FINAL REPORT

Asset Management Aided Through Vegetation Management/Zoysiagrass Along NC Roadsides

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08-30-2016

Technical Report Documentation Page

1. Report No. **FHWA/NC/2013-17**	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Asset Management Aided Through Vegetation Management/Zoysiagrass Along NC Roadsides		5. Report Date 08-30-2016
		6. Performing Organization Code
7. Author(s) Dr. Travis Gannon, Dr. Fred Yelverton, and Mr. Matt Jeffries		8. Performing Organization Report No.
9. Performing Organization Name and Address North Carolina State University – Department of Crop and Soil Sciences 100 Derieux Street NCSU Campus Box 7620 Raleigh NC 27695 7620		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address NC Department of Transportation Roadside Environmental Unit 1557 Mail Service Center Raleigh, NC 27699-1557		13. Type of Report and Period Covered Final Report 06-01-2012 to 05-31-2016
		14. Sponsoring Agency Code
15. Supplementary Notes:		

16. Abstract

Research experiments were designed and initiated to evaluate plant growth regulators and recently registered herbicides for vegetation management along North Carolina roadsides, as well as warm-season turfgrass seed and sod practices to utilize low-growing, mat-forming species that require reduced inputs. All experiments were repeated in location and/or time, and have produced three peer-reviewed publications to date in *Crop Science* or *Weed Technology* journals. Results from this project suggest plant growth regulators may be used to reduce annual mowing events, which can result in cost-savings as well as reduced mowing operator requirements in areas that pose increased safety risks. Greenhouse research identified NC agronomic and specialty crops that Esplanade (active ingredient: indaziflam), a relatively new PRE herbicide, may be safely applied near without objectionable drift concerns, while field trials evaluated this herbicide and others for warm-season release programs. Additionally, greenhouse research confirmed Esplanade and Proclipse (active ingredient: prodiamine) applied PRE provide excellent annual ryegrass (*Lolium multiflorum* L.) control. Field research identified herbicide application timings with respect to season and mowing operations to improve current vaseygrass (*Paspalum urvillei* Steud.) control programs. Lastly, zoysiagrass (*Zoysia* spp.) sodding field trials identified cultivars, planting preparation techniques, and planting timings that resulted in successful establishment along guardrails, while warm-season turfgrass seeding resulted in unacceptable establishment. This information may be utilized by the North Carolina Department of Transportation – Roadside Environmental Unit to help improve comprehensive vegetation management practices that reduce long-term inputs while providing safe thoroughfares for motorists.

17. Key Words Bermudagrass, seed establishment, sod establishment, plant growth regulator, vaseygrass, warm-season release, weed management.	18. Distribution Statement

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 49	22. Price

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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ACKNOWLEDGEMENTS

Support for this research was provided by the North Carolina Department of Transportation. The authors would like to thank personnel within the North Carolina Department of Transportation - Roadside Environmental Unit for their cooperation during the grant period.

SUMMARY

Research experiments were designed and initiated to evaluate plant growth regulators and recently registered herbicides for vegetation management along North Carolina roadsides, as well as warm-season turfgrass seed and sod practices to utilize low-growing, mat-forming species that require reduced inputs. All experiments were repeated in location and/or time, and have produced three peer-reviewed publications to date in *Crop Science* or *Weed Technology* journals. Results from this project suggest plant growth regulators may be used to reduce annual mowing events, which can result in cost-savings as well as reduced mowing operator requirements in areas that pose increased safety risks. Greenhouse research identified NC agronomic and specialty crops that Esplanade (active ingredient: indaziflam), a relatively new PRE herbicide, may be safely applied near without objectionable drift concerns, while field trials evaluated this herbicide and others for warm-season release programs. Additionally, greenhouse research confirmed Esplanade and Proclipse (active ingredient: prodiamine) applied PRE provide excellent annual ryegrass (*Lolium multiflorum* L.) control. Field research identified herbicide application timings with respect to season and mowing operations to improve current vaseygrass (*Paspalum urvillei* Steud.) control programs. Lastly, zoysiagrass (*Zoysia* spp.) sodding field trials identified cultivars, planting preparation techniques, and planting timings that resulted in successful establishment along guardrails, while warm-season turfgrass seeding resulted in unacceptable establishment. This information may be utilized by the North Carolina Department of Transportation – Roadside Environmental Unit to help improve comprehensive vegetation management practices that reduce long-term inputs while providing safe thoroughfares for motorists.

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Summary Presentation. Asset Management Aided Through Vegetation Management/Zoysiagrass on NC Roadsides.

INTRODUCTION

Roadside vegetation management is an arduous endeavor that balances providing safe travel routes with preserving road system infrastructure in an environmentally responsible manner (NCHRP, 2005). Currently, North Carolina (NC) manages vegetation along more state-funded roadsides (≈ 80,000 miles) than any other state in the US (Anonymous, 2012). Additionally, due to the varying climatic and edaphic conditions in NC, roadside vegetation managers are presented with a wide range of pest and turfgrass management scenarios that pose substantial ecologic and economic challenges to provide safe travel routes for motorists. Specific to motorist safety, one concern is vision impairment caused by excessive vegetation growth on road medians and shoulders, which the efforts of this research largely focus on directly via chemical and cultural practices to manage established vegetation, as well as indirectly through establishing new vegetation that provides comparatively superior low-growth characteristics.

Tall fescue (*Lolium arundinaceum* [Schreb.] S.J. Darbyshire) is a perennial, cool-season turfgrass that is adapted to cool subtropical and warm temperate climates that can pose vision impairment issues from its upright growth habit and seedhead development (Christians, 2011). From a 1999 statewide turfgrass composition survey in NC, 54% of roadside turfgrass (350,000 A) was principally tall fescue or tall fescue/bluegrass (*Poa* spp.) mixture (NCDA, 2001). Although tall fescue is a desirable turfgrass species on roadsides in adapted climates due to its drought, heat, and wear tolerance, its upright growth habit coupled with seedhead production can impair motorist vision (Hixson et al., 2007). Aside from the economic inputs required to maintain tall fescue at an acceptable height for motorist vision, mowing along roadsides poses safety concerns for motorists and transportation personnel (Gannon and Yelverton, 2011). Many transportation departments use plant growth regulators on roadsides to reduce mowing requirements, evapotranspiration rates, and thatch production (Beard, 2002). Plateau® (active ingredient: imazapic) is an imidazolinone herbicide that can be used for plant growth regulation at sublethal rates (Anonymous, 2011a; Senseman, 2007). Previous research has shown Plateau can suppress vegetative growth and seedhead development of various turfgrass species including tall fescue and bermudagrass; however, efforts have not determined if it reduces mowing events required in a growing season (Brosnan et al., 2011; Hixson et al., 2007). This information is needed for roadside vegetation managers to efficiently allocate resources required to maintain vegetation such that it does not impair motorist sightlines.

Vaseygrass (*Paspalum urvillei* Steud.) is an invasive, perennial C_4-grass throughout the southeast United States and California (USDA NRCS, 2015). Vaseygrass commonly infests pastures, roadsides, and other grass systems, and spreads predominately via seed (Ansong et al., 2015; Bryson et al., 2009; USDA, 2015). Due to its high tolerance of poorly drained soils, vaseygrass is well suited to grow in roadside areas that are not routinely mowed such as ditches and low-lying guardrails (Newman et al., 2003; personal observation). Vaseygrass has an upright growth habit and reaches 4 ft in height, which can require increased vegetation management efforts to mitigate impairment of motorist's sightlines (Bryson et al. 2009). Published research to date has not addressed vaseygrass control on roadsides. Therefore, information relating to vaseygrass-herbicide efficacy, as well as how herbicides are affected by cultural practices is needed to improve control efforts on NC roadsides.

Esplanade 200 SC® (active ingredient: indaziflam) is a PRE cellulose biosynthesis-inhibiting herbicide for annual broadleaf and grass control in use sites including managed roadsides, noncroplands, and railroads/rail yards (Anonymous, 2011b). While previous reports have shown is an effective herbicide for weeds common along NC roadsides (Brosnan et al., 2011; Brosnan et al., 2012; Gannon et al., 2013; Marble et al., 2013), research has not evaluated crop injury potential from off-target Esplanade movement. Off-target plant injury from Esplanade may occur from spray drift via PRE applications to soil prior to crop planting/transplanting or POST applications on crop foliage. Pesticide spray drift is defined as the physical movement of pesticide particles through the air away from the target site to an unintended area (US EPA, 2009). Herbicide drift may adversely affect neighboring crops (Pimentel, 2005), wildlife (Beketov and Liess, 2008; Snoo and van der Poll, 1999), and human health (Barnes et al., 1987; Lee et al., 2011). Currently, Esplanade label states to avoid applications where drift into sensitive areas, including non-labeled agricultural crops may occur. Due to the wide range of climatic and edaphic conditions in NC and throughout the southeastern US, a majority of field crops grown in the region are classified as "non-labeled agricultural crops" for Esplanade (Anonymous, 2011b). These major cash crops such as cotton, soybean, and tobacco, as well as many specialty fruit and vegetables crops. Therefore, Esplanade use along roadsides is not recommended without information regarding crop injury potential from Esplanade spray drift. This will allow roadside vegetation managers to determine when and where Esplanade may be applied throughout the southeast US to minimize off-target plant injury. The objective of this research was to measure plant injury from simulated Esplanade spray drift rates on select major agronomic and specialty crops.

Guardrails are structures installed along roads that can reduce the amount of damage and severity of personal injuries when motorists leave the roadway (AASHTO, 2002; USFHC, 2014). Although appropriately installed guardrails enhance motorist safety, their inherent design requires additional vegetation management inputs to maintain acceptable driving conditions. To address this issue, various vegetation management practices are employed; however, they impose varying degrees of unsustainable ecological and economical requirements. Establishing perennial, low-growing (≤ 6 in) vegetation along guardrails can result in reduced management inputs to maintain safe motorist conditions (AASHTO, 2004; Barton and Budischak, 2013; DE DOT, 2009; Hill and Horner, 2005). The Delaware Department of Transportation (DOT) reported cool-season grass seed mixtures require ≤ three mowing events yr^{-1}; however, these species are not suitable for most NC roadsides due to varying climatic conditions (DE DOT, 2009). Bermudagrass and zoysiagrass are warm-season turfgrasses that are adapted to subtropical, temperate, and tropical climates (Turgeon, 2008). Characteristics pertinent to their establishment along guardrails includes a low, prostrate growth habit, as well as favorable cold, drought, and salt tolerances (Turgeon, 2008). Previous research has shown bermudagrass and zoysiagrass can be successfully established from seed or sod; however, this commonly requires routine irrigation for a period of time after planting, which is not feasible along roadsides. Therefore, research evaluating the potential use of these turfgrass species in select roadside settings is needed to determine if they are viable options to reduce long-term management inputs.

MATERIALS AND METHODS

Tall Fescue Roadside Mowing Reduction from Plateau. Field research was initiated 25 Mar. 2013 and 26 Mar. 2014 on a roadside in Chatham County, NC (35°46'55.50" N lat; 79°30'41.97" W long) to evaluate the effect of Plateau application on tall fescue mowing requirements. Soil type was a Cid-Lignum complex silt loam (fine, mixed, semiactive, thermic

Aquic Hapludults) with a 6.1 pH and 1.8% w/w organic matter content. Visual tall fescue cover estimations at initiation averaged 59% over both experimental runs.

One wk prior to herbicide application, the entire trial area was mown to a 5 in height of cut, with debris mulched and returned to canopy (Toro Z Master 255 Mower, The Toro Co., Bloomington, MN). Herbicides were applied 01 Apr. 2013 and 02 Apr. 2014 in four side-by-side passes to plots measuring 20 by 40 ft with a CO_2-propelled boom comprised of four 11002 AIXR VS flat-fan nozzles (TeeJet Flat-Fan Nozzles®, Spraying Systems Co., Wheaton, IL) calibrated to deliver 20 gal A^{-1} at 26 psi. Evaluated herbicide treatments included Plateau (3.5 fl oz A^{-1}; BASF Corp., Research Triangle Park, NC) alone and tank-mixed with Confront® (1.5 pt A^{-1}: active ingredients: clopyralid + triclopyr; Dow AgroSciences LLC, Indianapolis, IN). Confront is commonly tank-mixed with other herbicides on roadside applications for additional broadleaf weed control, and it was included to determine its affect on tall fescue growth in Plateau-treated areas. To conform to herbicide labels, all treatments included a nonionic surfactant (NIS; Induce®, Helena Chemical Co., Collierville, TN) applied at 0.25% v/v (Anonymous, 2008, 2011a).

Following herbicide application, plots were mown when foliage height reached a predetermined intervention height of 9 or 12 in. Mowing was performed identically to pre-herbicide application specifications. Although set arbitrarily at 9 or 12 in, 12 in is the maximum vegetation height allowance practiced by numerous state departments of transportation including MN and MO (MN DOT, 2008; MO DOT, 2003). The lower intervention height (9 in) was included to determine if mowing at a more agronomically sound timing with respect to plant stress from vegetation removal via mowing improved tall fescue quality (Christians, 2011).

Three replications of each herbicide treatment-mowing height intervention combination were evaluated in a randomized complete block design. Nontreated-mown (both intervention heights) and nontreated-nonmown controls were included for comparisons. The aforementioned treatments were evaluated in adjacent, unique research areas in each experimental run.

Plots were visited routinely through 70 days after treatment (DAT) following herbicide application to evaluate growth and mowing commenced when intervention height was reached. Five foliage height measurements (in) $plot^{-1}$ were averaged and when vegetation reached an intervention height, mowing commenced in respective plots. Three tall fescue seedhead counts (seedheads ft^{-2} $plot^{-1}$) were recorded at 0, 28, 56, and 84 DAT. Visual tall fescue cover was estimated on a 0 (no cover) to 100% (complete cover) scale, as well as tall fescue injury on a 0 (no injury) to 100% (complete plant death) scale were also recorded at the aforementioned seedhead collection dates.

Statistical analyses were conducted by analysis of variance ($P = 0.05$) using general linear model procedures in SAS (Statistical Analysis Software®, Version 9.2; SAS Institute, Inc., Cary, NC). Due to varying tall fescue mowing dates across experimental runs, foliage height data were analyzed separately in 2013 and 2014, while data characterizing tall fescue cover, injury, and seedhead counts were analyzed across experimental runs. Fixed effect was herbicide-mowing intervention height treatments, while experimental run and replicate were considered random as described by Carmer et al. (1989). Means were separated according to Fisher's protected LSD ($P < 0.05$).

Herbicide Inputs and Mowing Affects Vaseygrass (*Paspalum urvillei*) Control. The presented research includes two field experiments, with the latter building off of the former. Experiment one evaluated the effect of various herbicide treatments and application timings in plots routinely mowed or nonmowed throughout the trial period. Based on results from run one of experiment one, which suggested vaseygrass control was enhanced from fall applications and mowing, experiment two was initiated. Experiment two evaluated identical herbicide treatments to experiment one at a fall-only timing, and investigated the effect of mowing prior to herbicide application on vaseygrass control.

Experiment One. Field research was conducted from 2012 to 2014 on a roadside in Duplin County, NC (Lat. 34°55'07.66" N, Long. 78°01'13.03" W) to evaluate the effect of mowing and herbicide application timing on vaseygrass control. Soil texture was a loamy fine sand, and the managed turfgrass was centipedegrass [*Eremochloa ophiuroides* (Munro) Hack.]. Herbicides included Intensity® (1 pt A^{-1}; active ingredient: clethodim; Loveland Products, Inc., Greeley, CO), Plateau® (8 fl oz A^{-1}; BASF Corp., Research Triangle Park, NC), Outrider® (2 oz A^{-1}; active ingredient: sulfosulfuron; Monsanto Co., St. Louis, MO), Pastora® (1.5 oz A^{-1}; active ingredients: metsulfuron + nicosulfuron; DuPont, Wilmington, DE), and Tribute Total® (3.2 oz A^{-1}; active ingredients: foramsulfuron + halosulfuron + thiencarbazone; Bayer Environmental Science, Research Triangle Park, NC). Herbicides selected for this research are currently registered for use on roadsides for POST control of various dicot and monocot weeds; however, excluding Plateau and Pastora, current labels do not include vaseygrass. Based on previous nonpublished research, Intensity, Tribute Total, and Outrider were included in the experiments. Herbicide application timings included fall-only and fall-plus-spring in run one, as well as an additional spring-only timing in run two. Fall applications were made on 16 Oct. 2012 and 01 Oct. 2013 in runs one and two, respectively, while spring applications were made on 17 Jun. 2013 and 18 Jun. 2014 in runs one and two, respectively. Average vaseygrass cover at fall herbicide application was 43%.

Prior to herbicide application in the fall, the entire trial area was mowed (4 in height of cut, debris removed) 6 wk before treatment (WBT), at which time mowing ceased in nonmowed plots. Routinely mowed plots were cut (4 in) throughout the trial period (6 WBT to 52 wk after fall treatment [WAFT]) when average vegetation height in nontreated plots reached a 12 in maximum allowance. Although set arbitrarily at 12 in, this maximum vegetation height allowance practiced by numerous state departments of transportation including Minnesota and Missouri (MN DOT, 2008; MO DOT, 2003). Including the 6 WBT cut, this totaled three fall mowing events in both experimental runs, and four (run one) and five (run two) spring-to-fall events the following growing season.

Herbicides were applied to plots measuring 6 by 10 ft with a CO_2-pressurized boom comprised of four 11002 AIXR VS flat-fan nozzles (TeeJet Flat-Fan Nozzles®, Spraying Systems Co., Wheaton, IL) calibrated to deliver 20 gal A^{-1} at 26 psi. All treatments included a nonionic surfactant (Alkyl Aryl Polyoxylkane ethers, alkanolamides, dimethyl siloxane, and Free Fatty Acids [Induce®; Helena Chemical Co., Collierville, TN]) at 0.25% v/v.

