PODF
PRAIRIE ORGANIC DEVELOPMENT FUND

LESSON 3
January 10, 2023

Pest Management with a Focus on Disease, Insects (and Weeds)

The Prairie Organic Development Fund

- Investment platform established to develop organic agriculture and marketing in the Canadian Prairies
- Builds resilience in the sector by investing in
  - organic provincial associations (Capacity Fund); and
  - high impact programs (Innovation Fund) related to marketing, research, policy, education and capacity development that have broad public benefit to the organic sector.

www.organicdevelopmentfund.org

The Prairie Organic Development Fund is grateful for the support of:

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We gratefully acknowledge funding from the Canadian Agricultural Partnership.

www.organicdevelopmentfund.org

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Department of Plant Science
Natural Systems Agriculture Lab
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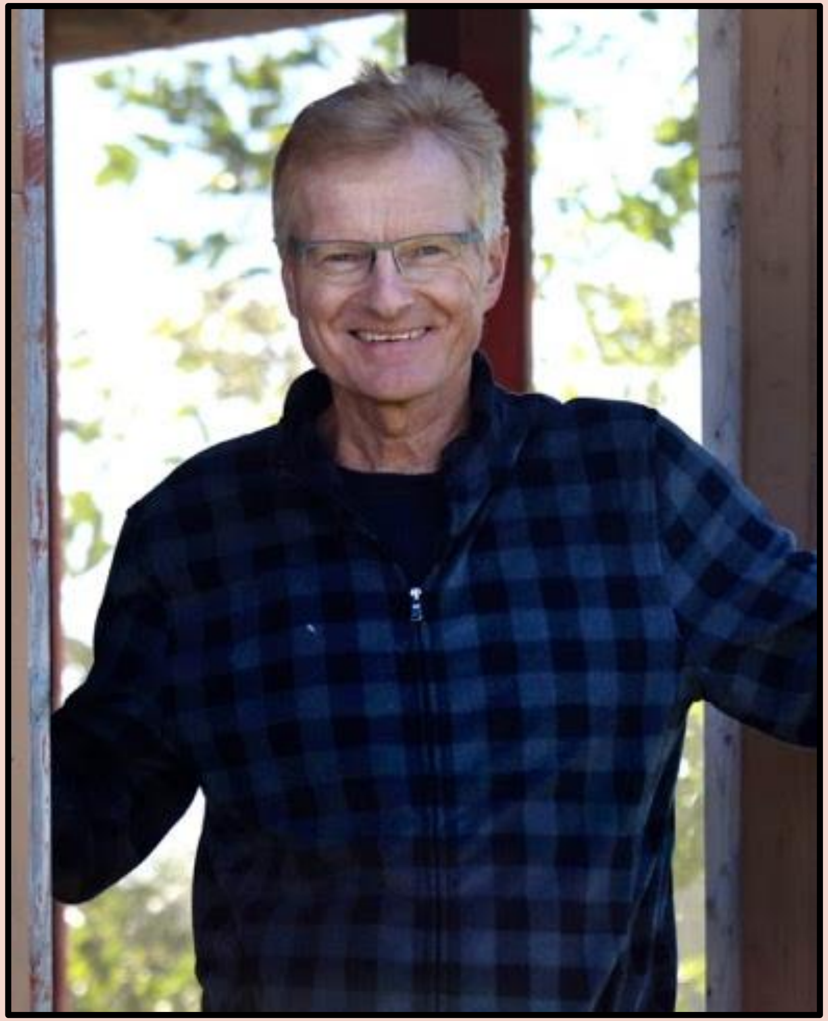
umanitoba.ca/outreach/naturalagriculture/



Organic Agronomy Training
Session 3. Insect and disease management

Disclaimer

- While Canada has an amazing group of scientists and extension workers with expertise in insect pest and plant disease management, far too little of their talent has been directed at organic production.

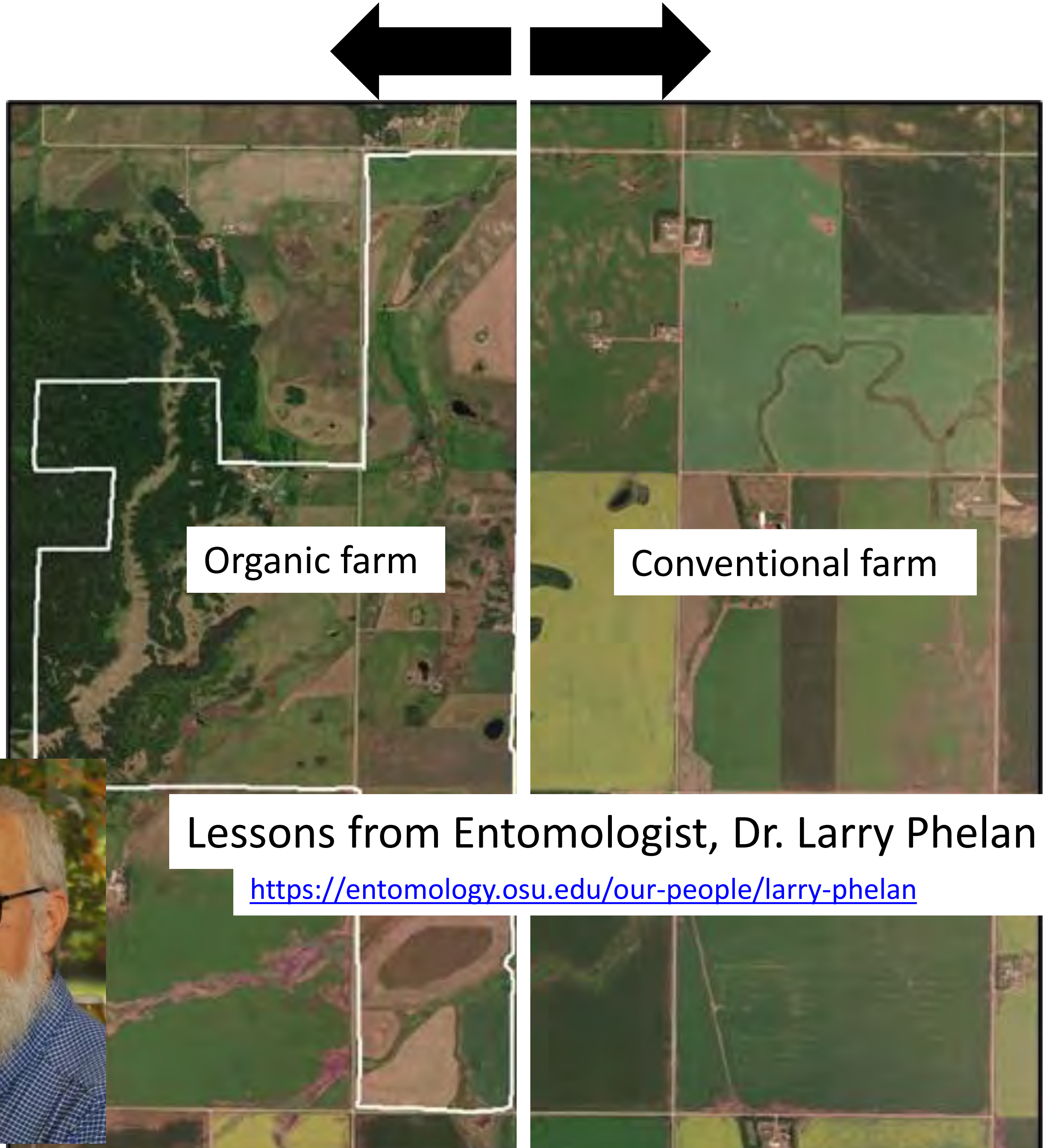
- This leaves us with many knowledge gaps.

Organic Agronomy Training
Session 3. Insect and disease management

Insects

- Vast majority of insects cause no problems.
- Pest problems less likely to occur in complex farm ecosystems.
- Intercropping and cover cropping can help reduce insects.
- Focus on cultivating beneficial insects in fields and on farms.
- Large-scale problems difficult – grasshoppers.

Figure 5. Clearwinged grasshopper adult



Lessons from Entomologist, Dr. Larry Phelan

https://entomology.osu.edu/our-people/larry-phelan

After planting maize (corn), female European corn borers were released into the greenhouse to determine egg-laying preferences. In each of 4 experiments, females consistently laid fewer eggs on corn plants in soil from organic farms than on plants in conventional soil.

Phelan, P.L., 2009. 9 Ecology-Based Agriculture and the Next Green Revolution. SUSTAINABLE AGROECOSYSTEM, p.97.

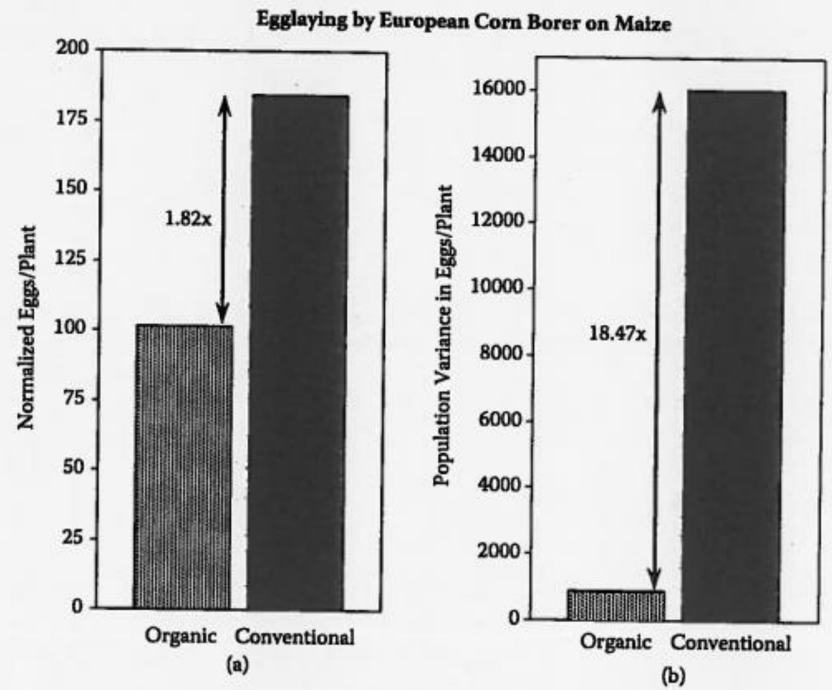
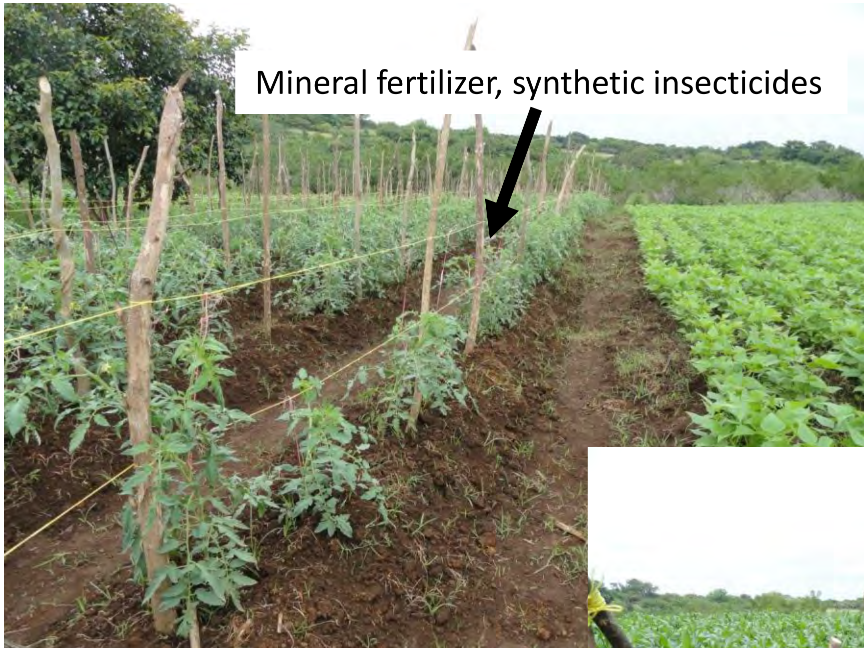


FIGURE 9.2 Meta-analysis of egg laying by *Ostrinia nubilalis*, the European corn borer, on maize planted in the greenhouse in soils collected from neighboring organic or conventional farms. Analysis conducted on results from four replicated factorial experiments with amendments of dairy cow manure, cow manure compost, or chemical fertilizer in each soil type: (a) mean egg laying by soil type across fertilizer treatments, normalized to account for differences in total egg laying among experiments, and (b) variance (sum of squares) in egg laying across fertilizer treatments and experiments.



Nicaraguan farm family

Organic: Composted manure, cover crop,
natural insecticide (neem tree)

Universidad Nacional Autónoma de Honduras

Universidad Nacional Agraria Nicaragua

Community-based Pest Management in Central American Agriculture

Funded by the Canadian International Development Agency (CIDA) through the University Partnerships in Cooperation and Development (UPCD) program.

University of Manitoba

Universidad de Costa Rica

Prevention – Avoid the problem

- Resistant varieties
- Crop rotation (green bridge)
- Intercropping (polyculture)
- Landscape diversity

Intervention – Deal with the problem once it arises

- Treat disease or insect

Variety Selection

Insect tolerant varieties

eg. Midge tolerant wheat

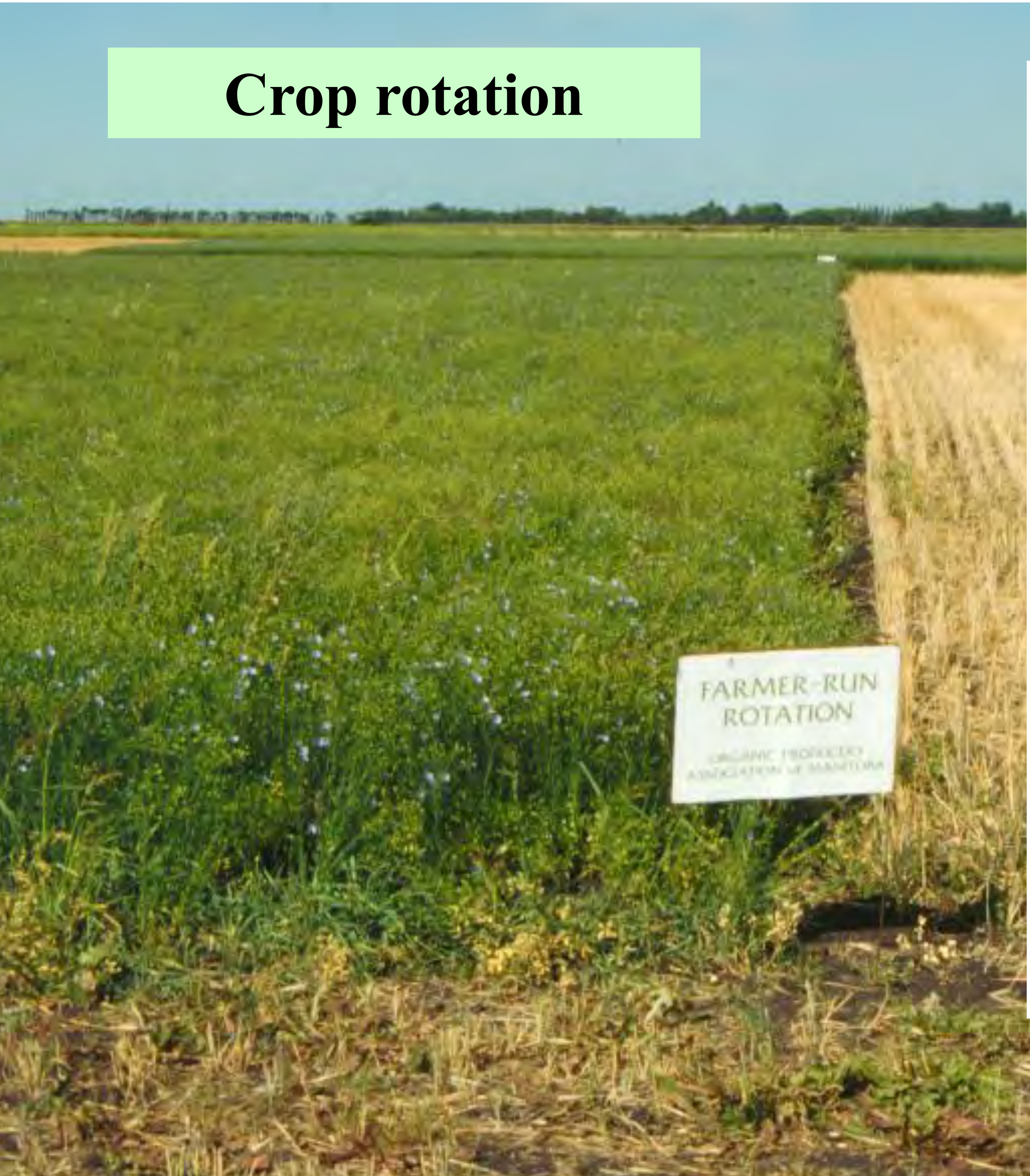
Tolerant variety	Refuge variety	Class	Year registered[a]
Unity	Waskada	CWRS	2007
Goodeve	AC Intrepid	CWRS	2007
Glencross	Burnside	CWES	2008
Fieldstar	Waskada	CWRS	2008
Shaw	AC Domain	CWRS	2009
CDC Utmost	Harvest	CWRS	2010
Vesper	Waskada	CWRS	2010
Conquer	5701PR	CPSR	2010
Enchant	AC Crystal	CPSR	2012
AAC Foray	AAC Penhold	CPSR	2014
AAC Prevail	CDC Plentiful	CWRS	2014
AAC Tenacious	AAC Crusader	CPSR	2014
CDC Titanium	Stettler	CWRS	2014
AAC Cameron	Carberry	CWRS	2015
AAC Jatharia	Carberry	CWRS	2015

