Weed Management in Organic Cropping Systems

Bill Curran and Dave Mortensen
Penn State University
2016

Weeds and Organic Management

- Number one pest on most organic farms
- A diverse set of cultural and mechanical control tactics works best for successful management
- Lots of interest in reducing tillage for annual crop production, but still being developed and refined

There is no single recipe

There are multiple views on how to approach managing the infestation and the right approach is very much farmer and farm operation specific.

Three contrasting views:

- Do what you can to reduce early season weed-crop competition, but time and labor drive management or
- Hone your skills at controlling the emerged weeds in your field or
- Work to reduce or eliminate the seedbank

Peacemeal Farm
Dix, ME

- 9 acres of vegetables and herbs
- Sells at farmers markets, resturants, and natural food stores
- Dependent on seasonal labor
- Lots of hand work

Courtesy of E. Gallandt, UME

NEW MORNING FARM

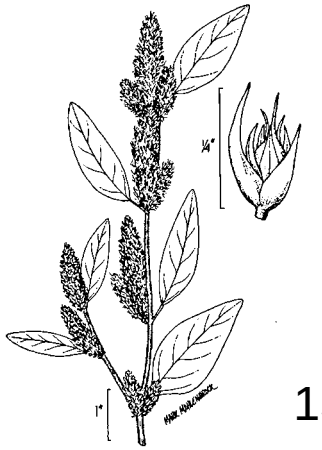
HOMEGROWN HOMEMADE

- Jim and Moie Crawford
- 95 acre certified organic vegetable farm in south central PA
- Direct market to DC and other areas
- Cooperate with Tuscarora Organic Growers Cooperative

The right tool for the job

Large crops and small weeds

- Zero tolerance for weeds getting up above the crop
- Manage the seedbank to the extent possible
- Timeliness and diversity of weeding tools critical
- Building the soil with rotational cover cropping



15,000 seeds

200 seeds

Beech Grove Farm –
Eric and Anne Nordell, Trout Run PA

- 6-acre market garden
- Each field divided into 12 half-acre plots
- Utilize on-farm resources, remain a two person operation, and stay debt-free by minimizing costs
- Direct market at farmers markets and through restaurants

“Weed the soil, not the crop”

- Zero tolerance for weed seeds
- Skim plowing
- Rotational cover cropping
  - cover crop / fallow / cover crop
  - timing of fallow alternates: spring / summer
  - fallow events include harrowing & cultipacking
- Intercropping
  - e.g., hairy vetch cover crop in onion, leek

Soil weed seed banks

Dixmont, ME

Trout Run, PA

Eric Gallandt, University of Maine. www.gallandt.wordpress.com

Which approach is right for you?

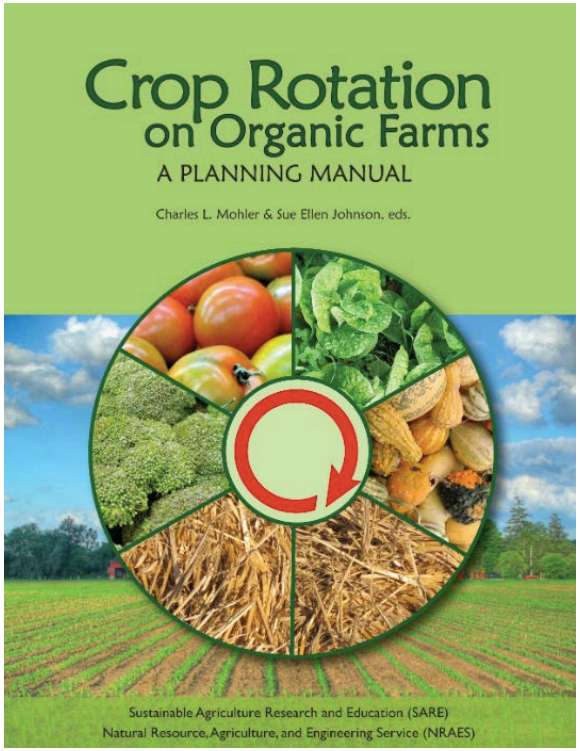
Focus on early season weed competition

The right tool for the job

Weed the soil, not the crop

It’s not a prescription

Organic Farming Resources



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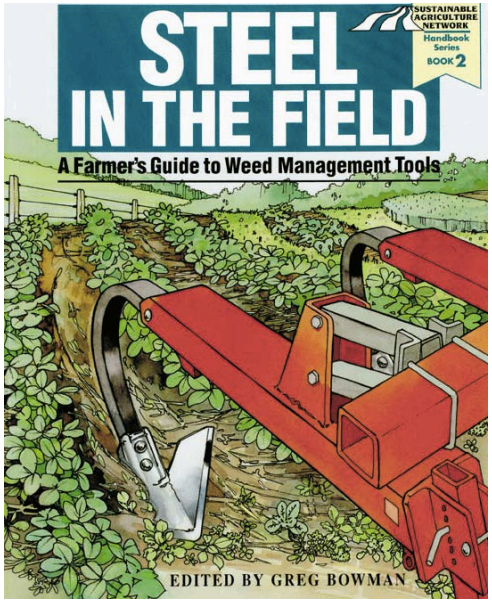
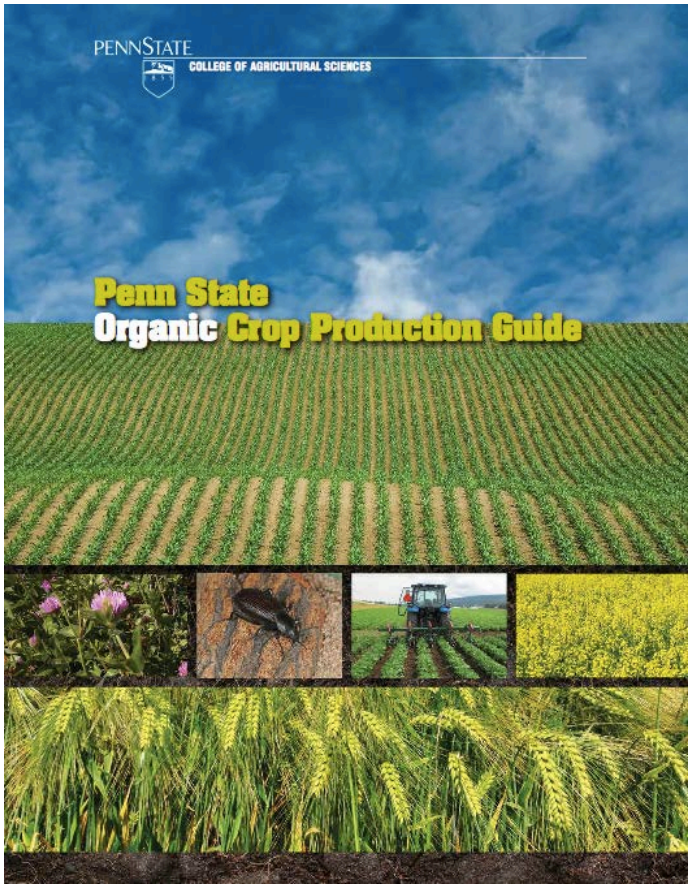
http://www.sare.org/publications/steel/steel.pdf

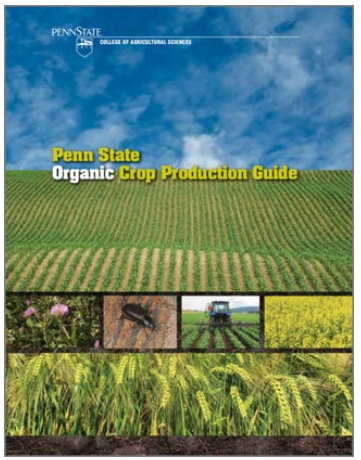




http://extension.psu.edu/publications/agrs-124

Penn State Organic Crop Production Guide

This guide was developed by Penn State Extension faculty and staff along with industry experts.



