including imazapic and sulfometuron (Goatley et al. 1996, 1998; Yelverton et al. 1997) and concluded that bahiagrass tolerance to these compounds is rate dependent. Imazapic provides bahiagrass seedhead suppression, but unacceptable injury has been documented in select cases. Yelverton et al. (1997) reported that imazapic (36, 53, or 71 g ha^{-1}) reduced bahiagrass turf quality in North Carolina at 4 and 8 WAT, although each had recovered by 16 WAT, whereas imazapic rates ≥ 71 g ha^{-1} should not be used unless some bahiagrass thinning is acceptable. Goatley et al. (1996) also concluded that bahiagrass sensitivity to imazapic was not only rate dependent but also suggested that it was dependent on application timing, with June applications providing more persistent bahiagrass injury than May applications. Johnson (1990) reported that imazethapyr, another imidazolinone compound, suppressed bahiagrass seedheads for 10 wk although it severely injured bahiagrass. Although injury observed from broadcast-applied PGRs in these experiments was not objectionable for roadside turf, Goatley et al. (1998) concluded that some bahiagrass injury from imazapic applications may be negated if the turf is mown 3 or 7 d before application. This may be of interest in other utility turf areas where phytotoxicity is objectionable.

Sulfometuron-methyl has also been evaluated for bahiagrass seedhead suppression along roadsides, although levels of bahiagrass injury vary. Peacock and Flanagan (1986) reported complete bahiagrass kill with sulfometuron-methyl, although they were evaluating increased rates (56 to 112 g ha^{-1}), indicating that results obtained may be largely rate dependent. McCarty et al. (1993) reported subtle bahiagrass injury with sulfometuron-methyl with sequential applications along roadsides.

Vegetative Height. In July 2003, vegetative height in PGR-treated plots was reduced, regardless of application method compared with the nontreated control (Table 2). The mowed nontreated control and BWB (which were mown at trial initiation) suppressed vegetative height (28 cm) the greatest compared with the nontreated control. Weedbug-treated plots were suppressed less relative to the nontreated and mowed nontreated controls. Although reduced compared with nontreated control in August, broadcast-spray, Weedbug, and BWB-applied PGRs suppressed vegetative height of bahiagrass by only 4 to 5 cm, which is likely negligible along roadsides.

In 2004, excluding BWB in August, each application method suppressed vegetative height at all evaluation times, compared with the nontreated and mowed nontreated controls. It is important to point out that the vegetative height of bahiagrass decreased in PGR-treated plots in June and July 2004. Cumulative rainfall during April through July 2004 was 9.4 cm less than the 30-yr average, which likely led to reduced bahiagrass growth (Table 3).

Similar to other parameters, previous research has suggested that select PGRs may suppress bahiagrass vegetative height.

Table 2. Vegetative height of bahiagrass after plant growth regulator (PGR) treatments applied by broadcast-spray, rotary-wick, or Burch wet-blade systems.[a]

	2003			2004		
Application method	June	July	August	June	July	August
	%					
Nontreated	20 a	40 a	38 a	11 a	15 a	17 a
Mowed nontreated	20 a	28 c	36 ab	11 a	17 a	18 a
Spray	20 a	31 bc	33 b	7 b	8 b	13 b
Weedbug	20 a	32 b	34 b	6 b	6 b	11 b
Burch wet blade	20 a	28 c	33 b	7 b	9 b	14 ab

[a] Data averaged over PGR and run. Means within a column followed by the same letter(s) are not different, according to Fisher's Protected LSD at $P = 0.05$.

Table 3. Recorded rainfall during experiment period vs. 30-yr average for each location.[a,b]

	Montgomery County		Fort Bragg	
	2003	30-yr average	2004	30-yr average
	cm			
April	11.1	8.1	6.0	8.3
May	19.9	7.5	8.5	8.0
June	8.8	10.6	10.4	11.4
July	17.8	12.6	7.1	13.7
August	20.5	12.0	22.8	12.8
Total	78.1	50.8	54.8	54.2

[a] Data provided by State Climate Office of North Carolina.

[b] Data collected 17.7 and 6.4 km from experiment site in 2003 and 2004, respectively.

Goatley et al. (1996) concluded that 56 g ha^{-1} imazapic reduced bahiagrass vegetative height by 33%, although they concluded that vegetative suppression with imazapic was not as pronounced as other measured parameters including seedhead suppression and height. Johnson (1990) reported vegetative suppression of bahiagrass through 4 WAT with a single application of imazethapyr, although two applications were required to obtain 6-wk suppression. PGR applications along bahiagrass roadsides are advantageous if they suppress foliar height, but the main characteristic of a successful PGR application is suppressing the number of emerged seedheads throughout the reproductive season.

