Factors that Affect Dislodgeable Foliar Residues and Environmental Fate of Pesticides

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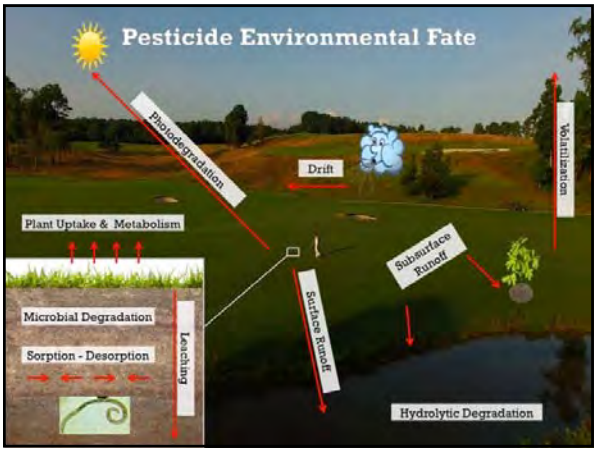
What We'll Talk About…

- What is pesticide environmental fate?
  - Why is it important?
- Dislodgeable foliar residues
  - Why is it important???
  - Current research
  - Research implications
  - Best management practices
- Questions???



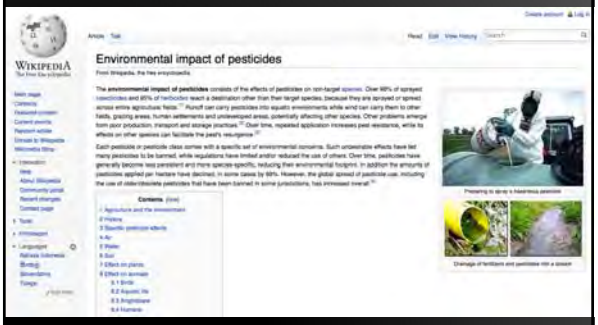
Pesticide Fate Research in Turfgrass… What is it???

- What happens to a pesticide after application?
  - What/who does it affect?
  - Where can you find it?
  - How long does it persist?

Pesticide Fate Research in Turfgrass… Why is it Important???

Preserve tools <u>today</u>,
while providing information required
for the implementation of best
application practices in the <u>future</u>

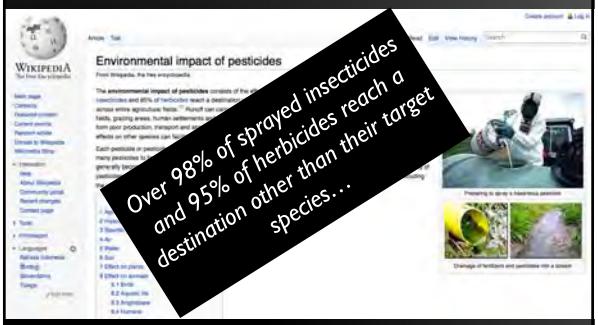
Pesticide Fate Research in Turfgrass… What is it???



Pesticide Fate Research in Turfgrass… Why is it Important???

- Keeping the right products on shelves
- Reduces potential for adverse effects on off-target areas and species
  - Environmental, ecological
    - Groundwater, surface water bodies
  - Human health effects
    - Worker and non-worker exposure

Pesticide Fate Research in Turfgrass… What is it???



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Pesticide Fate Research in Turfgrass… Why is it Important???

- Keeping the right products on shelves
  - MSMA
    - August 10, 2006: EPA proposed ban on all organic arsenicals
    - January 16, 2009: MAA research task force reaches agreement with EPA
    - September, 2012: EPA announced continued use of stocks
      - Athletic fields not on current labels
  - 2,4-D
    - Public concerns intensifying regarding its use
    - Re-registred in 2013
  - Imidacloprid
    - Linked to bee colony collapse
    - 2013 – European Union bans its use
  - Glyphosate
    - IARC (WHO) classified as probable carcinogen (Group 2A)
  - Sulfonylurea herbicides
    - Recent risk assessment

Arsenic from MSMA - Porewater

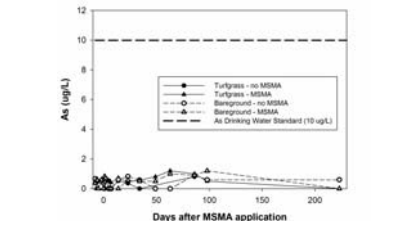

Figure 2. Arsenic concentrations in porewater from MSMA-treated and non-treated lysimeters.

