MANAGING SOIL HEALTH AND CROP DISEASES WITH BRASSICA COVER CROPS

Cornell University Cooperative Extension

Justin O'Dea, Sandy Menasha, Meg McGrath

Biofumigants and soil health

"The capacity of a soil to function, within ecosystem and land use boundaries, to sustain productivity, maintain environmental quality, and promote plant and animal health."

- **Good soil tilth***
- **Sufficient depth***
- **Sufficient but not excess nutrients***
- ***Small population of plant pathogens and insect pests*****
- **Good soil drainage***
- **Large population of beneficial organisms***
- **Low weed pressure***
- Free of chemicals and toxins that may harm the crop
- **Resistant to degradation***
- **Resilience when unfavorable conditions occur***

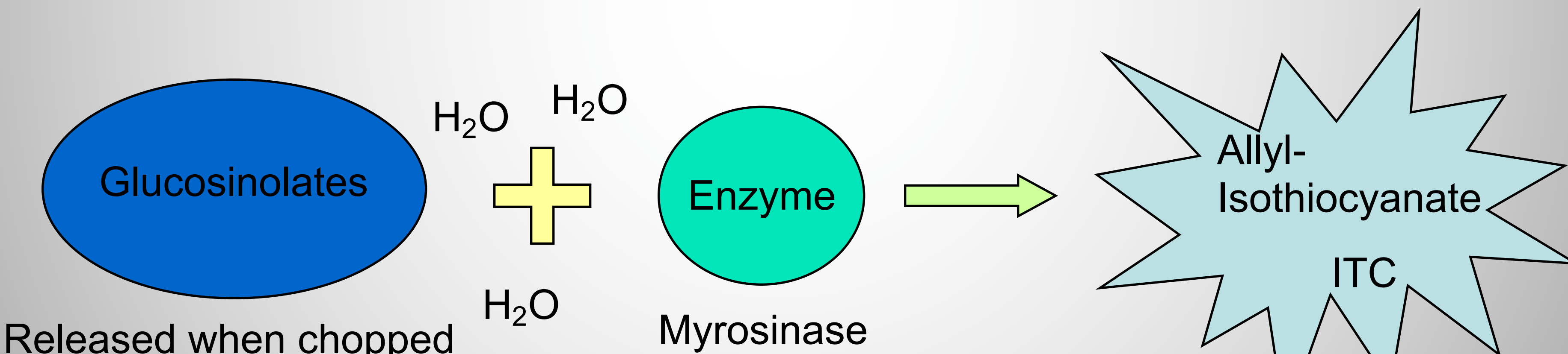
What is Biofumigation?

"The suppression of various soil-borne pests and diseases by naturally occurring compounds"

- Brassicas: mustard, arugula, and others like oilseed radish, rapeseed, canola et al.

How does it work?

- Brassicas naturally produce *glucosinolates*
  - Sulfur compound that makes certain brassicas “hot/spicy”
  - Essential component in biofumigation



  - Broad-spectrum fumigant
  - Need 10-60x typical biomass to equal Vapam concentration

Similar to compounds in *Vapam* (methyl-isothiocyanate)

Biofumigant Benefits

- Soil-borne disease suppression
  - Fusarium, Verticillium, Rhizoctonia, Pythium, Sclerotinia, Botrytis, Phytophthora, +
- Nematode suppression
  - Root knot and root lesion nematode
  - Potato cyst nematode suppression being studied
- Weed seed germination suppression

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Control of Soil-Borne Plant Pests Using Glucosinolate-Containing Plants

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University of Idaho
Moscow, Idaho 83844-2339

Plant and Soil **162**: 107–112, 1994.

Biofumigation: Isothiocyanates released from *Brassica* roots inhibit growth of the take-all fungus

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Key Laboratory of Plant Pathology of the Ministry of Education, Yunnan Agricultural University, Kunming, China

Potential Biofumigation Effects of *Brassica oleracea* var. *caulorapa* on Growth of Fungi

C. M. Fan[1], G. R. Xiong[1], P. Qi[1], G. H. Ji[1] and Y. Q. He[1,2]
Authors' addresses: [1]Key Laboratory of Plant Pathology of the Ministry of Education, Yunnan Agricultural University, Kunming 650201, China; [2]Faculty of Agronomics and Biotechnology, Yunnan Agricultural University, Kunming 650201
China (correspondence to Y. Q. He. E-mail: heyu

Plant and Soil **201:** 103–112, 1998.

Biofumigation potential of brassicas

III. In vitro toxicity of isothiocyanates to soil-borne fungal pathogens

M. Sarwar[1], J.A. Kirkegaard[1], P.T.W. Wong[2] and J.M. Desmarchelier[3]
[1]*CSIRO Plant Industry, GPO Box 1600 Canberra ACT 2601, Australia*,* [2]*Agricultural Research Institute, NSW Agriculture, Wagga Wagga NSW 2650, Australia and* [3]*CSIRO Division of Entomology, GPO Box 1700, Canberra 2601, Australia*

Mustard Green Manures Replace Fumigant and Improve Infiltration in Potato Cropping System

Andrew M. McGuire, Lauzier Agricultural Systems Educator, Washington State University Cooperative Extension, Grant-Adams Area, PO Box 37, Ephrata WA

Control of soilborne potato diseases using *Brassica* green manures ☆

Robert P. Larkin*, Timothy S. Griffin

USDA, ARS, New England Plant, Soil, and Water Laboratory, University of Maine, Orono, ME 04469, USA

Soil amendments with *Brassica* cover crops for management of Phytophthora blight on squash

Pingsheng Ji,[a]* Daouda Koné,[a,b] Jingfang Yin,[a] Kimberly L Jackson[a] and Alexander S Csinos[a]

Brassica Green Manure Amendments for Management of *Rhizoctonia solani* in Two Annual Ornamental Crops in the Field

Kimberly A. Cochran and Craig S. Rothrock[1]
Department of Plant Pathology, University of Arkansas, 217 Plant Science Building, 495 North Campus Drive, Fayetteville, AR 72701

Mustard biofumigation disrupts biological control by *Steinernema* spp. nematodes in the soil

Donna R. Henderson[a,b], Ekaterini Riga[a,b], Ricardo A. Ramirez[c], John Wilson[a,b], William E. Snyder[c,*]

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[b] *Department of Plant Pathology, Washington State University, Pullman, WA 99164, USA*
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HortScience 40(7):2016–2019. 2005.

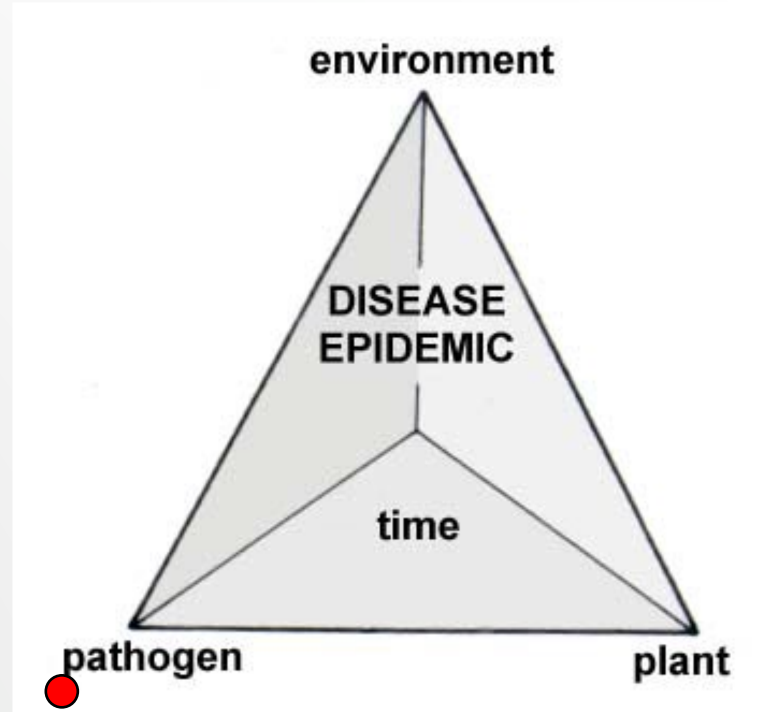
Mustard Cover Crops Are Ineffective in Suppressing Soilborne Disease or Improving Processing Tomato Yield

T.K. Hartz, P.R. Johnstone, E.M. Miyao,[1] and R.M. Davis[2]
Department of Plant Sciences, University of California, Davis, CA 95616

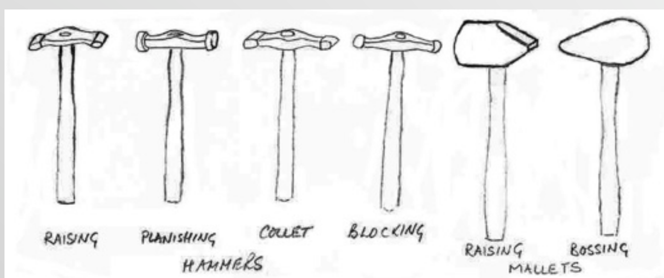
Mustard and Other Cover Crop Effects Vary on Lettuce Drop Caused by *Sclerotinia minor* and on Weeds

Tiffany A. Bensen and **Richard F. Smith,** University of California Cooperative Extension, Monterey County, Salinas 93901; **Krishna V. Subbarao,** University of California, Department of Plant Pathology, Davis 95616; **Steven T. Koike,** University of California Cooperative Extension; and **Steven A. Fennimore** and **Shachar Shem-Tov,** University of California, Department of Plant Sciences, Davis 95616

The Ecology of Plant Disease



- "The Disease Pyramid":
  - 4 Critical components
  - Manage any one,
    - Know how to manage!
    - Strategize!



  - Products are a helpful, powerful intervention tool
  - BUT…Integrated approaches are most effective!

