MANAGING SOIL HEALTH AND CROP DISEASES WITH BRASSICA COVER CROPS

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Soil health

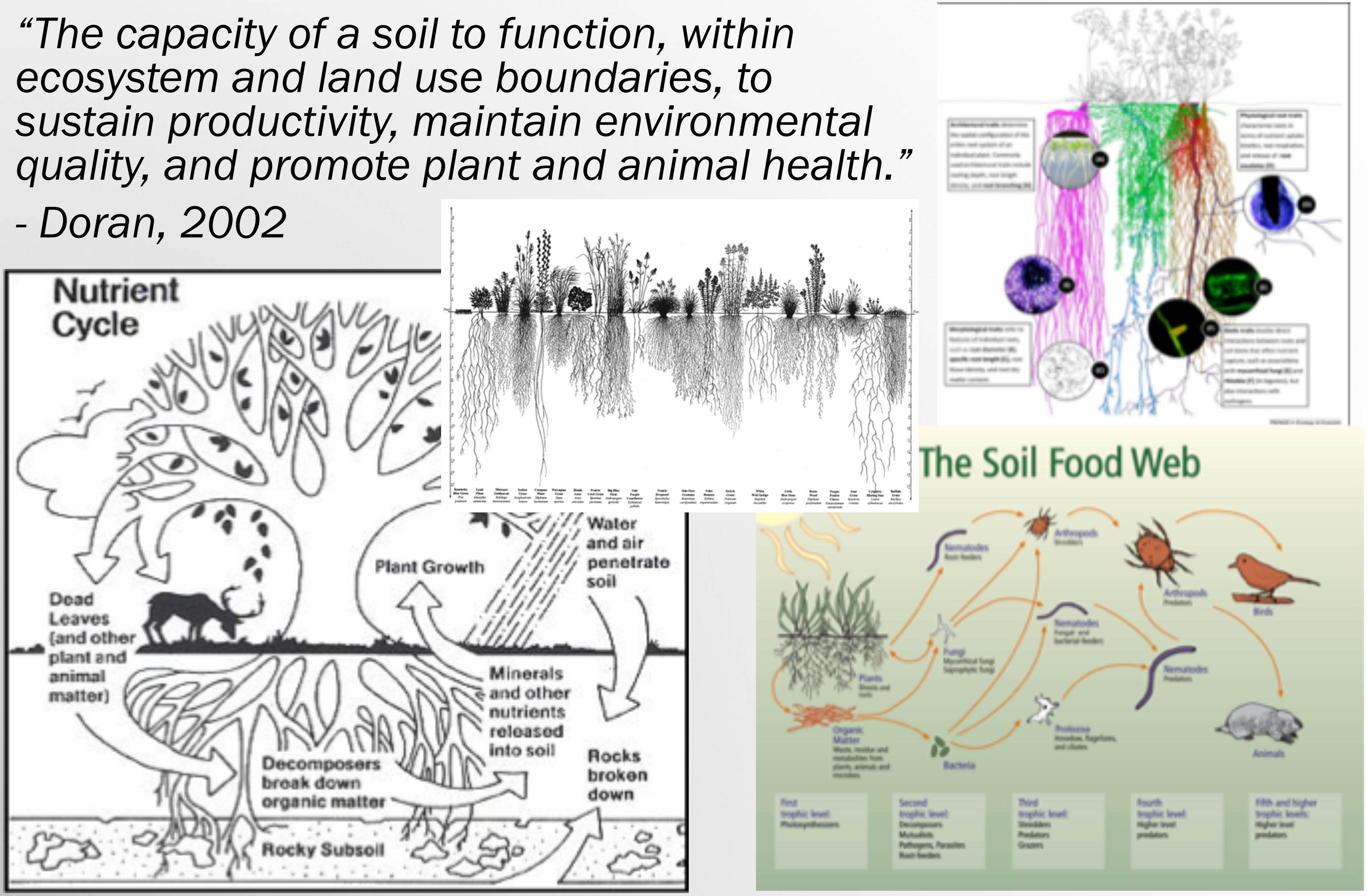
"The capacity of a soil to function, within ecosystem and land use boundaries, to sustain productivity, maintain environmental quality, and promote plant and animal health." – Doran 2002

- ☐ 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

Restoring services, function

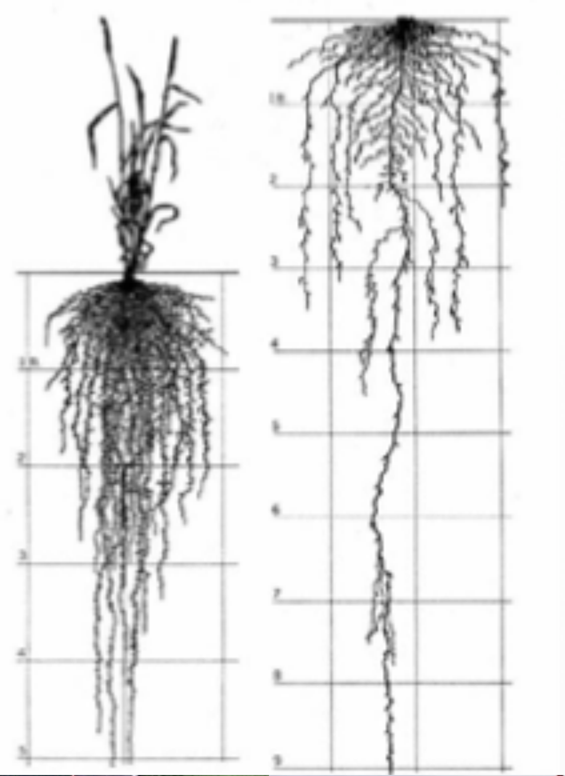
“The capacity of a soil to function, within ecosystem and land use boundaries, to sustain productivity, maintain environmental quality, and promote plant and animal health.”

- Doran, 2002



Understanding choices:

- Different root morphologies, architectures
- Different aboveground growth habits
- Different biomass qualities
- Different services
  - Balancing nutrient and non-nutrient services desired
  - Balancing species, management



Making good cover crop choices

- ☐ Identify services you want from a cover crop
- ☐ Identify cover crops that perform those services
- ☐ Understand how those cover crops affect nutrients
- ☐ Understand how to manage those cover crops for targeted services

Understanding cover crop services

- Non-nutrient services
  - Soil stabilization
  - Water management (use excess, reduce damage)
  - “Bio-tillage”
  - Mulching
  - Weed suppression
  - Soil-borne disease control
  - Pollinator attraction/refugia
  - Improved tilth
  - SOM building
    - Multiple improvements in soil resilience

Understanding cover crop services

- Nutrient services
  - Catch cropping
  - Nutrient scavenging
  - Nitrogen-fixation
  - Improved nutrient cycling
  - General increases in soil fertility
  - Moderated pH

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Understanding cover crop nutrient cycling services:

- N-fixers
  - Add N to soils, the only renewable nutrient
- Catch crops
  - Catch, recover volatile soil nutrients, convert into organic forms
    - Mostly N, S, B
    - Moderate loss; improve cycling, efficiency
- Nutrient scavengers
  - Scavenge soil solution for available static nutrients (P, cations), convert into organic forms
  - Incite nutrient release from minerals
  - Increase availability, cycling, of static nutrients
- Soil builders
  - Excel at building soil C (microbial substrate, humus)
  - Improved nutrient cycling via microbial activity (sugars, carbohydrates etc.) and nutrient exchange capacity (humus)
  - Moderate pH via increased buffering, cation exchange capacity (humus)

Brassica cover crops 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***
☐ ***<u>Small population of plant pathogens and insect pests**</u>***
☐ **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***

