

Weed Control in Tropical Turf and Roadside landscapes planted to native Hawaiian plants. 05/15/2015

Dr. Joe DeFrank – UH-TPSS
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Rey I. – TGD
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For more information on topics covered

<http://www.ctahr.hawaii.edu/deFrankJ/index.htm>

WEED CONTROL IN HAWAII WITH DR. JOE DEFRANK

Professor of Weed Science - University of Hawaii Department of Tropical Plant and Soil Science



[Weed Science 481-Fall 2011- Lecture notes and handouts](#)

[Weed ID Gallery - Economically Important weeds in vegetables, turf and potted ornamentals in Hawaii.](#)

[Streaming Media Content](#) ←

[Plants for People: Beverage Crops, Fall 2011 with Dr. Skip Bittenbender](#)

[ASHS 2011 WORKSHOP: Propagation Techniques of Select Tropical Ornamentals, Specialty Crops, and Native Plants in Hawaii](#)

[TPSS 491/711 Digital Tools for Scientific Content Fall 2012](#)



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[Web based resources for weed I.D. and control, problems weeds in warm season turf & Purple nutsedge control for gardens and ornamental nursery beds. \(posted 10/16/2012\)](#)

[Weed control recommendations-home turf, landscapes and gardens \(posted 06/01/2012\)](#)

[Weed control in Aiea ball field, Waipio Soccer Field issues and new rules for Aquatic weed control - CPS 12th Annual Seminar and Tradeshow \(posted 05/22/2012\)](#)

[Weed control update for warm season turf in Hawaii - Pacifica Ag. Tradeshow \(posted: 01/19/2012\)](#)

[Weed control Considerations for Potted Tropical Ornamentals and Turf \(posted: 02/09/2011\)](#)

[Aiea Baseball field weed cleanup - 2010 \(posted: 01/31/2011\)](#)

[Pili Grass as a Living Mulch in Tropical Vegetable Crop Production in Hawaii 2009.](#)

[Weed Control in Native Hawaiian Plants](#)

[Native Plants on Hawaii's Roadways](#)

[Restoring Native Habitats in Hawaii](#)

[Student presentations for Weed Science Lab, TPSS/PEPS 481](#)

[Herbicide and Growth Regulator Studies in Potted Ornamentals 2005 to 2007](#)

[Non-Weed Control Presentations \(posted 06/21/2011\)](#)

[HOME](#)



For more information on topics covered

Viewing tips for live seminar presentations – Open 2 browser windows
1- for video and 1 – for high resolution slides as pdf

The image shows two overlapping browser windows displaying a website. The website content includes a title, a paragraph of text, contact information for Dr. Joe DeFrank, and a table with four columns: Title of Presentation, Media format, Seminar Handout Links to referenced web resources, and Slide show images as pdf. The 'view lecture' link in the second column and the 'pdf' link in the fourth column of the table are circled in yellow in both windows.

Web Based Resources For Weed I.D. And Control, Problems Weeds In Hawaiian Turf And Purple Nutsedge Control In Gardens And Ornamental Nursery Beds - 2012

On October 12, 2012, Dr. DeFrank made a presentation to participants of the "DOD Pesticide Applicator Recertification & PMPAR Training NAVFAC Pacific and HIJIRSG" at Ford Island on Oahu. The participants are part of federal employee's pesticide certification program required of all pesticide handlers. This presentation covers Dr. DeFrank's selected web based resources for Hawaii weed I.D. and control recommendations. Problem sedge and broadleaf weeds are described and control recommendations for warm season turf are discussed. The presentation concludes with an in-depth description of the biology of Purple Nutsedge and IPM practices used to control this important weed with cultivation, systemic herbicides and woven black plastic weed mat.

For more information on this presentation contact:
Dr. Joe DeFrank
email.defrenk@hawaii.edu
Phone: 808-956-5698.

Suggested method to view streaming media and slideshow:

1. Open two browser windows, one will be used to view the "talking head" and the other will be used to view the slide show images as an Adobe pdf.
2. Click on the link to "view lecture", let the program download and start then hit pause.
3. In the second window open the pdf version of the slide show and once the first slide appears return to lecture and resume play.
3. With two windows open, one for the video and one for the slide show you can follow the lecture for the queues to change the slide image.

Title of Presentation	Media format	Seminar Handout Links to referenced web resources	Slide show images as pdf
Web based resources for weed ID and control, problems weeds of warm season turf and Purple nutsedge control. (posted 10/16/2012)	MPEG-4 view lecture	pdf	Click to download slide show