Three replications of a factorial treatment arrangement evaluating mowing (routinely mowed or nonmowed), herbicide treatments (5 herbicides), and application timings (fall-only or fall-plus-spring in runs one and two; spring-only in run two) were evaluated in a strip plot-randomized complete block design. Whole plot factor was mowing, while subplots were combinations of herbicides and application timings. Mowed and nonmowed-nontreated controls were included for comparison.

Experiment Two. Field research was conducted from 2013 to 2015 on a roadside in Craven County, NC (Lat. 35°07'46.45" N, Long. 77°08'33.38" W) to evaluate the effect of pre-herbicide application mowing interval on vaseygrass control. Soil texture was a silt loam, and the managed turfgrass was bahiagrass (*Paspalum notatum* Flueggé). Similarities between experiments one and two include mowing equipment, height of cut, and debris removal, as well as evaluated herbicides and nonionic surfactant inclusion.

The entire trial area was mowed 8 WBT and allowed to regrow for 2 wk before the pre-herbicide application interval mowing commenced. Intervals evaluated included mowing 6, 4, 3, 2, 1, or 0 WBT. Herbicides were applied 1 h after mowing at 0 WBT. Average vaseygrass cover at herbicide application was 58, 52, 45, 35, 28, and 27% following mowing 6, 4, 3, 2, 1, and 0 WBT, respectively, while average height was 24, 18, 13, 10, 7, and 4 in. Following herbicide application, plots were not mowed for the remainder of the growing season, and only once the following season after 40 WAT data collection.

Herbicide applications were made on September 18, 2013 and September 19, 2014 in runs one and two, respectively. Herbicides were applied to plots measuring 14 by 8 ft with a CO_2-propelled boom comprised of three 8002 XR VS flat-fan nozzles (TeeJet Flat-Fan Nozzles®, Spraying Systems Co., Wheaton, IL) calibrated to deliver 20 gal A^{-1} at 26 psi. The aforementioned treatments were evaluated in unique research areas in each experimental run.

Three replications of a factorial treatment arrangement evaluating mowing interval (6, 4, 3, 2, 1, or 0 WBT) and herbicide treatment (five herbicides) were evaluated in a strip plot-randomized complete block design. Whole plot factor was mowing interval, with herbicide treatment subplots. Nontreated controls were included for comparisons.

In experiment one, vaseygrass cover was visually estimated on a 0 (no cover) to 100% (complete cover) scale at 2, 4, 8, 40, 46, and 52 WAFT. Data collection in experiment two also included visual cover estimations; however, collection times varied due to earlier fall and no spring herbicide application timings. Additionally, the averages of three vaseygrass foliage height (in) and seedhead counts (seedheads ft^{-2}) were recorded. Data collection occurred at 4 and 8 wk after treatment (WAT) until dormancy onset, and the following summer at 40, 46, and 52 WAT.

Statistical analysis was conducted by ANOVA ($P = 0.05$) using MIXED procedures in SAS. Fixed effects were herbicide treatments (both experiments), mowing (experiment one), pre-herbicide application mowing interval (experiment two), and season of herbicide application (experiment one), while experimental run and replicate were considered random as described by Carmer et al. (1989). Main effects and their interactions are presented accordingly, with precedent given to significant interactions of increasing magnitude (Steel et al. 1997) and means were separated according to Fisher's protected LSD ($P < 0.05$).

Warm-Season Turfgrass Release Regimen Evaluations. Field research was conducted from 2013 to 2015 on roadsides in Craven County, NC (Lat. 35°07'46.45" N, Long. 77°08'33.38" W) and Wake County, NC (Lat. 35°37'29.01" N, Long. 78°30'35.06" W) to evaluate various warm-season release regimens for annual ryegrass (*Lolium multiflorum* L.) and vaseygrass control, respectively. Herbicides included various combinations of fall-only, spring-only, and fall-plus-spring applications of Intensity (1 pt A^{-1}; Loveland Products, Inc., Greeley, CO), Plateau (8 fl oz A^{-1}; BASF Corp., Research Triangle Park, NC), Proclipse 65 WG® (1.5 lb A^{-1}; active ingredient: prodiamine; Nufarm Americas Inc., Burr Ridge, IL), and Esplanade (3.5 of 5 fl oz A^{-1}; Bayer Environmental Science, Research Triangle Park, NC) (Tables 10 and 11). All applications included Confront (1 pt A^{-1}: Dow AgroSciences, Indianapolis, IN), Oust XP® (1 oz A^{-1}; active ingredient: sulfometuron; DuPont, Wilmington, DE), and NIS at 0.25% v/v (Induce®, Helena Chemical Co., Collierville, TN).

Fall and spring applications for annual ryegrass control were 24 Sep. 2013 and 27 May 2014. Vaseygrass fall applications were 10 Oct. 2013 and 19 Sep. 2014 in experimental runs 1 and 2, respectively, while spring applications were 08 Jun. 2014 and 17 Jun. 2015. Applications were made to 6 by 10 ft plots with a CO_2-pressurized sprayer calibrated to deliver 20 gal A^{-1} with four 8002 XR VS flat fan nozzles (TeeJet® flat-fan nozzles, Spraying Systems Company, Wheaton, IL) at 26 psi.

Plant cover was visually estimated on a 0-100% scale (0 = no cover, 100 = complete cover) 2, 4, 6, 8, 12, 16, 24, 32, and 40 WAT from the fall application for annual ryegrass, while vaseygrass was rated 2, 4, 32, 36, 40, and 48 WAT from the fall. Three replications of each treatment were evaluated in a randomized complete block design, which included nontreated checks. Data were subjected to ANOVA ($P = 0.05$) and means were separated according to Fisher's Protected LSD ($P < 0.05$) with the use of SAS general linear models.

Simulated Esplanade Drift Affects NC Agricultural Plant Growth. Greenhouse research (Method Road Greenhouse; Raleigh, NC) was conducted to evaluate the effect of Esplanade (Esplanade 200 SC®, Bayer Environmental Science, Research Triangle Park, NC) applied at simulated spray drift rates on various agricultural plant species. Simulated drift rates were evaluated at PRE and POST application timings. Esplanade was applied at 100, 20, 10, 5, or 2.5% of a 5 fl oz A^{-1} application rate (maximum application rate for warm-season release). Other herbicide treatments were included for comparison and applied at 10% of a typical NC roadside vegetation management rate (KC Clemmer, personal communication). These included Oust XP (10% drift of 0.75 oz A^{-1}, DuPont, Wilmington, DE), Streamline® (10% drift of 4 oz A^{-1}; active ingredients: aminocyclopyrachlor + metsulfuron; DuPont, Wilmington, DE), Confront (10% drift of 1 qt A^{-1}, Dow AgroSciences, Indianapolis, IN), and Milestone® (10% drift of 7 fl oz A^{-1}; active ingredient: aminopyralid; Dow AgroSciences, Indianapolis, IN). This simulated drift rate was selected based off previous reports stating comparable percentages of a ground-applied herbicide may be lost via drift (Hall, 1991; Maybank et al., 1978; Snoo and Witt, 1998).

Evaluated plant species included cotton, (*Gossypium hirsutum* L. 'DP 1252 B2RF'); bell pepper, (*Capsicum annuum* L. 'California Wonder'); soybean, [*Glycine max* (L.) Merr. 'SS 5911N R2']; squash, (*Cucurbita pepo* L. 'Early Prolific Straightneck'); tobacco, (*Nicotiana tabacum* L. 'K-326'); tomato, (*Solanum lycopersicum* L. 'Homestead 24'). Selected plants met one of the following criteria: 1) NC accounted for greater than 4% of total 2011 US receipts (cotton, bell pepper, squash, tobacco, and tomato); or 2) greater than 950,000 NC acres harvested in 2011 (soybean) (USDA ERS, 2013; USDA NASS, 2012). Furthermore, selected species are widely grown throughout the southeast US where Esplanade is used. This region accounts for 40, 45, 15, 44, 90, and 21% of the total cotton lint, bell pepper, soybean, squash, tobacco, and tomato receipts, respectively, within the US (USDA ERS, 2013). All plants were grown from seed (bell pepper, squash, and tomato: Wyatt Quarles Seed Company, Garner, NC; cotton, soybean, and tobacco: Southern States Cooperative, Inc., Richmond, VA) in plastic pots filled with a sand medium (pH 6.2) amended to increase soil organic matter to 3% w w^{-1} (Fafard® 4 Mix, Sun Gro Horticulture, Agawam, MA). Plastic pot soil surface area measured 28 in^2 (102 in^3) for bell pepper, soybean, squash, and tomato, with a larger container (79 in^2; 550 in^3) used for cotton and tobacco. Plants were irrigated daily by hand and grown under 95/70 °F day/night temperatures with supplemental lighting (350 $\mu mol\ m^{-2}\ s^{-1}$) to provide a 14 h day. Excluding a 2 wk period prior to and after herbicide treatment, plants were fertilized every 2 wk following emergence at 0.25 lb N 1,000 ft^{-2} (Peters Professional 20-20-20 Water Soluble Fertilizer, Scotts-Sierra Horticultural Products Company, Marysville, OH). Finally, pots were re-randomized weekly to minimize the effect of variation in greenhouse growth conditions.

To mimic common agricultural practices, plants for PRE treatment were seeded (cotton, bell pepper, soybean, and squash) or transplanted (tobacco and tomato) 48 h prior to treatment. To ensure uniform plant populations within pots, three seeds were sewn into each pot and the first seed to germinate was allowed to remain, while the others were selectively removed. All POST and PRE seeded plants were treated with a CO_2-pressurized sprayer calibrated to deliver 20 gal A^{-1} with one 8004 E flat fan nozzle (TeeJet® flat-fan nozzles, Spraying Systems Company, Wheaton, IL) at 26 psi. PRE transplanted plants were treated by diluting the appropriate amount of active ingredient that would contact the soil surface for a given herbicide application rate in 10 mL of tap water. Herbicide solutions were then uniformly syringed over the soil surface avoiding contact with foliage. These measures were taken due to the disruptive nature of transplanting on the soil surface, as treatment prior to transplanting may cause downward herbicide movement in the soil or non-uniform herbicide distribution throughout the profile. Pots were not irrigated 24 h prior to and following herbicide treatment.

Plant injury was visually estimated on a 0-100% scale (0 = no effect on plant, 100 = complete plant death) 18, 35, and 70 DAT. At 70 DAT, plant height was measured and above- and below-ground biomasses were harvested. Plant material was dried for 7 d at 160 °F. Plant harvest data were converted to percent reduction relative to the nontreated within a replicate using the following equation:

$$\%\ reduction = \{[(NT - T) / (NT)] \times 100\}$$

where *NT* and *T* equaled harvest data from a nontreated and treated pot, respectively.

Four replications of a 2-by-6-by-9 factorial treatment arrangement was evaluated in a randomized complete block design in each of two experimental runs. Factorial levels included 2 application timings (PRE or POST), 6 plant species (cotton, bell pepper, soybean, squash, tobacco, or tomato), and 9 herbicide treatments (Esplanade at five application rates or four herbicide standards). Data were subjected to ANOVA ($P = 0.05$). Plant species, herbicide, application timing, and experimental run were considered fixed effects. Main effects and their interactions are presented accordingly, with precedent given to interactions of increasing magnitude (Steel et al., 1997). Means were separated according to Fisher's Protected LSD ($P < 0.05$) with the use of SAS general linear models.

Zoysiagrass Sod Establishment Along Guardrails: Evaluations of Cultivars, Soil Preparation Techniques, and Planting Timings. Field research was initiated 17 Dec. 2012 and 03 Dec. 2013 along guardrails in Chatham County, NC, (35°43'41.99" N lat; 79°25'54.84" W long), Lee County, NC (35°28'10.22" N lat; 79°07'06.76" W long), and Yadkin County, NC (36°07'29.76" N lat; 80°49'30.83" W long) to evaluate the effect of cultivar, establishment timing, and soil preparation technique on zoysiagrass sod establishment and spread along guardrails. Sites were selected to represent the range of conditions where zoysiagrass could potentially be established in NC. More specifically, Yadkin County was included to compare winter survivability with the comparably warmer sites in Chatham and Lee Counties (Table 14). Lee County is a comparably younger road to Chatham and Yadkin Counties, with wider ranging edaphic conditions (Table 15). At all locations, research was conducted along guardrails with established vegetation underneath. Plots measuring 21 in width (width of sod strip) by 15 ft length were established along guardrails.

Zoysiagrass cultivars evaluated included two *Z. japonica* species, 'El Toro' or 'Meyer', and one *Z. matrella* species, 'Zeon'. Establishment timings included December (17 to 19 Dec. 2012 and 3 to 4 Dec. 2013), March (11 to 15 Mar. 2013 and 24 to 25 Mar. 2014), April (15 to 19 Apr. 2013 and 15 to 17 Apr. 2014), or May (13 to 17 May 2013 and 12 to 14 May 2014). Soil preparation techniques included stripping native vegetation with a sod cutter (21 in width by 2 in depth; Ryan™ Jr. Sod Cutter 12, Schiller Grounds Care, Johnson Creek, WI), tillage-alone (two passes at 24 in width by 3 in depth; RTN 60 Rotary Tiller, Bush Hog®, Selma, AL), or tillage + bed preparation prior to planting. Bed preparation simulated the result of using a mechanized angle broom (BA22 Angle Broom, Caterpillar©, Peoria, IL) to create a furrow (2 in depth), and was conducted via removal of soil and debris with bow rakes. To ensure sod viability, three samples (14 in^2) were taken at random from each cultivar at all establishment timings. Following collection, they were placed in a greenhouse (Method Road Greenhouses, Raleigh, NC) and grown for 56 d in a 95/73 °F cycle with supplemental lighting (350 μmol m^{-2} s^{-1}) to provide a 14 h d length, and irrigated twice d^{-1} with overhead irrigation. All sod in the presented research was confirmed viable.

Sod was planted, rolled to ensure soil contact, and irrigated once (0.5 in H_2O) within 24 h. Sod planted at Dec., Mar., and Apr. timings was fertilized once (44, 59, and 29 lb N, P, and K A^{-1}) following the Apr. installation, while fertility was delayed one mo for May establishment. Plots were not mown following installation, as they did not exceed an 18 in mowing intervention height. Herbicides and plant growth regulators were not applied to plots 1 mo prior to, and 23 mo following establishment.

Three replications of each cultivar-establishment timing-soil preparation technique combination were evaluated in a split plot-randomized complete block design. Whole plot was establishment timing, with cultivar-soil preparation technique subplots. The aforementioned establishment treatments were evaluated in unique research areas in each experimental run. Nontreated checks with no soil preparation technique were included for comparisons.

Visual zoysiagrass cover was estimated on a 0 (no cover) to 100% (complete cover) scale 24, 40, 90, and 125 wk after initial establishment (WAIE). Zoysiagrass intersection counts were also taken at these dates using a 3 by 8 ft grid (4 by 4 in spacing) placed in the center of each plot. The grid was partitioned into an inner grid (21 in by 3 ft) to quantify the original sod strip cover, and outer regions on both sides of the strip to quantify sod spread. Sod spread was calculated within a plot using the following equation:

$$\%\ spread = [(Z\text{intersections} / T\text{intersections}) \times 100]$$

where *Z*intersections and *T*intersections equaled the number of intersections with zoysiagrass present outside of the original sod strip and the total number of intersections (92) outside of the original sod strip, respectively.

Statistical analysis was conducted by analysis of variance ($P = 0.05$) using MIXED procedures in SAS. Fixed effects were cultivar, establishment timing, location, and soil preparation technique, while year and replicate were considered random as described by Carmer et al. (1989). Main effects and their interactions are presented accordingly, with precedent given to significant interactions of increasing magnitude (Steel et al., 1997). Means were separated according to Fisher's protected LSD ($P < 0.05$). Pearson correlation coefficients ($P = 0.05$) were calculated to quantify the relationship between visual zoysiagrass cover estimates and cover determined via zoysiagrass intersection counts.

Warm-Season Turfgrass Seeding on Roadsides: Evaluations of Species, Seeding Rates, and Seeding Timings. Field research was initiated 20 Mar. 2013 and 27 Mar. 2014 along guardrails in Lee County, NC (35°28'10.22" N lat; 79°07'06.76" W long) and Orange County, NC (36°04'17.70" N lat; 79°09'50.73" W long) to evaluate the effect of species, seeding rates, and seeding timings on roadside establishment success. Plots of varying dimensions (due to space confinements) were established to seed 500 ft^2 $plot^{-1}$.

Turfgrass species evaluated included 'Zenith' zoysiagrass and 'Riviera' hybrid bermudagrass [*Cynodon dactylon* (L.) Pers. × *Cynodon transvaalensis* Burtt-Davey], which were both seeded at 22 or 33 lb pure live seed A^{-1}. Prior to seeding, plots were mown to 3 inch height to improve seed planting, which was done with a tractor-mounted Tye® drill (10 shoots on 8 in spacing) to a 0.5 inch depth. Seeding timings in 2013 were 20 Mar., 24 Apr., and 17 May, and 27 Mar., 29 Apr., and 22 May in 2014. To ensure seed viability, subsamples were collected at all timings and grown under identical conditions to the aforementioned zoysiagrass sod. All seed in the presented research was confirmed viable. Due to no uniform emergence from 2013 seeding, which was suspected to be in part due to plant competition, Roundup was applied (1.4 lb glyphosate A^{-1}; 20 gal A^{-1}) 1 to 3 d prior to seeding in 2014. Plots were mown per routine DOT patterns following installation, while herbicides and plant growth regulators were not applied to plots for at least 12 months following seeding.

Visual turfgrass cover was estimated on a 0 (no cover) to 100% (complete cover) scale 4, 8, 12, 16, 20, 24, 52, 60, 68, and 76 wk after initial seeding. Three replications of each seeding timing-species-seeding rate were evaluated in a split plot-randomized complete block design. Whole plot was seeding timing, with species-seeding rate technique subplots. The aforementioned establishment treatments were evaluated in unique research areas in each experimental run. Nontreated checks with no soil preparation technique were included for comparisons.

FINDINGS AND CONCLUSIONS

Tall Fescue Roadside Mowing Reduction from Plateau.