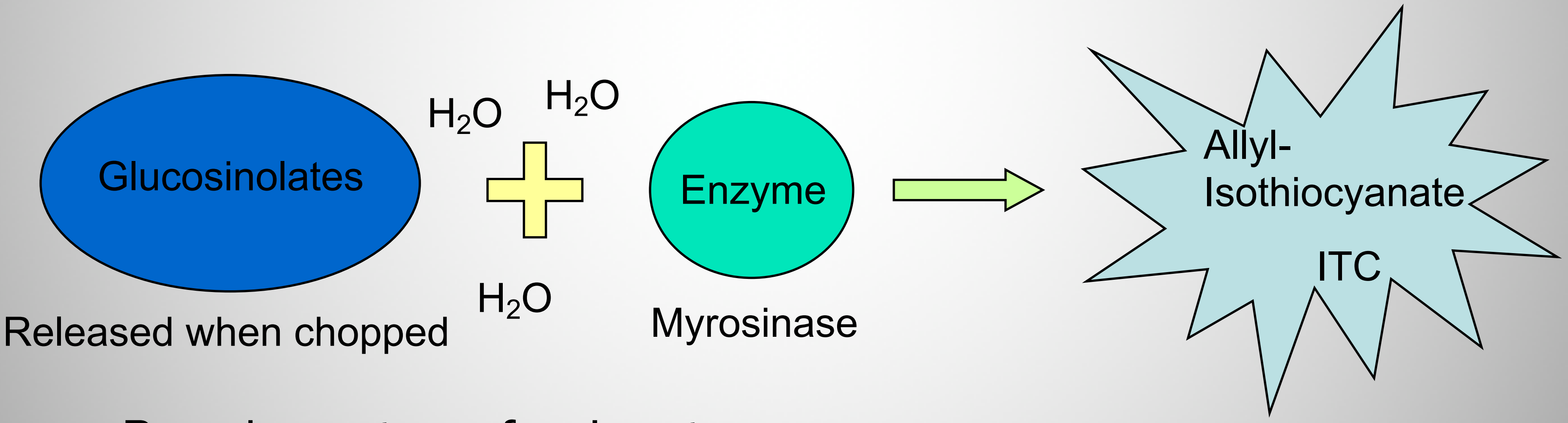
What is Biofumigation?

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

- Brassicas: esp. mustards, arugula

How does it work?

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



Glucosinolates

Released when chopped

H_2O H_2O H_2O

Enzyme

Myrosinase

Allyl-Isothiocyanate

ITC

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

Similar to active ingredient in *Vapam* (methyl-isothiocyanate)

Big hopes for Biofumigation

- 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

Big hopes for Biofumigation

CONTROL OF SOIL-BORNE PLANT PESTS USING GLUCOSINOLATE-CONTAINING PLANTS

Paul D. Brown and Matthew J. Morra

Department of Plant, Soil, and Entomological Sciences
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Moscow, Idaho 83844-2339

Plant and Soil **162**: 107–112, 1994.
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Biofumigation: Isothiocyanates released from *Brassica* roots inhibit growth of the take-all fungus

J.F. Angus[1], P.A. Gardner[1], J.A. Kirkegaard[1] and J.M. Desmarchelier[2]
[1]*CSIRO Division of Plant Industry, GPO Box 1600, Canberra, 2601, Australia and* [2]*CSIRO Division of Entomology, GPO Box 1700, Canberra, 2601, Australia*

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.
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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*

Applied results variable…

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,*]

Pathogenicity of *Phytophthora capsici* to *Brassica* Vegetable Crops and Biofumigation Cover Crops (*Brassica* spp.)

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

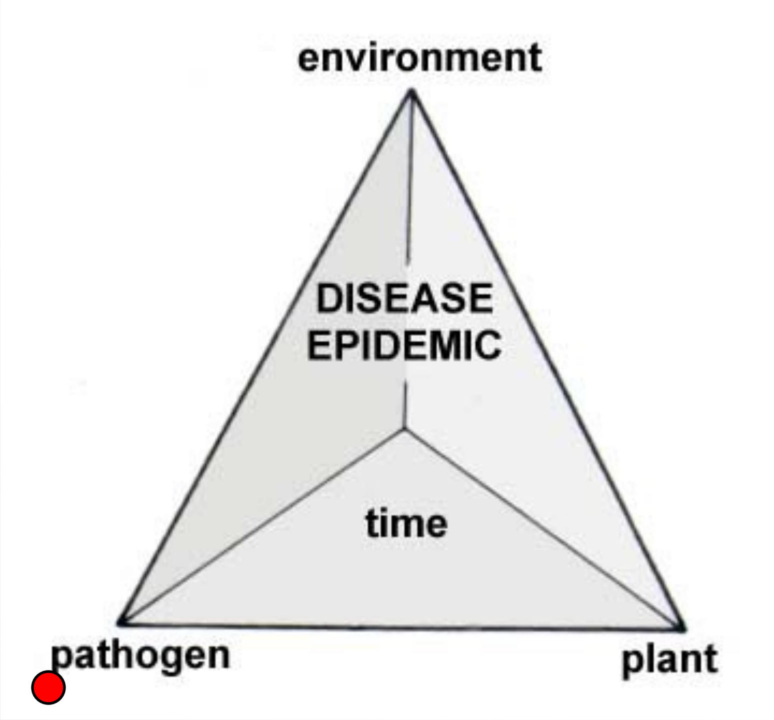
Mustard and Other Cover Crop Effects Vary on Lettuce Drop Caused by *Sclerotinia minor* and on Weeds

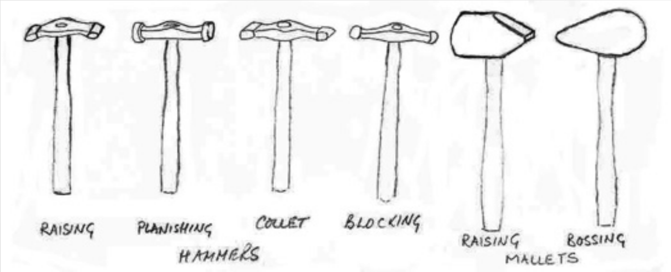
Tiffany A. Bensen and **Richard F. Smith,** University of California Cooperative Extension, Monterey County, Salinas 93901; **Krishna V. Subbarao,** University of California, Department of Plant Pathology, Davis 95616; **Steven T. Koike,** University of California Cooperative Extension; and **Steven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

Integrated management

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!

Brassica cover crops

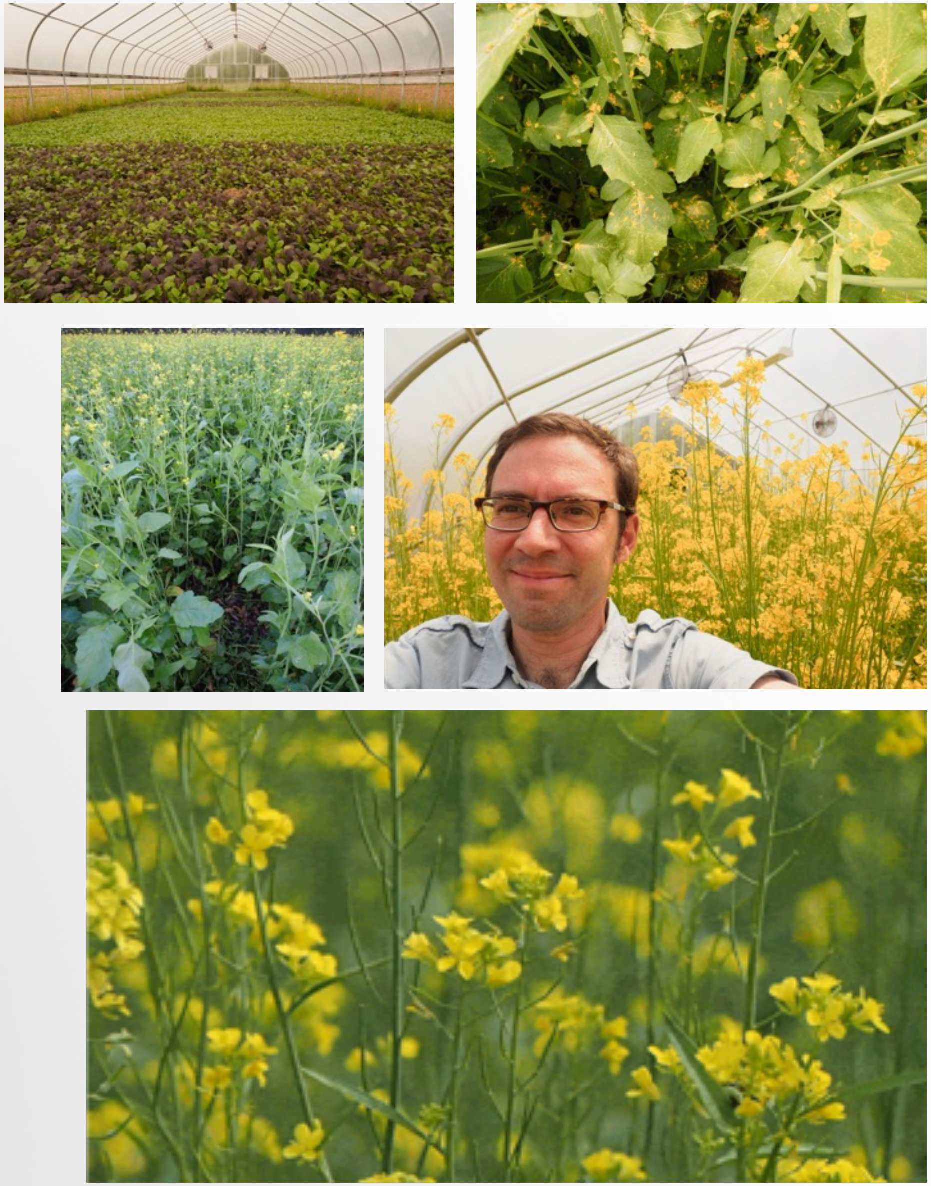
- All cool-season crops
  - Shoulder season timing
    - Spring or fall planting
- Daikon radish
  - “Tillage radish®”
- Oilseed radish
- Forage radish
- Turnip
- Mustards
- Arugula
- Rapeseed/canola




