New Fumigants for Strawberry Production in California

Dominus®, Paladin®, Trifecta®, and EDN®

Husein Ajwa

UCCE Emeritus

UCDAVIS
PLANT SCIENCES

Dominus®

Allyl isothiocyanate (AITC)

- **EPA Registration was granted Sept 2013 (Isagro USA)**
- **Synthetically produced biopesticide that is found in brassica**
- **Pre-plant Application rate: 200 – 350 lbs/a**
- **Small buffer zones, no FMP**

Selected properties of Dominus

CAS #	57-06-7
Boiling point	151°C
Vapor pressure	3.5 – 4 mm Hg
Vapor density (water = 1.0)	3.4
Density	1.0126 g/cm^3 @ 20˚C
Solubility in water	Slight, 2 g/L water @ 25˚C
Solubility in alcohol	Very soluble (1:8) in 80% ethanol
Henry's Law Constant	0.0002752 atm-m^3/mole
Molecular formula	C_4H_5NS
Molecular weight	99.1542 g/mol
Soil half-life, DT50)	Aerobic DT50 of less than 3 days

Paladin

Dimethyl disulfide (DMDS)

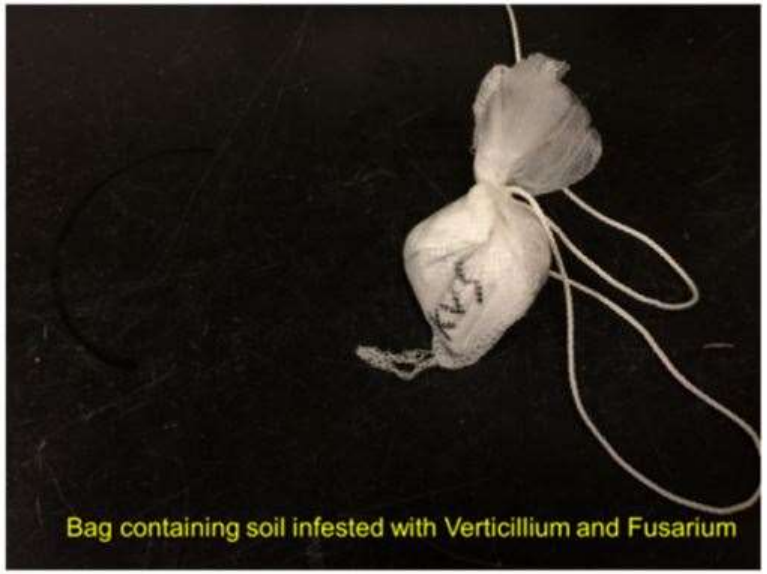
- **EPA Registration was granted in 2010 (Arkema)**
  Applied only under TIF

- **Used as a flavoring for an onion or garlic taste in processed cheese and meat (0.02-10 ppm)**