__Tall Fescue Stand Characteristics.__ All Plateau treatment combinations resulted in 0 to 20% injury, which persisted until foliage was mown once (data not shown). Regrowth showed no visual injury symptoms. The addition of Confront did not affect tall fescue injury. Although Plateau did not objectionably injure tall fescue in the presented research, increased application rates have been shown to control tall fescue (Anonymous, 2011a; Ruffner and Barnes, 2010).

Chemical inputs and mowing intervention height did not affect tall fescue cover compared to controls from 0 to 56 DAT, with cover ranging from 50 to 72% (Table 1). Compared to the nontreated-nonmown check at 84 DAT (48% cover), Plateau alone mown at 9 in (65%) and Plateau + Confront at both mowing intervention heights (66 and 76%) increased tall fescue cover; however, cover only varied between Plateau + Confront (12 in intervention height; 76%) and the respective nontreated–mown check (54%). Within Plateau treatments, adding Confront improved tall fescue cover when mown at a 12 in intervention height (from 57 to 76%), which may be due in part to enhanced weed control.

All Plateau-containing treatments provided 100% tall fescue seedhead suppression through 56 DAT; however, nonmown-Plateau treatment was not included to differentiate the effect of Plateau from mowing on seedhead suppression (Table 1). In general, mowing nontreated controls reduced seedhead counts compared to the nontreated-nonmown control from 28 to 84 DAT. Plateau-containing treatment reduced seedhead counts at 84 DAT (1 to 2 ft^{-2}) compared to nontreated check (4 to 13 ft^{-2}). Additionally, mowing at 9 or 12 in intervention height as a cultural practice reduced seedheads (4 to 5 ft^{-2}) compared to the nontreated–nonmown check (13 ft^{-2}). Lastly, adding Confront to Plateau treatment did not affect tall fescue seedhead production throughout the trial period.

Tall Fescue Mowing Requirements. In 2013, all Plateau-containing treatments reduced tall fescue foliage height compared to the nontreated-nonmown check from 16 to 39 DAT (Table 2). During this time, 9 and 12 in nontreated-mown checks required two and one mowing cycles, respectively. The first mowing event on Plateau-containing treated plots occurred at 49 DAT at the 9 in mowing height. Comparing tall fescue foliage height to the nontreated-nonmown check (16.5 in), Plateau-containing treatments suppressed foliage growth 9.1 to 10.2 in through 49 DAT. Increasing intervention height to 12 in delayed the first mowing event to 70 DAT following Plateau-containing treatments. Across intervention heights, Plateau-containing treatments affected tall fescue foliage growth similarly, with mowing requirement occurring on identical dates. Overall, Plateau-containing treatments reduced mowing requirements by two events through 70 DAT, with four and two events required at 9 in intervention height in nontreated and treated plots, respectively, and three and one events required at 12 in height, respectively.

In general, tall fescue mowing requirements in 2014 were similar to 2013. All Plateau-containing treatments reduced tall fescue foliage height compared to the nontreated-nonmown check from 13 to 38 DAT (Table 3). During this time, 9 and 12 in nontreated-mown checks required three and one mowing cycles, respectively. The first mowing event on Plateau-containing treated plots occurred earlier than 2013, at 38 DAT (9 in mowing height). Increasing intervention height to 12 in delayed the first mowing event to 59 d (Plateau alone) and 70 d (Confront tank-mix) following Plateau treatment. Overall, Plateau reduced mowing requirements by two to three events through 70 DAT, with five and two events required at 9 in intervention height in nontreated and treated plots, respectively, and three and one events required at 12 in height, respectively.

Research Implications. Data from this research suggest Plateau can effectively suppress tall fescue vegetative growth and seedhead development on roadside rights-of-way. Across intervention heights, Plateau application eliminated at least two mowing events per season. Data also suggest intervention height did not affect tall fescue cover, and mowing at 12 in resulted in one less mowing event $season^{-1}$. Therefore, practitioners should consider mowing at the 12 in intervention height to conserve resources. Additionally, Plateau persistence and plant uptake is affected by climatic conditions, which were relatively uniform across experimental runs, with air and soil temperatures variance $\leq$ 5% (May 2013) and 16% (Apr. 2014) from the 10 yr average, respectively (Table 4). Plateau dissipation occurs primarily through soil microbial activity, which is reduced by numerous factors including soil temperature and moisture (Mangels, 1991). Precipitation in the month of application (Apr.) was 29 to 40% greater than the 10 yr average, which may have created more favorable conditions for tall fescue growth regulation through enhanced root uptake (Anonymous, 2011a). Precipitation varied widely from the 10 yr average in Jun. (168% increase and 51% decrease in 2013 and 2014, respectively); however, mowing requirements remained consistent across experimental runs, with seven mowing events performed across all treatments in both yr. Overall, results suggest Plateau should be utilized in areas that are difficult or unsafe to mow/trim tall fescue. Additionally, Plateau application could be used as a cost-saving practice on tall fescue roadside rights-of-way.

Herbicide Inputs and Mowing Affects Vaseygrass (*Paspalum urvillei*) Control.
Experiment One. Across application timings at 40 WAFT, herbicide activity varied most notably with Intensity and Plateau in routinely mowed plots. Fall-only Intensity applied to routinely mowed vaseygrass (10% cover) decreased vaseygrass 19% compared to spring-only application (29%; Table 5). The opposite trend for Plateau was observed, with cover decreasing 22% comparing spring-only (9% cover) to fall-only (31%) application. Benefits of fall-plus-spring applications varied across herbicides. Routinely mowed, spring-applied Intensity did not improve vaseygrass control, as no differences were detected between fall-only (10% cover) and fall-plus-spring (8%) timings and both decreased cover more than spring-only (29%) application. Fall-plus-spring Plateau application to nonmowed vaseygrass (16% cover) decreased cover compared to spring-only (31%); however, cover did not differ between routinely mowed plots (9 and 7% cover, respectively). Nonmowed, fall-plus-spring Pastora application only reduced vaseygrass cover (26%) compared to fall-only application (48%). Excluding herbicide inputs, routine mowing reduced vaseygrass cover 17 to 20% across nontreated checks at 40 WAFT.

With single applications at 52 WAFT, Intensity provided maximum vaseygrass cover reduction compared to other herbicides when applied fall-only in routinely mowed (7% cover) and nonmowed (16% cover) plots (Table 6). Spring-only Plateau and Pastora application decreased cover relative to the nontreated, most notably when applied in conjunction with routine mowing (11 to 14% cover). Additionally, fall-plus-spring Plateau and Pastora decreased vaseygrass cover to ≤ 7%. Fall-plus-spring and spring-only Pastora application provided equal to, or greater vaseygrass cover reductions than Intensity and Plateau at 52 WAFT (across mowing regimens). Excluding fall-only applied Intensity and fall-plus-spring applied Pastora, all herbicide application timing combinations decreased vaseygrass cover more in routinely mowed compared to nonmowed plots. Additionally, mowing was required to reduce vaseygrass cover to < 10% in treated plots. Lastly, routine mowing reduced vaseygrass cover 32 to 35% in nontreated plots, suggesting it may have utility as a stand-alone cultural practice.

Experiment Two. Across 6, 3, and 2 wk pre-herbicide application mowing intervals at 4 WAT, Intensity and Plateau reduced vaseygrass seedhead production and height, while Pastora did not differ from the nontreated (Table 7). In general, differences from the nontreated in seedhead counts decreased as mowing interval decreased. Within Intensity and Plateau treatments, mowing intervals did not affect seedhead production, with counts ranging from 0.1 to 0.7 ft^{-2}.

At 40 WAT, Intensity, Plateau, and Pastora reduced vaseygrass cover and height from the nontreated (Table 8). Within these herbicides, Intensity and Plateau reduced cover (24 to 25% less than the nontreated) and height (5.9 to 6.3 in less than the nontreated) more than Pastora (cover reduction = 7%; height reduction = 2 in), which are notable reductions that may reduce roadside mowing requirements within a season. Vaseygrass seedhead production had not uniformly resumed at 40 WAT. Following data collection at 40 WAT, research areas were mowed and allowed to regrow for a 12 wk period.

At 52 WAT, Pastora did not affect vaseygrass cover or seedhead counts (46% cover; 3.5 seedheads ft^{-2}) compared to the nontreated (50%; 4.3 ft^{-2}; Table 8). Plateau and most notably, Intensity reduced vaseygrass cover and seedhead counts from the nontreated, with 23 and 12% cover, 1.0 and 0.7 seedheads ft^{-2}, respectively. Surviving vaseygrass in Intensity and Plateau plots did not show any herbicide symptoms at 52 WAT, and seedhead reductions align with cover reductions. Furthermore, no differences in vaseygrass height were detected across herbicide treatments at this time, which suggests vaseygrass control practices evaluated in this research would be required over multiple growing seasons for eradication.

At 40 WAT, vaseygrass mown 1 to 2 wk before Intensity treatment (WBIT; 1 to 2% cover) generally outperformed mowing 0 (6%) and 3 to 6 (3 to 11%) WBIT (Table 9). The same trend was observed at 52 WAT, with mowing vaseygrass 1 to 2 WBIT (4 to 6% cover) outranking 0 (13%), 3 (14%), 4 (13%), and 6 (23%) WBIT. Although there is only a 10% difference in vaseygrass cover at 52 WAT when vaseygrass mowing occurred 2 or 3 WBCT, 2 WBIT reduced cover 21% more than 3 WBIT (relative to the respective nontreated). These results agree with current Intensity label recommendations, which suggests allowing for perennial grass vegetation regrowth to 12 in (excluding johnsongrass) following mowing to promote foliar-Intensity uptake (Anonymous, 2011c).

Research Implications. These results indicate vaseygrass eradication from North Carolina roadsides may require management inputs over multiple growing seasons. Overall, routine mowing had a pronounced effect on reducing vaseygrass cover as a stand-alone cultural practice, and in most cases improved herbicide efficacy. While mowing decreased vaseygrass cover up to 35% at 52 WAT, this practice is inherently difficult in many areas vaseygrass infestations are most problematic due to issues associated with equipment operation in poorly drained soils. Under these circumstances, herbicide inputs can serve as a viable vaseygrass management input; however, efficacy varies based on herbicide and application timing. Optimal herbicide efficacy was obtained when Intensity was applied in the fall, while Plateau and Pastora were more efficacious in the spring. Additionally, Pastora applied in fall and spring to nonmowed vaseygrass reduced cover 47% 52 WAT, while Intensity and Plateau required mowing for comparable cover reductions. Aside from alternating herbicides based on application timing to optimize vaseygrass control, this practice will also serve as an herbicide resistance prevention measure due to the varying modes of action between Intensity (inhibition of acetyl coenzyme A carboxylase) and Plateau/Pastora (inhibition of acetolactate synthase) (Shaner et al., 2014). It should also be noted the evaluated herbicides that provided acceptable control also pose tolerance concerns to bahiagrass and centipedegrass, turfgrasses commonly managed in areas where vaseygrass encroaches. Ultimately, roadside vegetation managers should be cognizant of potential injury to desirable turfgrass species following herbicide application for vaseygrass control, which may reduce the competitive ability of desired species and create more conducive conditions for vaseygrass and other weed species to encroach.

Warm-Season Turfgrass Release Regimen Evaluations.
Annual Ryegrass Control. At 16 wk after fall treatment (WAFT), all treatments including fall-applied Esplanade or Proclipse resulted in 0% annual ryegrass cover (Table 10). Intensity or Plateau alone did not reduce cover (20 to 27%) from the nontreated (27%), and applying Esplanade or Proclipse only in the spring had no affect on annual ryegrass control. Visual cover data varied minimally between 16 WAFT, which was collected before spring treatment, and 40

WAFT, collected 5 wk after spring treatment. At 40 WAFT, applying Plateau in the fall and spring reduced annual ryegrass cover (17%) from the nontreated (33%); however, this does not warrant in situ application. Again, all fall-applied treatments including a PRE herbicide resulted in 0% cover at 40 WAFT, suggesting roadside vegetation managers should implement there use in annual ryegrass-infested areas. Additionally, these results suggest Esplanade application at the maximum single application rate is not required for excellent PRE annual ryegrass control. Further research should evaluate lower application rates of Esplanade and Proclipse to determine if acceptable annual ryegrass control can be obtained with reduced herbicide inputs.

Vaseygrass Control. Across two experimental runs, Intensity applied alone in the fall resulted in reduced vaseygrass cover (18 to 25%) compared to the nontreated (36 to 52%), while spring-applied Intensity (40%) did not vary from the nontreated at 48 WAFT (Table 11). Additionally, fall-plus-spring Intensity did not enhance control. As with other vaseygrass control field trials in this project, Plateau applied alone in the spring (25% cover) outperformed fall application (45 to 57%); however, this POST herbicide generally provided unacceptable control. When Intensity and Plateau were made in their respective optimal seasons, the addition of Esplanade or Proclipse reduced vaseygrass cover in select scenarios. This aligns with greenhouse research efforts during this project period evaluating PRE vaseygrass control from Esplanade and Proclipse. In short, seed collected from Sampson and Wake Counties were planted in unique plots treated with Esplanade (4, 5.5 or 7 fl oz A^{-1}) or Proclipse (1.9 lb A^{-1}). At 120 DAT, all Esplanade treatments resulted in 100% control, while Proclipse resulted in 88 to 90% control across Sampson and Wake seed (data not shown). Identifying PRE herbicides for vaseygrass control is notable, as this weed spreads predominantly via wind-dispersed seed. Overall, meaningful differences in vaseygrass cover between PRE herbicides did not occur, suggesting roadside vegetation managers can utilize either. Lastly, Intensity applied only in the fall in tandem with a PRE herbicide resulted in comparable to, or superior vaseygrass control than all fall-plus-spring treatments, which suggests management inputs can be reduced by making one compared to two applications if timed appropriately.

Research Implications. This highlights the importance of application timing for annual ryegrass control. PRE herbicide application prior to annual ryegrass germination in the fall resulted in 100% control. Furthermore, data suggest control is possible with reduced herbicide inputs, as fall-plus-spring control did not vary from fall-only. Vaseygrass results generally align with other field trials in this project, in that Intensity application in the fall resulted in superior control than the spring, and generally outperformed Plateau. The addition of a PRE herbicide to Intensity enhanced vaseygrass control in select scenarios, which is notable considering how rapidly this weed can spread via wind-dispersed seed. However, no evaluated treatment resulted in 100% vaseygrass control, suggesting management inputs will be required over multiple growing seasons to eradicate this weed from NC roadsides. Additionally, the evaluated POST herbicides pose tolerance concerns to bahiagrass and centipedegrass, which are commonly managed turfgrasses in vaseygrass-infested areas. Therefore, roadside vegetation managers should be cognizant of this prior to their use, and anticipate the need for practices promoting turfgrass' competitive ability to prevent vaseygrass encroachment

Simulated Esplanade Drift Affects NC Agricultural Plant Growth.

Plant Injury. In general, PRE Esplanade applications (≤ 20% drift) were safe on cotton, squash, and tomato, as injury was less than 14% (Table 12). Furthermore, PRE Esplanade (10% drift) on the aforementioned species caused less injury than Milestone (excluding squash), Streamline, and Confront, as plant injury was 76 to 96, 41 to 62, and 27 to 89% greater from each herbicide, respectively. Compared to PRE, POST Esplanade (20% drift) was more injurious on squash and tomato, as 62 and 66% more injury was observed from POST treatment, respectively. These data suggest that Esplanade applications should be made early in the growing season prior to squash and tomato establishment to minimize the potential for adverse effects. Overall, tobacco injury was less than 10% from both Esplanade application timings at ≤ 20% drift rates. Furthermore, PRE and POST Esplanade applied at 10% drift rate (8 and 9% injury, respectively) was less injurious to tobacco than Milestone (70 and 81%), Streamline (49 and 53%), and Confront (38 and 33%).

Esplanade applications should be made with caution in close proximity to existing bell pepper or soybeans fields, as well as areas where they are to be planted. Injury greater than 20% from the lowest Esplanade rate (2.5% drift) was only observed on bell pepper (POST) and soybean (PRE and POST), with both application timings at all other rates causing 20 to 100% injury. This simulated drift rate equates to 2.5% of a warm-season release maximum single application rate, which previous research has shown is possible when conditions are conducive for drift. Maybank et al. (1978) reported 1 to 8% of the applied spray volume may be lost to drift from ground sprayers.

Plant Above-Ground Biomass Reduction. Bell pepper and soybean were affected most by Esplanade treatments, as PRE and POST applied at 2.5% drift rate caused 43 and 25% above-ground biomass reduction, respectively, for bell pepper, while soybean was reduced 52 and 27%, respectively (Table 13). Cotton and tobacco above-ground biomass was reduced < 21% from ≤ 10% drift rates. This is important information due to the amount of each crop grown in NC on a national scale, as NC ranks fifth and first nationally in upland cotton and tobacco production, respectively (USDA NASS, 2012). Finally, excluding PRE applied bell pepper and soybean, Esplanade applied at 10% drift rate was safer across all plant species and application timings than one or more currently used herbicides. Across species, of the 12 potential differences between 10% Esplanade drift PRE and POST with each of the four comparative herbicide treatments, above-ground biomass was reduced more by Confront, Milestone, Streamline, and Oust in 9, 9, 8, and 2 instances, respectively.

Research Implications. Across all evaluated parameters, 10% Esplanade drift provided comparable or superior plant safety to all other herbicides when applied PRE (squash and tomato), POST (bell pepper and soybean), and PRE or POST (cotton and tobacco), respectively. While the intended use of the herbicides evaluated in this research varies, overall Esplanade provided comparable or superior plant safety to herbicides currently applied along roadsides, railways, and noncropland areas. Across application timings, Esplanade-plant safety ranked cotton > tobacco > tomato > squash > bell pepper > soybean. While this research supports Esplanade use along roadsides adjacent to many crops due to its superior plant safety when compared to other evaluated herbicides, it still poses an off-target plant injury risk.

Zoysiagrass Sod Establishment Along Guardrails: Evaluations of Cultivars, Soil Preparation Techniques, and Planting Timings.

