Weed ecology and management for organic production

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Outline

- Let’s talk experiments…
- Lecture stuff

1. Impacts of weeds
2. Ecological weed management principles
3. Integration→ Management strategies

1. Impacts of weeds

A. Yield loss!

B. Interfere with harvest

C. Pest interactions

D. Time, labor, and money spent controlling

1. Herbicide use in our conventional farming systems
2. Developing world
3. Organic farms…???

1a. Impacts of weeds—yield loss

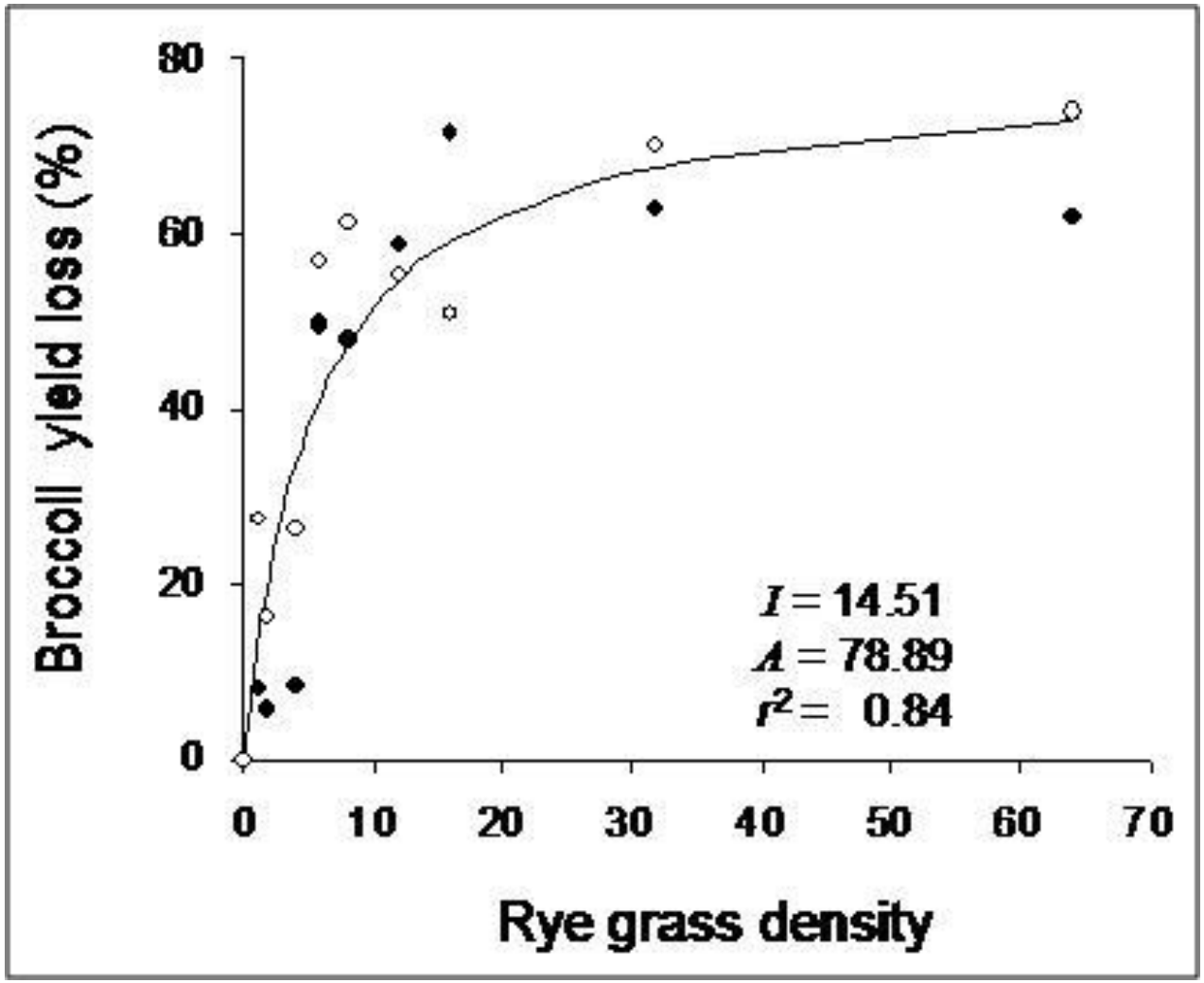
- **What percentage of all pesticides used in U.S. are herbicides?**

>60%

- **Estimates of average crop yield losses due to weeds range from 12-25% (Pimentel et al 2000; Parker and Fryer 1975).**

And this is WITH weed control measures!!!

1A. Impacts of weeds: Yield loss



..but results vary!!

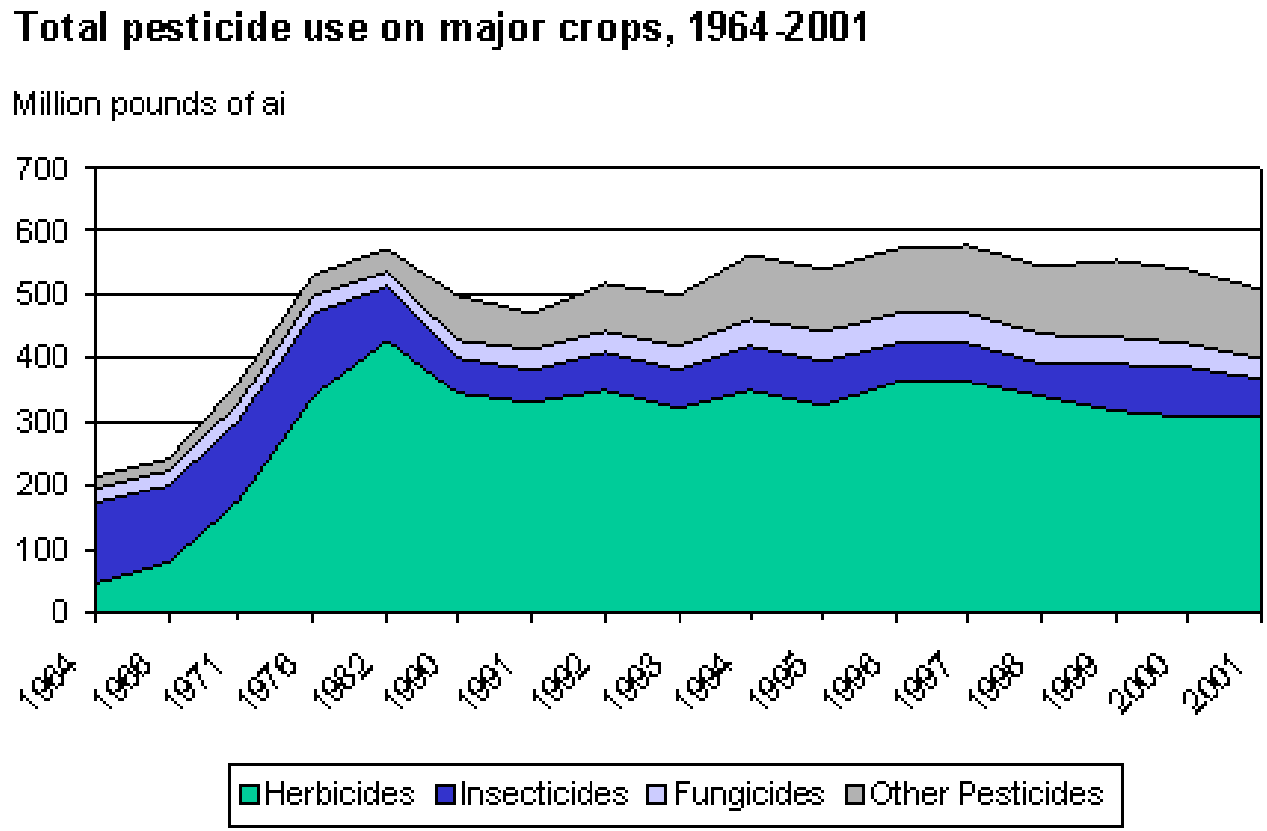
1B. Impacts of weeds: Harvest efficiency and indirect effects

Saginaw area; pepper harvest

1C. Impacts of weeds: Pest interactions

Tarnished plant bug on
Powell amaranth (*Amaranthus powellii*) in asparagus

1D.1 Impacts of weeds: Herbicide use in the US



Source: Economic Research Service

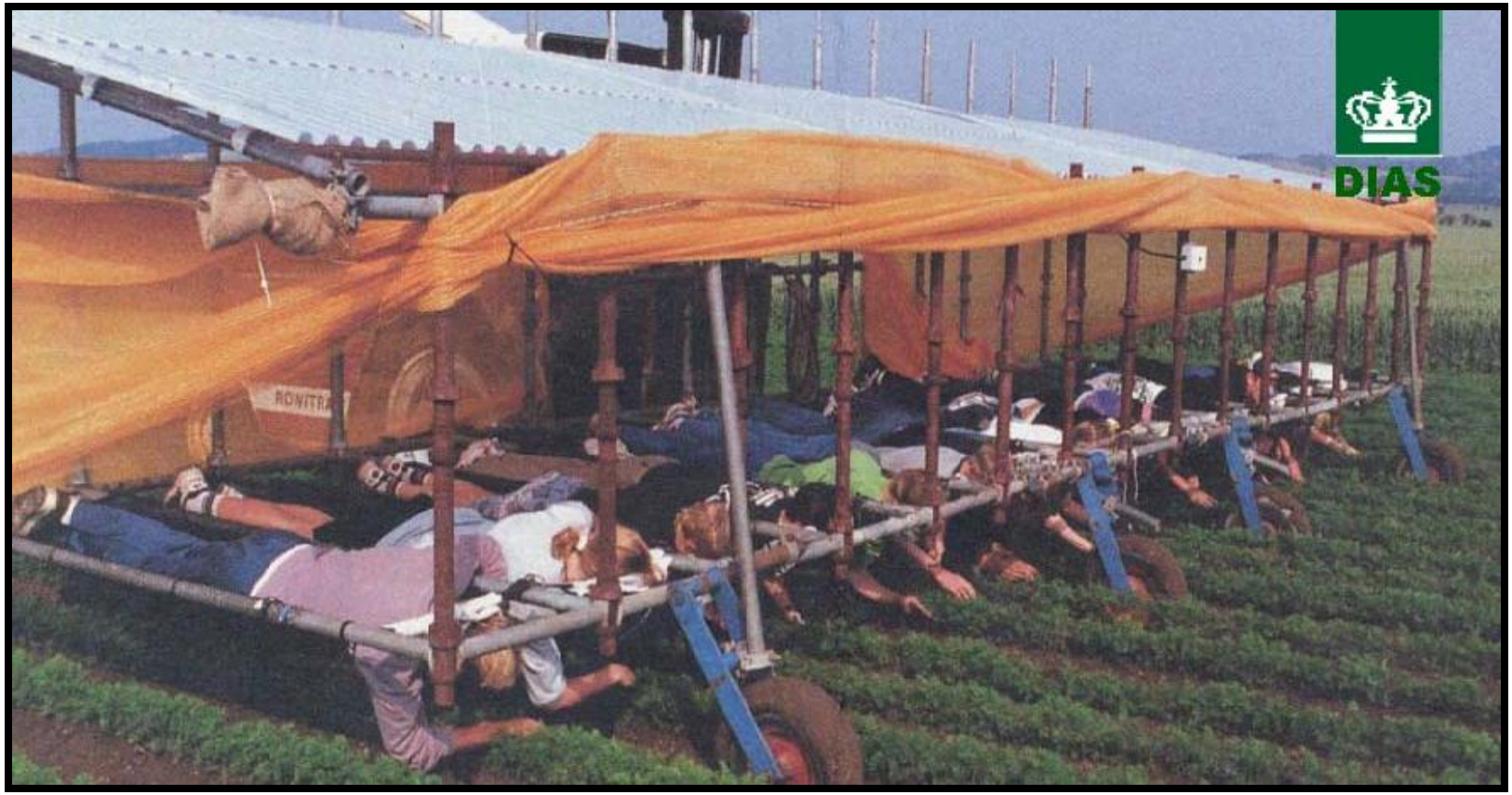
1D.2 Impacts of weeds: Developing world

1D.3 Impacts of weeds: Organic farms

On organic farms in U.S., weeds are generally considered the worst pest problem (OFRF 1999; Bond and Grundy 2001)

Organic asparagus—Oceana County, MI

1D.3 Impacts of weeds:
Costs of management



50 hrs/A in direct seeded organic carrots—what do you pay your labor?

Amount of manual weeding needed

- Costs
- Organization
- Availability

Crop	Management	Hour/ha (NL)
Onion	direct-sown	177
Carrot	direct-sown	152
Sugarbeet	direct-sown	82
Sugarbeet	transplanted	28
Vegetables	transplanted	46
Cereals	direct-sown	7

2. Ecological Weed Management

- groundwork: Characteristics of weeds
- Come up with 8-10 characteristics of weeds… what makes them “weedy”? Why are they so difficult to control? How are they similar to/different from insect pests?

2. Ecological weed management

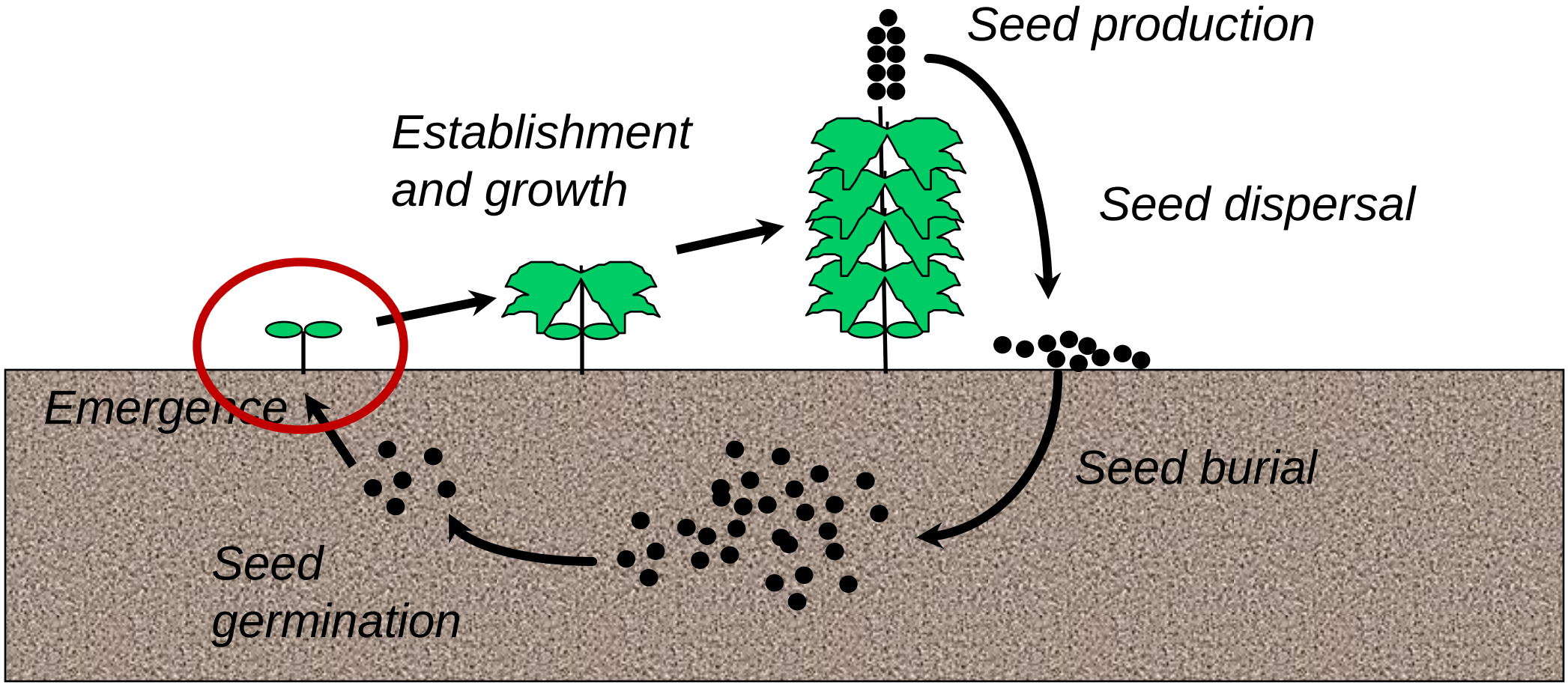
A. **Apply knowledge of weed life cycles to identify and target weak points**