Additional Benefits

- Adds organic matter
  - Improved soil fertility
  - Improves infiltration and water holding capacity
  - Improves soil aeration
  - Microbial community for nutrient cycling and disease suppression
- Attracts beneficials
- Weed suppression

Brassica cover crop characteristics:

- Diving taproot system
  - Infiltration improvement potential
  - High catch crop potential
    - Reach deeper soil layers quickly
    - Soluble nutrient recovery
      - Non-mycrorrhizal

Brassica cover crop characteristics

- Catch up to ~200 lbs ac N, depends on levels
  - Highly responsive to N levels
  - Need starter N to get going though (esp. spring)
- Catch other nutrients, water from deeper layers and return to surface
  - S recovery has been noted
- May be useful to soils with histories of intensive tillage
  - Compromised mycorrhizal community
  - Compaction

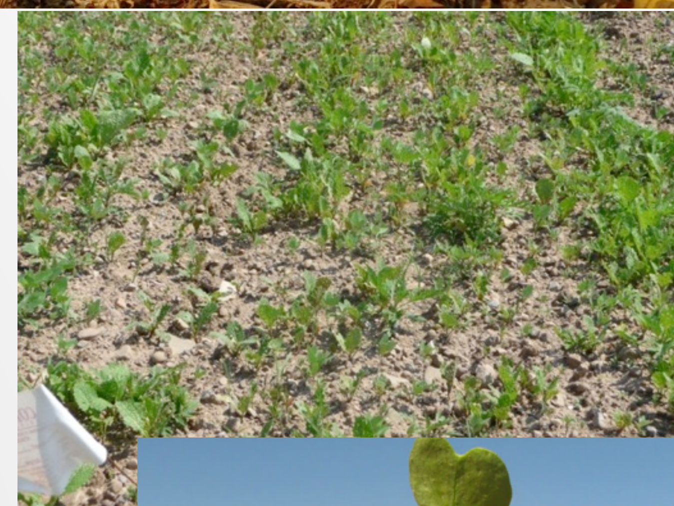


Table 2. Dry matter production (total and root), total N content in the catch crops and soil nitrate-N residues in the top 1.0 m of the soil in November, average 2 years (figures in brackets are SE, *n*=2)

	Total DM	Root DM	N content	Soil nitrate-N
	Mg ha^{-1}		kg N ha^{-1}	
F. radish	5.6 (0.4)	0.9 (0.4)	160 (6)	15 (5)
Winter rape	5.4 (0.7)	1.4 (0.0)	148 (2)	9 (2)
Phacelia	4.7 (0.8)	0.5 (0.2)	102 (4)	26 (7)
Rye	3.1 (0.4)	1.0 (0.0)	91 (4)	24 (12)
Oats	3.8 (0.6)	0.7 (0.1)	88 (19)	31 (5)
Italian ryegrass	5.4 (0.1)	1.9 (0.3)	123 (13)	24 (6)
Rye/vetch mix.	4.7 (1.2)	1.4 (0.4)	143 (27)	29 (9)
Hairy vetch	4.3 (1.7)	0.6 (0.1)	153 (33)	51 (18)
– no catch crop –	–	–	–	129 (31)
Malva sylvestris[a]	5.6	2.0	105	11
Agrostemma githago[a]	6.3	1.0	132	18

[a] Only included in 1 year.

Thorup-Kristensen, 2001

Table 3. Root intensity calculated for the whole depth of the minirhizotrons at four dates shown as number of weeks after sowing and approximate number of day °C after sowing, average 2 years (figures in brackets are SE, *n*=2)

	Root intensity (intersec. m^{-1} line on the minirhizotrons)			
	3 weeks 360 d °C	4 weeks 520 d °C	6 weeks 760 d °C	12 weeks 1320 d °C
F. radish	2.8(1.1)	11.5(0.8)	90(10)	138(4)
Rape	1.3(0.7)	4.8(0.3)	48(14)	108(13)
Phacelia	1.3(0.1)	8.2(1.4)	87(17)	160(29)
Rye	4.1(1.7)	6.9(2.1)	17(3)	35(2)
Oats	2.7(0.6)	5.1(0.1)	18(6)	34(3)
Ryegrass	1.3(1.1)	2.1(1.7)	10(4)	82(3)
Rye/vetch mixt.	2.7(0.1)	5.5(1.2)	16(7)	42(5)
Vetch	1.3(1.0)	2.3(1.2)	6(1)	18(2)
Malva[a]	0.4	2.1	19	58
Agrostemma[a]	0.3	0.6	13	65

[a] Only included in 1 year.

Thorup-Kristensen, 2001

Table 4. Regression parameters of rooting depth against temperature sum. The lag time is the estimated temperature sum until a rooting depth of 0.1 m is reached. Estimated temperature sum until a rooting depth of 1.0 m is obtained is shown for each crop.

	Lag time d °C	Depth penetration rate mm d^{-1} $°C^{-1}$	R^2	Depth after 1000 d °C M	Time to 1.0 m d °C
F. radish	301	2.0	0.99	1.5	751
Winter rape	397	2.3	0.94	1.5	789
Phacelia	377	1.7	0.99	1.2	908
Rye	222	1.2	0.97	1.0	1001
Oats	200	1.0	0.95	0.9	1134
Ryegrass	532	1.1	0.95	0.6	1375
Rye/vetch mixt.	250	1.1	0.99	0.9	1086
Vetch	342	0.9	0.96	0.7	1356
Malva[a]	431	1.7	0.95	1.1	960
Agrostemma[a]	572	1.5	0.98	0.7	1172

[a] Only included in 1 year.

Thorup-Kristensen, 2001

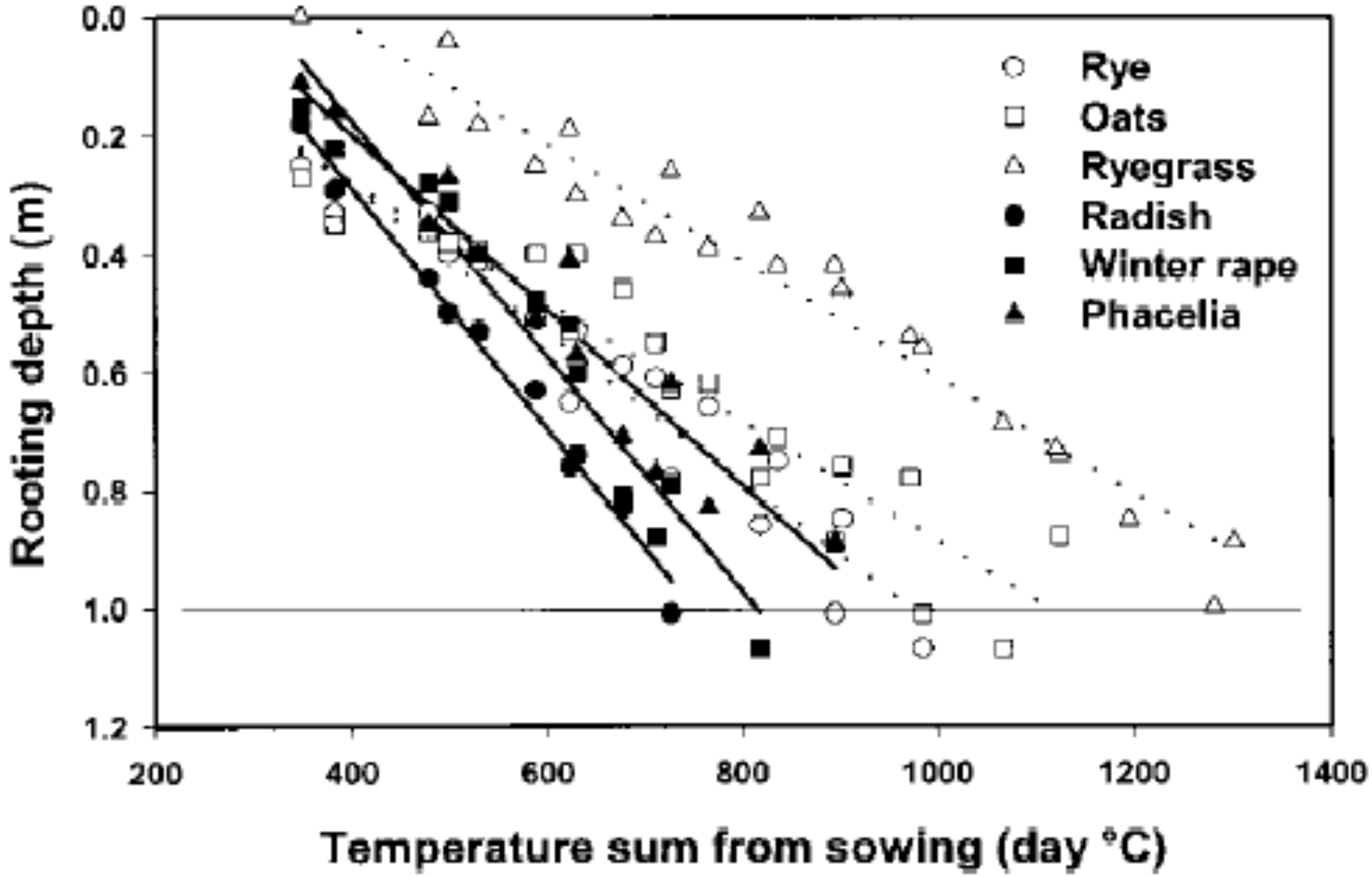


Figure 3. Depth penetration by catch crop roots during the autumn, data from each of the 2 years are shown. The statistics of the regressions are shown in Table 4.

