OGCSA Pest Management Webinar Series

Thank you for joining us.

We will begin at the top of the hour.

Presented By

Simplot
PARTNERS


J.T. BROSNAN, PH.D
@UTTURFWEEDS
WEED CONTROL OVERVIEW - NATURALIZED AREAS TO RESISTANCE MANAGEMENT


OLD COURSE HOTEL

2013 US Open - Merion


2014 US Open - Pinehurst #2

2015 US Open - Chambers Bay

Photo via google.com

OTHER THAN MAJORS

WHAT'S DRIVING THIS?

Photo courtesy of Josh Cook, Oak Tree National GC


E-Z-GO
MEANS TO
REDUCE MOWING

OTHER BENEFITS

- Wildlife and pollinator habitat
- Water conservation
- Reducing fuel use
- Free labor for other projects

AREAS REQUIRE

SPECIALIZED MANAGEMENT

AREAS REQUIRE

SPECIALIZED MANAGEMENT

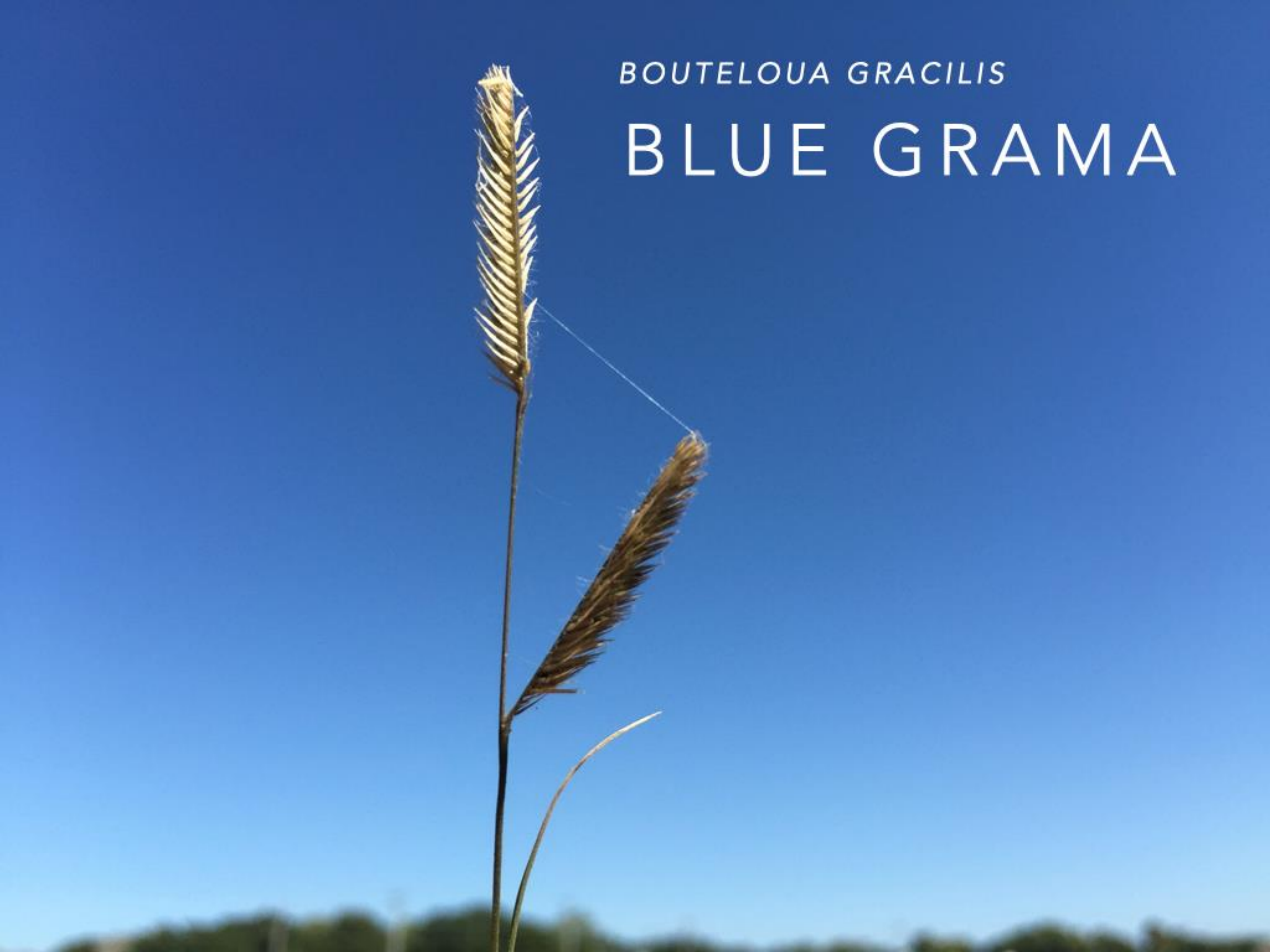
MOST COMMON

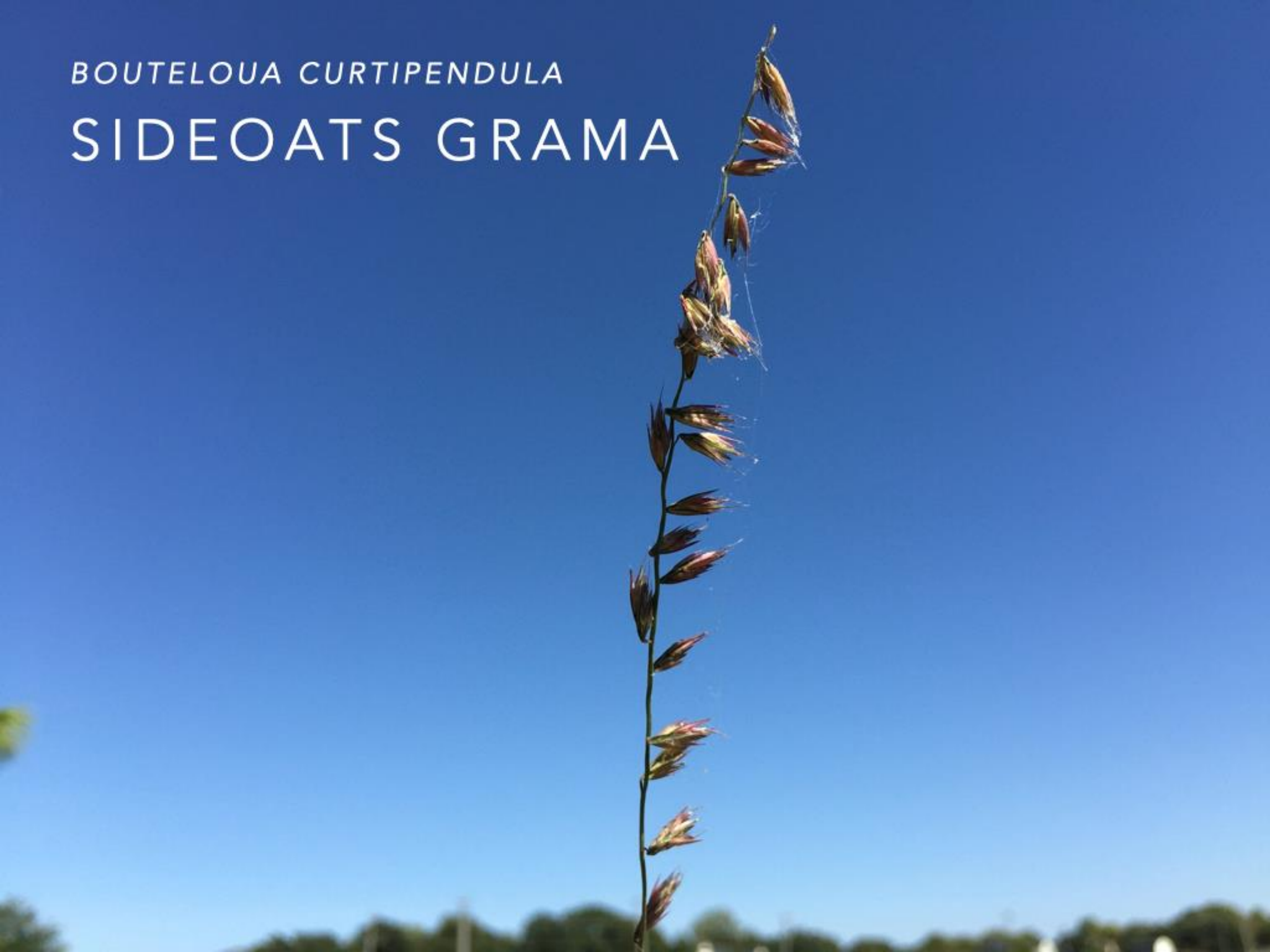
SPECIES USED

COOL-SEASON

FINE FESCUES


FedEx
St. Jude
Classic
PGA


BOUTELOUA GRACILIS
BLUE GRAMA


BOUTELOUA CURTIPENDULA
SIDEOATS GRAMA


Miscanthis


Ravenna Grass


Big Bluestem


Pennisetum

MANY OTHERS



GENERAL TRENDS

- Foundation of program is a spring PRE
    - Establishment year is VERY difficult
- Difficulty applying POST (tracking)
    - May need to spot spray
    - Specialized nozzles?
- Mowing/Burning during winter on C4 species

STARTS WITH

SPECIES SELECTION

University of Minnesota
Driven to Discover®

One Stop MyU: For Students, Faculty, and Staff

ENHANCED BY Google

Low Input Turf

Home | Project Objectives | Current Research | Resources | Our Team | News | Previous Research

Low Input Turf Using Fine Fescues

Video: Optimal Seeding Timings for Fineleaf Fescue from Rutgers University ›

Turfgrass researchers from Rutgers recently produced many interesting videos as part of their 2020 Virtual Turfgrass Research Field Day. This video features Brad Park, a laboratory researcher at Rutgers who conducts research as part of our Low Input Turf project, discussing research on optimal seeding times for fine fescues.

Read more >>>

Tuesdav. October 27. 2020 - 13:00

Follow us on social media!

Twitter

Facebook

Where to go for fine fescue information?

lowinputturf.umn.edu

FINE FESCUES

- Creeping red fescue (*Festuca rubra*)
    - Strong creeping red fescue (*Festuca rubra* spp. rubra)
    - Slender creeping red fescue (*Festuca rubra* spp. littoralis)
- Hard fescue (*Festuca brevipilla*)
- Chewing's fescue (*Festuca rubra* spp. fallax)
- Sheep fescue (*Festuca avina)*

TOLERANCES

	GROWTH	FULL SUN	SHADE	H20	SEED VIGOR
STRONG CR	RHIZ.	POOR	GOOD	FAIR	GOOD
SLENDER CR	SHORT RHIZ.	POOR	GOOD	GOOD	FAIR
HARD	BUNCH	GOOD	FAIR	GOOD	FAIR
CHEWING'S	BUNCH	FAIR	GOOD	GOOD	FAIR
SHEEP	BUNCH	GOOD	FAIR	EXC.	FAIR

Info via. Aaron Patton, Ph.D.

MIXTURES FOR ROUGHS

- Hard fescue (40%)
- Sheep fescue (40%)
- Creeping red (10%)
- Chewing's (10%)

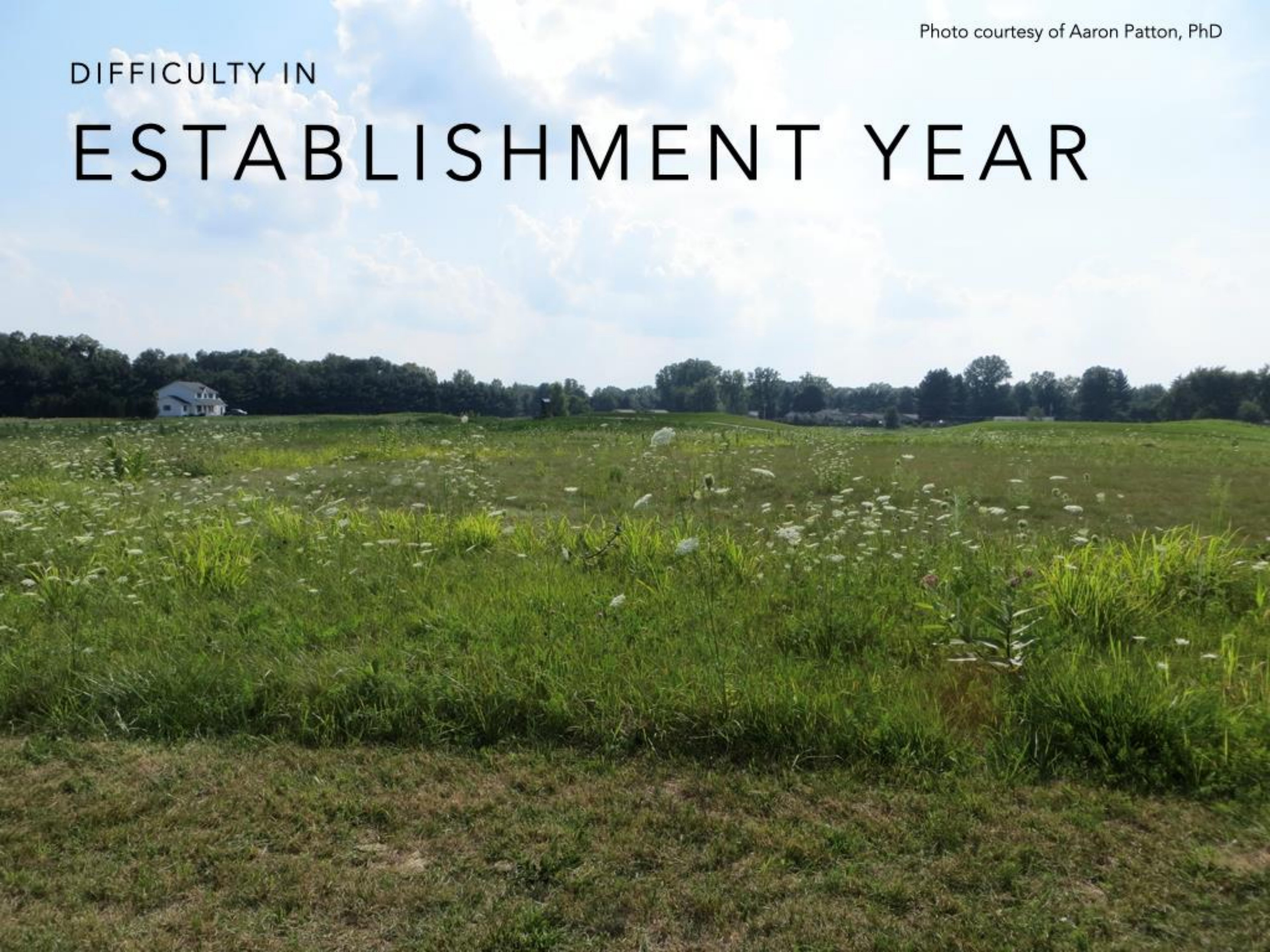


Photo courtesy of Aaron Patton, PhD
DIFFICULTY IN
ESTABLISHMENT YEAR

ESTABLISHMENT

- Slow to establish from seed (germination in 7-10 days)
- Typical rate is 5 lb/M
- Seed does not store well
  - Germination % test
  - Don't use material older than 6 months
- Mowing (after tillering) can help reduce weed pressure in establishment year

Info via. Aaron Patton, Ph.D.

MOWING

- Spring & Fall
  - Not in summer
  - Moisture stress (traffic?)
- Heights > 3 inches
- Reduced to 2-3 times annually
- Grow 6 to 12 inches in height

NUTRITION

- 2 lb N/M in year one, sequentially at seeding
- 1 lb N/M after establishment
    - Possibility to skip a year
- Tolerate wide range of soil pH

Info via. Aaron Patton, Ph.D.

PEST MANAGEMENT

- Herbicide use discouraged in establishment year
  - POST products for BLW after mature enough to mow
  - Some phyto possible
- Fine fescue will be injured by chlorothalonil

Info via. Aaron Patton, Ph.D.

FINE FESCUE HERBICIDES - PRE

- Pendulum AquaCap (pendimethalin)
- Barricade (prodiamine)
- Dimesnion (dithiopyr)
- Echelon (prod.+ sulfentrazone)
- Gallery (isoxaben)
- Crew (isoxaben + dithiopyr)
- Tupersan (siduron)
- Tower (dimethenamid-P)
- Balan (benefin)

GROUP **1** HERBICIDE

PULL HERE TO OPEN

Fusilade® II

Turf and ornamental herbicide

syngenta

Herbicide

For the control of grass weeds in landscape areas, roadsides, nurseries, greenhouses, flower beds, groundcovers, interiorscapes, parks, sports fields, golf courses, commercial and residential areas.

Active Ingredient:	
Fluazifop-P-butyl	
Butyl (*R*)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoate*	24.5%
Other Ingredients	75.5%
Total:	100.0%

Grass Weed Control in Fine Fescue turfgrass (Chewings, hard and creeping red fescue): Apply at 8-16 fl oz/A with a nonionic surfactant to actively growing grass (monocot) weeds. Application can be repeated after 28 days. Applications at the boot stage may reduce Fine Fescue seedheads. Use a minimum of 30 gallons water per acre. Only Fine Fescues are tolerant to these rates of Fusilade II Turf and Ornamental Herbicide.