HOME

2 items

Ornamental Nursery Beds - 2012

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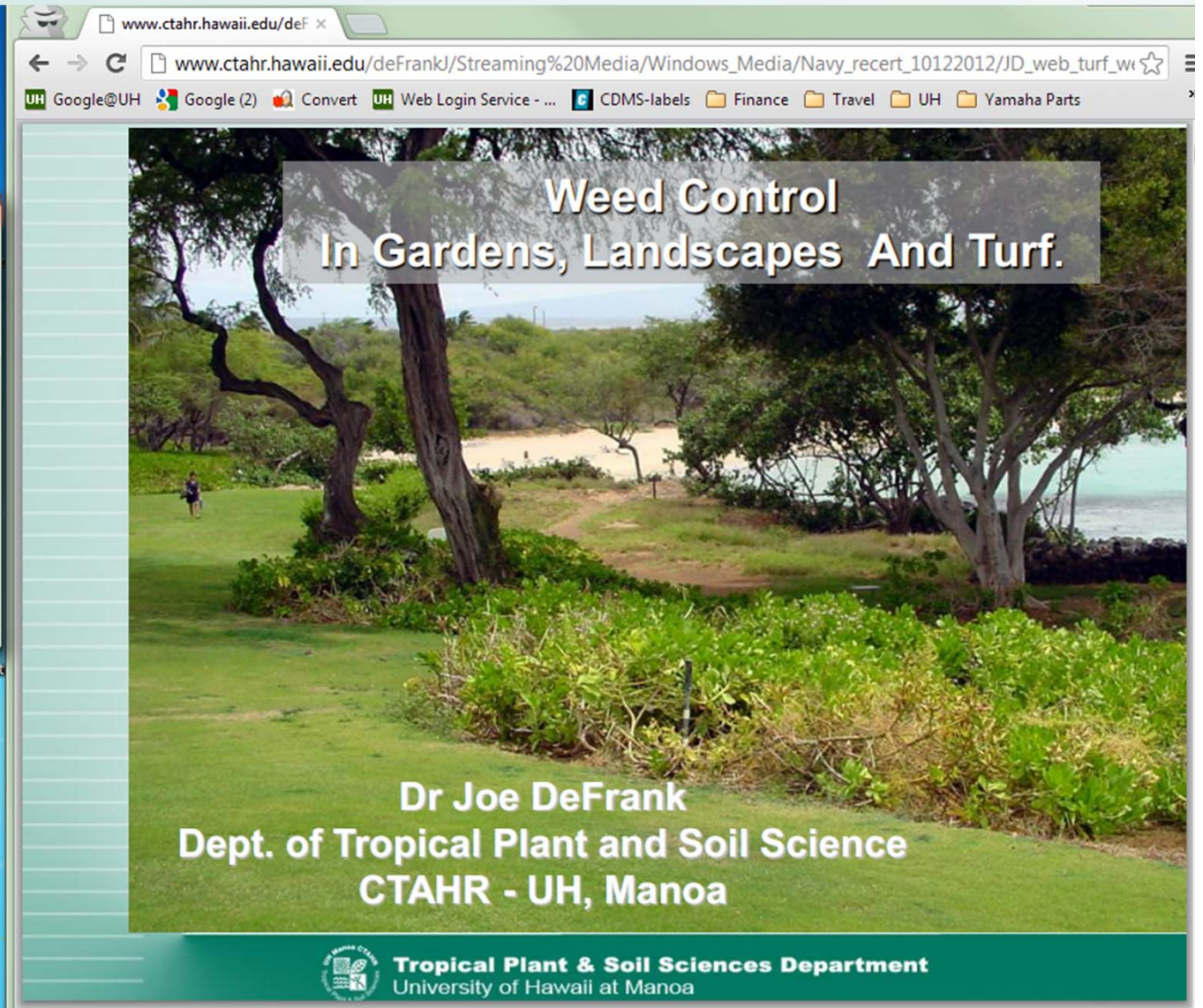
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Topics Covered – CPS – 2015

- 1. Grassy Weed ID for turf**
- 2. Time of year and weed control**
- 3. Lights Out – light exclusion for weed control during turf renovation**
- 4. Wipers for applying turf pesticides**
- 5. Native plant establishment of highway rights-of-way**



Grassy Weeds in Hawaiian Turf

Australian Carpet Grass

Hilo Grass

Goose grass

Dallisgrass

Love grass

Henry's and India CG

Star Grass

Smut grass

Pitted Beardgrass





Forest Starr & Kim Starr

Australian carpet grass

Axonopus compressus



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Hilo grass

Paspalum conjugatum



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Similar looking weedy grasses