Brassica cover crop characteristics:

- Weed suppression
  - Quick canopy closure
  - Quick vertical growth rate
- Can return abundant C to soils-

  50-60d growth =
  - ~2000-2500 lbs/ac C (~4500-7200 lbs. total biomass)
- Attracts beneficials



Brassica cover crop characteristics:

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

What you see of the radish is only part of the story. The small taproot drills deep into the soil, creating root channels that can alleviate compaction, and capturing deep soil nutrients.

Brassica cover crop characteristics

- Catch up to ~200 lbs ac N, depends on residual levels
  - Measured ~130-180 lbs/ac in mustards – will catch more than is applied
  - 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



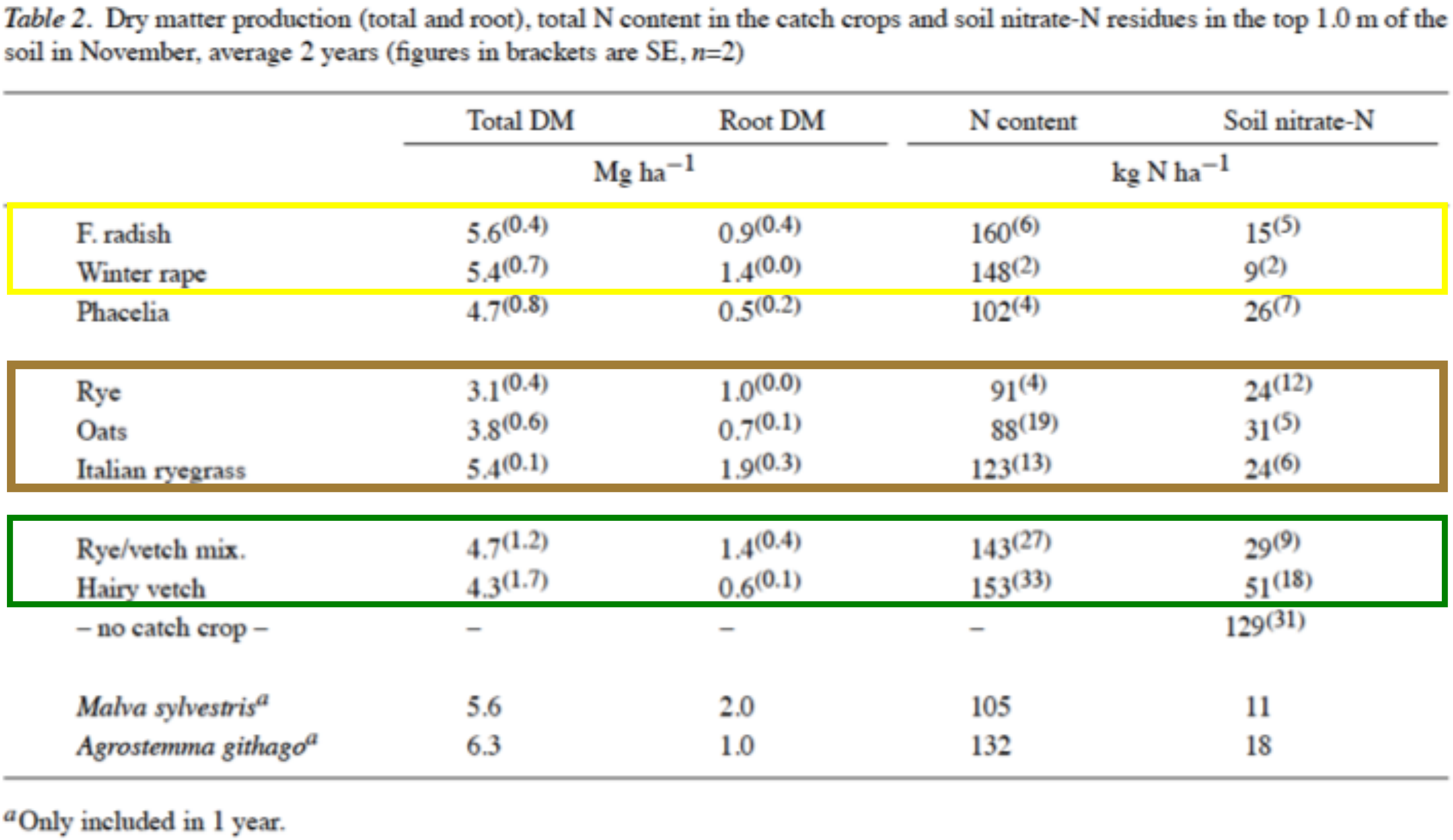


Table 2. Dry matter production (total and root), total N content in the catch crops and soil nitrate-N residues in the top 1.0 m of the soil in November, average 2 years (figures in brackets are SE, *n*=2)