Seedhead Suppression. Emerged bahiagrass seedheads are problematic because they impede motorist vision, thereby reducing safety. In 2003, broadcast-spray applications provided greater bahiagrass seedhead suppression than applications with the Weedbug or BWB (Table 4). The broadcast spray provided excellent seedhead suppression (93%) through July, although suppression decreased during August. The BWB provided 60% bahiagrass seedhead suppression in July, whereas the Weedbug only provided 31% suppression. Weedbug or BWB-applied PGRs provided only minimal suppression (approximately 30%) in August. Also during 2003, the mowed nontreated control increased bahiagrass seedhead production compared with the nontreated control. Similarly, Hixson et al. (2007) reported that mowing tall fescue along roadsides elicits a stimulatory effect likely due in part to mowing rejuvenating the plant and encouraging new growth. Increased bahiagrass seedhead production in 2003 experiments may also be due to above-normal rainfall. Cumulative rainfall for April through August 2003 was 27.3 cm above the 30-yr average (Table 3).

In 2004, all PGR-treated plots suppressed bahiagrass seedheads $\geq$ 80% relative to the nontreated control, regardless of application method. Further, the broadcast spray and Weedbug provided near-complete suppression through July and August (98 and 94%, respectively) (Table 4).

Excluding August 2003, these data indicate that a broadcast-spray PGR application may provide excellent season-long bahiagrass seedhead suppression along roadsides. Similarly, Yelverton et al. (1997) concluded that broadcast applications of imazapic (36 to 140 g ha^{-1}) were effective for suppressing bahiagrass seedheads through 16 WAT. Also,

Table 4. Bahiagrass seedhead suppression compared with nontreated control after plant growth regulator (PGR) treatments applied by broadcast-spray, rotary-wick, or Burch wet-blade systems.[a,b]

	2003		2004	
Application method	July	August	July	August
	%			
Mowed nontreated	−76 a	−105 a	−20 a	10 a
Spray	93 d	67 c	99 b	98 b
Weedbug	31 b	22 b	99 b	94 b
Burch wet blade	60 c	26 b	80 b	86 b

[a] Data averaged over PGR and run. Means within a column followed by the same letter(s) are not different, according to Fisher's Protected LSD at P = 0.05.

[b] Percentage suppression was determined by the equation: %Suppression = [1 − (seedhead count for each application method/seedhead count for nonmowed nontreated)] × 100.

Goatley et al. (1996) concluded that imazapic (56 g ha^{-1}) applied during May provided complete bahiagrass seedhead suppression through 8 WAT. Within these experiments, at no evaluation time did either BWB- or Weedbug™-applied PGRs enhance bahiagrass seedhead suppression compared with a broadcast-spray application. Similarly, Hixson et al. (2007) concluded that application placement equipment did not improve PGR efficacy along tall fescue roadsides, compared with broadcast applications.

Seedhead Height. Although it is most desirable to eliminate emerged seedheads along roadsides, emerged seedheads may be acceptable if they do not impede motorists' vision. In July 2003 and 2004, emerged seedhead height of PGR-treated plots was similar to the nontreated control, regardless of application method (Table 5). In August 2003, PGRs applied as a broadcast spray or through the Weedbug reduced emerged seedhead height compared with nontreated and mowed nontreated controls. In August 2004, emerged seedhead height in PGR-treated plots was similar to the nontreated control although reduced compared with the mowed nontreated control. Goatley et al. (1996) reported that imazapic rates $\geq$ 28 g ha^{-1} applied in May provided $\geq$ 88% bahiagrass seedhead height reduction at 8 WAT in 1992, whereas 28 g ha^{-1} only reduced seedhead height by 40% in 1993. These data indicate that the usefulness of evaluated PGRs to suppress emerged seedhead height may or may not be consistent across years and may be affected by environmental conditions such as rainfall, temperature, or location, among other factors. Although evaluated PGRs applied as a

Table 5. Bahiagrass seedhead height after plant growth regulator (PGR) treatments applied by broadcast-spray, rotary-wick, or Burch wet-blade systems.[a]

	2003		2004	
Application method	July	August	July	August
	cm			
Nontreated	68 a	75 b	48 a	52 ab
Mowed nontreated	73 a	81 a	50 a	58 a
Spray	64 a	65 c	38 a	44 b
Weedbug	64 a	66 c	38 a	45 b
Burch wet blade	64 a	72 b	41 a	45 b

[a] Data averaged over PGR and run. Means within a column followed by the same letter(s) are not different, according to Fisher's Protected LSD at P = 0.05.

broadcast spray or through application placement equipment may suppress bahiagrass seedhead height relative to nontreated or mowed nontreated controls, suppression observed within these experiments was negligible along roadsides.