Thorup-Kristensen, 2001

Mustard Green Manures Replace Fumigant and Improve Infiltration in Potato Cropping System

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Average Infiltration Rates, after consecutive 1" applications of ponded water

Rotation with mustard green manures (green-shaded rows)
Rotation without green manures

Date and Point in rotation	Average Infiltration Rates: 1st inch	2nd inch	3rd inch
	---in/min---		
September 3, 1999			
After wheat harvest	1.39a	0.48a	
After wheat harvest	0.13b	0.18b	
November 2, 2000			
After potato harvest	0.20b	0.19a	0.16
After sugarbeet harvest	0.39a	0.05b	
March 7, 2001			
Potatoes/winter	0.57a	0.10a	
Sugarbeets/winter	0.06b	0.05b	
March 5, 2002			
Potatoes/winter	0.14	0.09a	0.08
Fallow/winter	0.10	0.05b	

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Mustard Green Manures Replace Fumigant and Improve Infiltration in Potato Cropping System

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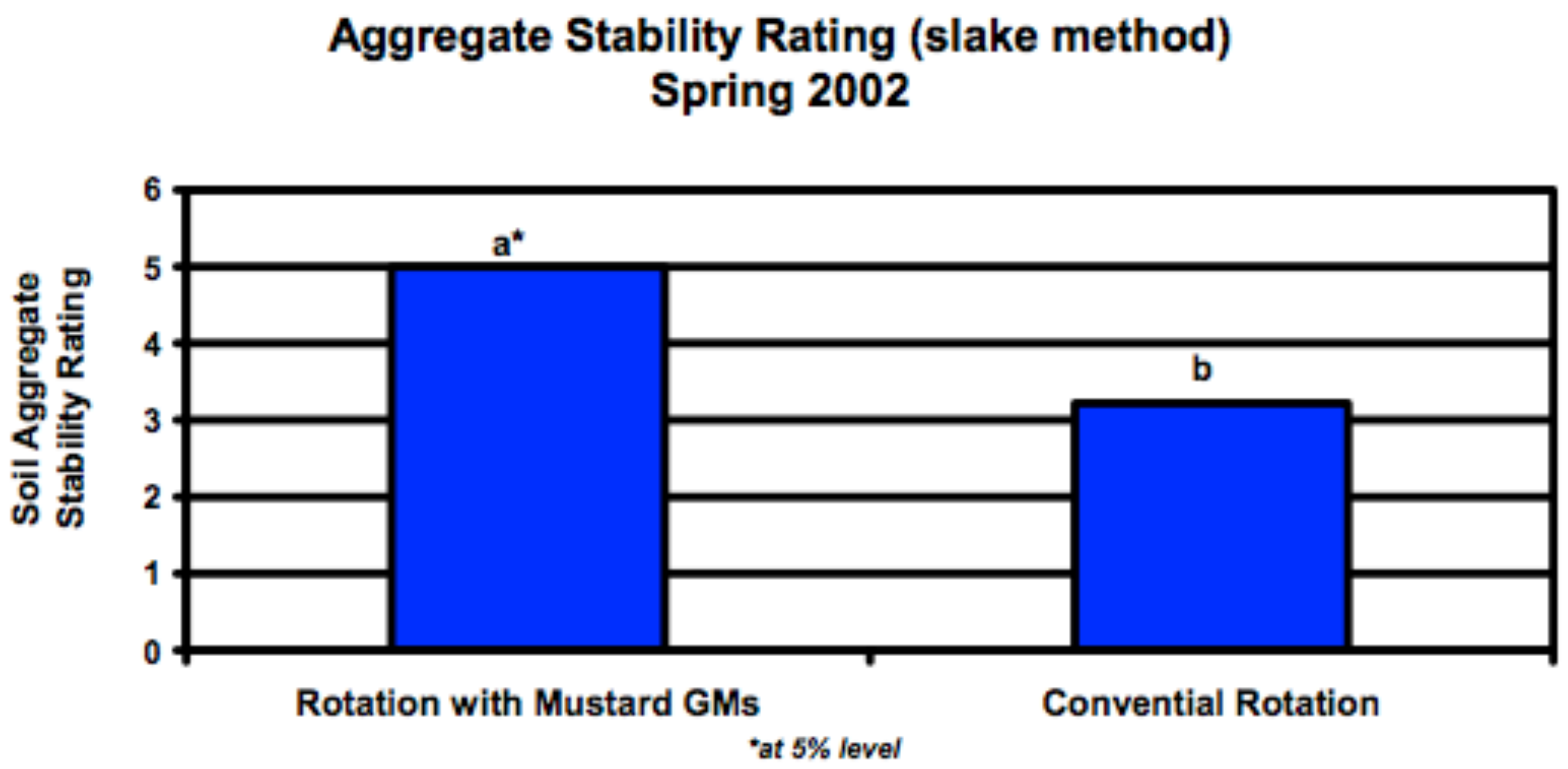

Growing for biofumigation

- Considerations
  - Species/variety with high *glucosinolate* content
    - 'Caliente' varieties (*B. juncea*)
    - 'Nemat' arugula (*Eruca sativa*)
    - 'Pacific Gold' (*B. juncea*)
    - 'Ida Gold' (*B. campestris*)
    - *White mustard (Sinapsis alba)*
    - *Rapeseed, Canola (B. napus)*
    - *Pennycress (Thlaspi arvense)*

Screening *Brassica* species for glucosinolate content

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Glucosinolate and isothiocyanate concentration in soil following incorporation of *Brassica* biofumigants

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BIOFUMIGANT COMPOUNDS RELEASED BY FIELD PENNYCRESS (*Thlaspi arvense*) SEEDMEAL[1]

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D. Gies

Growing for biofumigation

- Considerations
  - ***TREAT IT LIKE A CASH CROP!***
  - Crop rotation
    - Sequence before soilborne disease-sensitive cash crops
    - Sequence gaps, physical distance from brassica cash crops
    - Past herbicide?
  - Season timing (~50-60d growth)
    - Spring (April - June)
    - Winter (Sept - winterkill or May)
    - Late summer (Aug – Oct)*

Growing for biofumigation

- Seedbed preparation
  - Conditioning for small seeded crop
  - Weed-free
  - Pre-plant fertility
    - Soil test recommended P, K, micros for mustards
    - Starter N (~20 lbs mimimum, esp. in spring!!)
    - S (~20 lbs or ~6:1 N:S ratio; gypsum will not lower pH)
    - *Your biofumigation can only be as good as your fertility*

Growing for biofumigation

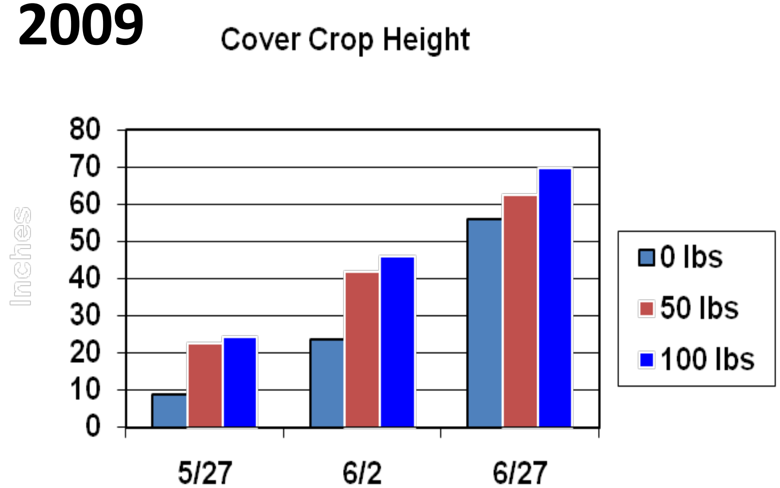
- Seeding
  - Use drill (rec'd) or broadcast
  - Seed depth: ¼ to ½"
  - Mustards: 10-12 lbs/ac
  - Arugula: 6-8 lbs/ac
    - Late seedings, shortened season > can increase rate

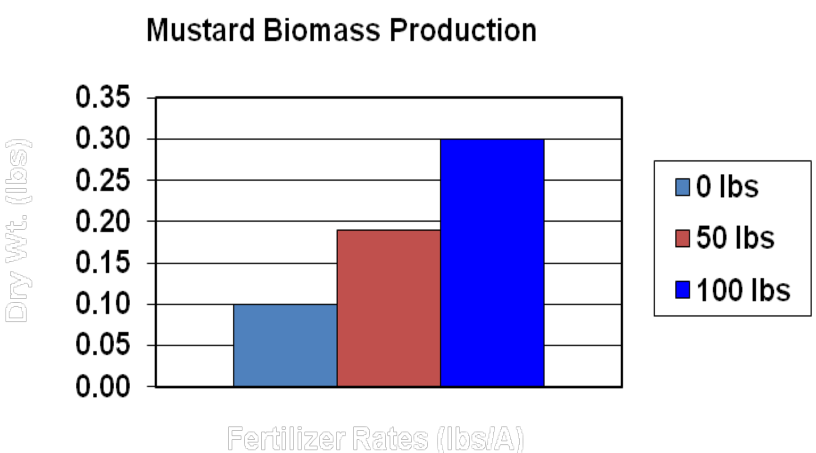
Growing for biofumigation

- Management
  - Topdress N (usually needed)
    - 50-100 lbs/ac total applied N is optimal
    - Depends on crop history, inherent fertility
  - Weed control?
  - Irrigate if droughty

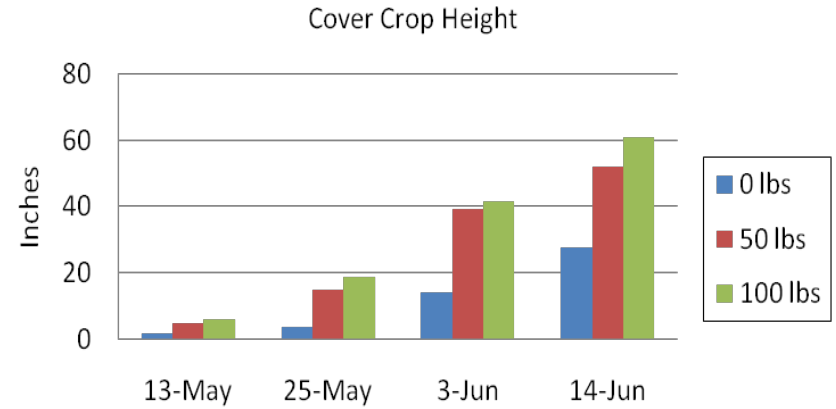
Nitrogen Fertility and Biomass Production