Organic farming information includes:

- soil properties, health, and fertility
- cover crops and crop rotations
- grain crops and forages
- weed, insect, and disease pest management

http://extension.psu.edu/publications/agrs-124

Weed management tactics for Organic Growers

- Crop rotation/sequence
- Primary and secondary tillage
- Hand weeding
- Cultivation
- Cover crops - dead mulches and green manures
- Cover crops - living mulches
- Crop residue management
- Planting date
- Planting arrangement and density
- Crop cultivar selection
- Intercropping
- Fertilization
- Preventing seed production
- Irrigation and drainage
- Thermal weed control
- Biological weed control
- Natural product herbicides

Weed Management Tactics

- Cultural
- Mechanical/Physical
- Chemical and Thermal

Weed Management Tactics

- Cultural – Number 1!
- Mechanical/Physical
- Chemical and Thermal

Cultural-Rotation Diversity

Cultural #1 - Crop Rotation/Diversity

- Impacts weed growth and reproduction through changes in:
  - Light, water, and nutrient conditions
  - Tillage and cultivation practices
  - Mowing and grazing
  - Chemical, physical, and biological characteristics of the soil

Diversified Cropping Systems = fewer problem weeds

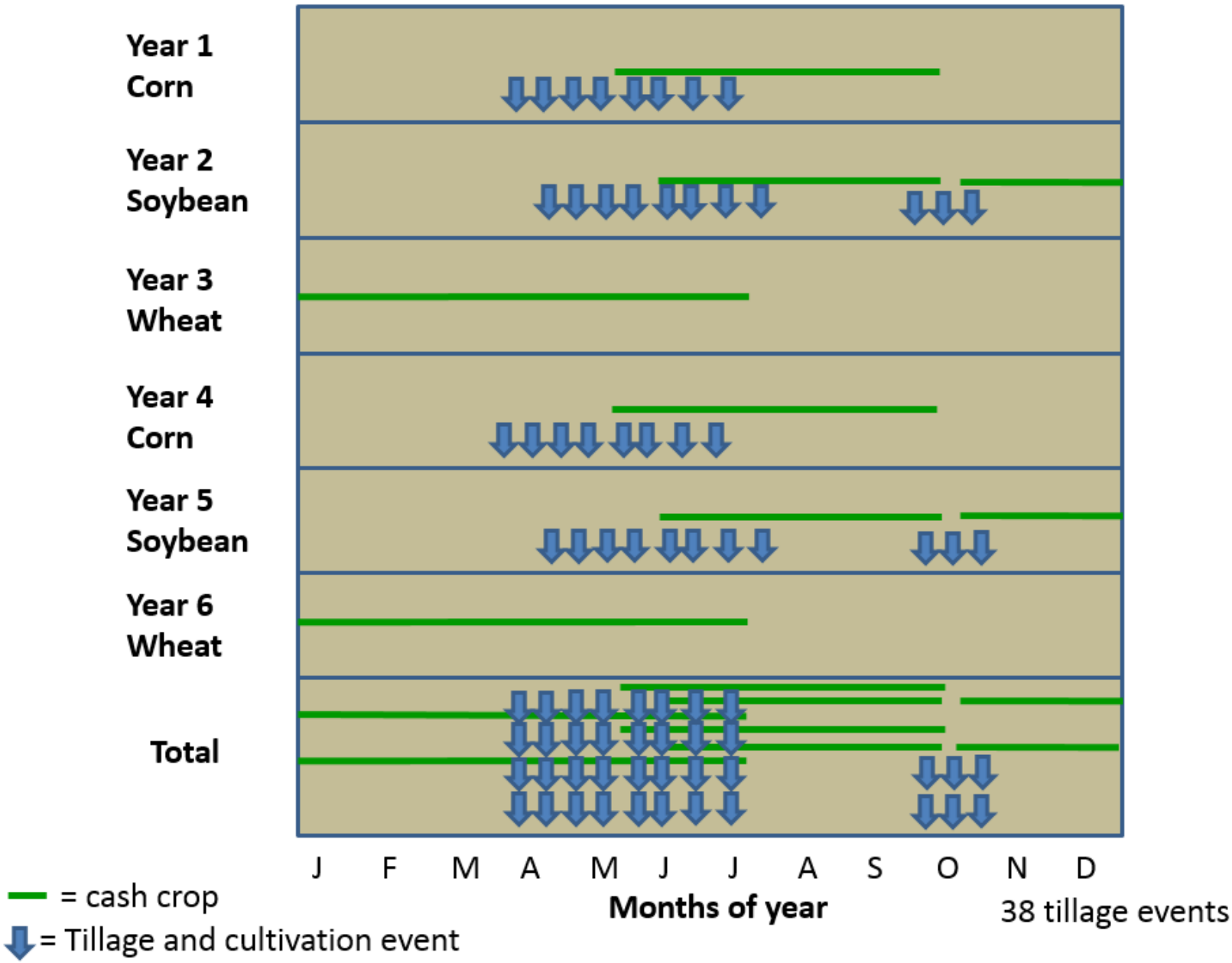
- More crops – summer, winter, perennial, planting date - cool, warm, etc.
- Different tillage mixed with no-till
- Cover crops and residue management
- Mowing, row cultivation, stale seedbed, others
- Fertility placement, variety selection, narrow rows, seed density, etc.

Crop rotation tactics

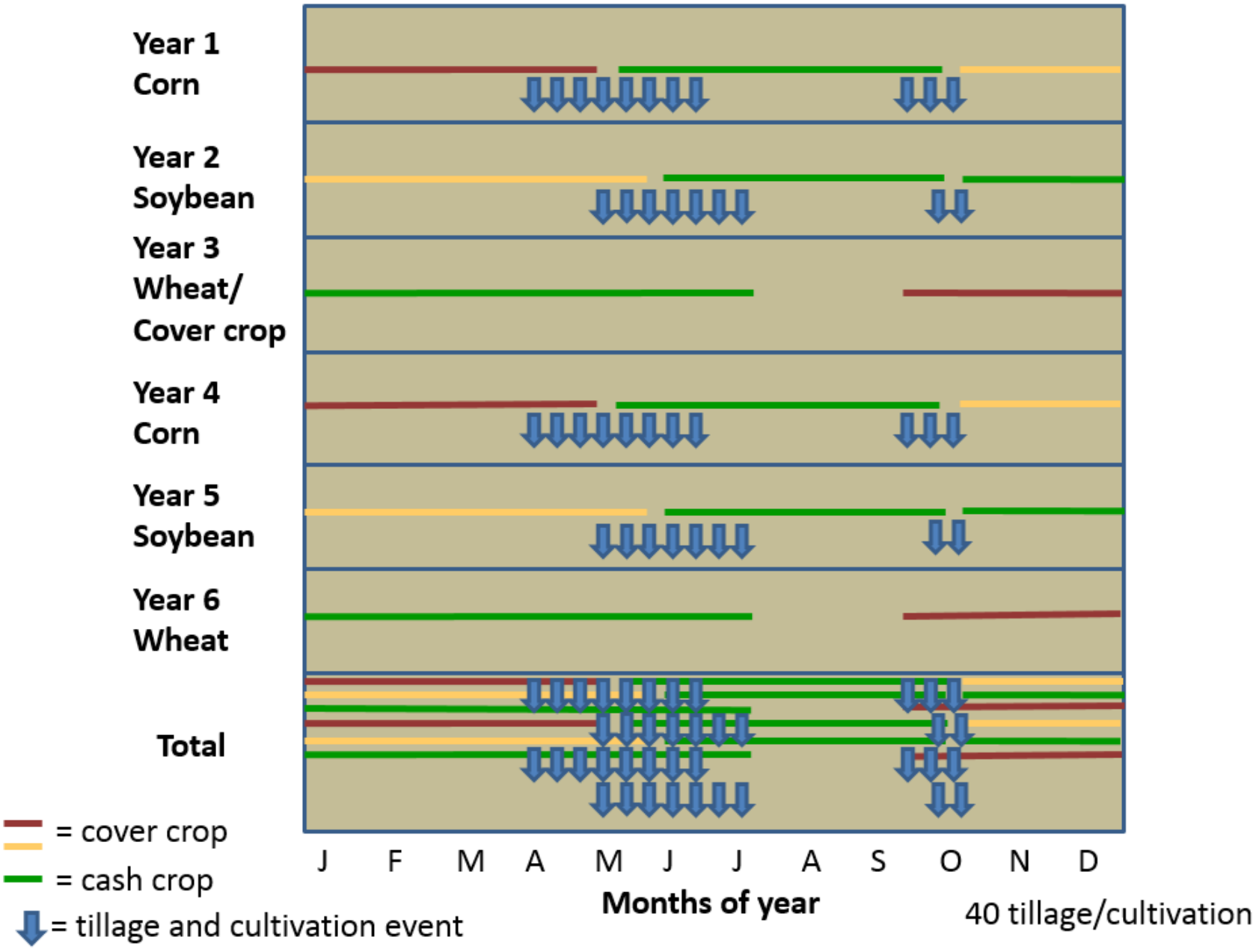
- Vary timing of crop management practices
  - Spring vs. fall
  - Early spring vs. late spring
  - Late summer vs. late fall
- Variation in soil conditions
  - Irrigated vs. dryland
  - Tillage vs. no-tillage
- Annual vs. perennial
- Seedling vs. transplant
- Incorporation of cover crops
- Intercropping