B. **Prevention easier than treatment**

C. **Thresholds: know when a weed is likely to cause problems, and when it can be left alone.**

D. **"Many little hammers": Use multiple tactics to maximize effectiveness and minimize risks**

2A. Annual weed life cycle

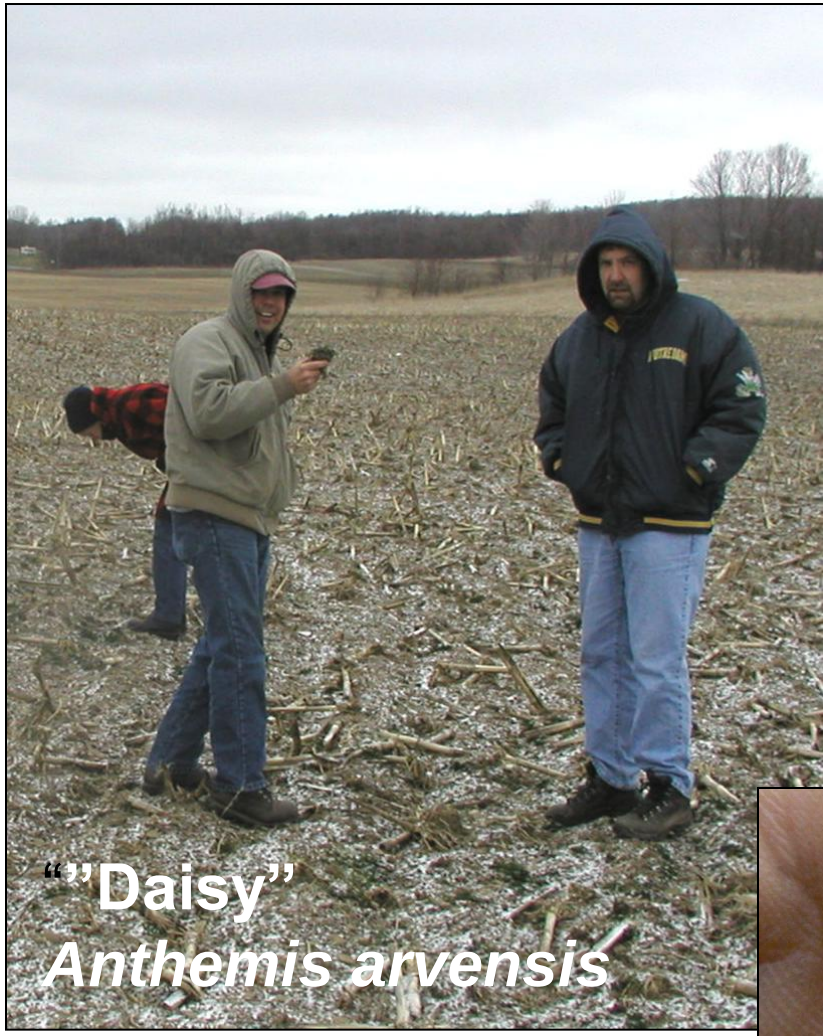


"Weed seedbank"

2A. Weed life cycles

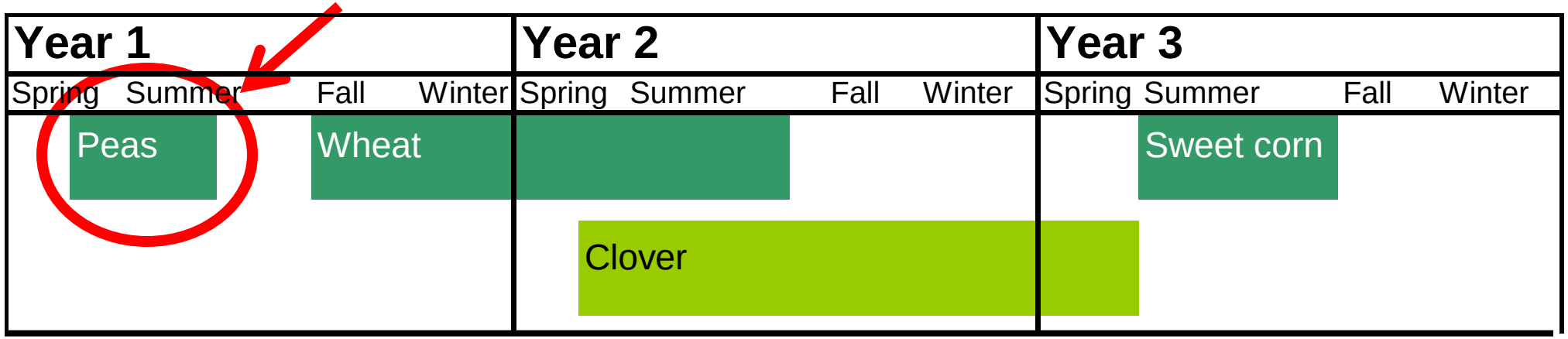
- Summer vs winter annuals
- Bienniels
- Perennials

2A. Case study: Corn chamomile in peas



Typical NY pea rotation

Problem occurs here….



…but when and how to best manage?

Corn chamomile in peas: Where is seed production occurring?

Wheat

Peas

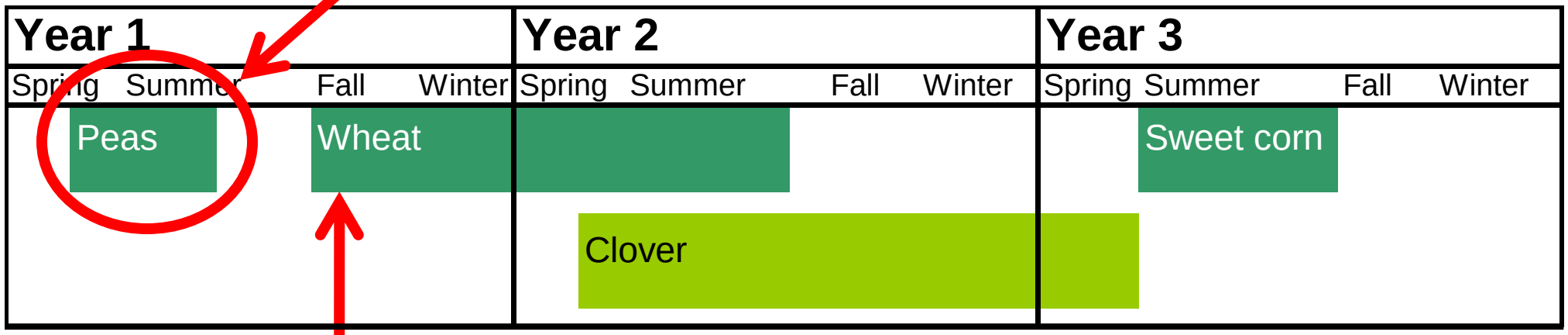
Results: Estimated seed production in rotational crops

Crop	1,000/m^2
Corn	0.0
Peas	0.1
Wheat	10.0

→ Prevention in peas requires better management in wheat

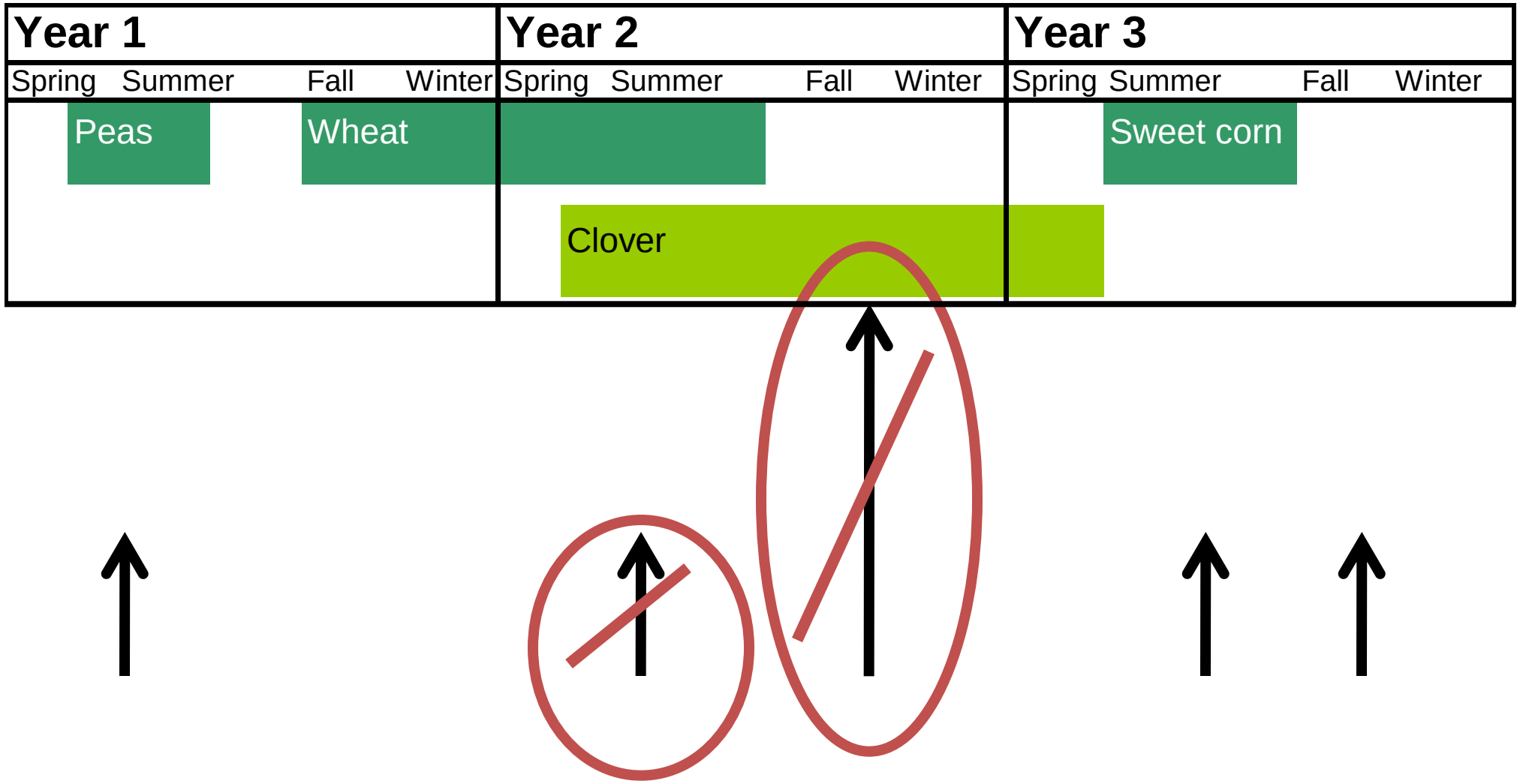
Corn chamomile in rotation

Problem occurs here….



Prevention best achieved here—these individuals producing most seed

Corn chamomile in rotation



Case where costs of cover crop outweigh benefits???

2. Ecological weed management

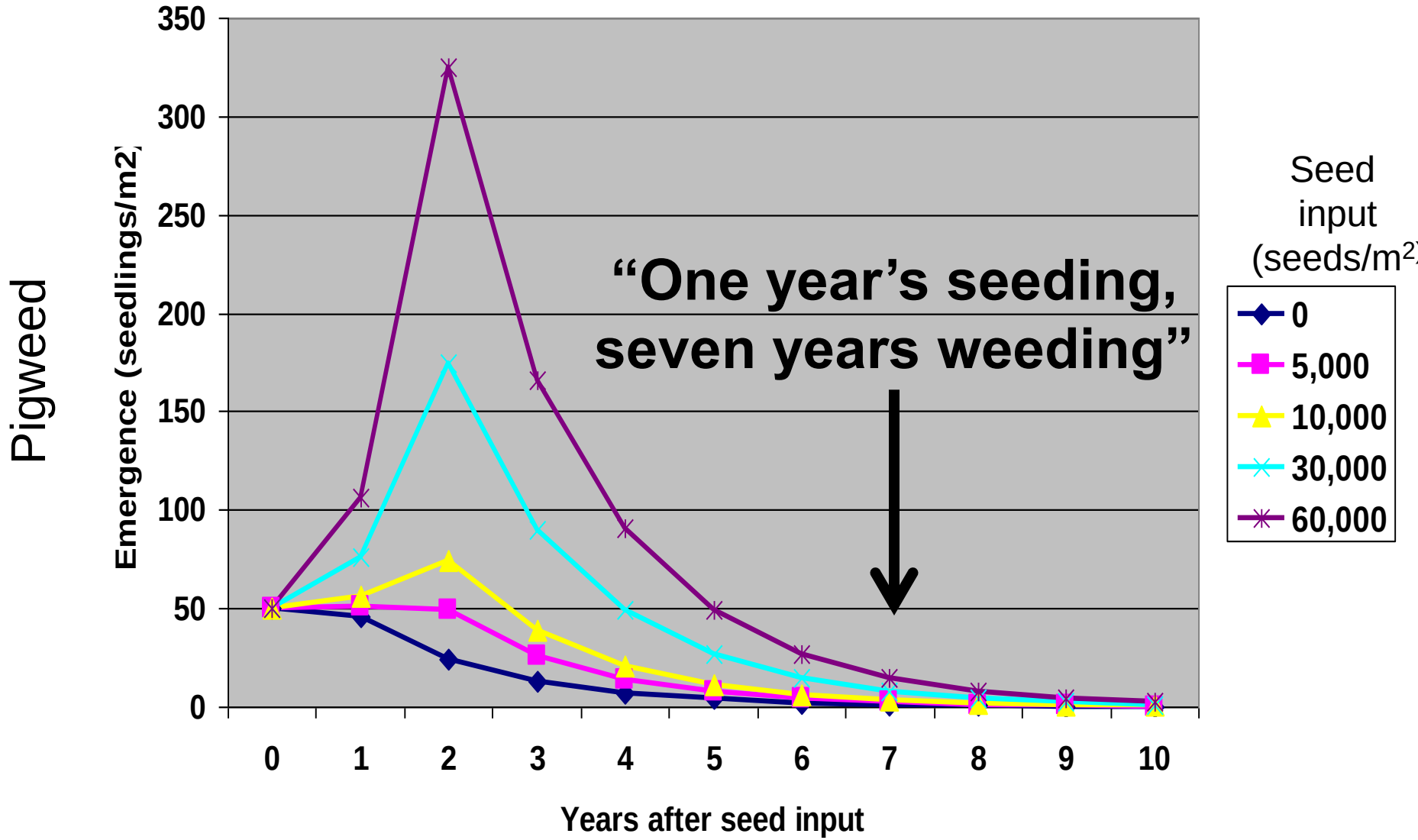
A. **Apply knowledge of pest life cycles** to identify and target weak points