Agriculture and Agri-Food Canada

Agriculture et Agroalimentaire Canada

Source: Country Guide

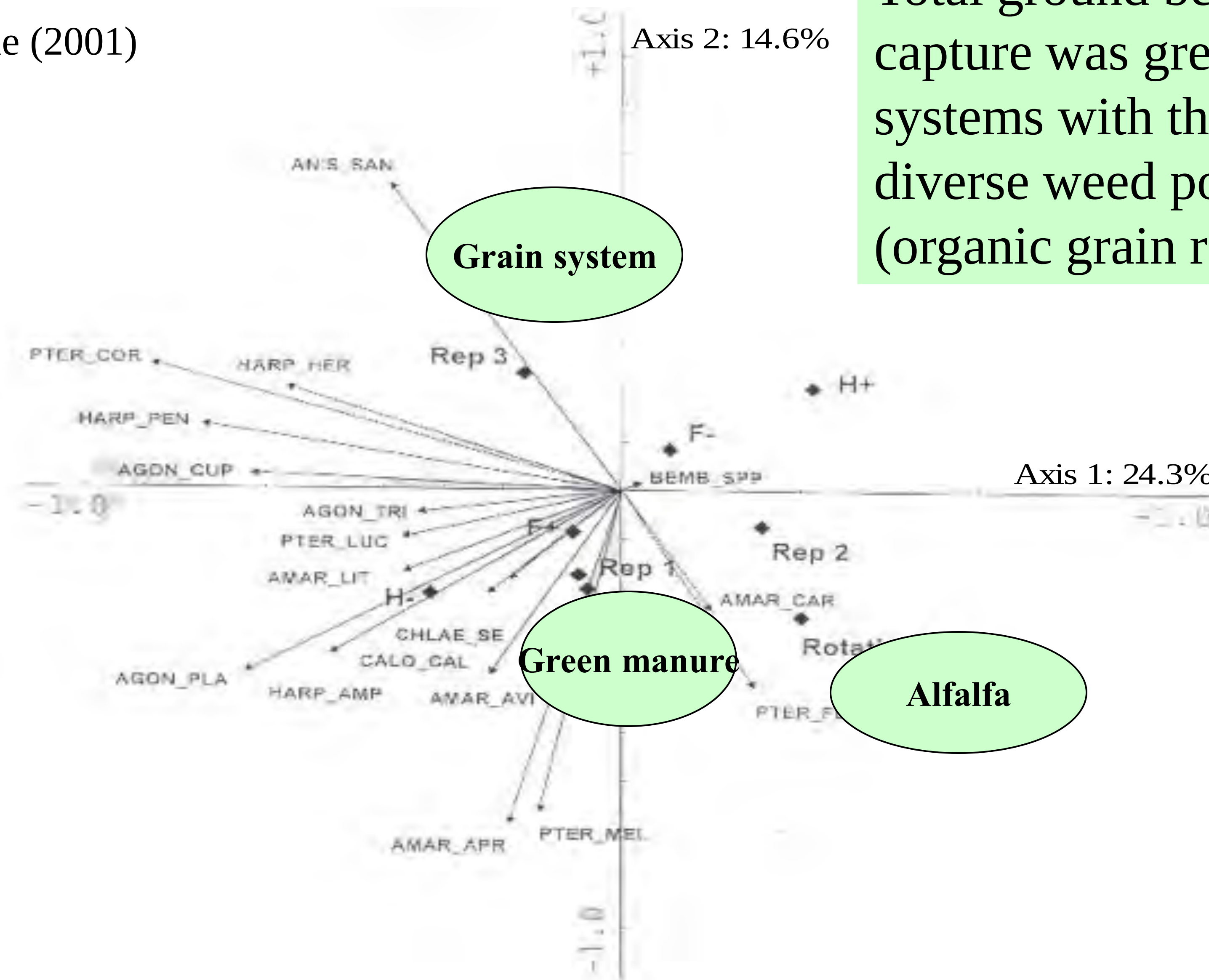
Crop rotation



Carabid beetle

Shauna Humble (M.Sc. 2001)

Humble (2001)



Total ground beetle capture was greatest in systems with the most diverse weed population (organic grain rotations)

The first and second RDA axes for ground beetle community composition, 1999. Total variation accounted for: 38.9%

better habitat due to increased humidity and abundant food supply.

- Ground beetle populations were least in the F-H+ system because of a lack of potential food source and poor habitat.
- Four consistent associations were observed between beetle and weed species, however. These were *Harpalus pensylvanicus* with red root pigweed; *Amara carinata* with stinkweed; *Agonum placidum* and *Calosoma calidum* with wild mustard. *Harpalus* and *Amara* are weed seed eaters.


Harpalus pensylvanicus

+


Red Root Pigweed


Agonum placidum


Calosoma calidum

+

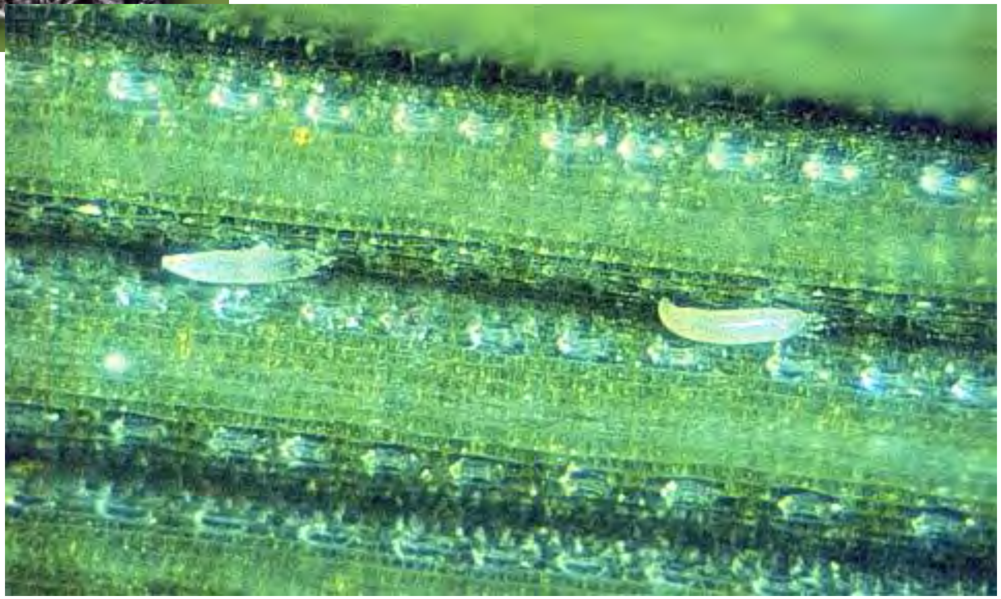

Wild Mustard

Why is this important?

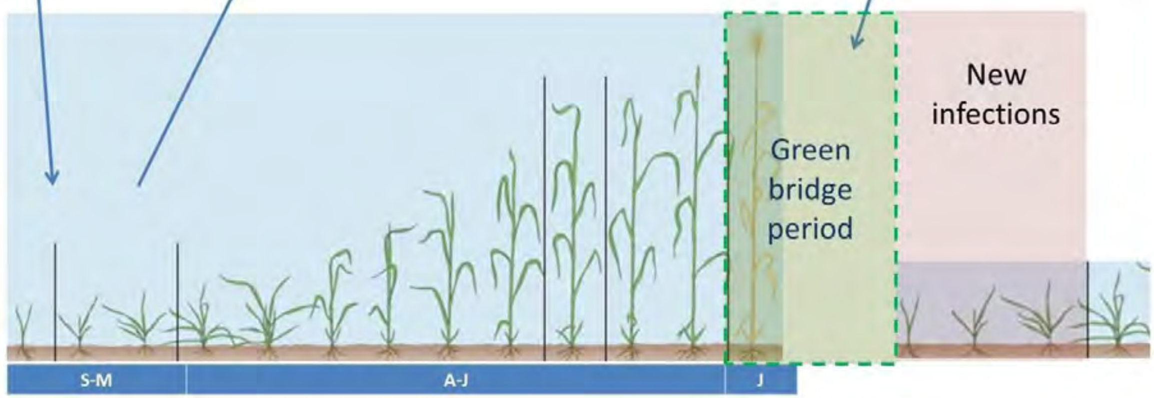
The association of *Harpalus* and *Amara* the weediest subplots (F+H-) suggests that these ground beetles may be used to sustainably manage weed populations through seed predation. Other studies have indicated that 50 to 80% of weed seeds in the soil may be consumed by insect seed predators. In this study, however, the abundance of weeds in the no herbicide plots (F+H- and F-H-) was too high for the beetles to reduce weed seeds significantly. Ground beetles may be more effective in an Integrated Pest Management (IPM) system where some herbicide is used to keep weed densities at levels lower

https://www.umanitoba.ca/outreach/naturalagriculture/articles/gltr_results_hist.html

Wheat curl mite spreads virus that causes wheat streak mosaic



Wheat curl mites survive between wheat crops on volunteer wheat and grassy weeds



Prevention – Avoid the problem

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Intervention – Deal with the problem once it arises

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Kristen McMillan, Agronomist in Residence, University of Manitoba

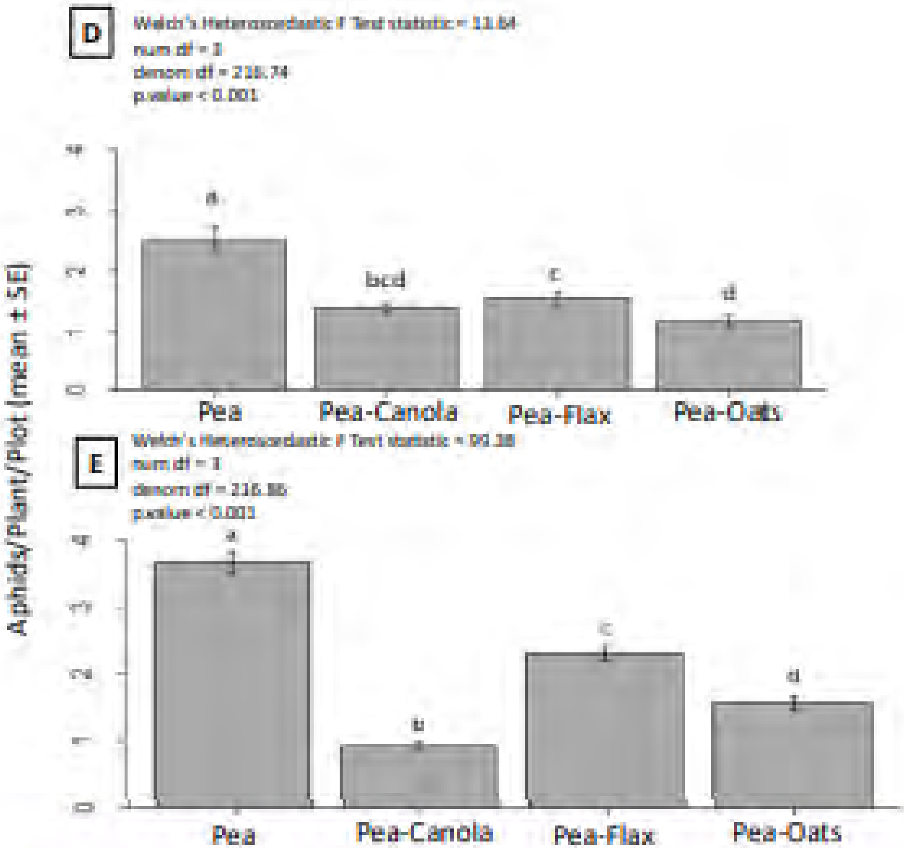

Fig. 9. Aphid counts on each treatment on July 03 (A), July 09 (B), July 17 (C), July 23 (D), and July 30 (E) in Arborg in 2020.

University of Manitoba

Critical Reviews in Plant Sciences, 29:123–133, 2010

ISSN: 0735-2689 print / 1549-7836 online
DOI: 10.1080/07352681003617483

Taylor & Francis
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Plant Volatiles-based Insect Pest Management in Organic Farming

Gitika Shrivastava,[1] Mary Rogers,[1] Annette Wszelaki,[1] Dilip R. Panthee,[2] and Feng Chen[1]
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[2]*Department of Horticultural Science, North Carolina State University, Mountain Horticultural Crops Research and Extension Center, Mills River, NC, USA*

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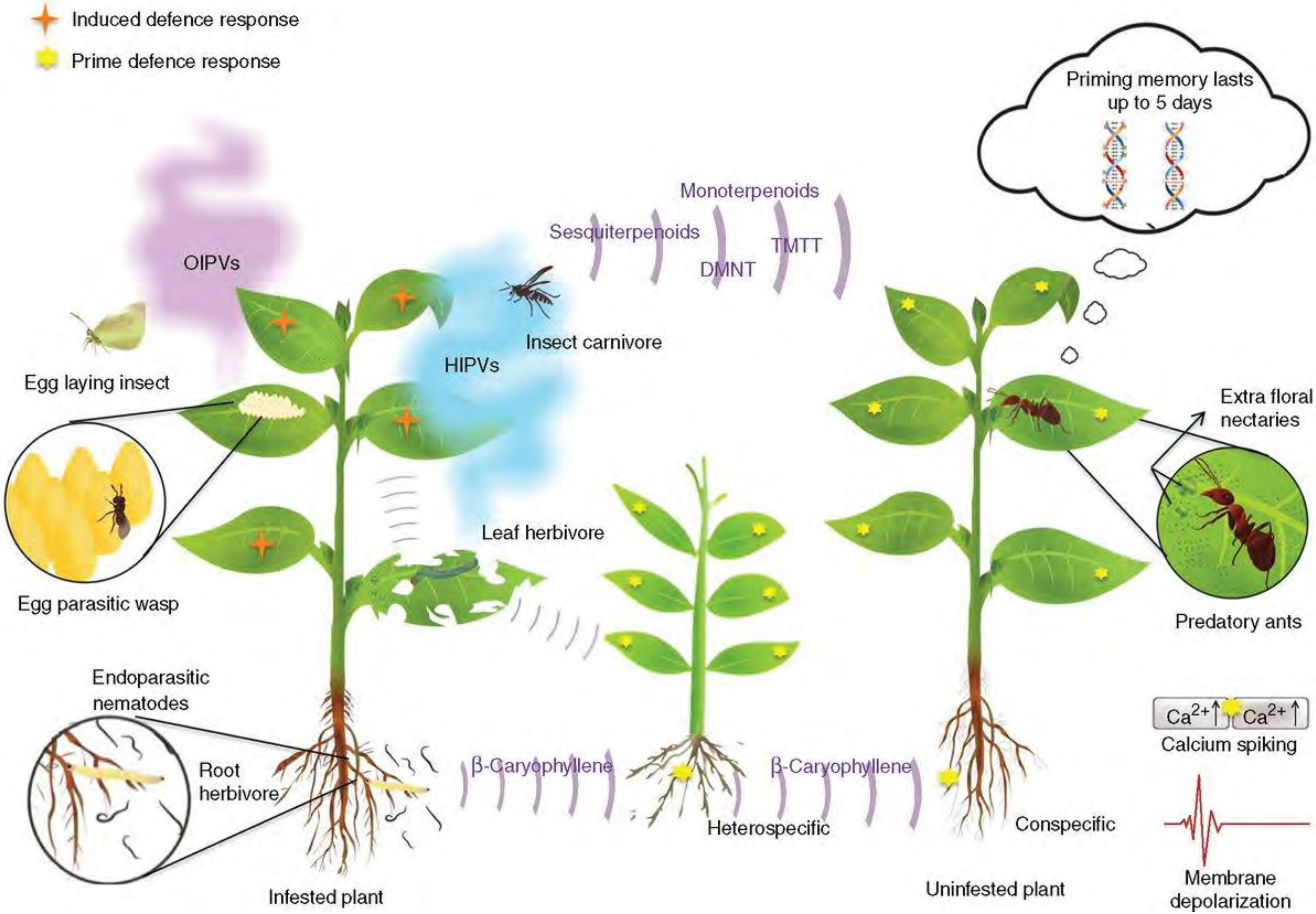
The population density of arthropod herbivores in polyculture is found to be lower than that in monoculture. In contrast, the population density of natural enemies, especially parasitoids, are found to be lower in monoculture (Andow, 1991). Growing plants of different species in close physical proximity may aid insect control in several different ways depending on the volatile traits of various plants (Perrin and Phillips, 1978; Uvah and Coaker, 1984).