Simple vs. More Complex Rotations

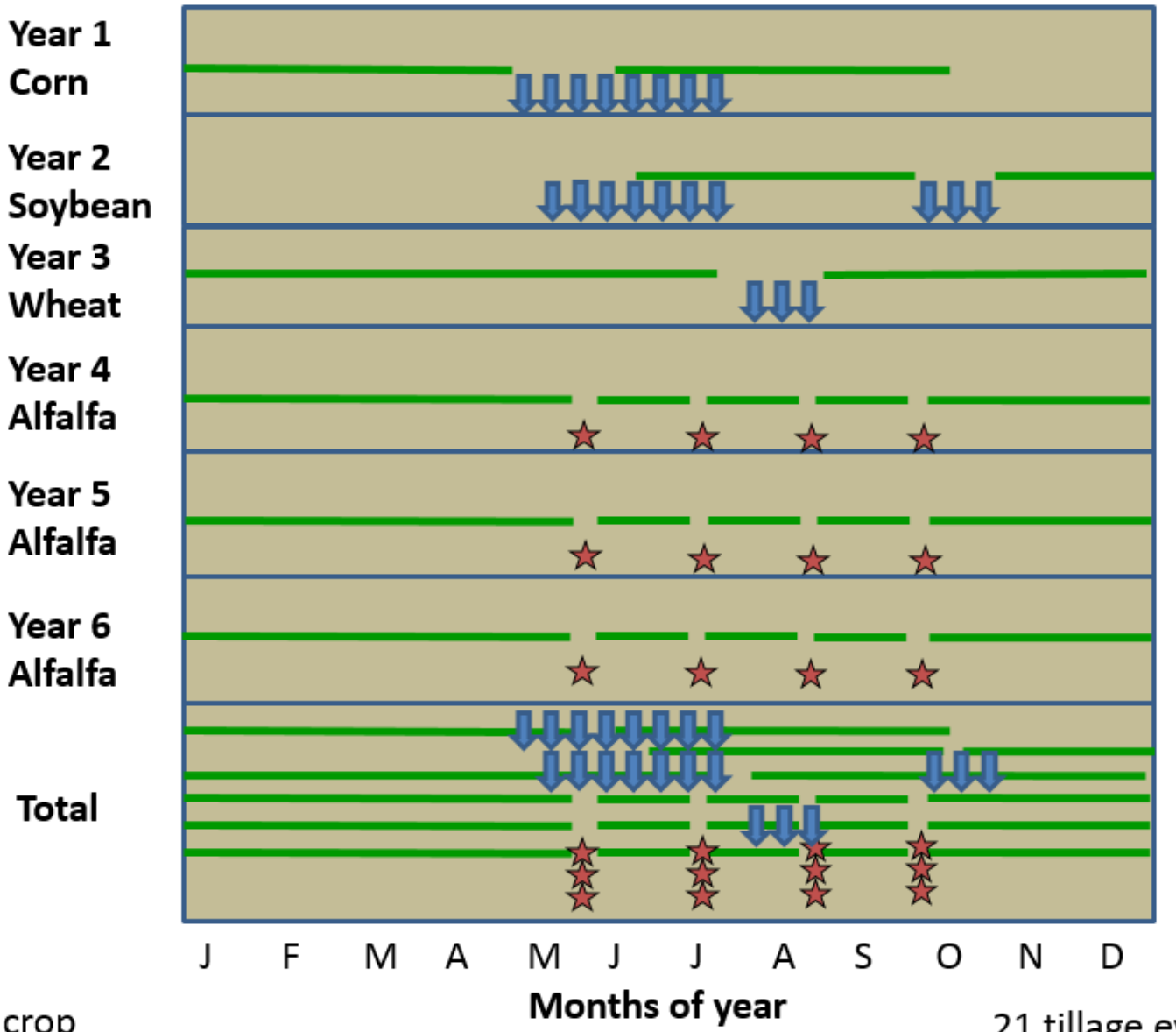
Three year organic rotation – 3 crops



Three-year organic rotation – 3 crops + 2 cover crops



Six year organic rotation – 4 crops



= cash crop

= tillage event

= mowing event

21 tillage events

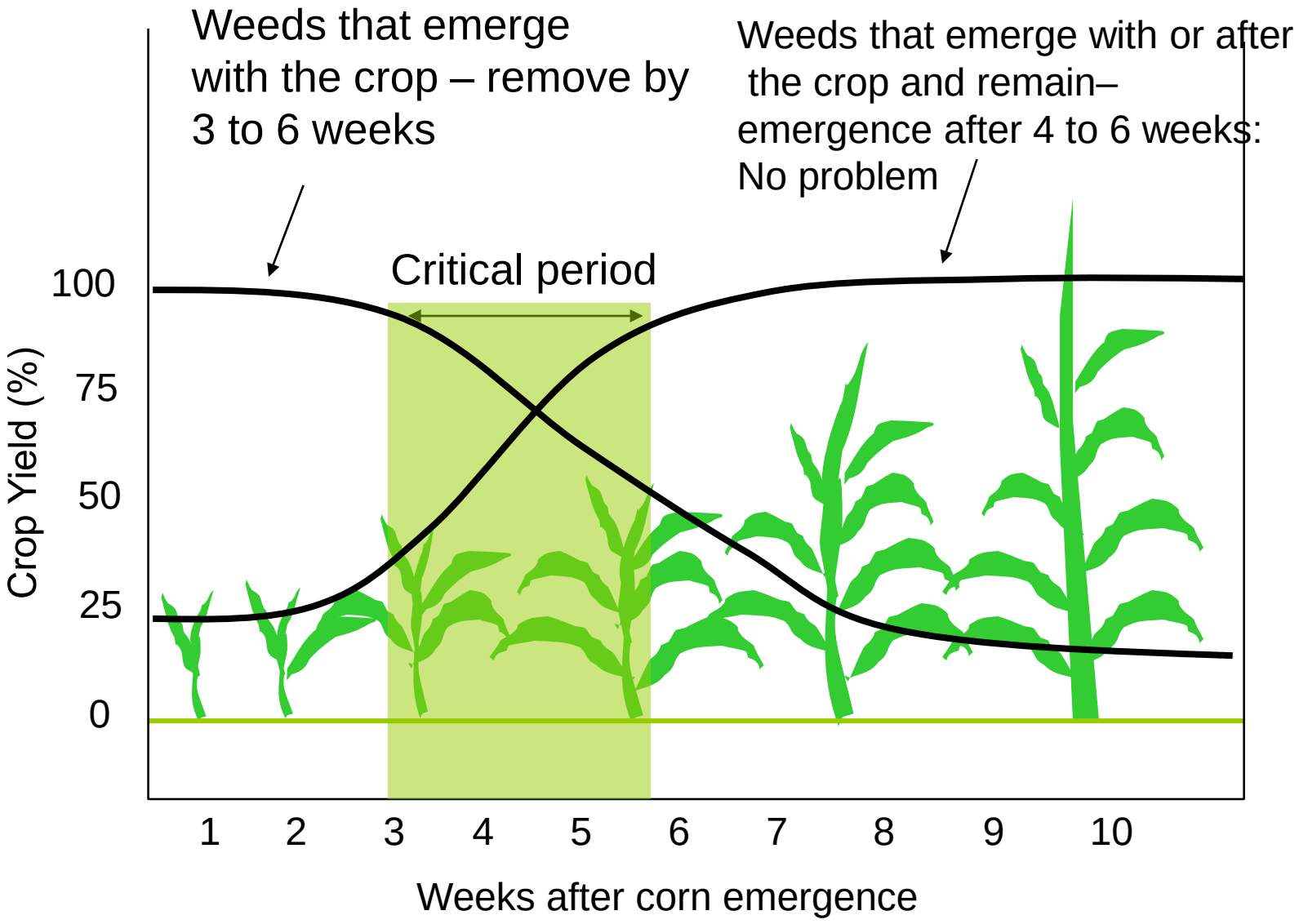
12 mowing

Cultural – Consider Plant Phenology

Cultural #2 – Know crop and weed phenology

- Phenology = Timing of lifecyle events – germination, emergence, growth, flowering, and maturation
  - "Critical period" – period where weeds must be controlled to prevent yield reduction
    - Remember different crops require different the weed-free periods or maximum yield (4-6 weeks for corn/soybean)
  - Herbicides, mechanical weeding, mulches aim at providing critical weed-free period – is it just 2 weeks or 12 weeks that is needed?