FINE FESCUE HERBICIDES - POST

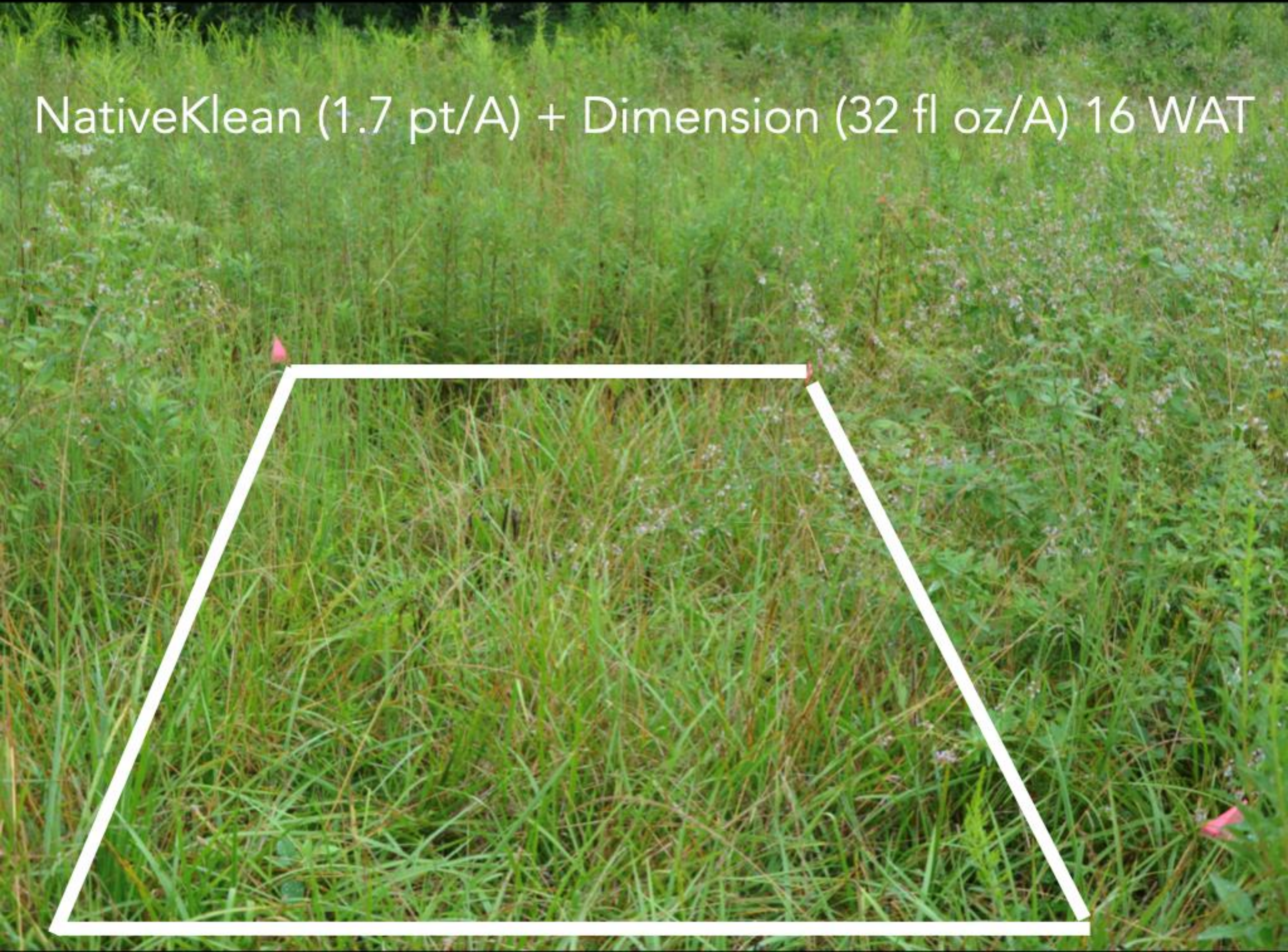
- Segment (sethoxydim)
- Acclaim Extra (fenoxaprop)
- Tenacity (mesotrione)
- Pylex (topramezone)
- SedgeHammer (halosulfuron)

- Drive XLR8 (quinclorac)
- Confront (triclopyr + clopyralid)
- Xonerate (amicarbazone)
- Dismiss (sulfentrazone)
- Quicksilver (carfentrazone)

- 2,4-D, Dicamba
- Numerous mixtures:
  - Escalade 2
  - Trimec
  - Powerzone
  - Speedzone
  - Q-4 Plus
  - Millenium Ultra 2
  - Momentum FX2
  - T-Zone

NativeKlean™
HERBICIDE

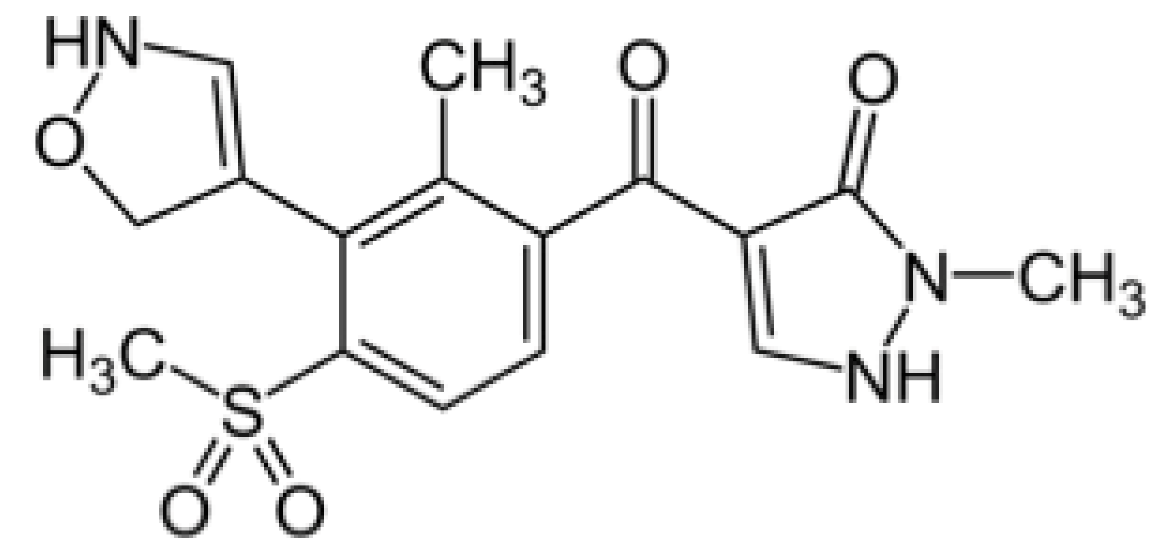
- New herbicide from Corteva
- Aminopyralid + 2,4-D (WSSA Group #4)
- 1.5 to 2.1 pt/A, max for year is 2.1 pt/A
- Timing based on target, e.g. Canada thistle = fall
- POST activity versus BLW with residual
    - Effective versus tall ironweed & Serecia lespedeza
    - May need pyridine for some species (e.g., Milkweed)


NativeKlean (1.7 pt/A) + Dimension (32 fl oz/A) 16 WAT


Non-treated check
at 16 WAT

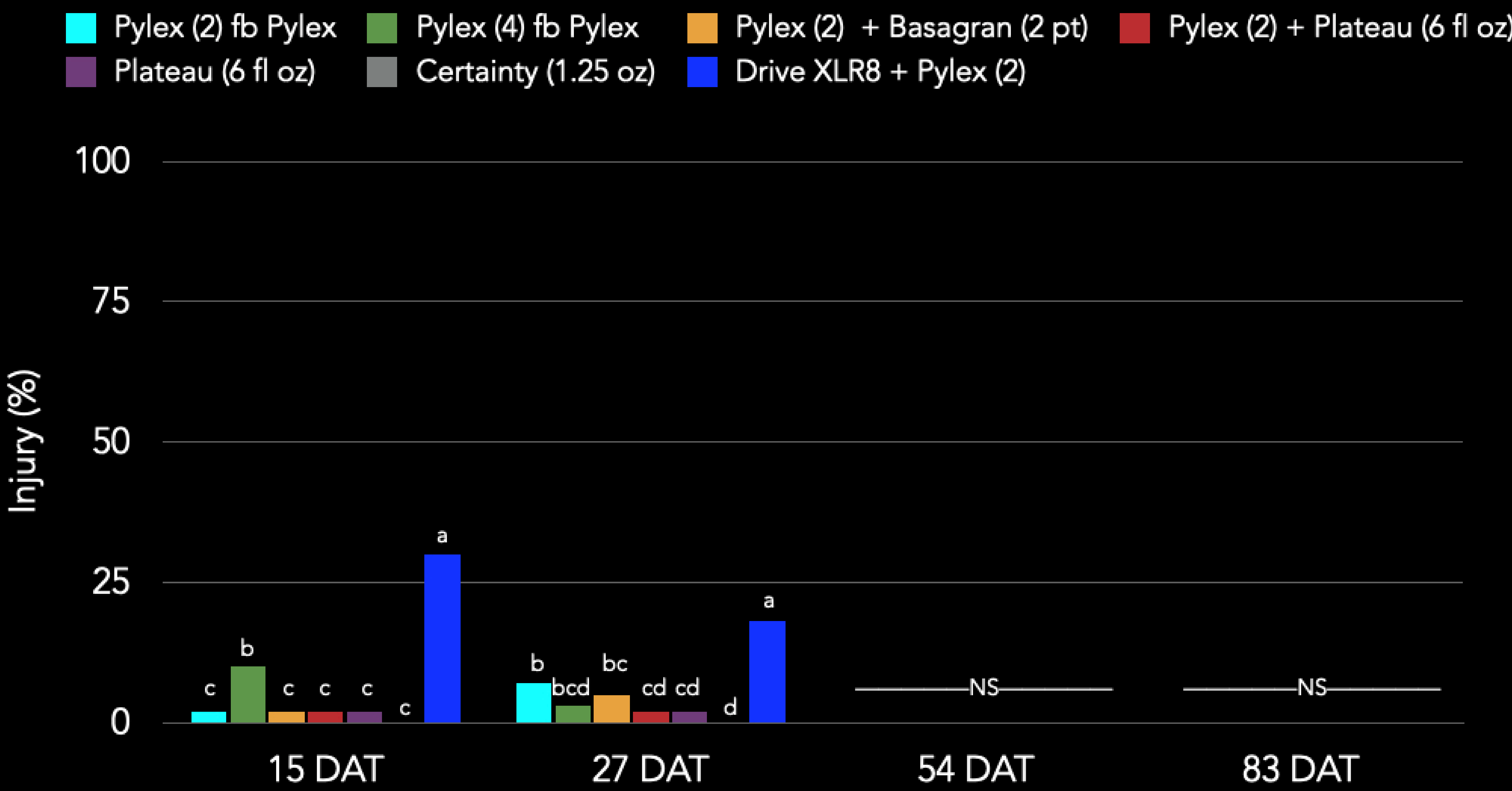
Pylex

- Topramezone
- HPPD inhibitor
- Grassy weed control
- Tall fescue, KBG, PR, FF….CBG?
- Rates of 0.5 to 2.0 fl oz/A with MSO surfactant
- Yearly max at 4 fl oz/A



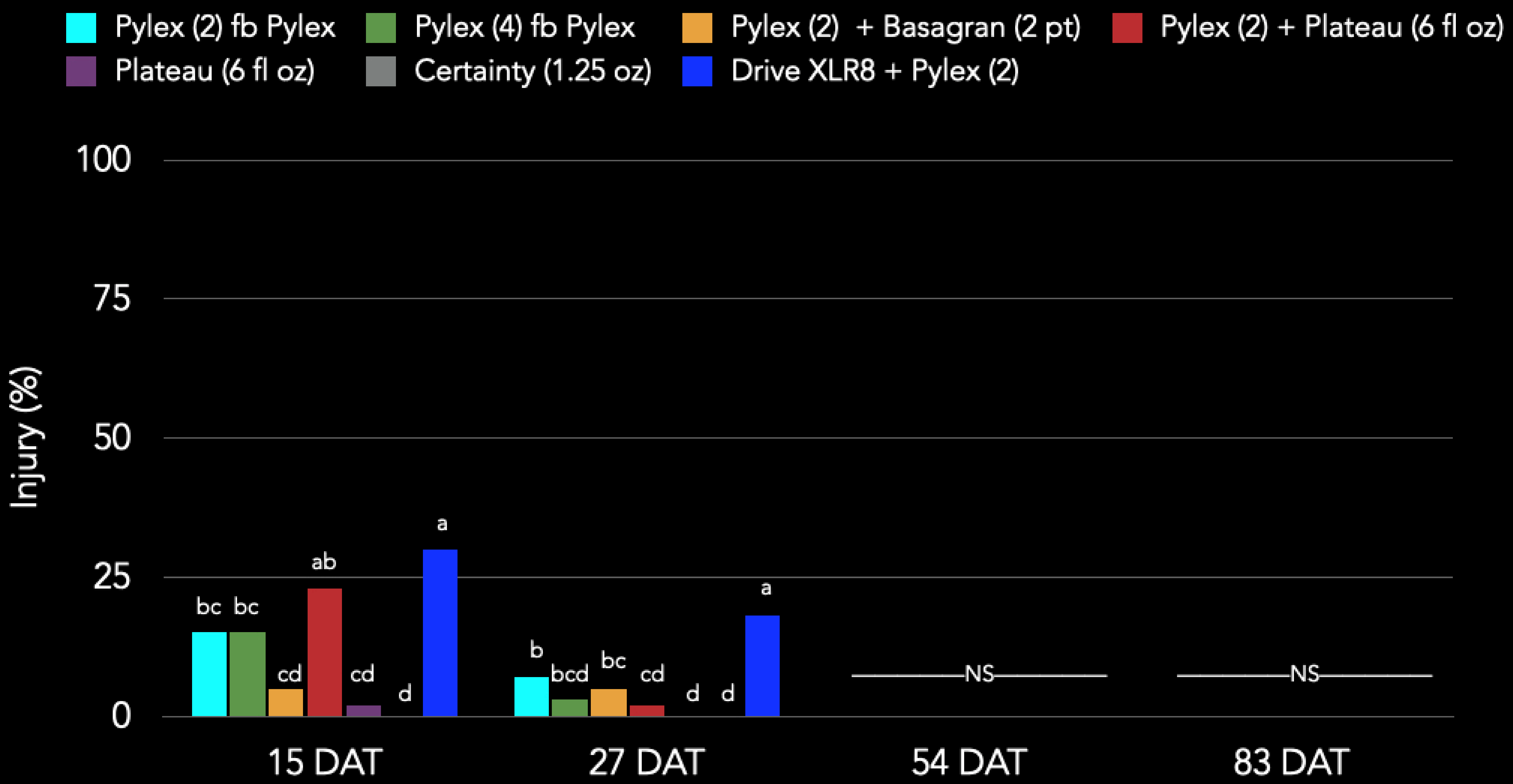

Safe for use in fine fescue naturalized areas with triclopyr as high as 3 fl oz/A

LITTLE BLUESTEM TOLERANCE



Treatments applied 13 May and 6 July at Lambert Acres G.C. (Alcoa, TN)
Means followed by same letter are not statistically different (P = 0.05)
All treatments included adjuvant according to label recommendations

WEEPING LOVEGRASS TOLERANCE



Treatments applied 13 May and 6 July at Lambert Acres G.C. (Alcoa, TN)
Means followed by same letter are not statistically different (P = 0.05)
All treatments included adjuvant according to label recommendations


RESEARCH ON
ORNAMENTAL GRASS TOLERANCE

HortScience 53(6):842–849. 2018. https://doi.org/10.21273/HORTSCI12989-18

Tolerance of Native and Ornamental Grasses to Over-the-top Applications of Topramezone Herbicide

S. Christopher Marble[1]
Department of Environmental Horticulture, University of Florida, Institute of Food and Agricultural Sciences, Mid-Florida Research and Education Center, 2725 South Binion Road, Apopka, FL 32703; and Department of Plant Sciences, University of Tennessee, 2431 Joe Johnson Drive, Knoxville, TN 37996

Matthew T. Elmore
Department of Plant Biology, School of Environmental and Biological Sciences, Rutgers, The State University of New Jersey, 59 Dudley Road, New Brunswick, NJ 08901

James T. Brosnan
Department of Plant Sciences, University of Tennessee, 2431 Joe Johnson Drive, Knoxville, TN 37996

Additional index words. landscape, golf course, natural areas, turf, weed control

Abstract. **Research was conducted to determine the tolerance of multiple native and ornamental grass species and one ornamental sedge species to over-the-top applications of the postemergence herbicide topramezone at three locations in the southeastern United States in 2016 and 2017. Fully rooted liners of selected grass species were outplanted into research plots in Apopka, FL; Dallas, TX; and Knoxville, TN in late spring, allowed time to establish (≈1–2 months) and then treated with two applications of topramezone at either 0.05 or 0.10 kg a.i./ha at 6–8 weeks intervals. Results showed that species including *Andropogon virginicus* (broomsedge), *Schizachyrium scoparium* 'The Blues' (little bluestem), *Tripsacum dactyloides* (eastern gamagrass), and *Tripsacum floridanum* (florida gamagrass) exhibited the greatest tolerance to topramezone with <10% injury to no injury being evident after each application of both herbicide rates tested. *Chasmanthium latifolium* (wild oats), *Eragrostis elliottii* 'Wind Dancer', *Muhlenbergia capillaris* (pink muhly), and *Spartina bakeri* (sandcord grass) were significantly injured (50% injury or greater) at both herbicide rates. Average injury observed on *Panicum virgatum* 'Shenandoah' (red switchgrass) (ranging from 39% to 100% injury) and *Sorghastrum nutans* (indian grass) (ranging from 0% to 40% injury) was higher in Florida than in Tennessee (injury ranging from 23% to 43% on red switchgrass and 0% to 10% on indian grass). Similarly, *Pennisetum alopecuroides* (dwarf fountain grass) showed higher tolerance in Texas (ranging from 0% to 34% injury) compared with those observed in Tennessee (ranging from 0% to 53% injury). Topramezone injury to *Carex appalachica* (appalachian sedge) was ≤18% following two applications at both rates tested. Although no injury was observed in appalachian sedge following a single application up to 0.1 kg a.i. in Florida, plants succumbed to heat stress and accurate ratings could not be taken following the second application. Because of variability observed, tolerance of red switchgrass, indian grass, dwarf fountain grass, and appalachian sedge to applications of topramezone deserves further investigation. There is potential for future use of topramezone for control of certain grass and broadleaf weeds growing in and around certain ornamental grass species. However, as there was significant variability in tolerance based on species and differences in cultivars, testing a small group of plants before large-scale application would be recommended.**

(Brzuszek and Harkess, 2009; Ozguner and Kendle, 2006).