Induced defence response
Prime defence response
Priming memory lasts up to 5 days
Monoterpenoids
Sesquiterpenoids
TMTT
DMNT
OIPVs
HIPVs
Insect carnivore
Egg laying insect
Extra floral nectaries
Leaf herbivore
Egg parasitic wasp
Predatory ants
Endoparasitic nematodes
Root herbivore
β-Caryophyllene
β-Caryophyllene
Heterospecific
Conspecific
Ca2+ Ca2+
Calcium spiking
Membrane depolarization
Infested plant
Uninfested plant

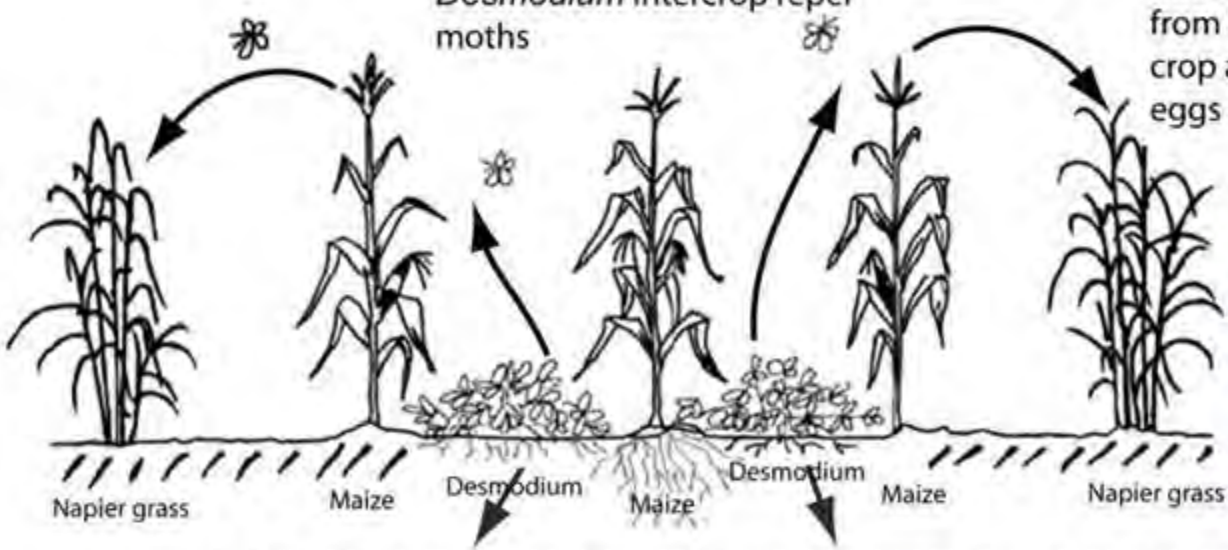
Case study: Push-pull planting systems to enhance productivity

Desmodium PUSHES away the insects by producing repellent volatile chemicals

Napier grass PULLS away the insects by producing attractive volatile chemicals

PUSH: volatile chemicals from *Desmodium* intercrop repel moths

PULL: volatile chemicals from Napier grass trap crop attract moths to lay eggs



Desmodium also produces allelochemicals that interfere with *Striga* parasitism, protecting the crop from yet another pest

ALLELOPATHY: chemicals exuded by *Desmodium* roots inhibit attachment of *Striga* to maize roots and cause suicidal germination of *Striga*

Reprinted from Khan, Z.R., Midega, C.A.O., Bruce, T.J.A., Hooper, A.M. and Pickett, J.A. (2010). Exploiting phytochemicals for developing a 'push–pull' crop protection strategy for cereal farmers in Africa. J. Exp. Bot. 61: 4185-4196, by permission of Oxford University Press.

Hassanali, Ahmed, Hans Herren, Zeyaur R. Khan, John A. Pickett, and Christine M. Woodcock. "Integrated pest management: the push–pull approach for controlling insect pests and weeds of cereals, and its potential for other agricultural systems including animal husbandry." *Philosophical Transactions of the Royal Society B: Biological Sciences* 363, no. 1491 (2008): 611-621.

618 A. Hassanali *et al.* *Integrated pest management*

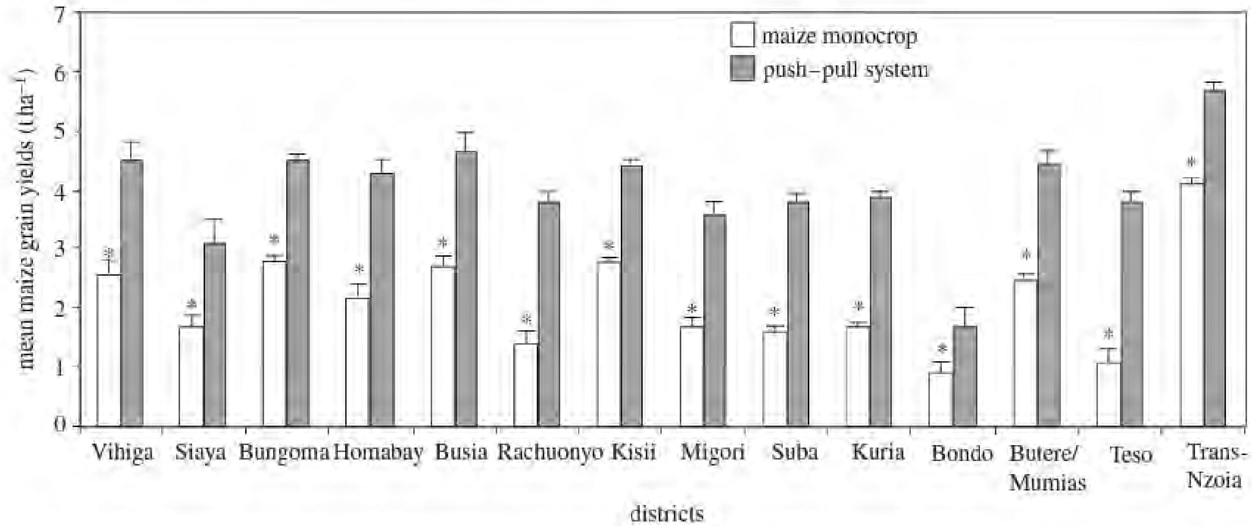
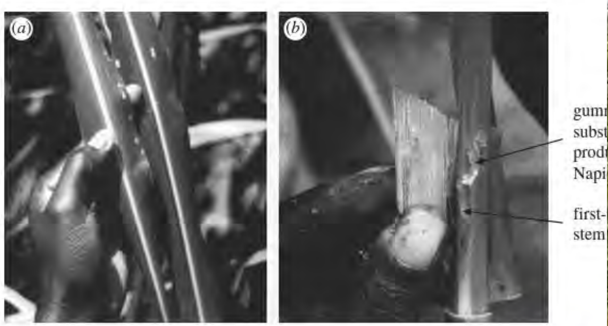


Figure 5. Yield differences in push–pull and control plots in 14 districts in Kenya during the 2005 long rains. Within a district, bars marked by asterisk are significantly lower ($p<0.05$, t-test).

4 A



ure 1. (*a*) Feeding marks of stem borer larvae on Napier leaves and (*b*) production of sticky exud
ponse to penetration by first- and second-instar stem borer larvae. Adapted from Khan & Picke

https://en.wikipedia.org/wiki/Push%E2%80%93pull_agricultural_pest_management

Intercropping with nonhost molasses grass (*Melinis minutiflora*) was found to significantly decrease stem borer infestation in the main crop as well as increase larval parasitism by parasitoid *Cotesia sesamiae*. Volatile compounds emitted by *M. minutiflora* were found to repel female stem borers and to attract females of *C. sesamiae* (Khan et al., 2007).

Trap crops

- “trap crops” are plants that attract insects
- Sawflies lay eggs in bromegrass rather than wheat
- Lygus bugs prefer cut alfalfa – so cut some strips around seed field
- Grasshoppers do not like certain pea varieties, so plant peas around flax crops
- Perennial strip around field, then till perennial after grasshoppers lay eggs in that strip.

Push pull system in dairy barn

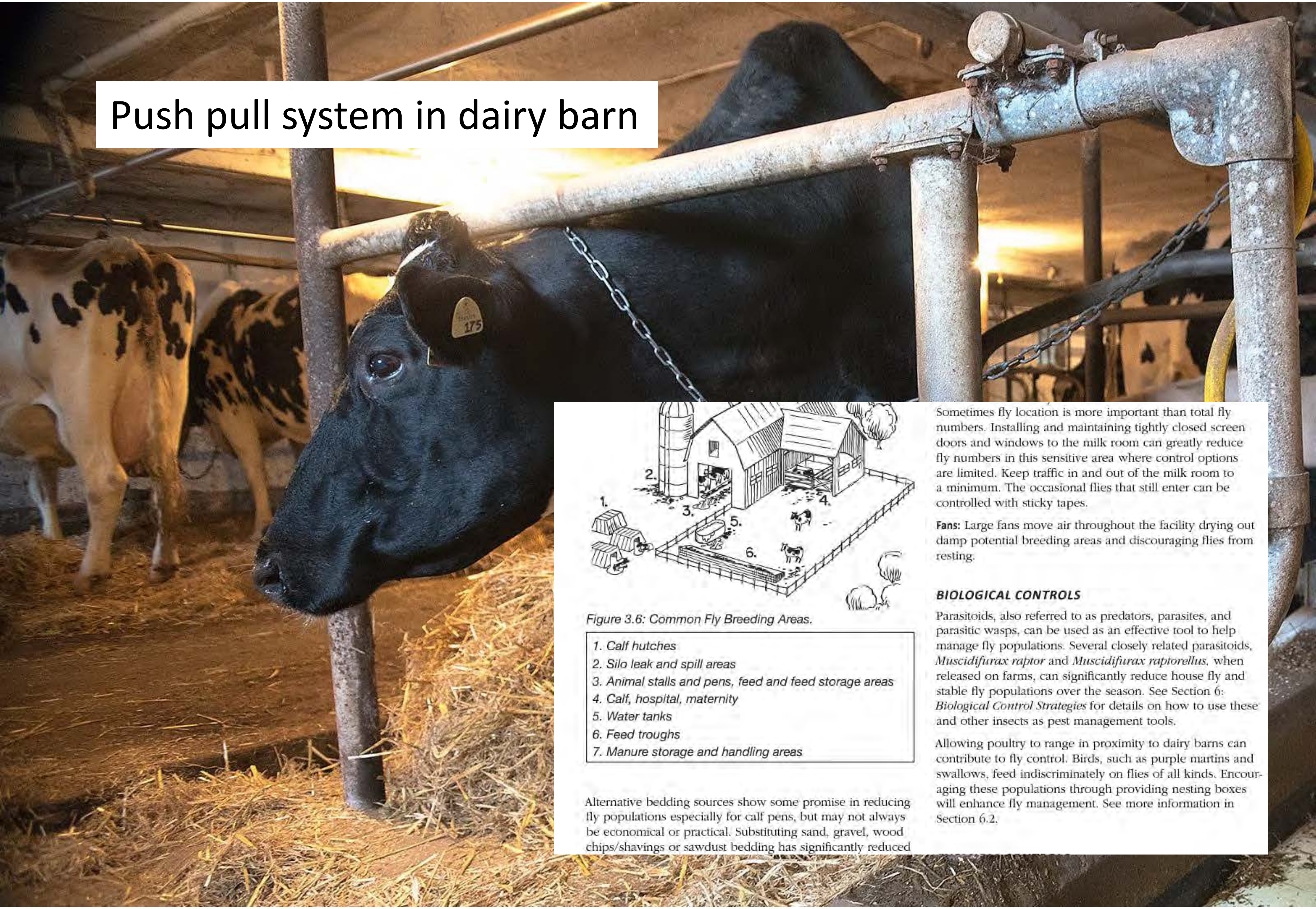


Figure 3.6: Common Fly Breeding Areas.

1. *Calf hutches*
2. *Silo leak and spill areas*
3. *Animal stalls and pens, feed and feed storage areas*
4. *Calf, hospital, maternity*
5. *Water tanks*
6. *Feed troughs*
7. *Manure storage and handling areas*

Alternative bedding sources show some promise in reducing fly populations especially for calf pens, but may not always be economical or practical. Substituting sand, gravel, wood chips/shavings or sawdust bedding has significantly reduced

Sometimes fly location is more important than total fly numbers. Installing and maintaining tightly closed screen doors and windows to the milk room can greatly reduce fly numbers in this sensitive area where control options are limited. Keep traffic in and out of the milk room to a minimum. The occasional flies that still enter can be controlled with sticky tapes.

Fans: Large fans move air throughout the facility drying out damp potential breeding areas and discouraging flies from resting.

BIOLOGICAL CONTROLS

Parasitoids, also referred to as predators, parasites, and parasitic wasps, can be used as an effective tool to help manage fly populations. Several closely related parasitoids, *Muscidifurax raptor* and *Muscidifurax raptorellus*, when released on farms, can significantly reduce house fly and stable fly populations over the season. See Section 6: *Biological Control Strategies* for details on how to use these and other insects as pest management tools.

Allowing poultry to range in proximity to dairy barns can contribute to fly control. Birds, such as purple martins and swallows, feed indiscriminately on flies of all kinds. Encouraging these populations through providing nesting boxes will enhance fly management. See more information in Section 6.2.

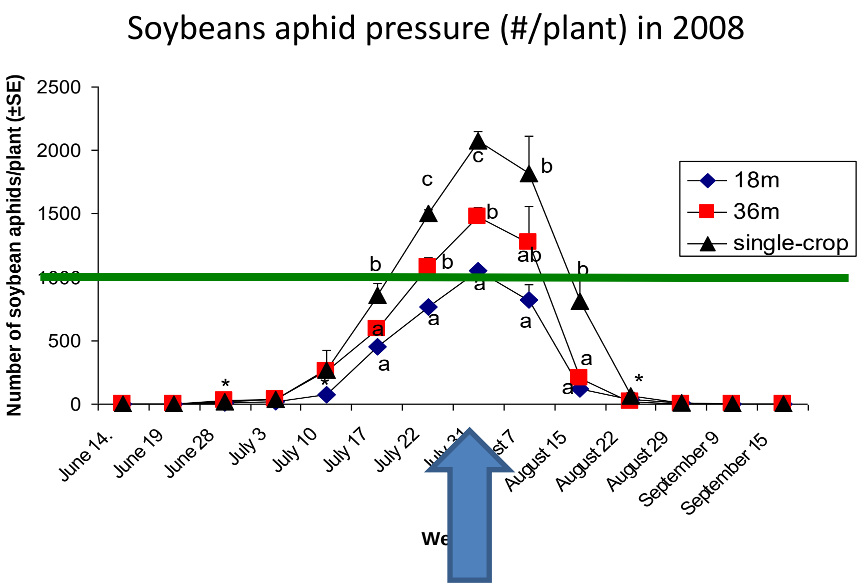
Strip cropping

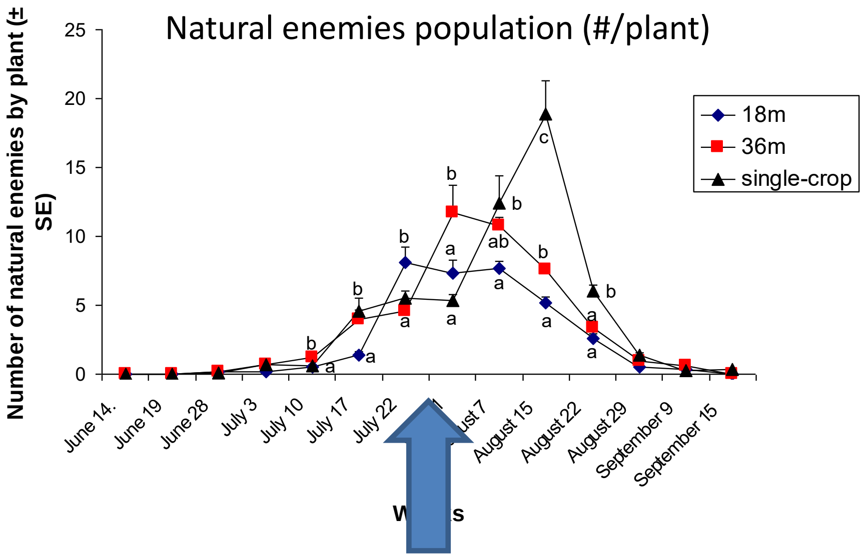
Thanks to Matthew Dewavrin, agr.

Les Fermes Longprés (2009) Ltée.

- 18m/36m strips (200ac)
- Rotation: Corn-Soybeans-Wheat-Fallow
- Prevention of insect pest outbreaks
- Quantified positive effect on insects natural predators diversity

Strip cropping





Labrie, G., Estevez, B. and Lucas, E., 2016. Impact of large strip cropping system (24 and 48 rows) on soybean aphid during four years in organic soybean. Agriculture, Ecosystems & Environment, 222, pp.249-257.