Translocation and fate of systemic herbicides or PGRs is not well understood after wet-blade applications and may explain some of the variability observed with similar types of application equipment (Wahlers et al. 1997b). Wahlers et al. (1997b) hypothesized that when a systemic herbicide is introduced to the cut stem, the herbicide diffuses laterally and translocates via the phloem; when applied to a cut stem, radiolabeled triclopyr and clopyralid were present in the roots within 48 h of application although most remained in the upper stem (Wahlers et al 1997b).

Within these experiments, application placement equipment performed similarly to broadcast-spray applications in some cases but never enhanced results. Similarly, Hixson et al. (2007) reported that application placement equipment did not enhance PGR efficacy when compared with broadcast-spray applications along tall fescue roadsides. Sellers and Mullahey (2008) reported reduced southern wax myrtle control with wet-blade technology compared with a broadcast-spray application, whereas Mullahey and Williams (2001) reported similar or increased tropical soda apple control with wet-blade vs. broadcast-spray applications. Henson et al. (2003) reported that wet-blade applications performed as well or better than foliar broadcast-spray applications for herbaceous weed control. Although some of the variability in efficacy present within the current experiments may be weather related, it is likely that variability will persist with these types of applications depending on target species, environmental conditions, pesticide, and timing of application, among other factors.

Application placement equipment has the potential to enhance vegetation management in low-maintenance turf areas such as roadsides; however, consistent and reliable results are essential for this technology to be adopted. In these experiments, application placement equipment did not enhance bahiagrass seedhead suppression compared with broadcast-spray applications of imazapic or sulfometuron-methyl. Future research is needed to evaluate additional species and determine if certain pesticide formulations should be avoided when using application placement equipment.

Sources of Materials

[1] Weedbug™, Centrogen, Inc., Unit 3, 40 Yarraman Place, Virginia, Queensland 4014, Australia.

[2] Wet-blade mower (BWB), Burch Company, 1515 Mockingbird Lane, Suite 820, Charlotte, NC 28209.

[3] Flat fan nozzle, Spraying Systems Co., P.O. Box 7900, Wheaton, IL 61089-7900.

[4] Plateau herbicide, BASF Corp., 26 Davis Drive, Research Triangle Park, NC 27709.

[5] Oust herbicide, E. I. duPont de Nemours and Co., 1007 Market Street, Wilmington, DE 19898.

[6] X-77® spreader (nonionic surfactant) (alkylphenol ethoxylate, alcohol ethoxylate, tall oil fatty acid, 2,2′ dihydroxydiethyl ether and dimethylpolysiloxane), Loveland Products, Inc., P.O. Box 1286, Greeley, CO 80632.

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Literature Cited

Anonymous. 1999. North Carolina Turfgrass Survey. 2001. North Carolina Department of Agriculture and Consumer Services.

Baker, R. D., L. B. McCarty, and D. L. Colvin. 1994. Bahiagrass (*Paspalum notatum* Flueggé) response to three years of sequential PGR applications. Proc. South. Weed Sci. Soc. 47:152.

Baker, R. D., L. B. McCarty, D. L. Colvin, J. M. Higgins, J. S. Weinbrecht, and J. E. Moreno. 1999. Bahiagrass (*Paspalum notatum*) seedhead suppression following consecutive yearly applications of plant growth retardants. Weed Technol. 13:378–384.

Beard, J. B. 2002. Turf management for golf courses, 2nd ed. Chelsea, MI: Ann Arbor Press.

Bohannan, D. R. and T. N. Jordan. 1995. Effects of ultra-low volume application on herbicide efficacy using oil diluents as carriers. Weed Technol. 9:682–688.

Burch, T. B. 2000. Apparatus and method for cutting and treating vegetation. U.S. Patent 6,125,621.

Christians, N. E. 1998. Fundamentals of turfgrass management. Chelsea, MI: Ann Arbor Press.

Fagerness, M. and D. Penner. 1998. Evaluation of V-10029 and trinexapac-ethyl for annual bluegrass seedhead suppression and growth regulation of five cool-season turfgrass species. Weed Technol. 12:436–440.

Goatley, J. M. Jr., V. L. Maddox, and R. M. Watkins. 1996. Growth regulation of bahiagrass (*Paspalum notatum* Flueggé) with imazaquin and AC 263,222. HortSci. 31:396–399.