Hilo grass

A. Carpet grass



Goose grass

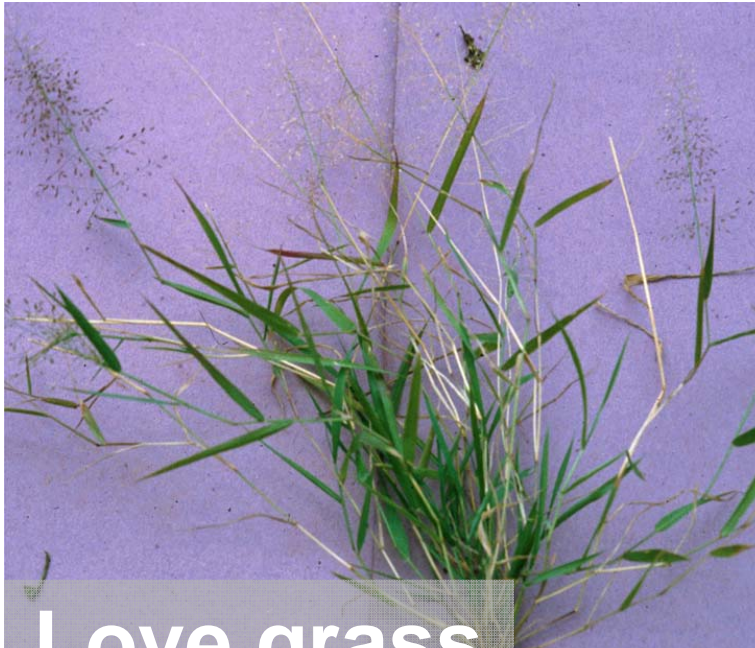
Eleusine indica



Dallisgrass

Paspalum dilatatum





Love grass

Eragrostis amabilis
Eragrostis tenella



Carolina Love grass

Eragrostis pectinacea



Forest & Kim Starr



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Henry's Crabgrass

Digitaria ciliaris



Forest & Kim Starr



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India Crabgrass

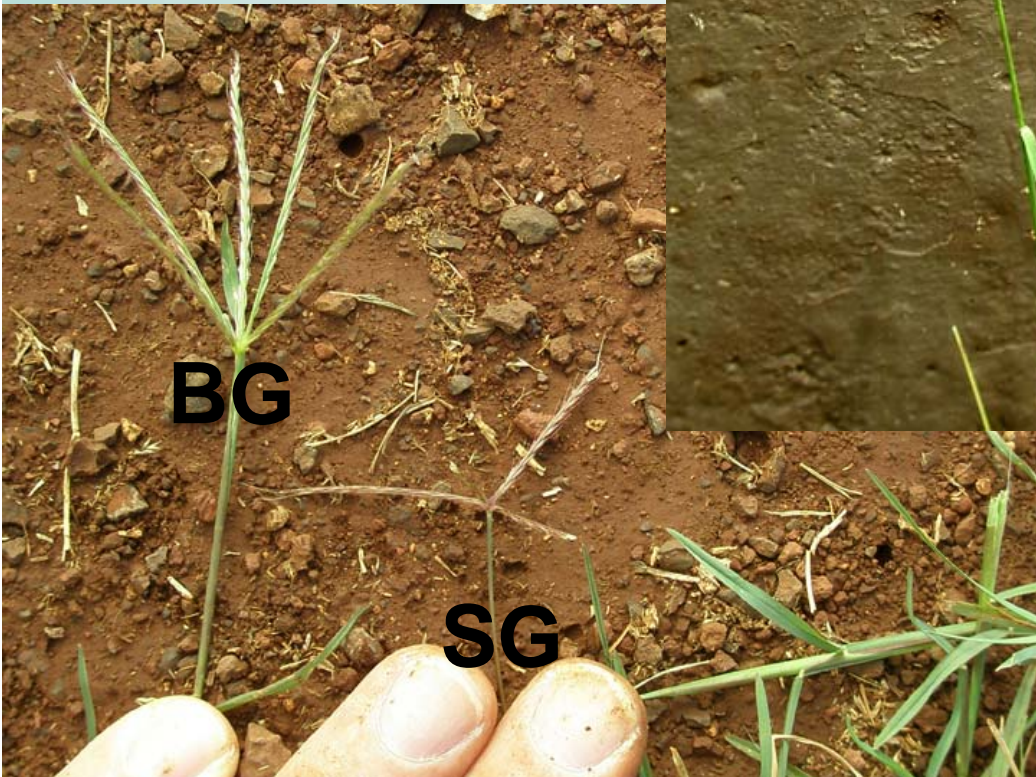
Digitaria longiflora



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Star Grass

Chloris divaricata



BG

SG



Star Grass



Smutgrass

Sporobolus indicus



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Pitted beardgrass

Bothriochloa pertusa



Forest Starr & Kim Starr



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Untreated 12/03/13



In the summer of 2013, field research, demonstrated the effectiveness of Tenacity + Sencor tank mix for the control of Goose grass and Love grass.

Prior to this time, a good “selective” chemical control program was not available for these two large well established grassy weeds in Hawaii.

**5oz Ten + 8oz Sen
102 DAS02
08/09 to 12/03/13**



“Selective” weed control has new meaning:

Selective used mean to good weed control mean little to no noticeable turf injury.

Now, selective control means is the injury, that is very noticeable, worth the weed control obtained?



Assumptions for TIME OF YEAR considerations for selective weed control based on case studies at the Waipio Soccer field (winter 2013 to summer 2014).

Municipal sport turf is the case study model

Winter season protocol

1. Nov.-March in Hawaii, Bermuda grass slow growing = semi dormant.
2. Weedy grass growth favored allowing for wider spread.
3. Cool wet weather reduces the effectiveness of certain herbicide who's mode of action is based on "growing the weeds to death".
4. Nov.-Dec.-Jan. slow time for sport turf use by community.
5. More tolerance of significant turf injury = yellowing and turf burn out.

**Tank mix of 5 oz/a Tenacity + 8 oz/a Sencor + 1% v/v MSO applied 2Xs
Provided near complete cleanup of Goose grass and Love grass with
common Bermuda grass recovery in 75-80 days
Dec.-Feb. period in Hawaii.**



Waipio Winter Season Case Study

**2013-Dec. Honolulu City and County treats
8 acres at Waipio**

**4 oz Tenacity + 8 oz Sencor + 1% MSO - 2X's
12/10 & 12/23/2013 – Winter Start Program**



22 DAS02 Ten(4 oz/a)+Sen (8 oz/a) – 01/06/14



42 DAS02 Ten(4 oz/a)+Sen (8 oz/a) – 01/26/14



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22 DAS02 Ten(4 oz/a)+Sen (8 oz/a) – 01/06/14



Dallis grass.



42 DAS02 Ten(4 oz/a)+Sen (8 oz/a) – 01/26/14



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22 DAS02 Ten(4 oz/a)+Sen (8 oz/a) – 01/06/14



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42 DAS02 Ten(4 oz/a)+Sen (8 oz/a) – 01/26/14



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42 DAS02 Ten(4 oz/a)+Sen (8 oz/a) – 01/26/14



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42 DAS02 Ten(4 oz/a)+Sen (8 oz/a) – 01/26/14



42 DAS02 Ten(4 oz/a)+Sen (8 oz/a) – 01/26/14



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Dismiss (6oz/a) + Barricade (10 oz/a) 2Xs for control of seedling Goose grass on

**GG control
w/Dismiss at pre-tiller-OK
Post tiller = NO-CAN.**



**Photos
8 DAS 1st Dism+Barr**



**Tropical
University**

**Optimum Goose grass size for
Dismiss activity is “pre-tiller” stage**

6-leaf pre-tiller



3-tiller goose grass



Timing isn't everything it's the only thing!



Winter Protocol

70 Days after T+S 2X's

Common Bermuda grass turf has filled in

22 DAS02 Ten(4 oz/a)+Sen (8 oz/a) – 01/06/14

Seedling goose grass control needed soon after larger weeds die and leave openings for weed seed germination.

70 DAS 2nd Ten+Sen - Photos on 03/03/14



Assumptions for TIME OF YEAR consideration for selective weed control based on case studies at the Waipio Soccer field (winter 2013 to summer 2014).

Municipal sport turf is the case study model

Summer season protocol

1. May-Aug. in Hawaii, Bermuda grass fast growing, fast recovery.
2. Weed growth faster too.
3. Hot sunny weather improves the effectiveness of certain herbicide who's mode of action is based on "growing the weeds to death".
4. June-Aug. main soccer tournament season, sport tourism an important economic consideration.
5. Less tolerance of significant turf injury due to high use pattern.

*To reduce turf injury with lower use rate of T+S tank mix
and get good weed control
weeds must be **setup** to enhance kill with post herbicides.*



**HC& C summer 2014 Waipio clean up
Experimental setup to low dose Tenacity + Sencor
Tank mix experiment.**

Summer 2014 protocol

- May 8, 2014: to activate turf & weed growth apply CN9 (10 gal/a) + Specticle (3.5 dry-oz/a).
- Enhances herbicide mode of action and reduces time for turf recovery to spray injury.