B. **Prevention** better than treatment

C. **Thresholds**: know when a weed is likely to cause problems, and when it can be left alone.

D. **"Many little hammers":** Use multiple tactics to maximize effectiveness and minimize risks

Future costs of seed production



Brainard 2002

2. Ecological weed management

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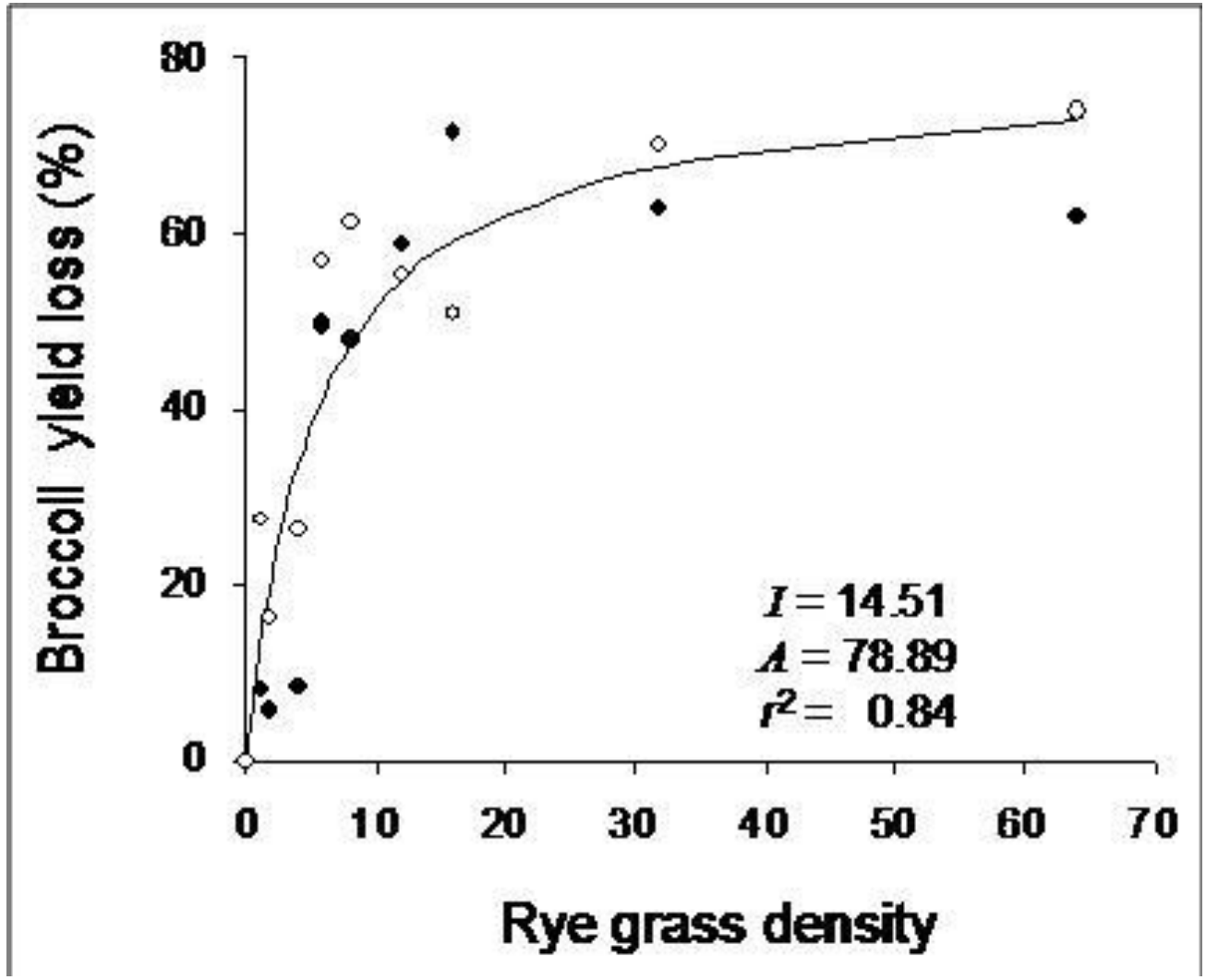
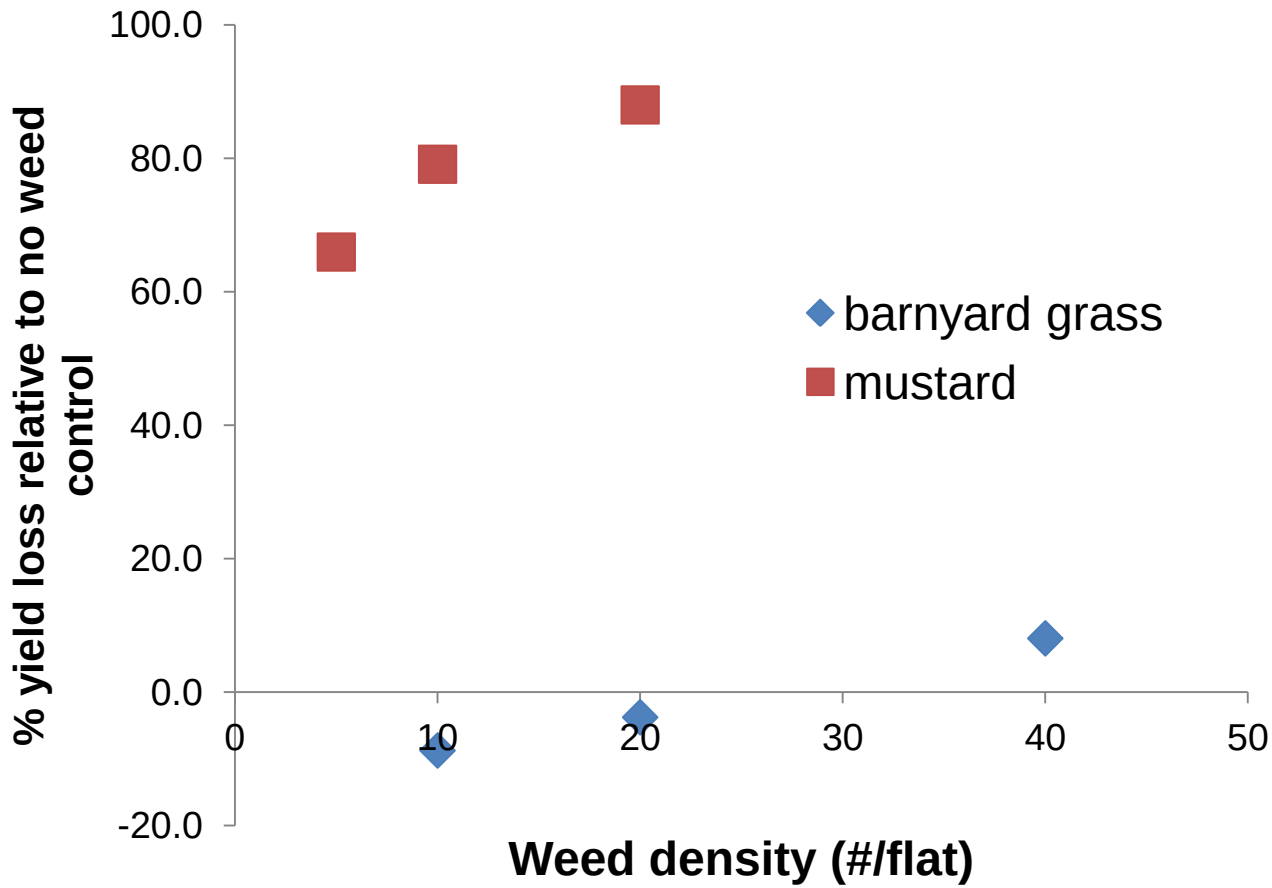
2.C Thresholds

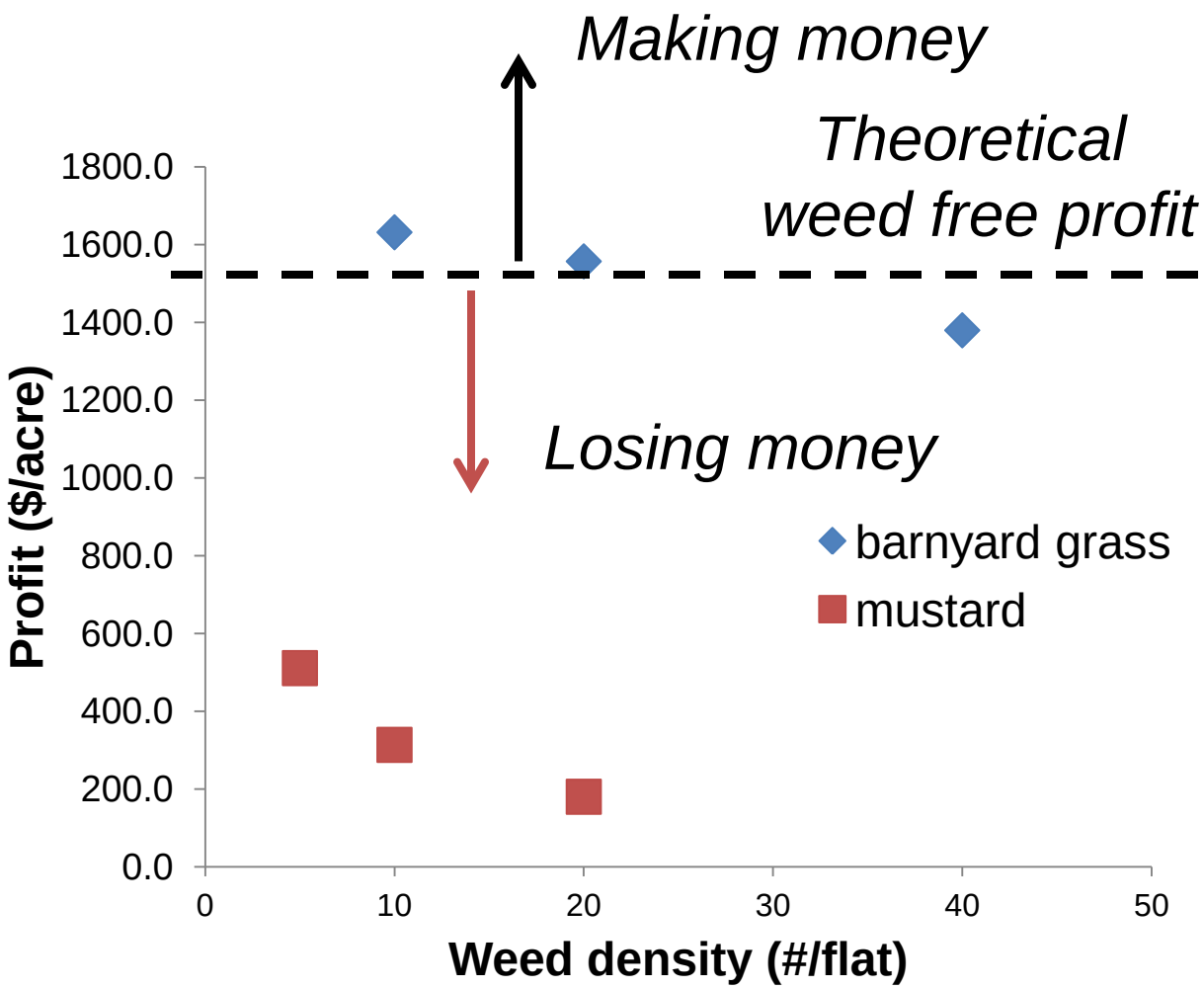


2.C Thresholds—peer-generated data!