Golf courses typically have areas referred to as "natural areas," which are areas on the course beyond the maintained rough (Dunning, 2014). These areas are often promoted for their ecological function (Nelson, 1997) but can present/pose design and maintenance issues for golf course superintendents (Dunning, 2014). These naturalized areas average 25.8 acres or about 17% of the total golf course area (Gelernter et al., 2017), creating a need for readily available, low-input, and aesthetically pleasing plant species in these spaces (Dunning, 2014; Florida Department of Environmental Protection, 2007). Ornamental and native grasses have been previously evaluated to determine their suitability and are now often used in these naturalized areas on golf courses (Dunning, 2014; Maddox et al., 2007; Voigt, 2002; Weston, 1990).

Although many of the most widely planted ornamental grass species are relatively resistant to disease, insect pests, or both (Thetford et al., 2009; Wilson and Knox, 2009), weed control continues to be a challenge for both landscape applicators and golf course superintendents managing large monocultures of ornamental grasses. Most of the research on ornamental grass tolerance to herbicide applications has focused on preemergence (PRE) herbicides labeled for use in container production. Research focusing on container-grown ornamental grasses has shown that many species are tolerant to over-the-top applications of common PRE herbicides including pendimethalin, prodiamine, isoxaben, and others (Cole and Cole, 2007; Glaze et al., 1980; Neal and Senesac, 1991). However, these herbicides would provide little benefit to areas already infested with weeds on golf courses or in landscapes.

A few studies have investigated the impacts of postemergence (POST) herbicides on ornamental grasses. Hubbard and Whitwell (1991) evaluated response of 12 ornamental grasses from nine genera to applications of three graminicides including fenoxaprop-ethyl, fluazifop-P-butyl, and sethoxydim. Significant injury, growth reduction, or both were noted among most species with all three herbicides with the exception of fenoxaprop-ethyl applications to *Calamagrostis arundinacea* 'Karl Foerster'. The authors also reported a high degree of tolerance in two other *Calamagrostis* cultivars [*C. arundinacea*

2016 ORNAMENTAL GRASS TRIAL

TOLERANT

BROOMSEDGE
FEATHER REED GRASS
LITTLE BLUESTEM
FAKAHATCHEE GRASS
MAIDENGRASS

**≤10% INJURY

Similar Results at UF and TAMU

2016 ORNAMENTAL GRASS TRIAL

TOLERANT

BROOMSEDGE
FEATHER REED GRASS
LITTLE BLUESTEM
FAKAHATCHEE GRASS
MAIDENGRASS

**≤10% INJURY

MARGINAL

DWARF FOUNTAINGRASS

SWITCHGRASS

**INJURY BUT RECOVERY

Similar Results at UF and TAMU

2016 ORNAMENTAL GRASS TRIAL

TOLERANT

BROOMSEDGE
FEATHER REED GRASS
LITTLE BLUESTEM
FAKAHATCHEE GRASS
MAIDENGRASS

**≤10% INJURY

MARGINAL

DWARF
FOUNTAINGRASS

SWITCHGRASS

**INJURY BUT
RECOVERY

AVOID

PRAIRIE DROPSEED
RIVER OATS
MUHLY GRASS
LOVEGRASS

** UP TO 73% INURY

Similar Results at UF and TAMU

2015 Fescue Native Areas Budget

		4	5	4	4	5	4	4	5	4	5	4	4				
	Product	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Rate/Acre	Prod./App	Total App	Fescue Native Total
Herb	Fusilade II			1	1	1	1	1	1					4.00	0.63	6	3.75
	Pylex									1	1			1.50	7.50	2	15.00
	Turflon Ester			1	1	1	1	1	1	1				32.00	1.25	7	8.75
					*	*		*									

Mowing in spring followed by
Early application -> winter annual weeds and bermudagrass

Summer applications -> summer annual grasses

Mowing in fall followed by
Fall applications -> bermudagrass

* spot treatments at interface for bermudagrass encroachment

Program courtesy of Josh Cook, Oak Tree National Golf Club

DIFFERENCES WITH

WARM SEASON SPECIES

SPECIMEN

PLATEAU®

herbicide

FOR WEED CONTROL, NATIVE GRASS ESTABLISHMENT AND TURF GROWTH SUPPRESSION ON PASTURES, RANGELAND AND NONCROP AREAS AND CONIFER PLANTATION SITE PREPARATION

Active Ingredient:	
Ammonium salt of imazapic (±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-methyl-3-pyridinecarboxylic acid*	23.6%
Other Ingredients:	76.4%
Total:	100.0%

TOLERANT GRASS SPECIES[1]

Prairiegrass		Plateau Rate (oz/A)[2]	
Common Name	**Genus Species**	**New Seeding**	**Established**
Big Bluestem	*Andropogon gerardii*	2-12	2-12
Little Bluestem	*Schizachyrium scoparium*	2-12	2-12
Indiangrass	*Sorghastrum nutans*	2-12	2-12
Bushy Bluestem	*Andropogon glomeratus*	—*	2-12
King Ranch Bluestem	*Bothriochloa ischaemum*	—	2-12
Silver Beard Bluestem	*Bothriochloa saccharoides*	—	2-12
Broomsedge	*Andropogon virginicus*	—	2-12
Fingergrass, Rhodes grass	*Chloris* spp.	—	2-12
Needlegrass	*Stipa* spp.	—	2-12
Needleandthread	*Stipa comata*	—	2-12
Kearny (Plains) Threeawn	*Aristida longespica*	—	2-12
Prairie Threeawn	*Aristida oligantha*	—	2-12
Prairie Sandreed	*Calamovilfa longifolia*	—	2-12
Smooth Bromegrass	*Bromus inermis*	—	2-12
Kentucky Bluegrass	*Poa pratensis*	—	2-12[4]
Sandberg's Bluegrass	*Poa sandbergii*	—	2-12
Wheatgrasses	*Agropyron* spp.	—	2-12
Bottlebrush Squirreltail	*Sitanion hystrix*	—	2-12
Russian Wild Ryegrass	*Elymus junceus*	2-6[2]	2-12
Sideoats Grama	*Bouteloua curtipendula*	2-8[3]	2-8
Blue Grama	*Bouteloua gracilis*	2-8[3]	2-8
Buffalograss	*Buchloe dactyloides*	2-4	2-8
Eastern Gamagrass	*Tripsacum dactyloides*	2-6[3]	2-8

[1] See individual grass sections for application timing.

[2] High rates may result in stunting and growth suppression.

ALS inhibitor

Broad spectrum weed control

Grass, BLW, Sedge

Some bermudagrass suppression at high rates

Certainty®
TURF HERBICIDE

CERTAINTY® TURF HERBICIDE IS A SELECTIVE HERBICIDE FOR CONTROL OF ANNUAL AND PERENNIAL GRASS AND BROADLEAF WEEDS IN HIGHLY MANAGED TURF, ORNAMENTAL AND NATIVE GRASS SITES.

Complete Directions For Use

EPA Reg. No. 524-534

2012-1

Read the entire label before using this product.

Use only according to label instructions.

Not all products recommended on this label are registered for use in California. Check the registration status of each product in California before using.

Read the "LIMIT OF WARRANTY AND LIABILITY" before buying or using. If terms are not acceptable, return at once unopened.

THIS IS AN END-USE PRODUCT. MONSANTO DOES NOT INTEND AND HAS NOT REGISTERED IT FOR REFORMULATION OR REPACKAGING.

1.0 INGREDIENTS

ACTIVE INGREDIENT:
Sulfosulfuron 75.0%
OTHER INGREDIENTS: 25.0%
100.0%

10.0 NATIVE GRASSES

This product generally has been shown to be safe for use on the warm-season native grasses listed in this section.

Big bluestem
Andropogon gerardii

Little bluestem
Schizachyrium scoparium

Bushy bluestem
Andropogon glomeratus

Blue grama
Bouteloua gracilis

Buffalograss
Bouteloua dactyloides

Indiangrass
Sorghastrum nutans

Lovegrass
Eragrostis curvula

Switchgrass
Panicum virgatum

ALS Inhibitor for Grass, BLW, and Sedge Control

2015 Warm Season Native Areas Budget

		4	5	4	4	5	4	4	5	4	5	4	4				
	Product	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Rate/Acre	Prod./App	Total App	Native Areas Total
Herb	Plateau			1	1	1	1	1	1	1	1	1		8.00	0.75	9	6.75
	Turflon Ester			1	1	1	1	1	1	1	1	1		32.00	3.00	9	27.00
						*		*	*	*							

Burning in February

Early applications -> winter annual weeds & bermudagrass

Mowing in June followed by
Summer applications -> summer annual grasses

Mowing in late August followed by
Fall applications -> bermudagrass

* spot treatments at interface for bermudagrass encroachment

Program courtesy of Josh Cook, Oak Tree National Golf Club

Integrated Program

SPRING PRE?

Integrated Program

Photo courtesy of Josh Cook, Oak Tree National GC

SPRING PRE?

Integrated Program

SPRING PRE?

BURNING?

Integrated Program


Photo courtesy of Josh Cook, Oak Tree National GC


Photo courtesy of Josh Cook, Oak Tree National GC

Photo courtesy of Josh Cook, Oak Tree National GC

Photo courtesy of Josh Cook, Oak Tree National GC

SPRING PRE?

BURNING?

Integrated Program

SPRING PRE?

BURNING?

Integrated Program

MOWING

SPRING PRE?

BURNING?

Integrated Program

MOWING

SPRING PRE?

BURNING?

