ILLINOIS

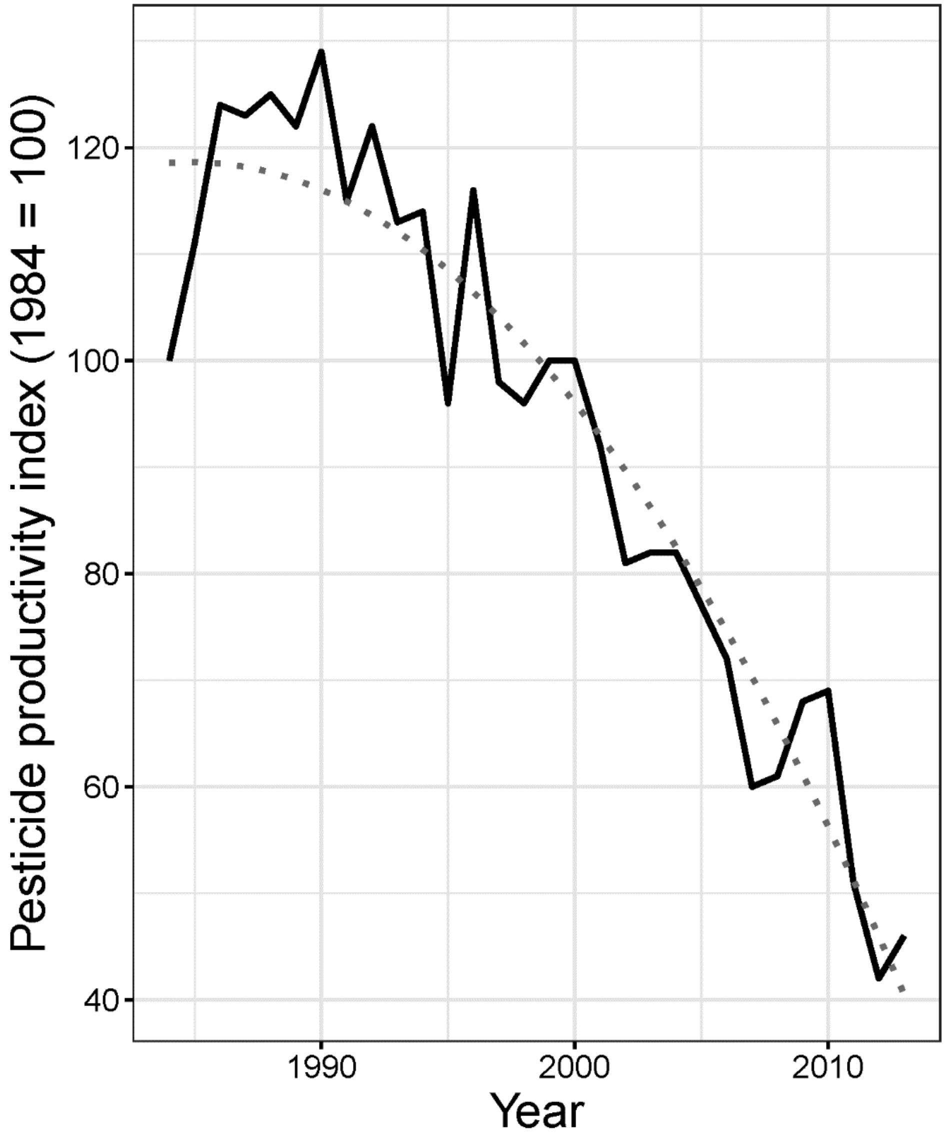
Crop Sciences

COLLEGE OF AGRICULTURAL, CONSUMER & ENVIRONMENTAL SCIENCES

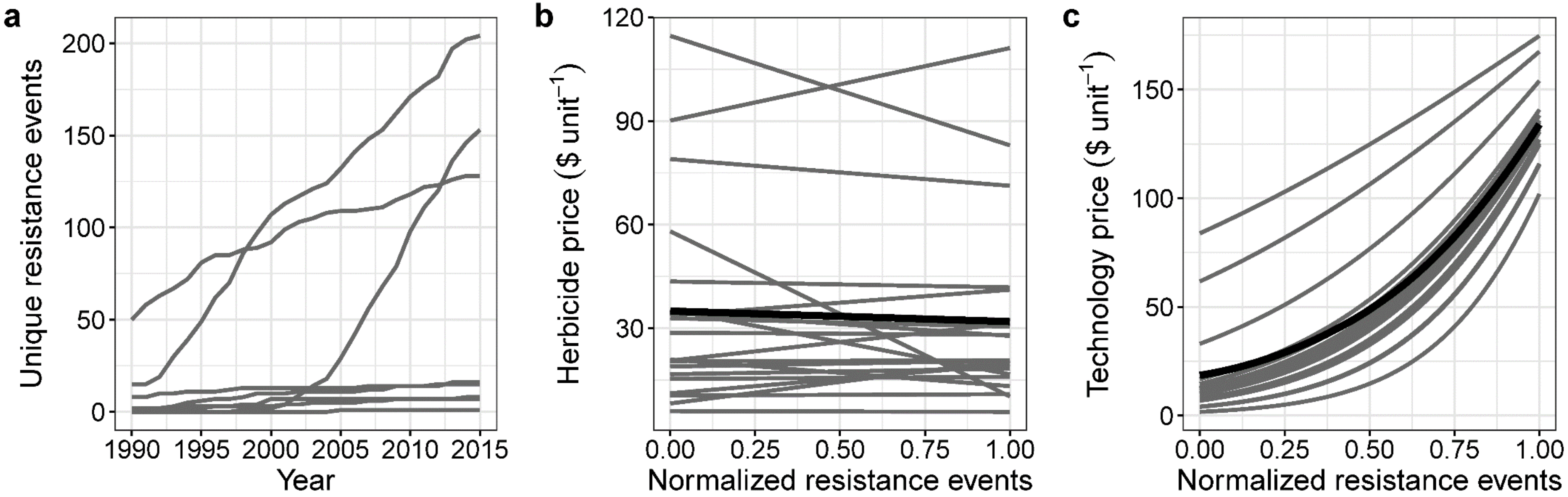
MORE THAN MEETS THE I

INTEGRATED WEED MANAGEMENT AND CROPPING SYSTEM DESIGN