Pre emergence for Broadleaf & certain grass weed control

Specticle

- Single AI compound – pre activity only
- Use on Bermuda with preemergence activity only
- Control of important broadleaf weed HI: horseweed, broadleaf plantain, prostrate spurge and oxalis.
- Control of grassy weeds include: Henry's crab grass, Goose grass, Guinegrass, Green Kyllinga.
- 4-5 months of Goose grass control with 3.7 oz/a.
- Irrigation required for activation.
- Pruning of new roots of weeds and turf to be expected.



HC& C summer 2014 Waipio clean up
Experimental setup to low dose Tenacity + Sencor
Tank mix experiment.

Summer 2014 protocol

- May 8, 2014 apply CN9 (10 gal/a) + Specticle (3.5 dry-oz/a)
- **26 DAYS**
- June 3, 2014 apply Revolver 26 liq-oz/a + Celsius 3 dry-oz/a + Liberate surfactant .25%.
- **17 DAYS**
- June 20, 2014, 2nd app Rev. + Cel.
- Visual cue for 2nd R+C application is 1-2 nodes of **new growth** on Goose grass



Commonly used post emergence for Goose grass weed control

Revolver

- Single AI product , post in turf.
- Use on Bermuda
- Control for Goose grass in HI,
- Systemic uptake, plant grows without essential components and dies.
- Active plant growth needed for uptake and activation



Commonly used Post emergence for Broadleaf & certain grass weed control

Celsius

- 3 AI mix, includes dicamba
- Use on Bermuda
- Control of important broadleaf weeds in HI: creeping beggars tic, broadleaf plantain, prostrate spurge, horse weed and oxalis.
- Control of grassy weeds include Love grass relative, Sandbur, Australian Carpet grass.
- Systemic uptake, multiple modes of actions.
- Active plant growth needed for uptake and activation.



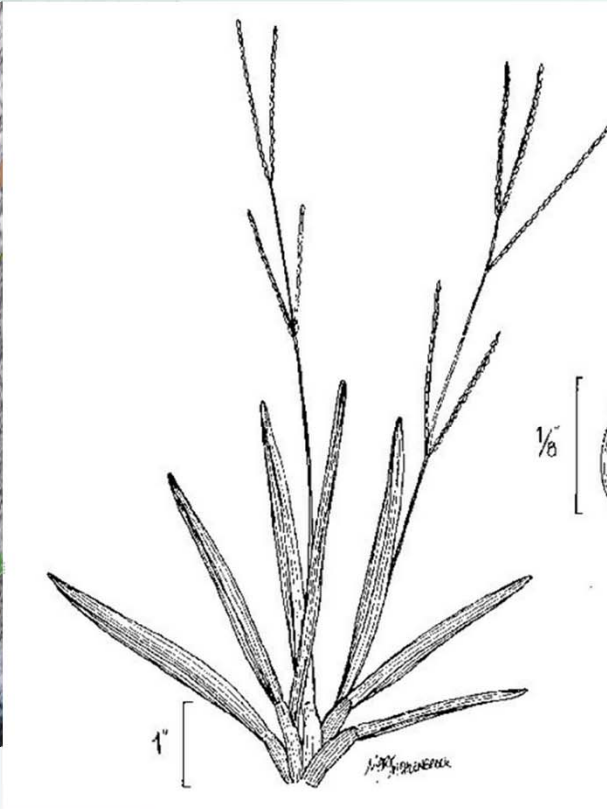
Celsius: Control of important broadleaf weed in HI: creeping beggartic, horse weed, broadleaf plantain, prostrate spurge, and oxalis.



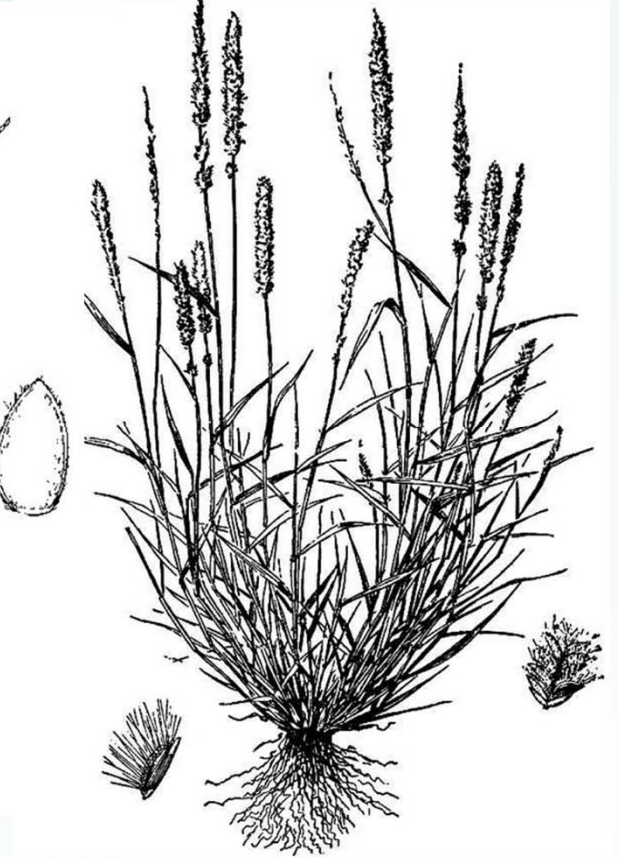
Celsius: Control of important grassy weeds: Sandbur, carpet grass & Love Grass relative = *Eragrostis ciliaris*



Sandbur-*C. echinatus*



Carpet grass-*A. affinis*



Gopher LG-*E. ciliaris*



HC& C summer 2014 Waipio clean up
Experimental setup to low dose Tenacity + Sencor Tank
mix experiment.