Critical Period of Weed Control



Cultural #2 – Know crop and weed phenology

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Phenology Example using crop rotation –

Rotate away from temperature & lifecycle related crops to help manage weed problems

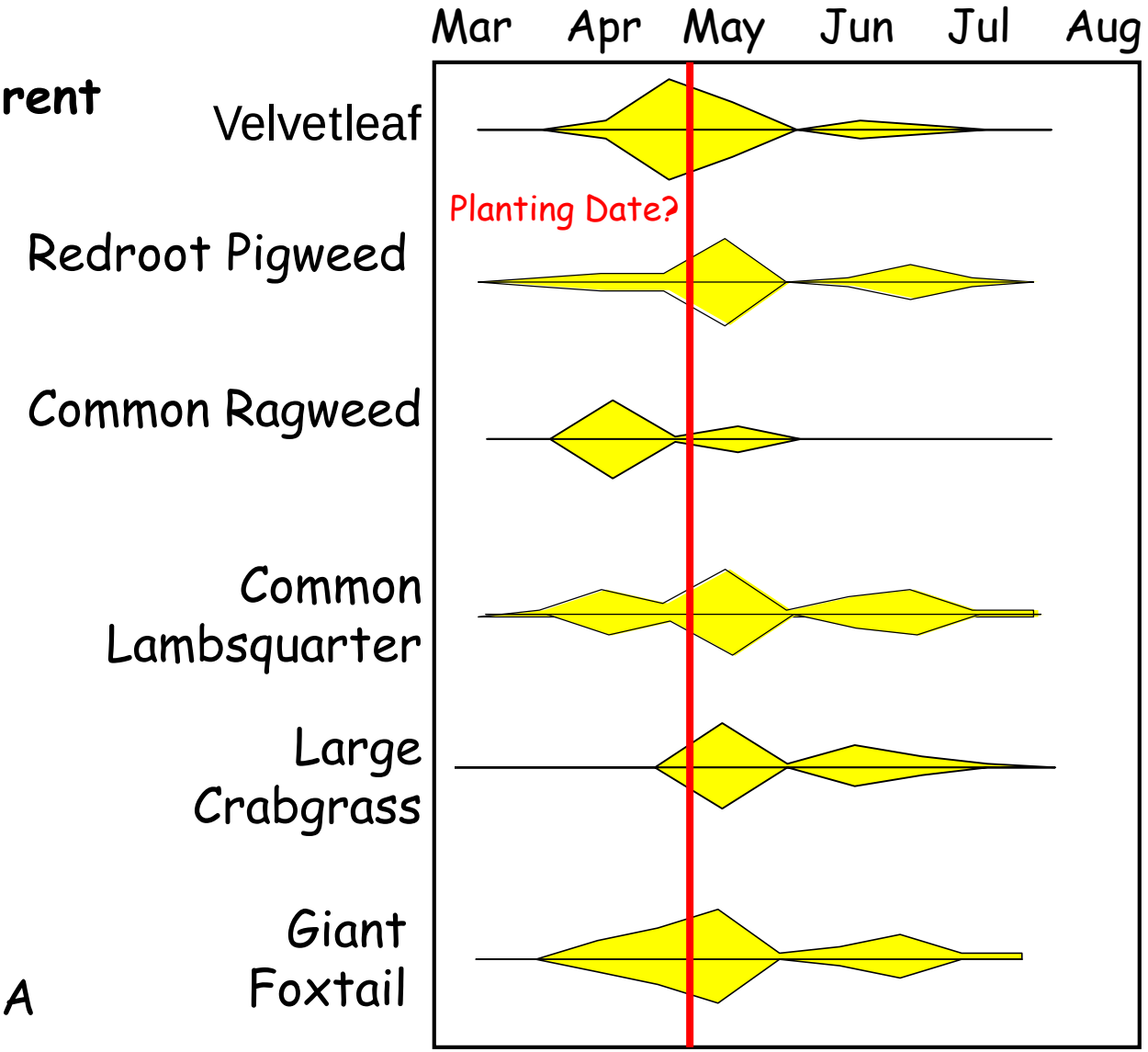
Fall	**Spring**	**Summer**	**Biennial/ Perennial**
Wheat	Corn	Sorghum	Alfalfa
Barley	Soybean	Buckwheat	Red Clover
Rye	Oats	Sunflower	Orchardgrass
Canola			Bromegrass
			Timothy

Weed Phenology - Emergence timing

- Understand when weeds germinate based on environment
- Optimize time of scouting
- Better match control strategies
  - Optimize time for tillage and crop planting to reduce weeds
  - Maximize effectiveness of mechanical controls (i.e. rotary hoeing and cultivation)

Weed Emergence Timing Chart

Weed species emergence at different times



Rock Springs, PA

Myers et al. 2004. PSU


Soybeans on Sep. 8
Tilled June 10
Tilled May 28

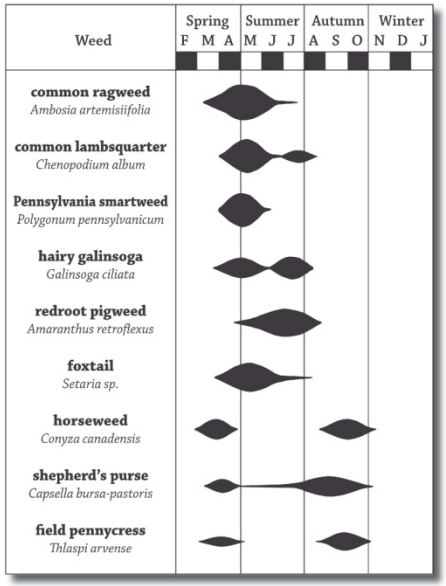
WEED GERMINATION PERIODICITY:

When Do Weeds Wake Up?

Tilling time *does* make a difference!

When we plant a grain or vegetable crop, we expect the seeds to germinate if the soils are warm enough and sufficiently moist. Seed germination for wild plants, including weeds, also requires sufficiently warm and moist soils, but in addition weed seeds possess controls that prevent seeds from germinating, called dormancy. Dormancy comes in a number of forms in weedy plants. Some seeds, like those of velvetleaf and morningglory, are hard-seeded. Here seeds remain "asleep" until the seedcoat is sufficiently etched by organic acids in the soil. Other seeds are sensitive to light, exhibiting the phytochrome response. Here, light quality, specifically a shift in the balance of near and far-red light, will wake seeds up (break dormancy). That shift in light or flash of light is provided by tillage.
Weed seeds, like crop seeds, are genetically programmed to germinate once a minimum temperature is exceeded. Unlike crop plants, weed seed germination can be "turned off" once the germination temperature range is exceeded. Recent research on seed dormancy has revealed that weed seed dormancy operates like a combination lock with a number of tumblers that must be aligned for the lock to be opened, for weed seeds to germinate. In effect, each of the tumblers represents an opening and when these tumblers or openings are aligned, seeds germinate. These tumblers define the germination period for each weed species. These periods have been a subject of considerable study and we know that some species germinate in the fall of the year, some in early summer, while others germinate in mid and late-summer. If any of the tumblers aren't aligned, the seeds don't germinate at all, persisting in the soil weed seedbank. Weed seed can persist in a dormant state for several years to decades.

Time of field operations can take advantage of germination periodicity. Tilling the soil early will stimulate early summer annual weeds, such as common ragweed and common lambsquarters, to germinate. Tilling three or four weeks later results in little or no common lambsquarter and common ragweed emergence. The scientific basis for delayed planting as a weed management practice is called ***weed seed germination periodicity***. Planting later in the season takes advantage of the fact that many weed seed have "gone back to sleep" for the remainder of the field season.



Proportion of weed seeds germinating throughout the season in central Pennsylvania.

Myers, M.W., W.S. Curran, M.J. Vangessel, B.A. Majek, D.A. Mortensen, D.D. Calvin, H.D. Karsten and G.W. Roth. 2005. Effect of soil disturbance on annual weed emergence in the northeastern United States. Weed Tech. 19:274-282.

Mortensen, D.A., L. Bastiaans and M. Sattin. 2000. The role of ecology in developing weed management systems: an outlook. Weed Research 40:49-62.

Matthew W., W.S. Curran, M.J. VanGessel, D.D. Calvin, D.A. Mortensen, B.A. Majek, H.D. Karsten, G.W. Roth. 2004. Predicting weed emergence for eight annual species in the northeastern United States. Weed Science 52:913-919.

PENNSTATE

Scientific Content: Dave Mortensen, Bill Curran, Matt Ryan, Andy Hulting, and Steven Mirsky, Weed Ecology and Management, Department of Crop and Soil Sciences, The Pennsylvania State University, University Park, PA.