- **Efficacy (Rates: 400 – 600 lbs/a)**

Laboratory Dose-Response Studies

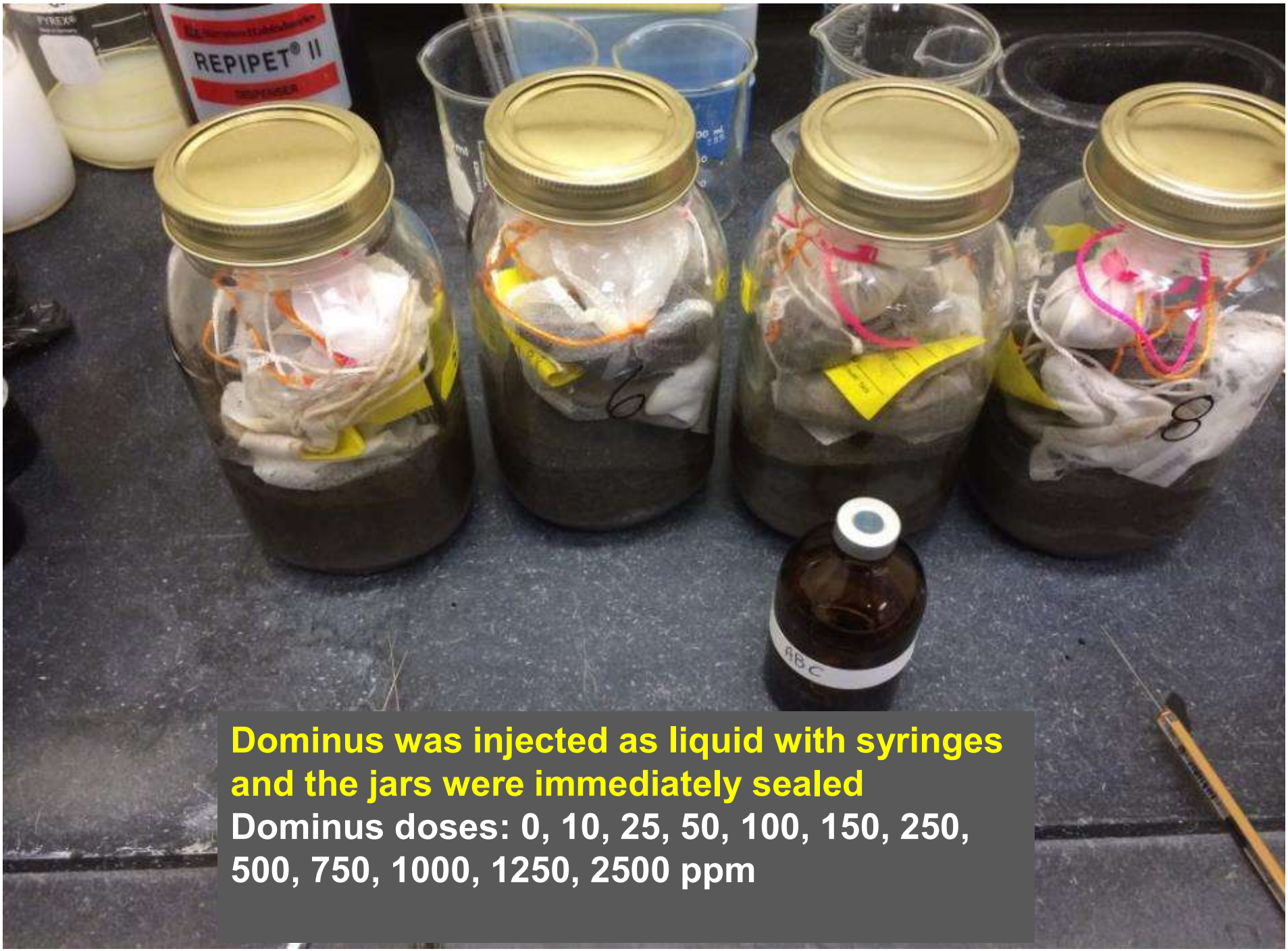

Bag containing soil infested with Citrus Nematode


Bag containing soil infested with Verticillium and Fusarium


Bag containing soil infested with Pythium


Bag containing soil infested with Phytophthora

Laboratory Dose-Response Studies

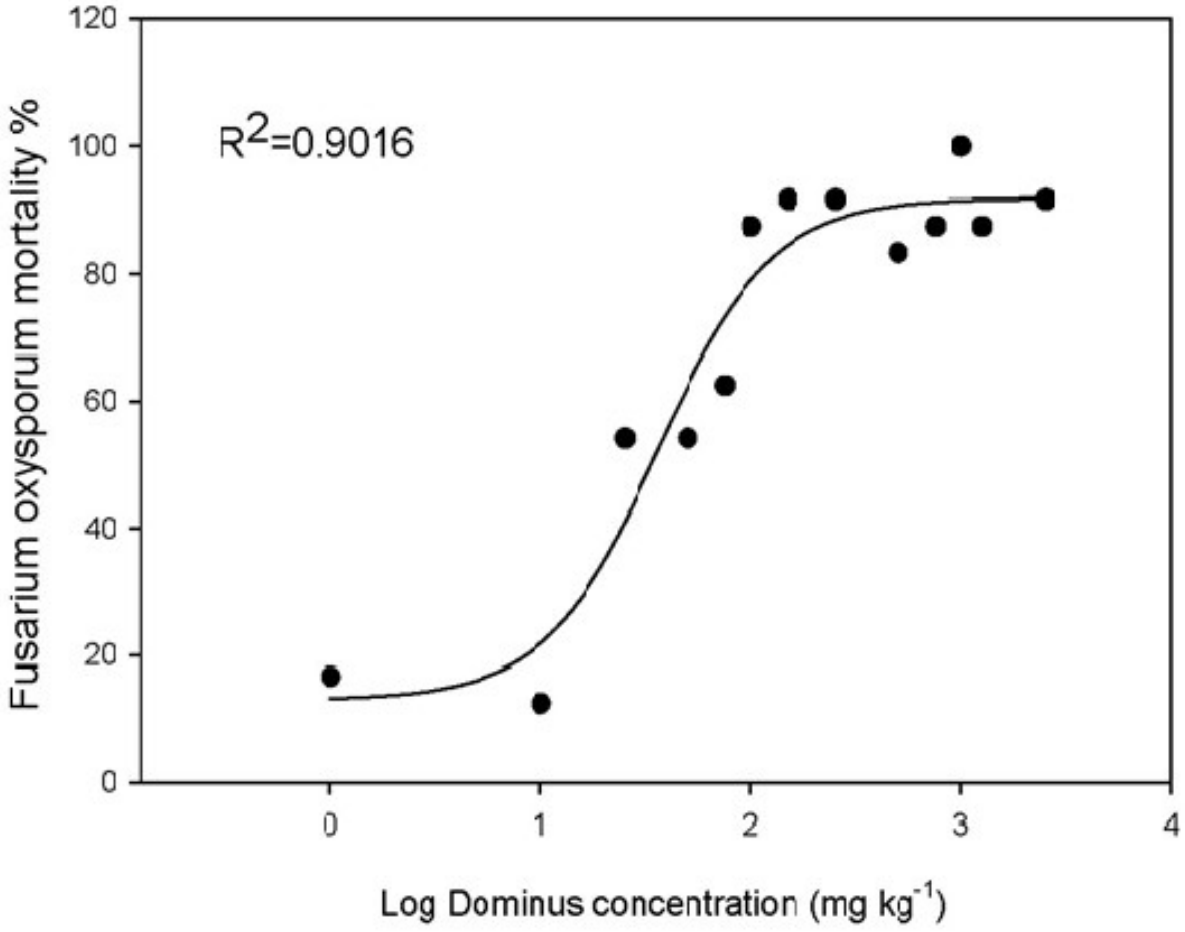


Dominus was injected as liquid with syringes and the jars were immediately sealed

Dominus doses: 0, 10, 25, 50, 100, 150, 250, 500, 750, 1000, 1250, 2500 ppm


The fumigated jars were placed
in incubators at 20°C for 24 hours
34
49
50
22
46

Dose-response curve



Dose (lbs/ac) required to control 90% of pathogen population (LD_{90})

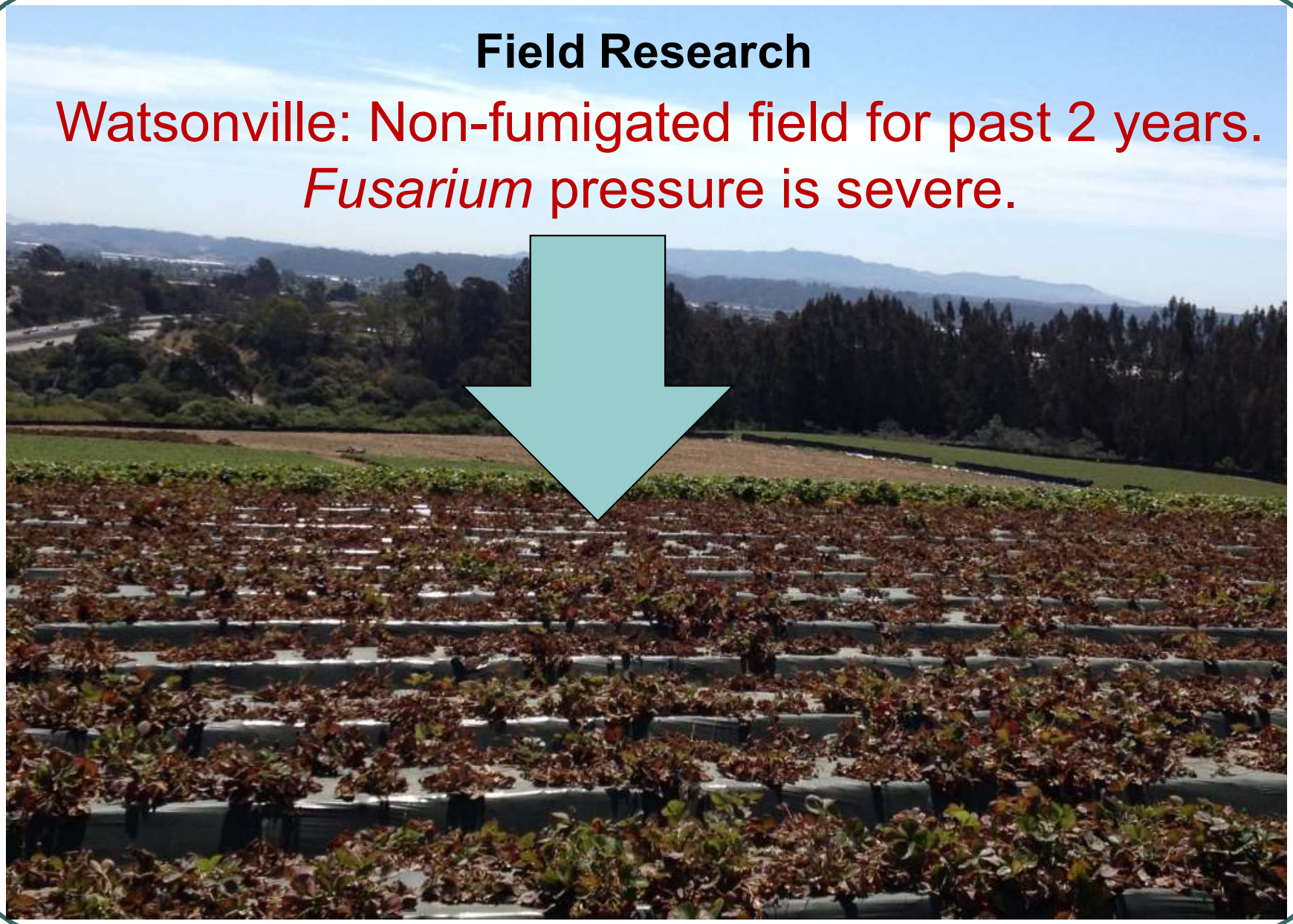
Fumigant	*Fusarium oxysporum*	*Verticillium dahliae*
Paladin (79:21)	315	406
Dominus (96%)	232	159
PicClor 60 (60:40)	146	230