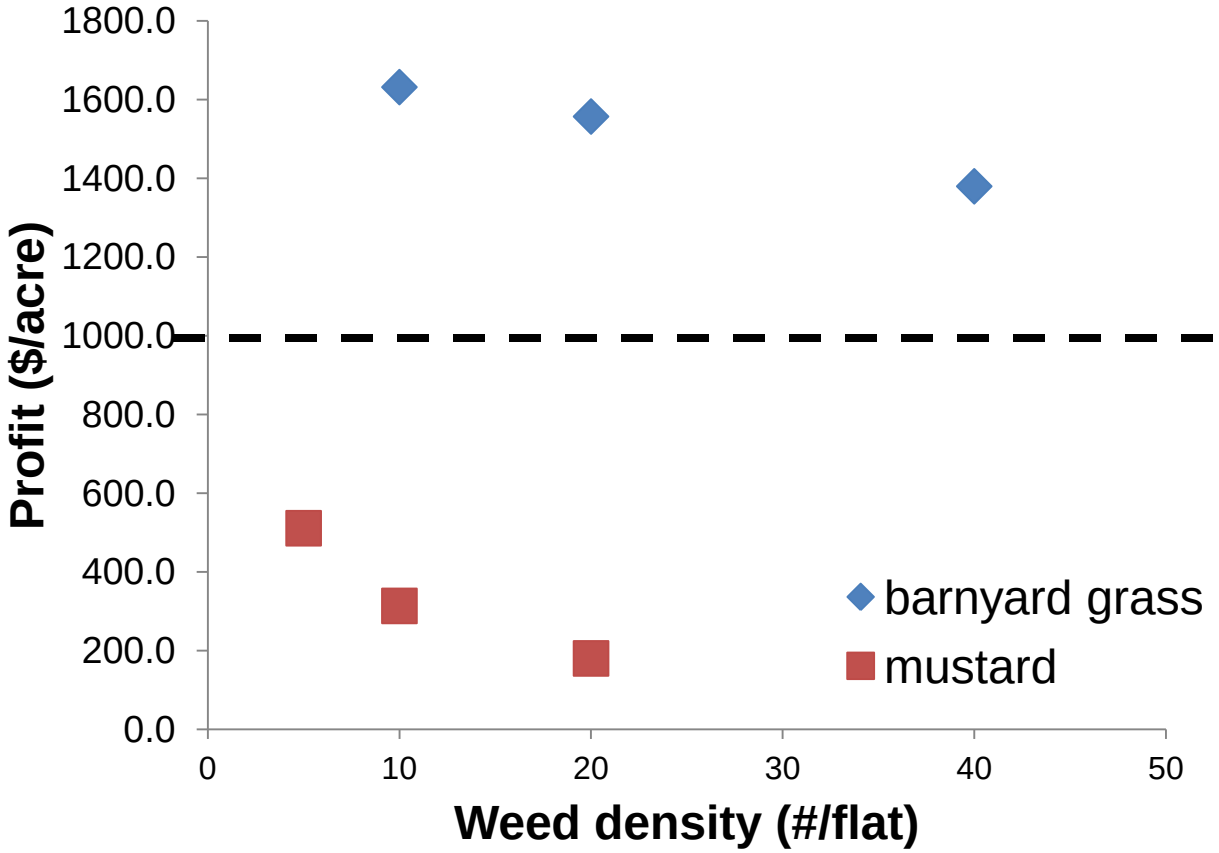
Data from HRT 341, Spring 2013

2.C Thresholds



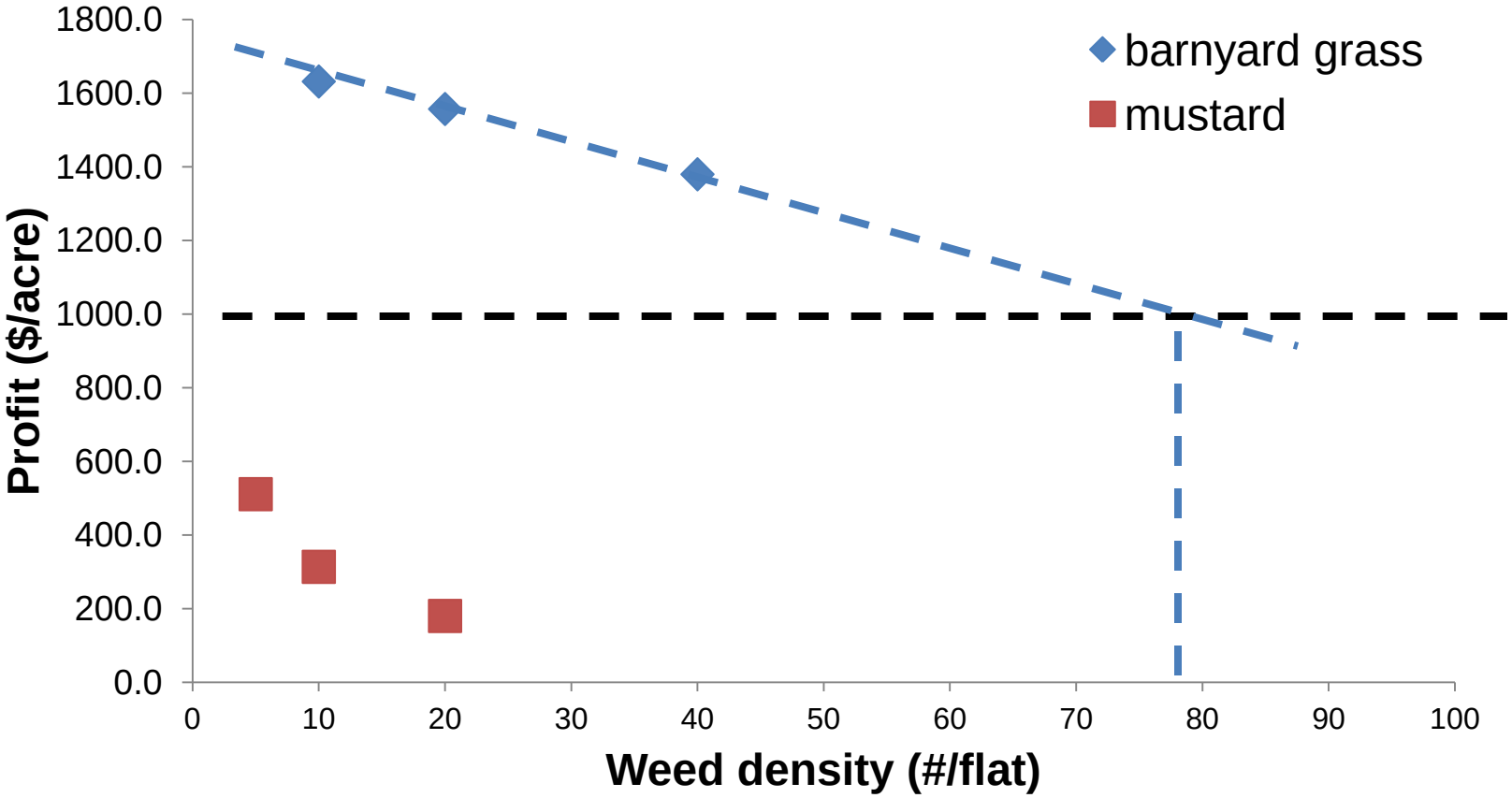
Convert to economic terms—basically inverting the yield loss curve

2.C Thresholds



Weed free profit - $500/acre for control measures

2.C Thresholds



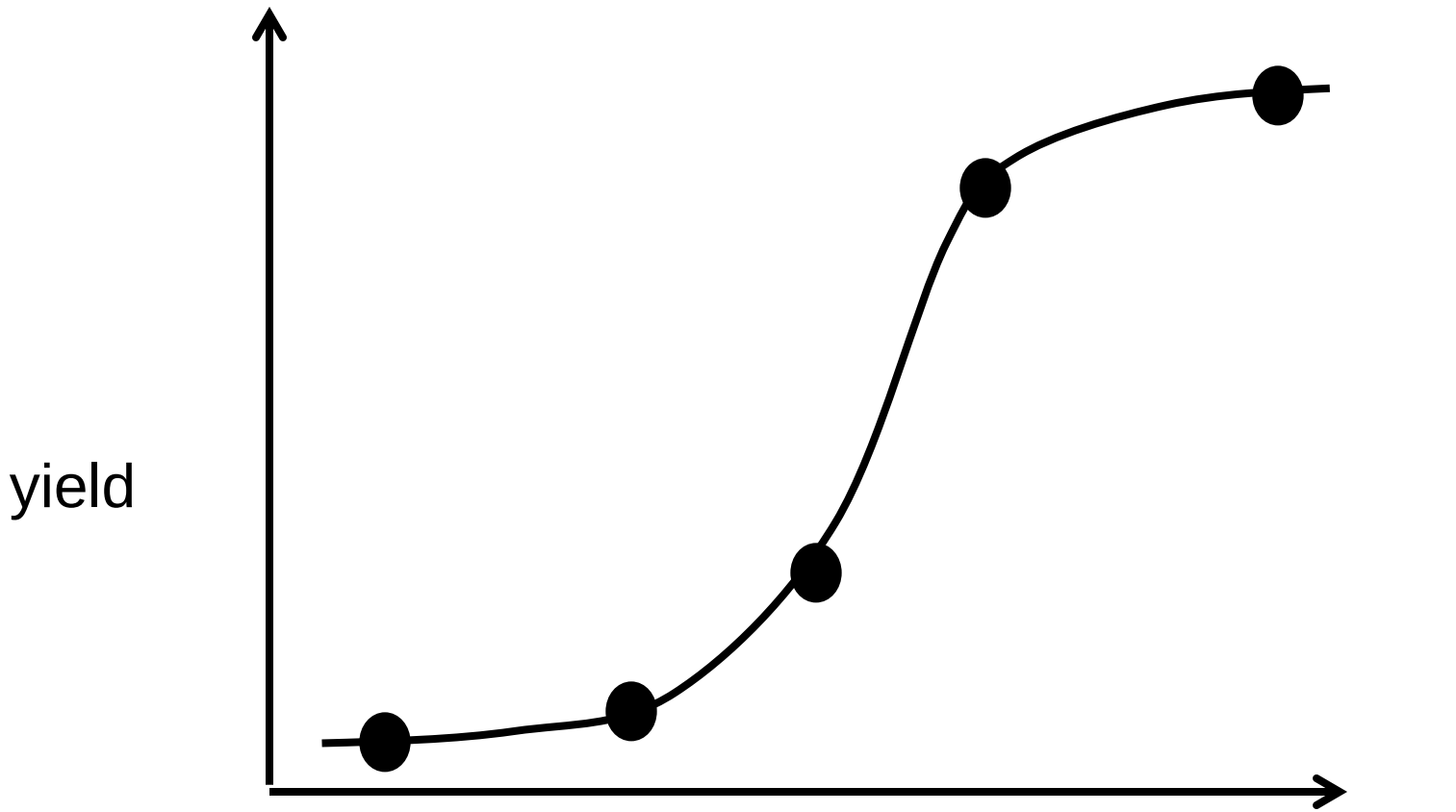
2C. Temporal thresholds—critical weed free periods

Idea: Weeds emerging really early in a growing season may not have sufficiently negative effect to justify weeding—biomass not enough to compete with crop.

Question: How long until you need to start weeding?

Typical experiment: Keep field weedy for different durations following crop emergence and then start controlling weeds. Evaluate crop yield.

2C. Temporal thresholds—critical weed free periods



Time spent weed free (until weed control stops)

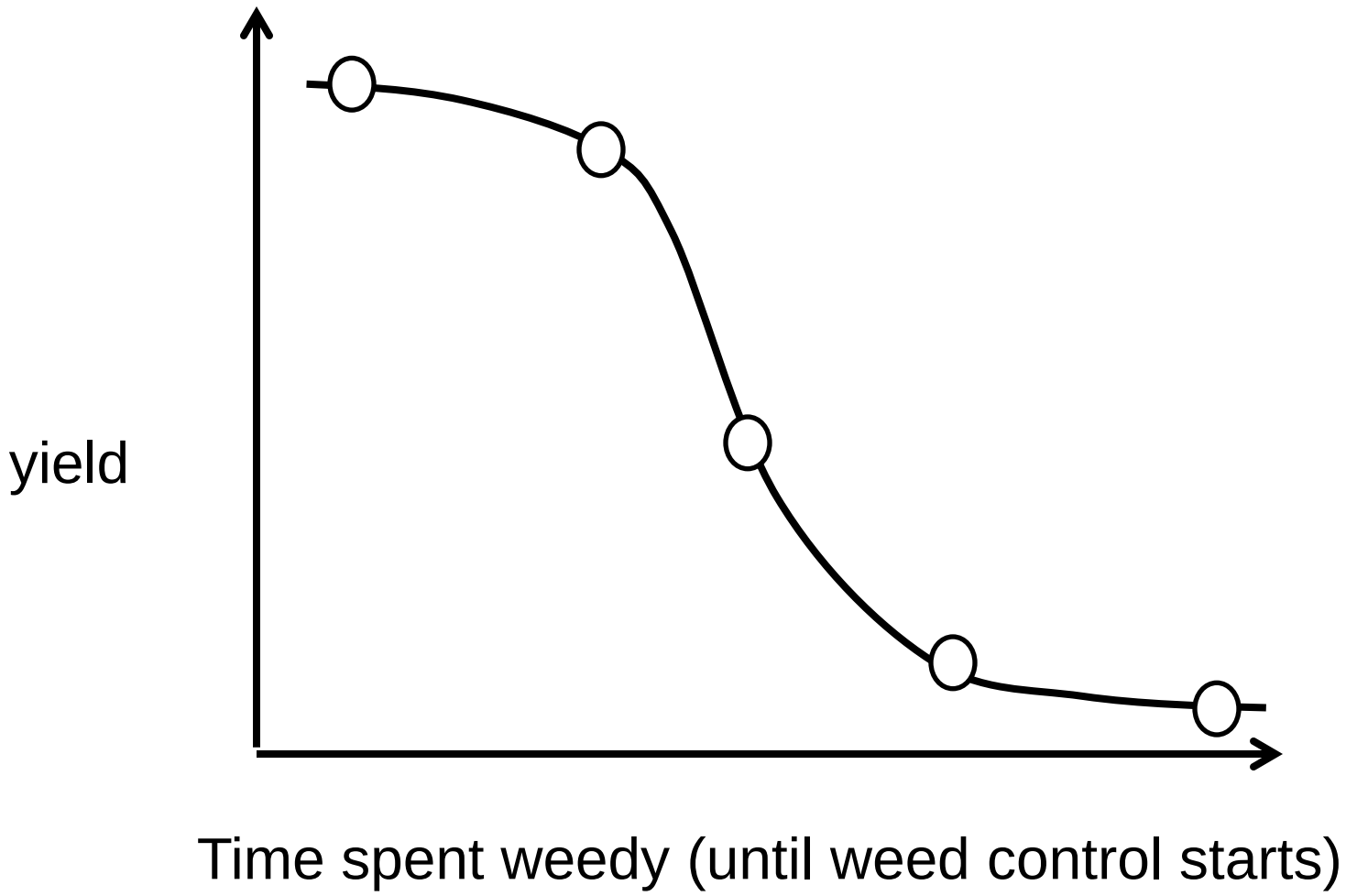
2C. Temporal thresholds—critical weed free periods

Idea: Weeds emerging late in a growing season may not have sufficiently negative effect to justify weeding.

Question: At what point does it make sense to let weeds go?

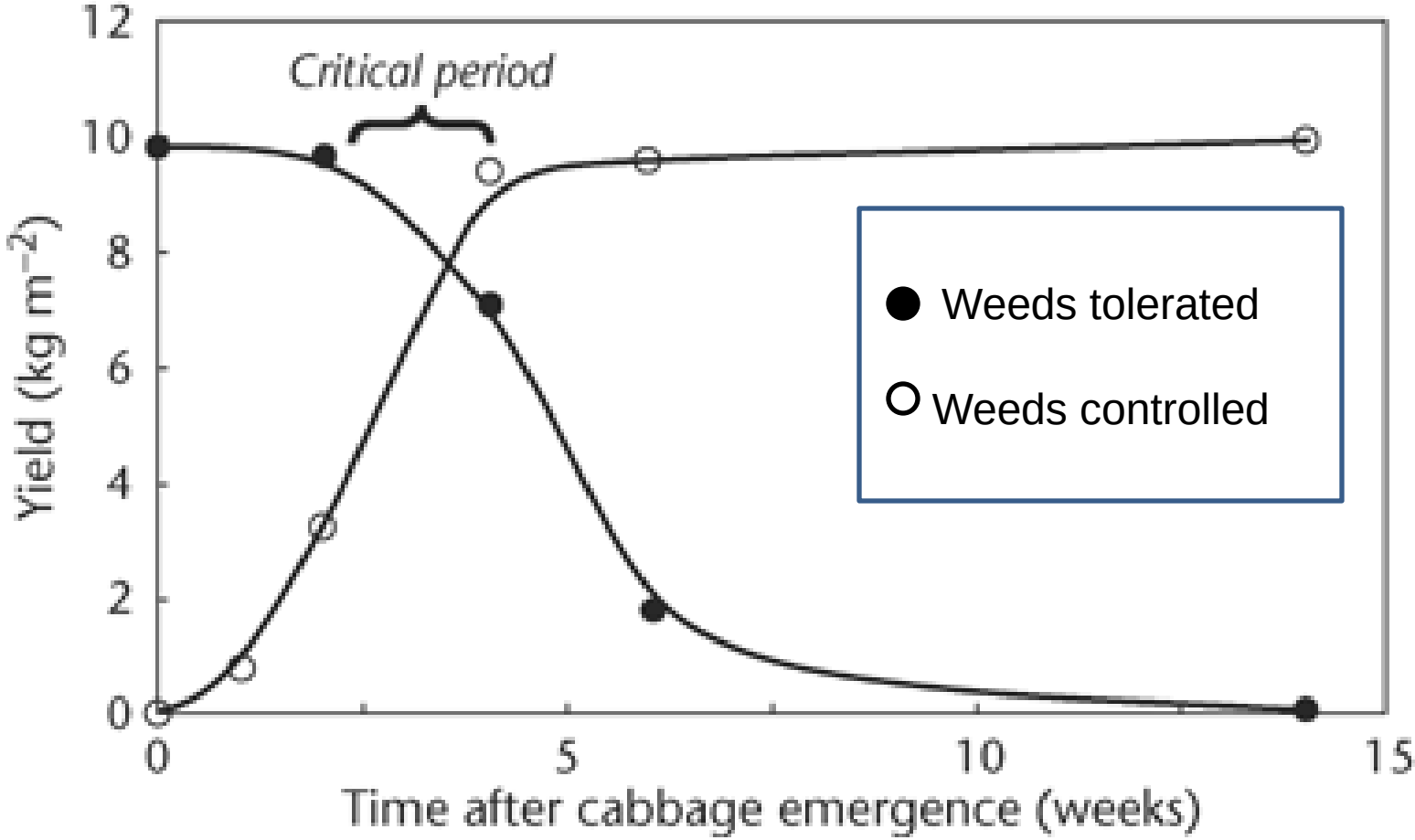
Typical experiment: Keep field weed-free for different durations following crop emergence and then let weeds go. Evaluate crop yield.

2C. Temporal thresholds—critical weed free periods



2C. Temporal thresholds—critical weed free periods

Combine these two curves



2C. Problems with weed threshold concept?