Integrated Program

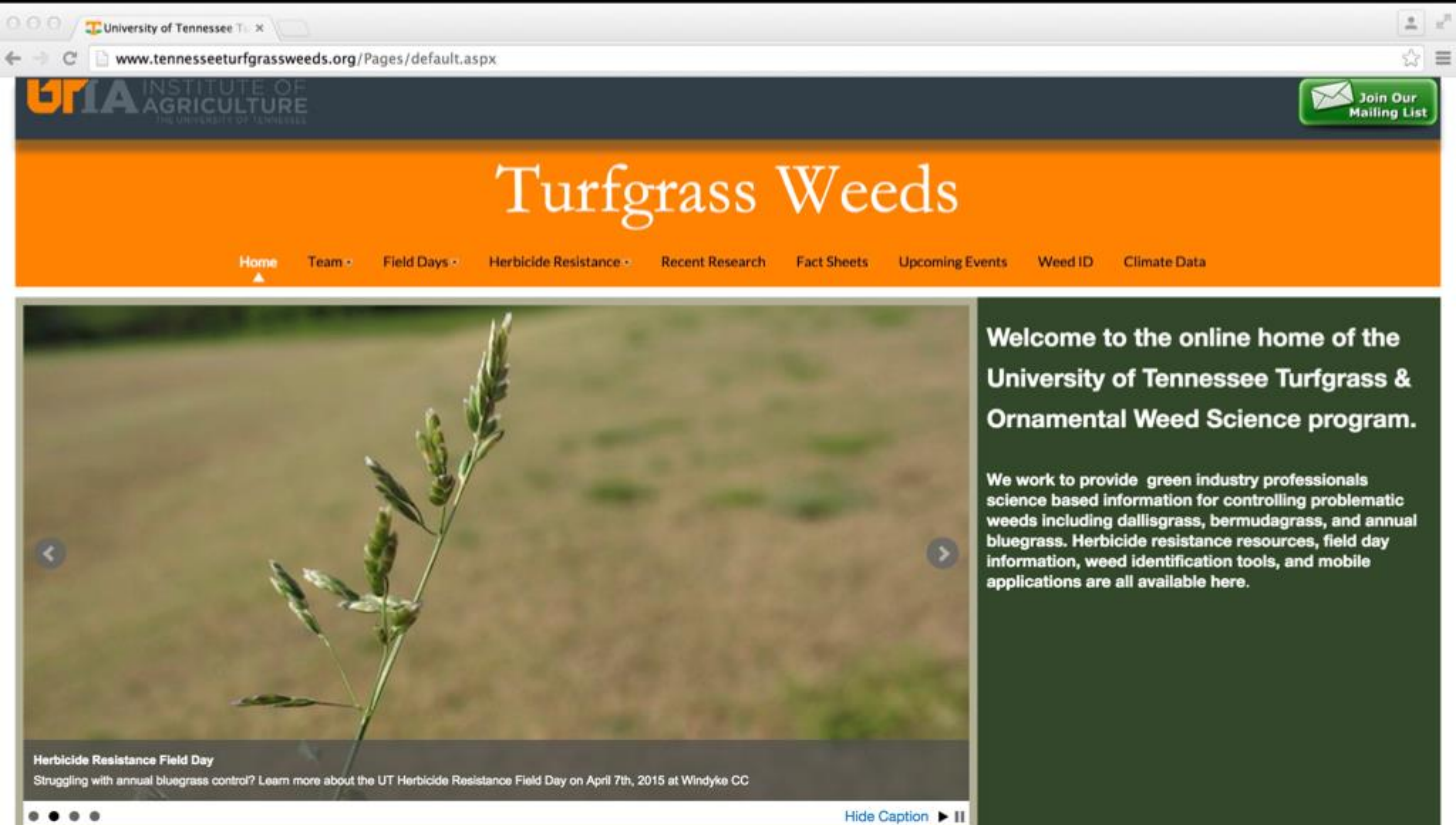
MOWING

HERBICIDE

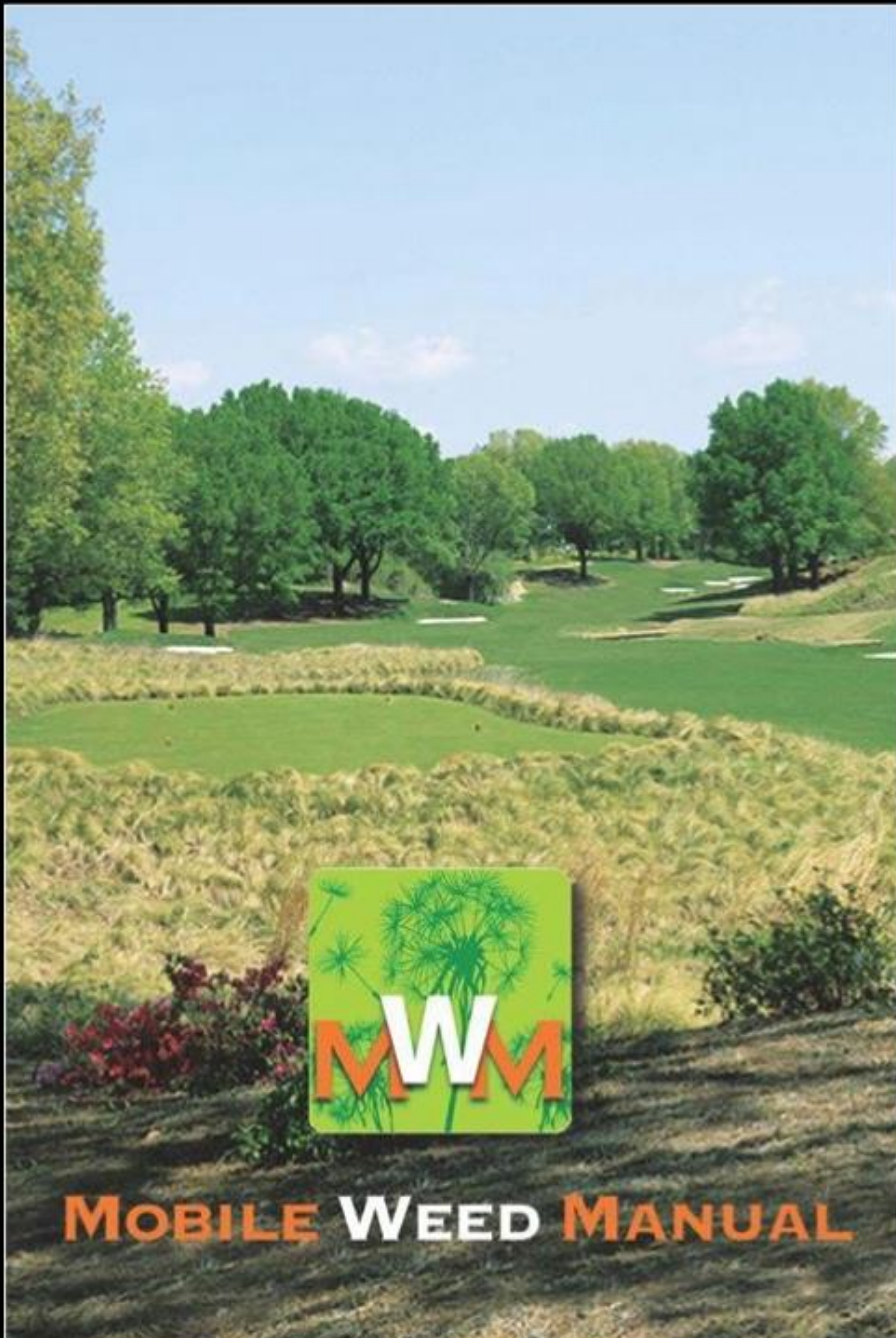
More herbicide options C3 vs C4

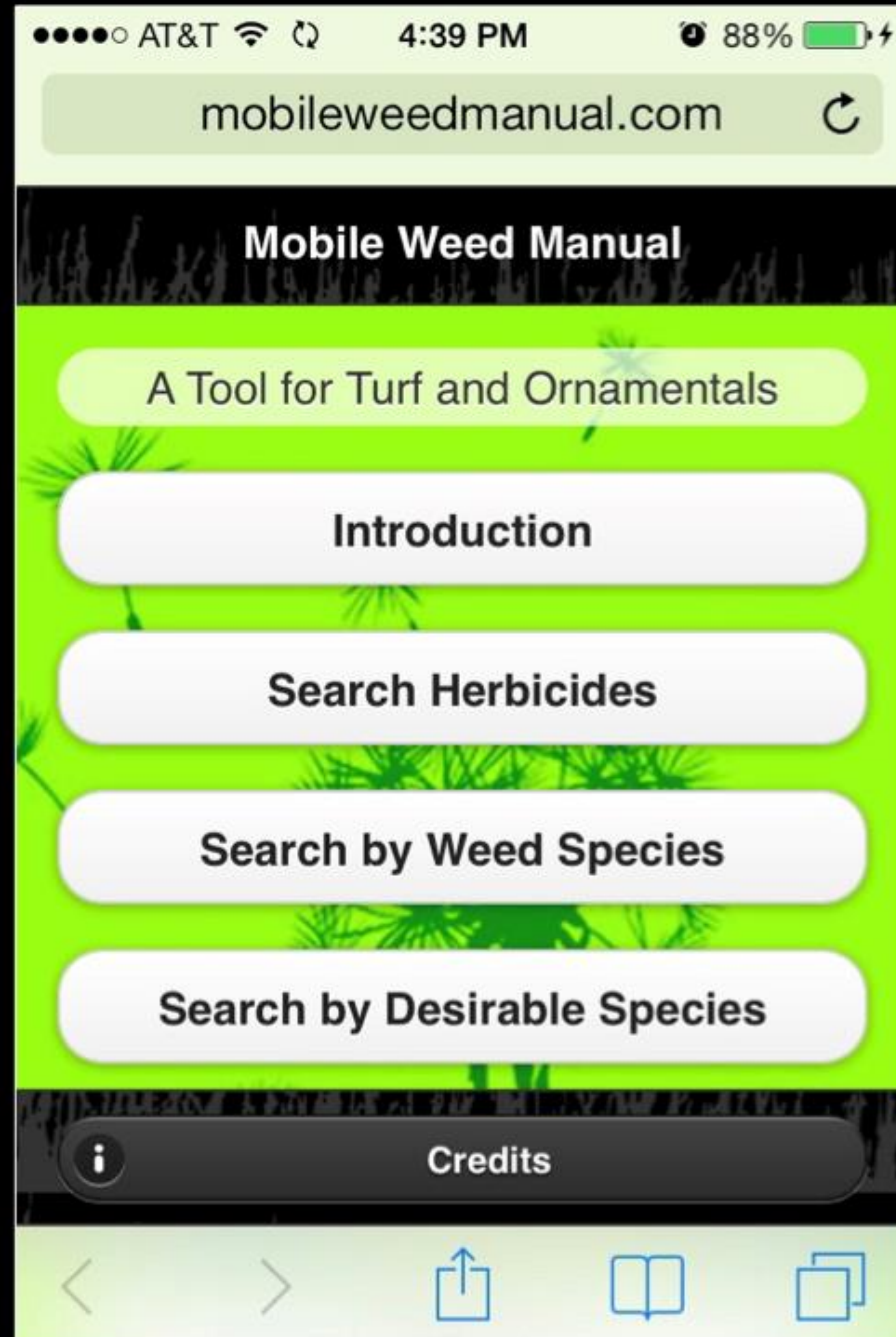
GENERAL COMMENTS ON HERBICIDES

- Test small scale areas first
- Many products have statements that allow evaluation on species not listed as tolerant on the label
    - You assume all risk
- Make sure product use site is golf course, ornamental planting, wildflower planting, etc.

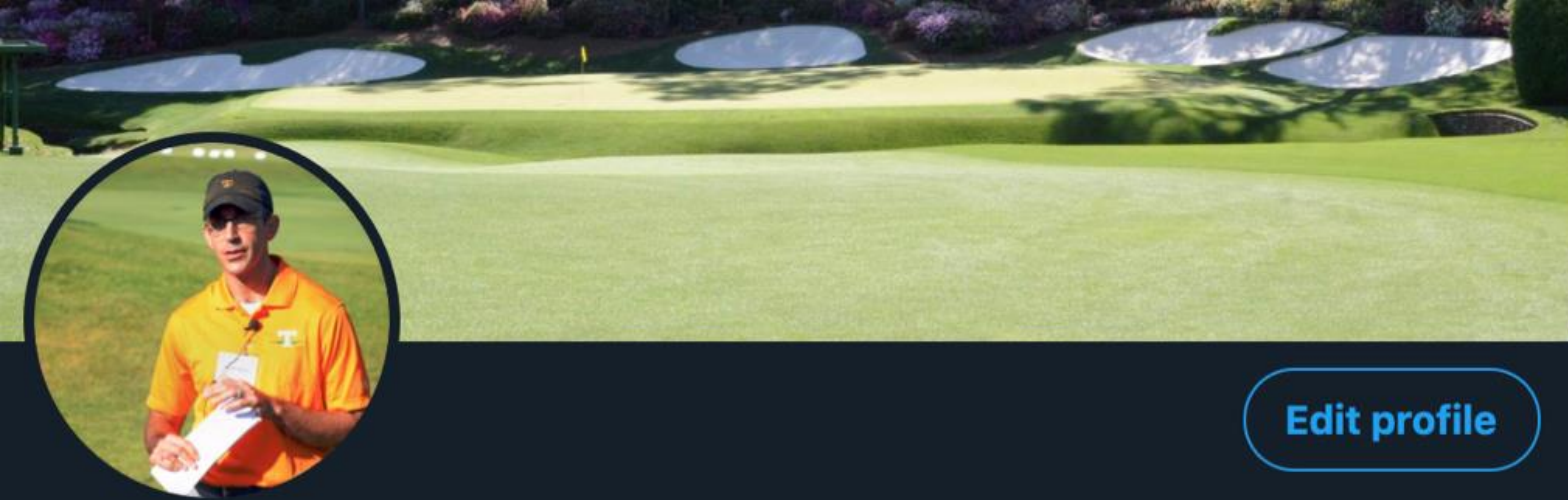


tnturfgrassweeds.org


MWM
Mobile Weed Manual


AT&T
4:39 PM
88%
mobileweedmanual.com
Mobile Weed Manual
A Tool for Turf and Ornamentals
Introduction
Search Herbicides
Search by Weed Species
Search by Desirable Species
Credits

Polling Question



Edit profile

Jim Brosnan, Ph.D.

@UTTurfWeeds

Professor, Univ. of Tennessee (@UTturfgrass) Director, UT Weed Diagnostics Center (@WeedDiagnostics) #Turf #Grass #Weeds #Science #Golf #Lawn #Resistance

University of Tennessee tnturfgrassweeds.org

Joined November 2013

2,706 Following **5,181** Followers


TENNESSEE

Questions?

- BREAK –

We will reconvene at 11:00am

Support Turfgrass Research & Education at OSU

For Tickets: Scan QR code or visit: www.oregonturfgrassfoundation.org

Break – We will reconvene at 11:00am

OLCA
OREGON LANDSCAPE CONTRACTORS ASSOCIATION

Simplot
PARTNERS

FAZIO BROS.
Sand Co., Inc.

PACIFIC
GOLF & TURF

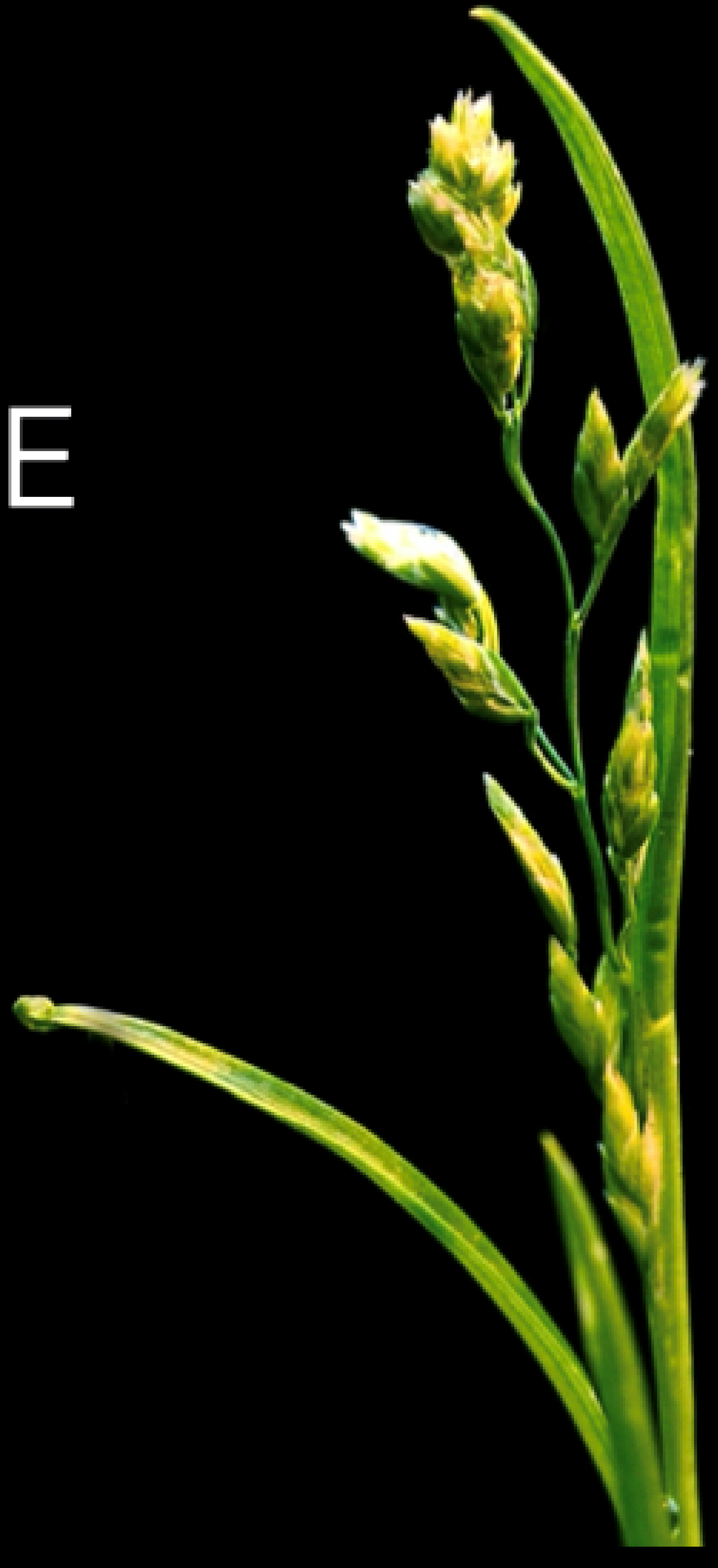
TARGET
SPECIALTY PRODUCTS

RAIN BIRD

WEED CONTROL AND HERBICIDE RESISTANCE ISSUES

J.T. BROSNAN
UNIVERSITY OF TENNESSEE

@UTTURFWEEDS



ISSUE #1

ACKNOWLEDGE THE THREAT OF HERBICIDE RESISTANCE

WHAT IS HERBICIDE RESISTANCE?

"THE ABILITY OF PLANT TO SURVIVE AND REPRODUCE FOLLOWING EXPOSURE TO A DOSE OF HERBICIDE NORMALLY LETHAL TO THE WILD TYPE"

Vencill et al. 2012. Weed Science

HOW THIS DIFFERS FROM

TOLERANCE

Resist Poa

USDA-SCRI ANNUAL
BLUEGRASS COLLECTIVE

POA ANNUA

RESISTANCE IS REAL

GCSAA
Golf Course Superintendents Association of America

EIFG
Environmental Institute for Golf

Received: 15 April 2020 | Accepted: 24 June 2020
DOI: 10.1002/cft2.20050

Crop, Forage & Turfgrass Management

APPLIED TURFGRASS SCIENCE

Herbicide resistance in annual bluegrass on Tennessee golf courses

James T. Brosnan[1] | Jose J. Vargas[1] | Gregory K. Breeden[1] | John M. Zobel[2]

[1] Dep. of Plant Sciences, Univ. of Tennessee, 112 Plant Biotechnology Building, 2505 EJ Chapman Drive, Knoxville, TN 37996, USA

[2] Dep. of Forest Resources, Univ. of Minnesota, 115 Green Hall, 1530 Cleveland Ave. N., St. Paul, MN 55108, USA

Correspondence
James T. Brosnan, Dep. of Plant Sciences, Univ. of Tennessee, 112 Plant Biotechnology Building, 2505 EJ Chapman Drive, Knoxville, TN 37996, USA.
Email: jbrosnan@utk.edu

Abstract
Research was conducted to determine the extent of herbicide resistance in annual bluegrass (*Poa annua* L.) randomly collected from Tennessee golf courses during 2018. Harvested plants were cultured for seed collection, with progeny screened for resistance to glyphosate (Roundup Pro; 32 fl oz acre^{-1}), foramsulfuron (Revolver; 17.4 fl oz acre^{-1}), simazine (Princep 4FL; 2 qt acre^{-1}), or prodiamine (Barricade 65WG; 0.001 mM). In postemergence herbicide screens, annual bluegrass collections were grouped based on survival percentage: resistant (>30% survival), segregating for resistance (5–30% survival), or susceptible (<5% survival). For prodiamine, annual bluegrass collections were screened in hydroponics and deemed resistant when <20% of plants exhibited symptoms of herbicide treatment (e.g., club roots), whereas those with >90% of plants showing symptoms were deemed susceptible; the remainder were intermediate and classified as segregating for resistance. In total, 64% of the annual bluegrass collections had some degree of resistance to glyphosate. Similarly, 21% had some degree of resistance to foramsulfuron, while 58% of annual bluegrass collections had some degree of resistance to prodiamine. Only 3% of the annual bluegrass collections were susceptible to simazine, and 25% of those surviving treatment were resistant to glyphosate or foramsulfuron. Multiple resistance to glyphosate, foramsulfuron, and simazine was reported in 4% of the annual bluegrass collections. The results of this research highlight the need for more diversified weed management strategies to control annual bluegrass on Tennessee golf courses.

1 | INTRODUCTION

Annual bluegrass (*Poa annua* L.) was ranked as the fourth most common turfgrass weed in the United States and Canada (Van Wychen, 2017) and has been found on all continents globally, including Antarctica (Chwedorzewska, 2008). The widespread distribution of annual bluegrass is related to the species' ability to tolerate a wide range of environmental conditions. Annual bluegrass is day neutral, with seed germinable across a wide range of air temperature and light conditions (Itoh, Kobayashi, & Ueki, 1997; Johnson & White, 1997; McElroy, Walker, & Wehtje, 2004). Two varieties of annual bluegrass are common in

Abbreviations: MTI, mitotic inhibiting; WSSA, Weed Science Society of America.

ALARMING NUMBERS

- 64% Glyphosate resistant
- 58% Barricade resistant
- 21% Revolver resistant
    - No greens
- >90% Princep resistant
- 25% multiple resistance (e.g., Princep + Revolver)
- 4% Resistant to EVERYTHING

Weed Technology

www.cambridge.org/wet

Herbicide-resistant weeds in turfgrass: current status and emerging threats

James T. Brosnan[1], Matthew T. Elmore[2] and Muthukumar V. Bagavathiannan[3]

[1]Professor, Department of Plant Sciences, University of Tennessee, Knoxville, TN, USA; [2]Assistant Professor, Department of Plant Biology, Rutgers University, New Brunswick, NJ, USA and [3]Associate Professor, Department of Soil and Crop Sciences, Texas A&M University, College Station, TX, USA

Symposium

Cite this article: Brosnan JT, Elmore MT, Bagavathiannan MV (2020) Herbicide-resistant weeds in turfgrass: current status and emerging threats. Weed Technol. **34:** 424–430. doi: 10.1017/wet.2020.29

Received: 8 November 2019
Revised: 1 January 2020
Accepted: 7 February 2020

Nomenclature:
Annual bluegrass, *Poa annua* L.; crabgrass, *Digitaria* spp.; goosegrass, *Eleusine indica* (L.) Gaertn

Keywords:
Multiple resistance; non-target site resistance (NTSR); target site resistance (TSR)

Author for correspondence:
James Brosnan, University of Tennessee, 2505 EJ Chapman Drive, Knoxville, TN 37996.
Email: jbrosnan@utk.edu

Abstract

Herbicide-resistant weeds pose a severe threat to sustainable vegetation management in various production systems worldwide. The majority of the herbicide resistance cases reported thus far originate from agronomic production systems where herbicide use is intensive, especially in industrialized countries. Another notable sector with heavy reliance on herbicides for weed control is managed turfgrass systems, particularly golf courses and athletic fields. Intensive use of herbicides, coupled with a lack of tillage and other mechanical tools that are options in agronomic systems, increases the risk of herbicide-resistant weeds evolving in managed turfgrass systems. Among the notable weed species at high risk for evolving resistance under managed turf systems in the United States are annual bluegrass, goosegrass, and crabgrasses. The evolution and spread of multiple herbicide resistance, an emerging threat facing the turfgrass industry, should be addressed with the use of diversified management tools. Target-site resistance has been reported commonly as a mechanism of resistance for many herbicide groups, though non–target site resistance is an emerging concern. Despite the anecdotal evidence of the mounting weed resistance issues in managed turf systems, the lack of systematic and periodic surveys at regional and national scales means that confirmed reports are very limited and sparse. Furthermore, currently available information is widely scattered in the literature. This review provides a concise summary of the current status of herbicide-resistant weeds in managed turfgrass systems in the United States and highlights key emerging threats.