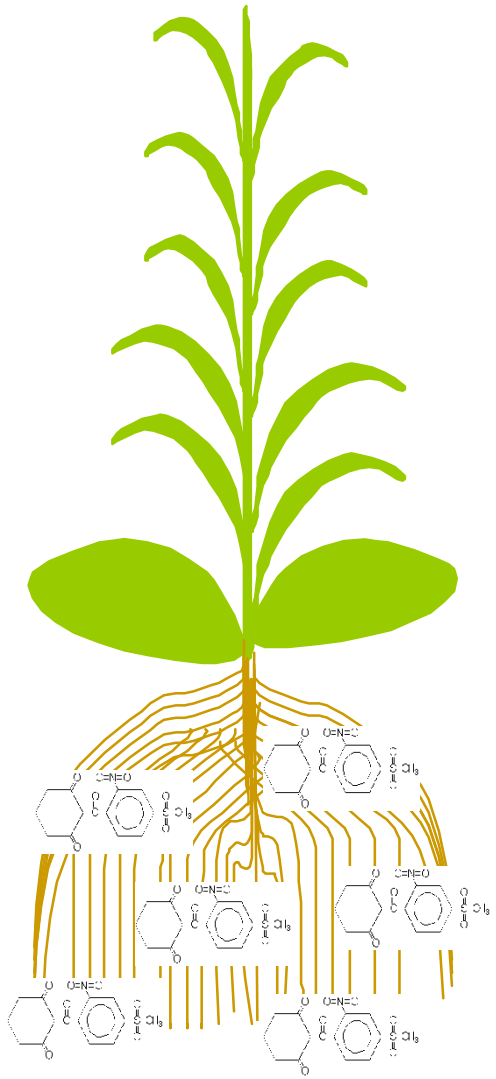
The RODALE INSTITUTE®

Data Visualization and Design: Libby Mortensen and Dave Mortensen. For additional copies email dmortensen@psu.edu

Cultural – Enhancing Crop Competition

Cultural #3 - Enhancing Crop Competition

- Early or late planting – before or after weeds
- Quick crop emergence
- Narrow row spacing
  - Effective for legumes and small grains
  - Maximum light interception – upright vs. horizontal leaves
- Cultivar selection
- Fertilizer type and placement – banded with crop and/or slow release
- Lots of other factors can enhance competitiveness



corn plant of the future:
allelopathic with big lower
leaves to shade the soil – Non GMO

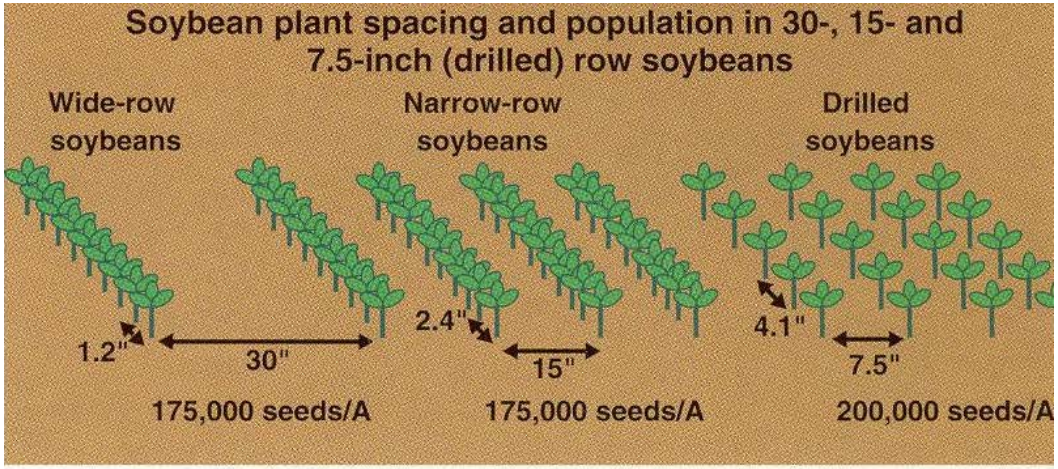


Figure 4. Soybean plant spacings and populations in wide-row and drilled soybeans. Source: Adam Davis.

Figure 5. Drilled (7.5-inch), 15-inch row and 30-inch row soybeans (left to right).

A competitive crop requires a good population

Organic growers should seed slightly more

Row spacing is one way to influence crop population

Anticipate cultivation requirements

Adam Davis 2005, Integrated Weed Management "One Years Seeding……"

Weed Management Tactics

- Cultural
- Mechanical/Physical
- Chemical and Thermal

Mechanical/ Physical

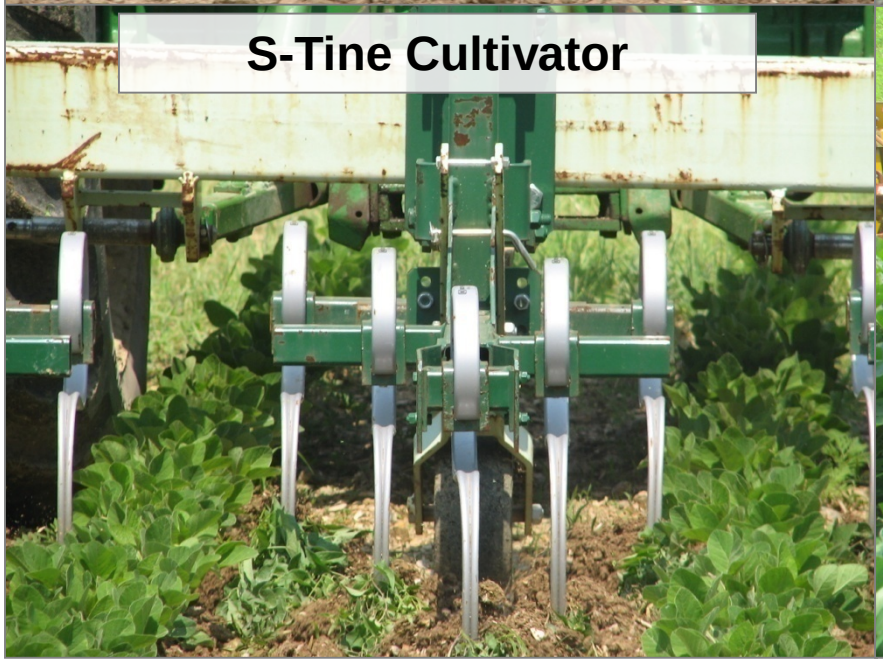
Often #1 tactic

Mechanical and Physical Control

- Tillage
  - Primary and secondary tillage
    - Plows, disks, field cultivators, rototillers, etc.
  - Blind tillage
    - Rotary hoes and tine weeders
  - Between row cultivation
    - Multiple/single sweep cultivators – low, medium, and high residue
    - Rolling cultivators
    - Horizontal disk cultivators
    - Others – brush weeders, finger weeders, torsion weeders, others


Moldboard Plow

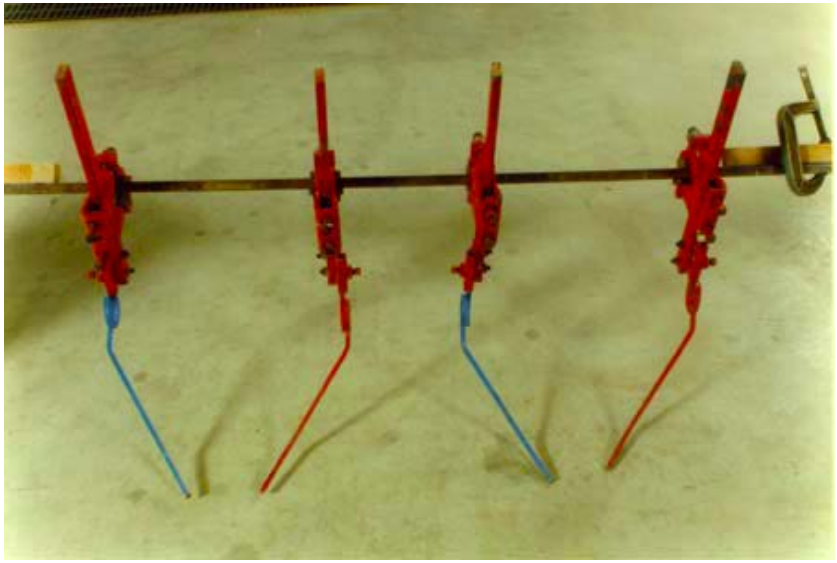

Rotary Hoe


S-Tine Cultivator

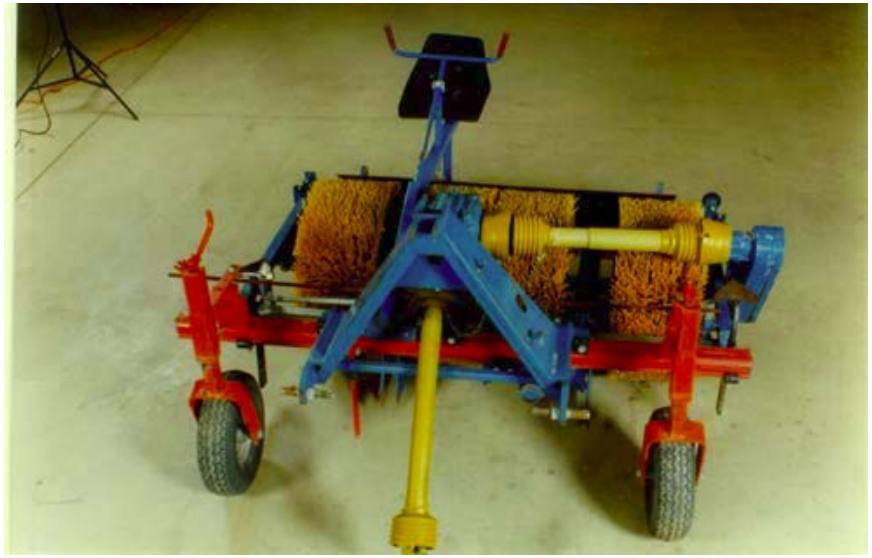

Straight-Shank Cultivator

Einbock flex-tine harrow

Bezzerides torsion weeder



Baertschi brush hoe



Buddingh finger weeder

Knowing just when to use just the right tool for just the right weed is critical to early season weed control.