Zoysiagrass Sod Strip Establishment. Overall, establishment success, which was set as > 60% cover, varied widely between years. Therefore, data are presented separately by year. Across locations in year 1, Dec. and Mar. establishment timings generally resulted in successful establishment (60 to 90% cover from 40 to 125 WAIE, excluding Lee – 'El Toro'), while results varied in Apr. and May (Table 16). 'El Toro' and 'Meyer' were largely established successfully in these months at Chatham and Lee locations, while cover of all cultivars planted in Yadkin was ≤ 53% by 125 WAIE. Across cultivars in year 1, planting 'El Toro' or 'Meyer' generally resulted in equal to, or greater cover at 40, 90, and 125 WAIE than 'Zeon'. El Toro' and 'Meyer' more readily establishing in roadside conditions may be in part to reduced water demands compared to 'Zeon'. Wherley et al. (2014) reported *Z. japonica* required less supplemental irrigation (≈15 to 20% of evapotranspiration rate) compared to *Z. matrella* (≈25 to 30%) to maintain acceptable quality over a 2 yr period. Furthermore, the National Turfgrass Evaluation Program (NTEP) reported 'El Toro' and ' Meyer' maintained higher quality ratings than 'Zeon' when grown under severe stress/no irrigation management, suggesting it is more drought tolerant (NTEP, 2001). Across locations in year 1, Chatham plantings generally resulted in equal to, or greater cover at 40, 90, and 125 WAIE compared to Lee and Yadkin. 'El Toro' and 'Meyer' successfully established at all timings in Chatham, while Lee and Yadkin plantings resulted in unsuccessful results largely in Apr. and May. Successful establishment at Chatham compared to Lee and Yadkin may be due in part to finer-textured soil with better moisture and nutrient retention (Table 15). Additionally, Chatham had the least encroachment pressure from surrounding vegetation, as it is a fescue-based roadside with minimal weed pressure (personal observation).

In year 2, sod establishment was less consistent across all evaluated variables. Overall, planting in year 2 resulted in poor cover at 40 and 90 WAIE, with only four location-cultivar-timing combinations providing successful establishment at 125 WAIE (Table 16). Poor establishment may be in part due to varying climatic conditions between years. In year 1, average Jan. air temperatures exceeded the 30 yr average at all sites, whereas it fell below the average in year 2 at all sites (Table 14). Additionally, temperatures below critical zoysiagrass freezing limits were only observed in year 2. Previous research has shown 'El Toro' vegetation viability declines at, or below 14 °F (Dunn et al., 1999). With 14 °F as a winter injury threshold, total d yr^{-1} at, or below this temperature were tallied for each site and compared to the 30 yr average at Chatham (3.6 d), Lee (4.6 d), and Yadkin (6.7 d). In year 1 of research, air temperature did not fall below this threshold, while 10, 7, and 14 d were observed at Chatham, Lee, and Yadkin, respectively, in year 2. Additionally, all 14 °F days occurred from Jan. to Mar., which may partially explain why Dec. and Mar. timings in year 2 did not provide comparable results to year 1. Precipitation at critical timing after planting also varied between years. At all locations, precipitation exceeded the 30 yr average in Jun. and Jul. in year 1, whereas it was 2 to 44% below the average in year 2, which may have also reduced sod survival.

At 40 WAIE in year 1, tillage + prep resulted in greater cover (68%) compared to tillage-alone (64%) and vegetation strip (62%), while at 90 and 125 WAIE techniques ranked tillage + prep (74 and 71%, respectively) > tillage-alone (70 and 67%, respectively) > vegetation strip (65 and 62%, respectively) (Table 17). Although zoysiagrass cover was lower in year 2 compared to year 1, planting techniques generally had a similar effect on establishment. Tillage-alone and tillage + prep resulted in greater cover at 40 WAIE (34 and 35%, respectively) than vegetation strip (29%). Planting techniques did not differ at 90 WAIE (29 to 31% cover), while tillage-alone treatments outranked vegetation strip at 125 WAIE. Although tillage + prep provided the best sod establishment in year 1, tillage-alone also provided successful establishment and 90 and 125 WAIE, and resulted in similar establishment in year 2. Therefore, excluding the preparation step to create a furrow prior to planting may be advisable in similar conditions, as it reduces equipment and personnel planting requirements and associated costs.

Zoysiagrass Sod Spread. Spread from the original strip was not observed in the year of planting. Minimal spread ($\leq$ 10%) was observed the year following planting. Overall, spread was predominantly observed in bareground areas or areas with thin vegetation downhill from the planted sod strip (personal observation). In many cases sod was planted downhill of the guardrail in the presented research, and sod spread data does not differentiate between growth under, or away from the guardrail. Additional research is needed to elucidate the effect of planting position on under-guardrail encroachment, which is the underlying premise of planting zoysiagrass sod along pre-existing guardrails.

Zoysiagrass spread differed between cultivars at 125 WAIE. Averaged over locations, 'El Toro' spread 11 and 16% more than 'Meyer' and 'Zeon' in year 1, respectively (Table 18). 'El Toro' also spread more than other cultivars in year 2. This agrees with NTEP (2001), which reported 'El Toro' average establishment rate doubled (50% establishment) 'Zeon' (25%) 8 wk after planting. Although the timescales vary widely between the presented research and NTEP (2001), these results agree with Unruh et al. (2013), who reported *Z. japonica* 'El Toro' and 'Meyer') are faster growers than *Z. matrella* ('Zeon').

Zoysiagrass spread differed between soil preparation techniques at 125 WAIE. In year 1, tillage + prep and tillage-alone resulted in 35 and 33% spread, respectively, while vegetation stripping prior to plant resulted in 24% (Table 19). In year 2, tillage + prep (13%) and tillage-alone (12%) resulted in greater spread than vegetation strip (9%). Overall, tillage practices resulted in greater sod spread, which may have been due in part to a wider area of soil-disruption (24 in) compared to vegetation stripping (21 in). From field observations, bareground was the first areas sod spread into. Additionally, vegetation stripping did not alleviate soil compaction to the extent of tillage, which commonly inhibits desirable plant growth on roadsides.

Research Implications. Discrepancy in establishment success between years limits implementation of results, as year 1 predominantly resulted in successful establishments, yet precipitation nearly doubled the 30 yr average at two locations (Lee and Yadkin) in Jun. and Jul. Although sod desiccation is a year-round concern, Jun. and Jul. are historically months that climatic conditions are particularly unsuitable for sod establishment in nonirrigated settings. Additionally, extreme cold ($\leq$ 14 °F) and hot (> 95 °F) temperatures with respect to zoysiagrass viability did not occur. Year 2 predominantly resulted in unsuccessful establishments, but precipitation fell below the 30 yr average at all locations in Jun. and Jul., and extreme cold temperatures occurred more frequently than the 30 yr average at all locations. When successful establishments occurred, Dec. and Mar. timings provided the most consistent results. Of the two, Mar. is recommended because it allows vegetation managers to better avoid planting sod that will be subject to extreme cold temperatures common to NC from Dec. to Feb., and improve establishment success potential. 'El Toro' and 'Meyer' outperformed 'Zeon' in sod strip survival, while 'El Toro' generally spread more than 'Meyer', which is of upmost importance in covering areas under guardrails that routine mowing is unable to maintain. Tillage-alone resulted in equivalent, or greater sod establishment and spread than tillage + prep and vegetation stripping. Additionally, it is the safest of the evaluated methods due to reduced equipment/personnel requirements, which should also reduce installation costs. Overall, the presented research confirms zoysiagrass sod can be established along NC guardrails in a range of environmental conditions. However, periods for successful sod establishment on roadsides are comparably smaller to other turfgrass systems due to reduced watering and other management inputs.

Warm-Season Turfgrass Seeding on Roadsides: Evaluations of Species, Seeding Rates, and Seeding Timings.

Results. Across all evaluated variables, < 5% seed emergence was observed throughout the research period. This is likely due in part to a combination of non-ideal soil conditions, inadequate moisture inputs, and existing plant competition. Roadside soils can pose issues for plant growth due from soil compaction associated with construction and management practices, fertility inputs, etc.. While soil strength was not measured at locations, conditions likely were not conducive for grass rooting. While bermudagrass and zoysiagrass seeding typically involve tillage or aggressive aerification/verticutting prior to planting, the approach used in the presented research of drilling seed is also performed. However, zoysiagrass seeding recommendations involve light, frequent irrigation until plants mature to a point where they can sustain from precipitation, which is not a feasible on roadside settings (Patton et al., 2006). Previous research has also documented failed bermudagrass seeding in Oklahoma and Indiana due to inadequate moisture inputs (Ahring et al., 1975; Patton et al., 2004). Additionally, previous research has shown bermudagrass and zoysiagrass establishment from seed is improved from post-seeding herbicide applications, which the evaluated research did not include (Lewis et al., 2012; Patton et al., 2006). While a pre-plant Roundup application was included in year 2, treatment effect dissipated throughout summer at both Chatham County (bahiagrass regrowth) and Orange County (summer annual encroachment) locations.

Research Implications. Results from this research do not warrant recommending bermudagrass or zoysiagrass seeding on NC roadsides; however, the potential for these grasses to reduce long-term management inputs coupled with seeding's significantly lower fiscal requirements than sodding suggests additional research which includes multiple years in combination with altered herbicide and plant growth regulator programs should be conducted to address the aforementioned growth condition concerns. Additionally, efforts should evaluate sprigging at various timings, as this planting method may provide a compromise between establishment success and fiscal requirements between seeding and sodding, making it more feasible for wide scale planting.

OVERALL CONCLUSIONS

- Tall Fescue Roadside Mowing Reduction from Plateau
    - Plateau reduces tall fescue mowing requirements
    - Tank-mixing Confront with Plateau did not affect tall fescue mowing requirements, but provides increased broadleaf weed control
- Herbicide Inputs and Mowing Affects Vaseygrass (*Paspalum urvillei*) Control

- Intensity, Pastora, and Plateau can be used for vaseygrass control, but season of application impacts efficacy
  - Ideally, vaseygrass should be mown 2 weeks prior to herbicide application
  - Herbicide inputs over multiple growing seasons will be required for vaseygrass eradication
- Warm-Season Turfgrass Release Regimen Evaluations
  - PRE herbicides should be utilized to prevent annual ryegrass (in the fall) and vaseygrass (in the spring) spread along roadsides
  - Overall, Esplanade and Proclipse provided comparable control
- Simulated Esplanade Drift Affects NC Agricultural Plant Growth
  - With appropriate spray drift-prevention practices, Esplanade is a safe herbicide for use on NC roadsides
    - Special caution should be taken near soybean fields
- Zoysiagrass Sod Establishment Along Guardrails: Evaluations of Cultivars, Soil Preparation Techniques, and Planting Timings
  - 'El Toro' was the best suited zoysiagrass cultivar for roadside establishment along guardrails
  - Soil should be tilled prior to sodding
  - Sod establishment timing should target late winter to balance avoiding extreme cold conditions prior to, and hot conditions following planting
- Warm-Season Turfgrass Seeding on Roadsides: Evaluations of Species, Seeding Rates, and Planting Timings
  - Results from the evaluated experimental approaches do not warrant recommending bermudagrass and zoysiagrass seeding on roadsides
  - Future research should evaluate long-term herbicide and plant growth regulator programs to promote seed establishment

RECOMMENDATIONS AND IMPLEMENTATION

Data from these projects cover a wide range of vegetation management considerations, which are unified by the intention to be implemented by NC DOT to reduce long-term inputs while providing safe thoroughfares for motorists. Plateau for tall fescue plant growth regulation should be integrated to reduce mowing requirements; however, roadside vegetation managers should be cognizant that this herbicide can indirectly promote weed encroachment through reduced turfgrass vigor. Therefore, application of other herbicides may be required to prevent unacceptable weed encroachment.

One such herbicide is Esplanade, which this research supports is a relatively safe product with regards to off-target movement and associated issues, and provides excellent control of many annual broadleaf and grassy weeds. However, Proclipse, a comparatively less expensive PRE herbicide, generally provided comparable control in warm-season release trials and should still be incorporated into vegetation management plans on select species to provide an additional herbicide mode of action, as well as fiscal savings.

At the onset of this project few, if any grassy weeds in the central and eastern portion of the state rivaled vaseygrass encroachment on NC roadsides, and associated management issues. Season of application and mowing timing affected herbicide efficacy in select cases. Intensity and Plateau application should be applied in the fall and spring, respectively, for optimal control;

however, routine mowing may also be needed to ensure vaseygrass control. Pastora required both fall and spring application, but should be considered where conditions do not favor routine mowing. Results from this research should be integrated by roadside vegetation managers both specifically for vaseygrass, as well as conceptually for weed issues of the future to conserve resources and reduce overall herbicide inputs.

Vegetation establishment research provided information for both current projects, as well as for future research to expand upon. Warm-season turfgrass seeding efforts were unsuccessful and additional cultivars, seeding methods, and post-application herbicide inputs should be evaluated to improve establishment rates. Due to high seed-water requirements during the establishment period coupled with roadside conditions, evaluating seeding in low-lying areas should be evaluated to see if success rates increase. If so, this would provide an added advantage of establishing low growing plants that require less mowing, which can be inherently challenging in low-lying areas. Vegetative establishment via sodding was a comparatively more successful research endeavor; however, results varied widely between years and considering the fiscal inputs required for sodding, were only acceptable in year 1. In year 1, 'El Toro' planted in March following tillage preparation resulted in the best combination of sod survival and spread, with the latter being of upmost importance to reduce mowing/trimming along guardrails. Planting earlier or later than March also resulted in successful establishments in year 1; however, roadside vegetation managers should be cognizant of the climatic stressors this may subject sod to. Such stressors likely contributed to comparatively poorer establishment in year 2, where winter was colder, spring was dryer, and summer was hotter. Ultimately, areas sodded in winter or spring may need additional water inputs in the months following planting if timely precipitation does not occur, and planning should reflect this prior to project commencement.

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APPENDICES

Table 1. Plateau (imazapic) applications on roadside tall fescue (*Lolium arundinaceum* [Schreb.] S.J. Darbyshire) affects cover and seedhead counts.[a-c]

Herbicide[d,e]	Mowing inter. height	Cover[f] 0 DAT	Cover[f] 28 DAT	Cover[f] 56 DAT	Cover[f] 84 DAT	Seedheads[g] 0 DAT	Seedheads[g] 28 DAT	Seedheads[g] 56 DAT	Seedheads[g] 84 DAT
	(in)	(%)				(No. ft^{-2})			
Plateau	9	58	63	62	65	0	0	0	2
Plateau	12	50	57	54	57	0	0	0	1
Plateau + Confront	9	60	63	62	66	0	0	0	2
Plateau + Confront	12	64	72	68	76	0	0	0	2
---	9	63	57	52	53	0	1	6	4
---	12	57	60	53	54	0	0	2	5
---	---	63	54	53	48	0	6	11	13
$LSD_{0.05}$		NS	NS	NS	14	NS	1	2	2

[a] Research conducted on a roadside in Chatham County, NC.

[b] Abbreviations: inter., intervention; DAT, d after treatment; NS, nonsignificant.

[c] Data pooled over experimental runs.

[d] Plateau and Confront applied at 3.5 fl oz A^{-1} and 1.5 pt A^{-1}, respectively, on 01 Apr. 2013 and 02 Apr. 2014.

[e] All applications included a nonionic surfactant at 0.25% v/v.

[f] Visual tall fescue cover estimated on a 0 (no cover) to 100% (complete cover) scale.

[g] Average of three counts $plot^{-1}$.

Table 2. Plateau (imazapic) affects tall fescue (*Lolium arundinaceum* [Schreb.] S.J. Darbyshire) roadside mowing requirements at two intervention heights in 2013.[a,b]

Herbicide[c,d]	Mowing inter. height	Foliage height[e] 16 DAT	26 DAT	39 DAT	49 DAT	56 DAT	70 DAT	Mowing cycles 0 to 70 DAT
	(in)	(in)						(No.)
IMA	9	6.3	6.7	8.3	9.1×[f]	7.5	9.4×	2
IMA	12	6.3	7.5	8.7	10.2	11.0	13.0×	1
IMA + CLO + TRI	9	6.3	7.1	8.7	10.2×	7.9	9.8×	2
IMA + CLO + TRI	12	6.7	6.7	8.7	9.8	10.2	13.4×	1
---	9	9.1×	7.1	9.4×	7.9	9.1×	9.4×	4
---	12	9.4	12.6×	9.1	11.8×	8.3	11.8×	3
---	---	8.7	11.8	15.0	16.5	18.5	20.5	0
$LSD_{0.05}$		1.2	3.1	2.8	3.5	2.4	3.5	

[a] Research conducted on a roadside in Chatham County, NC.
[b] Abbreviations: inter., intervention; DAT, d after treatment.
[d] Plateau and Confront applied at 3.5 fl oz A^{-1} and 1.5 pt A^{-1}, respectively, on 01 Apr. 2013.
[d] All applications included a nonionic surfactant at 0.25% v/v.
[e] Average of five measurements $plot^{-1}$.
[f] Denotes mowing event conducted after foliage measurements.

Table 3. Plateau (imazapic) affects tall fescue (*Lolium arundinaceum* [Schreb.] S.J. Darbyshire) roadside mowing requirements at two intervention heights in 2014.[a,b]

Herbicide[c,d]	Mowing inter. height	Foliage height[e] 14 DAT	25 DAT	38 DAT	48 DAT	59 DAT	70 DAT	Mowing cycles 0 to 70 DAT
	(in)	(in)						(No.)
IMA	9	5.9	7.1	9.4×[f]	7.5	9.1×	7.9	2
IMA	12	5.9	6.7	8.7	10.2	11.8×	7.5	1
IMA + CLO + TRI	9	5.9	6.7	9.4×	8.3	9.8×	8.3	2
IMA + CLO + TRI	12	5.5	6.3	9.4	10.6	11.4	13.4×	1
---	9	9.1×	9.4×	9.4×	7.5	9.8×	9.1×	5
---	12	9.4	12.6×	9.8	12.2×	8.7	11.8×	3
---	---	8.7	12.2	15.0	17.3	18.1	17.7	0
$LSD_{0.05}$		1.2	0.8	2.4	2.8	1.6	3.1	

[a] Research conducted on a roadside in Chatham County, NC.