- Through 200 DAT, porewater arsenic does not exceed 2 µg/L
- No difference in porewater arsenic concentrations for nontreated and MSMA-treated lysimeters

Pesticide Fate Research in Turfgrass… Why is it Important???

Keeping the wrong products off shelves too…

Pesticide Fate Research in Turfgrass… Why is it Important???

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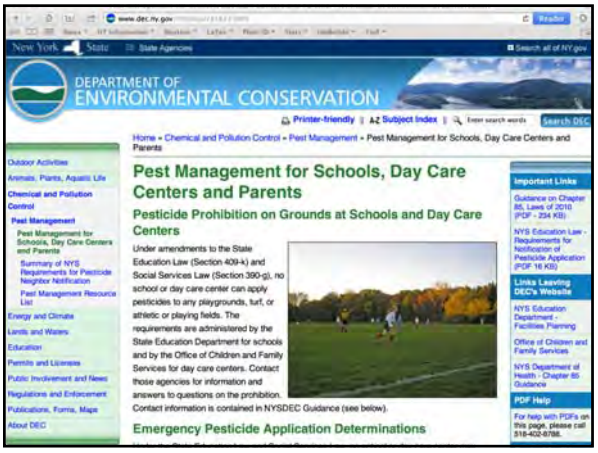
Pesticide Fate Research in Turfgrass… Why is it Important???

- Keeping the right products
- Reduces potential for a cts on off-target areas an ecies
  - Environmen ecological
  - W nd non-worker exposure
- proves comprehensive IPM plans

off-target movement = angry neighbors

Public Concern

- Public concern about pesticide use
  - *"For the price of a green lawn, we are poisoning our children."* (Family Circle Magazine, 1991)
- Legislative bans introduced
  - Montgomery County, Maryland has become first major municipality to ban use of pesticides on private lawns (Washington Post, Oct. 2016)



409-k) and Social Services Law (Section 390-g), no school or day care center can apply pesticides to any playgrounds, turf, or athletic or playing fields. The

Athletic Field Use

- Athletic fields commonly used throughout society
  - > 700,000 managed fields in the U.S. (NTEP 2003)
  - > 40% of the U.S. population ages 7 to 44 participate in baseball, football, golf, soccer and/or softball (U.S. Census 2009)

Center for EFFECTIVE GOVERNMENT

WHAT WE DO | RESOURCES | IN-DEPTH ARTICLES | BLOG | PRESS ROOM

Blog: The Fine Print

Maryland County Protects Residents from Unnecessary Lawn Pesticides

by Brian Gumm, 10/7/2015

Photo courtesy of: Sorochan and Brosnan

Tifway Bermudagrass After 15 Simulated Games

PETITION | LEGISLATION | HISTORY | OPT IN | OUR VOLUNTEERS | PARTNERS | RESOURCES | BLOG | CONTACT US

Take Action NOW! Pesticide Industry Files Suit Against Montgomery, MD Lawn Pesticide Law

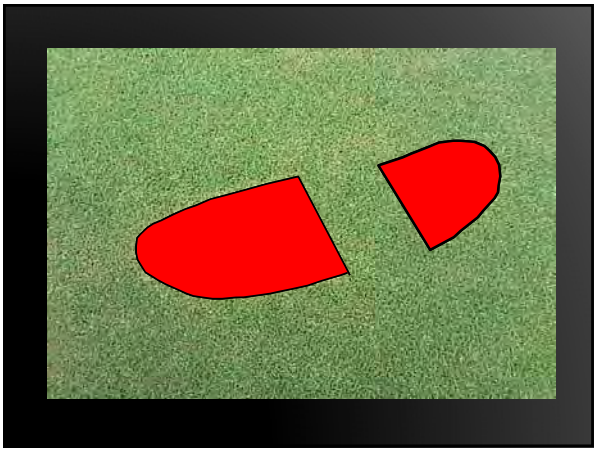
Fight back to protect Montgomery County MD! communities from Toxic Lawn Pesticides
go to: Bit.ly/defendpesticidelaw or petition page on Safe Grow Montgomery website!