White Thread Stage

- Most vulnerable stage in the life cycle
  - Key time to manage weeds

- Sensitive to environment
  - Moisture
  - Temperature
  - Pathogens
  - Physical barriers
  - Chemical toxins

Seedling Stage

- Vulnerable stage in lifecycle
- Still sensitive to environment
- Timing crucial for effective management

Too late for this one?

Mechanical: smaller vegetable farmers

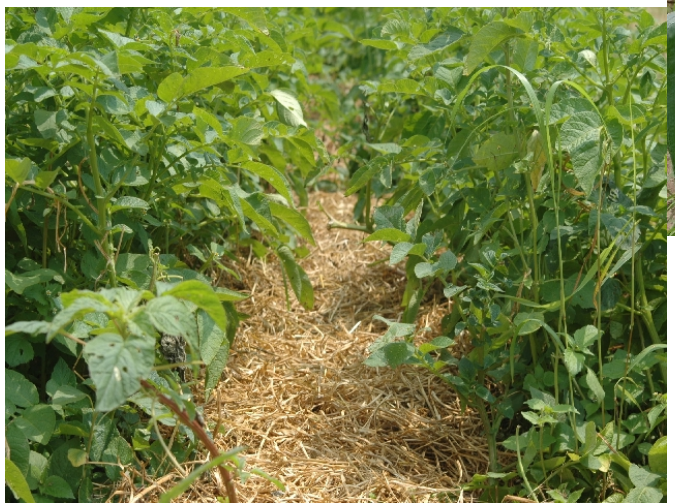
Courtesy of E. Gallandt, UME

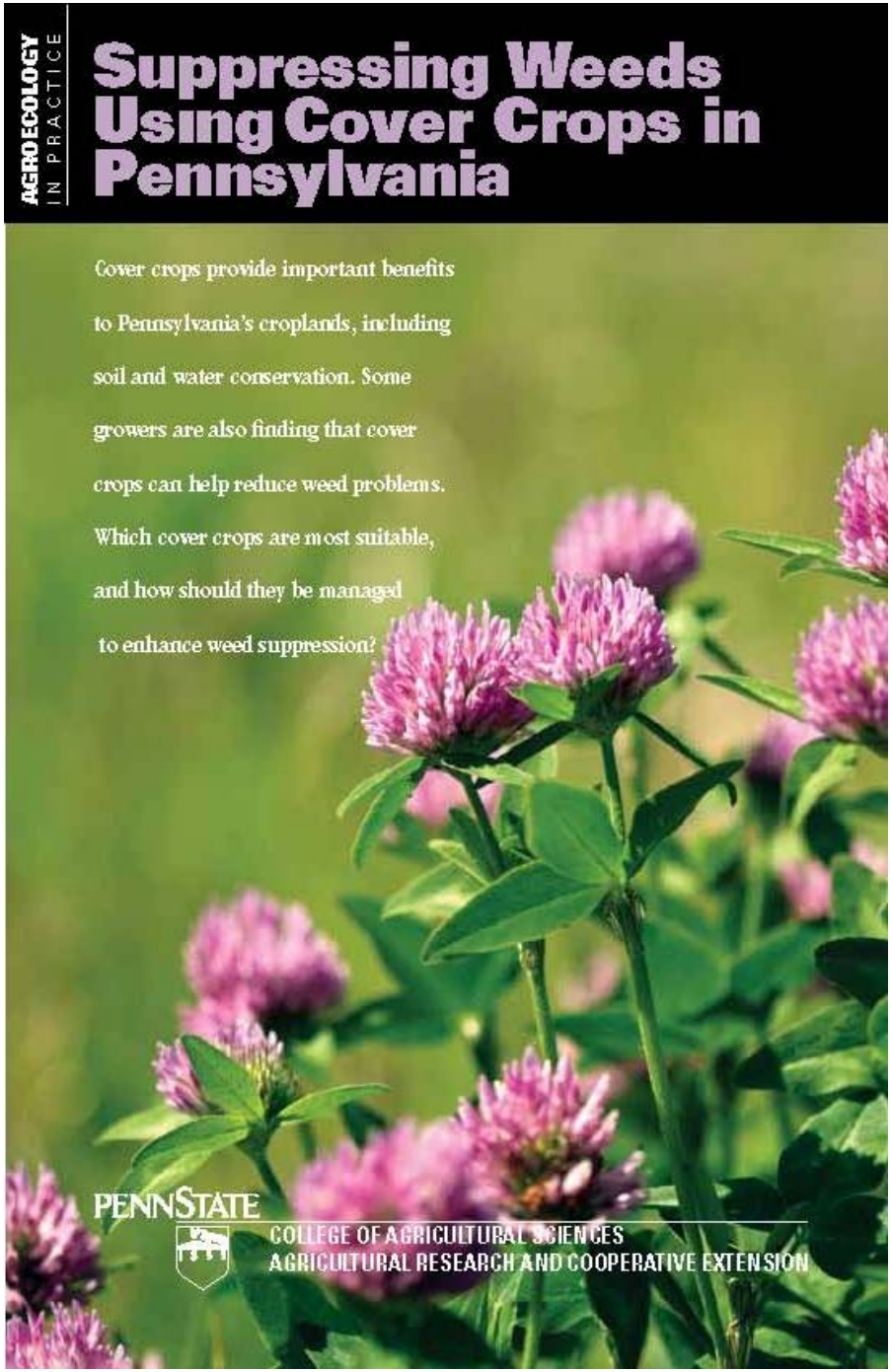

Allis Chalmers G Tractor
photo: Annens Machinery


www.mactrac.se
Swedish tractor – “vision guidance”
Courtesy of E. Gallandt, UME
BRÅNGEN

Mechanical/Physical cont.
Residue or Mulch Management

- Synthetic - plastics, polypropelene, others
- Plant based – paper, straw, bark, etc.
- Cover crops
  - Living
  - Killed