[b] Abbreviations: inter., intervention; DAT, d after treatment.

[d] Plateau and Confront applied at 3.5 fl oz A^{-1} and 1.5 pt A^{-1}, respectively, on 02 Apr. 2014.

[d] All applications included a nonionic surfactant at 0.25% v/v.

[e] Average of five measurements $plot^{-1}$.

[f] Denotes mowing event conducted after foliage measurements.

Table 4. Climatic conditions during Plateau (imazapic) for tall fescue (*Lolium arundinaceum* [Schreb.] S.J. Darbyshire) mowing reduction trial period vs. 10 yr average.[a,b]

	Air temperature[c]				Soil temperature[d]				Precipitation			
Year	Apr	May	Jun	Jul	Apr	May	Jun	Jul	Apr	May	Jun	Jul
	(°F)				(°F)				(in H_2O)			
2003 to 2012[e]	59	66	74	77	60	67	74	77	2.7	2.8	2.7	3.9
2013	59	65	73	76	58	67	75	77	3.7	2.6	7.3	4.8
2014	58	67	74	76	55	68	76	78	3.5	3.0	1.3	5.3

[a] Unique experimental runs initiated 25 Mar. 2013 and 26 Mar. 2014 on a roadside in Chatham County, NC.
[b] Climatic conditions recorded 5 miles from experiment site at the Siler City Airport Weather Station in Chatham County, NC.
[c] Air temperature recorded at 6 ft height.
[d] Soil temperature recorded at 4 in depth.
[e] Averaged over 10 yr period.

Table 5. Herbicide-by-application timing-by-mowing regimen interaction on vaseygrass (*Paspalum urvillei* Steud.) cover 40 wk after fall treatment.[a]

		Fall-only[b]		Fall + spring		Spring-only[c]	
Herbicide[d]	Herb. rate	Mowed	Nonmowed	Mowed	Nonmowed	Mowed	Nonmowed
	(A^{-1})	% cover[e]					
Intensity	1 pt	10	15	8	11	29	25
Tribute Total	3.2 oz	27	44	29	34	47	23
Plateau	8 fl oz	31	29	7	16	9	31
Pastora	1.5 oz	38	48	30	26	30	38
Outrider	2 oz	26	35	19	29	23	38
Nontreated	---	33	50	31	51	38	58
$LSD_{0.05}$		14					

[a] Two experimental runs conducted on a roadside in Duplin County, NC.
[b] Fall applications: 16 Oct. 2012 and 01 Oct. 2013; Spring applications: 17 Jun. 2013 and 18 Jun. 2014.
[c] Spring-only application evaluated only in run two.
[d] All herbicide applications included a nonionic surfactant at 0.25% v/v.
[e] Cover visually estimated on a 0 (no cover) to 100% (complete cover) scale.

Table 6. Herbicide-by-application timing-by-mowing regimen interaction on vaseygrass (*Paspalum urvillei* Steud.) cover 52 wk after fall treatment.[a]

		Fall-only[b]		Fall-plus-spring		Spring-only[c]	
Herbicide[d]	Herb. rate	Mowed	Nonmowed	Mowed	Nonmowed	Mowed	Nonmowed
	(A^{-1})	% cover[e]					
Intensity	1 pt	7	16	8	22	20	40
Tribute Total	3.2 oz	23	53	14	29	40	30
Plateau	8 fl oz	24	44	7	24	14	45
Pastora	1.5 oz	34	51	6	12	11	25
Outrider	2 oz	29	44	14	31	20	43
Nontreated	---	30	63	24	59	28	60
$LSD_{0.05}$		11					

[a] Two experimental runs conducted on a roadside in Duplin County, NC.
[b] Fall applications: 16 Oct. 2012 and 01 Oct. 2013; Spring applications: 17 Jun. 2013 and 18 Jun. 2014.
[c] Spring-only application evaluated only in run two.
[d] All herbicide applications included a nonionic surfactant at 0.25% v/v.
[e] Cover visually estimated on a 0 (no cover) to 100% (complete cover) scale.

Table 7. Herbicide-by-pre-herbicide application mowing interval interaction on vaseygrass (*Paspalum urvillei* Steud.) seedhead counts and the main effect of herbicide on vaseygrass height, 4 wk after treatment.[a,b]

Herbicide[c]	Herb. rate	Mowing wk before herbicide application						
		6	4	3	2	1	0	6 to 0
	(A^{-1})	Seedheads ft^{-2d}						(in)[e]
Intensity	1 pt	0.5	0.5	0.4	0.4	0.1	0.1	9.8
Tribute Total	3.2 oz	3.1	2.0	2.1	1.5	0.6	0.4	18.9
Plateau	8 fl oz	0.5	0.7	0.4	0.5	0.3	0.2	11.8
Pastora	1.5 oz	3.3	2.0	2.2	1.4	0.8	0.4	17.3
Outrider	2 oz	2.7	1.6	1.6	1.6	0.7	0.3	16.1
Nontreated	---	3.5	2.1	2.0	1.7	1.0	0.5	19.3
$LSD_{0.05}$		0.8						2.4

[a] Two experimental runs conducted on a roadside in Craven County, NC.
[b] Applications: 18 Sep. 2013 and 19 Sep. 2014.
[c] All herbicide applications included a nonionic surfactant at 0.25% v/v.
[d] Height and seedhead counts were averaged over three recordings $plot^{-1}$.
[e] Data pooled over pre-herbicide application mowing interval.

Table 8. Main effect of herbicide on vaseygrass (*Paspalum urvillei* Steud.) cover, height and seedhead counts 40 and 52 wk after treatment.[a-d]

		40 WAT		52 WAT		
Herbicide[e]	Herb. rate	Cover[f]	Height[g]	Cover	Height	Seedhead
	(A^{-1})	(%)	(in)	(%)	(in)	(No. ft^{-2})
Intensity	1 pt	5	7.1	12	24.8	0.7
Tribute Total	3.2 oz	21	12.2	42	27.6	3.6
Plateau	8 fl oz	6	7.5	23	26.4	1.0
Pastora	1.5 oz	23	11.4	46	28.3	3.5
Outrider	2 oz	23	12.6	44	27.2	3.8
Nontreated	---	30	13.4	50	28.3	4.3
$LSD_{0.05}$		5	2.0	7	NS	0.8

[a] Abbreviations: WAT, wk after treatment; NS, nonsignificant.
[b] Two experimental runs conducted on a roadside in Craven County, NC.
[c] Applications: 18 Sep. 2013 and 19 Sep. 2014.
[d] Data pooled over pre-herbicide application mowing interval.
[e] All herbicide applications included a nonionic surfactant at 0.25% v/v.
[f] Cover visually estimated on a 0 (no cover) to 100% (complete cover) scale.
[g] Height and seedhead counts were averaged over three recordings $plot^{-1}$.

Table 9. Intensity (clethodim) application-by-pre-herbicide application mowing interval interaction on vaseygrass (*Paspalum urvillei* Steud.) cover 40 and 52 wk after treatment.[a-d]

Mowing wk before treatment	40 WAT		52 WAT	
	Intensity	Nontreated	Intensity	Nontreated
	% cover[e]			
6	11	38	23	58
4	3	28	13	55
3	5	27	14	47
2	2	27	4	47
1	1	33	6	48
0	6	25	13	43
$LSD_{0.05}$	4	NS	6	NS

[a] Abbreviations: WAT, wk after treatment; NS, nonsignificant.
[b] Two experimental runs conducted on a roadside in Craven County, NC.
[c] Applications: 18 Sep. 2013 and 19 Sep. 2014.
[d] Intensity applied at 1 pt A^{-1} + nonionic surfactant at 0.25% v/v.
[e] Cover visually estimated on a 0 (no cover) to 100% (complete cover) scale.

Table 10. Effect of warm-season release treatments and application timings on annual ryegrass (*Lolium multiflorum* L.) cover.[a]

Herbicide (amount A^{-1})[d]	16 wk after fall treatment Fall	16 wk after fall treatment F + S	16 wk after fall treatment Spring	40 wk after fall treatment Fall	40 wk after fall treatment F + S	40 wk after fall treatment Spring
	% ryegrass cover					
Plateau (PLAT; 8 fl oz)	20	27	23	20	17	30
Intensity (INT; 1 pt)	20	25	25	17	23	23
Plateau (8 fl oz) + Proclipse (PRO; 1.5 lb)	0	0	23	0	0	23
Plateau (8 fl oz) + Esplanade (ESP; 3.5 fl oz)	0	0	20	0	0	20
Plateau (8 fl oz) + Esplanade (5 fl oz)	0	0	25	0	0	23
Intensity (1 pt) + Proclipse (1.5 lb)	0	0	30	0	0	17
Intensity (1 pt) + Esplanade (3.5 fl oz)	0	0	23	0	0	27
Intensity (1 pt) + Esplanade (5 fl oz)	0	0	30	0	0	30
PLAT (8 fl oz) + PRO (1.5 lb) fb PLAT (8 fl oz) + ESP (3.5 fl oz)	---	0	---	---	0	---
PLAT (8 fl oz) + PRO (1.5 lb) fb PLAT (8 fl oz) + ESP (5 fl oz)	---	0	---	---	0	---
PLAT (8 fl oz) + ESP (3.5 fl oz) fb PLAT (8 fl oz) + PRO (1.5 lb)	---	0	---	---	0	---
PLAT (8 fl oz) + ESP (5 fl oz) fb PLAT (8 fl oz) + PRO (1.5 lb)	---	0	---	---	0	---
INT (1 pt) + PRO (1.5 lb) fb INT (1 pt) + ESP (3.5 fl oz)	---	0	---	---	0	---
INT (1 pt) + PRO (1.5 lb) fb INT (1 pt) + ESP (5 fl oz)	---	0	---	---	0	---
INT (1 pt) + ESP (3.5 fl oz) fb INT (1 pt) + PRO (1.5 lb)	---	0	---	---	0	---
INT (1 pt) + ESP (5 fl oz) fb INT (1 pt) + PRO (1.5 lb)	---	0	---	---	0	---
Nontreated		27			33	
$LSD_{0.05}$		10			12	

[a] Abbreviations: F, fall; S, spring.
[b] Research conducted on a roadside in Wake County, NC
[c] Fall application: 24 Sep. 2013; Spring application: 27 May 2014.
[d] All herbicide treatments included Confront (1 pt A^{-1}), Oust XP (1 oz A^{-1}) and NIS (0.25% v/v)

Table 11. Effect of warm-season release treatments and application timings on vaseygrass (*Paspalum urvillei* Steud.) cover 48 wk after fall treatment.[a]

Herbicide (amount A^{-1})[d]	2013 to 2014			2014 to 2015		
	Fall	F + S	Spring	Fall	F + S	Spring
	% vaseygrass cover					
Plateau (PLAT; 8 fl oz)	57	25	25	45	22	25
Intensity (INT; 1 pt)	25	25	40	18	11	40
Plateau (8 fl oz) + Proclipse (PRO; 1.5 lb)	17	13	20	31	11	16
Plateau (8 fl oz) + Esplanade (ESP; 3.5 fl oz)	27	30	35	25	13	26
Plateau (8 fl oz) + Esplanade (5 fl oz)	27	14	32	28	11	19
Intensity (1 pt) + Proclipse (1.5 lb)	4	5	30	12	10	41
Intensity (1 pt) + Esplanade (3.5 fl oz)	12	5	25	13	8	29
Intensity (1 pt) + Esplanade (5 fl oz)	12	8	33	7	6	35
PLAT (8 fl oz) + PRO (1.5 lb) fb PLAT (8 fl oz) + ESP (3.5 fl oz)	---	14	---	---	23	---
PLAT (8 fl oz) + PRO (1.5 lb) fb PLAT (8 fl oz) + ESP (5 fl oz)	---	17	---	---	16	---
PLAT (8 fl oz) + ESP (3.5 fl oz) fb PLAT (8 fl oz) + PRO (1.5 lb)	---	18	---	---	27	---
PLAT (8 fl oz) + ESP (5 fl oz) fb PLAT (8 fl oz) + PRO (1.5 lb)	---	18	---	---	22	---
INT (1 pt) + PRO (1.5 lb) fb INT (1 pt) + ESP (3.5 fl oz)	---	13	---	---	6	---
INT (1 pt) + PRO (1.5 lb) fb INT (1 pt) + ESP (5 fl oz)	---	9	---	---	12	---
INT (1 pt) + ESP (3.5 fl oz) fb INT (1 pt) + PRO (1.5 lb)	---	18	---	---	8	---
INT (1 pt) + ESP (5 fl oz) fb INT (1 pt) + PRO (1.5 lb)	---	7	---	---	2	---
Nontreated		52			36	
$LSD_{0.05}$		18			12	

[a] Abbreviations: F, fall; S, spring.
[b] Research conducted on a roadside in Craven County, NC
[c] Fall application: 10 Oct. 2013 and 20 Sep. 2014; Spring application: 08 Jun. 2014 and 17 Jun. 2015.
[d] All herbicide treatments included Confront (1 pt A^{-1}), Oust XP (1 oz A^{-1}) and NIS (0.25% v/v)

Table 12. Effect of simulated spray drift rates on plant injury 70 d after treatment.[a,b]

Herbicide (A^{-1})	% drift	Cotton		Pepper		Soybean		Squash		Tobacco		Tomato	
		PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
		% injury											
Esplanade (5 fl oz)	100	13	35	100	96	100	96	80	100	43	64	21	100
Esplanade (5 fl oz)	20	13	23	90	59	100	54	1	63	8	9	4	70
Esplanade (5 fl oz)	10	3	19	74	24	90	29	1	48	8	9	4	57
Esplanade (5 fl oz)	5	0	18	54	20	43	23	1	30	8	4	8	26
Esplanade (5 fl oz)	2.5	0	13	39	15	8	19	0	6	4	3	4	13
Milestone (7 fl oz)	10	79	86	93	99	100	99	24	54	70	81	100	100
Streamline (4 oz)	10	45	35	77	72	75	50	63	28	49	53	45	86
Confront (1 qt)	10	30	29	57	70	100	100	71	69	38	33	93	94
Oust XP (0.75 oz)	10	38	40	25	36	28	35	74	11	11	9	13	19
LSD[c]		24		29		25		27		14		17	

[a] Abbreviations: PRE, pre-emergent; POST, post-emergent.
[b] Injury rated on a 0 to 100% scale, where 0% was no injury and 100% was complete plant death.
[c] LSD ($P < 0.05$) for comparing PRE and POST treatments within species.

Table 13. Effect of simulated spray drift rates on plant above-ground biomass reduction 70 d after treatment.[a-c]

		Cotton		Pepper		Soybean		Squash		Tobacco		Tomato	
Herbicide (A^{-1})	% drift	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
		% reduction											
Esplanade (5 fl oz)	100	33	49	100	99	100	91	85	89	55	74	26	85
Esplanade (5 fl oz)	20	32	22	93	68	100	61	13	52	14	16	11	68
Esplanade (5 fl oz)	10	18	20	90	36	88	41	21	42	12	18	9	50
Esplanade (5 fl oz)	5	11	15	72	44	93	22	8	43	17	12	6	28
Esplanade (5 fl oz)	2.5	11	13	43	25	52	27	5	13	9	11	5	18
Milestone (7 fl oz)	10	90	89	98	99	100	98	49	17	77	90	60	91
Streamline (4 oz)	10	67	49	95	86	94	50	82	42	33	75	52	77
Confront (1 qt)	10	54	44	73	80	100	96	89	68	35	37	82	91
Oust XP (0.75 oz)	10	71	36	39	43	40	48	89	29	20	23	18	25
LSD[d]		29		28		24		24		14		22	

[a] Abbreviations: PRE, pre-emergent; POST, post-emergent.
[b] Plant material dried for 7 d at 160 °F.
[c] Percent above-ground biomass reduction, relative to the nontreated check.
[d] LSD ($P < 0.05$) for comparing PRE and POST treatments within species.

Table 14. Climatic conditions during zoysiagrass (*Zoysia* spp.) establishment periods vs. 30 yr average.[a,b]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
	Average air temperature (°F)[c]											
(Chatham)												
1983 to 2012	39	43	51	59	67	75	78	77	70	59	50	42
2013	43	42	43	53	63	75	78	74	67	60	42	44
2014	35	42	39	57	69	76	77	75	71	62	45	45
(Lee)												
1983 to 2012	41	44	52	60	68	75	79	78	71	60	51	43
2013	46	44	45	61	67	75	78	75	69	62	49	47
2014	38	44	47	61	70	76	78	75	72	63	47	45
(Yadkin)												
1983 to 2012	38	41	49	57	65	73	77	75	69	58	48	40
2013	40	38	41	57	63	74	76	73	67	58	44	41
2014	31	40	42	56	66	74	72	72	69	58	42	41

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
	Precipitation (in H_2O)											
(Chatham)												
1983 to 2012	3.8	3.4	4.6	3.3	3.7	3.5	4.5	4.1	4.3	3.6	3.6	3.1
2013	3.0	2.8	2.5	0.0	2.1	3.5	4.7	1.8	0.4	1.1	2.3	2.8
2014	1.4	2.0	1.9	2.0	3.0	1.7	6.2	4.6	2.1	2.1	3.7	3.8
(Lee)												
1983 to 2012	3.6	3.3	4.0	2.9	3.6	4.5	5.2	4.6	4.2	3.5	3.3	2.8
2013	2.6	3.9	1.4	4.9	3.5	10.0	9.3	3.3	2.8	0.8	3.0	5.1
2014	2.4	2.5	4.5	5.3	3.5	2.1	3.4	5.9	5.0	2.0	4.0	4.1
(Yadkin)												
1983 to 2012	3.5	3.1	4.3	3.7	3.8	4.2	4.7	3.9	4.0	3.2	3.1	3.5
2013	6.5	3.5	2.2	4.0	3.3	6.9	8.3	4.9	3.0	2.2	4.3	5.6
2014	2.7	3.2	3.4	3.9	4.6	2.0	3.0	7.6	2.6	2.2	4.3	2.2

[a] Experimental runs initiated 17 Dec. 2012 and 03 Dec. 2013 on roadsides in Chatham, Lee, and Yadkin Counties, NC.
[b] Climatic conditions recorded 3, 6, and 16 miles from research sites in Chatham, Lee, and Yadkin Counties, NC, respectively.
[c] Air temperature recorded at 6 ft height.