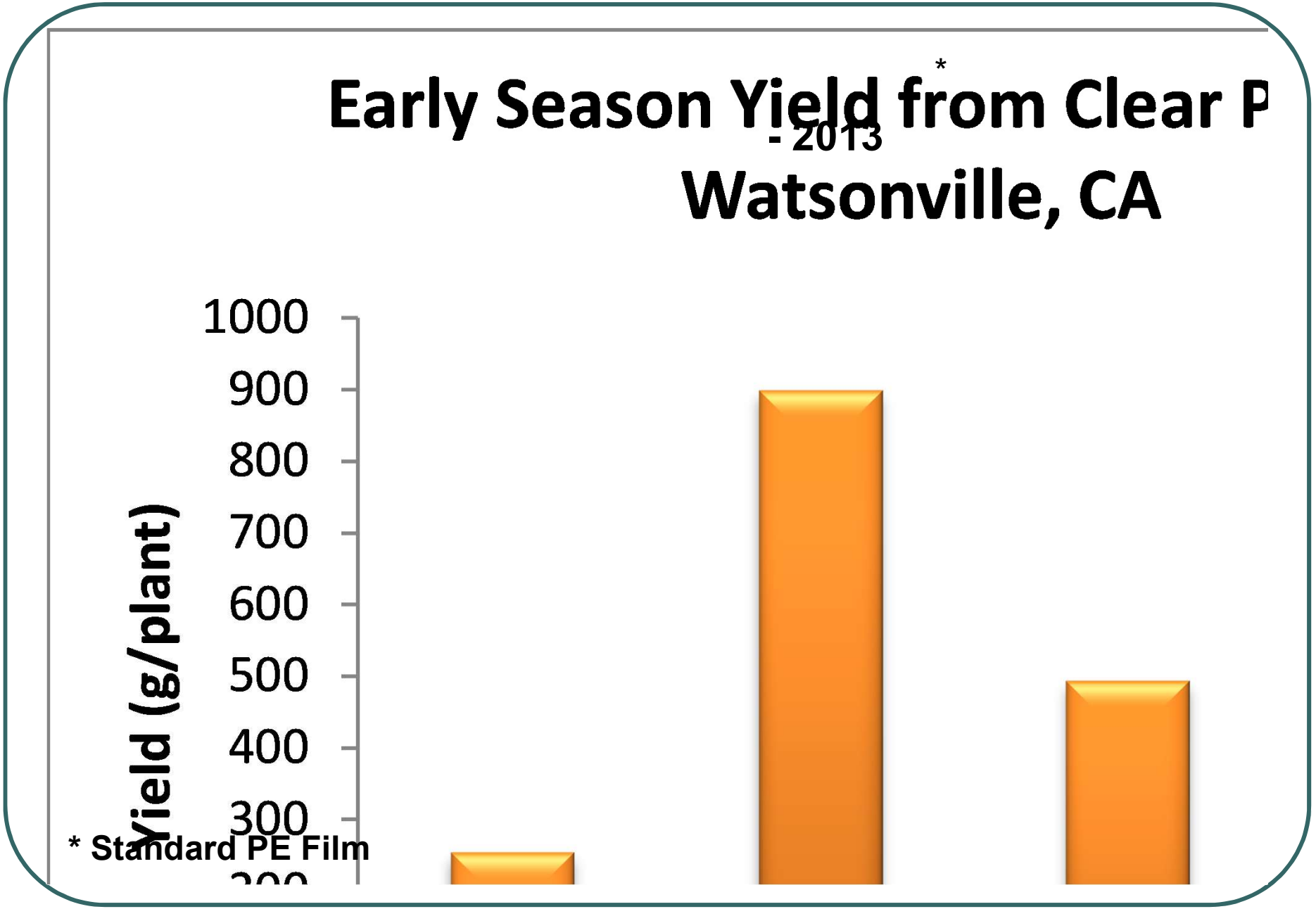
1 mg/kg = 2 lbs/ac for a soil depth of 6.7 inches