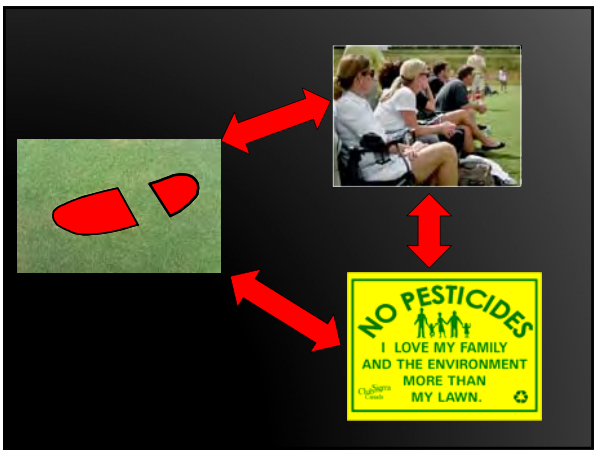
Photo courtesy of: Sorochan and Brosnan

Large Crabgrass After 15 Simulated Games

Athletic Field Management

- Weeds (and other pests) can reduce playing surface strength and uniformity…
  - SAFETY CONCERNS!!!





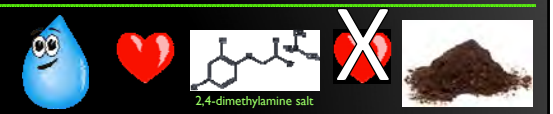
Dislodgeable Foliar Residues

- "Residues that may be transferred to the skin as a result of contact and are available for dermal absorption or ingestion." (EPA 1997)

2,4-Dimethylamine Salt (2,4-D)

- POST broadleaf weeds
- Registration dates
  - 1944: United States (US)
  - 1950's: Internationally
- Turfgrass use sites
  - Golf courses, sod farms, home lawns, athletic fields, etc.
  - 2006 to 2007
    - 34% of US use (7.3 million kg) was applied to non-cropland areas including turfgrass

2,4-D Can Dislodge from Turfgrass



HIGH water solubility
K_s = 796,000 mg L^{-1} (pH 5)

LOW soil sorption
K_{oc} = 20 mL g^{-1}

Dislodged Pesticide = Human Exposure???

- It depends… (on a lot of things)
- Pesticide risk = toxicity + exposure
  - "The dose makes the poison" - *Paracelsus*
  - Toxicity
    - LD_{50} – lethal dose required to kill 50% of a population
      - Decreasing value = increasing toxicity
  - Exposure
    - Acute
      - Single exposure or multiple exposures in < 24 hr period
    - Chronic
      - Repeated exposure over an extended period of time

(K_s = 796,000 mg L^{-1} at pH 5)

+

(K_{oc} = 20 mL g^{-1})

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Ultimate goal is to develop best management practices to minimize dislodgeable foliar residues

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+

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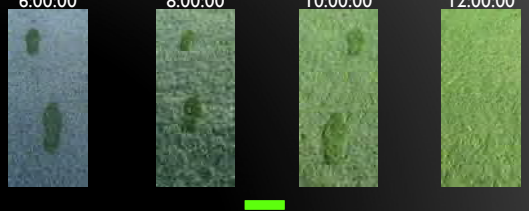

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Readily dislodged from turfgrass???

Experimental Approach

- All Soccer Projects -

2,4-D Dislodge Measurement

- 2,4-D dislodge via soccer ball roll
  - Size 4 soccer ball for ages 8 to 12 yr (FIFA)
    - Double-wrapped with a 5 by 120 cm absorbent material
  - Rolled over a 12 ft distance

- Modified EPA method MRID 420453-01
  - High performance liquid chromatography–Diode array detector
  - LOD = 1 mg kg^{-1}

Experiment Initiation

- 24 hr prior to initiation area was:
  - Mown (clippings collected)
  - Irrigated to field capacity
- 2,4-D was applied:
  - to 2.5 x 13.3 ft plots (3 ft alleys)
  - via a single nozzle (8004 E), CO_2-pressurized sprayer calibrated to deliver 20 gal A^{-1} (lowest labeled carrier volume)
  - at 1.9 lb ai A^{-1} (highest labeled application rate)
  - at 14:00 to ensure foliage was dry and allow > 5 hr sunlight

Experimental Design & Statistical Analyses

- Randomized complete block design
- Three replicates
  - Nontreated checks included to ensure trial area was not contaminated and for lab residue recovery analysis
- Data subjected to ANOVA ($P < 0.05$)
- Means separation according to Fisher's Protected LSD ($P = 0.05$)
- Pearson correlation coefficients ($P < 0.05$) to compare dislodgeability with environmental conditions