Table 15. Soil conditions at zoysiagrass (*Zoysia* spp.) establishment research sites.

Location	Series	Texture	Taxonomic class	% of location^{-1}[a]
Chatham	Georgeville	Silty clay loam	Fine, kaolinitic, thermic Typic Kanhapludults	27
---	---	Silt loam	---	73
Lee	Cecil	Sandy loam	Fine, kaolinitic, thermic Typic Kanhapludults	34
---	Durham	Loamy sand	Fine-loamy, siliceous, semiactive, thermic Typic Hapludults	17
---	Fuquay	Loamy sand	Loamy, kaolinitic, thermic Arenic Plinthic Kandiudults	12
---	Mayodan	Sandy loam	Fine, mixed, semiactive, thermic Typic Hapludults	2
---	Pacolet	Sandy loam	Fine, kaolinitic, thermic Typic Kanhapludults	23
---	Pinkston	Silt loam	Coarse-loamy, mixed, semiactive, mesic Ruptic–Ultic Dystrudepts	12
Yadkin	Clifford	Sandy loam	Fine, kaolinitic, mesic Typic Kanhapludults	52
---	---	Sandy clay loam	---	16
---	Fairview	Sandy clay loam	Fine, kaolinitic, mesic Typic Kanhapludults	17
---	Nathalie	Sandy loam	Fine, kaolinitic, mesic Typic Kanhapludults	15

[a] Data obtained from the USDA NRCS (2016).

Table 16. Location-by-cultivar-establishment timing interaction on zoysiagrass (*Zoysia* spp.) sod cover data in years 1 and 2.[a]

		Year 1											
		40 WAIE[b,c]				90 WAIE				125 WAIE			
Location	Cultivar	Dec.	Mar.	Apr.	May	Dec.	Mar.	Apr.	May	Dec.	Mar.	Apr.	May
		% cover[d]											
Chatham	El Toro	79	86	64	62	87	89	82	86	82	82	80	80
---	Meyer	88	89	84	88	89	90	86	92	90	89	88	83
---	Zeon	89	86	46	50	90	88	77	75	82	80	69	63
Lee	El Toro	60	78	69	36	63	64	60	45	58	52	64	58
---	Meyer	68	77	76	86	68	78	72	87	68	72	74	88
---	Zeon	77	61	70	6	71	70	61	16	77	70	58	32
Yadkin	El Toro	79	79	56	29	79	77	66	35	77	71	53	31
---	Meyer	76	83	54	49	77	82	63	57	77	76	52	35
---	Zeon	76	73	26	13	80	76	38	18	67	62	35	24
$LSD_{0.05}$[e]		10				11				12			
		Year 2											
		40 WAIE				90 WAIE				125 WAIE			
Location	Cultivar	Dec.	Mar.	Apr.	May	Dec.	Mar.	Apr.	May	Dec.	Mar.	Apr.	May
		% cover											
Chatham	El Toro	70	19	64	30	67	22	52	31	58	46	59	48
---	Meyer	13	40	29	26	22	29	40	31	44	38	56	43
---	Zeon	53	13	25	22	44	15	23	10	54	28	47	26
Lee	El Toro	47	49	25	24	47	54	36	27	56	59	50	33
---	Meyer	26	22	41	1	15	51	49	8	27	57	61	20
---	Zeon	20	57	41	4	25	66	49	29	33	67	61	25
Yadkin	El Toro	62	38	4	73	36	25	1	14	41	38	9	61
---	Meyer	5	23	14	54	10	22	13	38	14	36	27	57
---	Zeon	43	34	3	74	33	22	3	30	47	37	8	62
$LSD_{0.05}$		14				14				14			

[a] Data pooled over soil preparation techniques.
[b] Abbreviation: WAIE, wk after initial establishment.
[c] WAIE: 40, 09 Sept. 2013 and 11 Sept. 2014; 90, 09 Sept. 2014 and 11 Sept. 2015; 125, 11 May 2015 and 28 Apr. 2016.
[d] Zoysiagrass cover estimated on a 0 (no cover) to 100% (complete cover) scale.
[e] $LSD_{0.05}$ for comparisons within an experimental run-evaluation date.

Table 17. Main effect of soil preparation technique on zoysiagrass (*Zoysia* spp.) sod cover data in year 1.[a]

	Year 1			Year 2		
Method	40WAIE[b,c]	90 WAIE	125 WAIE	40 WAIE	90 WAIE	125 WAIE
	% cover[d]					
Strip	62	65	62	29	29	39
Till-alone	64	70	67	34	31	46
Till + prep	68	74	71	35	31	44
$LSD_{0.05}$[e]	3	3	4	4	NS	4

[a] Data pooled over cultivars, establishment timings, and locations.
[b] Abbreviation: WAIE, wk after initial establishment; NS, nonsignificant.
[c] WAIE: 40, 09 Sept. 2013 and 11 Sept. 2014; 90, 09 Sept. 2014 and 11 Sept. 2015; 125, 11 May 2015 and 28 Apr. 2016.
[d] Zoysiagrass cover estimated on a 0 (no cover) to 100% (complete cover) scale.
[e] $LSD_{0.05}$ for comparisons within an experimental run-evaluation date.

Table 18. Location-by-cultivar interaction on zoysiagrass (*Zoysia* spp.) sod spread data 125 wk after initial establishment in years 1 and 2.[a,b]

Location	Cultivar	Year 1	Year 2
		% spread[c]	
Chatham	El Toro	52	22
---	Meyer	35	0
---	Zeon	26	10
Lee	El Toro	25	24
---	Meyer	18	0
---	Zeon	13	10
Yadkin	El Toro	16	15
---	Meyer	8	2
---	Zeon	5	5
$LSD_{0.05}$[d]		9	4

[a] Data pooled over establishment timings and cultivars.
[b] Evaluation dates: 11 May 2015 and 28 Apr. 2016.
[c] Spread = [(*Z*inter / *T*inter) x 100], where *Z*inter and *T*inter equaled the number of intersections (4 by 4 in) with zoysiagrass present outside of the original sod strip and the total number of intersections (92) outside of the original sod strip, respectively.
[d] $LSD_{0.05}$ for comparisons within an evaluation date.

Table 19. Main effect of soil preparation technique on zoysiagrass (*Zoysia* spp.) sod spread data 125 wk after initial establishment in years 1 and 2.[a,b]

Method	Year 1	Year 2
	% spread[c]	
Strip	24	9
Till-alone	33	12
Till + prep	35	13
$LSD_{0.05}$[d]	5	3

[a] Data pooled over cultivars, establishment timings, and locations.
[b] Evaluation dates: 11 May 2015 and 28 Apr. 2016.
[c] Spread = [(*Z*inter / *T*inter) x 100], where *Z*inter and *T*inter equaled the number of intersections (4 by 4 in) with zoysiagrass present outside of the original sod strip and the total number of intersections (92) outside of the original sod strip, respectively.
[d] $LSD_{0.05}$ for comparisons within an evaluation date.

Asset Management Aided Through Vegetation Management/Zoysiagrass on NC Roadsides

October 27, 2016

Travis W. Gannon
Fred H. Yelverton
Matt D. Jeffries

NC STATE TURF RESEARCH

North Carolina State University

Objectives

- Tall fescue roadside mowing reduction from Plateau
- Vaseygrass control
- Warm-season release programs
- Simulated Esplanade drift affects on NC plants
- Zoysiagrass sod establishment along guardrails
- Warm-season turfgrass seeding on roadsides

NC STATE
TURF RESEARCH

Objectives

- Tall fescue roadside mowing reduction from Plateau
- Vaseygrass control
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- Zoysiagrass sod establishment along guardrails
- Warm-season turfgrass seeding on roadsides

NC STATE
TURF RESEARCH

PGR vs. Mowing in Cool-Season Turf

- Highway 421; Chatham County
- Trial initiations: 3/25/13 and 3/26/14
  - Entire area mown to 6” height of cut (HOC)
- Herbicide/PGR treatments:
  - Plateau (3.5 fl oz A^{-1})
  - Plateau (3.5 fl oz A^{-1}) + Confront (1.5 pt A^{-1})
- Mowing intervention heights:
  - 9” HOC
  - 12” HOC
  - No mow

NC STATE TURF RESEARCH

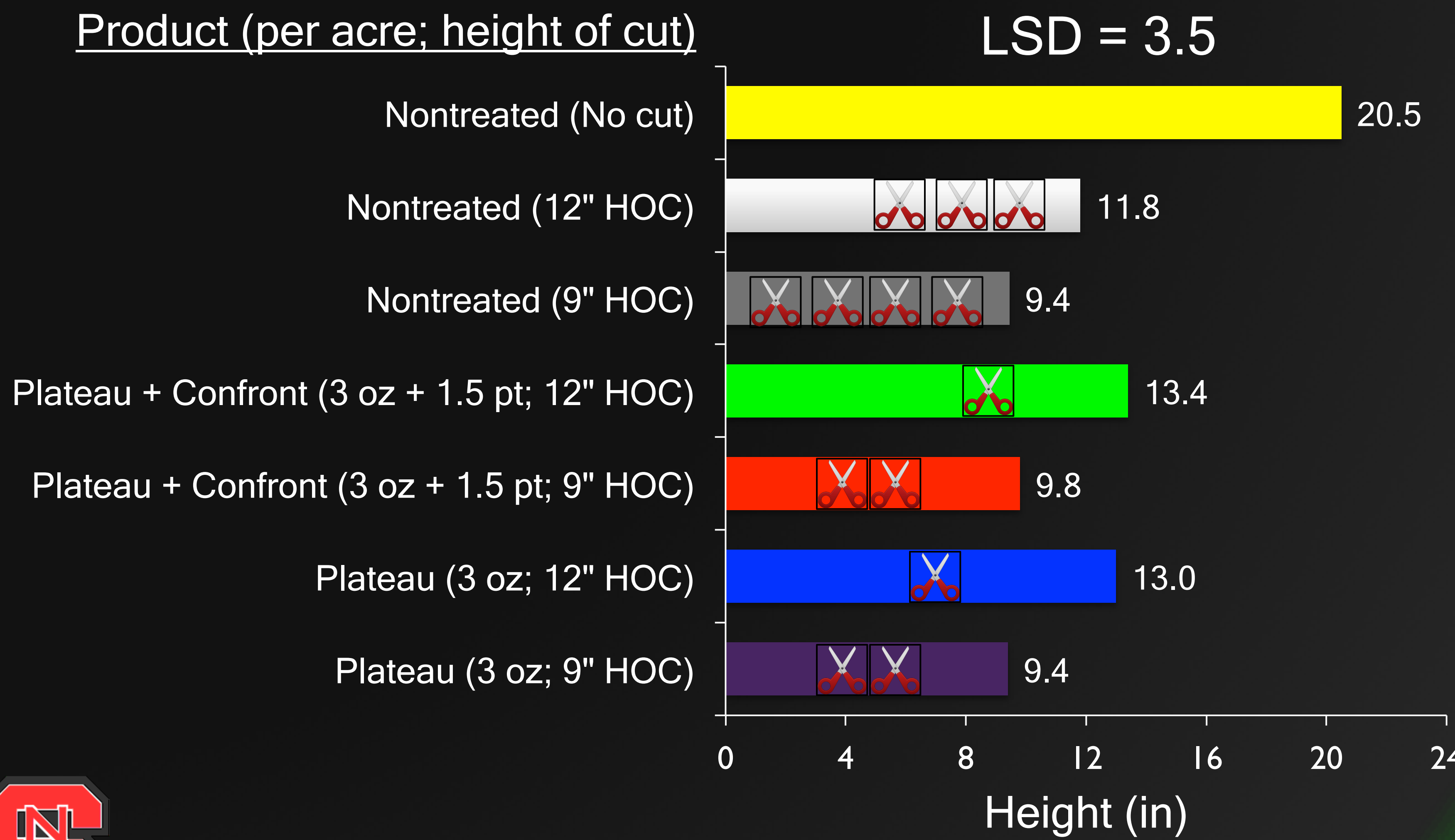
PGR vs. Mowing in Cool-Season Turf

- Plant height measured over time following herbicide/PGR applications
  - When > 50% turf within a plot reached a 9” or 12” intervention height, the entire plot was mown to 6”
  - Number of mowing events required relative to nontreated turf was recorded

NC STATE
TURF RESEARCH

Results

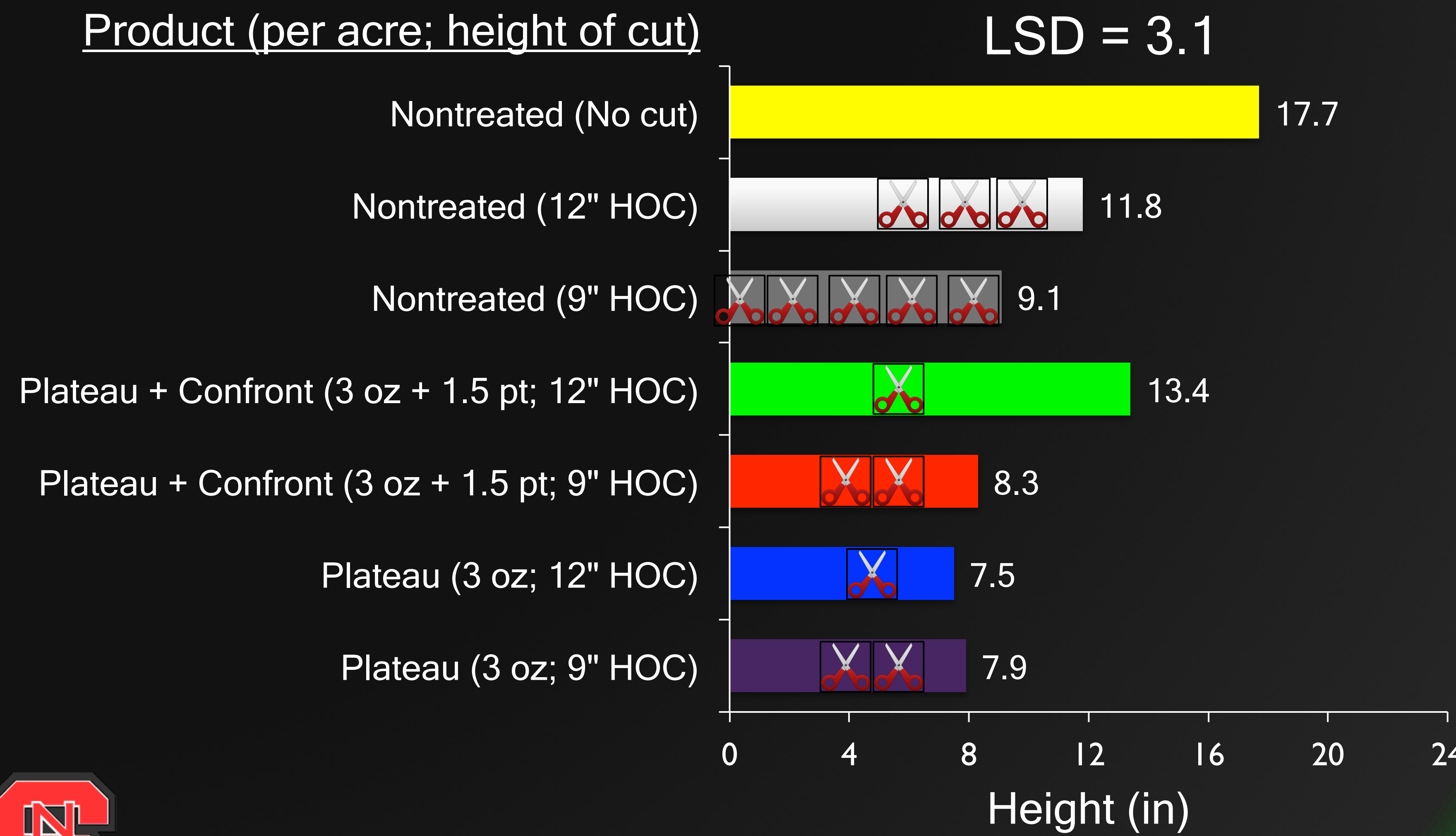
Fescue Height 70 DAT - 2013



NC STATE TURF RESEARCH

Highway 421; Chatham County.
Application made Apr-01-2013. Data collected Jun-17-2013.