Strip cropping

Wheat acted as a refuge for lady bugs, which were then able to move to the soybean and control the aphids.

Edible buffer zones – Fruit trees

Farming for parasatoids
Insects controlling other insects!

Ichneumonide.

Parasitoids of potential pest insects Insects that paras
their immature stages these parasitoids live in or on th
living as adults. Many of the parasitoids of insects in M
have what looks like a stinger, but they use this to lay

Parasitoids Important in Managing Potential Crop Pests in Manitoba

PARASITOIDS	MAJOR CROP FEEDING INSECT HOST OR PREY
Macroglenes penetrans (Pteromalidae)	Wheat midge
Glypta prognatha (Ichneumonidae)	Banded sunflower moth
Diadegma insulare (Ichneumonidae)	Diamondback moth
Microplitis plutellae (Braconidae)	Diamondback moth
Banchus flavescens (Ichneumonidae)	Bertha armyworm
Pediobius eubius (Eulophidae)	Hessian fly
Platygaster hiemalis (Platygasteridae)	Hessian fly
Aphidius ervi (Aphidiidae)	Aphids
Aphidius smithi (Aphidiidae)	Aphids

Fly Parasitoids Important in Managing Potential Crop Pests in Manitoba

PARASITOID	MAJOR CROP FEEDING INSECT HOST OR PREY
Athrycia cinerea (Tachinidae – Tachinid flies)	Bertha armyworm, etc.
Villa spp. (Bombyliidae – Bee flies)	Cutworms
Blaesoxipha atlanis (Sarcopgagidae – Flesh flies)	Grasshoppers

https://www.gov.mb.ca/agriculture/crops/insects/pubs/predatorsofinsectsfactsheet.pdf

10 orders of insects and arachnids that help manage crop pests:Beneficial insect. Dr. John Gavloski, Manitoba Agriculture

1. Ordonata: dragonflies, damselflies
2. Orthoptera: crickets
3. Dermaptera: earwigs
4. Thysanopterta: predacious thrips
5. Hemiptera: minute pirate bugs, damsel bugs, stink bugs
6. Neuroptera: green lacewings
7. Coleoptera: ground beetles, rove beetles, lady beetles
8. Diptera: tachinid flies, hover flies, stiletto flies
9. Hymenoptera: parasitic wasps, ants
10. Araneida: spiders

Here is an excellent website showing images of different beneficial insects

https://www.country-guide.ca/crops/a-guide-to-beneficial-insects/

Using insects to control other insects: Example from Quebec

Evaluating the use of flower strips in a biological and integrated pest

Evaluating the use of flower strips in a biological and integrated pest

https://www.irda.qc.ca/en/services/agricultural-practices/organic-farming/

Journal of Animal Ecology

British Ecological Society

Journal of Animal Ecology 2010, **79,** 491–500 doi: 10.1111/j.1365-2656.2009.01642.x

How do landscape composition and configuration, organic farming and fallow strips affect the diversity of bees, wasps and their parasitoids?

Andrea Holzschuh[1]*, Ingolf Steffan-Dewenter[2] and Teja Tscharntke[1]

[1] *Agroecology, Georg-August University, Waldweg 26, D-37073 Göttingen, Germany; and* [2] *Population Ecology Group, Department of Animal Ecology I, University of Bayreuth, Universitätsstraße 30, 95440 Bayreuth, Germany*

Organic farming has an advantage when it comes to keeping diversity on the landscape.

5. We conclude that the conversion of cropland into non-crop habitat may not be a sufficiently successful strategy to enhance wasps or other species that suffer more from isolation than from habitat loss. Interestingly, habitat connectivity appeared to be enhanced by both higher edge densities and by organic field management. Thus, we conclude that high proportions of conventionally managed and large crop fields threaten pollination and biological control services at a landscape scale.

Summarizing some of the observations so far – using work by Khan in Africa

Google Scholar

ZEYAUR R KHAN

icipe

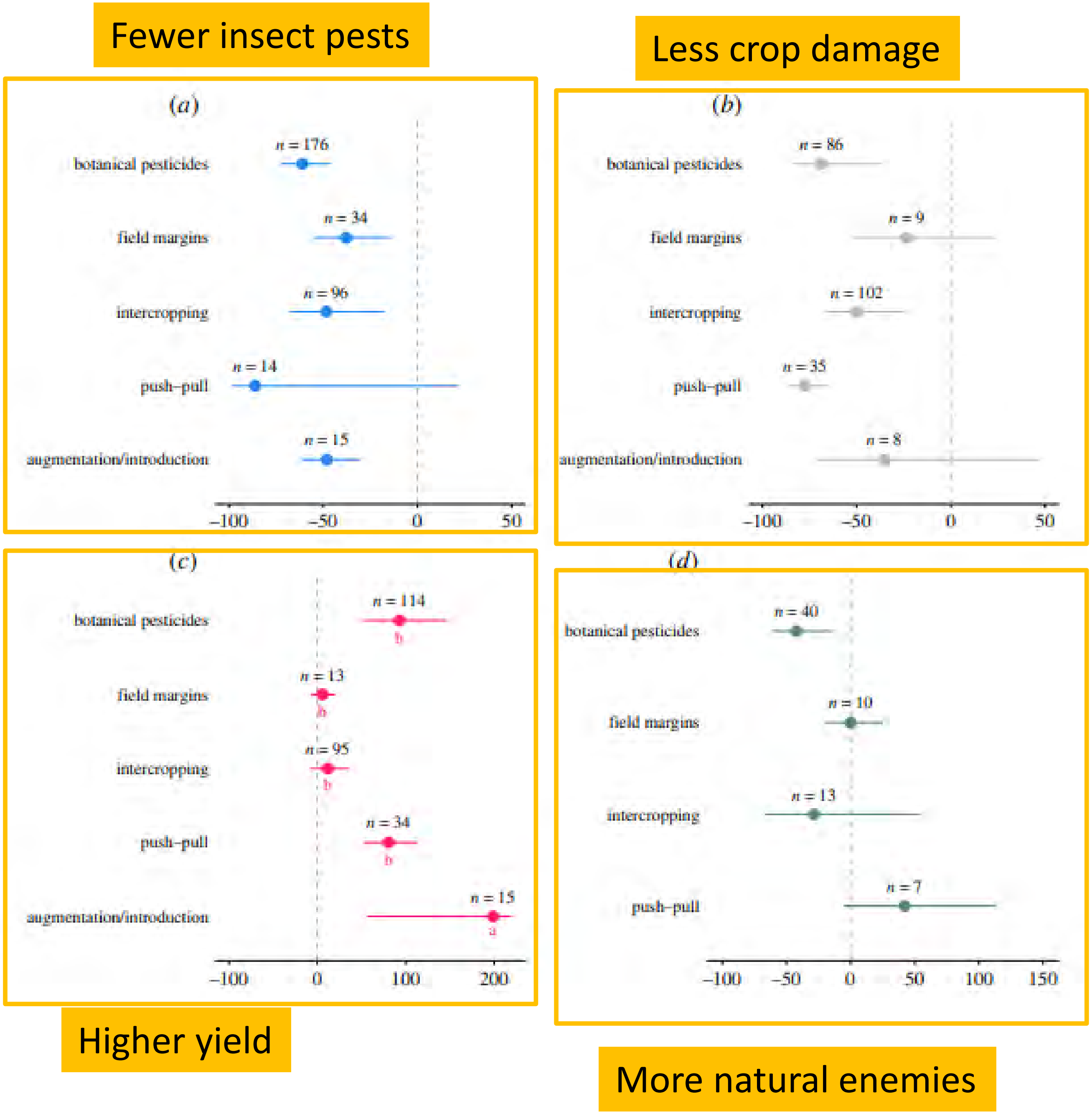
Verified email at icipe.org

Chemical Ecology Insect Behavior Habitat Management

Table 1. Definitions of biological control interventions included in the meta-analysis.

biocontrol intervention	description
botanical pesticides	insecticidal compounds in the form of water, oil or powder extracted from the leaves, seeds, pods, roots, bark, flower or fruits, of plants known to have pesticidal properties either from cultural knowledge or laboratory experiment
augmentation/ introduction	increase the number of parasitoids, predators or entomopathogens by releasing the natural enemy (introduction, inoculation and inundation) or by supplying their food resources
intercropping	simultaneous cultivation of plant species in the same field for most of their growing period, e.g. cereal and beans or other food plants
push–pull	intercropping of maize or other crops with perennial fodder legumes (e.g. *Desmodium* spp.) to repel (push) pests. A trap crop, a perennial fodder (Napier grass or *Brachiaria* spp.) is planted around the plot to attract (pull) pests away from the crop
field margins	strip of land between the crop and the field boundaries sown with wildflowers and/or legumes, grass only or naturally regenerated
landscape effect	the effect of distance of cultivated areas to natural habitat, non-crop habitat and/or landscape complexity on the delivery of biocontrol

Ratto, F., Bruce, T., Chipabika, G., Mwamakamba, S., Mkandawire, R., Khan, Z., Mkindi, A., Pittchar, J., Sallu, S.M., Whitfield, S. and Wilson, K., 2022. Biological control interventions reduce pest abundance and crop damage while maintaining natural enemies in sub-Saharan Africa: a meta-analysis. *Proceedings of the Royal Society B*, *289*, p.20221695.



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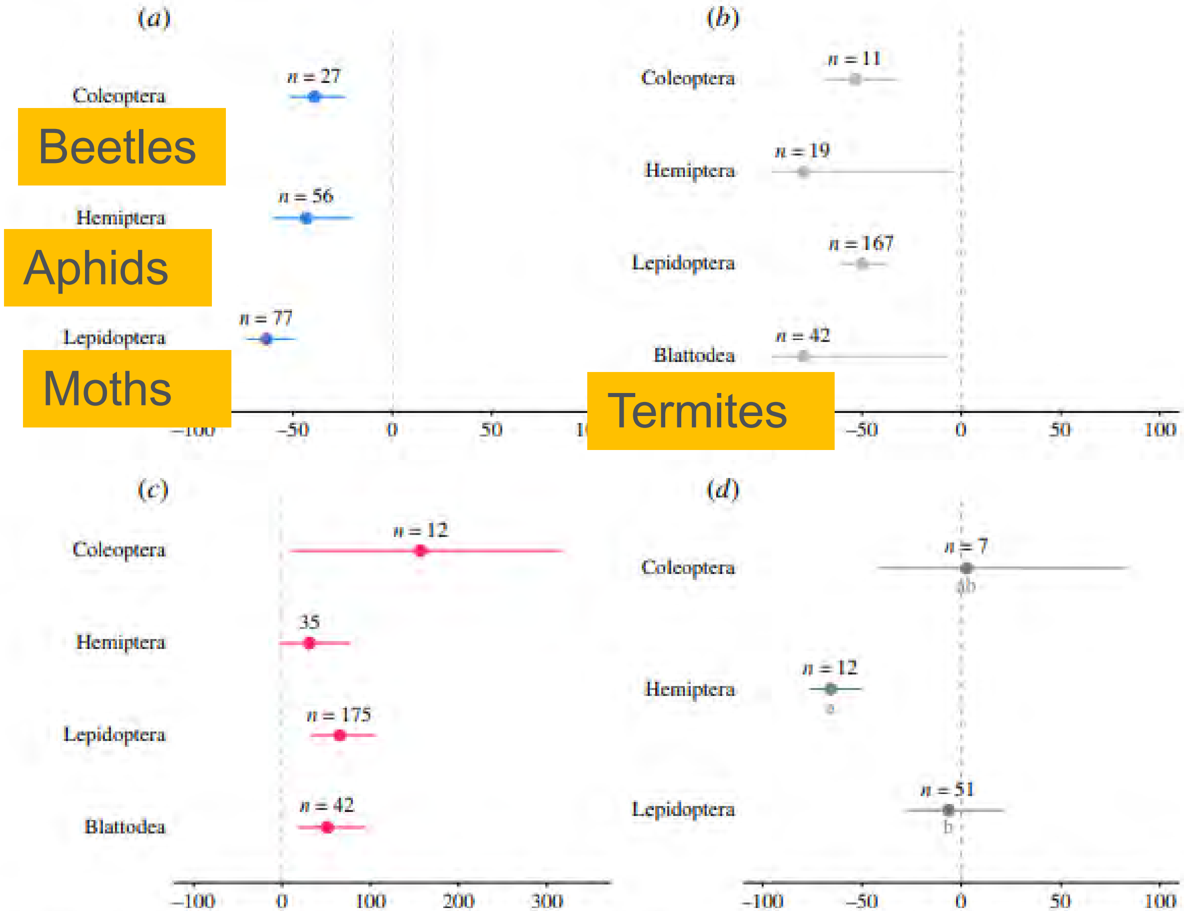

Figure 5. Changes in (*a*) pest abundance, (*b*) crop damage, (*c*) yield and (*d*) natural enemy abundance when biocontrol interventions are implemented compared to untreated crops (untreated/monocropping). The values are expressed in percentage with 95% bias-corrected confidence intervals categorized as Coleoptera, Hemiptera, Lepidoptera and Blattodea where available. Results that cross zero indicate no significant difference between control and treatment groups; *n* = number of effect sizes. (Online version in colour.)

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Blaesoxipha atlanis (Sarcopgagidae – Flesh flies)	Grasshoppers

How to organize the farm to promote parasitoids?


Figure 1. Twostriped grasshopper adults

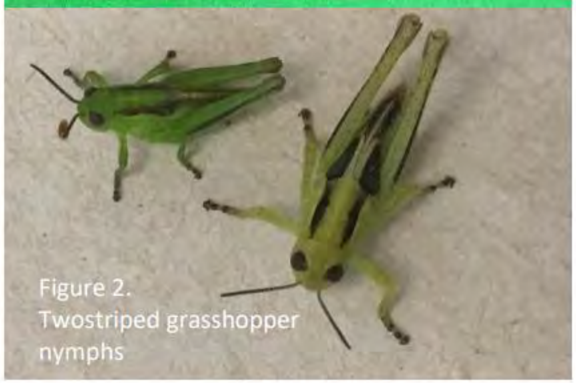


Figure 2. Twostriped grasshopper nymphs


Figure 3. Migratory grasshopper


Figure 7. Packard grasshopper adult


Figure 8. Packard grasshopper nymph

Manitoba


Figure 5. Clearwinged grasshopper adult

There are 85 species of grasshoppers in Manitoba, and 180 species in Canada. There are four species of grasshoppers on the Canadian prairies that, when populations get high, can potentially be pests of crops.

Lentils

Wheat seeds eaten

Photo credits: Allison Squires

Flax bolls eaten

"We observed in our pea/oat grazing mix that the grasshoppers would eat the oats and leave the peas. Pastures were also impacted, especially alfalfa. As the season went on and everything was drying up the grasshoppers had much less green to eat and we found that they would even go for the Russian thistle still growing in the fields. All of our caragana trees in the yard site were stripped bare".

Allison Squires

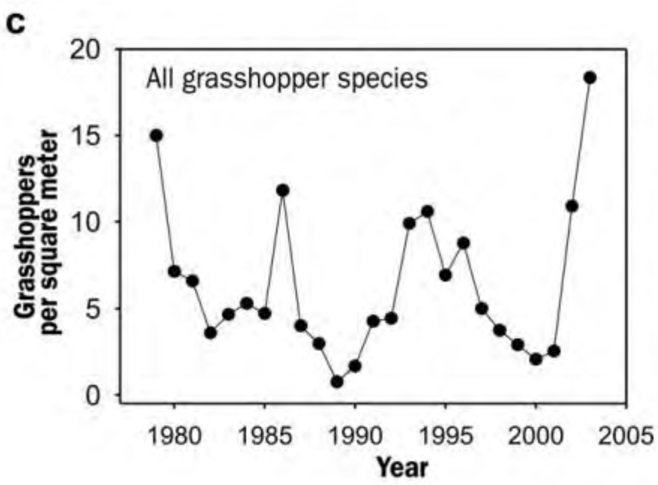


Figure 2. (a, b) Grasshopper survey maps illustrating the interyear variability and large spatial extent of grasshopper outbreaks throughout the western United States. Even though a smaller area was sampled in 1998 (a) than in 2005 (b), grasshopper densities greater than approximately 18 per square meter (m^2), shown in red, occurred over a larger geographic area in 1998. Yearly adult grasshopper survey maps are generated on the basis of surveys of adult grasshoppers conducted in most western states by the US Department of Agriculture's Animal and Plant Health Inspection Service, Plant Protection and Quarantine. (c) Average densities of adult grasshoppers from a Nebraska sandhills grassland over a 25-year span at Arapaho Prairie, located in Arthur County, Nebraska. Samples were taken in early August from the same location each year, using standard counts of 160 to 200 rings with an area of 0.1 m^2 per ring.

www.biosciencemag.org *September 2006 / Vol. 56 No. 9* • **BioScience** 745

"Grasshoppers are a reminder that nature works in cycles. In hot dry years, they can get ahead of their enemies. In cool wet years, natural predators and parasites will get the better of them. Our extensive cereal cropping feeds the population booms in grasshopper cycles". Brenda Frick, Univ of Saskatchewan

https://www.producer.com/opinion/organic-methods-for-tackling-grasshoppers-organic-matters/

Figure 3. Migratory grasshopper

Recent research on native rangeland also indicates that different intensities and schedules of cattle grazing (e.g., season-long versus twice-over rotational grazing) affect vegetation structure and species composition, which in turn influence grasshopper performance and the likelihood of population outbreaks (figure 4; Onsager 2000). Outbreak densities were observed in pastures with season-long grazing, but not in twice-over rotational pastures, in years in which outbreaks were likely (figure 4).