Dr. Adam Davis, Prof. & Head



Davis & Frisvold 2017



Davis & Frisvold 2017

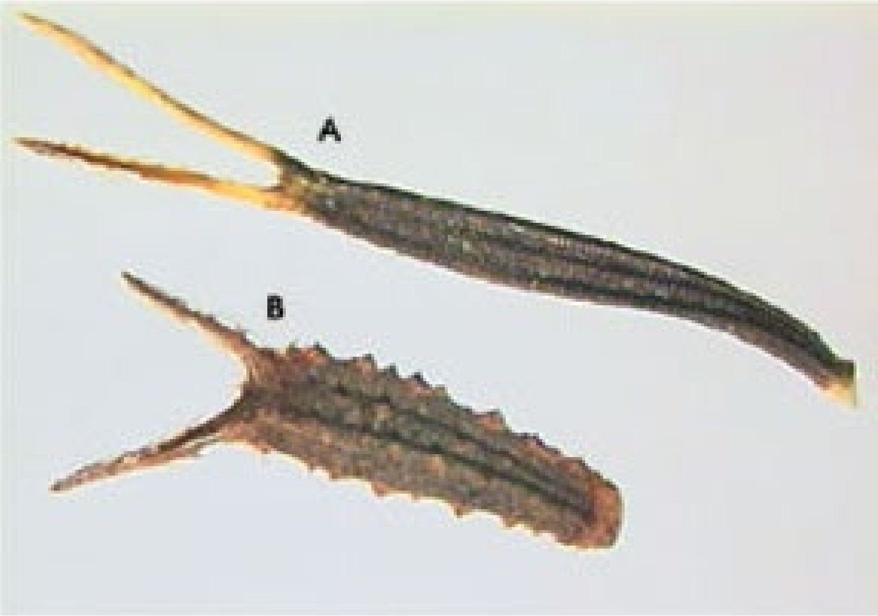
Outline of presentation

- Weed management = managing evolution
- Lessons learned on-farm
- Integrated weed management and cropping system design