- Often not host specific. 100s of weeds, more difficult to establish thresholds for all.
- Weed density can be very patchy in fields… how to sample? Different than pheremone traps for insects because weeds are not mobile.
- Density not tightly linked to competitiveness since
  - Unlike insects, one weed can be many different sizes and hence inflict different levels of damage
  - Seed production. Not controlling a weed can result in direct future yield losses via seed production
- Timing may be more important than density…

2. Ecological weed management

A. **Apply knowledge of pest life cycles to identify and target weak points**

B. **Prevention better than treatment**

C. **Thresholds: know when a weed is likely to cause problems, and when it can be left alone.**

D. **"Many little hammers": Use multiple tactics to maximize effectiveness and minimize risks**

2D. “Many little hammers”

1. Mechanical

2. Cultural

Weeds

3. Biological

4. Chemical

Most organic growers currently rely on mechanical weed management

2D.1 Cultivation

Rotary Hoe

Inter-row cultivation

2.D.1 the favorite cultivation tool of organic farmers…

Image searching for "types of hoes" isn't as bad as you think

2D.1 Cultivation efficacy in organic snap beans

2D.1 Problems with cultivation?

2D. “Many little hammers”

1. Mechanical

2. Cultural

Weeds

3. Biological

4. Chemical

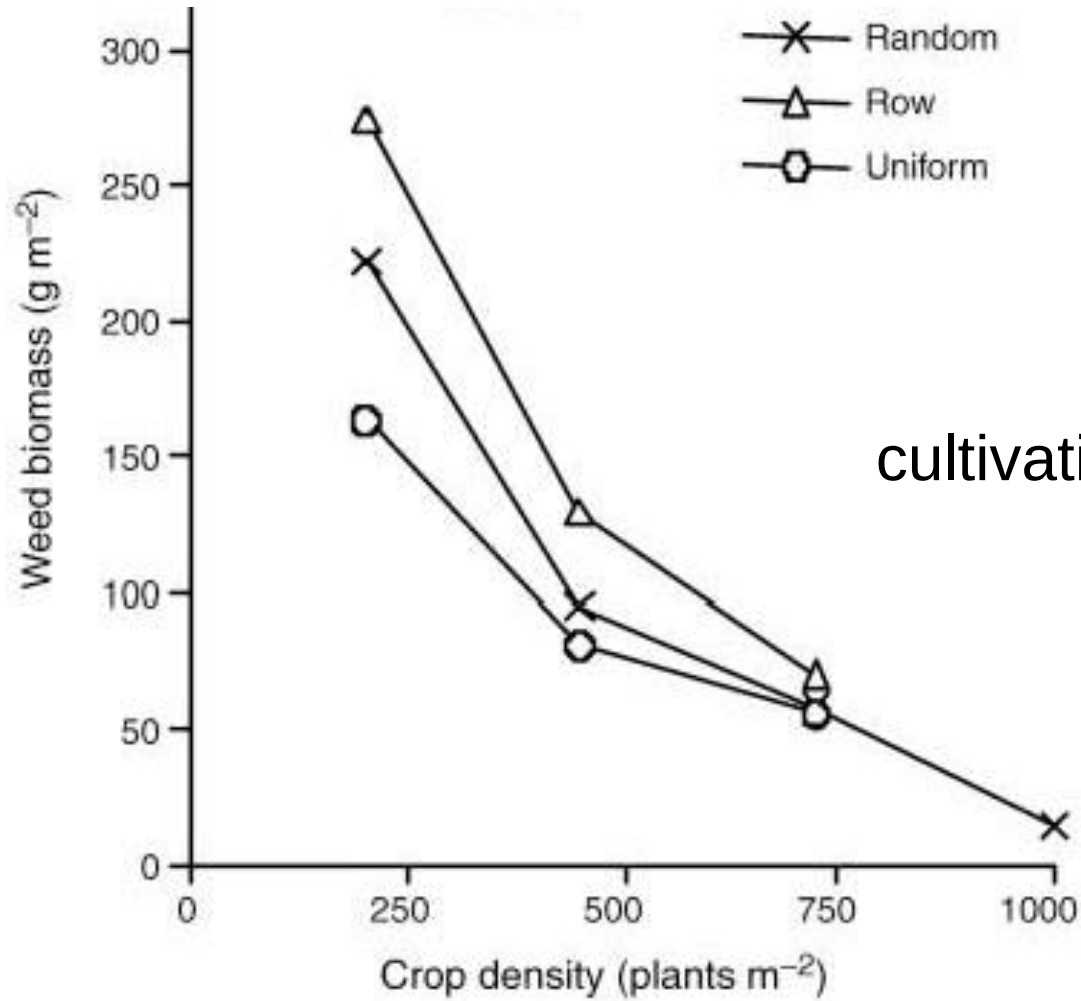
2D.2 Cultural control

1. Grow healthy competitive crops
2. Utilize crop rotations to break weed life cycles
3. Manipulate weed seed germination
   - Stale/false seed bed
   - Delayed emergence
4. N fertility management

2D.2.1 Cultural Weed Control:
Grow Healthy Competitive Crops

- **Select competitive resistant varieties**
- **Provide optimal growing conditions**
- **Irrigate and fertilize crop, not weeds**
- **Transplant to give crop head-start**
- **Increase planting density and planting uniformity**

2D.2.1 Crop density and spatial uniformity effects on weeds in spring wheat



cultivation?

Olsen et al. (2005) Weed Research 45: 316-321

2D.2.2 Cultural Weed Control:
Crop Rotation

- **Life cycles of problematic weeds often match life cycles of crops**
- **Crop rotation can help reduce weed problems by disrupting weed life cycles**

2D.2.2 Crop rotation: Downy brome in wheat

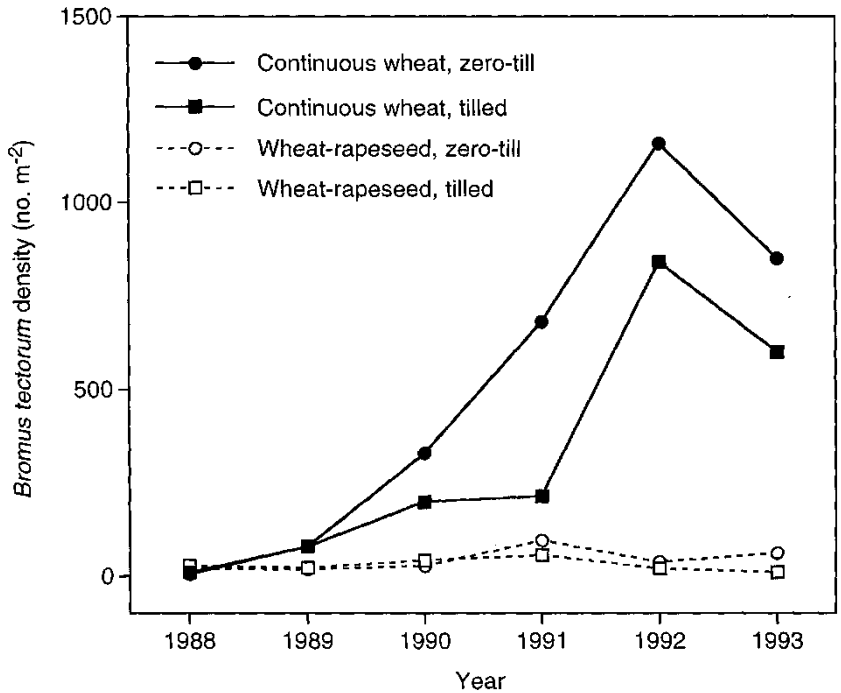


Figure 7.2 Density of *Bromus tectorum* plants in winter wheat grown in rotation with rapeseed or in continuous monoculture, with or without tillage, in an experiment conducted in Alberta, Canada. (Adapted from Blackshaw, 1994.)

Blackshaw 1994

Avoid letting weed species that have very persistent seed in the seedbank go to seed.

Table 2. Persistence of common weed seeds in the soil seedbank.

Weed species	Years required for 50 percent reduction in seed number	Years required for 99 percent reduction in seed number
common lambsquarters	12	78
velvetleaf	8	56
field pennycress	6	38
common cocklebur	6	37
yellow foxtail	5	30
prostrate knotweed	4	30
Pennsylvania smartweed	4	26
redroot pigweed	3	20
annual bluegrass	3	19
shepherd's-purse	3	19
chickweed	3	18
curly dock	3	17
common waterhemp	2	16
common groundsel	2	14
ivy leaf morningglory	< 2	11
barnyardgrass	< 2	10
common ragweed	< 1-1/2	10
large crabgrass	< 1-1/2	8
wild mustard	< 1	7
giant foxtail	< 1	5
common sunflower	< 1/2	2
hemp dogbane	< 1/2	2
giant ragweed	<1/2	2
kochia	< 1/2	2

Sources: Burnside et al. (1996), Buhler and Hartzler (2001), Dawson and Bruns (1976), Lewis (1973), and Roberts and Feast (1972).

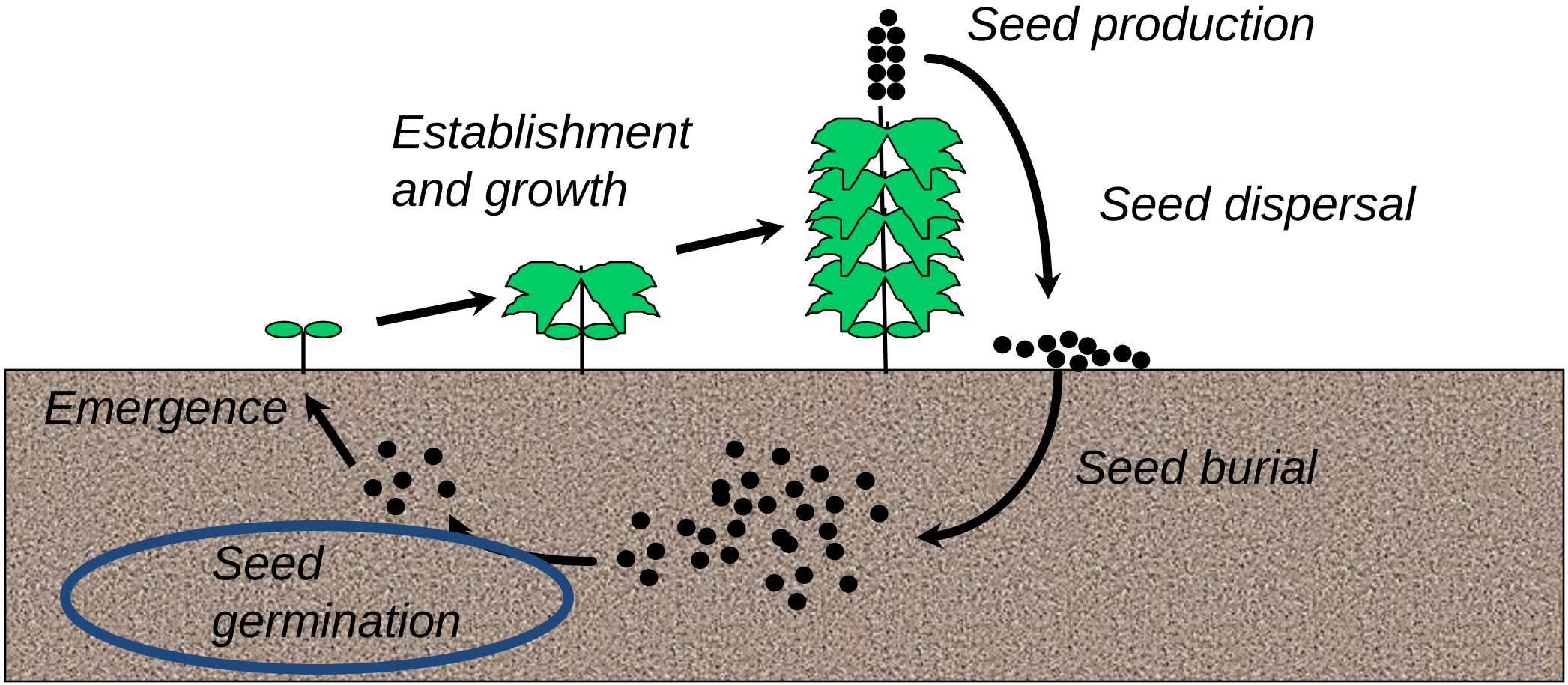
Davis et al. MSU Extension Bulletin E-2931

2D.2.3 Cultural weed control
Manipulating weed germination

Two general strategies

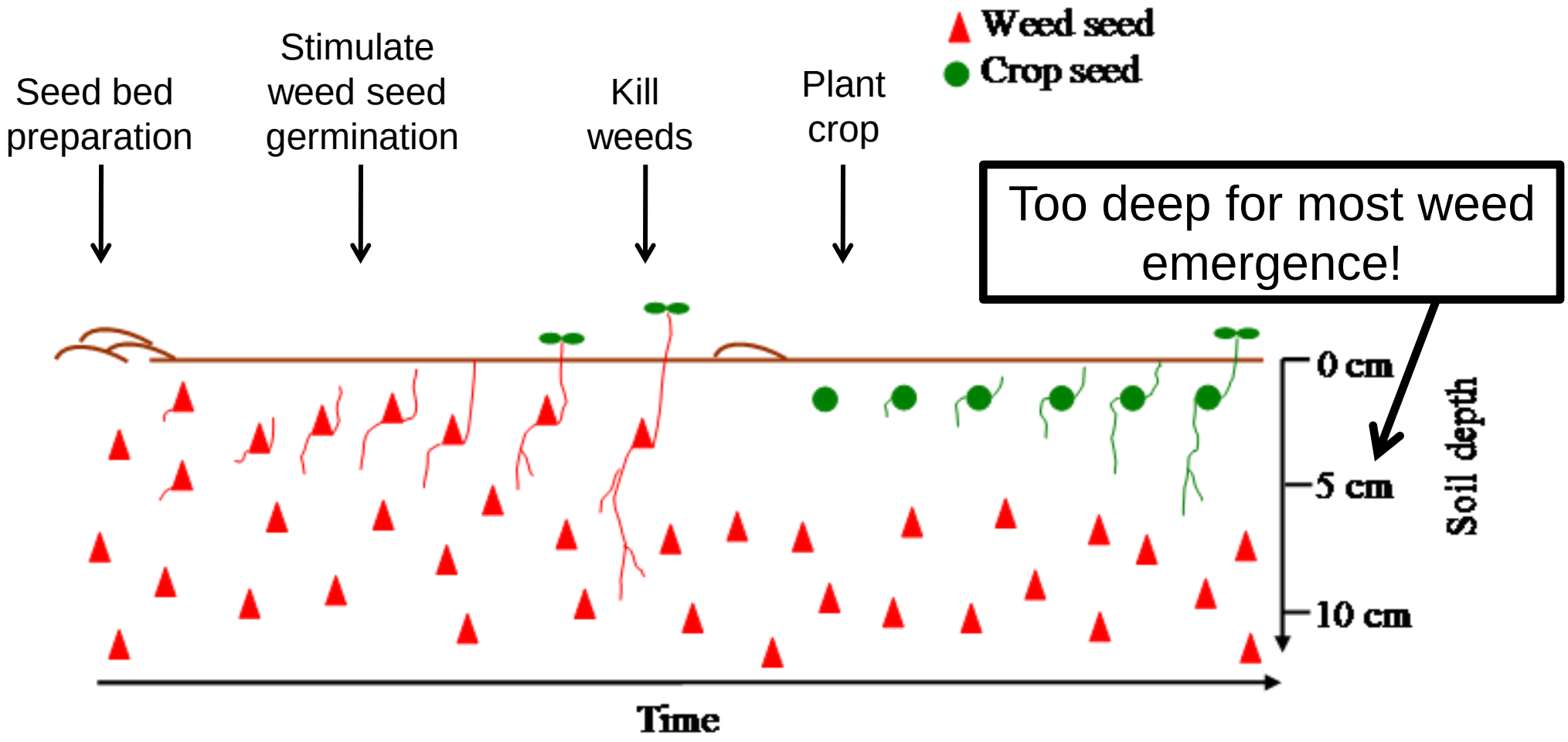
- Stimulate germination in absence of crop and kill weeds = “stale seed bed” or “bare summer fallow”
  - Tillage and irrigation can stimulate
  - Flaming, herbicides = good ways to kill weed seedlings without stimulating further emergence
- Inhibit germination during early crop growth (remember weeds might be ok if they emerge later…)
  - Irrigation best at this (trickle tape)