	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

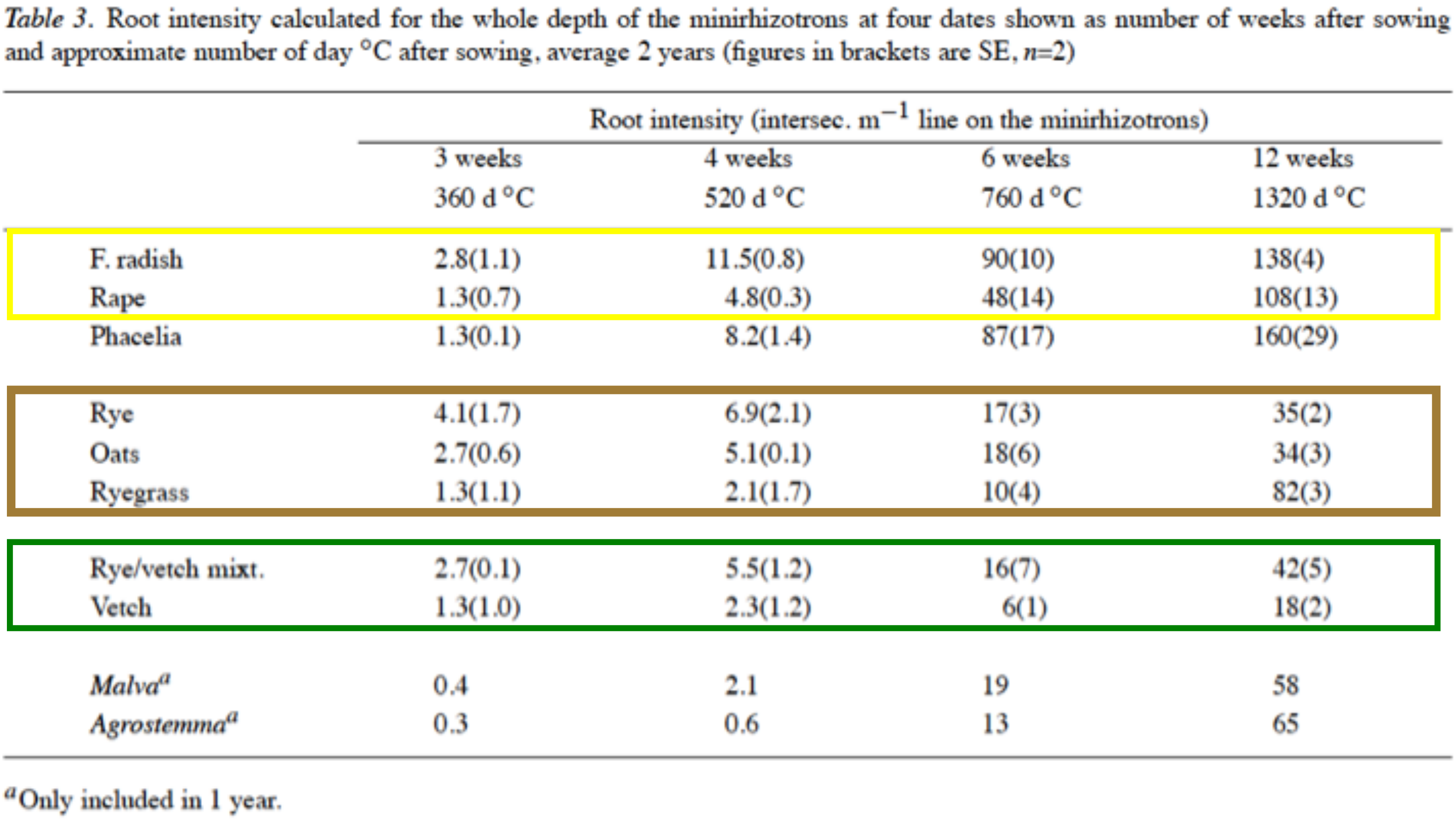


Table 3. Root intensity calculated for the whole depth of the minirhizotrons at four dates shown as number of weeks after sowing and approximate number of day °C after sowing, average 2 years (figures in brackets are SE, *n*=2)

	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

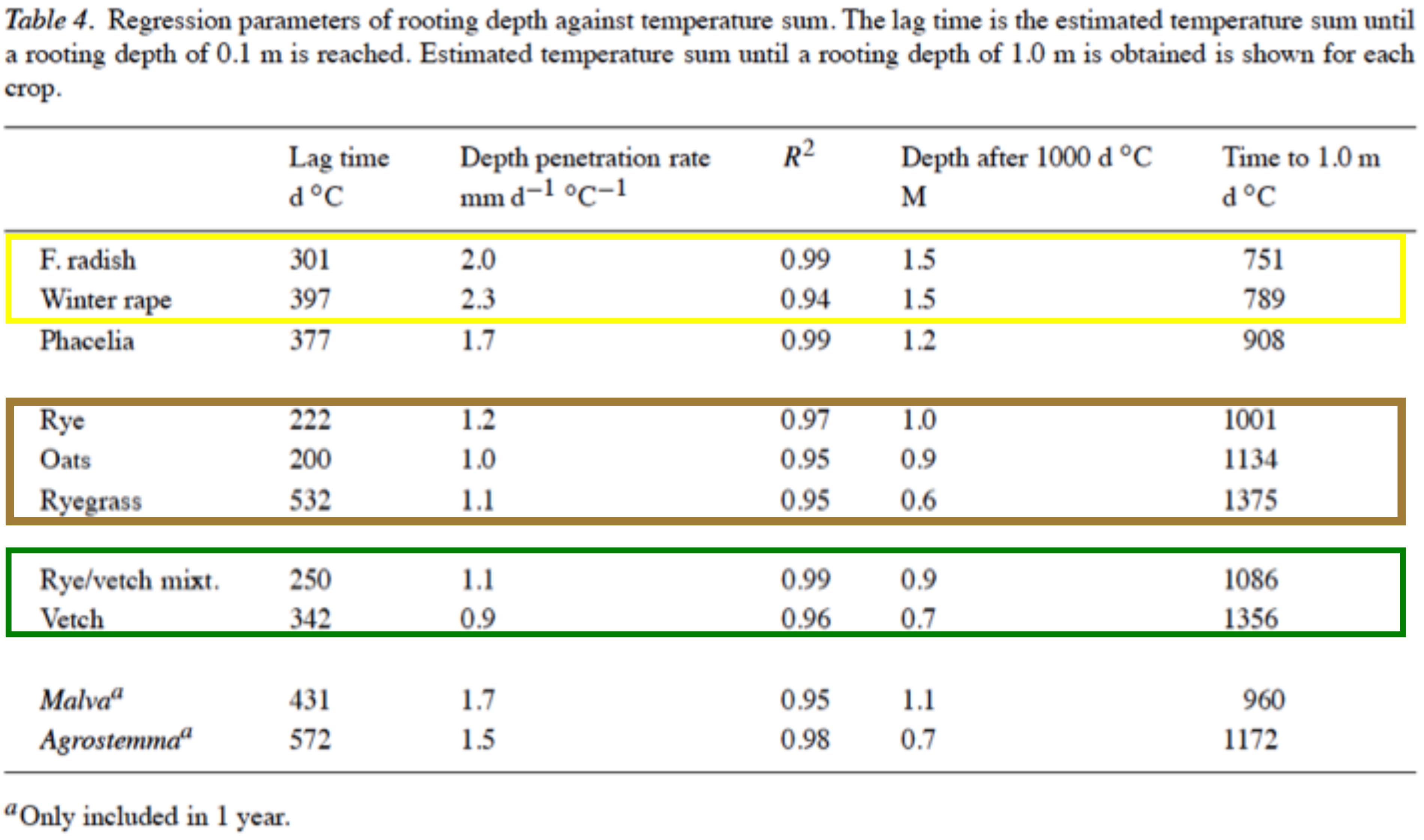


Table 4. Regression parameters of rooting depth against temperature sum. The lag time is the estimated temperature sum until a rooting depth of 0.1 m is reached. Estimated temperature sum until a rooting depth of 1.0 m is obtained is shown for each crop.

	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

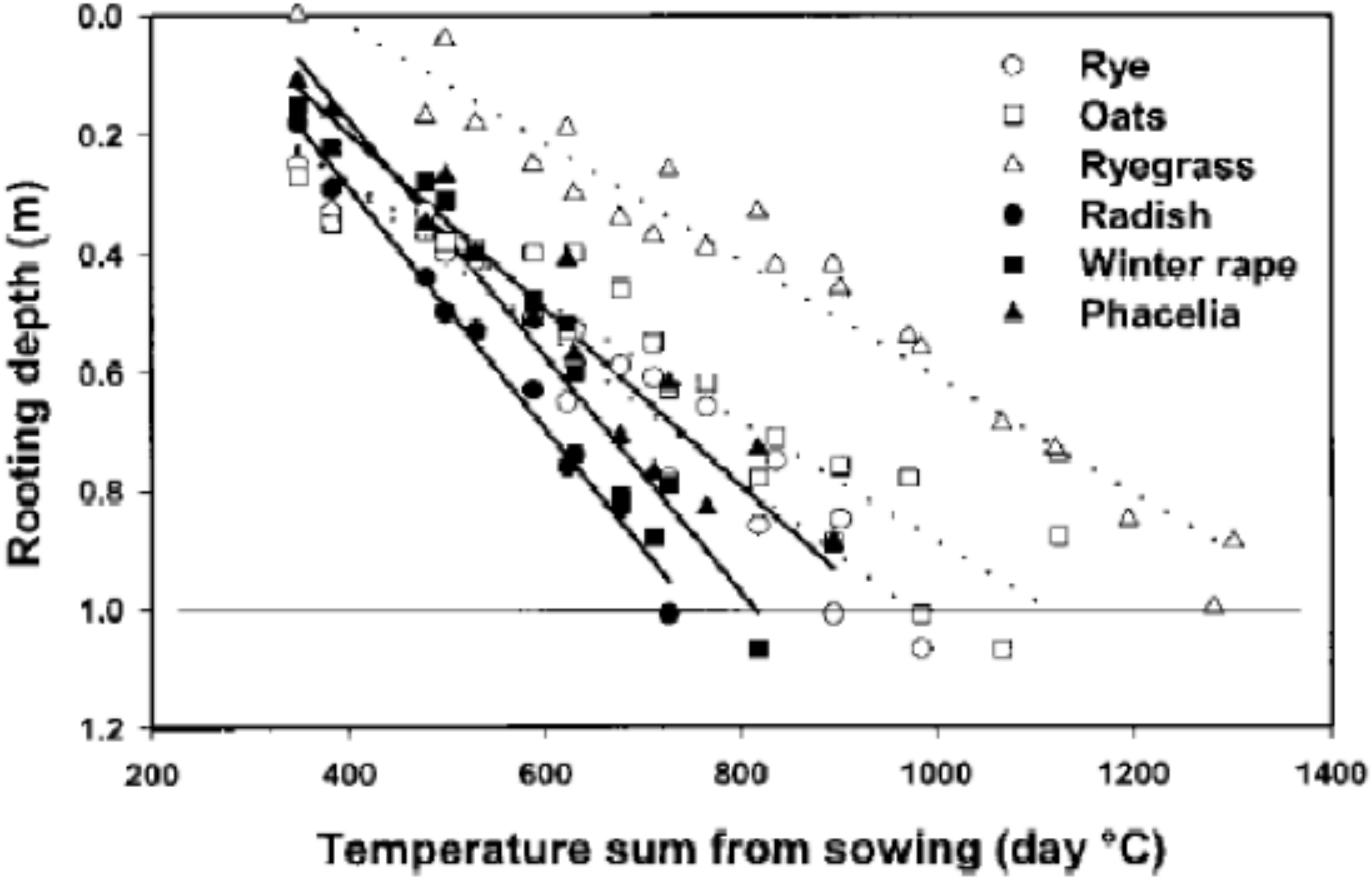
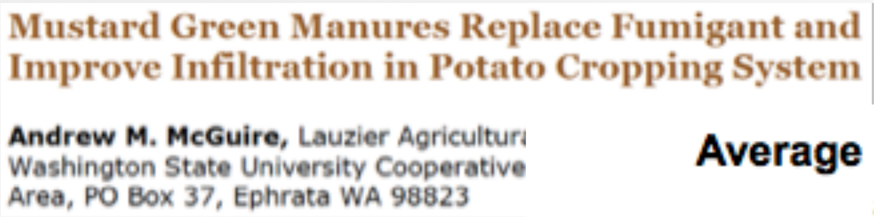