Differences in grasshopper responses were consistent with the hypothesis that differences in microhabitat structure resulting from the two grazing management practices (e.g., increased canopy cover during critical periods of grasshopper development and decreased amounts of bare ground in the rotational system) altered grasshopper thermoregulatory capacities and consequently affected development and survival (Onsager 2000).

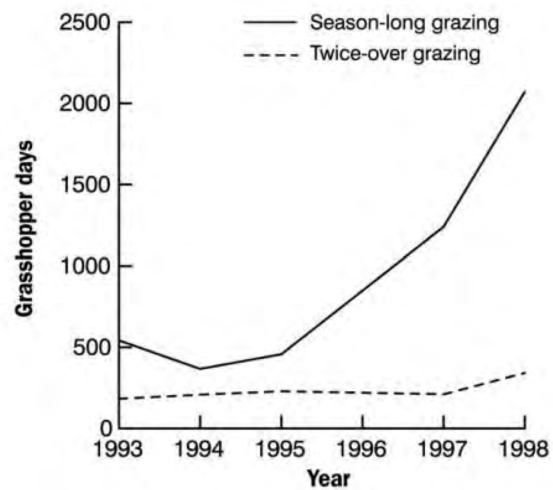


Figure 4. Grasshopper days, an index of cumulative seasonal abundance, in season-long (solid line) and twice-over rotational (dashed line) grazing management pastures in western North Dakota from 1993 to 1998. Grasshopper days were calculated by plotting population densities for third-instar or larger grasshoppers over the course of a summer and then determining the area under the resulting curve. Modified from Onsager (2000).

Outbreak prevention

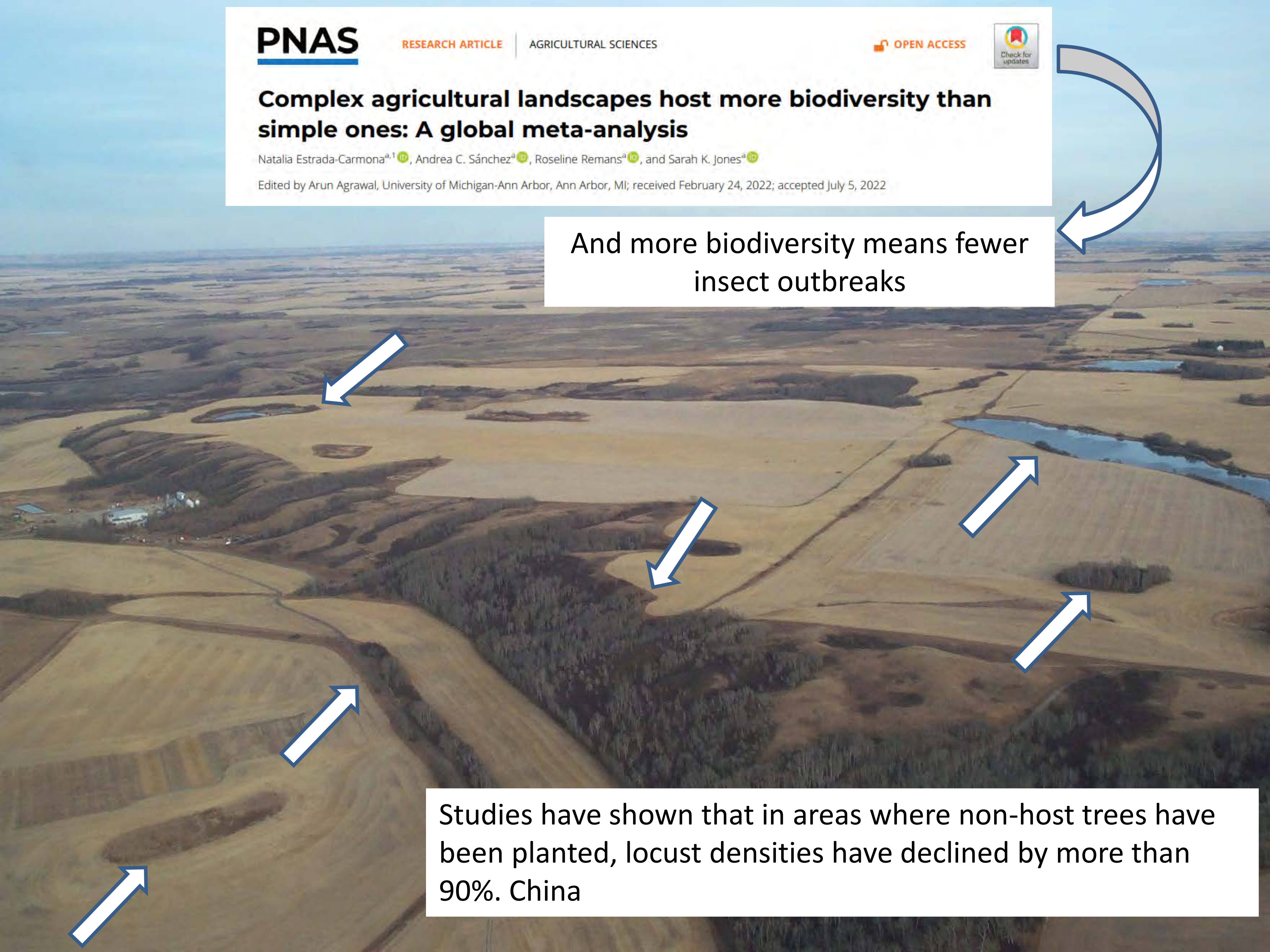
- poor egg laying sites
- shred forage (eg. CRP in Texas)
- grazing management
- alternating availability of bare ground and canopy cover affects optimal thermoregulation (Onsager, 2000).
- landscape diversity so that more non-pest grasshoppers present
- habitat manipulation to slow nymphal development (tillage, fire, cover crops?)

Intervention

- limit food supply (grasshoppers are food limited)
- keep grasshoppers from becoming adults

Suppression

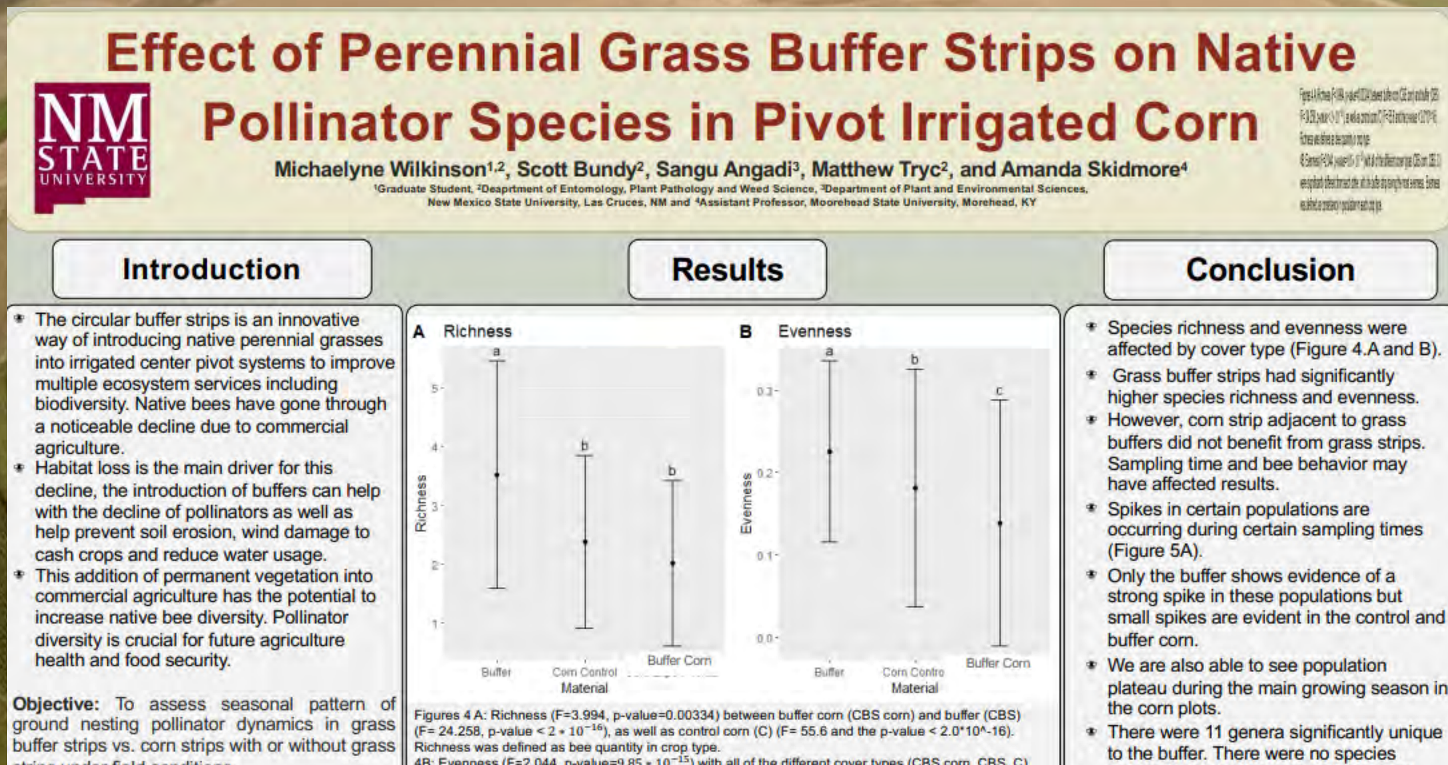
- Biological control


PNAS
RESEARCH ARTICLE
AGRICULTURAL SCIENCES
OPEN ACCESS
Check for updates
Complex agricultural landscapes host more biodiversity than simple ones: A global meta-analysis
Natalia Estrada-Carmona[a,1], Andrea C. Sánchez[a], Roseline Remans[a], and Sarah K. Jones[a]
Edited by Arun Agrawal, University of Michigan-Ann Arbor, Ann Arbor, MI; received February 24, 2022; accepted July 5, 2022
And more biodiversity means fewer insect outbreaks
Studies have shown that in areas where non-host trees have been planted, locust densities have declined by more than 90%. China

Organic farm within white lines

Which farm more “insect pest resilient?”

Perennial buffer strips, Dr. Sangu Angadi, New Mexico State University



Effect of Perennial Grass Buffer Strips on Native Pollinator Species in Pivot Irrigated Corn

Michaelyne Wilkinson[1,2], Scott Bundy[2], Sangu Angadi[3], Matthew Tryc[2], and Amanda Skidmore[4]

[1]Graduate Student, [2]Deaprtment of Entomology, Plant Pathology and Weed Science, [3]Department of Plant and Environmental Sciences, New Mexico State University, Las Cruces, NM and [4]Assistant Professor, Moorehead State University, Morehead, KY

Introduction

- The circular buffer strips is an innovative way of introducing native perennial grasses into irrigated center pivot systems to improve multiple ecosystem services including biodiversity. Native bees have gone through a noticeable decline due to commercial agriculture.
- Habitat loss is the main driver for this decline, the introduction of buffers can help with the decline of pollinators as well as help prevent soil erosion, wind damage to cash crops and reduce water usage.
- This addition of permanent vegetation into commercial agriculture has the potential to increase native bee diversity. Pollinator diversity is crucial for future agriculture health and food security.

Objective: To assess seasonal pattern of ground nesting pollinator dynamics in grass buffer strips vs. corn strips with or without grass strips under field conditions.

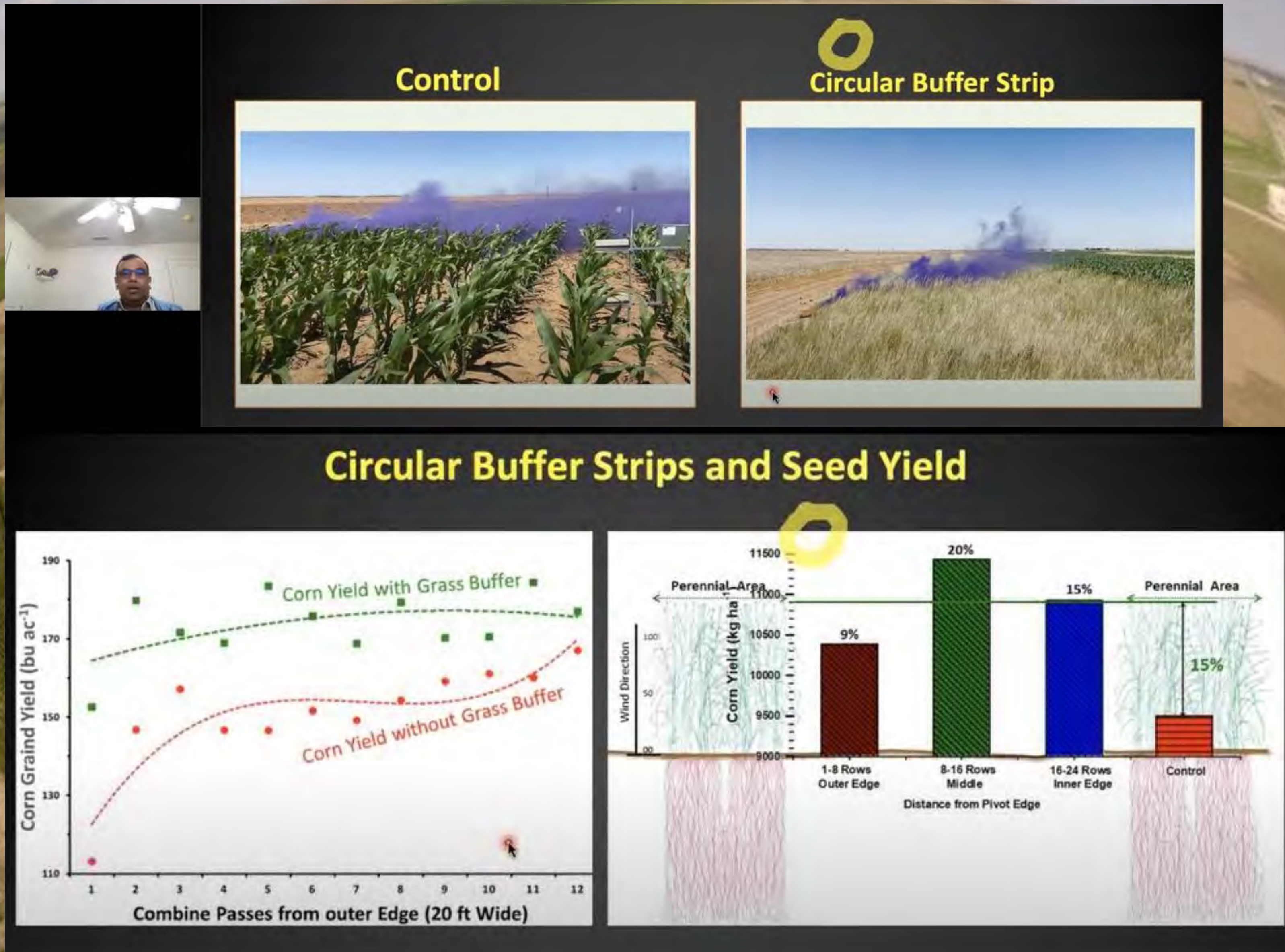
Results

Figures 4 A: Richness (F=3.994, p-value=0.00334) between buffer corn (CBS corn) and buffer (CBS) (F= 24.258, p-value $< 2 * 10^{-16}$), as well as control corn (C) (F= 55.6 and the p-value < 2.0*10^-16). Richness was defined as bee quantity in crop type.
4B: Evenness (F=2.044, p-value=$9.85 * 10^{-15}$) with all of the different cover types (CBS corn, CBS, C)

Conclusion

- Species richness and evenness were affected by cover type (Figure 4.A and B).
- Grass buffer strips had significantly higher species richness and evenness.
- However, corn strip adjacent to grass buffers did not benefit from grass strips. Sampling time and bee behavior may have affected results.
- Spikes in certain populations are occurring during certain sampling times (Figure 5A).
- Only the buffer shows evidence of a strong spike in these populations but small spikes are evident in the control and buffer corn.
- We are also able to see population plateau during the main growing season in the corn plots.
- There were 11 genera significantly unique to the buffer. There were no species

Perennial buffer strips, Dr. Sangu Angadi, New Mexico State University



Prevention – Avoid the problem

- Resistant varieties
- Crop rotation (green bridge)
- Intercropping (polyculture)
- Landscape diversity

Intervention – Deal with the problem once it arises

- Treat disease or insect


Fan blows beetles off plants into the interrow space
Then flamer kills the beetles
Entrust
SC