2D.2.3 Manipulating weed seed germination



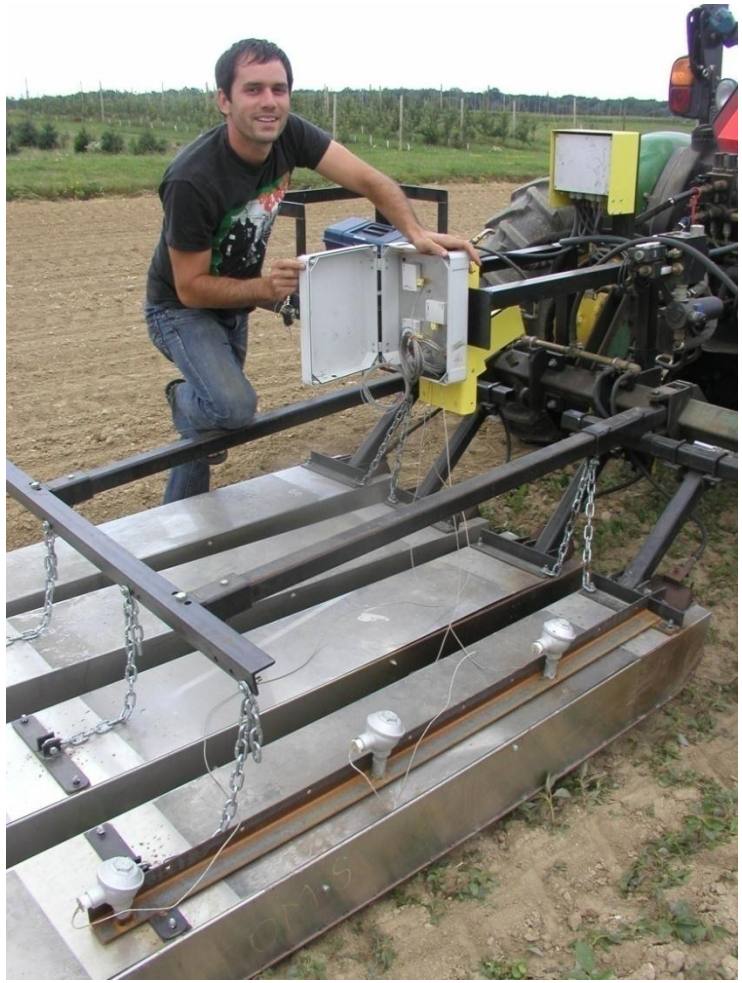
"Weed seedbank"

2D.2.3 “Stale seed bed”: stimulate germination and kill weeds BEFORE crop emergence



http://www.steamweeding.co.nz/information/index.html

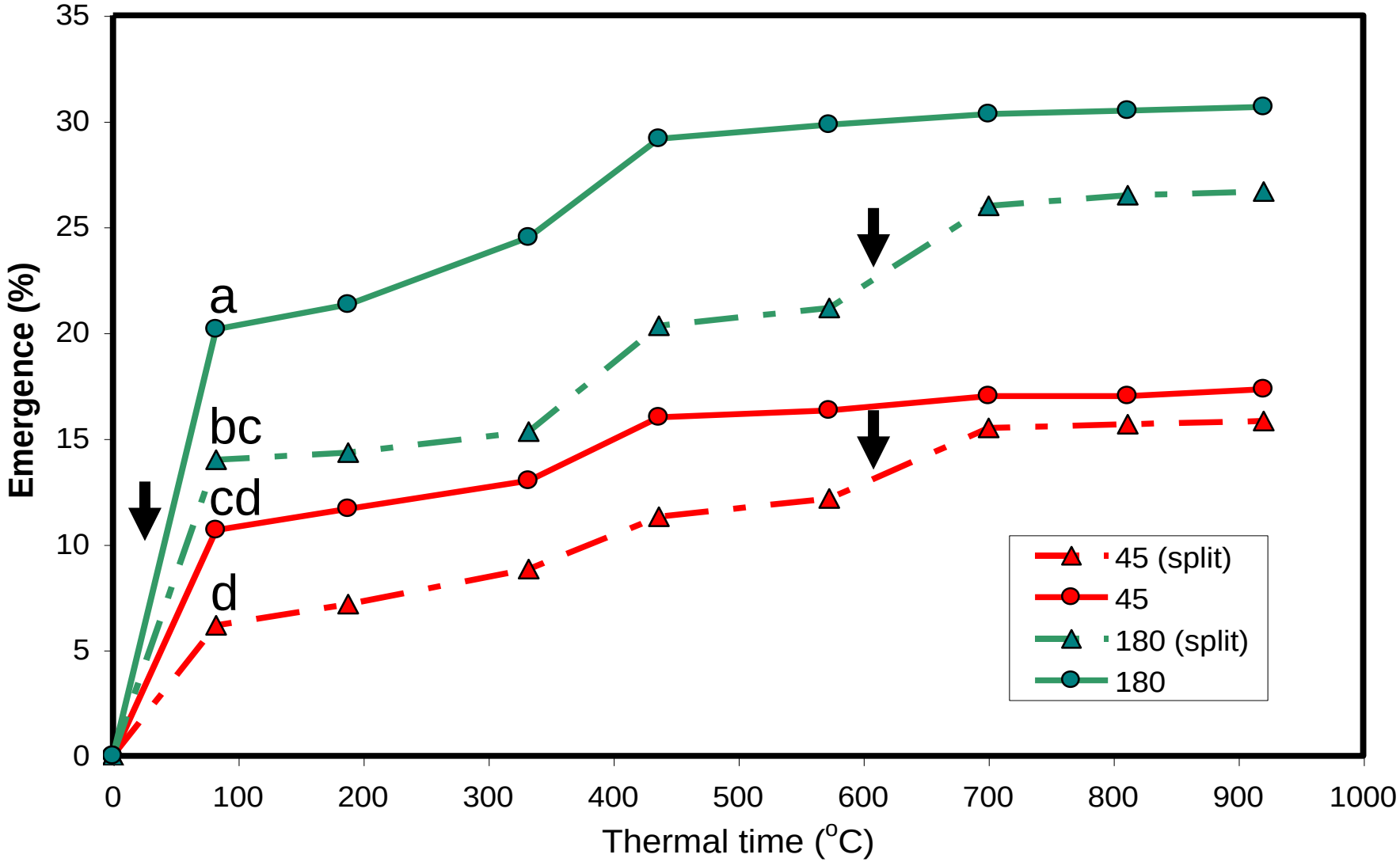
2D.2.3 Flame-Weeding!!!



2D.2.4 Cultural weed control
N Fertility management

- Germination and growth of many weeds is stimulated by nitrogen
- Target fertilization both temporally and spatially to meet crop needs

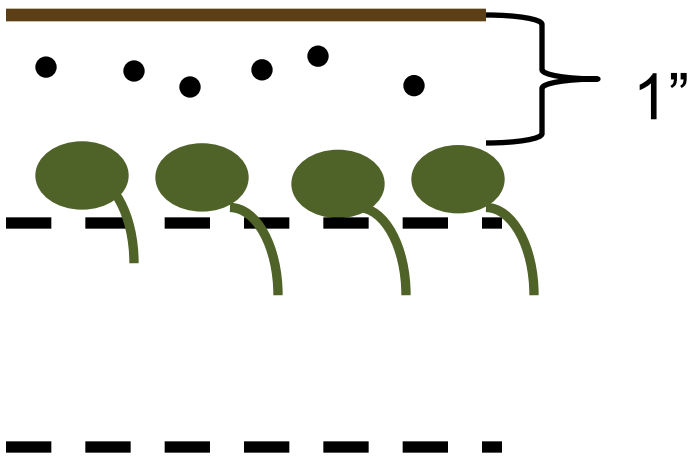
2D.2.4 Reduced or split N can reduce weed emergence and growth

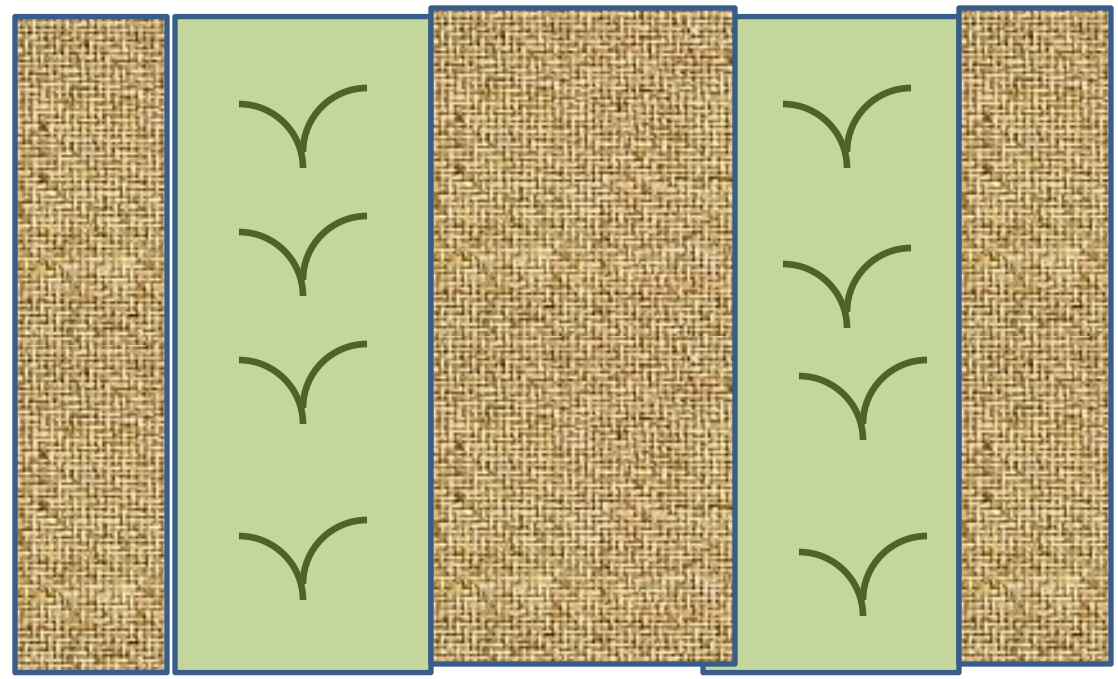


Brainard, DiTommaso and Mohler 2006

2D.2.4 Spatial N manipulation

- Deep fertilizer placement vs broadcast
- Strip management—legumes in, cereals out.





2D. “Many little hammers”

1. Mechanical

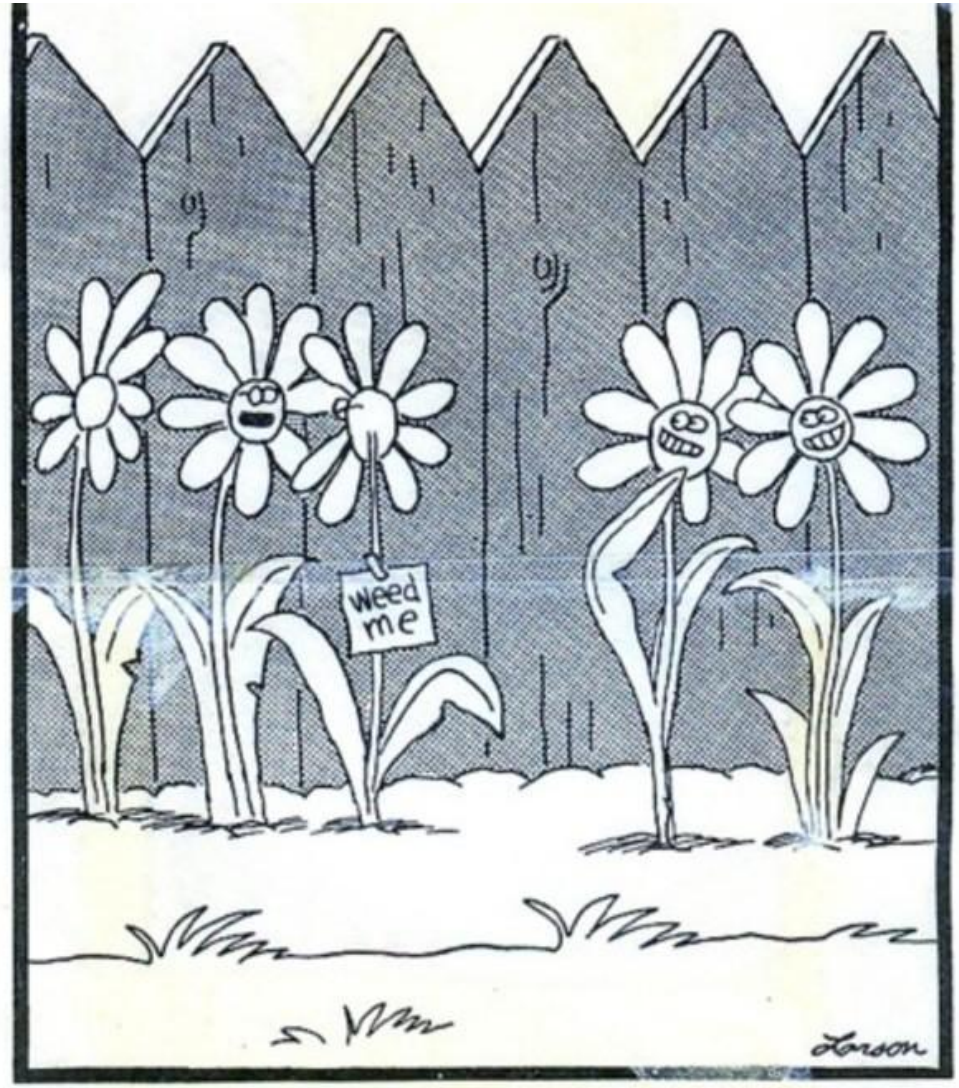
2. Cultural

Weeds

3. Biological

4. Chemical

2D.3 Biological weed control?