Raw materials of evolution

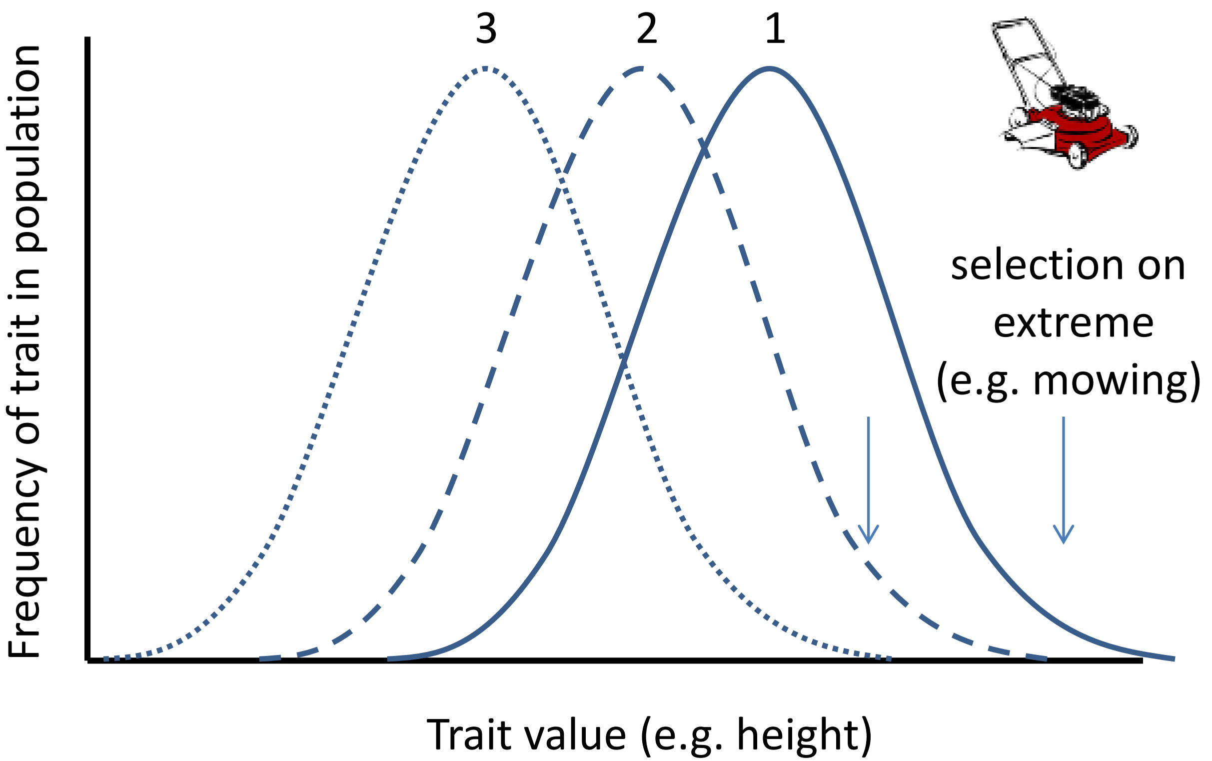
- Heritable, variable trait
- Selection pressure: envir. condition affecting **fitness** value (= # of offspring) of a trait