Summer 2014 protocol

- May 8, 2014 apply CN9 (10 gal/a) + Specticle (3.5 dry-oz/a)
- **26 DAYS**
- June 3, 2014 apply Revolver 26 liq-oz/a + Celsius 3 dry-oz/a + Liberate surfactant .25%.
- **17 DAYS**
- June 20, 2014, 2nd app Rev. + Cel.
- **40 DAYS**
- Old roots dead & New root growth from Goose and Love grass stem nodes, **CUE** to start next spray with different mode of action, 83 DA-Spec.



**Weed pressure in foreground this area not sprayed with
Revolver & Celsius shows large Goose grass**



**Weed pressure in foreground this area not sprayed with
Revolver & Celsius shows large Goose grass**



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**40 DAS2 Rev. & Cel. mostly Love grass some GG
at start of low dose T+S on 08/01/14**



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40 DAS2 Rev+Cel =
Easy extraction of
NORMAL looking Love
grass





Love grass



Goose grass

Compromised main roots allows flush of new roots.
Specticle in place to prevent root penetration into soil,
provides wider window for post herbicide application and
preemergence control of weed seed germination.
Low dose Tenacity + Sencor to complete weed control
process after **setup** with Rev + Cel.

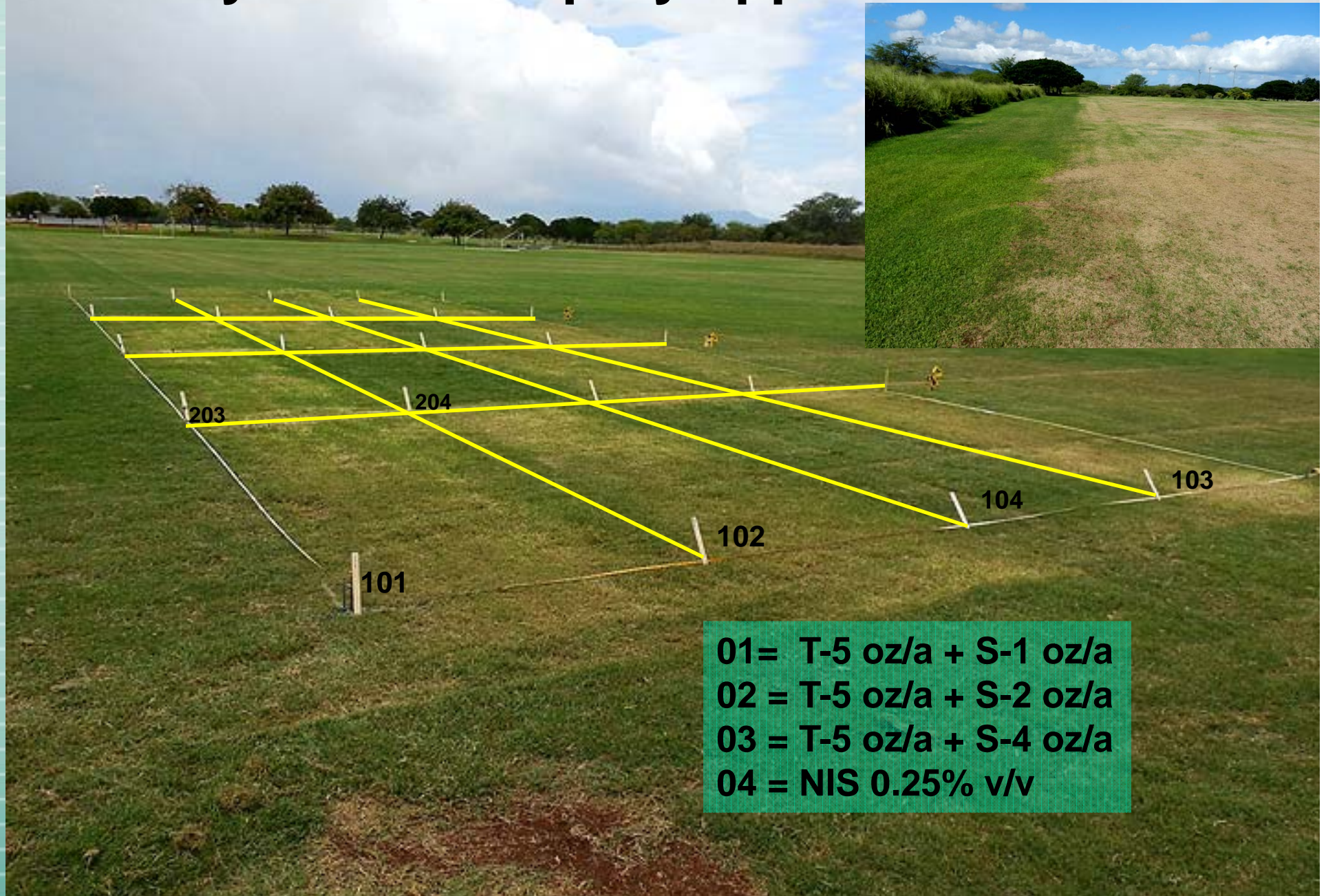


**Low dose Tenacity + Sencor Tank mix study
42 Days after 2nd Rev. + Cel. Application
Started 08/01/2014, 2nd app 11 days later.**

Treatment # 2Xs	Herbicides	Amount/a
1	Tenacity + Sencor + NIS (Excel 90) 0.25%	5 liq-oz/a + 1 dry-oz/a
2	Tenacity + Sencor + NIS (Excel 90) 0.25%	5 liq-oz/a + 2 dry-oz/a
3	Tenacity + Sencor + NIS (Excel 90) 0.25%	5 liq-oz/a + 4 dry-oz/a
4	NIS (Excel 90) 0.25%	



7 days after 1st spray application 08/08/14



01= T-5 oz/a + S-1 oz/a
02 = T-5 oz/a + S-2 oz/a
03 = T-5 oz/a + S-4 oz/a
04 = NIS 0.25% v/v