Following Initiation

- For 6 days plots were:
  - not mown
  - covered during rainfall

- Dislodge measured 0, 1, 2, 3, 6, 12 & 24 d after treatment

Objectives

- Compare dislodgeable foliar residues:
  - over days after treatment (DAT) and time within a day (TWD)
  - in overseeded vs non-overseeded bermudagrass
  - when irrigated vs. non-irrigated after treatment

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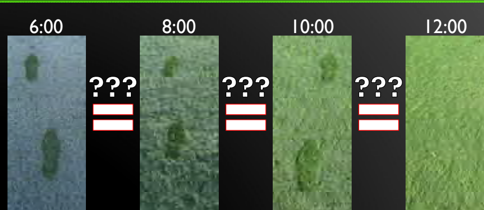
Effect of Time Within a Day (TWD) on Dislodgeable 2,4-D Over Time.[a-c]

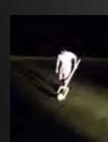
TWD[e]	DAT[d] 1	2	3	6	12[f]
	% of applied				
5:00	4.0	2.2	0.8	0.2	ND
7:00	3.7	2.0	1.0	ND	ND
9:00	3.5	1.7	0.8	ND	ND
11:00	0.5	0.0	0.0	ND	ND
13:00	0.0	0.0	0.0	ND	ND
$LSD_{0.05}$	1.1	1.3	0.9	NS	---

[a] Cheesecloth strip (104 in^2) was wrapped twice around a soccer ball and rolled over a unique 2,4-D treated area (720 in^2) at each collection timing.
[b] (0 DAT – 0 hr – 11.3 % of applied) (0 DAT – 1 hr – 0.5% of applied)
[c] Data averaged over two experimental runs.
[d] Abbreviations: DAT, days after treatment; ND, non-detectable.
[e] TWD presented are eastern standard time.
[f] Data from 12 DAT not included in statistical analysis.

Daily Fluctuations



- Dislodge measured daily at 5:00, 7:00, 9:00, 11:00 or 13:00 EST



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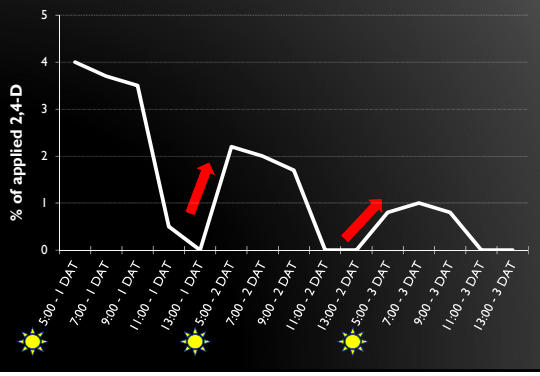

Conclusions
Days After Treatment and Time Within Day

- Why is 2,4-D more dislodgeable in AM compared to PM???
  - 2,4-D's high water solubility coupled with climatic conditions favoring wet turfgrass

Conclusions
Days After Treatment and Time Within Day

- Following application, 2,4-D dislodgeability decreases as:
  - TWD increases
    - Trend only observed through 3 DAT
  - DAT increases
    - 5 times more 2,4-D was dislodged at 5:00, 1 DAT than 5:00, 3 DAT
- More 2,4-D dislodged in subsequent morning than previous afternoon
- Dislodgeability changes as atmospheric conditions change
  - 2,4-D dislodgeability increases as:
    - Relative humidity increases
    - (Air temperature – dew point) decreases
    - Leaf wetness increases
    - Time from sunrise decreases

Pearson correlation coefficients for the relationships between climatic parameters with dislodgeable 2,4-D following an application on a simulated soccer field.[a]

Climatic parameters	% dislodged of the applied					
	1 DAT[b]		2 DAT		3 DAT	
	r	*p-val*	*r*	*p-val*	*r*	*p-val*
RH	0.79	0.005	0.82	< 0.0001	0.60	0.0176
AT - DP	-0.89	0.0003	-0.82	0.0002	-0.64	0.0107
LW	0.67	0.0061	0.90	< 0.0001	0.53	0.0399
|TFS|	-0.86	< 0.0001	-0.83	0.0001	-0.53	0.0407

[a] Climatic conditions recorded on site at the Lake Wheeler Turf Field Lab (Raleigh, NC, USA).