Figure 3. Depth penetration by catch crop roots during the autumn, data from each of the 2 years are shown. The statistics of the regressions are shown in Table 4.

Thorup-Kristensen, 2001



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

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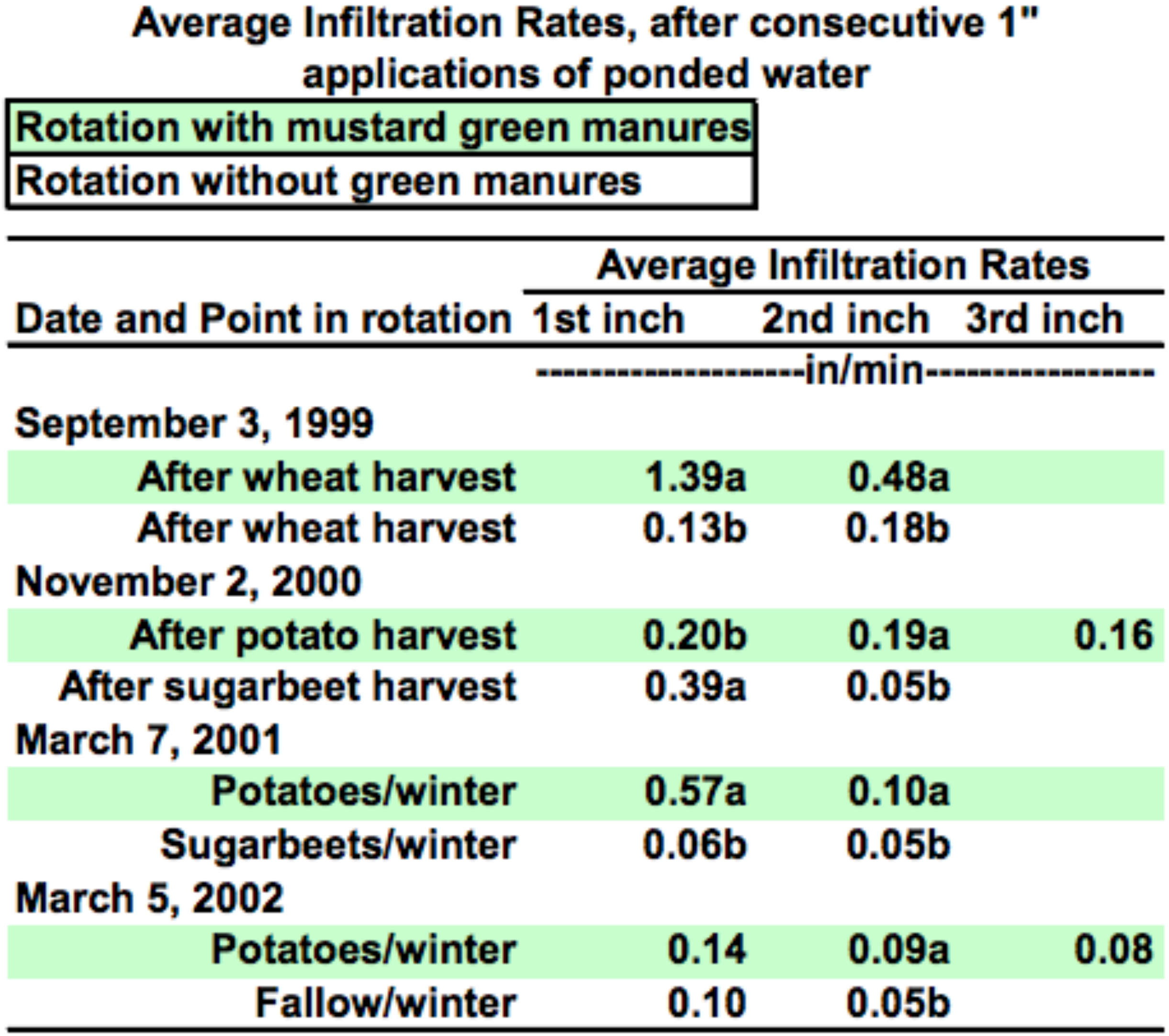

Average Infiltration Rates, after consecutive 1" applications of ponded water

Rotation with mustard green manures
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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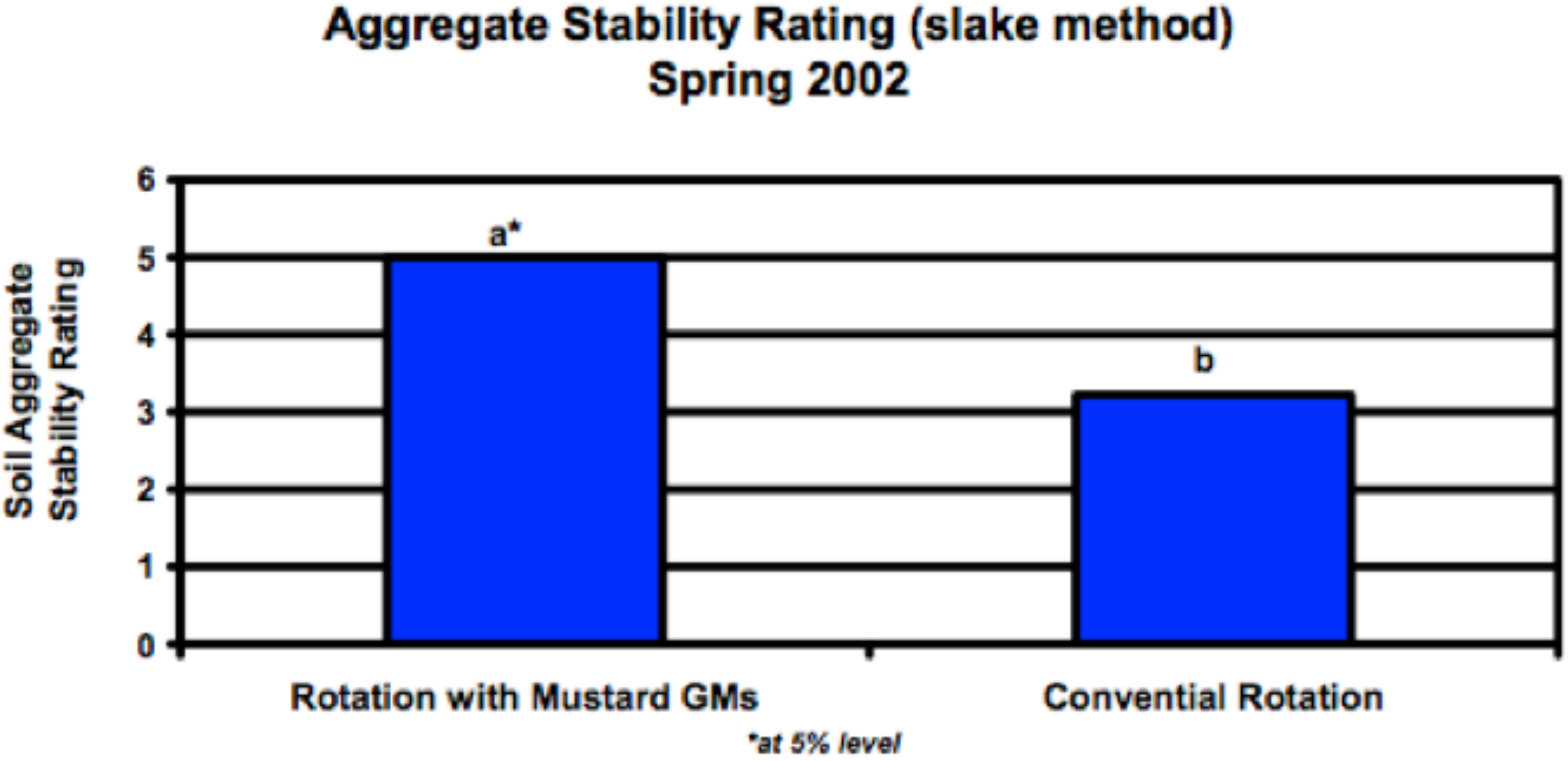