7 DAS1
Trt-01
5 OZ/A-T
1 OZ/A-S



7DAS1
Trt -02
5 OZ/A-T
2 OZ/A-S





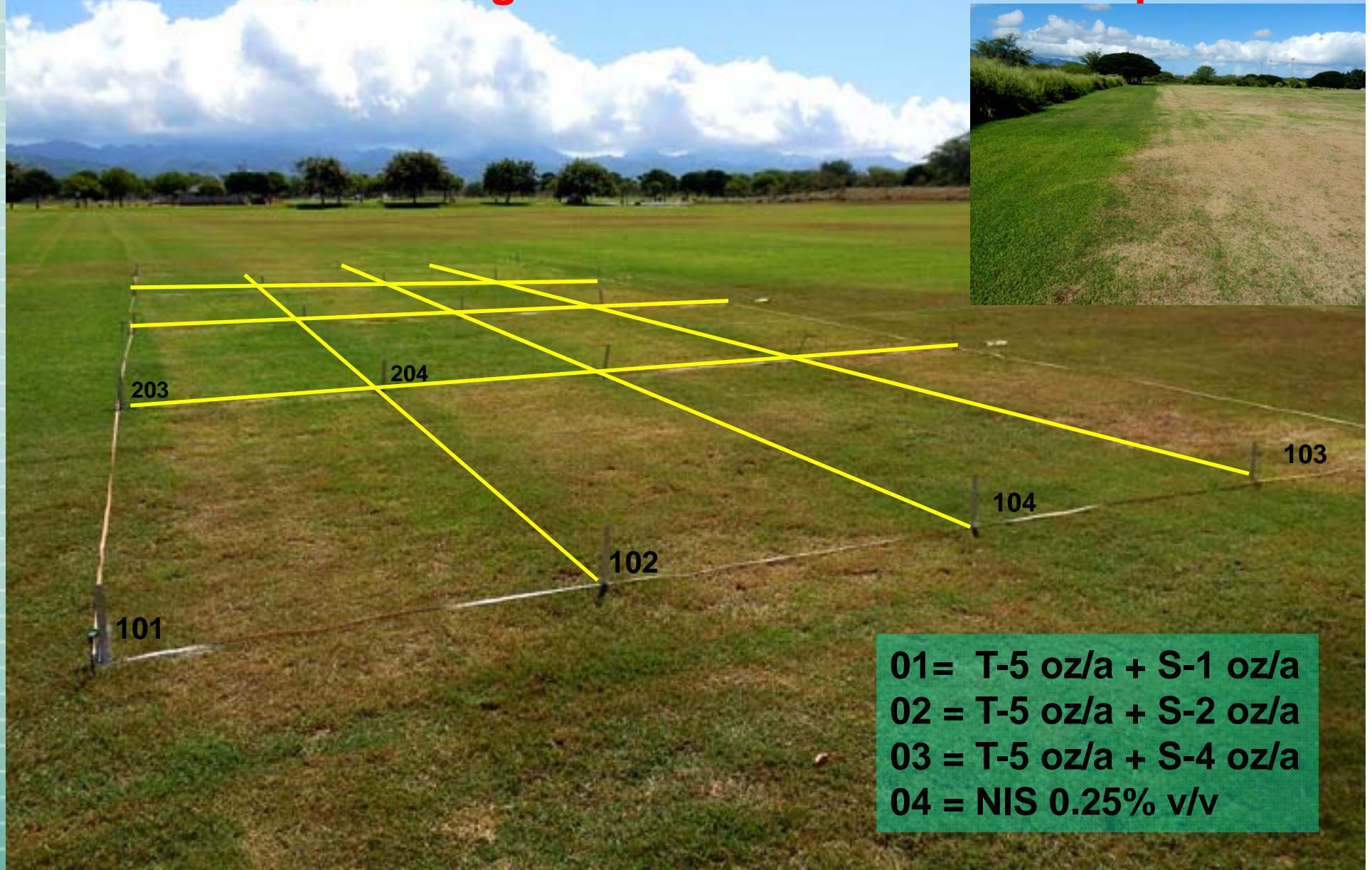
Pre-spray LG roots



7DAS1
Trt 03
5 OZ/A-T
4 OZ/A-S

8 days after 2nd spray application 08/20/14

Note frosting in areas where turf was scalped



0 Day
5 OZ/A-T
2 OZ/A-S

Start

54 days
from start of
T+S spray

38 DAS2
5 OZ/A-T
2 OZ/A-S

End



Comparison of time of year impact on:

Herbicide type, sequence and rates for Love and
Goose grass control in Bermuda Grass sport turf in
Hawaii

Spray treatment	Winter* Dec.-Jan 2013	Summer June-Aug 2014	# of Apps
Specticle	-	3.5 oz/a	1
Rev. + Cel.	-	26 L-oz R + 3 D-oz/a	2
Tenacity	4 L-oz/a	5 L-oz/ for LG only	2
Sencor	8 D-oz/a	2-4 D-oz/a for GG + LG	2
Surfactant	1% MSO	.25% NIS	
Days to recover After 2 nd app. T+S	75-80	14-20	



“Lights Out” Using Light Exclusion for Weed control during turf renovation

Appropriate Sites and Concept

1. Public parks, school fields & private residences
2. Eliminate herbicides for turf and weed removal during turf renovation
3. Use geotextile woven plastic weed fabric for weed/old turf kill.
4. Requires time, irrigation & fertilizer to accelerate renovation process



“Lights Out” for sport turf renovations





Demonstration at UH Manoa Magoon Research and Teaching Facility
Weedy “Zenith” zoysia grass planting with weed = Nutsedge, Creeping indigo, Henry’s crab grass, Prostrate spurge, Goose grass, Swollen finger grass and Australian carpet grass.

Covered grass and weeds for 21 days 09/11/14 to 10/02/14 with woven plastic weed mat.