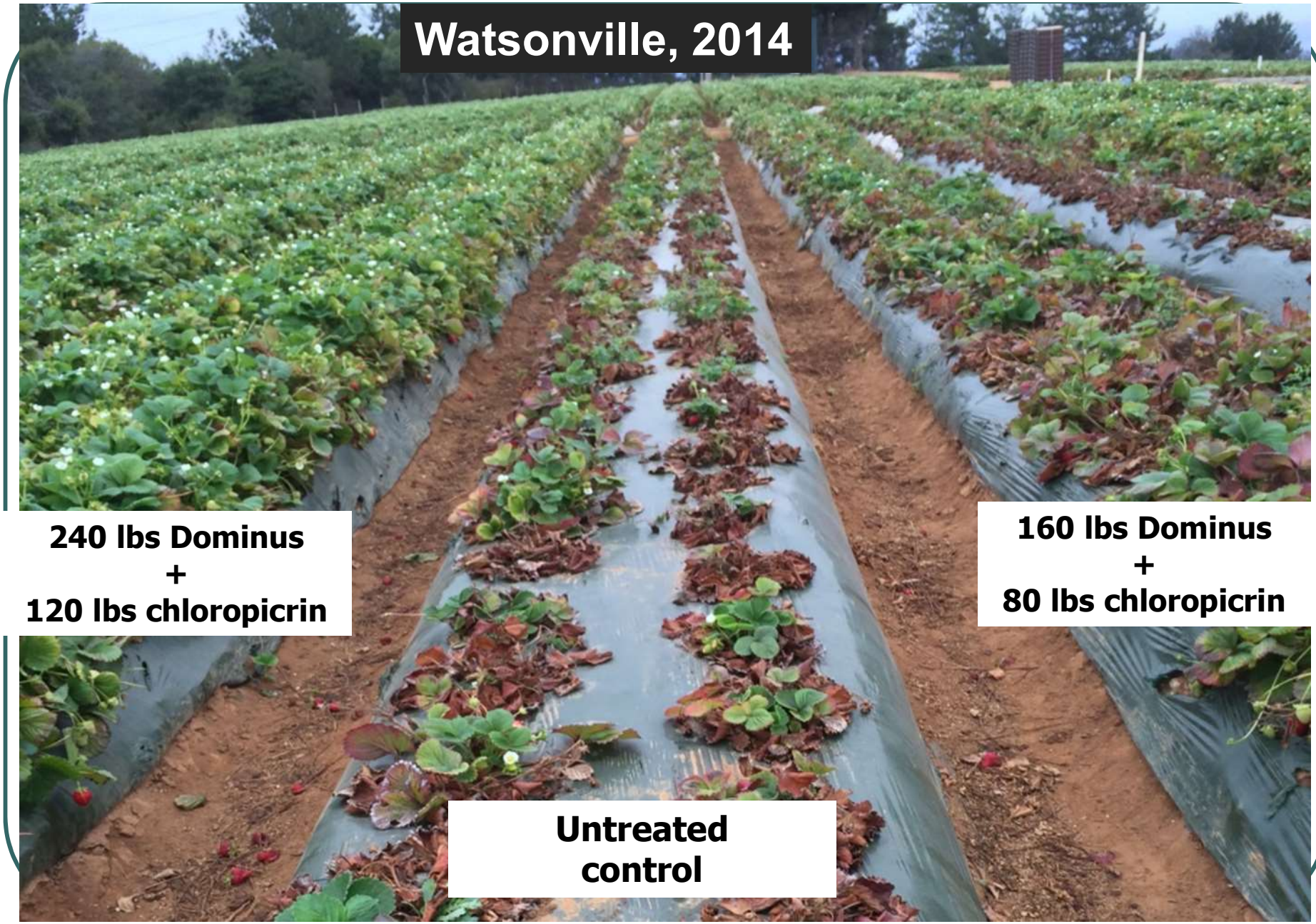
Field Research

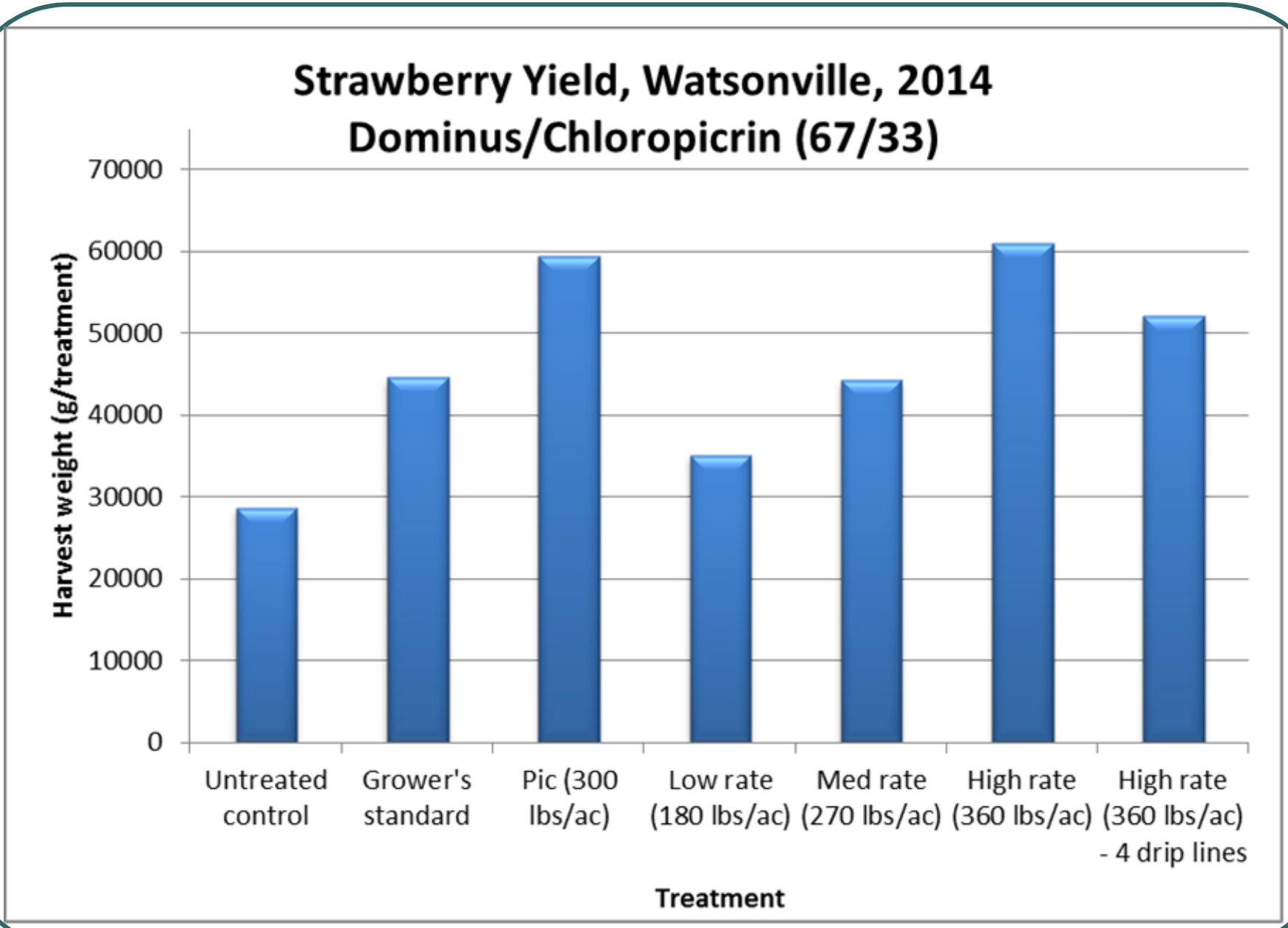
Watsonville: Non-fumigated field for past 2 years.