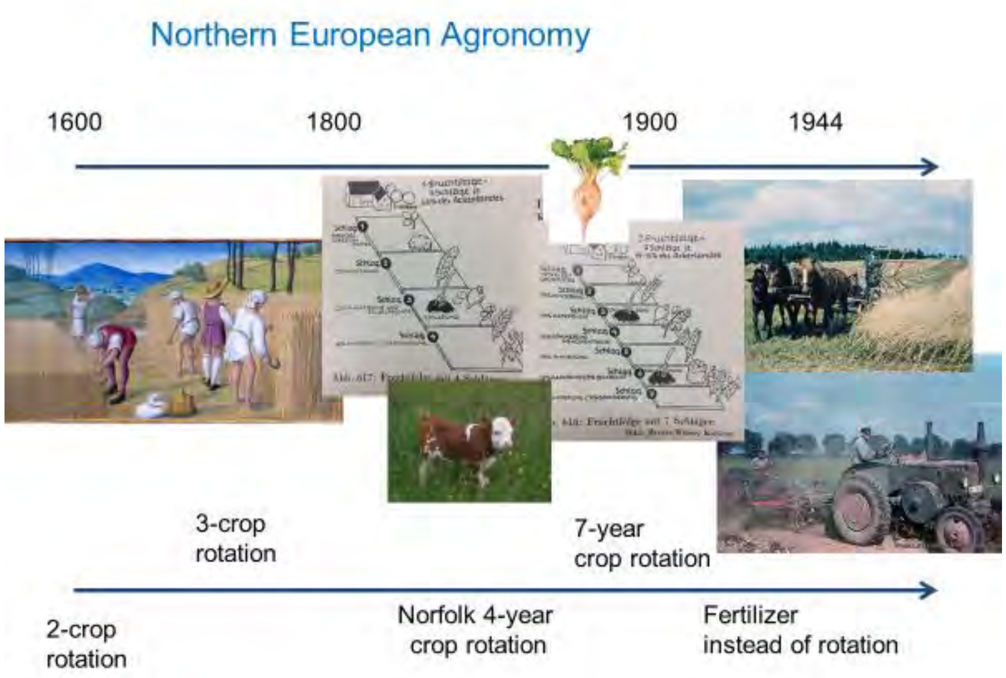
Diseases

Source: Manitoba Agriculture

Lesson 3. Insect and disease management

Diseases

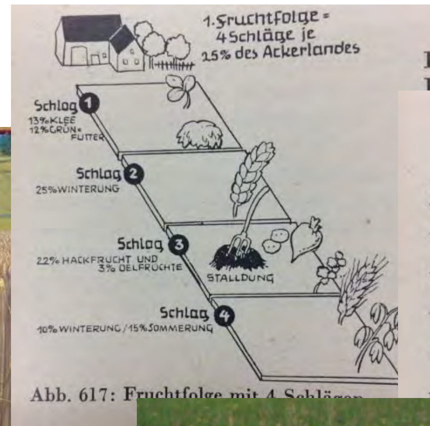
- Diseases controlled through sanitation, rotation, diversity and monitoring (eg. field scouting).
- Healthy, biologically active soils critical to keeping disease levels low.
- Intercropping and cover cropping can help reduce disease.
- Some biological approaches can suppress disease (eg., compost tea).

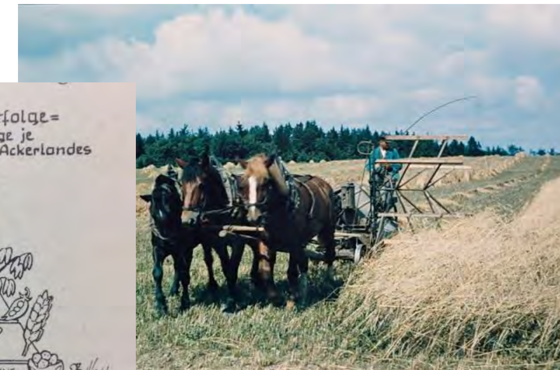


https://www.youtube.com/watch?v=XSKSxLHMv9k

Northern European Agronomy

1600 1800 1900 1944





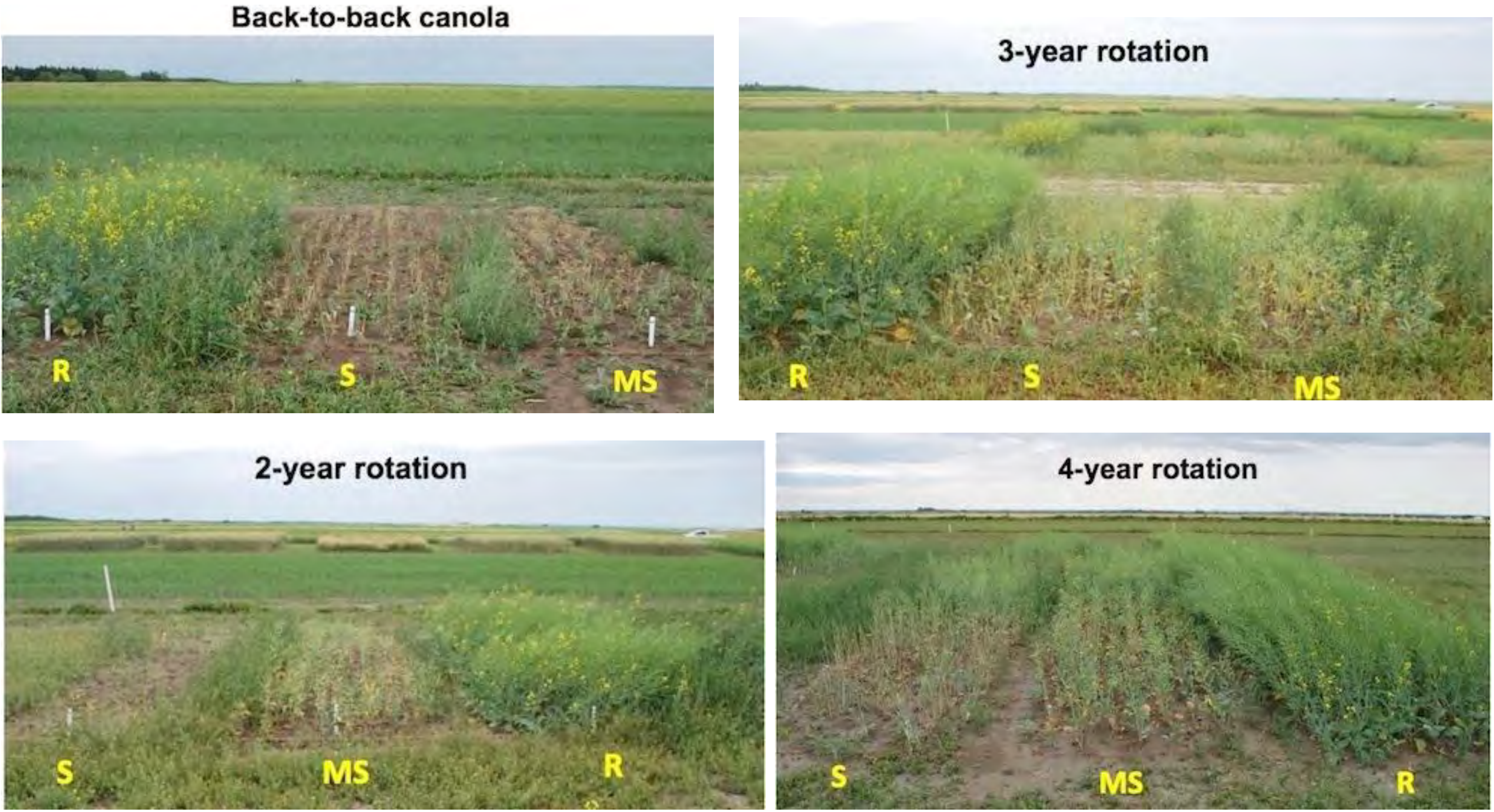
3-crop rotation

7-year crop rotation

2-crop rotation

Norfolk 4-year crop rotation

Fertilizer instead of rotation



“The photos show how rotation, especially for MS and S varieties, improves yield. Rotation also plays an important role for growers relying on R varieties in clubroot infested fields. Short rotations using resistant varieties will select quickly for clubroot pathotypes that are not controlled by the genetic resistance. This can rapidly eliminate the value of the resistance trait on those fields, which is a situation that has already been experienced in canola and cole crops around the world”. Peng, Quebec.

http://www.canolawatch.org/2013/04/04/rotations-role-in-clubroot-management/

Plant breeders are in a race to stay ahead of clubroot by looking for alternative sources of resistance to develop new hybrids with protection against new virulent pathotypes. As the clubroot threat continues to evolve, canola varieties with multiple effective resistance genes are the first line of defense, offering additional protection and durability. Crop rotation is central to long-term disease management and will help preserve the resistance genetics currently available.

Coreen Franke, R&D Pathology Research, Nutrien

Table 1. General control tactics and specific measures used at different stages of pathogen invasion in organic in comparison with conventional crop production[7,13,15,96]

Invasion stage/general approach	Specific practices	Frequency in organic in comparison with conventional crop production
Colonization prevention		
Sanitation	Pathogen-free seed, debris destruction, flaming; steaming	Similarly common; rare
Temporal asynchrony	Late or early planting/harvest with respect to pathogen or vector arrivals	More common
Non-conducive conditions	Crop rotation; repellent cultivars; enhanced soil suppressiveness by organic amendments, biochar; calcium carbonate, dolomitic lime, gypsum	Longer rotation; similar cultivars; more organic amendments; similar non-synthetic inorganic amendments
Synthetic chemical barrier	Preventive foliar sprays with synthetic insecticides, nematicides, acaricides, fungicides or bactericides; botanical pesticides containing petroleum derivatives	Absent
Spatial isolation	Crops sown distant from pest/pathogen hosts, weeds, non-crop hosts removed; barrier crops or natural strips	Occasional; barriers and natural strips more common
Prevent landing	Vector trapping, reflective mulches, oil sprays	Similarly occasional
Population regulation		
Host plant resistance	Suboptimal plant quality (low fertilization), classical genetic resistance, crop spacing	More common
Intercropping	Mixed cultivars, mixed cropping, strip cropping, green manures	More common
Competition and antagonism	Enhanced microbial activity and diversity to reduce pathogen populations (compost, chitin, compost teas, plant extracts, humates, microbial products as spray or seed treatment)	More common
Unsuitable environment	Ventilation, humidity and temperature control (greenhouses), humidity control by irrigation	Similarly common
Curatives after establishment[a]		
Synthetic pesticides	Various systemic and contact insecticides and fungicides; synthetic pyrethroids	Absent; exceptional
Organics	Soaps, oils, compost teas, acetic acid	More common
Inorganics	Sulfur dust and sprays, diatomaceous earth, micronutrients (Si or Zn); copper sulfate, copper hydroxide, bordeaux mixture, potassium phosphite, potassium bicarbonate, potassium silicate	More common; in some countries
Botanicals	Plant extracts without petroleum-based synergists (pyrethrum, nicotine, neem, horsetail, seaweed, yucca)	Rare or common
Inundative biological control	Parasitoids (e.g. parasitic wasps), bacteria (e.g. *Bacillus thuringiensis*, *B. subtilis*, *Pseudomonas*), fungi (e.g. *Trichoderma*)	Occasional (no petroleum-based synergists or carriers)
Physical removal	Trapping, vacuuming, handpicking	Occasional, similar to CF

[a] In the plant pathology literature, only systemic fungicides with kickback action are considered to be curative, but here we include any pesticides that limit further spread of pests and diseases in the plant population.

van Bruggen, AHC, A. Gamlielb and M. R Finckhc. 2016. Plant disease management in organic farming systems Pest Manag Sci 2016; 72: 30–44

The new Green Revolution: Sustainable intensification of agriculture by intercropping

CrossMark

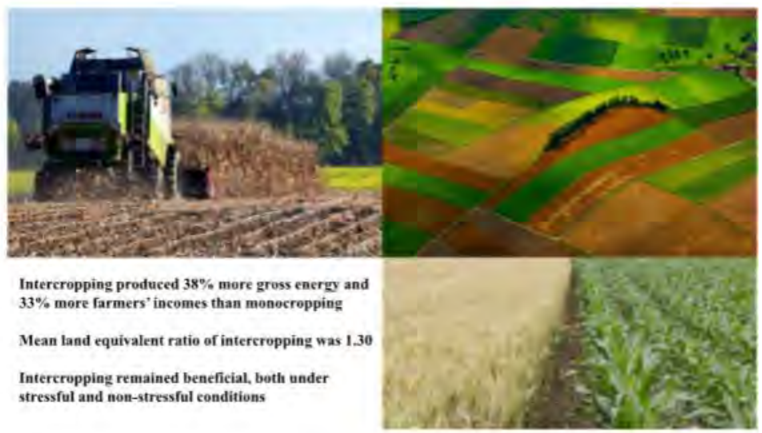
Marc-Olivier Martin-Guay [a], Alain Paquette [b], Jérôme Dupras [a], David Rivest [a,*]

[a] Département des sciences naturelles and Institut des sciences de la forêt tempérée (ISFORT), Université du Québec en Outaouais (UQO), 58 rue Principale, Ripon, QC J0V 1V0, Canada
[b] Département des sciences biologiques, Université du Québec à Montréal, CP 8888, Succursale Centre-ville, Montréal QcH3C 3P8, Canada

HIGHLIGHTS

- Global productivity potential of intercropping was determined using a meta-analysis.
- Global land equivalent ratio of intercropping was 1.30.
- Land equivalent ratio of intercropping did not vary through a water stress gradient.
- Intercropping increases gross energy production by 38%.
- Intercropping increases gross incomes by 33%.

GRAPHICAL ABSTRACT



Martin-Guay, M.O., Paquette, A., Dupras, J. and Rivest, D., 2018. The new green revolution: sustainable intensification of agriculture by intercropping. Science of the total environment, 615, pp.767-772.

Fig. 1. Locations of all intercropping experiments that were retrieved from the literature, together with global aridity data in the background. Point size indicates the number of intercrops that were associated to each experimental site. The aridity index increases in humid environments, and decreases in arid environments. The experiments span the globe and include various climates.

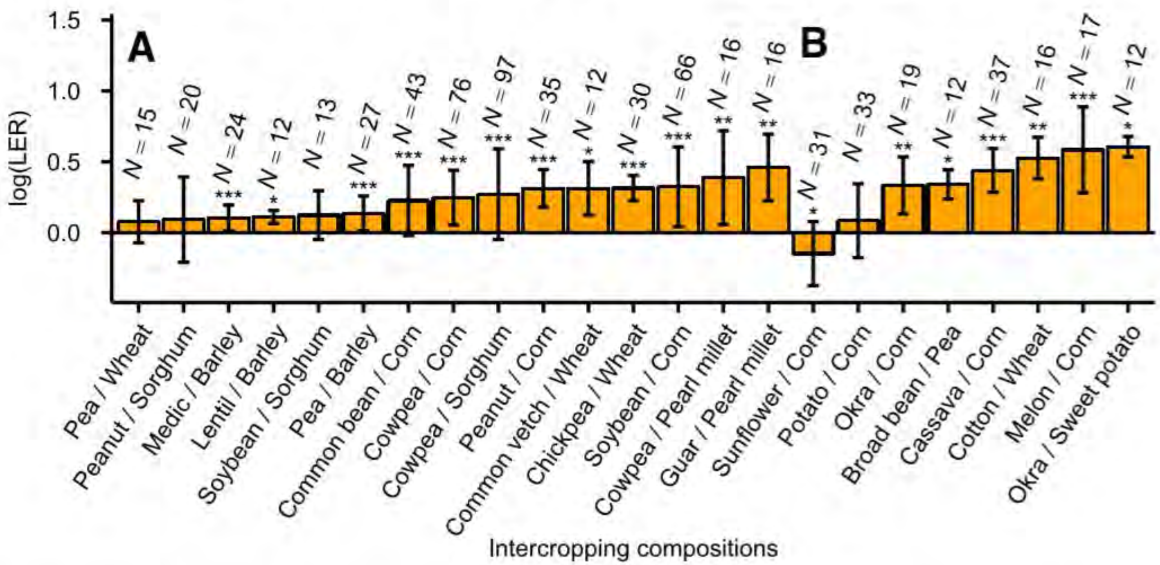
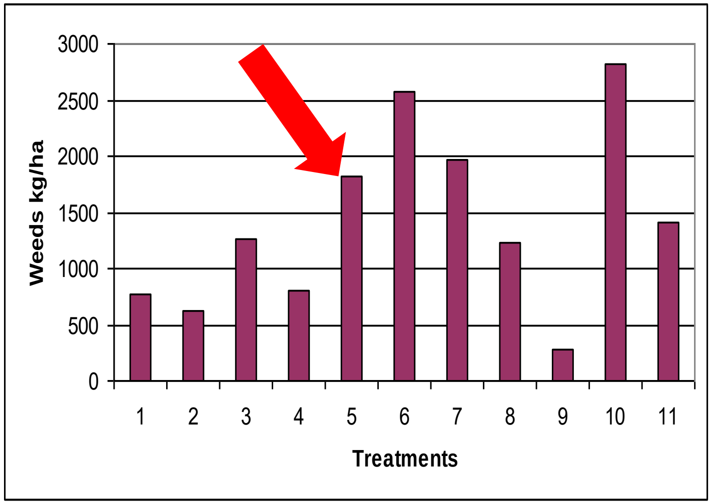


Fig. 3. Average land equivalent ratio (LER) for all distinct intercropping compositions with > 10 occurrences in the dataset. A = legume/non legume; B = other intercropping compositions. LER is log-transformed, meaning that positive values represent beneficial intercrops. Even though there is great variability within- and between- compositions, most (18 of the 23) have a clear potential for land sparing. Presence of a legume/non-legume interaction does not seem to influence intercropping performance. Error bars are standard deviation. Above each column, the number of intercrops having each composition is indicated, as well as the result of a conservative Wilcoxon signed-rank test with Bonferroni correction of the significance thresholds. Significance levels are: * $P < 0.002$; ** $P < 0.00004$; *** $P < 0.000004$.