Flora practical jokes

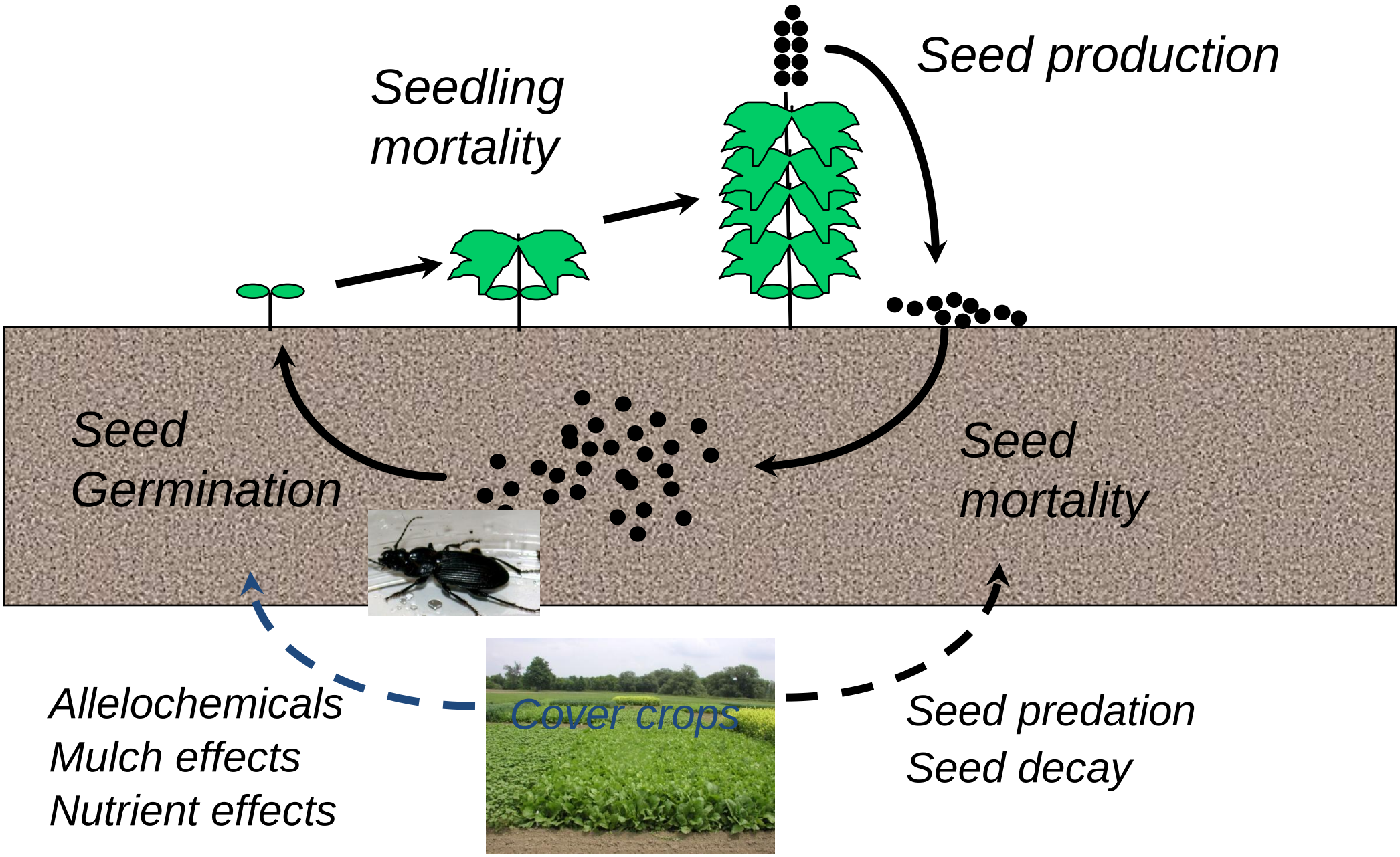
Gary Larson

2D.3 Biological weed control

- **Herbivores**
- **Pathogens**

“classic” biological control

- **Cover crops**
- **Seed predators**


Seedling mortality
Seed production
Seed Germination
Seed mortality
Allelochemicals
Mulch effects
Nutrient effects
Cover crops
Seed predation
Seed decay

2D.3 Results : Buckwheat residue effects

Wheat

→ No effect on wheat yield in green-house or field

Corn chamomile

→ Reductions in emergence and growth in ¾ of studies

Buckwheat Bare

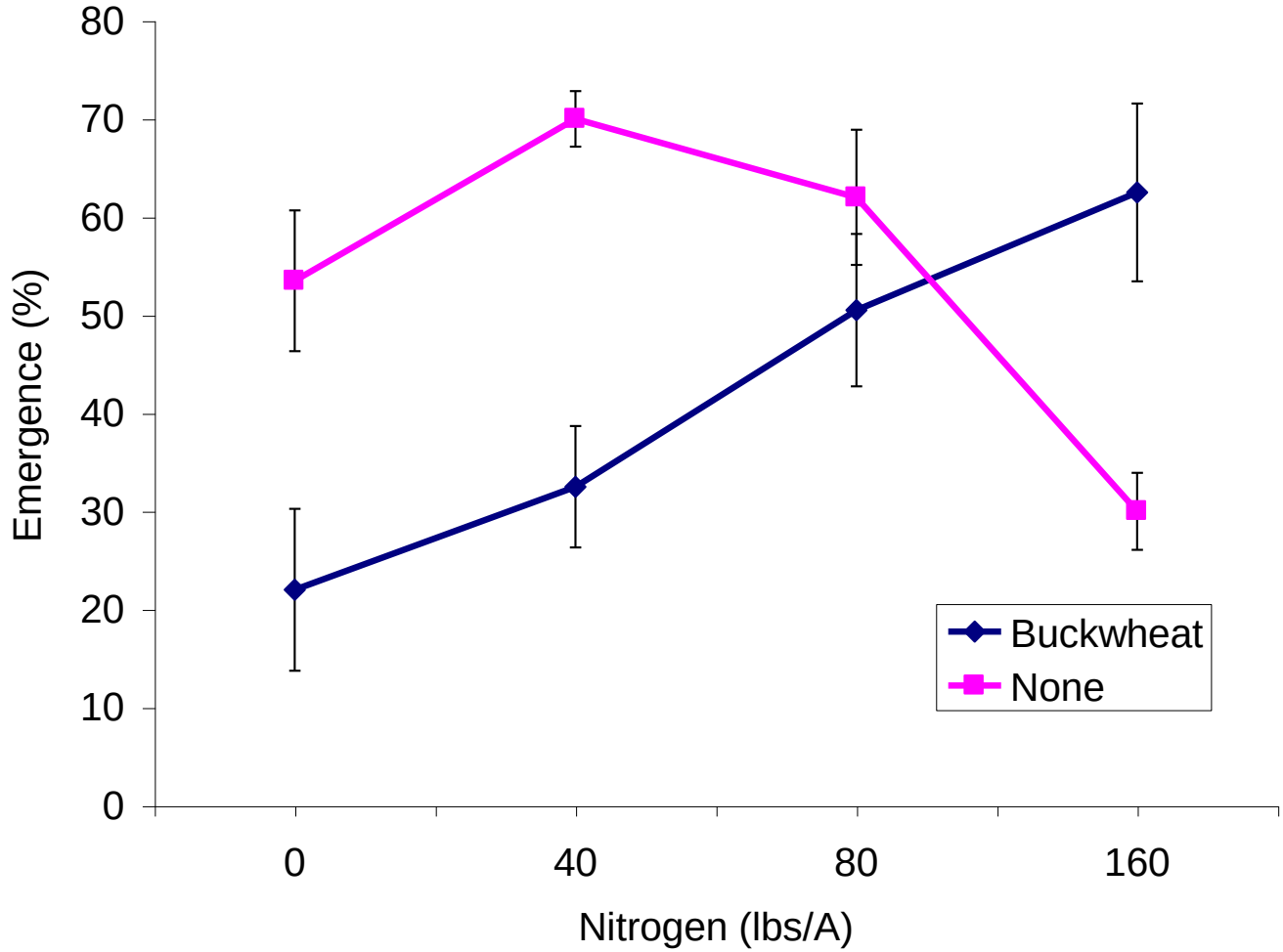
2D.3 What is mechanism?

Buckwheat Bare

Hypotheses?

-
-
-
-

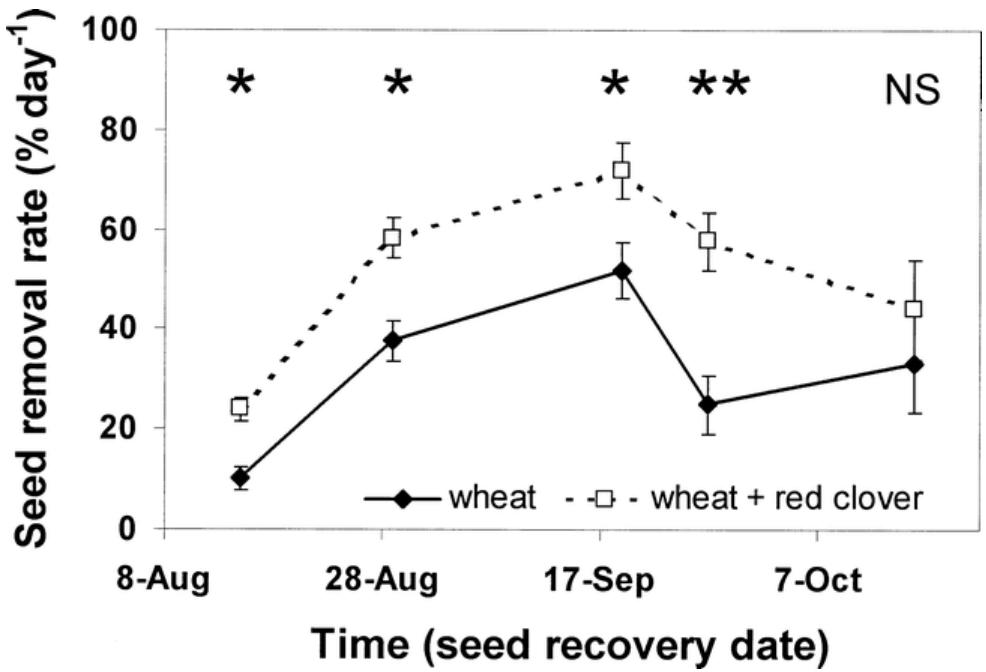
2D.3 Buckwheat effects on weed emergence Shepherd's-purse and N interactions

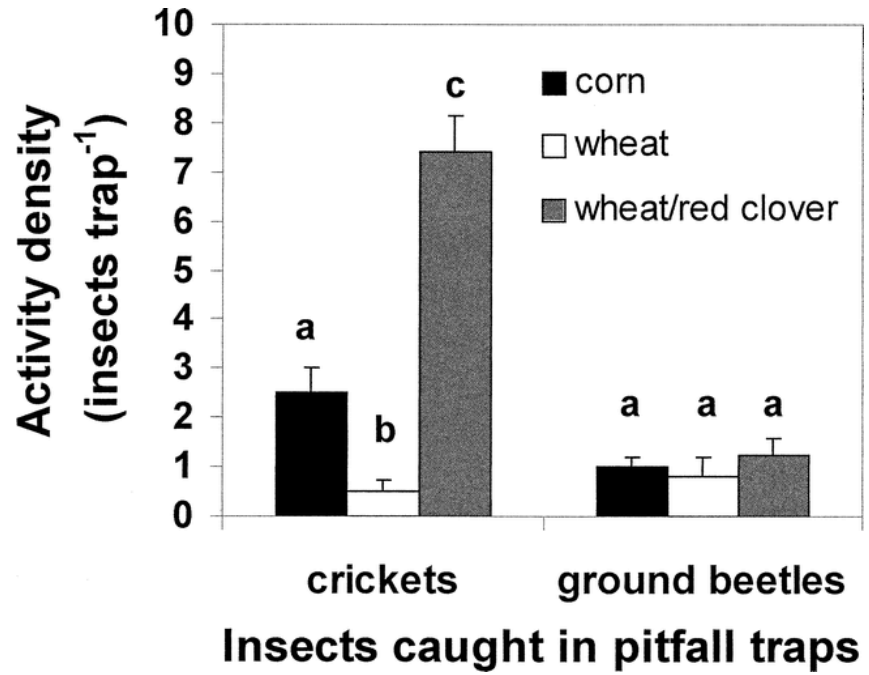


Kumar et al. unpublished

2D.3 Seed Predation

Ex. Red clover effects on weed **seed predation**





Davis & Liebman 2003

2D.3 Red clover in wheat: Effects on seed production?

2D. “Many little hammers”

1. Mechanical

2. Cultural

Weeds

3. Biological

4. Chemical

2D.4 Chemical weed control

http://www.purewatergazette.net/images/weed.gif

2D.4 Organic herbicides?

trt #	trt	Prod. Conc. (%)	GPA	Mustard NY	CA	DE	MN[1]	MI	PA1[2]	PA2	PA3	Avg
1	Vinegar	5	70	77.5	5.0	88.0	45.7	15.0	11.3	71.3	85.0	49.9
2	Vinegar	10	70	87.5	12.5	93.0	85.7	63.8	51.3	78.8	95.0	71.0
3	Vinegar	15	70	80.0	26.2	96.0	78.6	65.0	68.8	93.8	100.0	76.0
4	Vinegar	20	70	95.0	61.2	95.0	90.0	91.3	73.8	93.8	100.0	87.5
5	Matran EC	5	35	46.3	17.5	56.0	0.0	2.5	6.3	38.8	23.8	23.9
6	Matran EC	10	35	58.8	82.5	81.0	5.7	27.5	47.5	77.5	96.3	59.6
7	Matran EC	15	35	62.5	92.5	86.0	40.0	22.5	58.8	77.5	100.0	67.5
8	Matran EC	20	35	73.8	95.0	90.0	43.1	43.8	75.0	95.0	100.0	77.0
	LSD (P=.05)			14.2	15.8	14.0		27.7				
Weather Data												
	Temp			72.0	45.0	80?		84.0	65.0	81.0	90.0	
	RH			57.0	66.0	88.0		41.0	56.0	60.0	96.0	
	cloud			60.0	30.0			0.0	95.0	15.0	0.0	
Leaf Stage				3-4	3	<=3	4	4	4	4	4	

[1] Based on biomass data

[2] Three sepearate trials were conducted in PA.

Brainard et al, unpublished

What do you think about organic herbicides?

- Advantages?
- Disadvantages?

3. Integration of “many little hammers”

1. Mechanical

2. Cultural

Weeds

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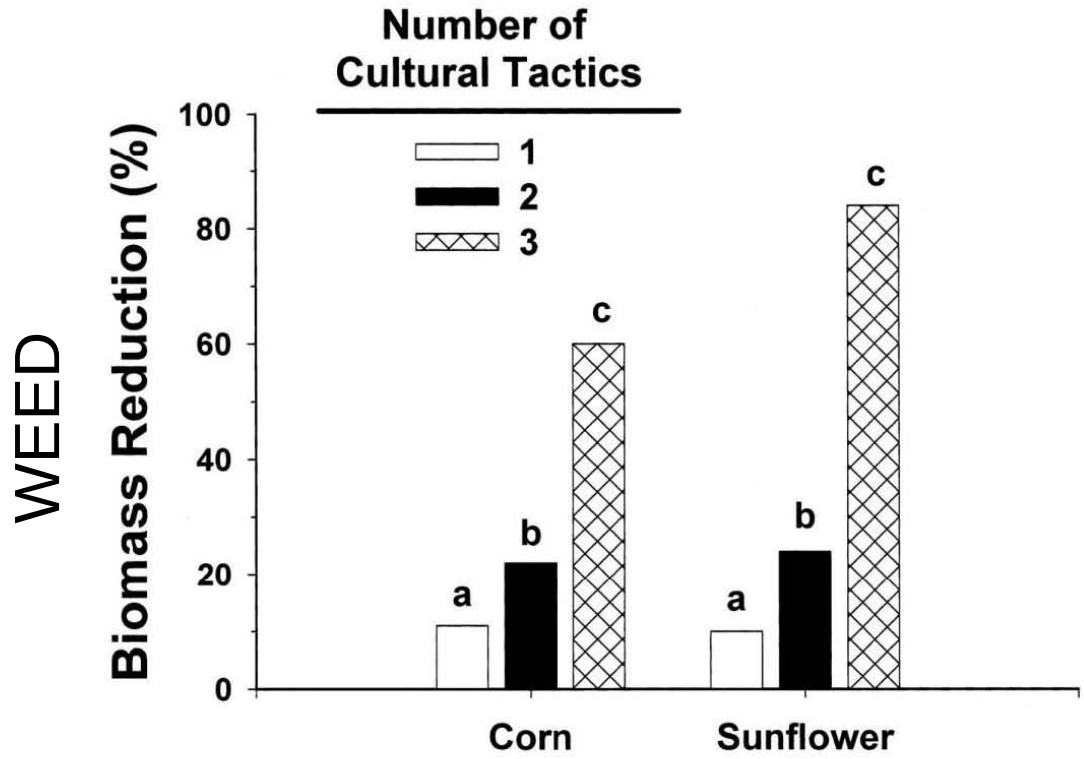
4. Chemical

3. Integration—management strategies



"Many little hammers": Synergistic effects of cultural tactics on weed biomass production in corn and sunflower. Tactics included increased seeding rates, narrower row spacing, fertilizer placement, and delayed planting.Treatments were compared with conventional systems used by producers. Anderson (2005), Agron. J. 97: 1579-1583.