Fusarium pressure is severe.




Early Season Yield from Clear P*
- 2013
Watsonville, CA
1000
900
800
700
600
500
400
300
Yield (g/plant)
* Standard PE Film


Watsonville, 2014
240 lbs Dominus
+
120 lbs chloropicrin
160 lbs Dominus
+
80 lbs chloropicrin
Untreated
control


Strawberry Yield, Watsonville, 2014
Dominus/Chloropicrin (67/33)
Harvest weight (g/treatment)
70000
60000
50000
40000
30000
20000
10000
0
Untreated control
Grower's standard
Pic (300 lbs/ac)
Low rate (180 lbs/ac)
Med rate (270 lbs/ac)
High rate (360 lbs/ac)
High rate (360 lbs/ac) - 4 drip lines
Treatment

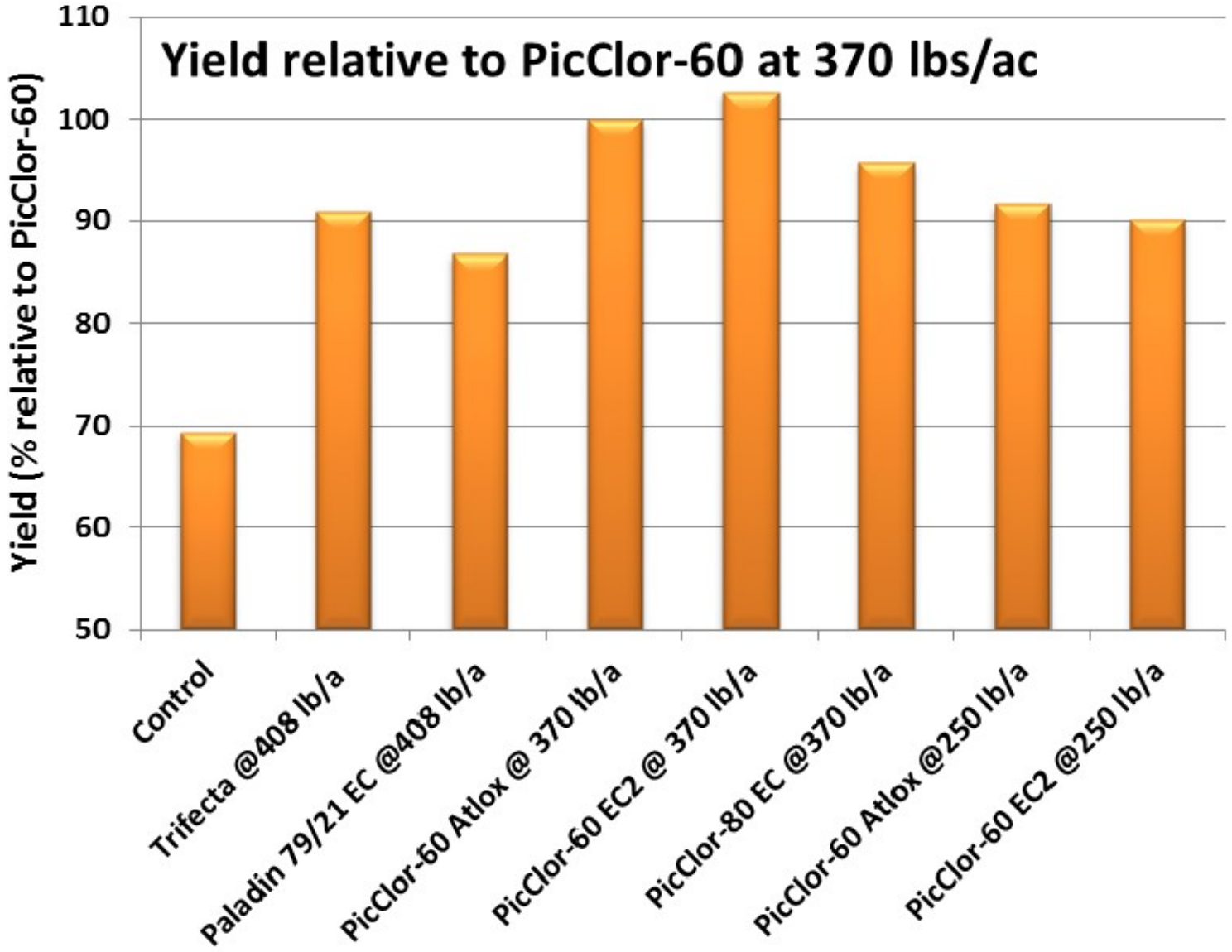
DRIP FUMIGATION
Dominus Treatments, 2014-2015