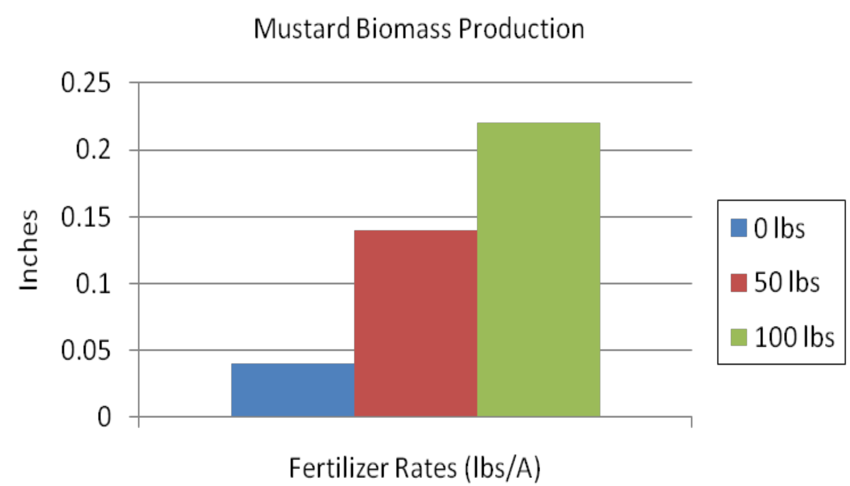
2009





2010





cf. Sandy Menasha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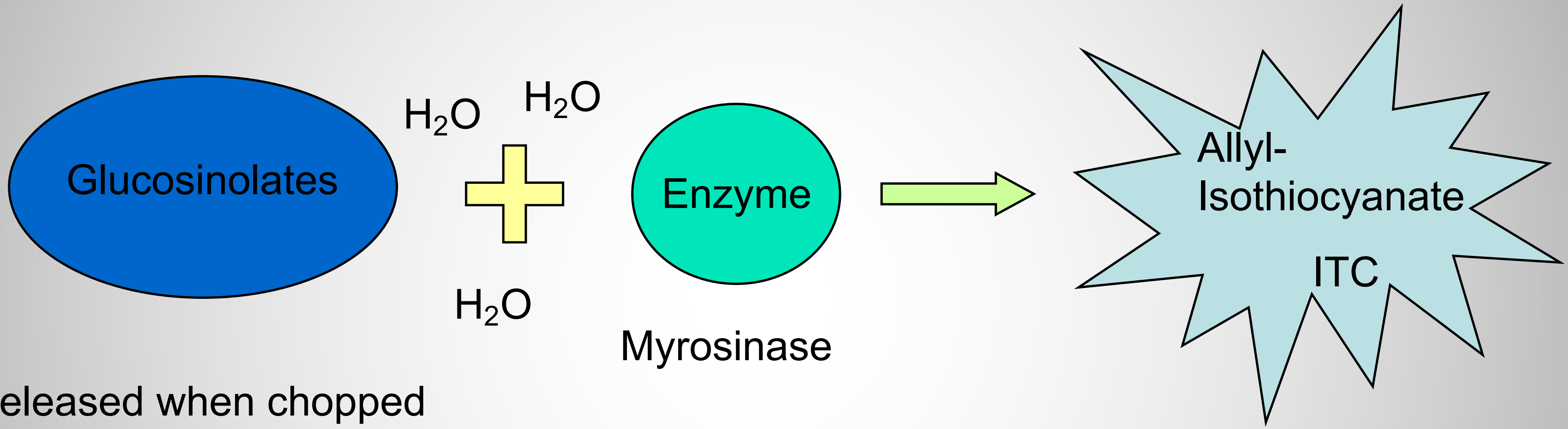
Growing for biofumigation

- What to Expect:
  - Begins flowering after ≥30 d usually ~2½-3'
    - Let it flower away!
  - Viable seed 6 weeks from flower
  - Doubles in height after flowering
  - Grows up to ~5 ft
  - Incorporate 2-4 weeks after flower
  - Biofumigation potential drops after maturity
    - Mustard weed seed after maturity


D. Gies

Biofumigation



Released when chopped

Similar to compounds in *Vapam*
(methyl-isothiocyanate)

- In sequence:
  - Chop > incorporate > seal > (irrigate?)
- ITC is a volatile gas: Activity time is limited!

Biofumigation

- Equipment
  - Mower (flail is rec'd)
    - Ruptures brassica cells, releases glucosinolates
  - Tillage implement (rototiller rec'd)
    - Increases biofumigant contact with soil borne pathogens
  - Packing implement (cultipacker rec'd)
    - Seals in ITC biofumigant gas
  - Irrigation lines if droughty
    - Assures conversion of glucosinolates to ITCs
    - Assures start of 7-14 day biofumigation period
    - Helps seal soil surface to retain ITC gas

D. Gies

Biofumigation

- ~10 day biofumigation recommended
- Should inhibit weed seed germination by default
- SO- do not plant crops in biofumigating soils also- poor germ risk!
- Light tillage after biofumigation period will help assure release of any remaining gases
- *Heavier soils may hold in gas more?*
  - *Also may not biofumigate as thouroughly?*

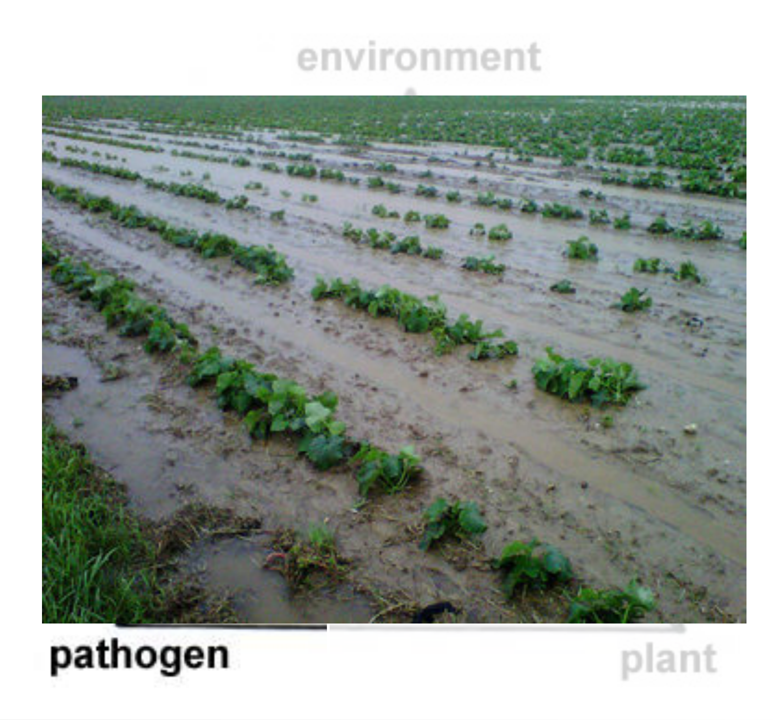
Ecology of P-Cap

"P-Cap"

Phytophthora capsici:

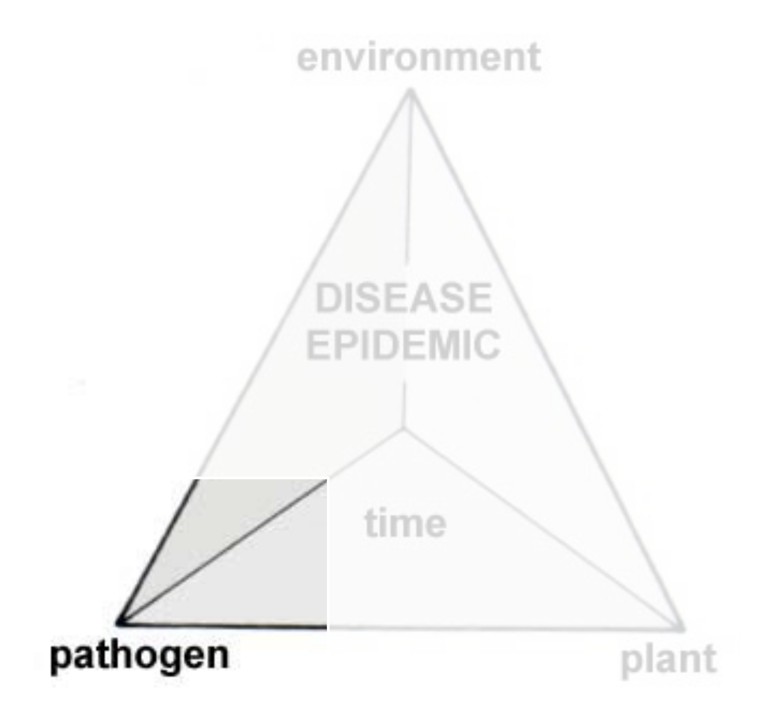
"pepper destroyer"

- Water mold
  - *moves in water*
  - *thrives* in water
    - NOT *Phytophthora infestans*- "late blight"- can be air-transported
  - Floods & P-cap: downside of bottomland ground
  - Changing climate ↑ heavy downpours



Ecology of P-Cap

- Super-pathogen
  - Two spore types
    - Short-lived, in-season
      - 1 squash= hundreds of millions of spores
      - Motile (swimming zoospores)
    - Long-lived, overwintering (at least 10 yrs.)
      - Two mating types needed, but common
      - Reside in soils