[b] Abbreviations: DAT, days after treatment; RH, relative humidity; AT, air temperature; DP, dew point; LW, leaf wetness; TFS, time from sunrise.

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Days After Treatment and Time Within Day

- Why is 2,4-D more dislodgeable in AM compared to PM???

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- Compare dislodgeable foliar residues:
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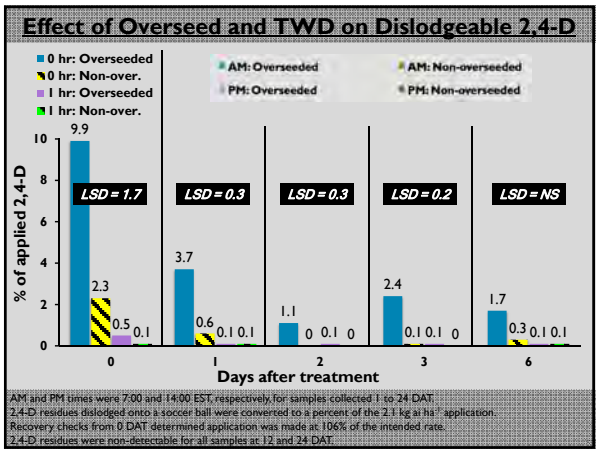
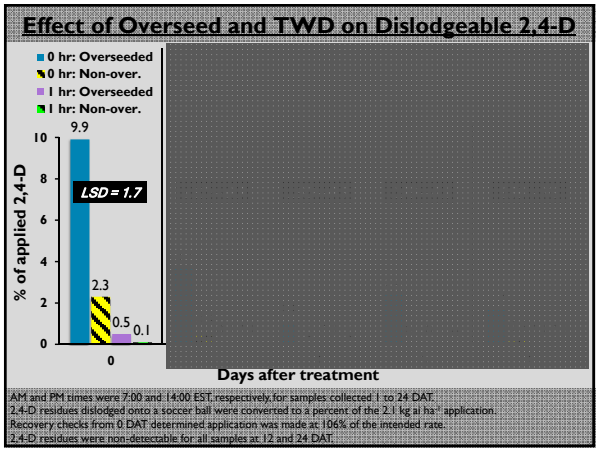
  - when irrigated vs. non-irrigated after application

???



Conclusions
Overseeded vs Non-Overseeded

- 2,4-D in overseeded and non-overseeded bermudagrass:
  - > 19 times less dislodged after 1 hr drying period
    - ≤ 0.5% of the applied dislodged at 1 hr
  - ≤ 0.1% of the applied dislodged at PM samplings from 1 to 6 DAT
    - Overseed = Non-overseed
  - Dislodgeable residues not detected beyond 6 DAT
- Overseeded vs. non-overseeded bermudagrass
  - Greater 2,4-D was dislodged in overseeded bermudagrass at all AM sample timings from 1 to 6 DAT
- Overseeded bermudagrass
  - 2,4-D re-suspends on turfgrass
  - 1.7% of the applied 2,4-D dislodged at 6 DAT!!!



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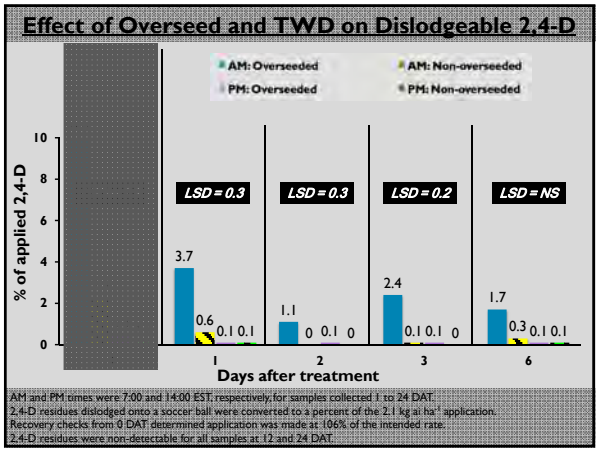

Conclusions
Overseeded vs Non-Overseeded

- Why is 2,4-D more dislodgeable in overseeded compared to non-overseeded bermudagrass???
  - Compared to dormant bermudagrass, overseeded areas have:
    - More above-ground biomass, leaf area = more pesticide spray interception
    - Perennial ryegrass vegetation = waxy surface that does not favor 2,4-D sorption