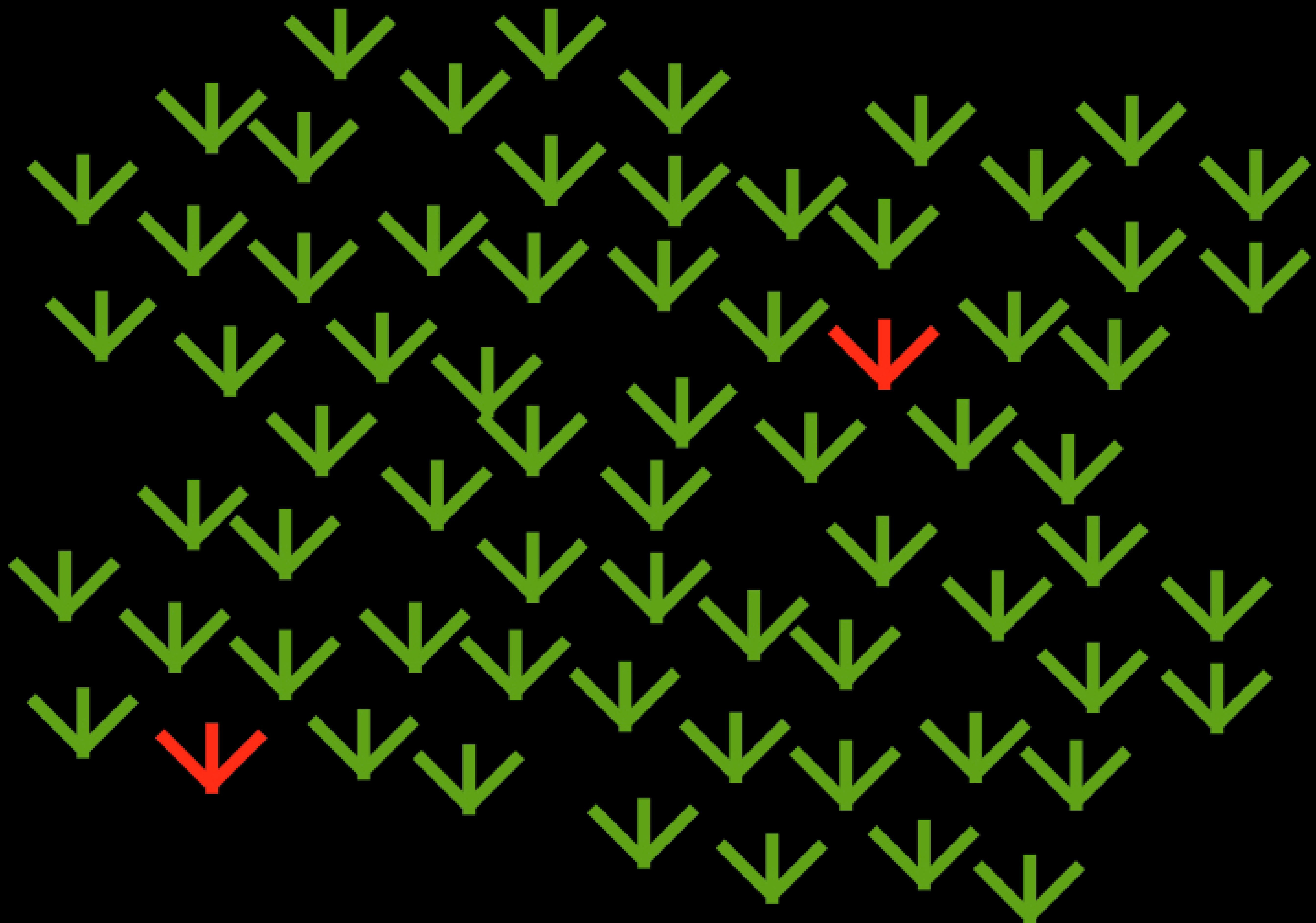
More than just *Poa annua*

COMMON TRENDS

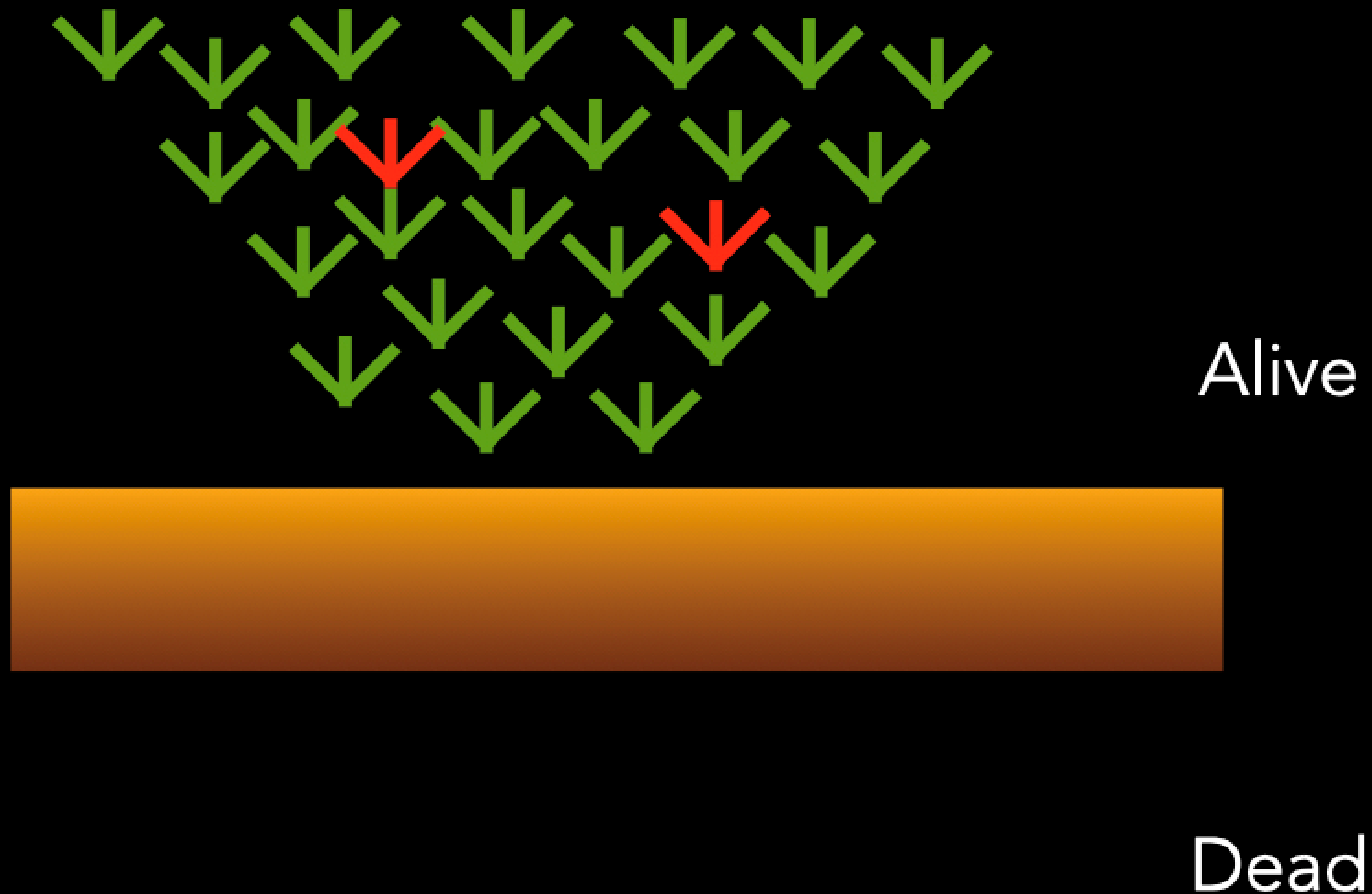
- Continued use of same herbicides without rotation
- Lack of diversified weed management/IPM
- “I spray product X for weed Y”