Aggregate Stability Rating (slake method)
Spring 2002

*at 5% level

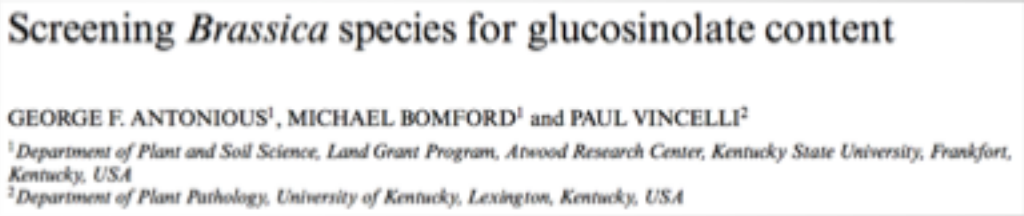
Growing for biofumigation

- Considerations
  - Species/variety with high *glucosinolate* content

    Fungal pathogen-oriented
    - ‘Caliente’ varieties (*B. juncea*)*
    - ‘Pacific Gold’ (*B. juncea*)

    Nematode-oriented
    - ‘Nemat’ arugula (*Eruca sativa-* overwintering)
    - ‘Ida Gold’ *(Sinapsis alba)*

    Other:
    - *Rapeseed, Canola (B. rapa/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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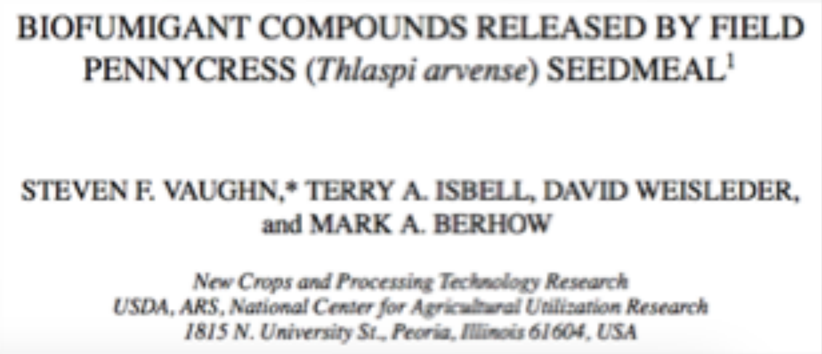

BIOFUMIGANT COMPOUNDS RELEASED BY FIELD PENNYCRESS (*Thlaspi arvense*) SEEDMEAL[1]

STEVEN F. VAUGHN,* TERRY A. ISBELL, DAVID WEISLEDER, and MARK A. BERHOW

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1815 N. University St., Peoria, Illinois 61604, USA

D. Gies

Growing for biofumigation

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

Growing for biofumigation

- Seedbed preparation
  - Conditioning for small seeded crop
  - Weed-free
  - Pre-plant fertility
    - Soil test recommended P, K, micros for mustard
    - 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*

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Growing for biofumigation

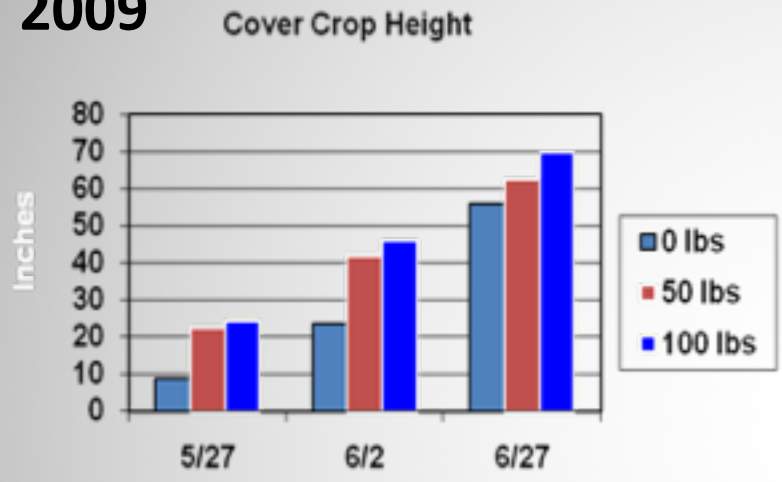
- Seeding
  - Use drill (rec'd) or broadcast
  - Seed depth: ¼ to ½"
  - Mustards: 10-12 lbs/ac
  - Arugula: 6-8 lbs/ac
    - Late seedings, shortened season, dry, broadcast > can increase rate
  - Small seeded- assure adequate moisture

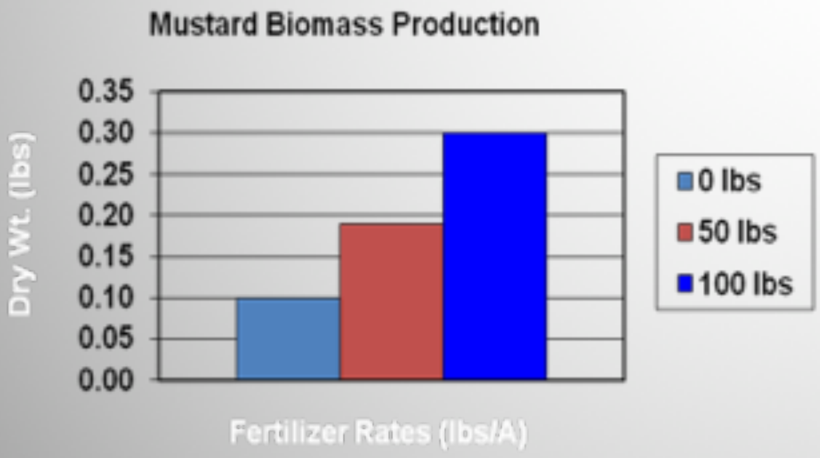
Growing for biofumigation

- Management
  - Topdress N (usually needed)
    - 50-100 lbs/ac total applied N is optimal, some go as high as 150
    - Depends on crop history, inherent fertility
    - You will get back more N in biomass than you applied
      - C:N = ~14:1
  - Irrigate if droughty

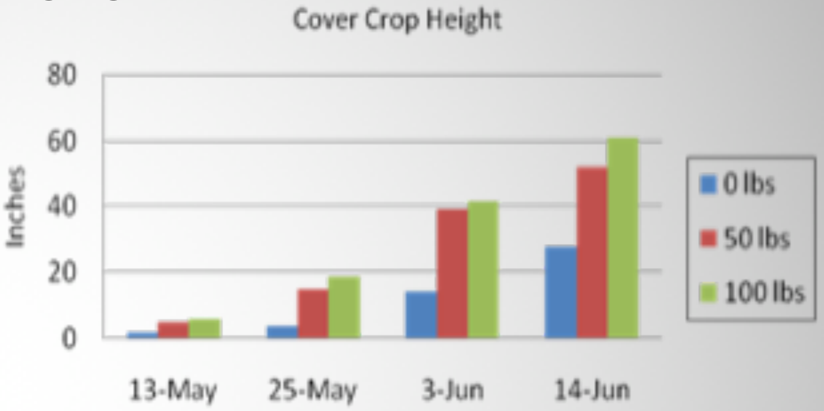
Nitrogen Fertility and Biomass Production