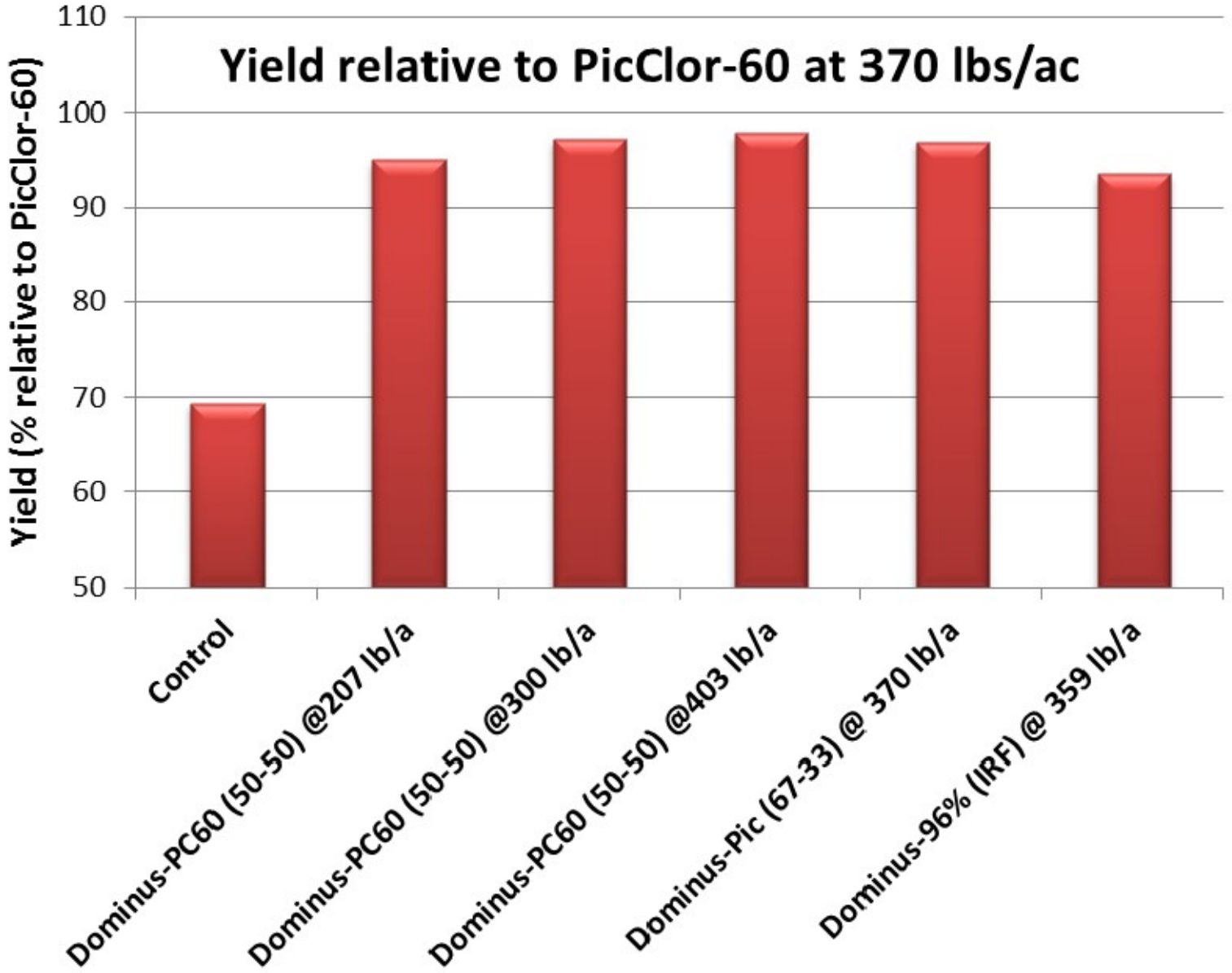
Treatment	Rate (lbs/ac)
Dominus/PicClor-60 (50/50)	207
Dominus/PicClor-60 (50/50)	300
Dominus/PicClor-60 (50/50)	403
Dominus/Chloropicrin (67/33)	370
Dominus (96%)	359

Paladin and PicClor-80, 2014-2015

Treatment	Rate
PicClor-80 (80% chloropicrin)	370 gal/ac
Paladin 79:21	408 lbs/ac
Trifecta (DMDS/Pic/1,3-D)	408 lbs/ac

Rates are per treated acre. Broadcast equivalent = treated acre rate x 0.63


Yield relative to PicClor-60 at 370 lbs/ac
Yield (% relative to PicClor-60)
110
100
90
80
70
60
50
Control
Trifecta @408 lb/a
Paladin 79/21 EC @408 lb/a
PicClor-60 Atlox @ 370 lb/a
PicClor-60 EC2 @ 370 lb/a
PicClor-80 EC @370 lb/a
PicClor-60 Atlox @250 lb/a
PicClor-60 EC2 @250 lb/a


Yield relative to PicClor-60 at 370 lbs/ac
Yield (% relative to PicClor-60)
110
100
90
80
70
60
50
Control
Dominus-PC60 (50-50) @207 lb/a
Dominus-PC60 (50-50) @300 lb/a
Dominus-PC60 (50-50) @403 lb/a
Dominus-Pic (67-33) @ 370 lb/a
Dominus-96% (IRF) @ 359 lb/a

Summary
Dominus (IRF-135)

- **No phytotoxicity or plant injury was observed when planting 10 days after fumigation.**
- **Dominus alone or with Chloropicrin (50/50) produced strawberry yields >94% compared to the standard PicClor-60 EC at 370 lbs/ac.**

2016 research

- **to evaluate optimum amount of irrigation water for drip fumigation of a new emulsifiable concentrate formulation of Dominus for strawberry production in California.**

- **to evaluate the effect of an azeotrope on the mobility of Dominus in soil.**

  - ***The focus of this presentation is to evaluate the overall yields during the growing season of 2015-2016.***