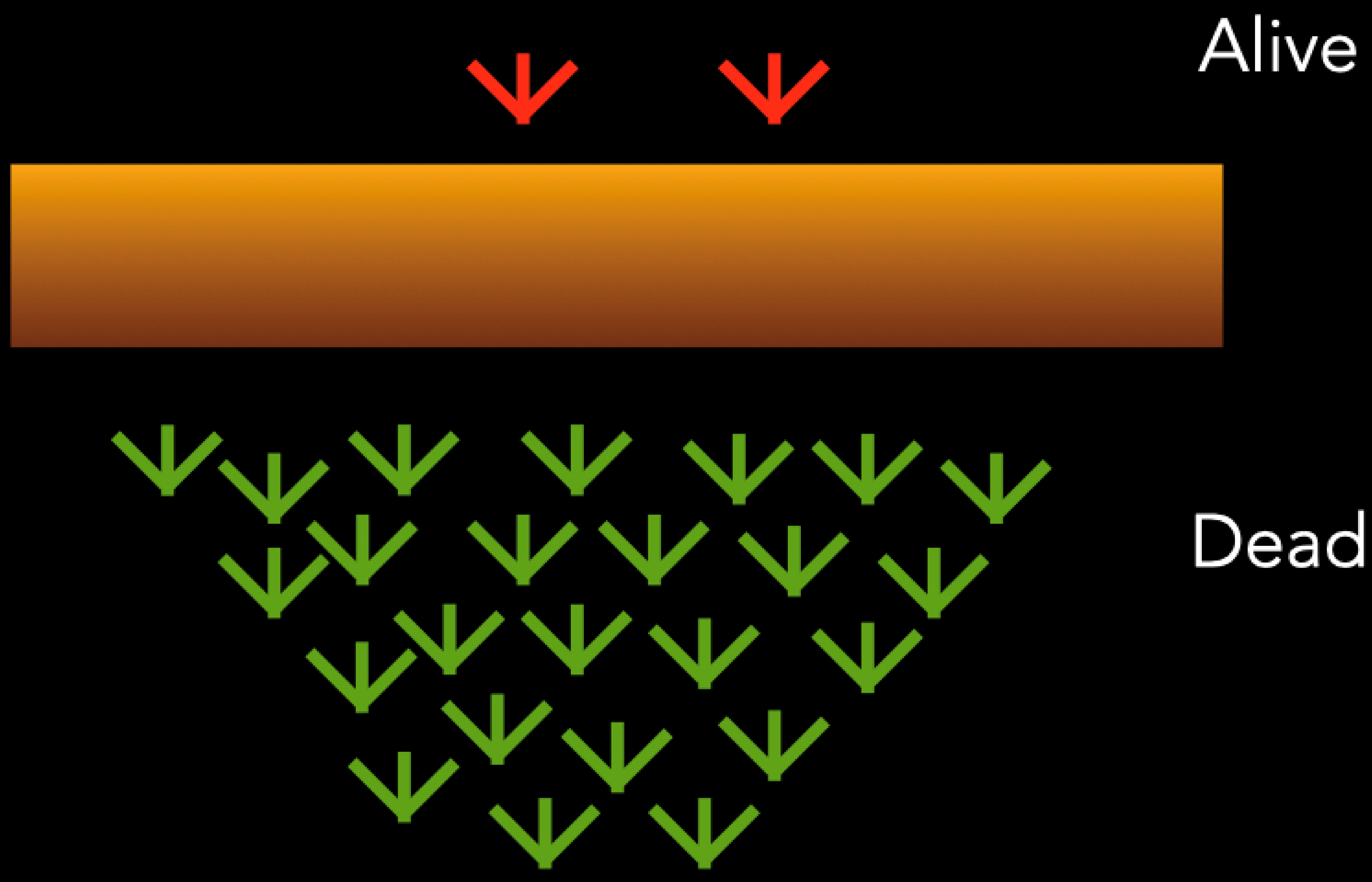
TRY TO THINK OF

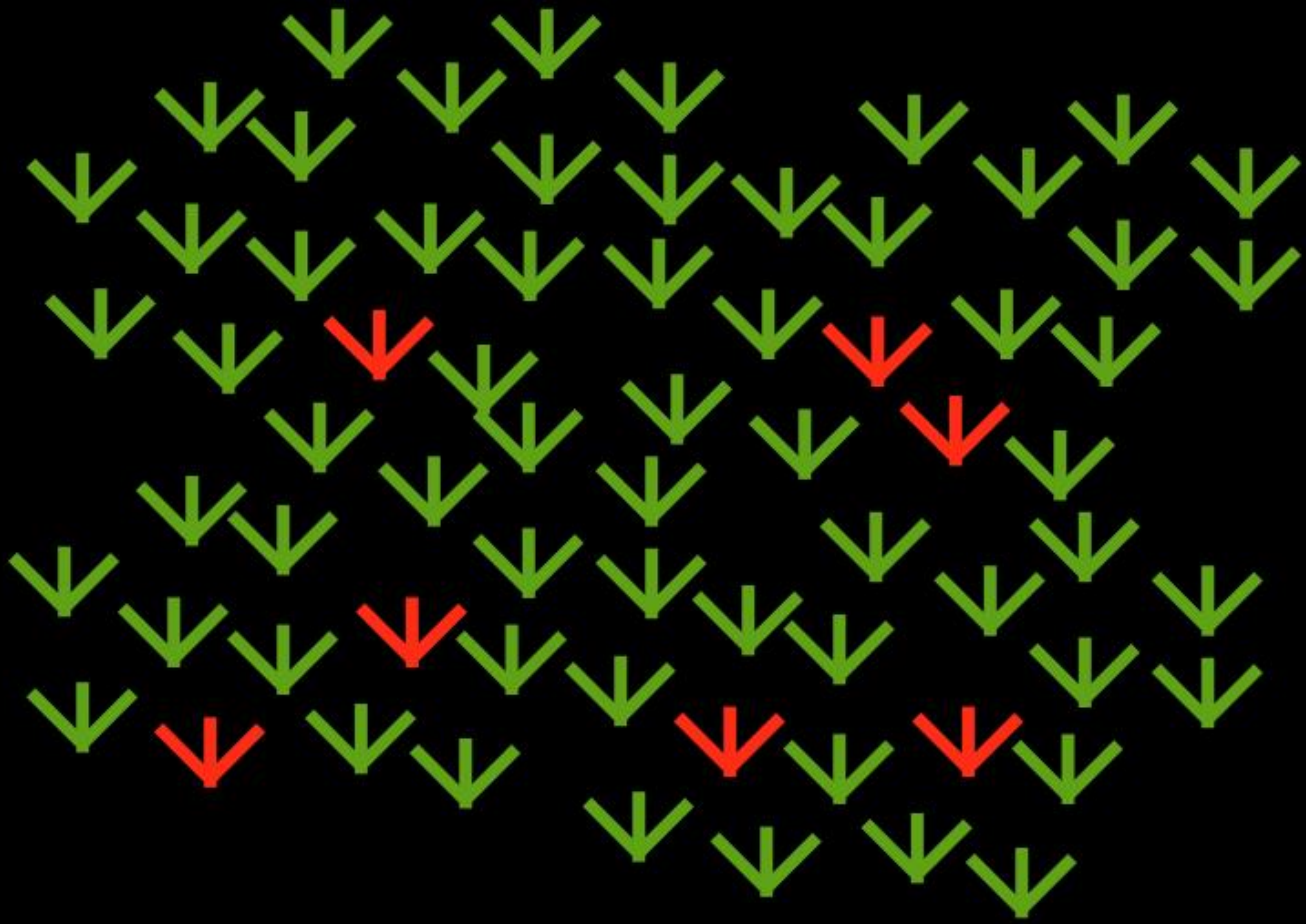
HERBICIDES AS SIEVES



A Population of Weeds


Alive
Dead

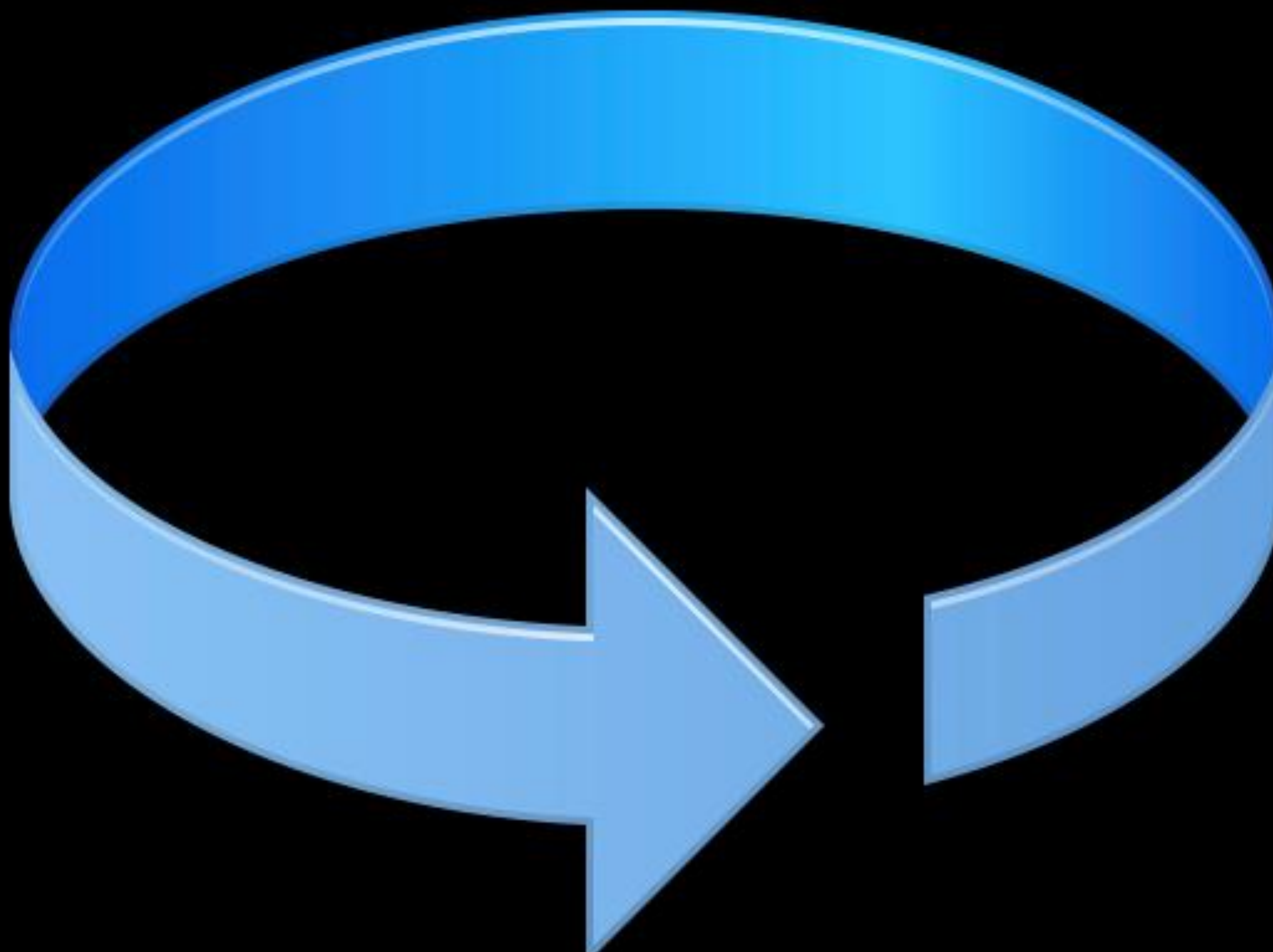

Alive
Dead

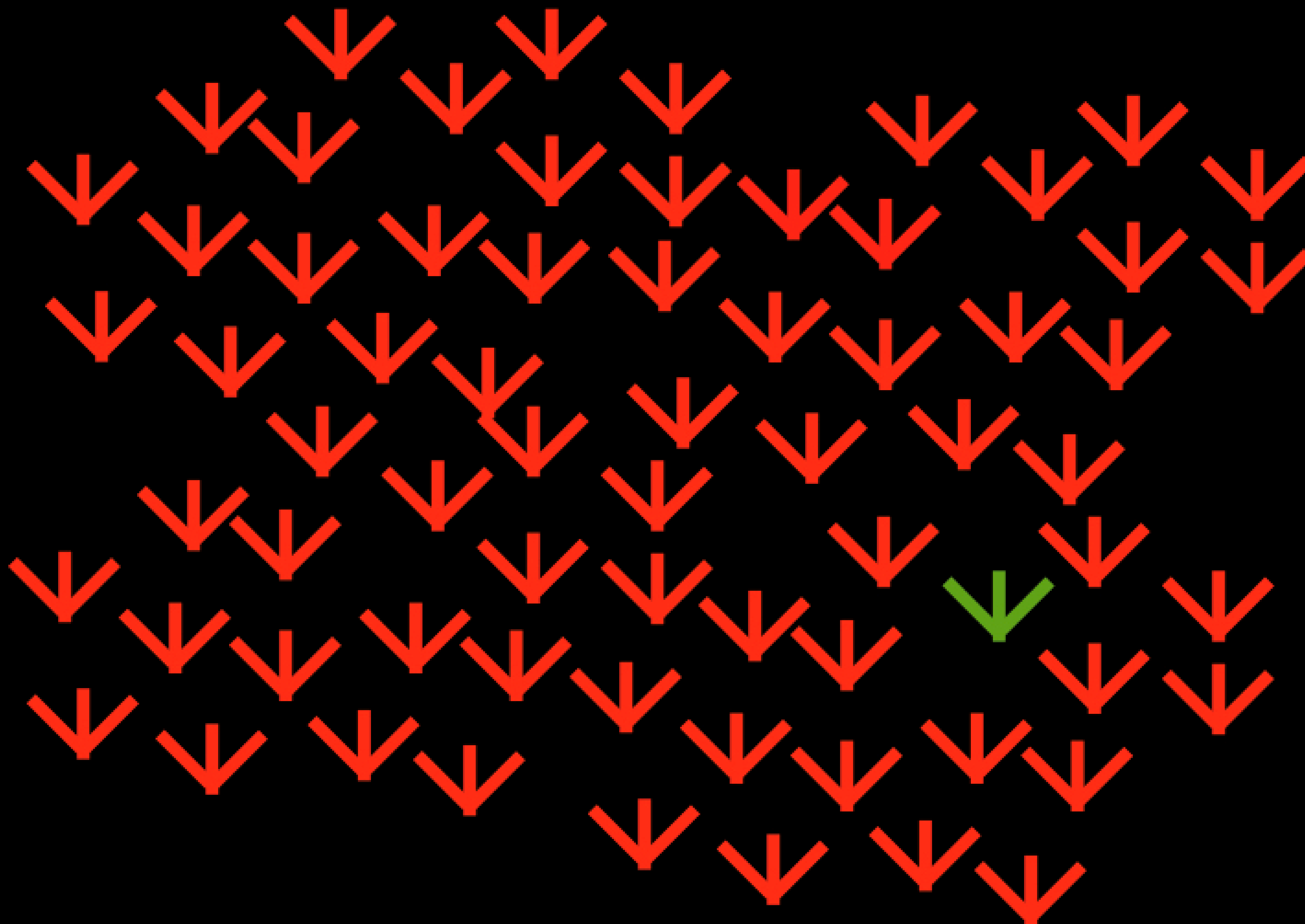


A Population of Weeds

IF YOU KEEP USING

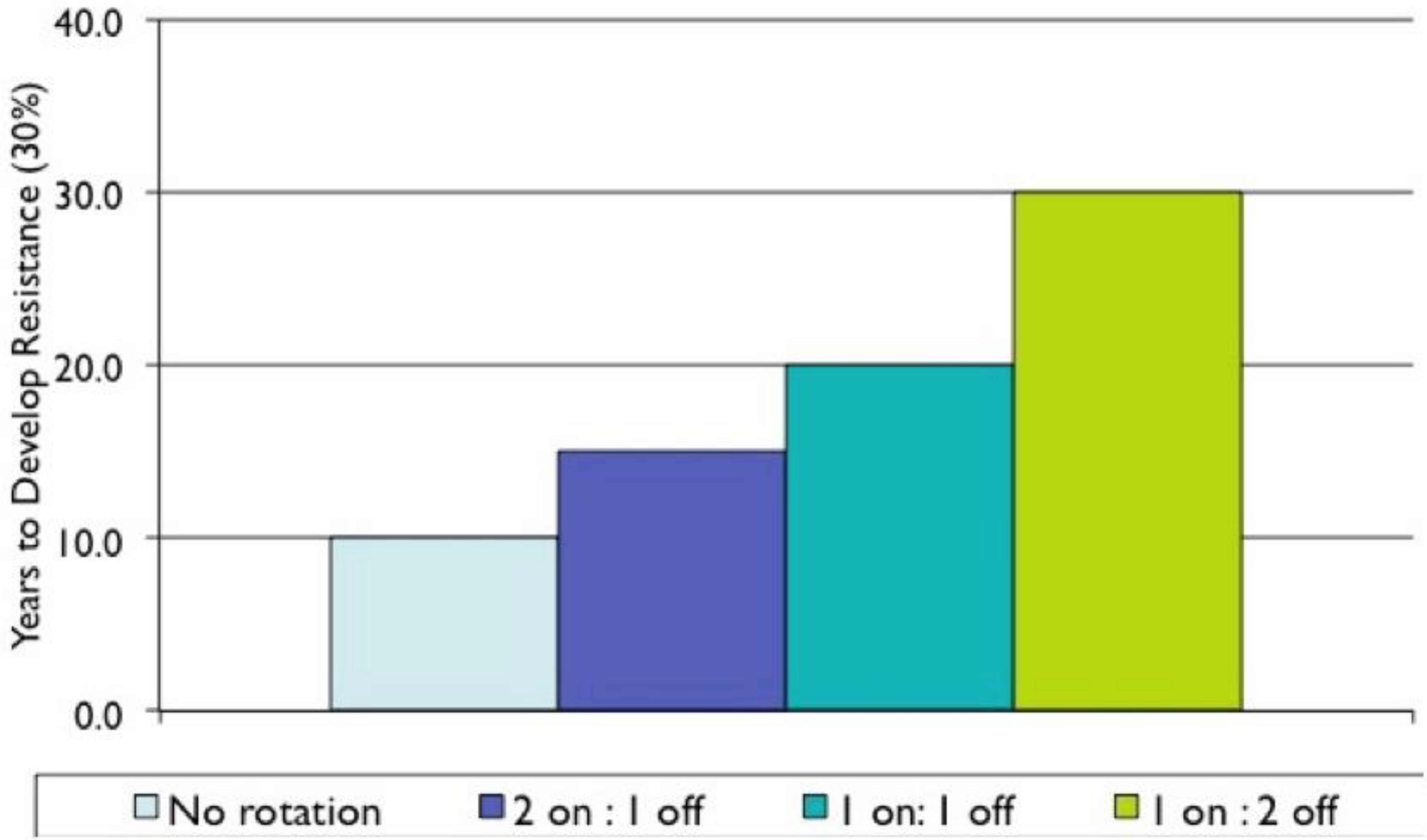
THE SAME SIEVE





Same Population of Weeds….Becomes Resistant

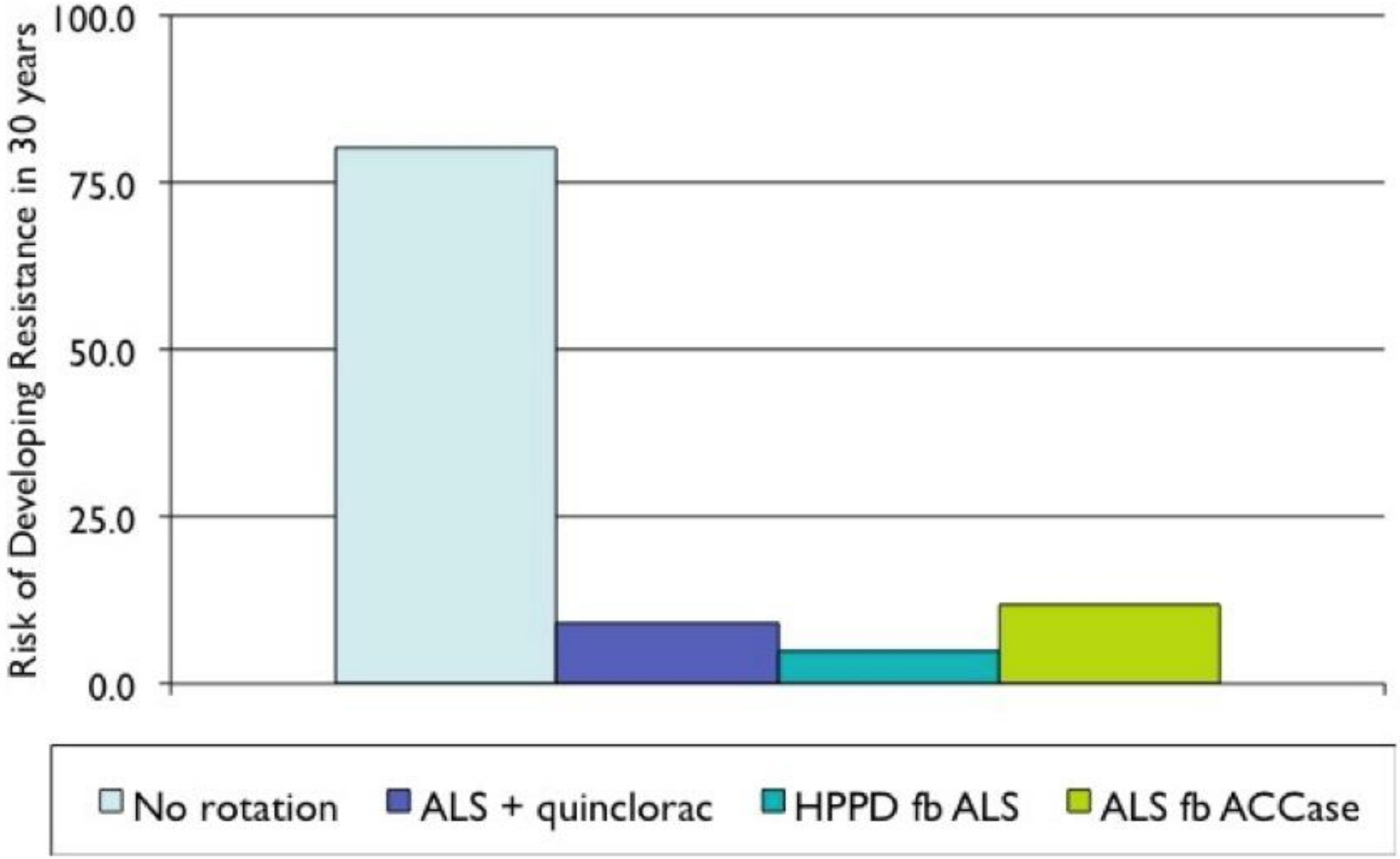
Modeled Effects of Rotation on Triazine Resistance



*Assumes rate for 95% control, 2 yr seed life, fitness = 1

Gressel and Segel. 1990. Weed Technol. 4:186-198

Modeled Effects of Rotation/Mixtures on ALS Resistance



Resistance (20%) observed within 4 years with ALS only program

Bagavathiannan et al. 2014. Weed Tech. 28:89-103

HOW DO I

CHANGE SIEVES?

GROUP **27** HERBICIDE

PULL HERE TO OPEN

Tenacity®

syngenta

Herbicide

A herbicide for the selective contact and residual control of weeds in ornamental turfgrasses

Active Ingredient:

Mesotrione*	40.0%
Other Ingredients:	60.0%
Total:	**100.0%**

Contains 4 lbs. of active ingredient mesotrione per gallon.

*CAS No. 104206-82-8

KEEP OUT OF REACH OF CHILDREN.

CAUTION

See additional precautionary statements and directions for use in attached booklet.

EPA Reg. No. 100-1267

EPA Est. 100-NE-001

SCP 1267A-L1C 1010
332200

1 gallon
Net Contents

SPECIMEN

GROUP	4	HERBICIDE

DRIVE® XLR8

HERBICIDE

Active Ingredient:

dimethylamine salt of quinclorac: 3,7-dichloro-8-quinolinecarboxylic acid	18.92%
Other Ingredients:	81.08%
Total:	100.00%

Equivalent to:

1.50 lbs quinclorac: 3,7-dichloro-8-quinolinecarboxylic acid equivalent per gallon

EPA Reg. No. 7969-272

EPA Est. No.

Dow AgroSciences

Dimension® 2EW

SPECIALTY HERBICIDE

Provides control of listed annual grasses and broadleaf weeds in:

- **Established lawns**
- **Commercial sod farms**
- **Ornamental and sports turf (including but not limited to sport fields, golf course fairways, roughs, tee boxes, unimproved turfgrass areas)**
- **Container grown ornamentals**
- **Field-grown ornamentals**
- **Landscape ornamentals**
- **Non-cropland such as: airports, barrow ditches, cemeteries, communication transmission lines, electrical power and utility rights-of-way, fencerows, gravel pits, hard-surface cracks, industrial sites, military lands, mining and drilling areas, non-irrigation ditch banks, gas and oil pads, parking lots, petroleum tank yards, pipelines, pump stations, railroads, roadsides, debris retention areas, service roads, solar fields, storage areas or yards, substations, vacant lots and other non-crop residential and commercial areas**
- **Natural areas (open space) such as: restoration sites, campgrounds, parks, prairie management, trails and trailheads, recreation areas, wildlife openings and wildlife habitat and management areas**
- **Christmas tree farms**

In New York State, this product may be used by commercial applicators only, at no more than 2 pints (0.5 lb active ingredient) per acre per year. In Nassau and Suffolk counties of New York, do not exceed 1 pint per acre per year of this product (equivalent to 0.25 lb of active ingredient per acre).

GROUP	3	HERBICIDE

TURFGRASS SCIENCE
at the UT Institute of Agriculture

Understanding How Turfgrass Herbicides Work

Gregory K. Breeden, UT Extension Specialist, Turfgrass Weed Science
James T. Brosnan, Associate Professor, Turfgrass Weed Science
Javier Vargas, Research Associate, Turfgrass Weed Science
Department of Plant Sciences

Herbicides are chemicals that inhibit normal plant growth processes resulting in death of susceptible weeds. The processes by which herbicides kill weeds are called modes of action while the location where these effects occur at the cellular level is termed the site of action or the mechanism of action. The Weed Science Society of America (WSSA) uses a numerical system to group herbicides by mechanism of action. A more detailed description of this numerical system is presented in Table 1.

Continual reliance on herbicides that employ the same mechanism of action has led to the evolution of herbicide-resistant weeds in turfgrass, as well as in other agricultural systems. Developing weed management programs utilizing herbicides that employ different mechanisms of action is critical to both preventing and managing herbicide resistant weeds. It is recommended to rotate herbicides that employ different mechanisms of action as often as possible, as well as implementing cultural practices that maximize turf competition and limit weed encroachment. Table 2 lists single active ingredient herbicides used in turfgrass by mechanisms of action group number. These WSSA group numbers can also be found on most herbicide labels as well (Figure 1).