21 days of coverage killed off Zoysia thatch and grassy weeds but stimulated Purple nutsedge germination from underground tubers



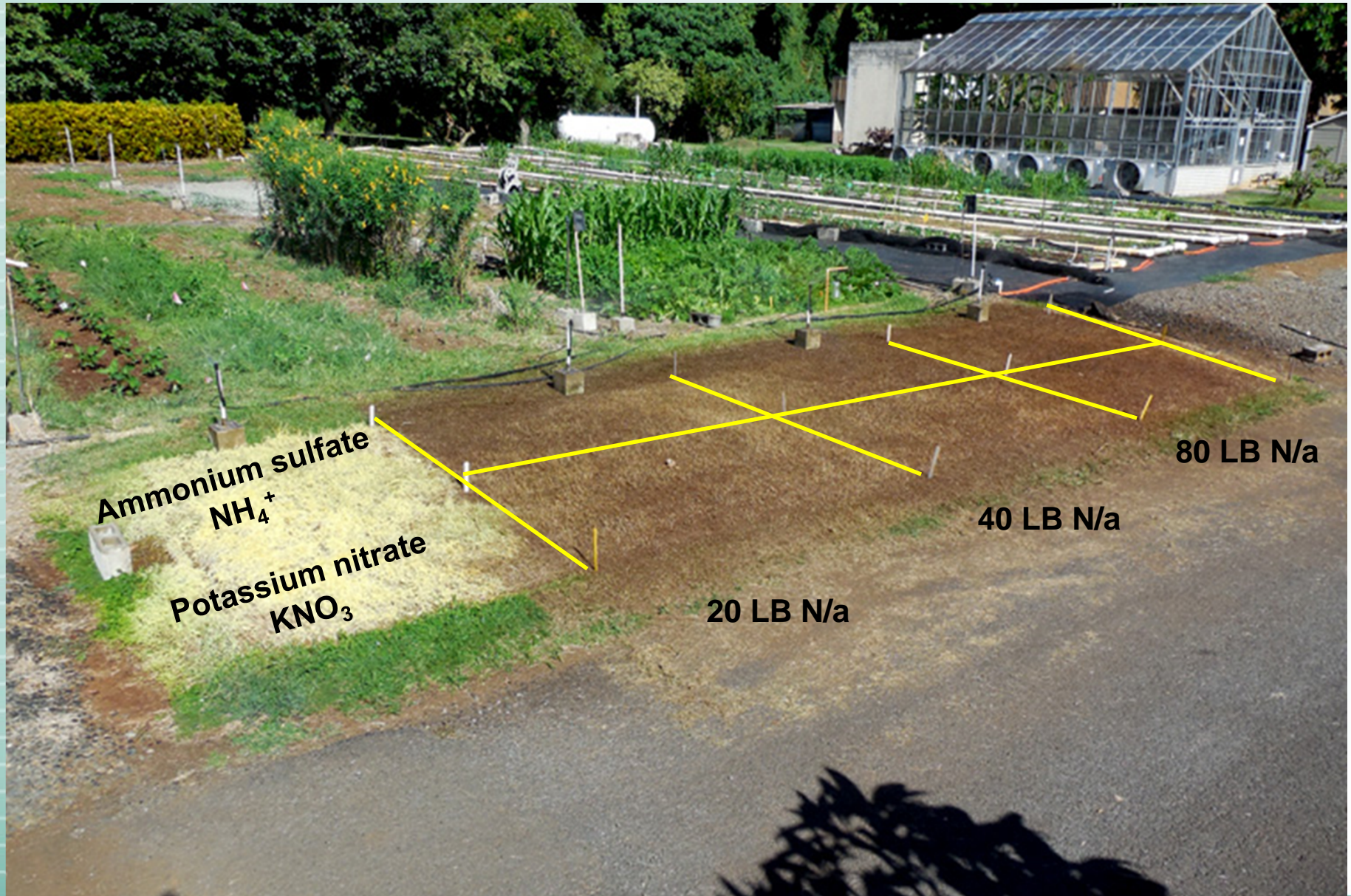
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Verticut old thatch and weeds and remove all surface plant materials



2 fertilizer forms applied at 3 rates – compare weed seed germination stimulation





Weeds grow back from seed and old turf returns from underground stems and roots.



Weeds grow for 14 days and then the weed mat is reapplied 2nd time to kill newly germinated weed seedlings



With 2 weeks of 2nd coverage all weed seedling killed and more nutsedge grows. Verticut to remove nutsedge stems, remove any turf regrowth and direct seed with “Riviera” Bermuda grass applied at 3.0 lb/1000 ft.²



“Riviera” Bermuda grass seed applied at 3.0 lb/1000 ft.²



**Seed covered with hydromulch cap and irrigation
applied for maximum growth**



**At 33 days after planting Bermuda grass & weeds have filled the space.
Fertilizer plots split: ½ untreated and ½ treated with post herbicides**



Bermuda grass and weeds grow. At 33 days after planting apply post herbicide. Applied tank mix of Monument .4 oz/a + Manor/Blade .3 oz/a + .25% NIS = Excel 90



At 33 days after planting apply post herbicide.

20 LB N/a

40 LB N/a

80 LB N/a

Ammonium sulfate NH_4^+						
Potassium nitrate KNO_3						
	1X	UNTR	2X	UNTR	4X	UNTR
	Monument .4 oz/a + Manor/Blade .3 oz/a		Monument .8 oz/a + Manor/Blade .6 oz/a		Monument 1.6 oz/a + Manor/Blade 1.2 oz/a	

Maximum label rate: Manor/Blade = 1.0 oz/a

Monument = .53 oz/a with 1.7 oz/a/yr.



54 DAYS AFTER SPRAY APPLICATION

20 LB N/A
Potassium nitrate
 KNO_3

20 LB N/A
Ammonium sulfate
 NH_4^+

1X
Monument .4 oz/a +
Manor/Blade .3 oz/a

1x M&M



UNTR

Maximum label rate: Manor/Blade = 1.0 oz/s
Monument = .53 oz/a with 1.7 oz/a/yr.

54 DAYS AFTER SPRAY APPLICATION

40 LB N/A

Potassium nitrate
 KNO_3

40 LB N/A

Ammonium sulfate
 NH_4^+

2X
Monument .8 oz/a +
Manor/Blade .6 oz/a

2x M&M



UNTR

Maximum label rate: Manor/Blade = 1.0 oz/s

Monument = .53 oz/a with 1.7 oz/a/yr.