3. Integration of tactics: Nordell Example

3. Nordell's "bioextensive" vegetable crop rotation

Year 1				Year 2				Year 3				Year 4			
Spring	Summer	Fall	Wint.	Spring	Summer	Fall	Wint.	Spring	Summer	Fall	Wint.	Spring	Summer	Fall	Wint.
Clover	Bare fallow	Rye/ Vetch			Late crop (Broccoli)	Rye			Bare fallow	Oats/ peas		Early crop (Onions)	Clover		

Cash crops

Cover crops

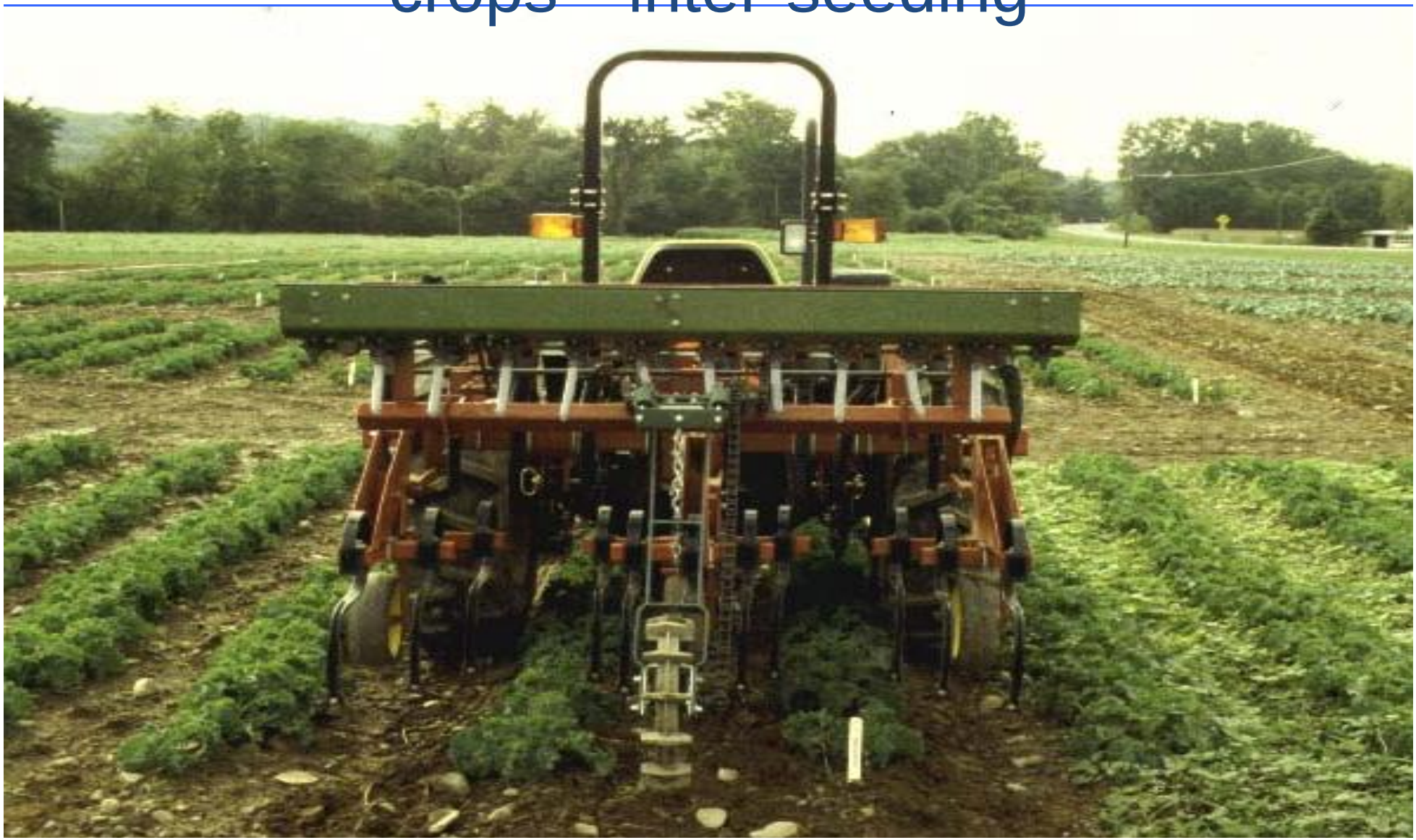
Look at ratio of cover crop:cash crop…

Key features:

- Prevention
- Stale seed beds/Bare summer fallow
- Rotation: Alternating early, late crops
- Cover crops
- Cultivation

Nordell and Nordell, 1996

3. Combining cultivation and cover crops—inter-seeding



3. Interseeding timeline

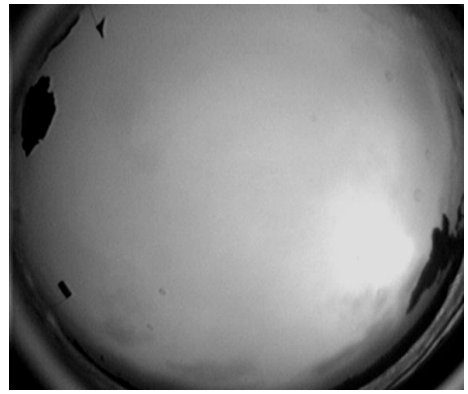
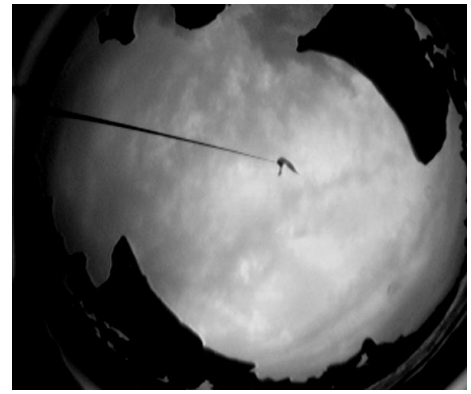
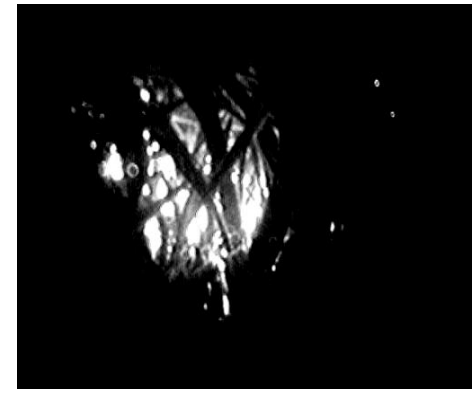
Late July

August

September

Following spring

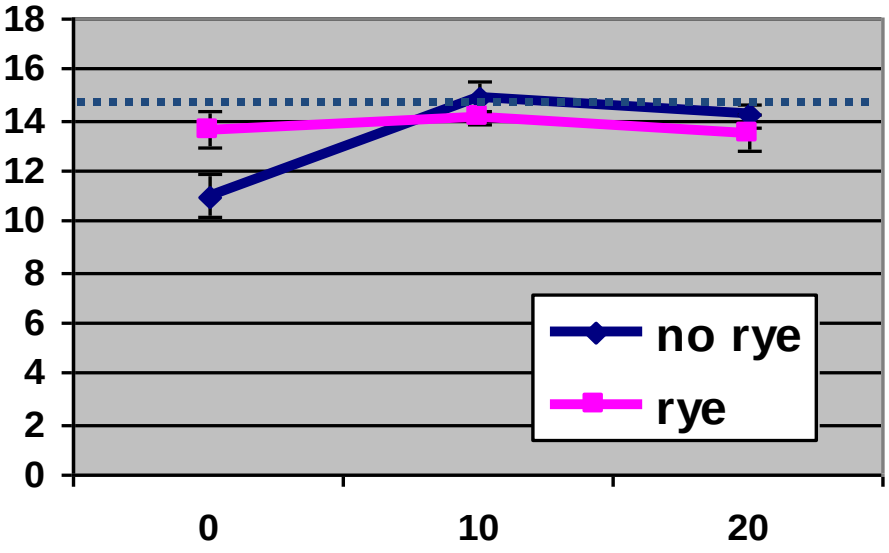
3. Interseeding—early canopy closure

	11 DAT	22 DAT	38 DAT
No Rye			
Rye			

Brainard and Bellinder, 2002

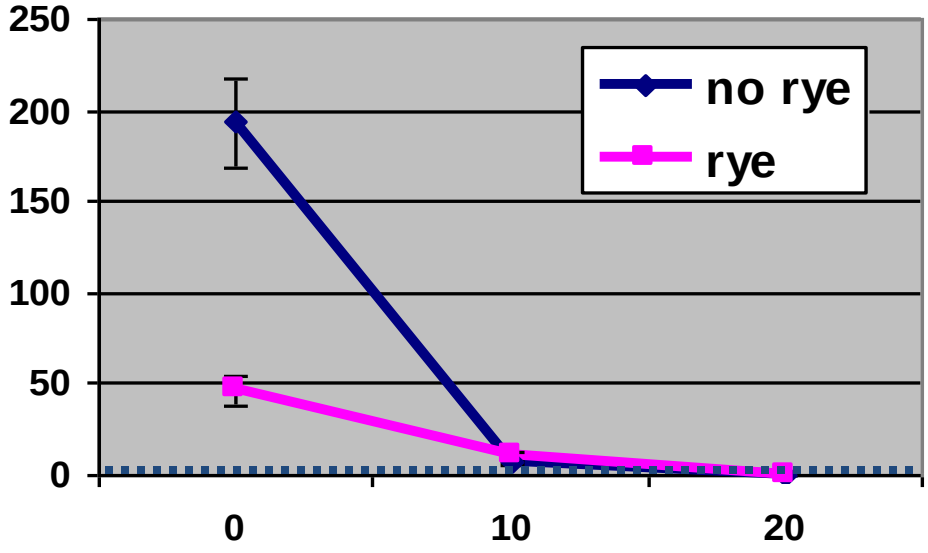
3. Interseeding yields, 2000

Broccoli
yield (T/ha)



Timing of last cultivation (DAT)

Weed dry weight
(g/m^2)

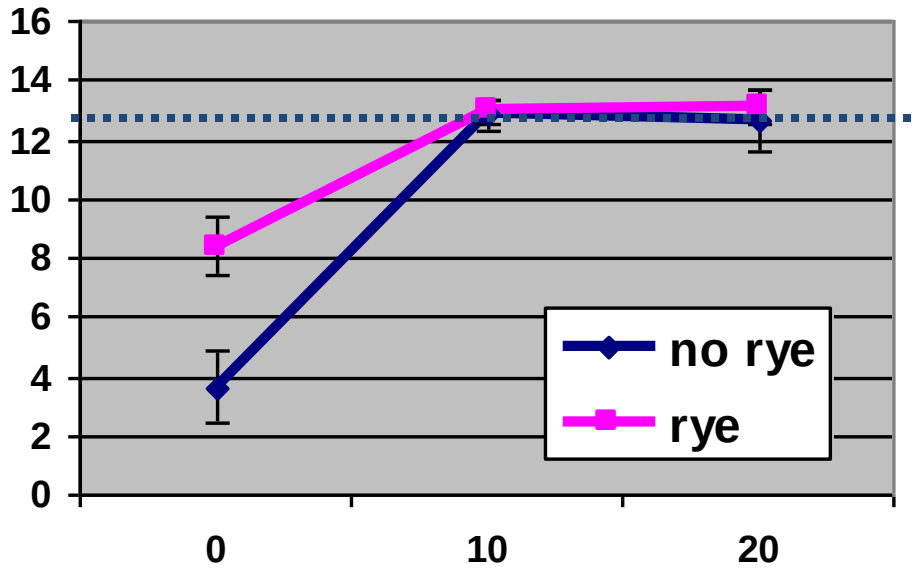


Timing of last cultivation (DAT)

Brainard and Bellinder 2004

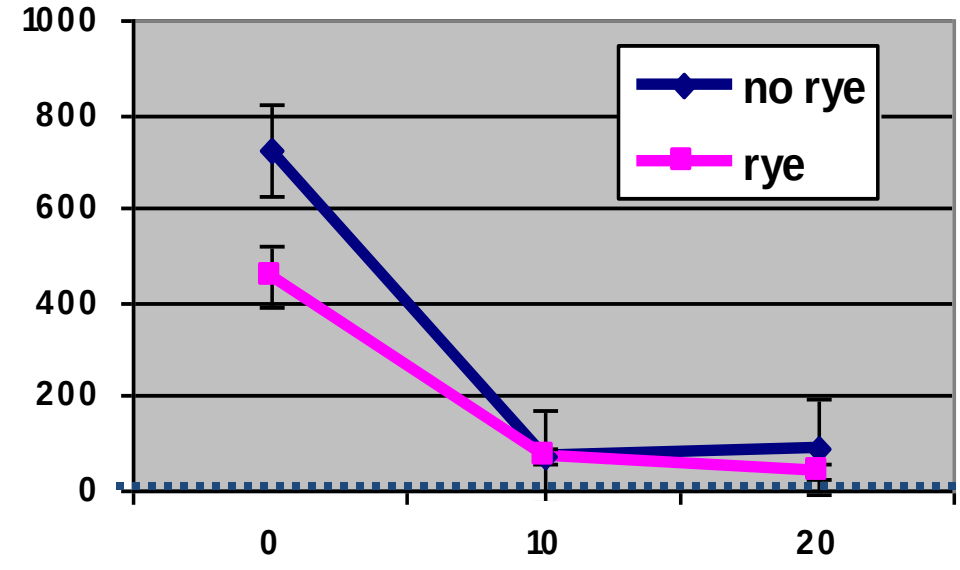
3. Interseeding yields, 2001

Broccoli
yield (T/ha)



Timing of last cultivation (DAT)

Weed dry weight
(g/m^2)



Timing of last cultivation (DAT)

Brainard and Bellinder 2004

Some key points

Prevention is critical. Easier to avoid seed production than to promote seed predation and decay.

Knowledge of the biology and ecology of weeds is useful for determining optimal management strategy

Mechanical control (cultivation) has been foundation of organic weed management, but has limitations.

Cultural practices like crop rotation, planting density etc have great potential.

“Many little hammers” necessary for successful management

Exercise:

- What have we talked about today that might conflict with managing insect pests?
- When you design your farm, what tactics would you include? Why? What would you not include? Why not?