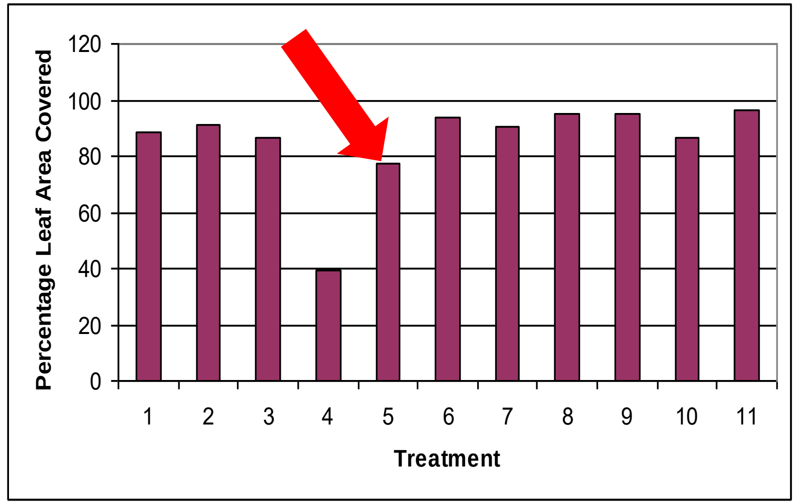
Lana Shaw,
Redvers, SK

Scott Chalmers,
WADO, Melita,
MB

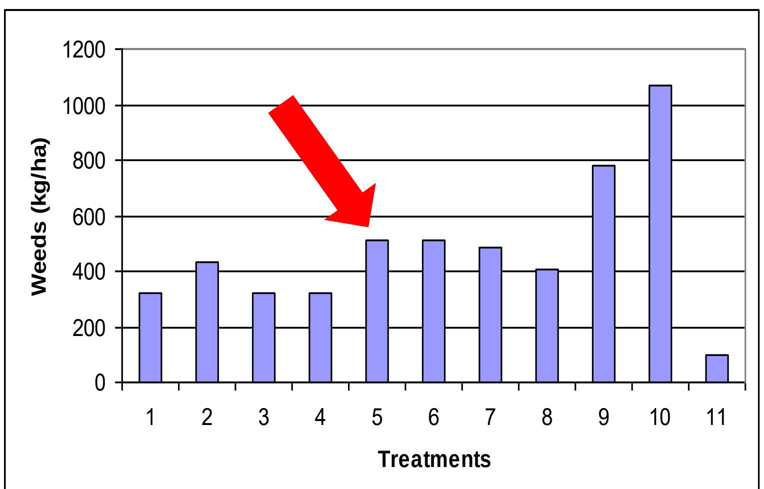
Wheat – pea intercrops (weeds and wheat leaf diseases)

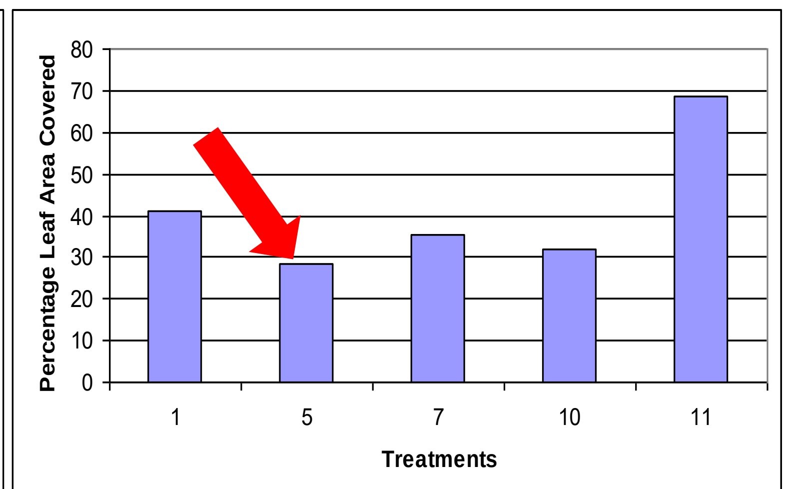


Weed Biomass at Harvest



% Leaf Area Covered by Disease





Treatments
1. Wheat+Oats
2. Wheat+Barley
3. Wheat+Spring Rye
4. Wheat+Flax
5. Wheat+Field Pea
6. Wheat+Mustard
7. Wheat+Red Clover
8. Wheat+Hairy Vetch
9. Wheat+ Annual Ryegrass
10. Half-rate wheat
11. Full-rate wheat

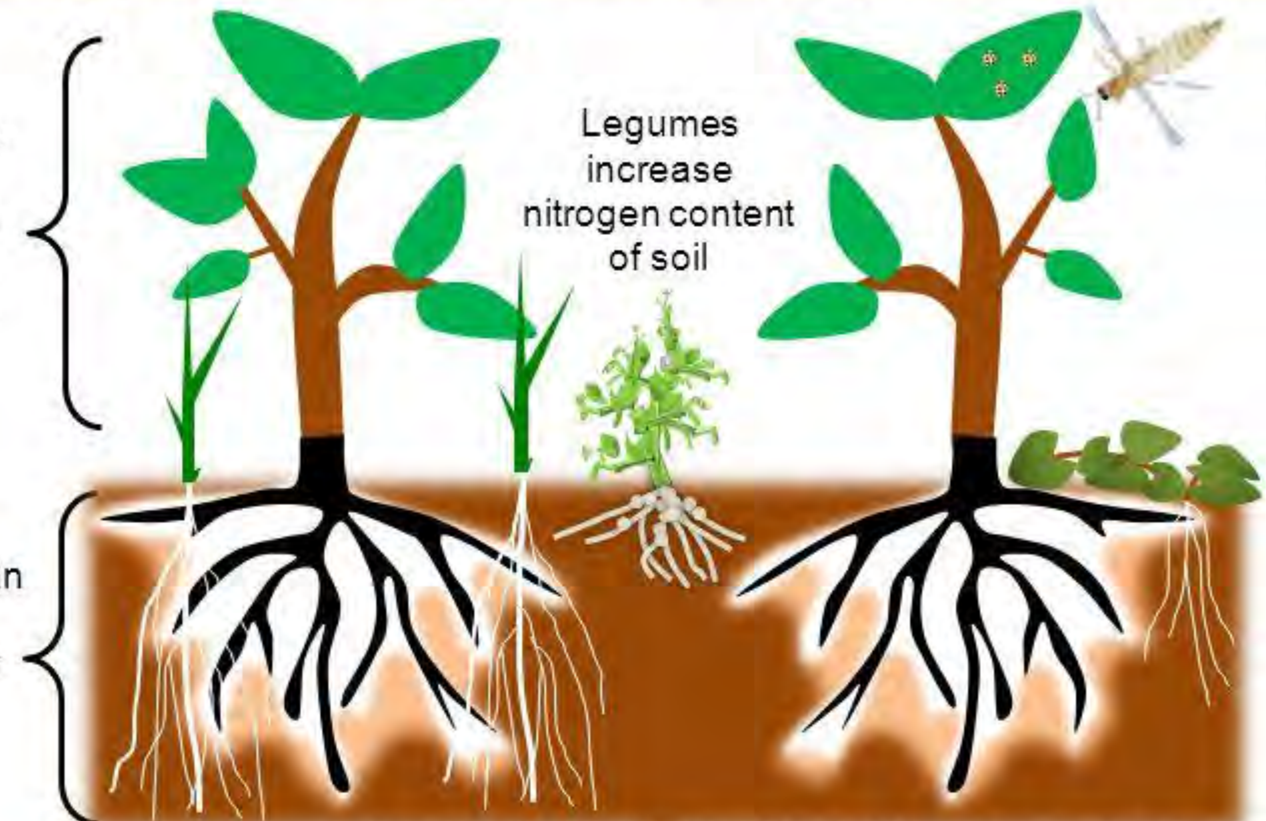
Pridham, J.C. and Entz, M.H., 2008. Intercropping spring wheat with cereal grains, legumes, and oilseeds fails to improve productivity under organic management. *Agronomy Journal*, *100*(5), pp.1436-1442.

Intercropping and crop rotation confer many benefits

The total yields of fields grown with two or more species at the time or in alternating years can be higher than the most productive monocultures

Different crown heights can accommodate different light requirements

Different root distributions can minimize competition for nutrients



Rotating crops reduces pest populations

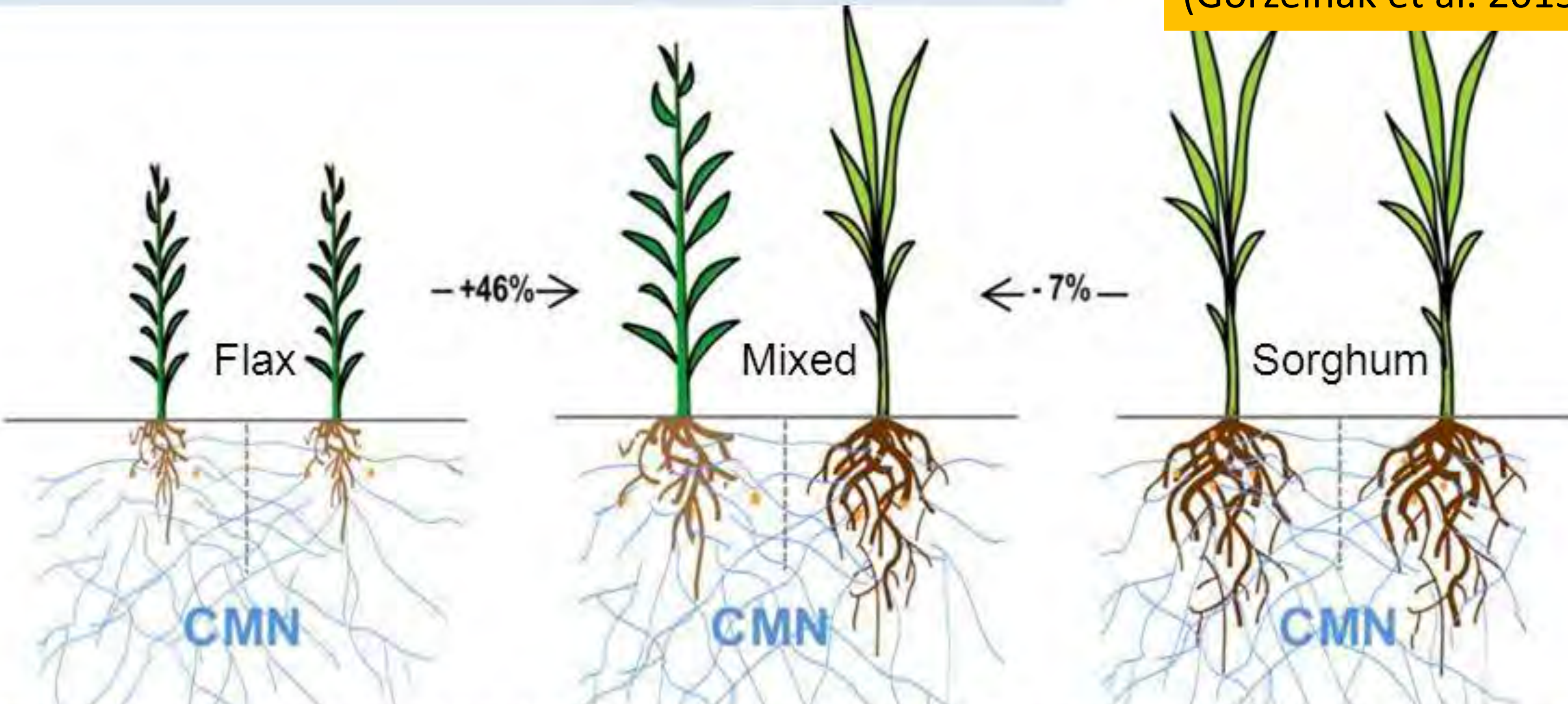
Ground-hugging plants can suppress weeds

See Horton, J.L. and Hart, S.C. (1998). Hydraulic lift: a potentially important ecosystem process. Trends Ecol. Evol. 13: 232-235. Lee, J.-E., Oliveira, R.S., Dawson, T.E. and Fung, I. (2005). Root functioning modifies seasonal climate. Proc. Natl. Acad. Sci. USA. 102: 17576-17581.

A common mycorrhizal network can facilitate resource sharing

Intercropping with sorghum drastically enhanced flax's growth (+46% increase). Nutrient uptake was facilitated via the common mycorrhizal network (CMN)

AMF's motivation is insurance – to diversify it's C sources (Gorzelnak et al. 2015).



Walder, F., Niemann, H., Natarajan, M., Lehmann, M.F., Boller, T. and Wiemken, A. (2012). Mycorrhizal networks: common goods of plants shared under unequal terms of trade. Plant Physiol. 159: 789-797.

Which crops form mycorrhizae?

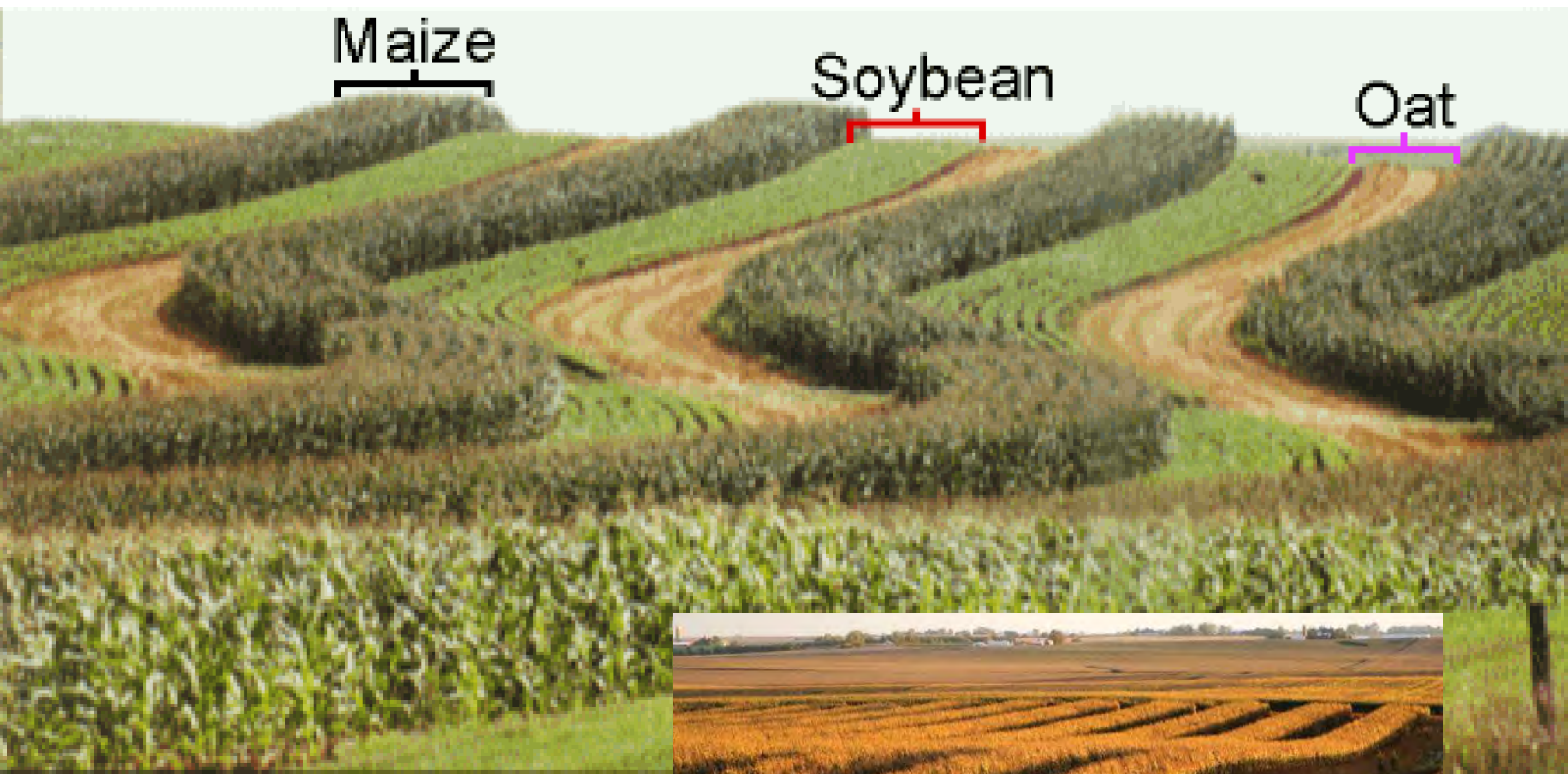
Group I: Very Mycorrhizal

- Corn
- Flax
- Sunflower
- Peas
- Beans
- Potato

Group II: Mycorrhizal

- Wheat
- Oat
- Barley

(Plenchette, 1983)


Maize
Soybean
Oat


PRODUCTION 37

Registration sought for mustard-based biopesticide

Allyl isothiocyanate has been used in a variety of products for decades, and it's not possible to patent the active ingredient.