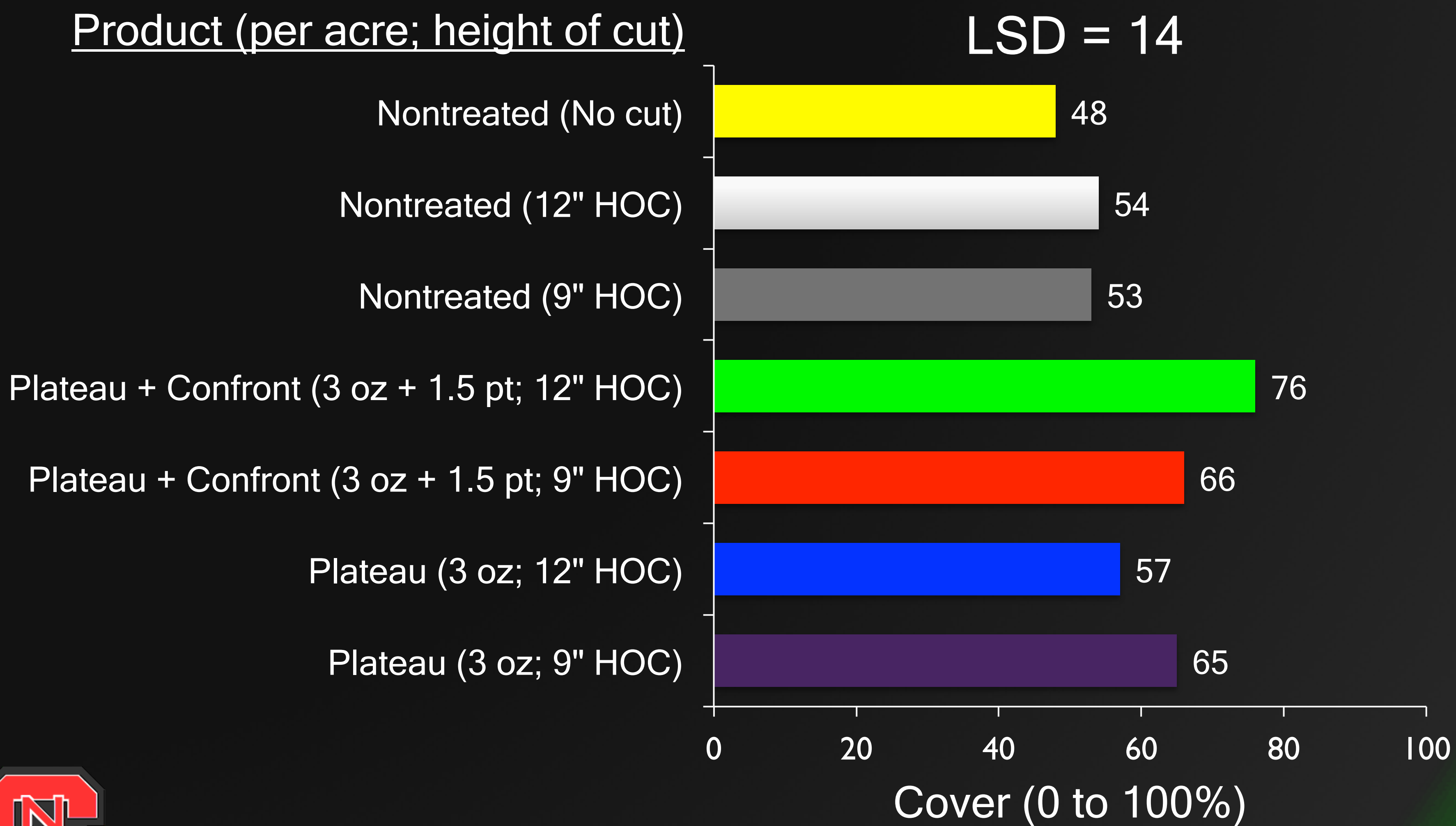
Fescue Height 70 DAT - 2014



NC STATE TURF RESEARCH

Highway 421; Chatham County.
Application made Apr-02-2014. Data collected Jun-18-2014.

Fescue Cover 84 DAT - 2013 & 2014



NC STATE TURF RESEARCH

Highway 421; Chatham County.
Data collected Jun-24-2013 and Jun 25-2014.

Conclusions

- PGR eliminated 2 to 3 mowing events across HOCs
  – Treated and nontreated turf grew at same rates after first mowing
- Mowing at 9” HOC did not improve tall fescue cover, and required one extra mowing
- Confront increased fescue cover 18% (avg. over HOC)
- Seedhead suppression from Plateau
  – 100% through 56 DAT
  – > 85% through 84 DAT (compared to nontreated-nonmown)

NC STATE
TURF RESEARCH

Objectives

- Tall fescue roadside mowing reduction from Plateau
- Vaseygrass control
- Warm-season release programs
- Simulated Esplanade drift affects on NC plants
- Zoysiagrass sod establishment along guardrails
- Warm-season turfgrass seeding on roadsides

NC STATE
TURF RESEARCH

Experiments

- Vaseygrass herbicide efficacy, as affected by:
  - *Experiment 1*: Season of application and mowing
  - *Experiment 2*: Pre-application mowing interval

- Herbicides similar across experiments
  - Plateau (8 fl oz A^{-1})
  - Pastora (1.5 oz A^{-1})
  - Outrider (2 oz A^{-1})
  - Intensity (1 pt A^{-1})
  - Tribute Total (3.2 oz A^{-1})

All included NIS @ 0.25% v/v

NC STATE
TURF RESEARCH

Experiment 1
Materials and Methods

- Application timings
  - Fall-only (mid-October)
  - Fall + Spring
  - Spring-only (mid-June)
- Mowing
  - Nonmown
  - Routinely mown
    - Cut to 4” when average height reached 12”

NC STATE
TURF RESEARCH

Experiment 2
Materials and Methods

- Application timing
  - Fall-only
- Pre-application mowing interval
  - 6, 4, 3, 2, 1, or 0 wk before treatment (WBT)

Mowing/debris removal; October 2, 2012

Herbicide applications; October 16, 2012

NC STATE
TURF RESEARCH

Experiment 1 Vaseygrass Cover

Herbicide X App Timing X Mowing

52 Weeks After Fall Treatment

Herbicide[d]	Herb. rate (A^{-1})	Fall-only[b] Mowed	Fall-only[b] Nonmowed	Fall-plus-spring Mowed	Fall-plus-spring Nonmowed	Spring-only[c] Mowed	Spring-only[c] Nonmowed
		% cover[e]					
Intensity	1 pt	7	16	8	22	20	40
Tribute Total	3.2 oz	23	53	14	29	40	30
Plateau	8 fl oz	24	44	7	24	14	45
Pastora	1.5 oz	34	51	6	12	11	25
Outrider	2 oz	29	44	14	31	20	43
Nontreated	---	30	63	24	59	28	60
$LSD_{0.05}$		11					

NC STATE TURF RESEARCH

Experiment 1 Vaseygrass Cover

Herbicide X App Timing X Mowing

52 Weeks After Fall Treatment

Herbicide[d]	Herb. rate (A^{-1})	Fall-only[b]		Fall-plus-spring		Spring-only[c]	
		Mowed	Nonmowed	Mowed	Nonmowed	Mowed	Nonmowed
		% cover[e]					
Intensity	1 pt	7	16	8	22	20	40
Tribute Total	3.2 oz	23	53	14	29	40	30
Plateau	8 fl oz	24	44	7	24	14	45
Pastora	1.5 oz	34	51	6	12	11	25
Outrider	2 oz	29	44	14	31	20	43
Nontreated	---	30	63	24	59	28	60
$LSD_{0.05}$		11					

NC STATE
TURF RESEARCH

Experiment 2 Vaseygrass Cover

Herbicide

52 Weeks After Treatment

Herbicide[e]	Herb. rate	Cover	Height	Seedhead
	(A^{-1})	(%)	(in)	(No. ft^{-2})
Intensity	1 pt	12	24.8	0.7
Tribute Total	3.2 oz	42	27.6	3.6
Plateau	8 fl oz	23	26.4	1.0
Pastora	1.5 oz	46	28.3	3.5
Outrider	2 oz	44	27.2	3.8
Nontreated	---	50	28.3	4.3
$LSD_{0.05}$		7	NS	0.8

NC STATE
TURF RESEARCH

Experiment 2 Vaseygrass Cover

Herbicide

52 Weeks After Treatment

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	(A^{-1})	(%)	(in)	(No. ft^{-2})
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Plateau	8 fl oz	23	26.4	1.0
Pastora	1.5 oz	46	28.3	3.5
Outrider	2 oz	44	27.2	3.8
Nontreated	---	50	28.3	4.3
$LSD_{0.05}$		7	NS	0.8

NC STATE
TURF RESEARCH

Experiment 2 Vaseygrass Cover

Intensity X Mowing Interval

40 and 52 Weeks After Treatment

Mowing wk before treatment	40 WAT Intensity	40 WAT Nontreated	52 WAT Intensity	52 WAT Nontreated
	% cover			
6	11	38	23	58
4	3	28	13	55
3	5	27	14	47
2	2	27	4	47
1	1	33	6	48
0	6	25	13	43
$LSD_{0.05}$	4	NS	6	NS

NC STATE TURF RESEARCH

Objectives

- Tall fescue roadside mowing reduction from Plateau
- Vaseygrass control
- Warm-season release programs
- Simulated Esplanade drift affects on NC plants
- Zoysiagrass sod establishment along guardrails
- Warm-season turfgrass seeding on roadsides

NC STATE
TURF RESEARCH

Experimental Approach

- Trial sites and applications
  - Annual ryegrass: Wake County, NC
    - Fall: 9-24-13; Spring 5-27-14
  - Vaseygrass: Craven County, NC
    - Fall:10-10-13 and 9-19-14; Spring: 6-8-14 and 6-17-15
- Herbicides
  - Intensity (1 pt A^{-1})
  - Plateau (8 fl oz A^{-1})
  - Proclipse (1.5 lb ai A^{-1})
  - Esplanade (3.5 or 5 fl oz A^{-1})
  - All included NIS, Confront (1 pt A^{-1}) & Oust XP (1 oz A^{-1})
- Combinations of Fall-only, Spring-Only, or Fall + Spring

Effect of warm-season release treatments and application timings on annual ryegrass (*Lolium multiflorum* L.) cover.[a]

	16 wk after fall treatment			40 wk after fall treatment		
Herbicide (amount A^{-1})[d]	Fall	F + S	Spring	Fall	F + S	Spring
	% ryegrass cover					
Plateau (PLAT; 8 fl oz)	20	27	23	20	17	30
Intensity (INT; 1 pt)	20	25	25	17	23	23
Plateau (8 fl oz) + Proclipse (PRO; 1.5 lb)	0	0	23	0	0	23
Plateau (8 fl oz) + Esplanade (ESP; 3.5 fl oz)	0	0	20	0	0	20
Plateau (8 fl oz) + Esplanade (5 fl oz)	0	0	25	0	0	23
Intensity (1 pt) + Proclipse (1.5 lb)	0	0	30	0	0	17
Intensity (1 pt) + Esplanade (3.5 fl oz)	0	0	23	0	0	27
Intensity (1 pt) + Esplanade (5 fl oz)	0	0	30	0	0	30
PLAT (8 fl oz) + PRO (1.5 lb) fb PLAT (8 fl oz) + ESP (3.5 fl oz)	---	0	---	---	0	---
PLAT (8 fl oz) + PRO (1.5 lb) fb PLAT (8 fl oz) + ESP (5 fl oz)	---	0	---	---	0	---
PLAT (8 fl oz) + ESP (3.5 fl oz) fb PLAT (8 fl oz) + PRO (1.5 lb)	---	0	---	---	0	---
PLAT (8 fl oz) + ESP (5 fl oz) fb PLAT (8 fl oz) + PRO (1.5 lb)	---	0	---	---	0	---
INT (1 pt) + PRO (1.5 lb) fb INT (1 pt) + ESP (3.5 fl oz)	---	0	---	---	0	---
INT (1 pt) + PRO (1.5 lb) fb INT (1 pt) + ESP (5 fl oz)	---	0	---	---	0	---
INT (1 pt) + ESP (3.5 fl oz) fb INT (1 pt) + PRO (1.5 lb)	---	0	---	---	0	---
INT (1 pt) + ESP (5 fl oz) fb INT (1 pt) + PRO (1.5 lb)	---	0	---	---	0	---
Nontreated		27			33	
$LSD_{0.05}$		10			12	

[a] Abbreviations: F, fall; S, spring.

[b] Research conducted on a roadside in Wake County, NC

[c] Fall application: 24 Sep. 2013; Spring application: 27 May 2014.

[d] All herbicide treatments included Confront (1 pt A^{-1}), Oust XP (1 oz A^{-1}) and NIS (0.25% v/v)

Effect of warm-season release treatments and application timings on vaseygrass (*Paspalum urvillei* Steud.) cover 48 wk after fall treatment.[a]

Herbicide (amount A^{-1})[d]	2013 to 2014 Fall	2013 to 2014 F + S	2013 to 2014 Spring	2014 to 2015 Fall	2014 to 2015 F + S	2014 to 2015 Spring
	% vaseygrass cover					
Plateau (PLAT; 8 fl oz)	57	25	25	45	22	25
Intensity (INT; 1 pt)	25	25	40	18	11	40
Plateau (8 fl oz) + Proclipse (PRO; 1.5 lb)	17	13	20	31	11	16
Plateau (8 fl oz) + Esplanade (ESP; 3.5 fl oz)	27	30	35	25	13	26
Plateau (8 fl oz) + Esplanade (5 fl oz)	27	14	32	28	11	19
Intensity (1 pt) + Proclipse (1.5 lb)	4	5	30	12	10	41
Intensity (1 pt) + Esplanade (3.5 fl oz)	12	5	25	13	8	29
Intensity (1 pt) + Esplanade (5 fl oz)	12	8	33	7	6	35
PLAT (8 fl oz) + PRO (1.5 lb) fb PLAT (8 fl oz) + ESP (3.5 fl oz)	---	14	---	---	23	---
PLAT (8 fl oz) + PRO (1.5 lb) fb PLAT (8 fl oz) + ESP (5 fl oz)	---	17	---	---	16	---
PLAT (8 fl oz) + ESP (3.5 fl oz) fb PLAT (8 fl oz) + PRO (1.5 lb)	---	18	---	---	27	---
PLAT (8 fl oz) + ESP (5 fl oz) fb PLAT (8 fl oz) + PRO (1.5 lb)	---	18	---	---	22	---
INT (1 pt) + PRO (1.5 lb) fb INT (1 pt) + ESP (3.5 fl oz)	---	13	---	---	6	---
INT (1 pt) + PRO (1.5 lb) fb INT (1 pt) + ESP (5 fl oz)	---	9	---	---	12	---
INT (1 pt) + ESP (3.5 fl oz) fb INT (1 pt) + PRO (1.5 lb)	---	18	---	---	8	---
INT (1 pt) + ESP (5 fl oz) fb INT (1 pt) + PRO (1.5 lb)	---	7	---	---	2	---
Nontreated		52			36	
$LSD_{0.05}$		18			12	

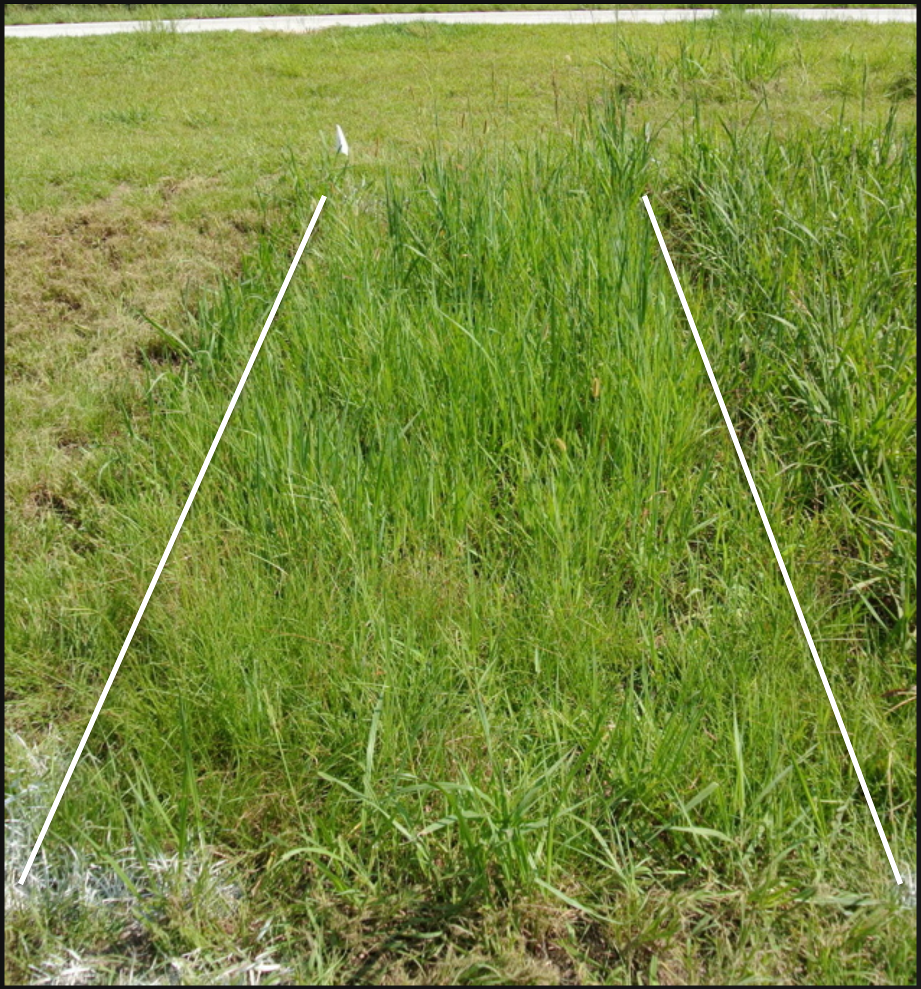
[a] Abbreviations: F, fall; S, spring.

[b] Research conducted on a roadside in Craven County, NC

[c] Fall application: 10 Oct. 2013 and 20 Sep. 2014; Spring application: 08 Jun. 2014 and 17 Jun. 2015.