Objectives

- Compare dislodgeable foliar residues:
  - over days after treatment (DAT) [illegible] within a day (TWD)
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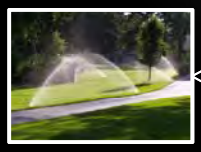
  - when irrigated vs. non-irrigated after treatment



Irrigated
24 hours after treatment

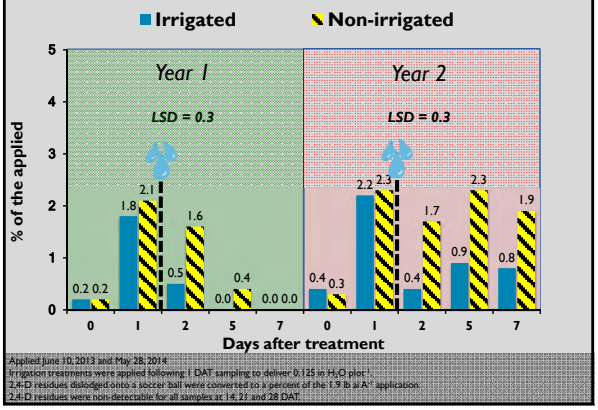
Non-irrigated
For 6 days after treatment

Project Objectives

Quantify 2,4-D dislodge, as affected by:

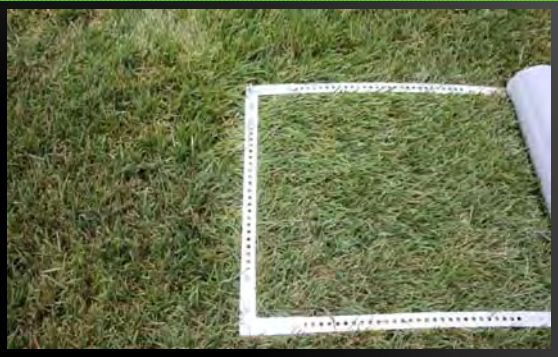
1. **sampling method**
1. **turfgrass species**

Effect of Irrigation on Dislodgeable 2,4-D



Applied June 10, 2013 and May 28, 2014
Irrigation treatments were applied following 1 DAT sampling to deliver 0.125 in H_2O plot^{-1}.
2,4-D residues dislodged onto a soccer ball were converted to a percent of the 1.9 lb ai A^{-1} application.
2,4-D residues were non-detectable for all samples at 14, 21 and 28 DAT.

Modified California Roller on Tall Fescue



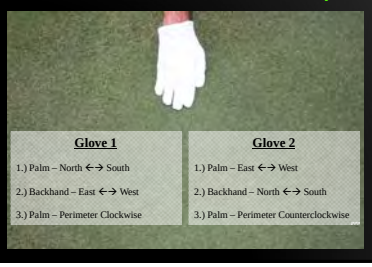
Conclusions
Irrigation

- Across both years:
  - No differences before irrigation was applied
  - After 2 DAT:
    - Less 2,4-D was dislodged in irrigated than non-irrigated turfgrass
      - < 1% of the applied was dislodged from irrigated turfgrass
      - 1.6 to 2.3% of the applied was dislodged from non-irrigated turfgrass
        - *1.9% of the applied was dislodged at 7 DAT in year 2!!!*
  - After 14 DAT, non-detectable 2,4-D residues
- Research implications
  - Light irrigation/rainfall following 2,4-D application reduces dislodgeable residues
    - Balance weed control and reducing dislodgeability

Treatments Evaluated

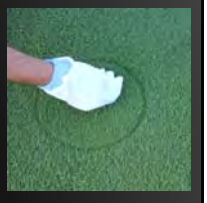
- Factorial of sampling methods and turfgrasses:
  - Hand wipe, ball roll or Mod. California roller
  - Creeping bentgrass, hybrid bermudagrass or tall fescue

Hand wipe



Glove 1
1.) Palm – North ↔ South
2.) Backhand – East ↔ West
3.) Palm – Perimeter Clockwise

Glove 2
1.) Palm – East ↔ West
2.) Backhand – North ↔ South
3.) Palm – Perimeter Counterclockwise