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Ecology of P-Cap

Ecology of P-Cap

- Broad host range
  - Select Solanaceae:
    - Pepper, eggplant, tomato-
      - *NOT* Potato
    - *Weeds:* Eastern black horsenettle
  - Cucurbits (all; pumpkin, squash, melons etc.)
  - Select Legumes
    - Snap beans, limas
  - Other Weeds
    - Warm season: Velvetleaf, Common purslane*

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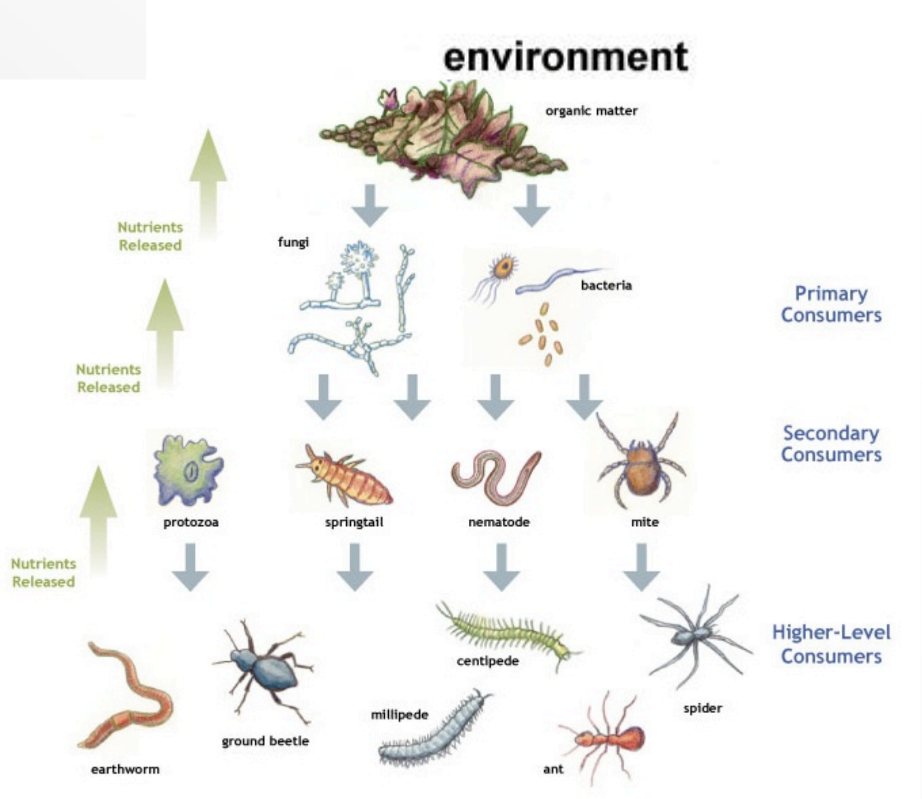
Ecology of P-Cap

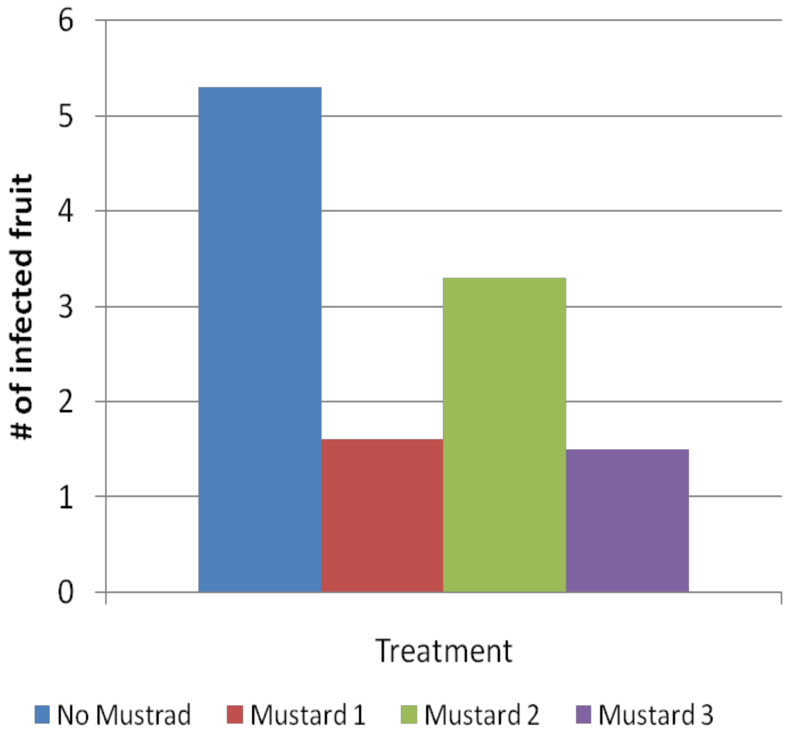
- WET!
  - Standing water
    - Over irrigation
    - Poor drainage
  - Wet Soils
    - Bare soil – splashing
    - Mud- boots, equipment
  - Poor soil health
    - Exhausted, overworked soils
    - Dysfunctional and/or weak soil food web



Healthy zucchini only after mustard. 8-15-08 Phytophthora blight.

Phytophthora Fruit Rot Incidence

2009

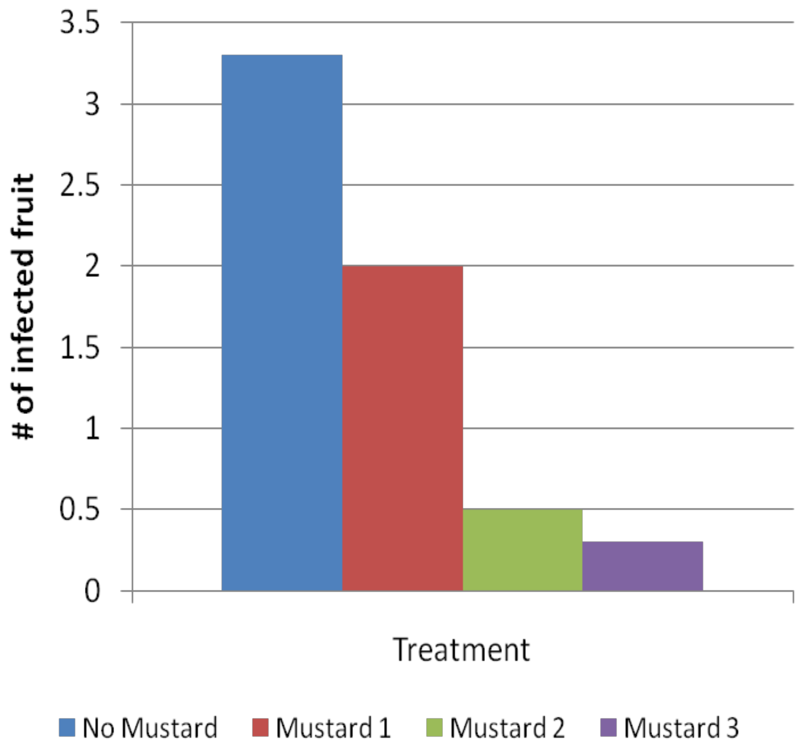


0 lb/A

50 lb/A

100 lb/A

2010



0 lb/A

50 lb/A

100 lb/A

cf. Sandy Menasha

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Integrated Phytophthora Blight Management in Vegetable Crops with Enhanced Soil Health From Cover Crops, Reduced Tillage, and Brassica Biofumigation

- Integrated management:
  Current IPM guidelines + biofumigation & reduced tillage
  - Biofumigation reduces inoculum (fumigation, burial)
  - Reduced tillage reduces contact with inoculum
  - Biofumigation + reduced tillage fosters soil health improvement
- 2-year field research component
- 7 on farm trial sites, plot study at LIHREC
- Biofumigation & RT vs. standard practice, C, N returned to soils, infiltration rates
- Year one: Brassica biomass C and N, cucurbit yields