Manitoba researchers say that the mustard should be flailed rather than mowed and that it should be incorporated within a few minutes because isothiocyanates can volatilize within 20 minutes of chopping. *Photo: MHPEC (video screenshot)*

https://spudsmart.com/exterminating-verticillium-wilt-from-potato-fields-with-mustard-biofumigation/

Williams-Woodward, J.L., Pfleger, F.L., Fritz, V.A. and Allmaras, R.R., 1997. Green manures of oat, rape and sweet corn for reducing common root rot in pea (Pisum sativum) caused by Aphanomyces euteiches. *Plant and Soil*, *188*(1), pp.43-48.

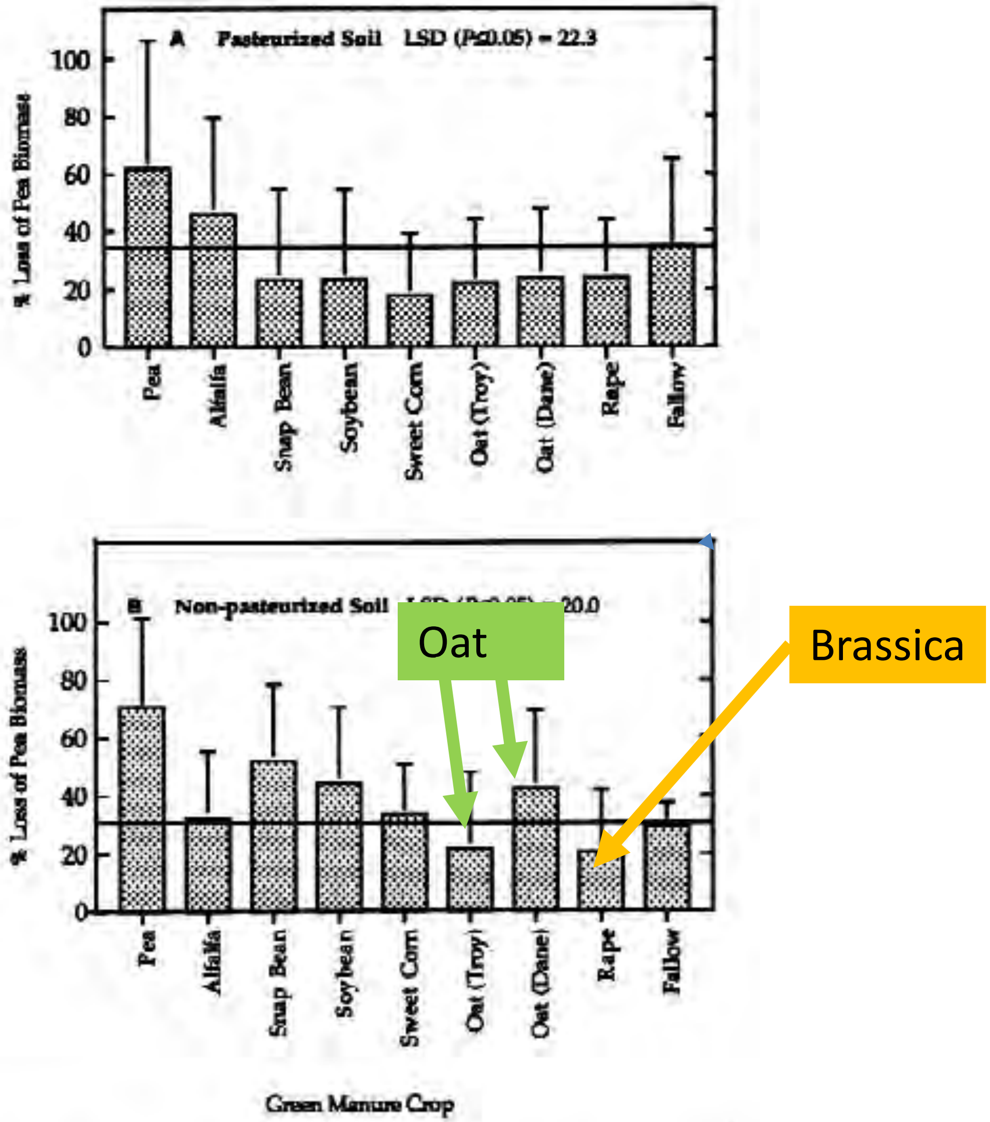


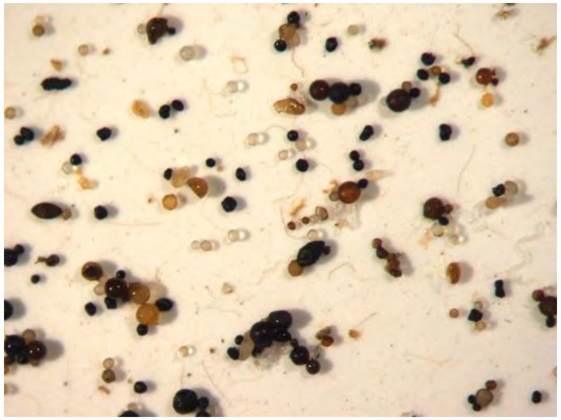
Figure 1. Loss of pea biomass (vine + root fresh wt) from plants grown in soil infested with *Aphanomyces euteiches* as a percentage of the pea biomass in the non-infested control soil. **A**) Pasteurized soil. **B**) Non-pasteurized soil. Lines above bars represent the standard deviations and the line across the figure corresponds to biomass loss in the fallow treatment.

44 Fungistatic compounds such as avenacin and saponins in <u>oat tissues</u> cause lysis of zoospores and inhibition of oospore formation and germination (Mitchell and Deacon, 1985).

Mitchell, R.T. and Deacon, J.W., 1986. Differential (host-specific) accumulation of zoospores of Pythium on roots of graminaceous and non-graminaceous plants. *New Phytologist*, *102*(1), pp.113-122.

The question of diseases in pea-based intercrops

- *Aphanomyces* – a fungus that affects peas (and alfalfa) that can last in soil 10 years
- No effective seed treatment control
- Factors that increase *aphanomyces* include:
  - Wet soils
  - Soil compaction
- Factors that reduce *aphanomyces* damage include:
  - AMF protection of root surface
  - Certain green manure plants
    - Oats
    - Cruciferous plants (mustards, etc)



Mycorrhiza discussed next class

Compost tea

What is it…

Table 1 Definitions of terms used interchangeably with compost tea or in association with the compost tea production or application process

Term	Definition	References
Composting	A biological process through which microorganisms convert organic materials into useful end-products, which may be used as soil conditioners and/or organic fertilizers, plant growth substrates and biological control agents	Modified from Buchanan and Gliessman [45]; Stoffella and Kahn [46]
Compost	The solid particulate products of composting, which are extracted during the maturation and curing phase are referred to as compost.	Paulin and O'Malley [47]; Litterick and Wood [2]
Vermicompost	The process of worms digesting organic matter to transform the material into a beneficial soil amendment.	NOSB [36]
Vermicompost tea	Filtered products of vermicompost fermented in water for more than 1 h.	Modified from Litterick *et al.* [33]
Compost leachate	Liquid that has leached through a compost pile and collects on the ground, compost pad, or collection ditches, puddles, and ponds.	NOSB [36]
Compost slurry	A term used to describe non-aerated compost tea prior to filtration.	Cronin et al. [48]
Compost tea additives	Materials apart from compost and water that are added in the process of making compost tea, which are presumed to sustain and enrich microbial growth.	NOSB [36]
Amended extracts	These compost extracts have been fermented with the addition of specific nutrients or combined with isolated microorganisms before application.	Weltzien [49]
Manure extract	Water suspension containing raw, non-disinfected manure; when the suspension is maintained for several hours or more it is sometimes referred to as manure tea.	NOSB [36]
Suppressive compost tea	A suppressive compost tea provides or changes the environment so that the pathogen does not establish or persist, establishes but causes little or no damage, or establishes and causes disease for a while but thereafter the disease is less important, although the pathogen may persist.	Modified from Cook and Baker [50]
Spreader	An adjuvant that reduces the surface tension of spray droplets, thus allowing them to spread evenly over leave surfaces rather than lying in beads.	Mahaffee and Scheuerell [10]
Sticker	An adjuvant that enhances the ability of compost teas to adhere to plant surfaces.	Mahaffee and Scheuerell [10]
Protectant	An adjuvant that protects microbes from stresses mainly due to desiccation and UV light.	Mahaffee and Scheuerell [10]

Table 1. Effects of different organic management approaches on the incidence and severity of late blight of potato and tomato.

Fungicide

Foliar compost tea

Treatment	Potato			Tomato	
	% incidence	% infected leaves per plant	% Leaf area diseased	% Incidence	Severity
T1	60.33a	38.23a	65.00a	100.00	8.87a
T2	14.24f	18.53d	27.00e	100.00	6.06d
T3	12.88f	18.75d	27.00e	100.00	8.33abc
T4	42.29b	38.23a	53.33bc	91.67	6.06d
T5	44.43b	26.19bc	54.00bc	91.67	7.51a-d
T6	26.59d	30.56b	48.33c	100.00	7.52a-d
T7	60.30a	21.70cd	60.00ab	100.00	7.06cd
T8	18.67e	25.73bc	38.67d	100.00	8.71ab
T9	22.74de	23.27cd	38.67d	100.00	6.20d
T10	37.48c	27.00bc	49.33c	100.00	7.20bcd
LSD	4.088	6.285	6.472	-	1.435
Level of significance	*	*	*	NS	*

T_1 (Control with no spray), T_2 (Control with fungicide spray), T_3 (Compost tea or extract as foliar spray), T_4 (Compost tea or extract as soil drenching), T_5 (Poultry litter extract as soil drenching), T_6 (Compost as soil application), T_7(Poultry litter as soil application), T_8 (Biopesticide as soil application), T_9(BAU-Biofungicide as foliar spray) and T_{10} (Mustard Oil Cake as soil application)

Islam, M.R., Mondal, C., Hossain, I. and Meah, M.B., 2013. Organic management: an alternative to control late blight of potato and tomato caused by Phytophthora infestans. International Journal of Theoretical & Applied Sciences, 5(2), pp.32-42.

Table 2: Effects of different organic management approaches on the major growth and yield parameters of potato and tomato.

Fungicide
Foliar compost tea

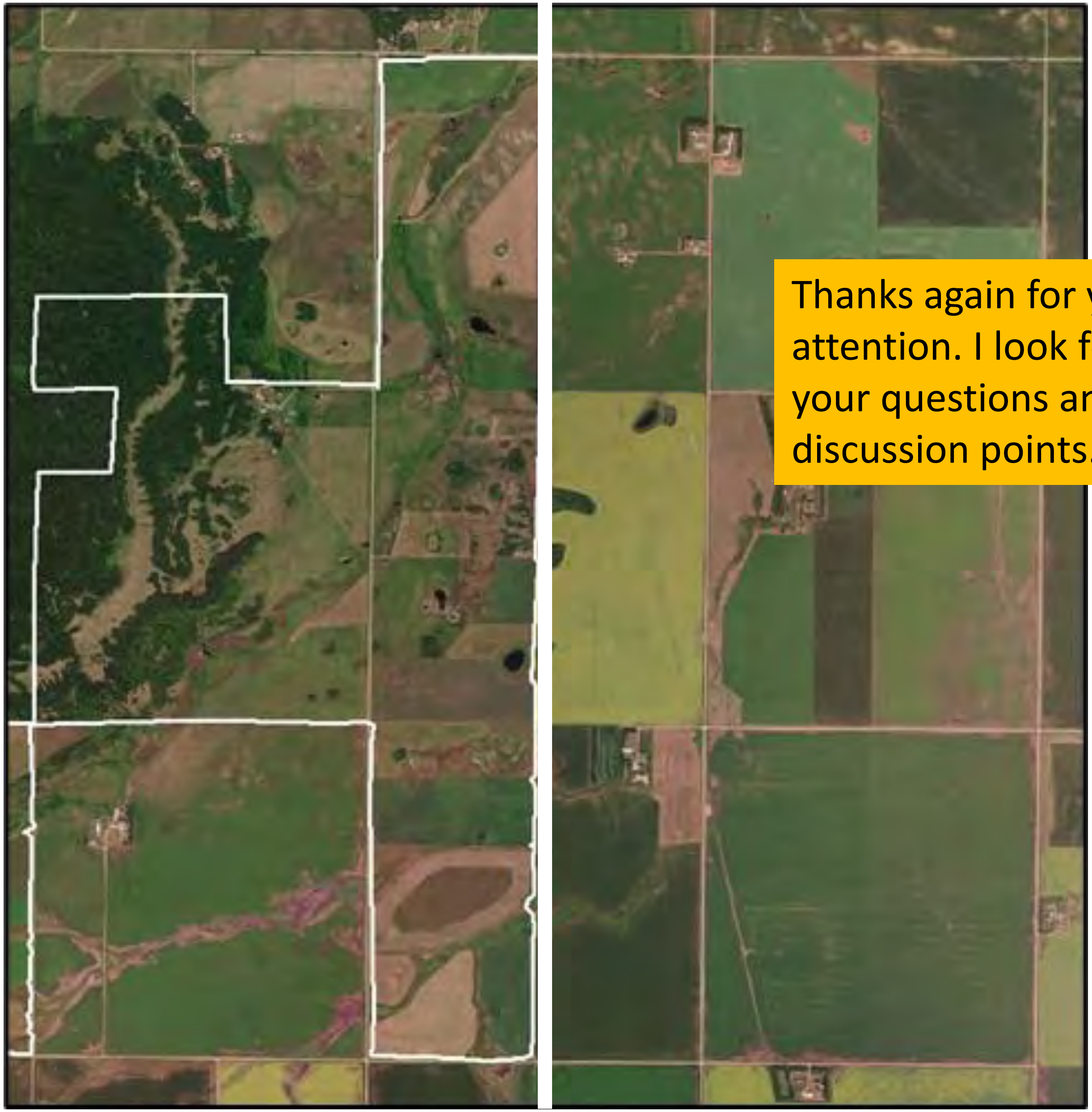
Treatments	Potato			Tomato		
	Plant height (cm)	Number of plants	Yield per ha (t/ha)	Plant height (cm)	Number of branches per plant	Fruit yield per ha (
T1	21.77abc	3.61	12.20f	78.00d	3.83c	43.40e
T2	21.06bc	2.91	22.40bcd	84.41bc	4.99bc	53.70c
T3	23.50abc	3.80	28.50a	79.33d	4.00c	49.70d
T4	19.63cd	3.89	17.40e	97.75a	8.20a	90.60a
T5	22.00abc	3.76	20.80cde	95.50a	5.65bc	65.60b
T6	15.87d	4.04	25.50abc	86.33b	4.50c	57.60c
T7	24.90ab	3.26	22.00b-e	76.50d	4.66c	49.40d
T8	21.46abc	3.72	18.00de	82.41c	5.15b	47.00de
T9	20.33c	3.44	23.00bc	85.67b	5.17b	55.00c
T10	25.57a	3.25	26.43ab	78.25d	4.79bc	48.80d
LSD	3.832	-	4.470	2.842	0.856	3.978
Level of significance	*	NS	*	*	*	**

T_1 (Control with no spray), T_2 (Control with fungicide spray), T_3 (Compost tea or extract as foliar spray), T_4 (Compost tea or extract as soil drenching), T_5 (Poultry litte soil drenching), T_6 (Compost as soil application), T_7 (Poultry litter (soil application), T_8 (Biopesticide as soil application), T_9 (BAU-Biofungicide as foliar spray) and T_{10} (Mustard Oil Cake as soil application)
* Means with the same letter in [redacted]

CONCLUSION

Compost tea as foliar spray in case of potato and as soil drenching in tomato may be the best alternative approach to control late blight of potato and tomato with higher economic return. However, the suitability of compost tea as a technology to control plant diseases needs to be evaluated against wide range of pathogens in other crop plants as compared to other biological means of plant disease control.

Islam, M.R., Mondal, C., Hossain, I. and Meah, M.B., 2013. Organic management: an alternative to control late blight of potato and tomato caused by Phytophthora infestans. International Journal of Theoretical & Applied Sciences, 5(2), pp.32-42.



Thanks again for your attention. I look forward to your questions and discussion points.

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