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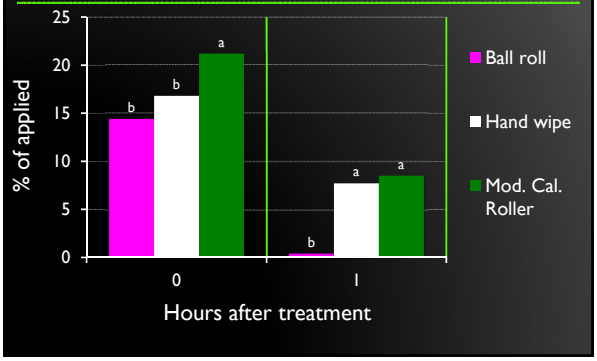
Ball roll

2,4-D Dislodge from Turfgrass

Day of application – Main effect of sample method



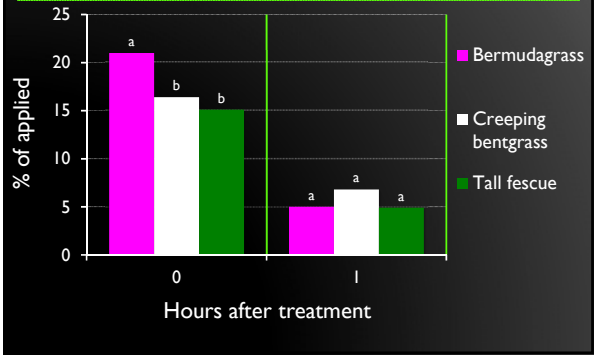
Treatments Evaluated

- Factorial of sampling methods and turfgrasses:
  - Hand wipe, ball roll or Mod. California roller
  - Creeping bentgrass, hybrid bermudagrass, or tall fescue

Modified California roller

2,4-D Dislodge from Turfgrass

Day of application – Main effect of turfgrass



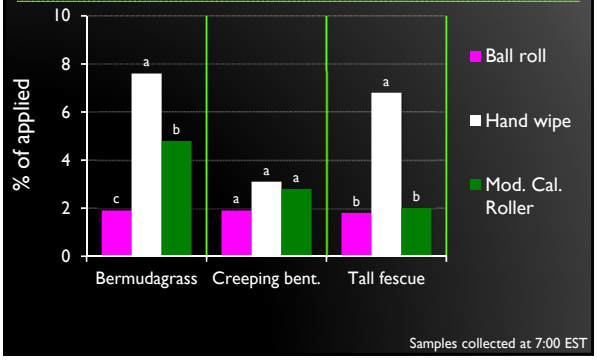
Treatments Evaluated

- Factorial of sampling methods and turfgrasses:
  - Hand wipe, ball roll or Mod. California roller
  - Creeping bentgrass, hybrid bermudagrass, or tall fescue

CB: 0.15 in HB: 2 in TF: 3.5 in

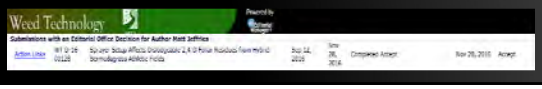
2,4-D Dislodge from Turfgrass

3 days after application – Turfgrass x Method



2,4-D Dislodge Conclusions

- System characteristics affect 2,4-D dislodge
  - Can vary between turfgrass species
  - Canopy moisture presence increases dislodge
  - Can vary by sampling method
- To reduce 2,4-D dislodge
  - Irrigate areas 24 hours after treatment
  - Increase spray carrier volume
    - 80 GPA > 40 GPA = 20 GPA
  - Use nozzles delivering coarse spray droplets
    - AIXR > DG = XR



Potential Human Exposure

Post-application Dermal Exposure Algorithm – Physical Activities on Turf

Exposure resulting from contacting previously treated turf while performing physical activities is calculated as shown below. As discussed in *Section 1.3.4* residential post-application exposure assessment must include calculation of exposure on the day of application. Therefore, though an assessment can present exposures for any day "t" following the application, it must include "day 0" exposure.

$$E = TTR_t * CF1 * TC * ET \quad (3.3)$$

where:

E	=	exposure (mg/day);
TTR_t	=	turf transferable residue on day t (μg/cm²);
CF1	=	weight unit conversion factor (0.001 mg/μg);
TC	=	transfer coefficient (cm²/hr); and
ET	=	exposure time (hr/day).

- TTR_t = ????
- CF1 = 0.001 mg ug^{-1} (conversion factor)
- TC = 49,000 cm^2 hr^{-1} (avg. for toddlers; EPA 2012)
- ET = 1.5 hr (avg. for toddlers; EPA 2012)

Implications

So what does this all mean for human exposure?!?!?