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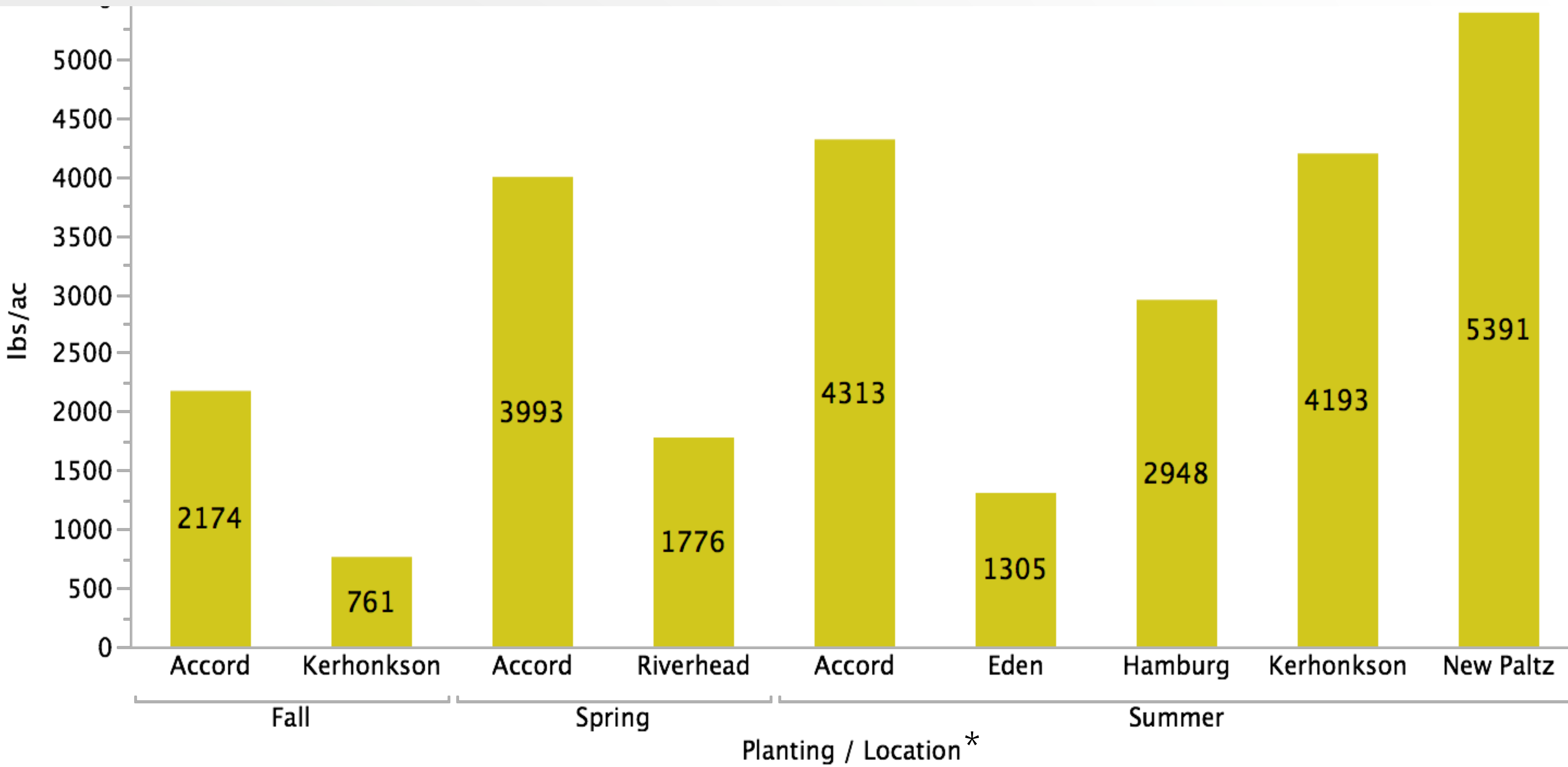
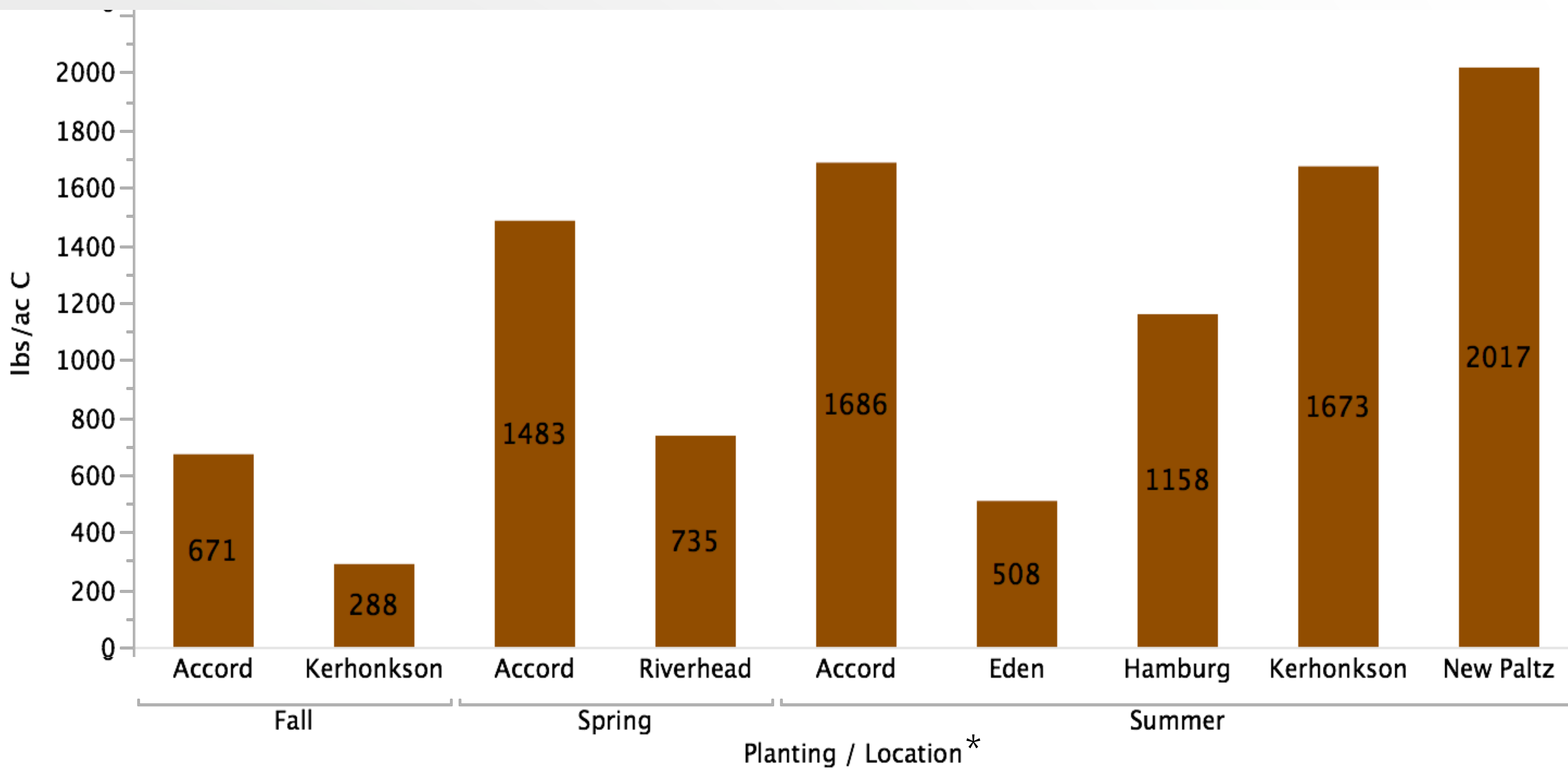
Prelim. data, on-farm ’15: Cvr. crop biomass



* Riverhead = Long Island site, Accord, Kerhonkson, Newpaltz = Hudson Valley sites, Eden, Hamburg = western NY sites.
Fall planting = ‘Nemat’ arugula, spring and summer plantings = ‘Caliente’ mustard.

Prelim. data, on-farm '15: Cover crop carbon



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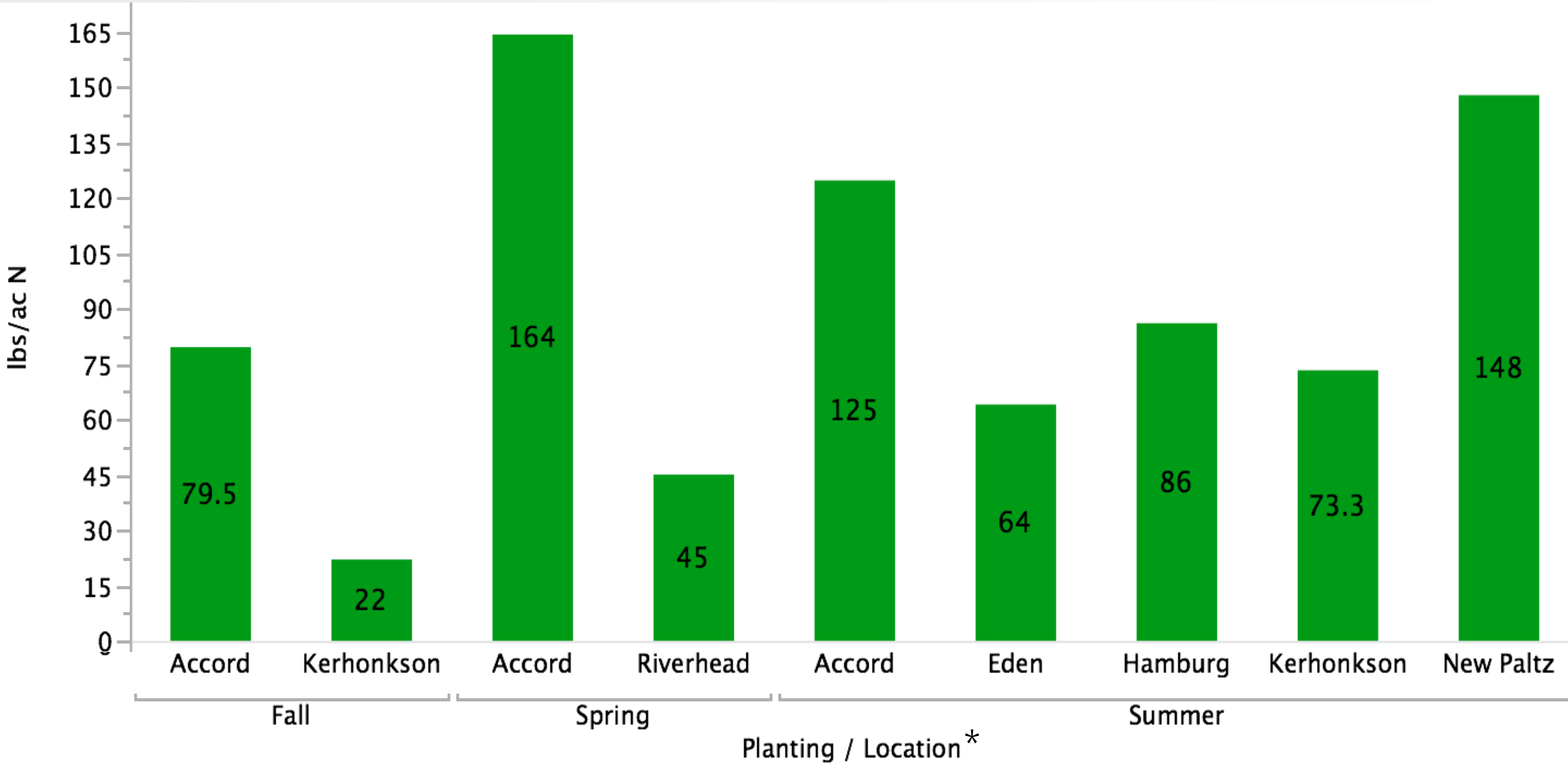
Prelim. data, on-farm '15: Cvr. Crop nitrogen