Goatley, J. M. Jr., V. L. Maddox, and R. M. Watkins. 1998. Bahiagrass response to a plant growth regulator as affected by mowing interval. Crop Sci. 38:196–200.

Gover, A. E., J. M. Johnson, and L. J. Kuhns. 2004. Evaluation of imazapic as a growth regulator in roadside tall fescue. Proc. Northeast. Weed Sci. Soc. 58:34–35.

Gover, A. E., T. L. Watschke, C. W. Spackman, and R. W. Parks. 1995a. Response of tall fescue to mefluidide in combination with flurprimidol, paclobutrazol, or trinexapac-ethyl. Proc. Northeast. Weed Sci. Soc. 49:192–193.

Gover, A. E., T. L. Watschke, C. W. Spackman, and R. W. Parks. 1995b. Response of tall fescue to fall or spring application of plant growth regulator treatments. Proc. Northeast. Weed Sci. Soc. 49:190–191.

Henson, S. E., W. A. Skroch, J. D. Burton, and A. D. Worsham. 2003. Herbicide efficacy using a wet-blade application system. Weed Technol. 17:320–324.

Hixson, A. C., T. W. Gannon, and F. H. Yelverton. 2007. Efficacy of application placement equipment for tall fescue (*Lolium arundinaceum*) growth and seedhead suppression. Weed Technol. 21:801–806.

Johansson, T. 1998. Preventing stump regrowth with a herbicide-applying tree cutter. Weed Res. 28:353–358.

Johnson, B. J. 1990. Response of bahiagrass (*Paspalum notatum*) to plant growth regulators. Weed Technol. 4:895–899.

Lee, C. R. 2000. Implementation guidance for the control of undesirable vegetation on dredged material. DOER Technical Notes Collection–ERDC TN-DOER-C20, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

McCarty, L. B., D. L. Colvin, and R. D. Baker. 1993. Sequential year application of PGRs for bahiagrass seedhead suppression. Proc. South. Weed Sci. Soc. 46:232.

McCarty, L. B., L. C. Miller, and D. L. Colvin. 1990. Tall fescue root-growth rate following mefluidide and flurprimidol application. HortSci. 25:581–581.

McCullough, P. E., H. B. Liu, L. B. McCarty, and T. Whitwell. 2004. Response of 'TifEagle' bermudagrass to seven plant growth regulators. HortSci. 39:759–1762.

Moreno, J. E., L. B. McCarty, and D. L. Colvin. 1992. Bahiagrass seedhead control with plant growth regulators. Proc. South. Weed Sci. Soc. 45:288.

Mullahey, J. and M. Williams. 2001. Weed control using the Burch wet blade mower. 2001 Florida Beef Cattle Short Course. 71–79.

Murphy, T. R., L. B. McCarty, and F. H. Yelverton. 2005. Turfgrass plant growth regulators. Pages 705–714. *in* L. B. McCarty, ed. Best Golf Course Management Practices, 2nd ed. Upper Saddle River, NJ: Prentice-Hall.

Peacock, C. H. and M. S. Flanagan. 1986. Effects of plant growth regulators on bahiagrass. Proc. Plant Growth Regul. Soc. Am. 13:41–45.

Rademacher, W. 2000. Growth retardants: effects on gibberellin biosynthesis and other metabolic pathways. Annu. Rev. Plant Physiol. Plant Mol. Biol. 51:501–531.

Sellers, B. A. and J. J. Mullahey. 2008. Broadcast vs. wet-blade herbicide applications for Southern wax myrtle (*Myrica cerifera*) control. Weed Technol. 22:286–289.

Skroch, W. A., A. D. Worsham, S. E. Henson, and R. L. Wahlers. 1998. Efficacy and application with the Burch wet blade system. Proc. South. Weed Sci. Soc. 51:218.

Spak, D., J. DiPaola, W. Lewis, and C. Anderson. 1993. Tall fescue sward dynamics. 2. Influence of 4 plant growth regulators. Crop Sci. 33:304–310.

Turgeon, A. J. 1996. Turfgrass Management. 4th ed. Upper Saddle River, NJ: Prentice-Hall.

Wahlers, R., J. Burton, E. Maness, and W. Skroch. 1997a. Physiological characteristics of a stem cut and blade delivery method of application. Weed Sci. 45:746–749.

Wahlers, R., J. Burton, E. Maness, and W. Skroch. 1997b. A stem cut and blade delivery method of herbicide application for weed control. Weed Sci. 45:829–832.

Yelverton, F. H., L. B. McCarty, and T. R. Murphy. 1997. Effects of imazameth on the growth of *Paspalum notatum* Flueggé: Int. Turfgrass Soc. 8:1085–1094.

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