Penn State Ag Publications
Catalog No. UC210

http://pubs.cas.psu.edu/FreePubs/PDFs/uc210.pdf

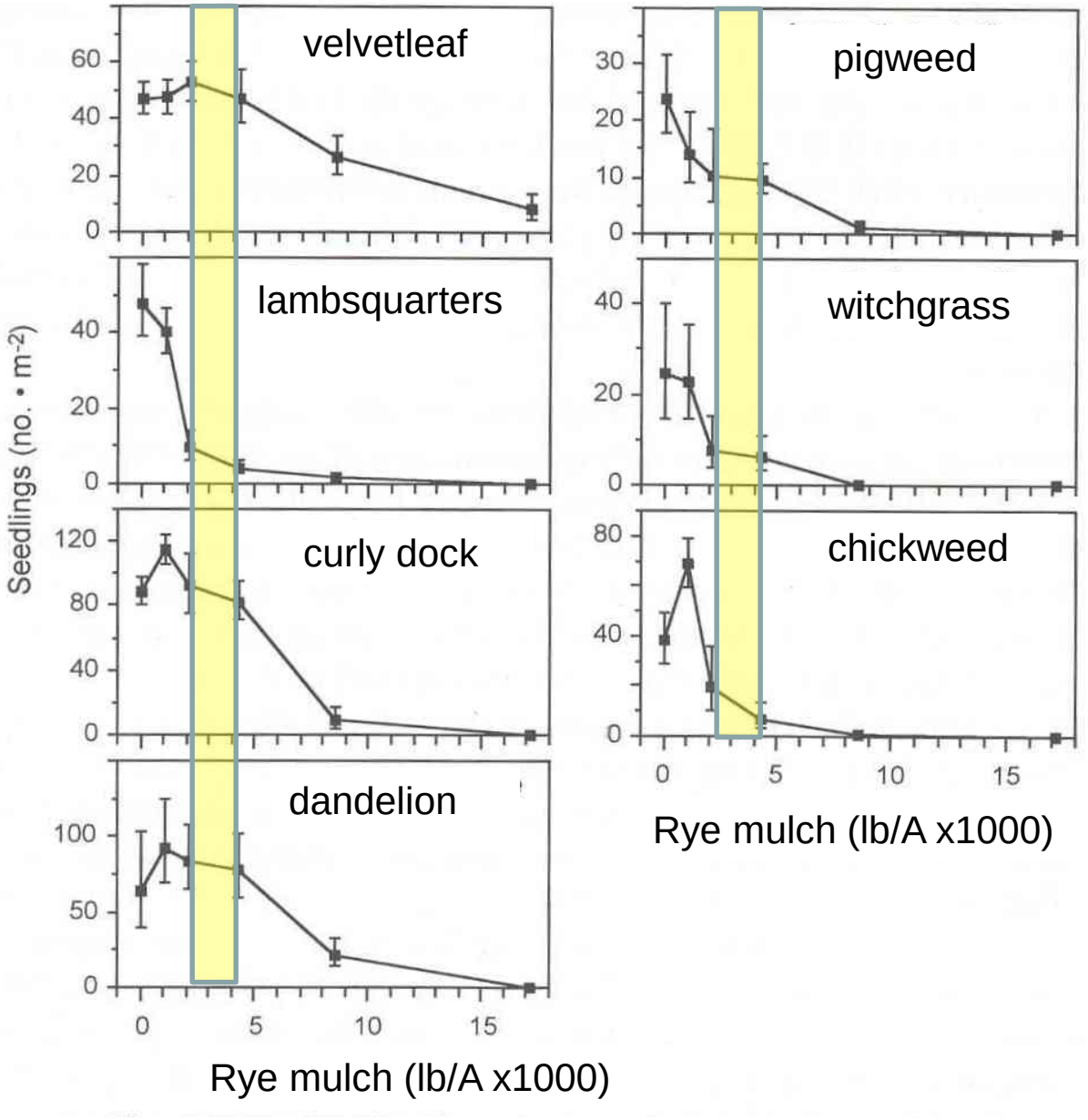
Weed Suppression by Cover Crops

- **Competition** - While a cover crop is alive it competes with weeds for space, nutrients, and light, interfering with the growth of weeds.
- **Physical suppression** - The mulch layer created by a killed cover crop interferes with germination and establishment of weeds while the mulch is intact, both by preventing germination and by physically interfering with establishment. This is especially effective against small-seeded weeds.
- **Allelopathy** - Some cover crops, such as forage radish and cereal rye, release chemical compounds which inhibit weed growth. This is known as allelopathy.
- **Cover crop control** - The disturbance created by spraying, mowing, tilling, or rolling a cover crop to control it can interfere with weed emergence and growth, especially when it occurs just prior to germination, emergence, or weed seed production.

winter cover crops can help reduce winter annual weeds


Winter rye
Forage radish
No cover
University of Maryland

Rolled hairy vetch mulch in corn 5 - 6 weeks after planting (Central VA)

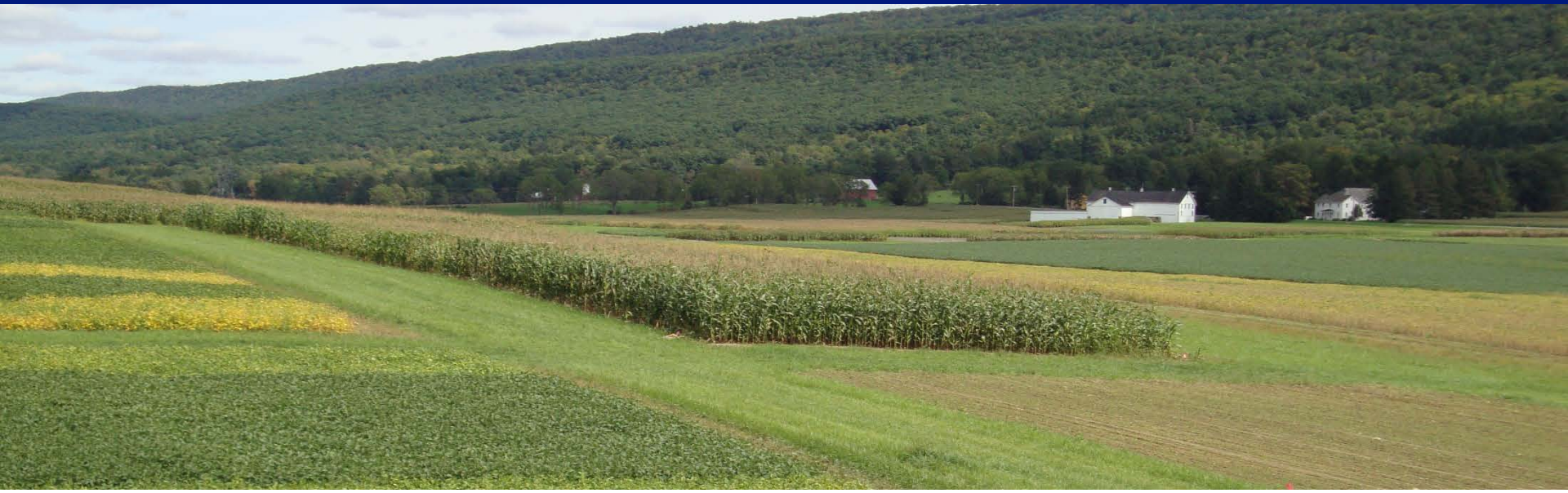


As rye mulch increases, weed density decreases

Effect of rye mulch biomass on weed seedling density (Mohler and Teasdale, 1993)

No-till organic
Challenging……

Reduced-Tillage Organic Systems Experiment (ROSE) – 2010-2013



Can we manage potential factors limiting yield and develop a cropping system that integrates rotational no-till in organic production?

Penn State **Extension**

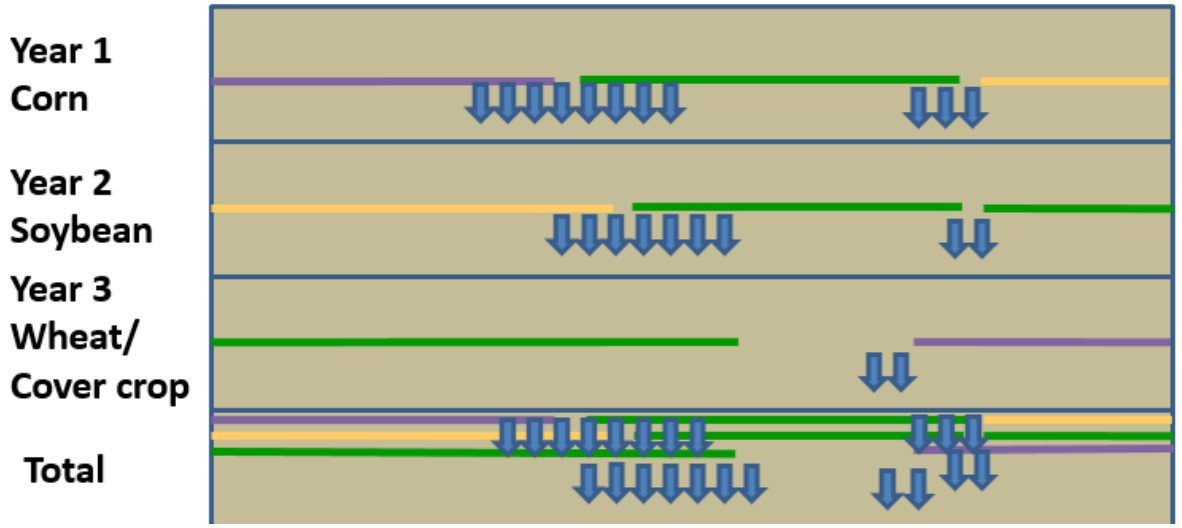
USDA NIFA

United States Department of Agriculture
National Institute of Food and Agriculture