Figure 1. The Weed Society of America (WSSA) uses a numerical system to group herbicides by mechanism of action. The WSSA group number can be found on most herbicide labels.

Mode of Action	Mechanism of Action	WSSA Action Group	Chemical Family	Active Ingredient	Ex. Trade Names
Synthetic Auxin	Not Well Understood	4	Phenoxy	2,4-D	Various
				MCPP	
				MCPA	
				2,4-DB	
			Benzoic Acid	dicamba	Banvel
			Pyridine Carboxylic Acid	clopyralid	Lontrel
				fluroxypyr	*NA
				triclopyr	Garlon
		4 & 26**	Quinoline Carboxylic Acid	quinclorac	Drive XLR8
Photosynthesis Inhibitor	Photosystem II Inhibitor	5	Triazine	atrazine	AAtrex
				simazine	Princep
			Triazinone	metribuzin	Sencor
			Triazolinone	amicarbizone	Xonerate
Photosynthesis Inhibitor	Photosystem II Inhibitor	6	Nitrile	bromoxynil	Buctril
			Benzothiadiazinone	bentazon	Basagran
Photosynthesis Inhibitor	Photosystem II Inhibitor	7	Urea	siduron	Tupersan
Lipid Biosynthesis Inhibitor	Not Well Understood	8	Phosphorodithioate	bensulide	Bensumec
Amino Acid Synthesis Inhibitor	EPSP Synthase Inhibitor	9	Glycine	glyphosate	Roundup Pro
Nitrogen Metabolism	Glutamine Synthetase Inhibitor	10	Phosphinic Acid	glufosinate-ammonium	Finale
Cell Membrane Disrupter	Protoporphyrinogen Oxidase (PPO) Inhibitor	14	Aryl Triazinone	carfentrazone	Quicksilver
				sulfentrazone	Dismiss
			N-phenylphthalimide	flumioxazin	Sureguard
			Oxadiazole	oxadiazon	Ronstar
			Pyrazole	pyraflufen-ethyl	Octane
Shoot Growth Inhibitor	Long Chain Fatty Acid Inhibitor	15	Chloroacetamide	dimethenamid	Tower
				metolachlor	Pennant

You Need to Play Zone Defense

WEEDS THAT WON'T DIE

Glyphosate at 88 fl oz/A


FIRST CASE OF 2,4-D RESISTANCE

Buckhorn plantain

Before Resistance

HERBICIDE	COST
TRIMEC (64 FL OZ/A) - SPRING	$528
TRIMEC (64 FL OZ/A) - FALL	$528
APPLIED ACROSS 40 ACRES	

$1,520 = $26/acre

Buckhorn plantain

Before Resistance

HERBICIDE	COST
TRIMEC (64 FL OZ/A) - SPRING	$528
TRIMEC (64 FL OZ/A) - FALL	$528
APPLIED ACROSS 40 ACRES	

HERBICIDE	COST
LONTREL (1.33 PT/A)	$4,480
GALLERY (23 FL OZ/A)	$4,700
APPLIED ACROSS 40 ACRES	

$1,520 = $26/acre

Buckhorn plantain

Before Resistance

HERBICIDE	COST
TRIMEC (64 FL OZ/A) - SPRING	$528
TRIMEC (64 FL OZ/A) - FALL	$528
APPLIED ACROSS 40 ACRES	

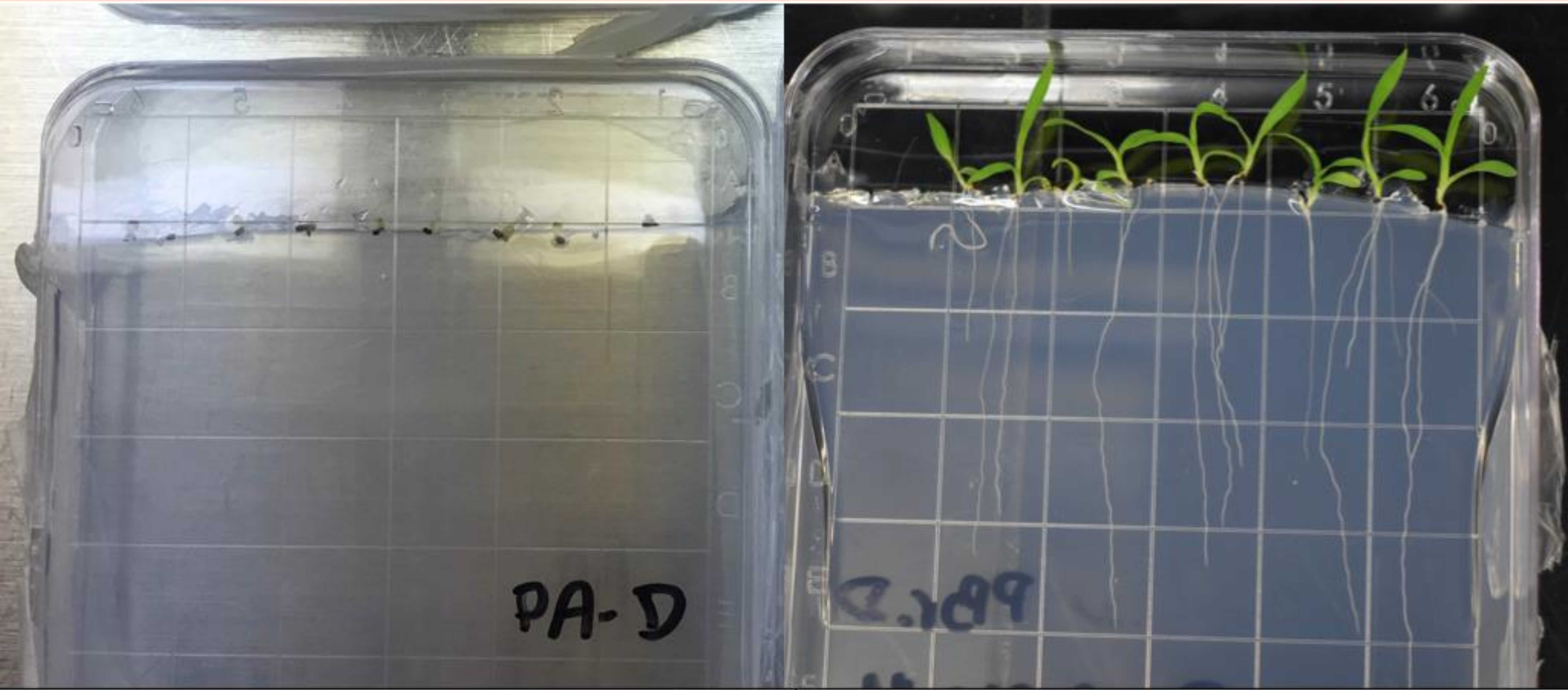
$1,520 = $26/acre

After Resistance

HERBICIDE	COST
LONTREL (1.33 PT/A)	$4,480
GALLERY (23 FL OZ/A)	$4,700
APPLIED ACROSS 40 ACRES	

$9,180 = $229/acre

Resistance to Dithiopyr in NJ



Susceptible population	Resistant Population

Slide by: M. Elmore, Rutgers Univ.

FIRST REPORT

YELLOW NUTSEDGE (*CYPERUS ESCULENTUS*) RESISTANCE TO HALOSULFURON

Research Article

Received: 12 August 2014 Revised: 27 September 2014 Accepted article published: 11 October 2014 Published online in Wiley Online Library:

(wileyonlinelibrary.com) DOI 10.1002/ps.3922

First report of resistance to acetolactate-synthase-inhibiting herbicides in yellow nutsedge (*Cyperus esculentus*): confirmation and characterization

Parsa Tehranchian,[a*] Jason K Norsworthy,[a] Vijay Nandula,[b] Scott McElroy,[c] Shu Chen[c] and Robert C Scott[d]

Abstract

BACKGROUND: Yellow nutsedge is one of the most problematic sedges in Arkansas rice, requiring the frequent use of halosulfuron (sulfonylurea) for its control. In the summer of 2012, halosulfuron at 53 g ha^{-1} (labeled field rate) failed to control yellow nutsedge. The level of resistance to halosulfuron was determined in the putative resistant biotype, and its cross-resistance to other acetolactate synthase (ALS) inhibitors from four different herbicide families. ALS enzyme assays and analysis of the ALS gene were used to ascertain the resistance mechanism.

RESULTS: None of the resistant plants was killed by halosulfuron at a dose of 13 568 g ha^{-1} (256× the field dose), indicating a high level of resistance. Based on the whole-plant bioassay, the resistant biotype was not controlled by any of the ALS-inhibiting herbicides (imazamox, imazethapyr, penoxsulam, bispyribac, pyrithiobac-sodium, bensulfuron and halosulfuron) tested at the labeled field rate. The ALS enzyme from the resistant biotype was 2540 times less responsive to halosulfuron than the susceptible biotype, and a Trp_{574}-to-Leu substitution was detected by ALS gene sequencing using the Illumina HiSeq.

CONCLUSION: The results suggest a target-site alteration as the mechanism of resistance in yellow nutsedge, which accounts for the cross-resistance to other ALS-inhibiting herbicide families.

SEDGE AND KYLLINGA HERBICIDES

TRADE NAME	GROUP #	TOLERANT TURF	KYLLINGA EFFICACY
DISMISS NXT	14	CBG, FF, KBG, PR, TF	G
SEDGEHAMMER	2	CBG, FF, KBG, PR, TF	P
CELERO	2	CBG, FF, KBG, PR, TF	E

ALS Resistant Kyllinga


"A GOAL
WITHOUT A PLAN
IS JUST A
WISH."
–ANTOINE DE SAINT-EXUPERY

APP	PRODUCT
1	APPEAR + SECURE
2	APPEAR + DACONIL ACTION
3	DACONIL ACTION + BRISKWAY
4	APPEAR + SECURE
5	APPEAR + DACONIL ACTION
6	AVID + HERITAGE
7	ACELPRYN
8	DACONIL ACTION + MEDALLION
9	PROVAUNT
10	AVID + HERITAGE
11	DACONIL ACTION + MEDALLION
12	PROVAUNT
13	AVID + HERITAGE
14	DACONIL ACTION + VELISTA
15	BRISKWAY
16	DACONIL ACTION +VELISTA
17	BRISKWAY
18	DACONIL ACTION
19	AVID + HERITAGE
20	SECURE + HEADWAY
21	APPEAR + DACONIL
22	SECURE + HEADWAY
23	APPEAR + DACONIL ACTION

Disease Management Plan

Source: www.syngenta.com

APP #	PRODUCT
1	DIMENSION
2	TRIMEC CLASSIC

Weed Management Plan

MASSIVE AMOUNTS OF

SEED IN SOIL

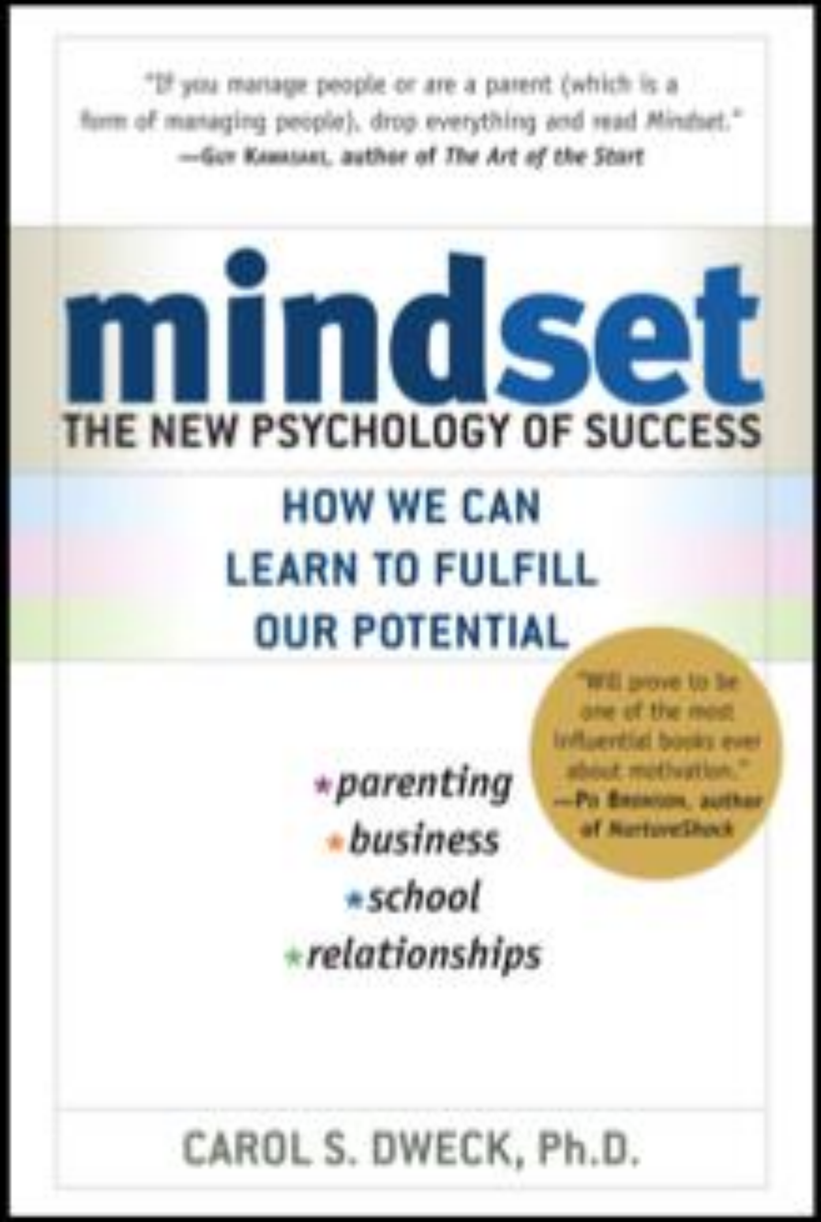
MASSIVE AMOUNTS OF

SEED IN SOIL


Emergence is a Moving Target

THIS YEAR CONSIDER

PROGRAMMATIC THINKING

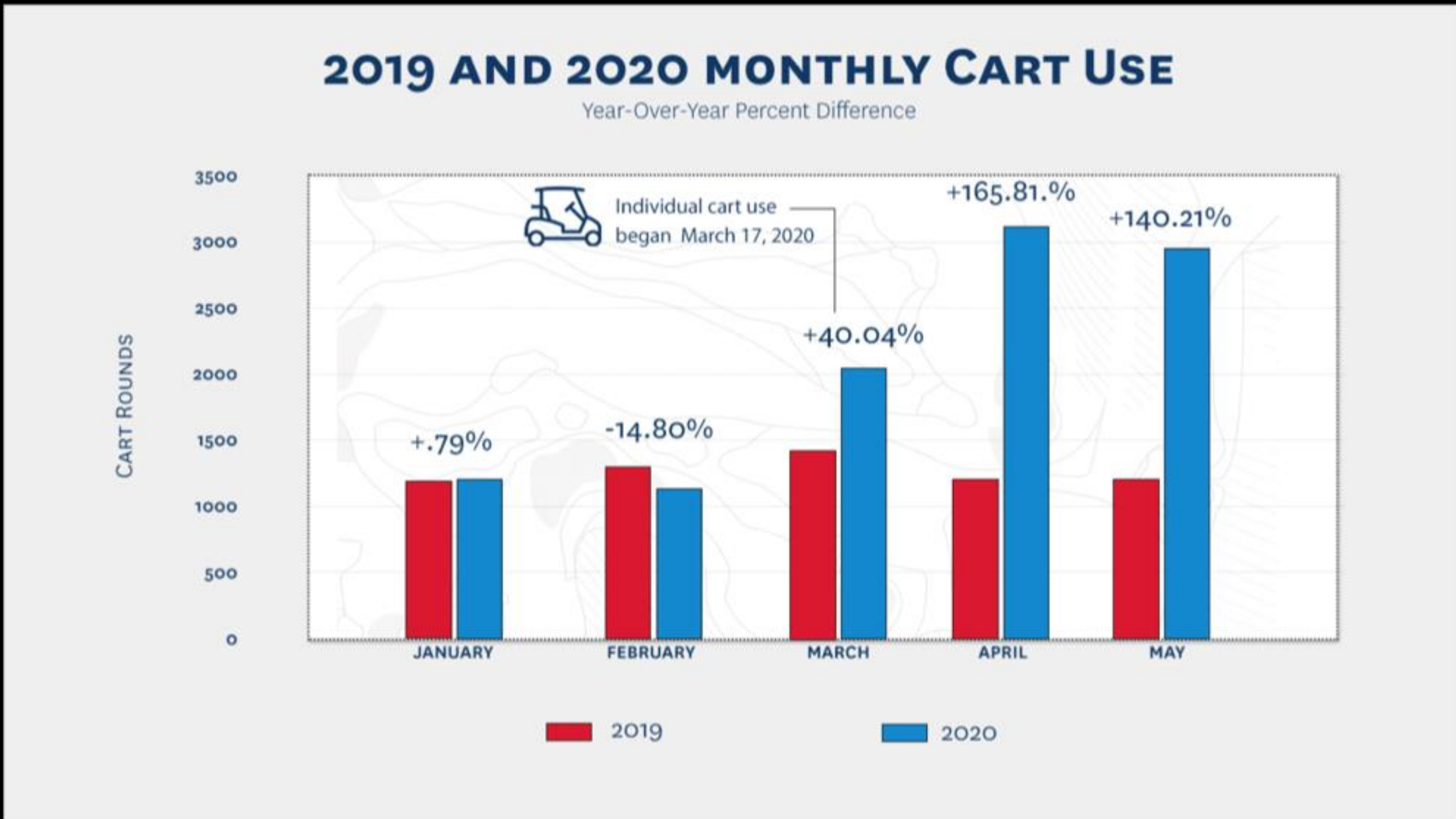


ADVANTAGES TO PROGRAMS

- Expose weeds to multiple modes of action to prevent selection pressure for resistance
    - Mixtures or rotations
- Can (and probably should be) property specific
- **Change your approach based on what you LEARNED the previous season** —> You're always getting better

PROGRAMMING KEY

- Take notes during the season, both success and failures
- Make changes based on what you observed
- Don’t just chalk it up to bad weather, bad luck, etc.