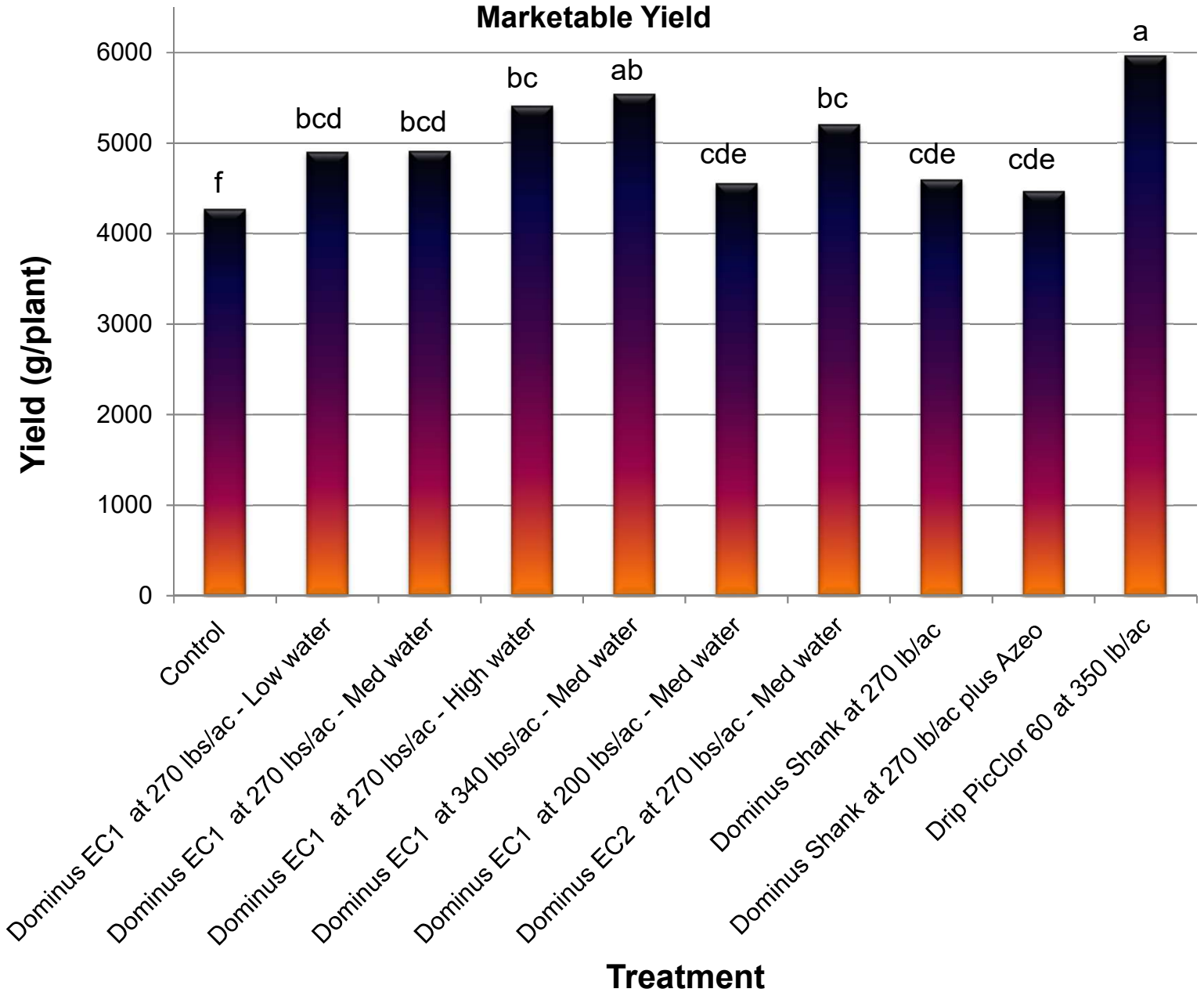
Dominus Treatments, 2015-2016

DOMINUS EC1- Low water (0.6”)	270 lb/ac
DOMINUS EC1- Med water (1.0”)	270 lb/ac
DOMINUS EC1- High water (1.4”)	270 lb/ac
DOMINUS EC1- Med water (1.0”)	340 lb/ac
DOMINUS EC1- Med water (1.0)	200 lb/ac
DOMINUS **EC2**- Med water (1.0”)	270 lb/ac
DOMINUS Shank	270 lb/ac
DOMINUS- Shank plus Azeotrope	270 lb/ac
Drip PicClor-60 EC	350 lb/ac

Shank injection: 2 shanks spaced 10 inches apart

AITC and a fluorocarbone azeotrope mixture was applied at a 50/50 ratio to soil (270 lbs/ac of AITC) using 2 shanks/bed at 8” deep.

Results


Marketable Yield
Yield (g/plant)
6000
5000
4000
3000
2000
1000
0
f
bcd
bcd
bc
ab
cde
bc
cde
cde
a
Control
Dominus EC1 at 270 lbs/ac - Low water
Dominus EC1 at 270 lbs/ac - Med water
Dominus EC1 at 270 lbs/ac - High water
Dominus EC1 at 340 lbs/ac - Med water
Dominus EC1 at 200 lbs/ac - Med water
Dominus EC2 at 270 lbs/ac - Med water
Dominus Shank at 270 lb/ac
Dominus Shank at 270 lb/ac plus Azeo
Drip PicClor 60 at 350 lb/ac
Treatment

Summary
Dominus (IRF-135)

- **Strawberry yields increased with increasing the amount of water used to apply Dominus.**
- **Adding an Azeotrope to Dominus did not improve Dominus diffusion in the soil.**
- **A new emulsifier and other azeotropic combinations are being evaluated.**

FATE OF ETHANEDINITRILE (C_2N_2) FUMIGANT IN SOIL

→ EDN™ FUMIGAS manual for fumigation

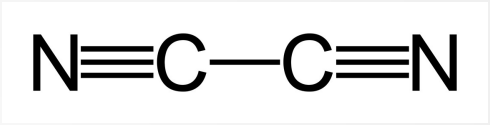
THE LINDE GROUP

Linde

EDN™ FUMIGAS fumigant.

Manual for fumigation.

Selected Properties of Ethanedinitrile



Product Brand Name:	EDN (ETHANEDINITRILE, C_2N_2)
USEPA Reg. No.:	62719-321
% Active Ingredient:	99.58%
Chemical Family:	DiCyanogen
Color, Odor.	Colorless gas, almond-like odor.
Molecular Formula:	C_2N_2
Molecular Weight:	52
CAS No.:	460-19-5
Density:	Gas: 2.189 mg/cm^3 @ 20^{o}C Liquid: 989 mg/cm^3 @ -40^{o}C
Boiling Point:	-20°C
Vapor Pressure:	5.16 bar @ 21.1^{O}C
Solubility in water @101.325kPa@20°C	450 cm^3/100 cm^3 water

Properties of EDN

- It diffuses through soils quickly.
- Threshold Limit Value (TLV Human) = 10 ppm or 21 mg/m^3.
- LC_{50} (inhalation) 350 ppm/1 hour (rat).
- LDL_o (subcutaneous) 13 mg/kg (rabbit).
- **It is effective in controlling soil-borne fungal pathogens, nematodes, and many weeds.**

PRELIMINARY INVESTIGATION OF ETHANEDINITRILE FOR CONTROL OF WEEDS AND NEMATODES IMPORTANT TO FLORIDA PRODUCTION SYSTEMS

Erin N. Rosskopf* and Nancy Kokalis-Burelle
USDA, ARS, U.S. Horticultural Research Lab, Ft. Pierce, FL
Gary L. Peterson
USDA ARS NAA, Foreign Disease-Weed Science Research Unit, Fort Detrick, MD
Colin Waterford
CSIRO, Entomology, Canberra, ACT 2601, Australia

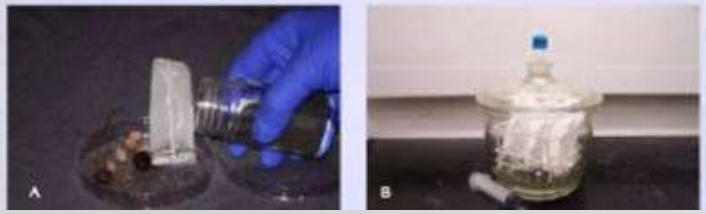
Background

Previous experiments conducted in Australia with ethanedinitrile have demonstrated control of weeds and diseases of importance to the production of a variety of crops (Ren *et al.*, 2002). Pests included seed and soilborne fungi (Smith *et al.*, 2003) as well as plant-parasitic nematodes. Weed control in these trials was most effective when plots were tarped and was dependent upon species (Mattner *et al*, 2003; Ren *et al.*, 2003).