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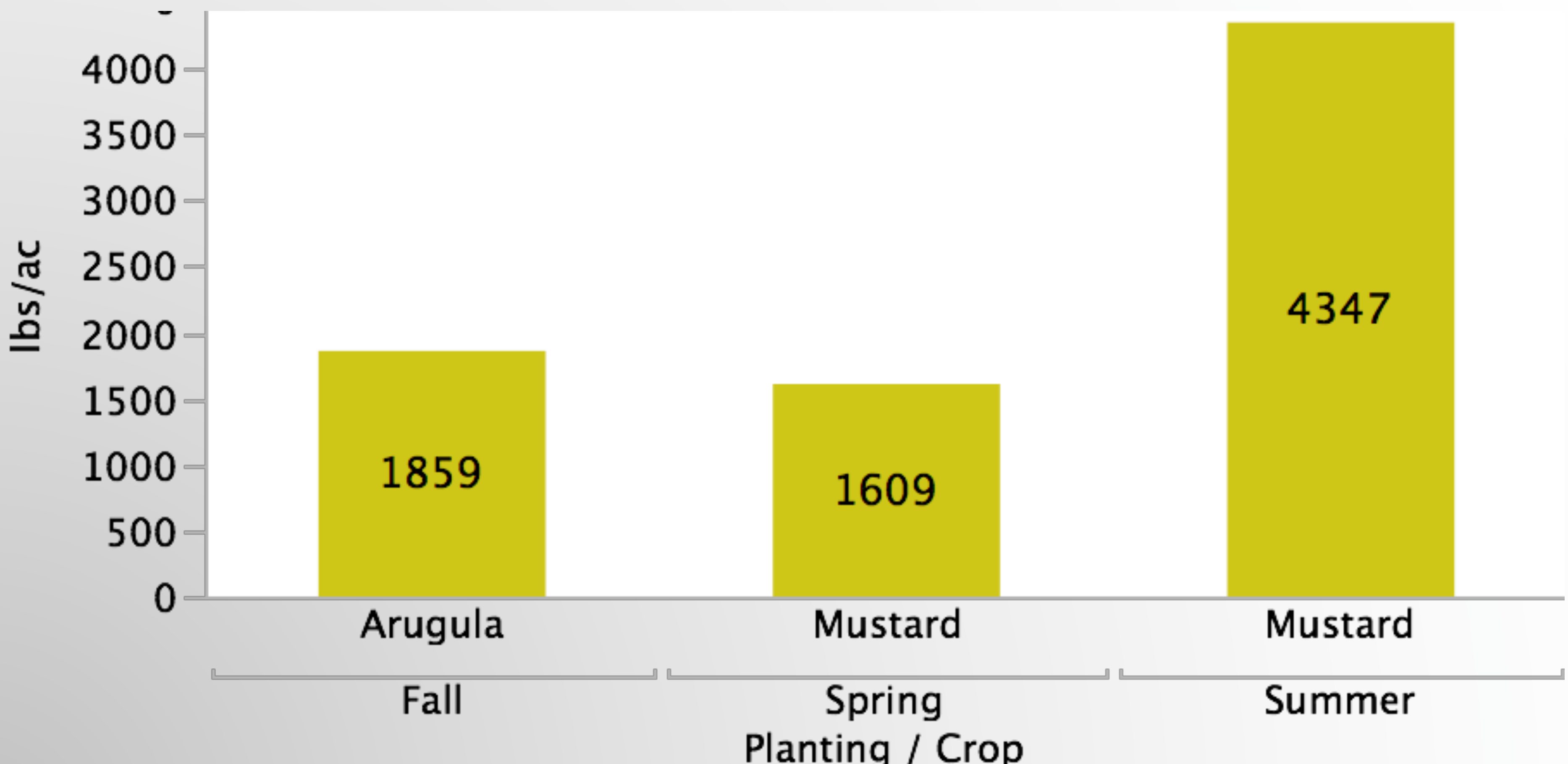
Prelim. data, LIHREC '15: Cvr. crop biomass



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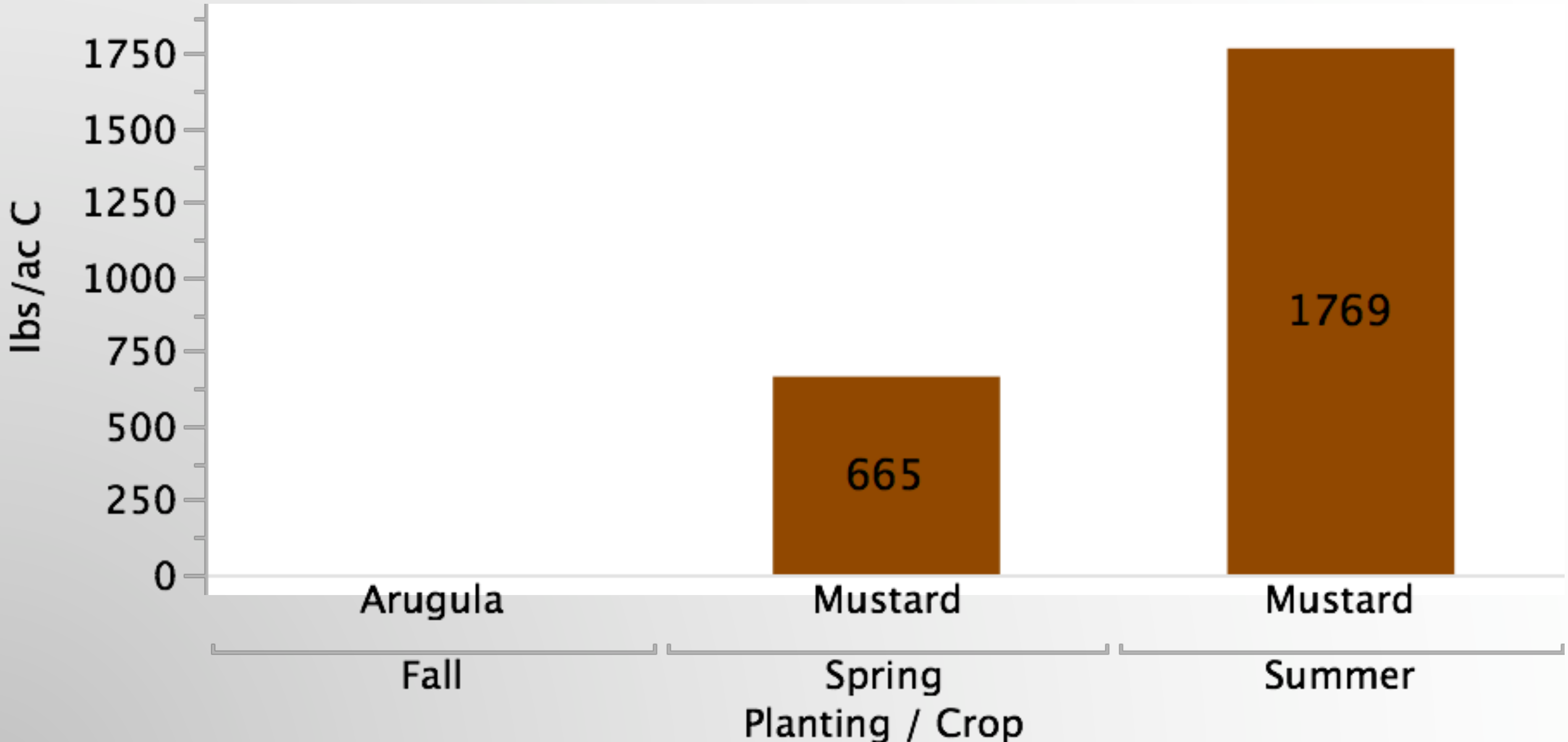
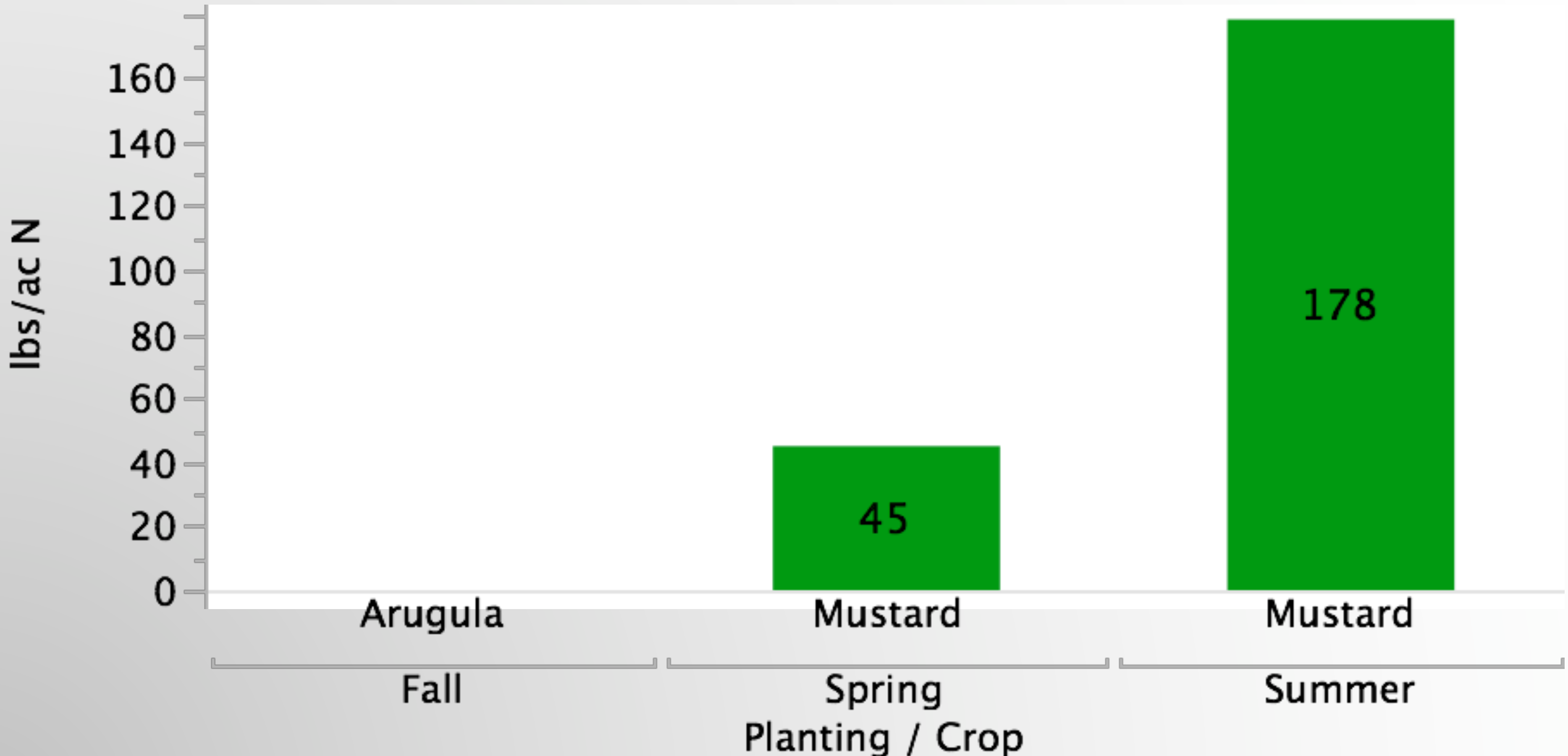
Prelim. data, LIHREC '15: Cvr. crop biomass