54 DAYS AFTER SPRAY APPLICATION

80 LB N/A
Potassium nitrate
 KNO_3

80 LB N/A
Ammonium sulfate
 NH_4^+

4X
Monument 1.6 oz/a +
Manor/Blade 1.2 oz/a

4x M&M



UNTR

Maximum label rate: Manor/Blade = 1.0 oz/s

Monument = .53 oz/a with 1.7 oz/a/yr.

UNTR 54 DAP

20 LB N/A

40 LB N/A

80 LB N/A

Potassium nitrate KNO_3

Ammonium sulfate NH_4^+



CONCLUSIONS ON LIGHTS OUT FOR TURF RENOVATION

1. Light exclusion for 21 days kills off large grassy weeds.
2. Nutsedge population reduced by stimulation to germinate and then above ground parts removed.
3. Fertilizer can increase weed seed germination, makes 2nd covering more effective for grassy weed control.
4. 80 lb/a N more effective than 20 & 40 lb/a.
5. Ammonium sulfate appeared more effective than potassium nitrate.
6. 33 day old Riviera Bermuda grass well tolerated
 - a) 0.3 to 1.2 oz/a Manor/Blade = metsulfuron methyl.
 - b) 0.4 to 1.6 oz/a Monument = trifloxysulfuron.

Maximum label rate: Manor/Blade = 1.0 oz/s
Monument = .53 oz/a with 1.7 oz/a/yr.





**Improved weed wick for
fast growing weeds in new
turf plantings**



Factors for wiper applications

1. Pre application growth activation of weeds and turf.
2. Sufficient height difference between weeds & turf.
3. Glyphosate at 15-20% (20-25 oz/gal) for wiping weeds.
4. 2-3 day delay mowing and irrigation after app.



Hoakalei wiper cleanup of 8 acres



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Hoakalei wiper cleanup of 8 acres



Hoakalei wiper cleanup of 8 acres



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Hoakalei wiper cleanup of 8 acres



Hoakalei wiper cleanup of 8 acres



Hoakalei wiper cleanup of 8 acres



Hoakalei wiper cleanup of 8 acres



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Production of Native Hawaiian Plant Seeds & Installation of Native Dry-Land Plants On Hawaii's Roadside areas



Statutory justification for the use of native vegetation as roadside vegetation.

The Clean Water Act - cannot discharge polluted runoff to “Waters of the United States”

- The term pollutant includes: solid waste, sewage, soil municipal, and agricultural waste.
- Release of polluted storm water runoff allowed under the National Pollution Discharge Elimination System ((NPDES) pursuant to Section 402(b) of the CWA



The NPDES permits issued to HDOT requires the composition and enforcement of a Storm Water Management Plan

Oahu Storm Water Management Program Plan



State of Hawaii Department of Transportation
Highways Division



PROTECT
OUR
WATER
MĀLAMA I KA WAI

March 2007



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SWMP has BMP's for chemical application to roadways

State of Hawaii Department of Transportation
Highways Division



PROTECT
OUR
WATER
MĀLAMA I KA WAI
OFFICE OF WATER QUALITY AND PROTECTION
March 2007

CHAPTER 9 Pollution Prevention and Good Housekeeping 9-1

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Native vegetation as roadside ground covers = compliance to SWMP

9.2.3 Non-Chemical Solutions

In order to develop sustainable and durable landscapes with an Hawaiian sense of place, HDOT Highways is developing a Statewide Sustainable Landscape Master Plan, which is scheduled to be completed by the end of 2009. The objective of the plan is to develop a list of plants that can be used in highway landscaped areas that have a lifespan of 15-plus years, are durable, and where their natural form is preferred. These plants would require little or no maintenance (e.g., little or no application of fertilizers and herbicides), no irrigation, are cost effective, and reflect Hawaii's sense of place. **Native species meeting these criteria** will be prioritized in the list, which will be categorized by annual rainfall and typical locations. Once completed, the plan will be distributed to HWY-OM and HDOT Highways design managers, and be made available to landscape architects working on HDOT Highways projects.

DOT-Funded Projects 2013-2016

Project Objectives

1. Develop establishment and maintenance protocol for plantings of Native HI plants on roadside areas.
2. Describe seed harvest index and seed cleaning protocols for 4 grass and 5 broadleaf species.
3. Install 8,000 ft² plantings of 5 broadleaf native HI plants for roadside seed producing at Halawa.
4. Install roadside demonstration planting to simulate native dry land ecosystem on roadside area



Install roadside demonstration plantings to simulate native dry land ecosystem on roadside areas. - Molokai Land Trust Exclusion Area



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Recommendations for all DOT contracts
For large scale establishment of mixed stand of native
dryland plants landscape on roadways

1. Protocol for dryland ecosystem installation starts with weed eradication period, then 4 phase approach. Irrigate to Grow weeds, kill weeds & repeat.
2. **Phase 1:** drop Pili grass seed on drip line and cap
3. **Phase 2:** fertilize and mow to develop plant structure that maximizes seed production
4. **Phase 3:** seed laden mulch used to populate between row space
5. **Phase 4:** Into clean stand of Pili grass, plant native broadleaf plants into heavy mulch.



Irrigation to grow weeds and then apply herbicides for kill of perennials, 6-9 months



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Weed free site ready for foundation species = Pili grass



1. Last few weed can be manually removed.



Phase 1: drop seed on drip line and cap



Phase 1: drop seed on drip line and cap

1/2 lbs./100 linear ft – at least 2 live seed per linear foot



Phase 1: drop seed on drip line and cap



Phase 1: drop seed on drip line and cap – Pili grass seedling 2-wks



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Phase 1: drop seed on drip line and cap

Use hydro mulch applicator to apply pre-herbicide to between row space
Apply Ronstar 50 WP 2.5 lbs./a,



Phase 1: drop seed on drip line and cap



Phase 1: drop seed on drip line and cap
Broadleaf weeds removed with selective herbicides



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Phase 2: fertilize and mow grass. Adds mulch and conditions plants for heavy seed production.



Phase 3: seed laden mulch to populate between row space.



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Phase 4: broadleaf natives planted into Pili mulch = simulated dryland ecosystem.



Phase 4: broadleaf natives planted into Pili mulch = simulated dryland ecosystem.





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