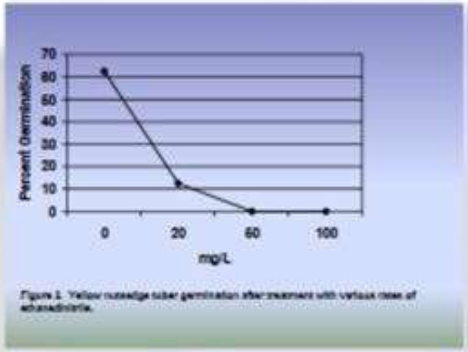
Methods

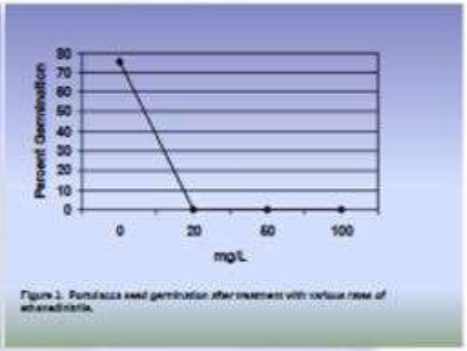
- A preliminary *in vitro* experiment was conducted with seeds of several weed species of importance in vegetable and ornamental production systems in Florida, and with root-knot nematode (*Meloidogyne incognita*) infested soil.

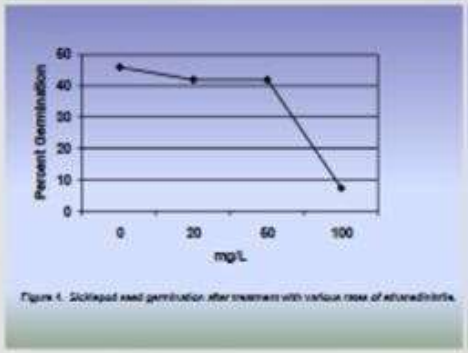
- The prepared weed and nematode inoculum were placed in open desiccators of measured volume, allowed to equilibrate to the test relative humidity, sealed, and injected with a test amount of EDN through a gas septum port, having first withdrawn an equivalent volume of air (Figure 1).

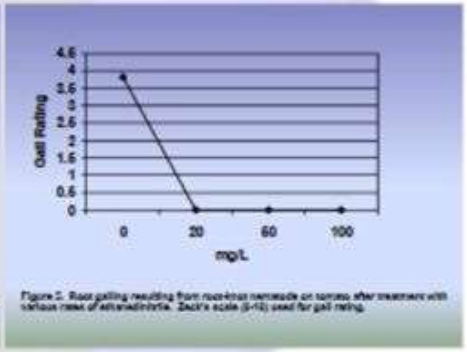


Results









Research Objectives:

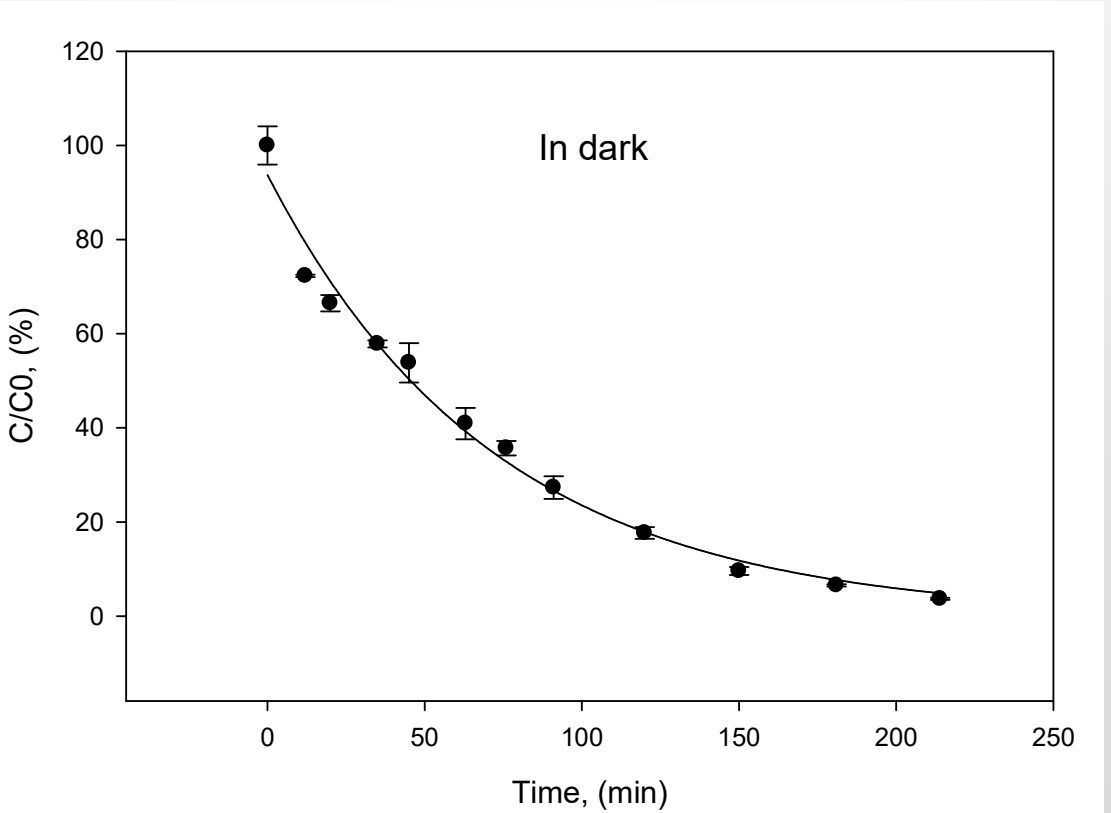
1. To evaluate the persistence (degradation) of EDN in different soil types.

2. To measure the production and disappearance of EDN's main metabolites in different soil types.

EDN degrades very rapidly in air, soil, and water. The half-life:

- **in air: 100 days (light) to 150 days (dark).**
- **in soil and water: minutes to days, depending on the pH and temperature.**

Example:
EDN hydrolysis in pH 7.0 solution at 23°C.



EDN degradation in water (hydrolysis) as a function of pH and temperature

pH/ Temp. (°C)	pH 4.0	pH 7.0	pH 9.0
10	80 *days	257 min	6.0 min
23	28# days	49 min	4.5 min
40	1.5 days	11 min	1.7 min

Summary

- Application rates might need to be adjusted based on soil pH and temperature.
- EDN metabolites are expected to degrade to non-toxic compound within days after fumigation.
- Possible degradation products:
  - $NCCN + 2H_2O \rightarrow HCN + HOCN$
    - $HOCN + H_2O \rightarrow NH_3 + CO_2$
    - $HCN + H_2O \rightarrow HC(O)NH_2 + H_2O \rightarrow HCO_2^- + NH_4^+$
- HCN converts into thiocyanate (SCN) and eventually into $SO_4 + NH_3 + CO_2$ or forms precipitates with metals (eg., Fe)


THE UNIVERSITY OF CALIFORNIA
LET THERE BE LIGHT