Cover crops substituting for tillage

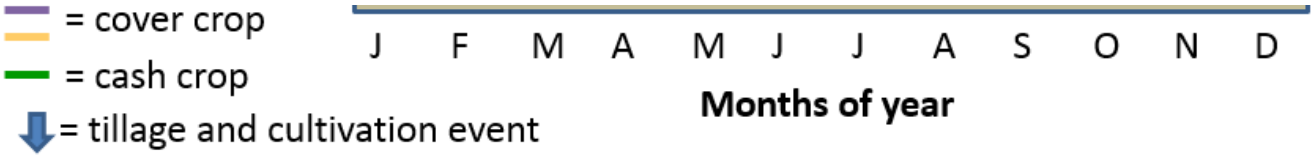
- Cover crop-based organic rotational no-till
  - Terminate cover crops with roller-crimper to form mulch
    - Cover crop must be susceptible to mechanical control
  - No-till plant cash crops
  - Rely on mulch for early season weed control
    - Need at least 4,000 to 6,000 lbs/A
    - Even more farther south

Tillage-based vs. rotational no-till



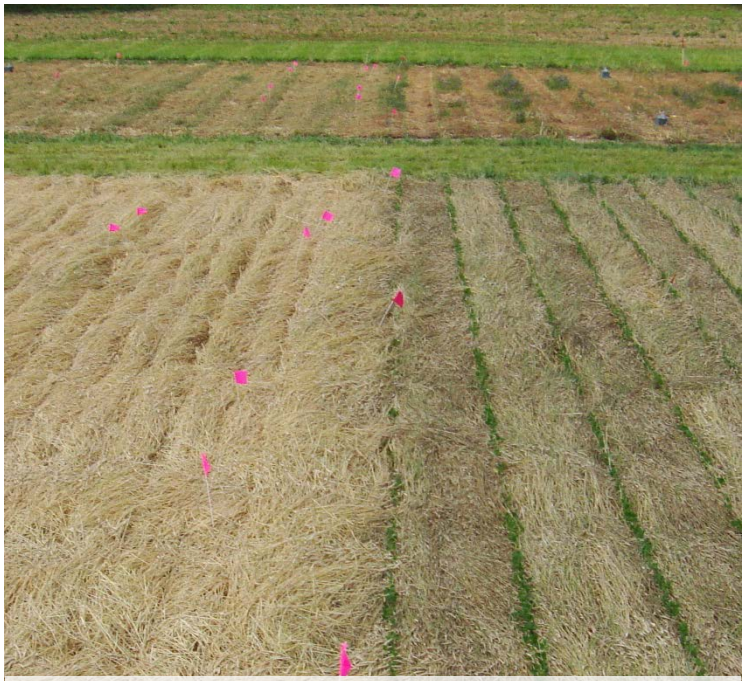
22 tillage/cultivation

vs.



ROSE (2010 – 2013): Project Summary

High-residue inter-row cultivation



Delay Cash Crop Planting Date

Project Summary: Developed cultural and mechanical strategies that:

1) Consistently grew high biomass cover crops
2) High residue cultivation provided effective supplemental weed control
3) Effectively controlled weeds below economic thresholds
4) Promoted conservation biocontrol of early-season invertebrate pests

ROSE (2010 – 2013): Project Summary

Effect of planting date on volunteer rye

Effect of high-residue on crop establishment

Project Summary: Agronomic challenges include:

1) Consistent termination of cover crops with roller-crimper
2) Consistent cash crop establishment in high-residue mulches
3) Low to average cash crop yields
4) Constrained nutrient management due to narrow agronomic windows
5) Narrow window for fall cover crop establishment following harvest

ROSE 2.0 2014-2017

- Varing tillage intensity and timing
- Frost seeding clover in spelt
- Interseeding cover crops in corn
- Injecting manure
- Greater focus on nutrient dymanics

Winter 2015
Volume 5, Issue 1

Manure Injection on 15-inch row spacing prior to spelt planting (credit: Mazzone)

Inside this Issue:

Have questions or comments about something you've read or seen in *The ROSE Review?*

Contact:

John Wallace, jmw309@psu.edu or Mary Barbercheck, meb34@psu.edu

The ROSE Review

Reduced-tillage Organic Systems Experiment Newsletter

A New ROSE in Bloom

Welcome to the latest issue of the ROSE Review! The ROSE Review was started in 2010 to connect project collaborators and stakeholders so we could share the latest news on our USDA Organic Research and Education Initiative (OREI) funded project, *Improving Weed and Insect Management in Organic Reduced-tillage Systems*. Our last ROSE Review, issued in winter 2013, marked the end of field research (2010-2013) and a period of transition. It has been an eventful two years, so please allow us to catch you up on ROSE activities!

Our PhD candidates, Clair Keene (Plant Science) and Ariel Rivers (Entomology), spent much of the past two years synthesizing data collected during the ROSE project (2010-2013). This was not a small task, given that the cropping system study was evaluated at three Mid-Atlantic locations: Penn State's Russell E. Larson Agricultural Research and Education Center (RELARC) in Rock Springs PA, the USDA's Henry A. Wallace Beltsville Agricultural Research Center in Beltsville MD, and University of Delaware's Carvel Research and Education Center in Georgetown DE. Several journal articles are slated for publication in upcoming years. Our research technicians, Mark Dempsey and Christy Mullen, also worked diligently to obtain organic certification of our Penn State ROSE research site (~ 5 ac) in the winter of 2014. Alas, no ROSE bloom lasts forever. Clair, Ariel and Mark are starting new and exciting careers in sustainable agriculture this winter, and our Maryland and Delaware collaborators, Steven Mirsky and Mark VanGessel, remain close but have initiated new and exciting lines of research.

During this period of transition, we took time to identify both successes and challenges that emerged from the ROSE. Our project evaluated a cover crop-based, rotational no-till system using a corn-soybean-wheat rotation, which utilized the roller-crimper to terminate overwintering cover crops and enabled no-till planting of summer cash crops into rolled cover crop mulches. Encouragingly, rolled cover-crop mulches promoted conservation biological control of early-season invertebrate pests and our cultural and mechanical weed management strategies kept weeds below yield-limiting levels during the three-year organic transition. However, we also found that inconsistencies related to cover crop termination with the roller-crimper and planting into high levels of cover crop residue can result in volunteer cover crops and below-optimum crop yields. In addition, we found that short agronomic windows for manure management and cover crop establishment are likely obstacles to grower adoption of these strategies.

In the fall of 2014, a new ROSE bloomed that draws on our previous successes and tackles persistent challenges. We are excited to introduce "ROSE 2.0", which we have come to call our new USDA-OREI funded project (2014-2018), *A Reduced-Tillage Toolbox: Alternative Approaches for Integrating Cover Crops and Reduced-Tillage in an Organic Feed and Forage System*. In this ROSE Review, you will learn about the details of our new experiments. You will meet new students, technicians and collaborators. And finally, you will get an initial look at summary results from our first crop year. We hope you enjoy!

High residue cultivation in corn (credit: Mazzone)

http://agsci.psu.edu/organic/research-and-extension/rotational-no-till

Weed Management Tactics

- Cultural
- Mechanical/Physical
- Chemical and Thermal

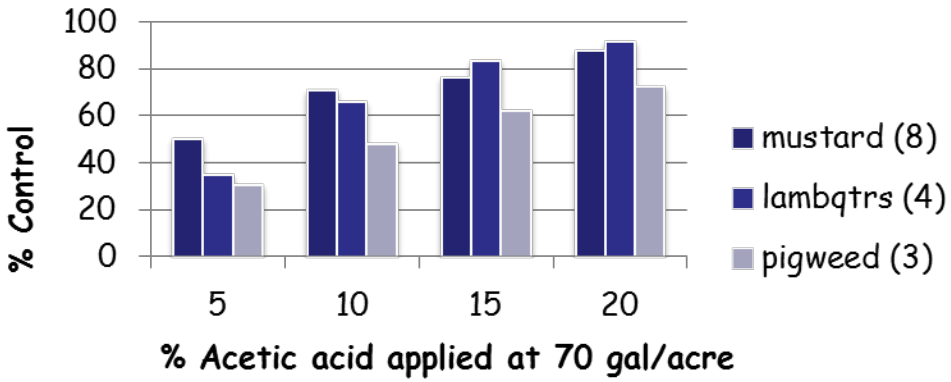
Herbicides and Thermal

Herbicides

- Acetic acid (vinegar)
- Clove leaf oil
- Lemon grass oil
- Corn gluten meal

Thermal

- Flaming (propane)
- Steam sterilization
- Solarization – cover moist soil with clear plastic




103
20% Vinegar
+Nu-Film P
60 GPA
3 DAA


Courtesy of Stevan Knezevic, Univ. Nebraska

Take Home Messages

- Understanding weed life cycles and how weeds interact with crops is important for successful weed management
- Crop success is more likely with less weed seeds in the soil, and growers should actively manage to prevent weed seed additions
- Diversity is essential for overall system resilience, and for effective long-term management success
- An integrated approach that uses rotation, mowing, and tillage diversity along with proactive targeted management (hand weeding, flaming, etc.) is necessary for success in organic agriculture

Questions?