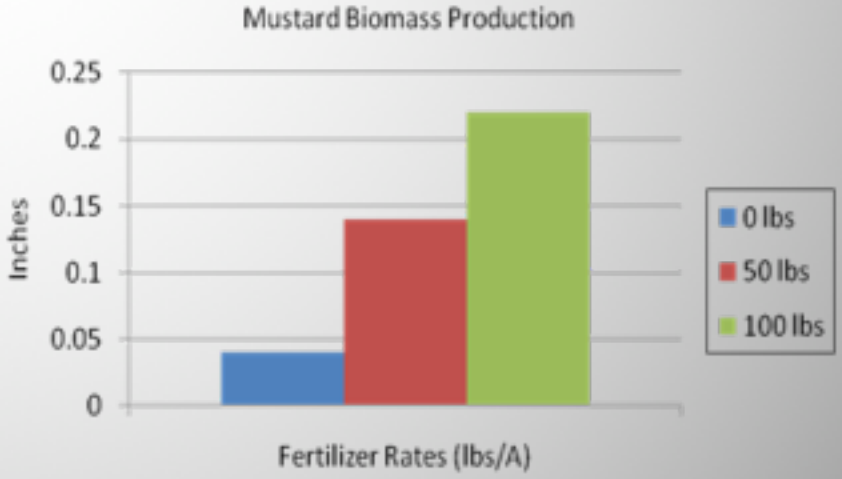
2009





2010

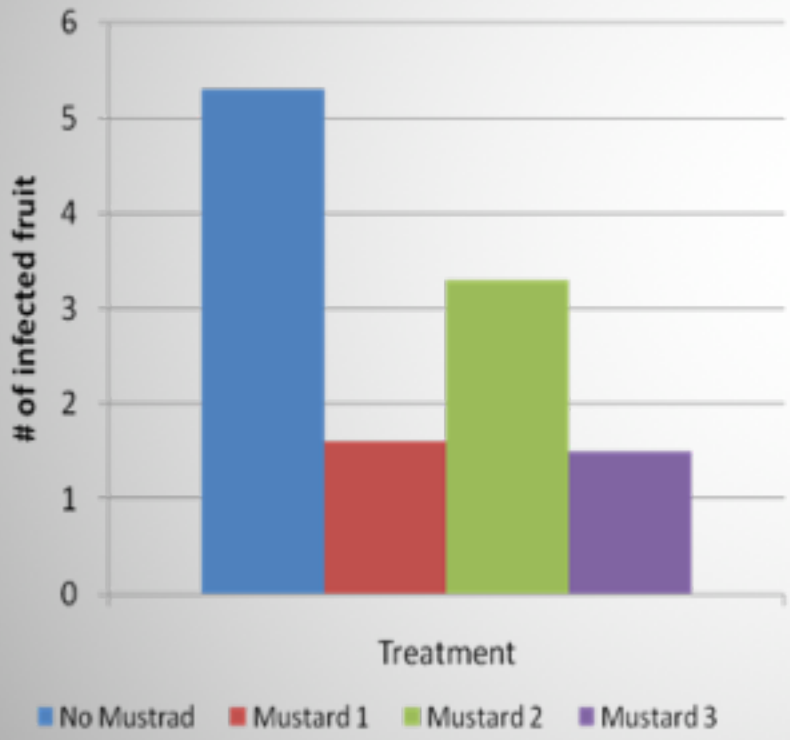




cf. Sandy Menasha

Phytophthora Fruit Rot Incidence

2009

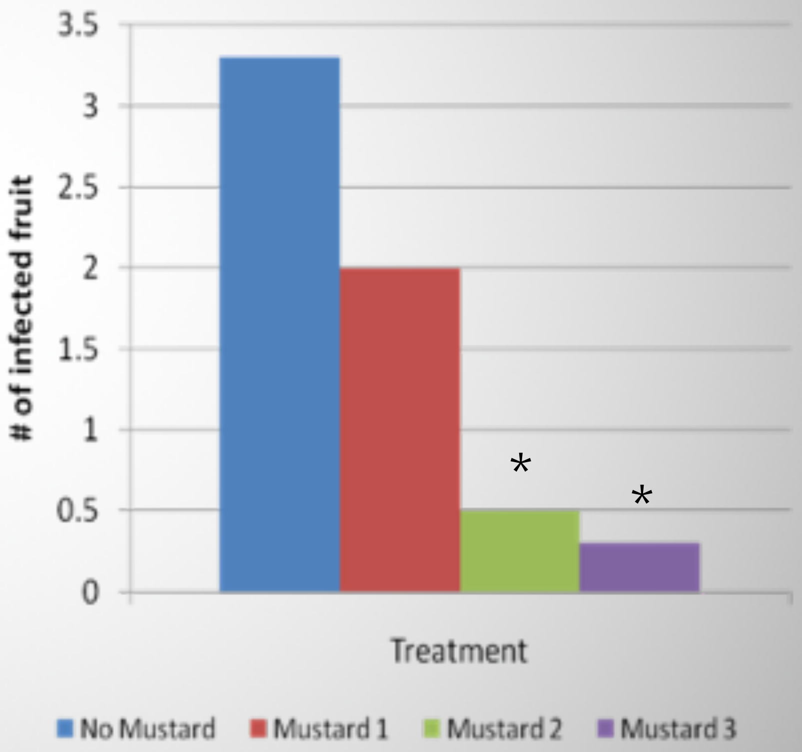


0 lb/A

50 lb/A

100 lb/A

2010



0 lb/A

50 lb/A

100 lb/A

cf. Sandy Menasha

Growing for biofumigation

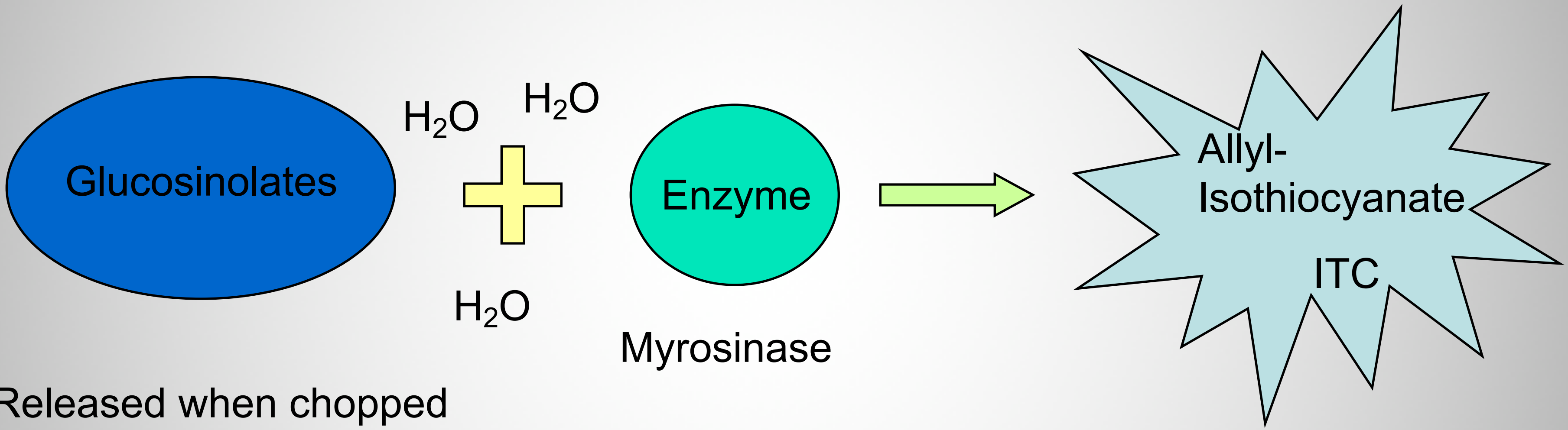
- What to Expect:
  - Begins flowering after ≥30 d usually ~2½-3’
    - Let it flower away!
  - Viable seed 6 weeks from flower
  - Doubles in height after flowering
  - Grows up to ~5+ ft
  - Incorporate 2-4 weeks after flower
  - Biofumigation potential drops after maturity
    - Mustard weed seed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


@ 60 days


wells lamont

D. Gies

Facilitate Biofumigation reaction in the field



Glucosinolates

H_2O H_2O + H_2O

Enzyme

Myrosinase

Allyl-Isothiocyanate

ITC

Released when chopped

Similar to active ingredient in *Vapam* (methyl-isothiocyanate)

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

Biofumigation

- Equipment
  - Mower (flail is rec'd)
    - Ruptures brassica cells, releases glucosinolates, myrosinase
  - 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?*

Biofumigation take Home Points

- Mindset: **Treat it like a crop!**
- Use varieties selected for biofumigation
- Good seedbed prep, weed control
- Ample fertility, moisture
- Seed timely for 50-60 days growth
- Follow biofumigation steps
- Consider issues w/brassica diseases, residual herbicides
- View biofumigation as one tool of many
- Consider other benefits of cover crop
  - N catch cropping, & fertility improvement
  - SOM building, infiltration, soil-quality improvement

Avoiding brassicas?