[d] All herbicide treatments included Confront (1 pt A^{-1}), Oust XP (1 oz A^{-1}) and NIS (0.25% v/v)

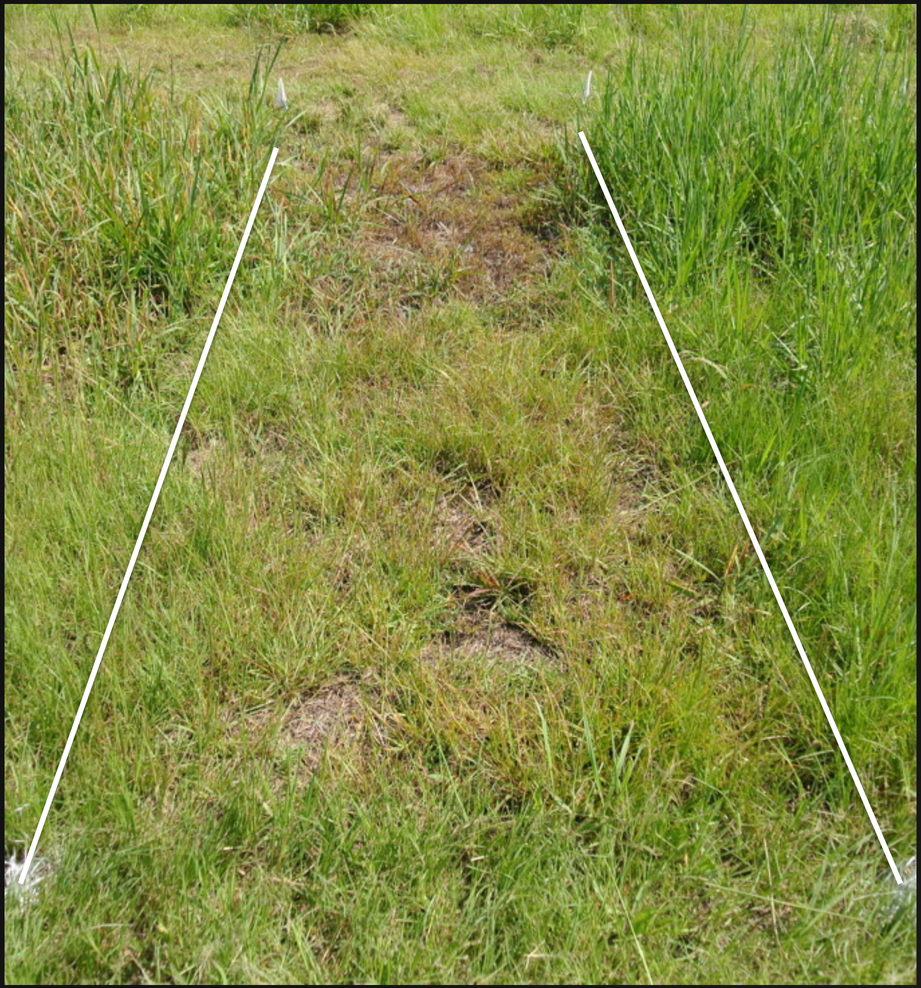
Vaseygrass 6 Weeks After Spring Trt - 2014



Plateau fb Plateau

Nontreated

Vaseygrass 6 Weeks After Spring Trt - 2014



Intensity fb Intensity

Nontreated

Conclusions

- PRE herbicides:
  - effectively controlled annual ryegrass (fall-applied)
  - reduced vaseygrass cover (spring-applied)
- Minimal differences observed between PREs
- Vaseygrass control
  - Single application: Plateau in spring; Intensity in Fall
  - Best treatments were Intensity in Fall and Spring + PRE

Objectives

- Tall fescue roadside mowing reduction from Plateau
- Vaseygrass control
- Warm-season release programs
- Simulated Esplanade drift affects on NC plants
- Zoysiagrass sod establishment along guardrails
- Warm-season turfgrass seeding on roadsides

NC STATE
TURF RESEARCH

Esplanade™ 200 SC

- Loading rate
  - 200 g ai L^{-1}
- Plant activity
  - PRE control of annual broadleaves and grasses
- Use sites
  - Roadsides, rights-of-way, hardscapes, railroads, non-irrigated ditch banks, etc.

NC STATE TURF RESEARCH

Esplanade

Off-target plant injury may occur from drift via:

1. PRE application to soil prior to crop planting/ transplanting
2. POST application on crop foliage

NC STATE TURF RESEARCH

Materials and Methods

- Plant species evaluated
  - Portion grown in Southeast US, 2011*
    - Squash - 44%
    - Bell pepper - 45%
    - Cotton lint - 40%
    - Soybean - 15%
    - Tobacco - 90%
    - Tomato - 21%

NC STATE TURF RESEARCH

* USDA Economic Research Service. 2013. Farm Income and Wealth Statistics.

Materials and Methods

- Simulated spray drift rates evaluated
- Esplanade
  - 100%
  - 20%
  - 10%
  - 5%
  - 2.5%
- Milestone
  - 10%
- Streamline
  - 10%
- Confront
  - 10%
- Oust XP
  - 10%

NC STATE TURF RESEARCH

Materials and Methods

- Simulated spray drift rates evaluated
- Esplanade
  - 100%
  - 20%
  - *10%*
  - 5%
  - 2.5%
- Milestone
  - *10%*
- Streamline
  - *10%*
- Confront
  - *10%*
- Oust XP
  - *10%*

NC STATE TURF RESEARCH

Results

Table 1. Average dry above-ground biomass reductions from PRE 10% simulated drift rates 70 d after treatment.[1, 2]

Herbicide	% drift	Cotton	Pepper	Soybean	Squash	Tobacco	Tomato	*Avg.*
		% reduction						
Esplanade	10	18*	90	88	21*	12*	9*	*40*
Milestone	10	90	98	100	49	77	60	*79*
Streamline	10	67	95	94	82	33	52	*71*
Confront	10	54	73	100	89	35	82	*72*
Oust XP	10	71	39*	40*	89	20	18	*46*
Avg.		*60*	*79*	*84*	*66*	*35*	*44*	

[1] Abbreviations: PRE, pre-emergent; A.I., active ingredient; INDAZ, indaziflam; AMNP, aminopyralid; AMCP, aminocyclopyrachlor; MET, metsulfuron; CLOP, clopyralid; TRI, triclopyr; SULFO, sulfometuron.

[2] Plant material dried for 7 d at 70 °C

NC STATE TURF RESEARCH

Results

Table 1. Average dry above-ground biomass reductions from POST 10% simulated drift rates 70 d after treatment.[1, 2]

Herbicide	% drift	Cotton	Pepper	Soybean	Squash	Tobacco	Tomato	*Avg.*
		% reduction						
Esplanade	10	20*	36*	41*	42	18*	50	***35***
Milestone	10	89	88	98	17*	90	91	***79***
Streamline	10	49	86	50	42	75	77	***63***
Confront	10	44	80	96	68	37	91	***69***
Oust XP	10	36	43	48	29	23	25*	***34***
Avg.		***48***	***67***	***67***	***40***	***49***	***67***	

[1] Abbreviations: POST, post-emergent; A.I., active ingredient; INDAZ, indaziflam; AMNP, aminopyralid; AMCP, aminocyclopyrachlor; MET, metsulfuron; CLOP, clopyralid; TRI, triclopyr; SULFO, sulfometuron.

[2] Plant material dried for 7 d at 70 °C

NC STATE TURF RESEARCH

PRE Soybean 70 DAT[1,2]


Nontreated


Esplanade (10%)[3]


Milestone (10%)


Streamline (10%)


Confront (10%)

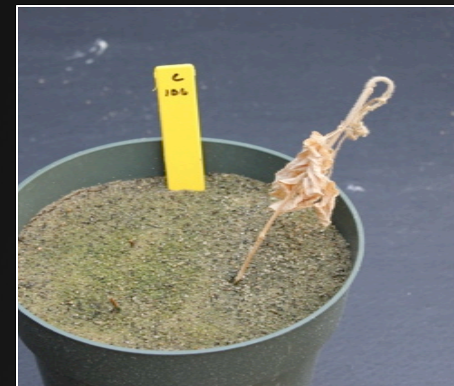

Oust XP (10%)

[1] Abbreviations: PRE, pre-emergence; DAT, days after treatment.
[2] Images taken 1-11-13.
[3] Herbicide (% simulated drift rate).

POST Soybean 70 DAT[1,2]

Nontreated

Esplanade (10%)[3]



Milestone (10%)

Streamline (10%)

Confront (10%)

Oust XP (10%)

[1] Abbreviations: POST, post-emergence; DAT, days after treatment.
[2] Images taken 2-12-13.
[3] Herbicide (% simulated drift rate).

PRE Tobacco 70 DAT[1,2]

Nontreated

Esplanade (10%)[3]

Milestone (10%)

Streamline (10%)

Confront (10%)

Oust XP (10%)

[1] Abbreviations: PRE, pre-emergence; DAT, days after treatment.
[2] Images taken 1-11-13.
[3] Herbicide (% simulated drift rate).

POST Tobacco 70 DAT[1,2]


Nontreated


Esplanade (10%)[3]


Milestone (10%)


Streamline (10%)

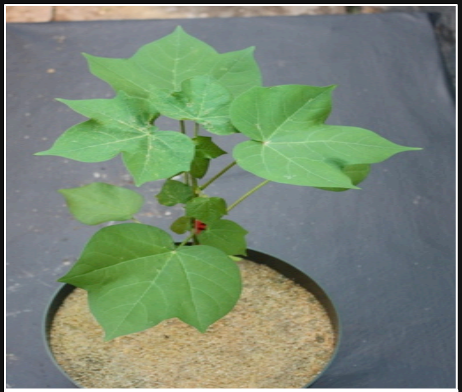

Confront (10%)


Oust XP (10%)

[1] Abbreviations: POST, post-emergence; DAT, days after treatment.
[2] Images taken 2-12-13.
[3] Herbicide (% simulated drift rate).

PRE Cotton 70 DAT[1,2]

Nontreated



Esplanade (10%)[3]

Milestone (10%)

Streamline (10%)

Confront (10%)

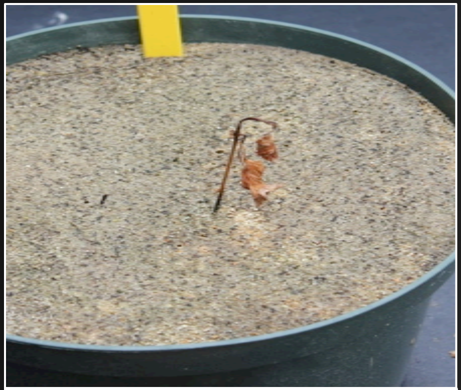
Oust XP (10%)

[1] Abbreviations: PRE, pre-emergence; DAT, days after treatment.
[2] Images taken 1-11-13.
[3] Herbicide (% simulated drift rate).

POST Cotton 70 DAT[1,2]

Nontreated

Esplanade (10%)[3]



Milestone (10%)

Streamline (10%)

Confront (10%)

Oust XP (10%)

[1] Abbreviations: POST, post-emergence; DAT, days after treatment.
[2] Images taken 2-12-13.
[3] Herbicide (% simulated drift rate).

Conclusions

- Across all evaluated parameters, Esplanade at 10% simulated drift rate provided comparable/superior plant safety to all other herbicides when applied:
  - PRE: squash and tomato
  - POST: pepper and soybean
  - PRE and POST: cotton and tobacco

NC STATE
TURF RESEARCH

Conclusions

- 2.5% Esplanade drift reduced > 20% root mass on:
  - Cotton (POST)
  - Pepper (PRE and POST)
  - Soybean (PRE and POST)
  - Squash (PRE)
  - Tomato (POST)

NC STATE TURF RESEARCH

Objectives

- Tall fescue roadside mowing reduction from Plateau
- Vaseygrass control
- Warm-season release programs
- Simulated Esplanade drift affects on NC plants
- Zoysiagrass sod establishment along guardrails
- Warm-season turfgrass seeding on roadsides

NC STATE
TURF RESEARCH

Locations

- Elkin, Wilkes County; Highway 421
  - Weather Station: Wilkes County Airport (KUKF)
- Siler City, Chatham County; Highway 421
  - Weather Station: Siler City Airport (K5W8)
- Sanford, Lee County; Sanford Bypass
  - Weather Station: Lee County Airport (KTTA)

NC STATE
TURF RESEARCH

Sod Prep Techniques

- Sod cutter
  - 21” strips cut; cutting depth adjusted to match sod
  - Debris removed with hand tools
- Till Only
  - 24” strips tilled to 4” depth
  - Debris not removed
- Till + Rake (Furrow)
  - 24” strips tilled to 4” depth
  - Debris removed with hand tools to create 2” furrow

NC STATE
TURF RESEARCH

Sod Cutter

NC STATE
TURF RESEARCH

Till-only

NC STATE
TURF RESEARCH

Till + Furrow

NC STATE
TURF RESEARCH

Plot Overview
Lee County

NC STATE
TURF RESEARCH

Materials and Methods

- Sod install timings
  - Late December
  - Mid-March
  - Mid-April
  - Mid-May
- Zoysia cultivars
  - ‘Meyer’
  - ‘El Toro’
  - ‘Zeon’
- Data collection
  - Water inputs
  - Weather records
  - Turf
    - Spring greenup
    - Cover
    - Lateral spread

NC STATE
TURF RESEARCH

Results

NC STATE
TURF RESEARCH

Zoysia Sod Cover

Location X Cultivar X Establishment Timing

125 Weeks After Initial Planting

		Year 1				Year 2			
Location	Cultivar	Dec.	Mar.	Apr.	May	Dec.	Mar.	Apr.	May
		% cover							
Chatham	El Toro	82	82	80	80	58	46	59	48
---	Meyer	90	89	88	83	44	38	56	43
---	Zeon	82	80	69	63	54	28	47	26
Lee	El Toro	58	52	64	58	56	59	50	33
---	Meyer	68	72	74	88	27	57	61	20
---	Zeon	77	70	58	32	33	67	61	25
Yadkin	El Toro	77	71	53	31	41	38	9	61
---	Meyer	77	76	52	35	14	36	27	57
---	Zeon	67	62	35	24	47	37	8	62
$LSD_{0.05}$[e]		12				14			

NC STATE TURF RESEARCH

Zoysia Sod Cover

Planting Technique

40 to 125 Weeks After Initial Planting

Method	Year 1			Year 2		
	40WAIP	90 WAIP	125 WAIP	40 WAIP	90 WAIP	125 WAIP
	% cover					
Strip	62	65	62	29	29	39
Till-alone	64	70	67	34	31	46
Till + prep	68	74	71	35	31	44
$LSD_{0.05}$[e]	3	3	4	4	NS	4

NC STATE TURF RESEARCH

Zoysia Sod Spread

Location X Cultivar

125 Weeks After Initial Planting

Location	Cultivar	Year 1	Year 2
		% spread[c]	
Chatham	El Toro	52	22
---	Meyer	35	0
---	Zeon	26	10
Lee	El Toro	25	24
---	Meyer	18	0
---	Zeon	13	10
Yadkin	El Toro	16	15
---	Meyer	8	2
---	Zeon	5	5
$LSD_{0.05}$[d]		9	4

NC STATE TURF RESEARCH

Zoysia Sod Spread

Planting Technique

125 Weeks After Initial Planting

Method	Year 1	Year 2
	% spread[c]	
Strip	24	9
Till-alone	33	12
Till + prep	35	13
$LSD_{0.05}$[d]	5	3

NC STATE
TURF RESEARCH

Zoysia Cover 281 - 260 DAI

- Dec/17/13 - Jan/7/13 installation timing -

‘Zeon’

‘El Toro’

‘Meyer’

NC STATE TURF RESEARCH

Sanford Bypass; Lee County. Images taken Sep-14-13.

Zoysia Cover 197 DAI

- Mar/11/13 installation timing -

'Zeon'

'El Toro'

'Meyer'

NC STATE TURF RESEARCH

Sanford Bypass; Lee County. Images taken Sep-14-13.

Zoysia Cover 162 DAI

- *Apr/15/13 installation timing* -

'Zeon'

'El Toro'

'Meyer'

NC STATE TURF RESEARCH

Sanford Bypass; Lee County. Images taken Sep-14-13.

Zoysia Cover 134 DAI

- *May/13/13 installation timing* -

'Zeon'

'El Toro'

'Meyer'

NC STATE TURF RESEARCH

Sanford Bypass; Lee County. Images taken Sep-14-13.

Zoysia Sod Survival Conclusions

- Install timings
  - December = March > April > May
- Zoysia cultivar
  - ‘El Toro’ > ‘Zeon’ = ‘Meyer’
- Install techniques
  - Till + Rake = Till > Sod Cutter
    - Till-alone recommended due to less labor required
- Locations
  - Siler City > Sanford = Elkin

NC STATE TURF RESEARCH

Zoysia Sod Spread Conclusions

- Install timings
  - December = March = April = May
- Zoysia cultivar
  - ‘El Toro’ > ‘Zeon’ = ‘Meyer’
- Install techniques
  - Till + Rake = Till > Sod Cutter
    - Tillage disturbed more soil surrounding sod strip
- Locations
  - Siler City > Sanford = Elkin

NC STATE
TURF RESEARCH

Zoysia Sod Spread Conclusions

- Install timings
  - December = March = April = May
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  - ‘El Toro’ > ‘Zeon’ = ‘Meyer’
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NC STATE TURF RESEARCH

Zoysia Sod Spread Conclusions

NC STATE
TURF RESEARCH

Objectives

- Tall fescue roadside mowing reduction from Plateau
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- Warm-season turfgrass seeding on roadsides

NC STATE TURF RESEARCH

Seeded Zoysia/Bermuda on Roadsides

- Locations
  - Interstate 40; Orange County
  - Sanford Bypass; Lee County
- Evaluated species
  - ‘Zenith’ zoysiagrass
  - ‘Riviera’ hybrid bermudagrass
- Seed establishment rates: 22 or 33 lb PLS A^{-1}
- Seed dates
  - 3/20/13; 3/27/14 (Roundup app before seeding in yr 2)
  - 4/24/13; 4/22/14
  - 6/17/13; 5/22/14

NC STATE
TURF RESEARCH

Seeded Zoysia/Bermuda on Roadsides

- Locations
  - Interstate 40; Orange County
  - Sanford Bypass; Lee County
- Evaluated species
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  - 4/24/13; 4/22/14
  - 6/17/13; 5/22/14

NC STATE TURF RESEARCH

Seeded Zoysia/Bermuda on Roadsides

- Locations

  - 4/24/13; 4/22/14
  - 6/17/13; 5/22/14

NC STATE
TURF RESEARCH

Seeded Zoysia/Bermuda on Roadsides

- To date, <5% germination has not been observed across both species, seeding rates, and locations
  - Likely due to:
    - Inadequate soil moisture
    - Soil compaction
    - Light competition from established vegetation

Interstate 40; Orange County. Image taken Apr-24-2013 at seeding.

NC STATE TURF RESEARCH

Based on this Research…

- Plateau reduces tall fescue mowing
- Vaseygrass control is difficult, but possible
- WSR provides control of troublesome weeds
- Esplanade drift generally should not be an issue
- Zoysia sod can be successfully established along NC guardrails
- Bermuda and zoysia seeding is not recommended

NC STATE
TURF RESEARCH

Questions???

NC STATE
TURF RESEARCH