Potential Human Exposure

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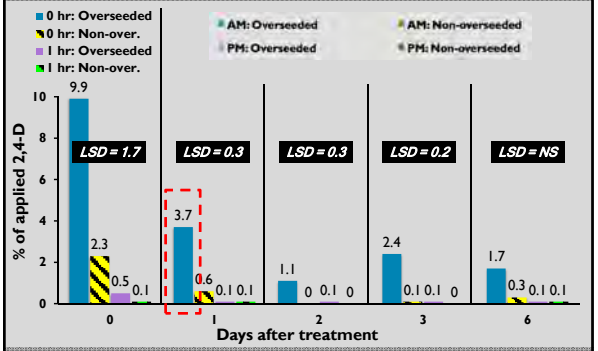
Potential Human Exposure

Standard Operating Procedures for Residential Pesticide Exposure Assessment

October 2012

Health Effects Division
Office of Pesticide Programs
Office of Chemical Safety and Pollution Prevention
U.S. Environmental Protection Agency
Washington, DC

Effect of Overseed and TWD on Dislodgeable 2,4-D



AM and PM times were 7:00 and 14:00 EST, respectively, for samples collected 1 to 24 DAT.
2,4-D residues dislodged onto a soccer ball were converted to a percent of the 2.1 kg ai ha^{-1} application.
Recovery checks from 0 DAT determined application was made at 106% of the intended rate.
2,4-D residues were non-detectable for all samples at 12 and 24 DAT.

Potential Human Exposure

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TC	= transfer coefficient (cm²/hr); and
ET	= exposure time (hr/day).

- TTR_t = 0.77 ug cm^{-2} (1 DAT, 7:00 EST; Overseeded)
- CF1 = 0.001 mg ug^{-1} (conversion factor)
- TC = 49,000 cm^2 hr^{-1} (avg. for toddlers; EPA 2012)
- ET = 1.5 hr (avg. for toddlers; EPA 2012)

Potential Human Exposure

- EPA 2,4-D doses for human risk assessment:
  - Short term dermal (< 30 d) = 25 mg kg^{-1} d^{-1}
  - Intermediate term dermal (1 – 6 mo) = 15 mg kg^{-1} d^{-1}
  - Long term dermal (> 6 mo) = 5 mg kg^{-1} d^{-1}
- Average body mass of U.S. children, ages 2-3 = 14 kg
  - Short term: 25 mg kg^{-1} d^{-1} x 14 kg = 350 mg 2,4-D d^{-1}
  - Intermediate term: 15 mg kg^{-1} d^{-1} x 14 kg = 210 mg 2,4-D d^{-1}
  - Long term: 5 mg kg^{-1} d^{-1} x 14 kg = 70 mg 2,4-D d^{-1}

E = 57 mg d^{-1} (one ball roll)

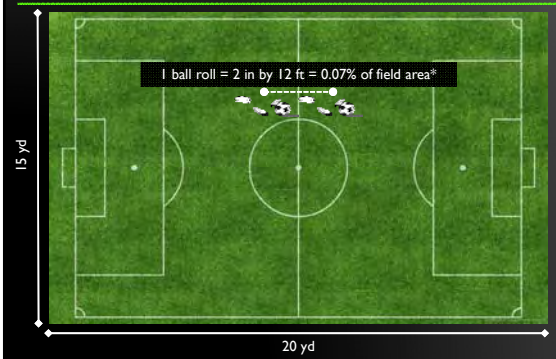
Dermal absorption factor (EPA) = 10% = 5.7 mg 2,4-D d^{-1}

Short term = 1.6% of allowance

Intermediate term = 2.7% of allowance

Long term = 8.1% of allowance

Potential Human Exposure



* Minimum recommended dimensions for < 6 yr children (US Youth Soccer Organization)*

Best Management Practices to Minimize 2,4-D Dislodgement

- Turfgrass managers and athletic field schedulers should coordinate 2,4-D (and other pesticides) applications with events to provide an appropriate buffer period to minimize human exposure.
- Workers and non-workers should enter athletic fields treated with 2,4-D with caution for 2-3 d following application.
  - Data suggest afternoon hours are safe for re-entry
- Irrigate 2,4-D treated areas 24 hr following application

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Questions???