Source: @USGAGrnSection

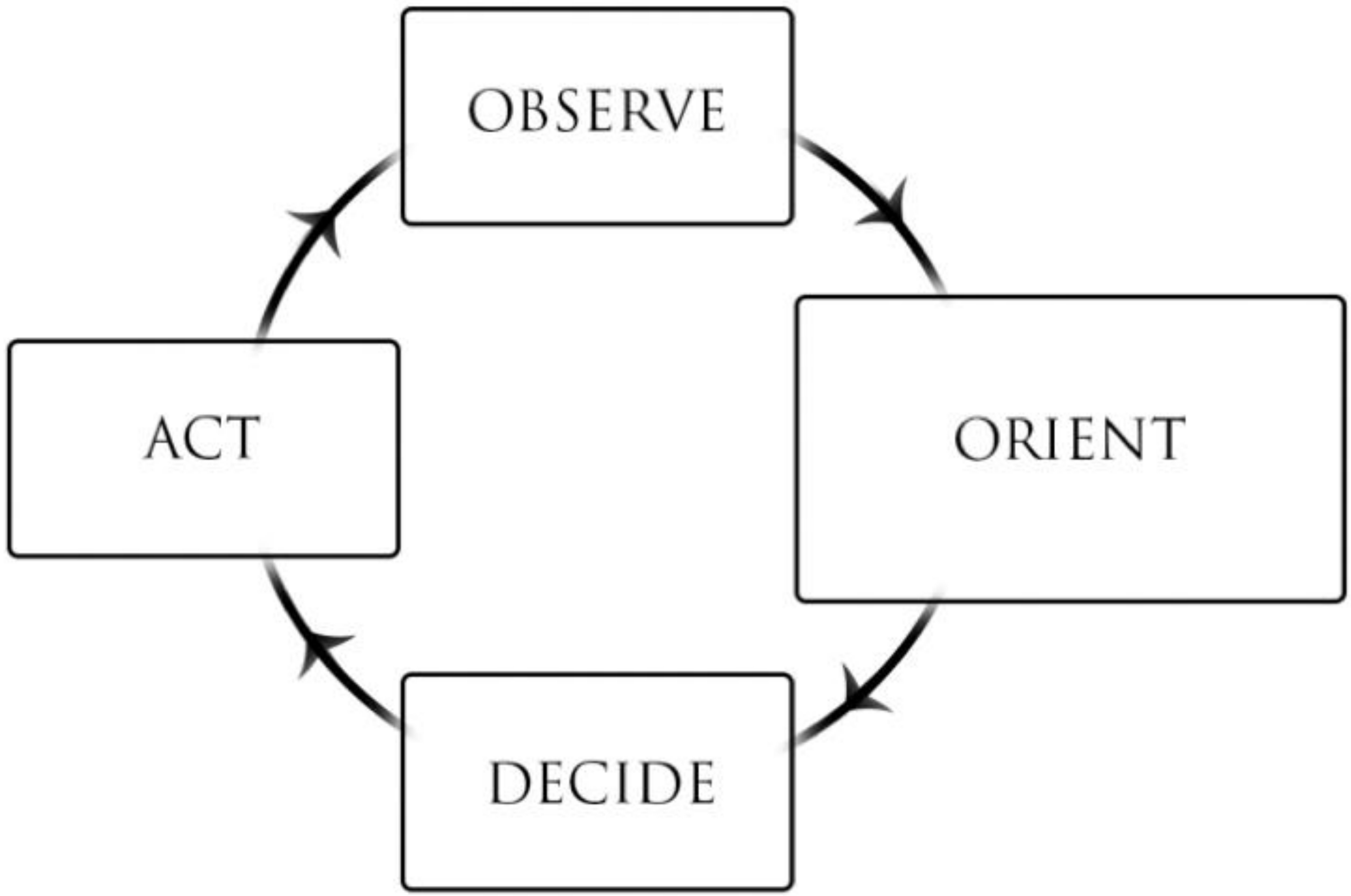
Cornell Turfgrass
@Cornell_Turf

Using the Turf Analyzer program on drone photos to highlight cart traffic. These were taken before noon! Increased cart traffic + dry conditions making this a common sight in NY this year

8:40 AM · Sep 2, 2020 · Twitter Web App

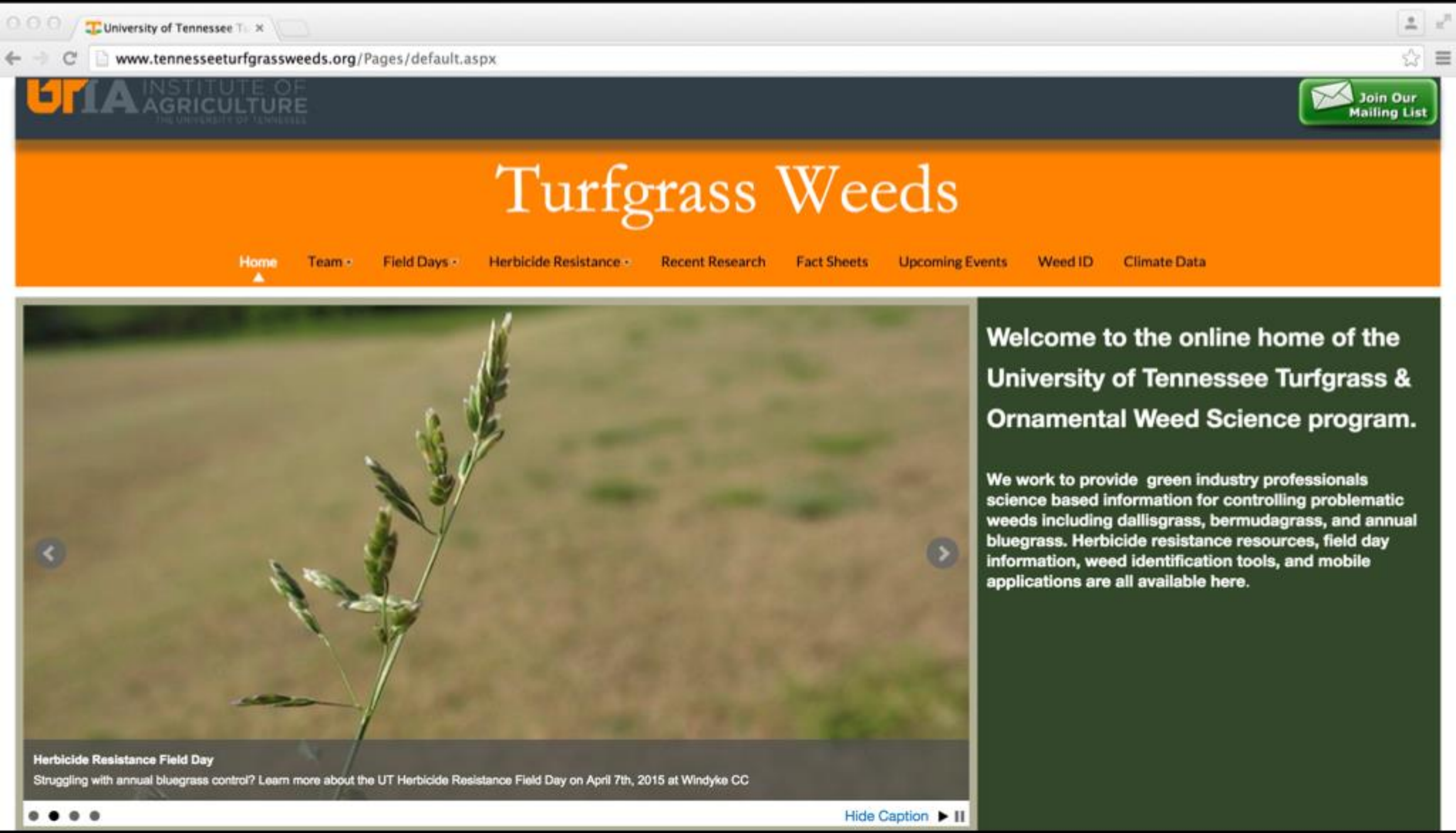
THE OODA LOOP

Col. John Boyd, USAF

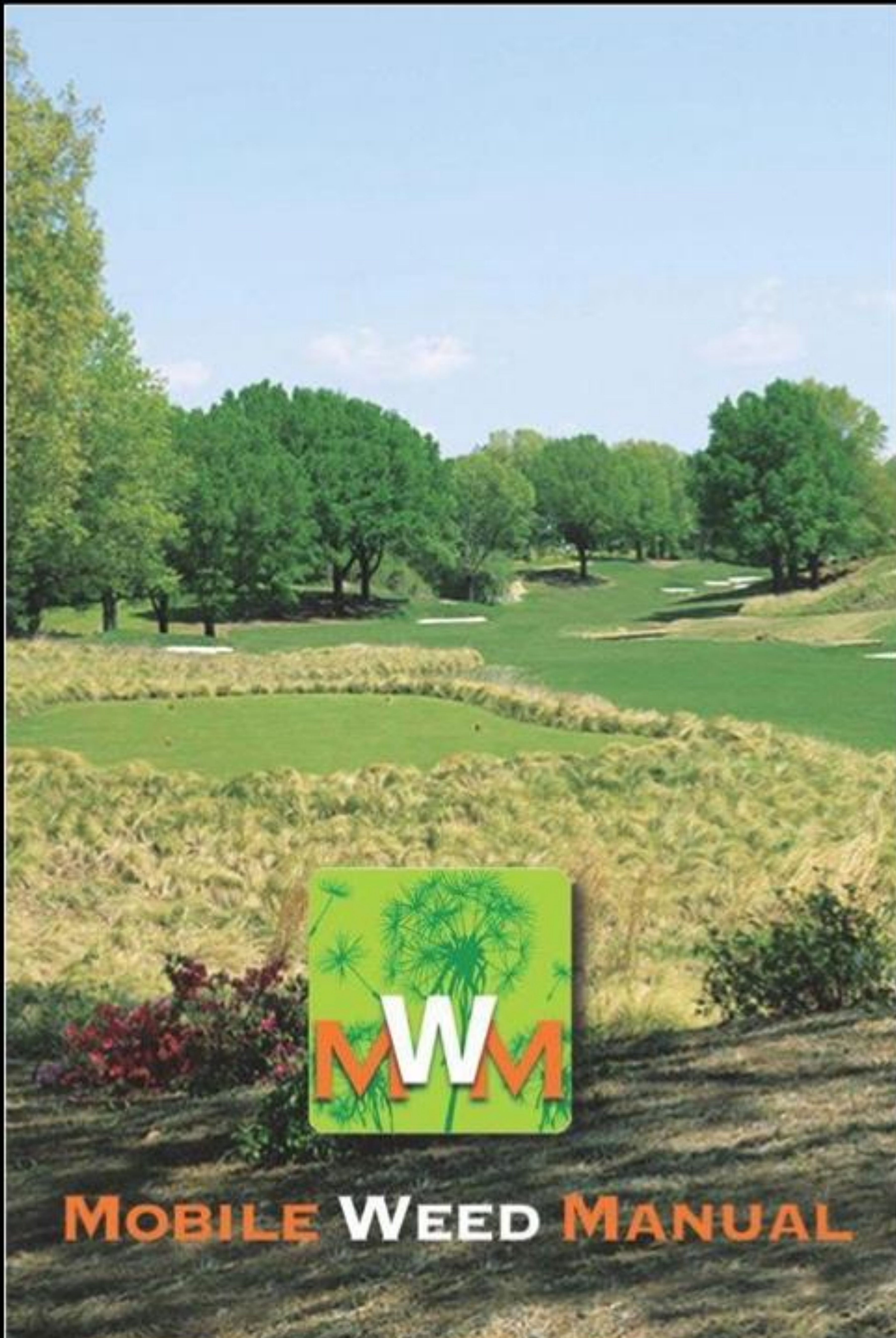


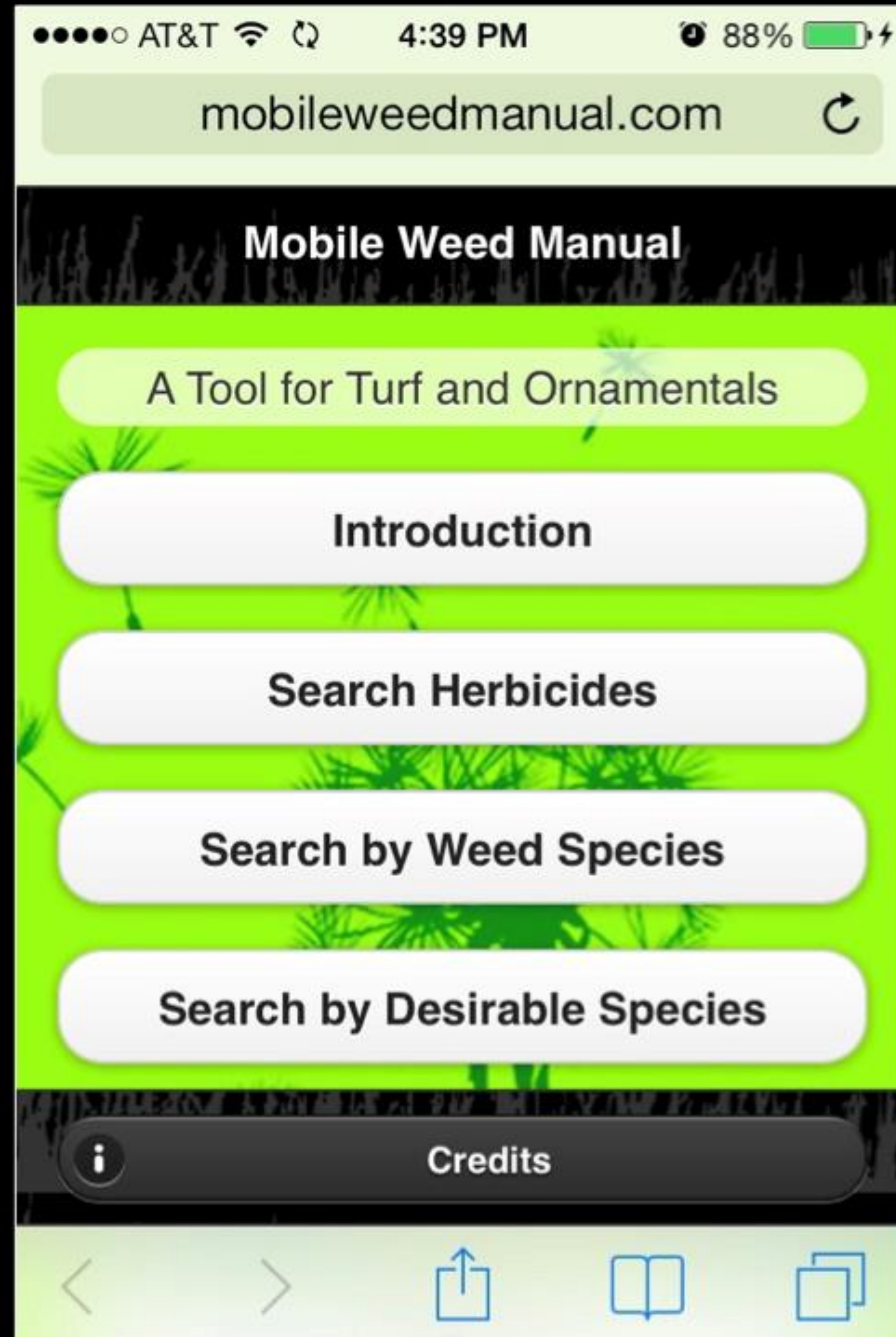
You are QB1!

These are tools to help



tnturfgrassweeds.org


MWM
MOBILE WEED MANUAL


AT&T
4:39 PM
88%
mobileweedmanual.com
Mobile Weed Manual
A Tool for Turf and Ornamentals
Introduction
Search Herbicides
Search by Weed Species
Search by Desirable Species
Credits

Polling Question

@UTTurfWeeds | jbrosnan@utk.edu



TENNESSEE
T

Questions?

OGCSA Industry Partners

- Platinum -

FAZIO BROS. Sand Co., Inc.

TURF STAR WESTERN TSW EST. 1912

PACIFIC GOLF & TURF

RMT EQUIPMENT

Simplot PARTNERS

- Gold -

RAIN BIRD

TARGET SPECIALTY PRODUCTS

WILBUR-ELLIS

WINFIELD UNITED Professional

- Silver -

Amvac
BASF
Bayer
General Tree Service
Helena Agri-Enterprises
Nufarm
Pacific Sports Turf
Perfect Drive & Utility Vehicles
Pure Seed / Tee 2 Green
Syngenta
JNB Transport

- Bronze -

Baer Design Group
HD Fowler
Midstate Fertilizer
Milroy Golf System
Planet Turf
Schneider Water Services
The Andersons

December 9, 2020
GCSAA Education Points Code
999-23432-31019

Thank You For Attending!

Question?

ogcsa@ogcsa.org

Oregon Chapter GCSAA
Golf Course Superintendents Association of America

OLCA
OREGON LANDSCAPE CONTRACTORS ASSOCIATION