Prelim. data, LIHREC '15: Cvr. crop carbon

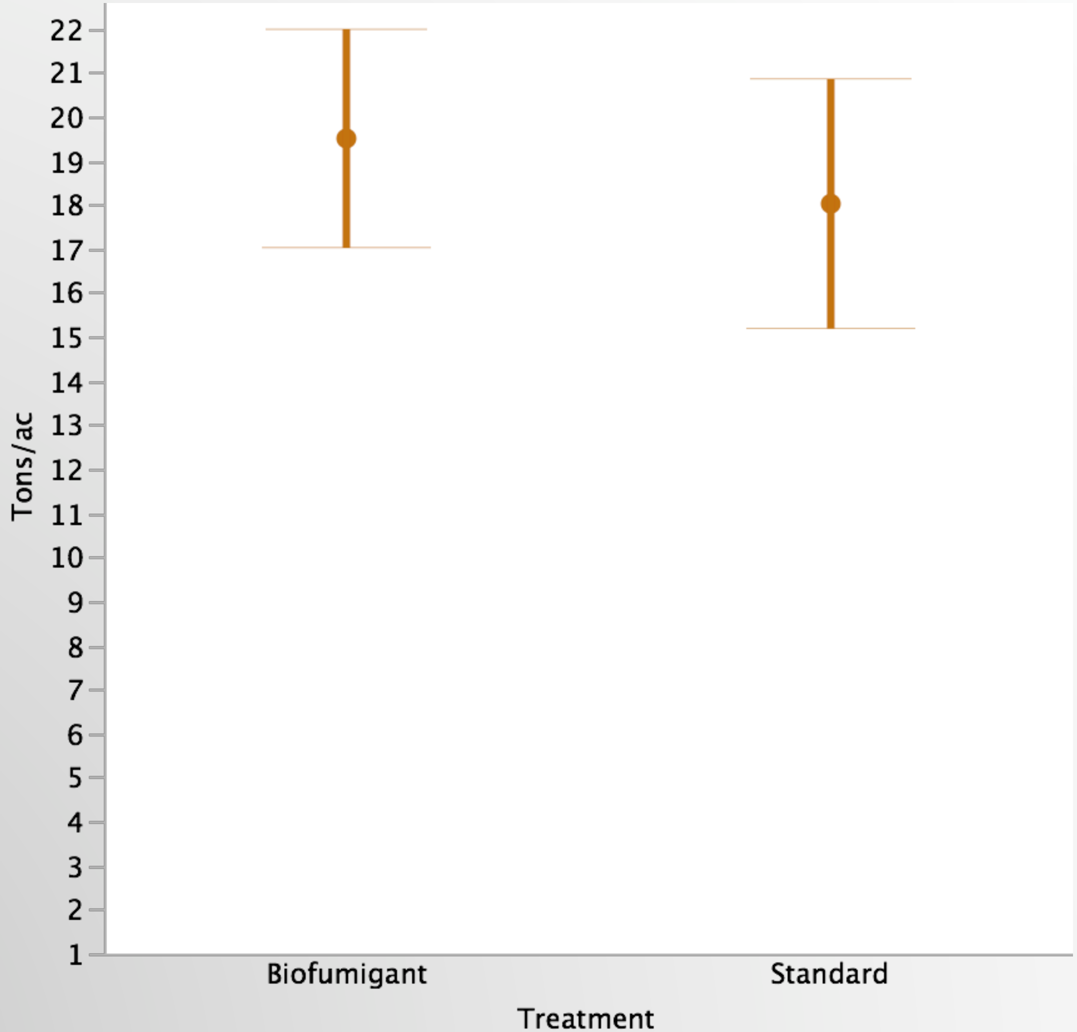


Cornell University
Cooperative Extension, Ulster County

Prelim. data, LIHREC '15: Cvr. crop nitrogen

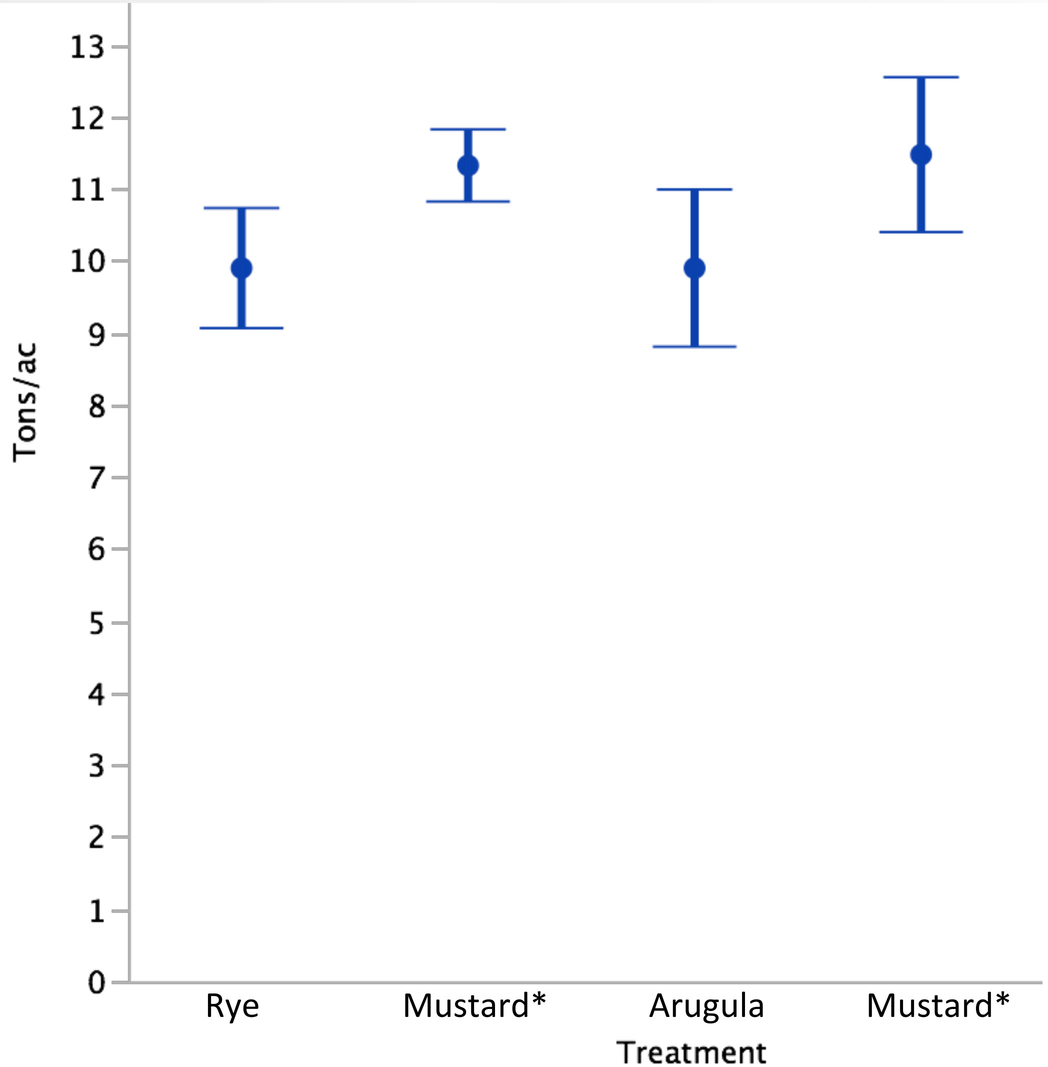


Prelim. data, on-farm '15: Pumpkin yield



Where(40 rows excluded)
Each error bar is constructed using 1 standard error from the mean.

Prelim. data, LIHREC '15: Kubocha yield



Each error bar is constructed using 1 standard error from the mean.

Prelim. data, on-farm '15: Phytophthora

- A little, but overall, **negligible**!
  - Hypothesis: Generally dry conditions.



2016 Reduced tillage year…

Biofumigation take Home Points

- Mindset: **Treat it like a crop!**
- Good seedbed prep, weed control
- Seed timely for 50-60 days growth
- Ample fertility, moisture
- Follow biofumigation steps
- *Nemat does not overwinter in NY*
- View biofumigation as one tool of many
- Consider other benefits of cover crop
  - SOM building, soil quality improvement
  - N catch cropping, & fertility improvement

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