Disease contamination

- Black leg (seed-borne, persistent)
- Black rot (seed-borne, persistent)
- Clubroot (soil-borne, tenacious)
- Alternate hosting
  - Ex: Sclerotinia (generalist)

> Use Certified Seed

> Sanitation practices

Brassica seed production regions

- Pollen contamination
- Disease quarantines

> Seed pinning maps

> Extension contacts

Pests

- Flea beetle

> Separate from cash crop plantings

Production of Brassica Seed Crops in Washington State: A Case Study on the Complexities of Coexistence

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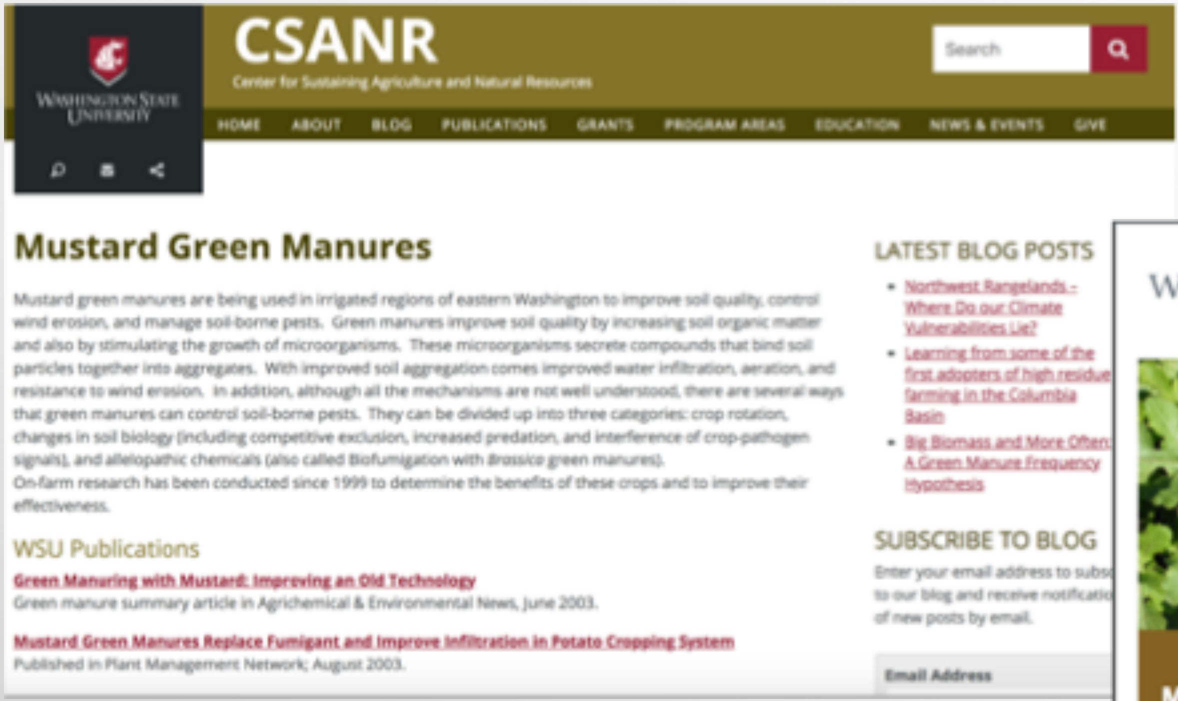

Mustard Green Manures

Mustard green manures are being used in irrigated regions of eastern Washington to improve soil quality, control wind erosion, and manage soil-borne pests. Green manures improve soil quality by increasing soil organic matter and also by stimulating the growth of microorganisms. These microorganisms secrete compounds that bind soil particles together into aggregates. With improved soil aggregation comes improved water infiltration, aeration, and resistance to wind erosion. In addition, although all the mechanisms are not well understood, there are several ways that green manures can control soil-borne pests. They can be divided up into three categories: crop rotation, changes in soil biology (including competitive exclusion, increased predation, and interference of crop-pathogen signals), and allelopathic chemicals (also called Biofumigation with *Brassica* green manures).
On-farm research has been conducted since 1999 to determine the benefits of these crops and to improve their effectiveness.

WSU Publications

Green Manuring with Mustard: Improving an Old Technology
Green manure summary article in Agrichemical & Environmental News, June 2003.

Mustard Green Manures Replace Fumigant and Improve Infiltration in Potato Cropping System
Published in Plant Management Network; August 2003.

LATEST BLOG POSTS

- Northwest Rangelands – Where Do our Climate Vulnerabilities Lie?
- Learning from some of the first adopters of high residue farming in the Columbia Basin
- Big Biomass and More Often: A Green Manure Frequency Hypothesis

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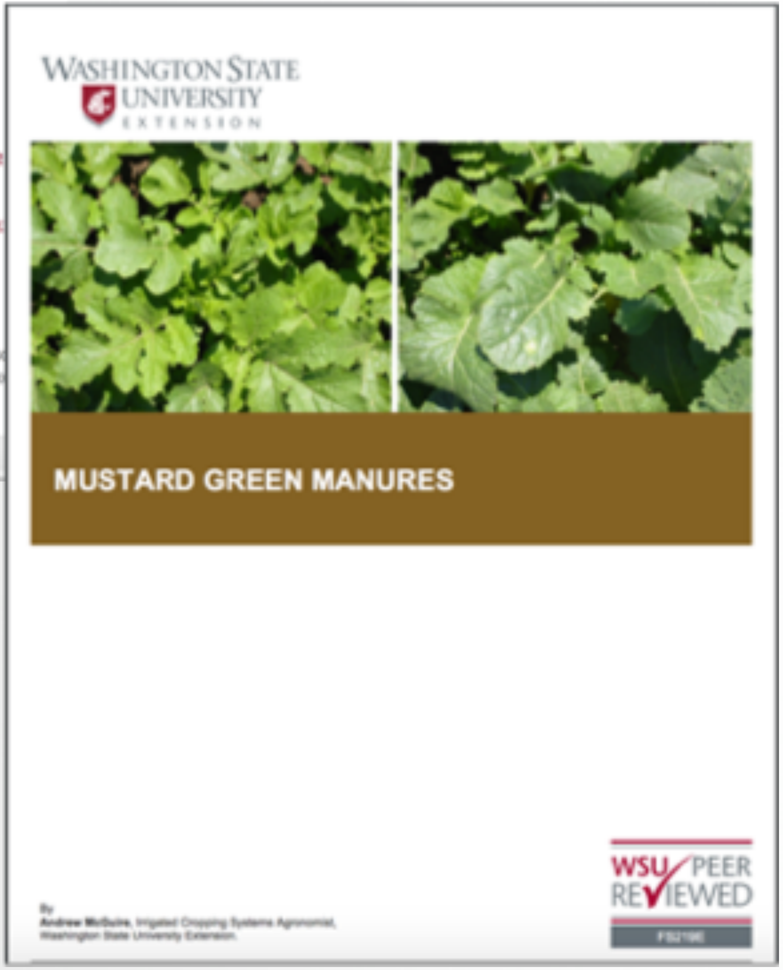

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MUSTARD GREEN MANURES

By
Andrew McGuire, Irrigated Cropping Systems Agronomist, Washington State University Extension.

Cornell University
Cooperative Extension

http://vegetablemdonline.ppath.cornell.edu/NewsArticles/biofumigation-phytophtora.html

Questions?