continuous variation

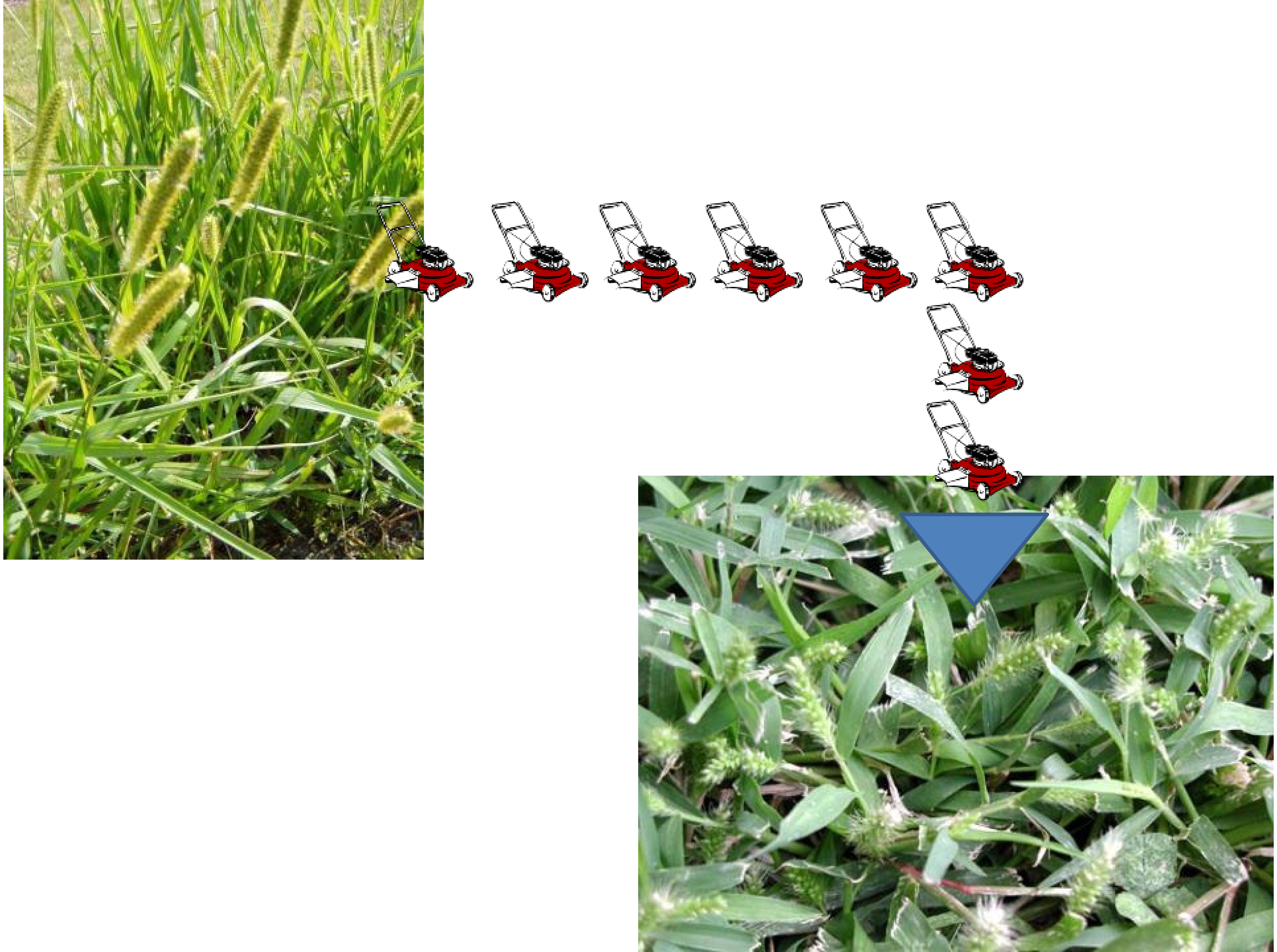


discontinuous variation

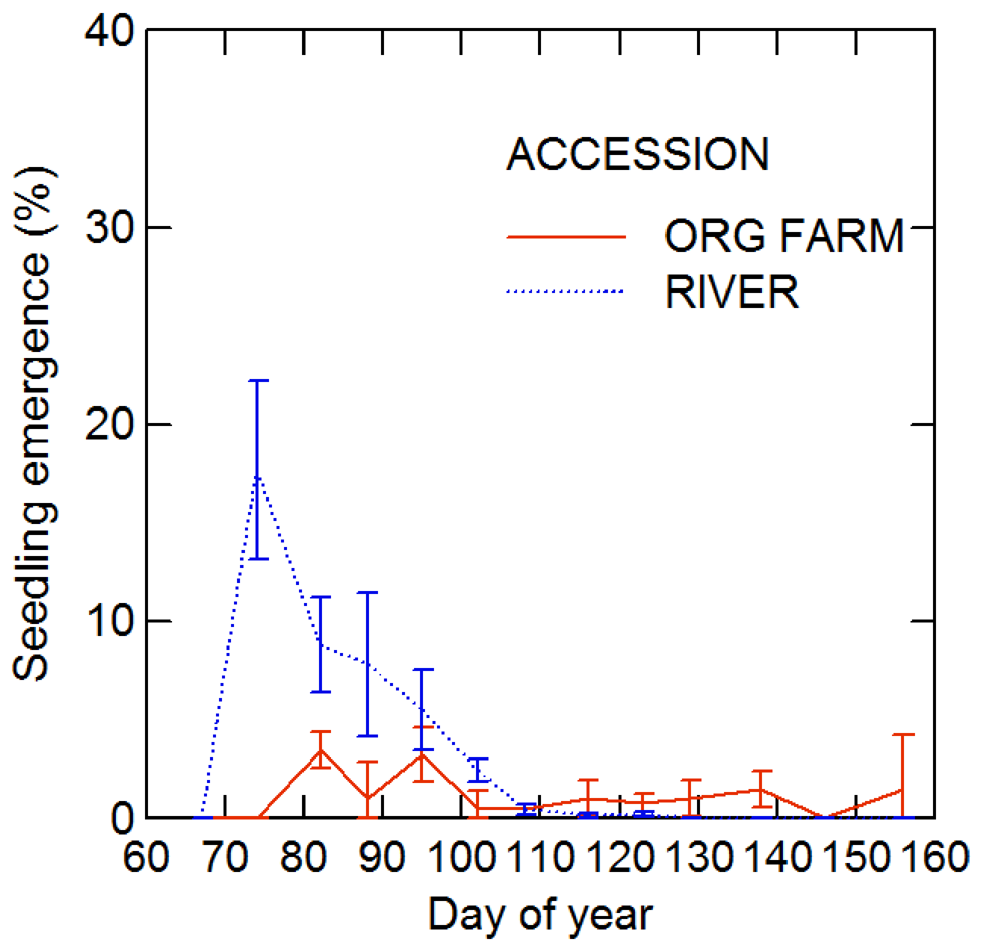
Evolution: directional selection



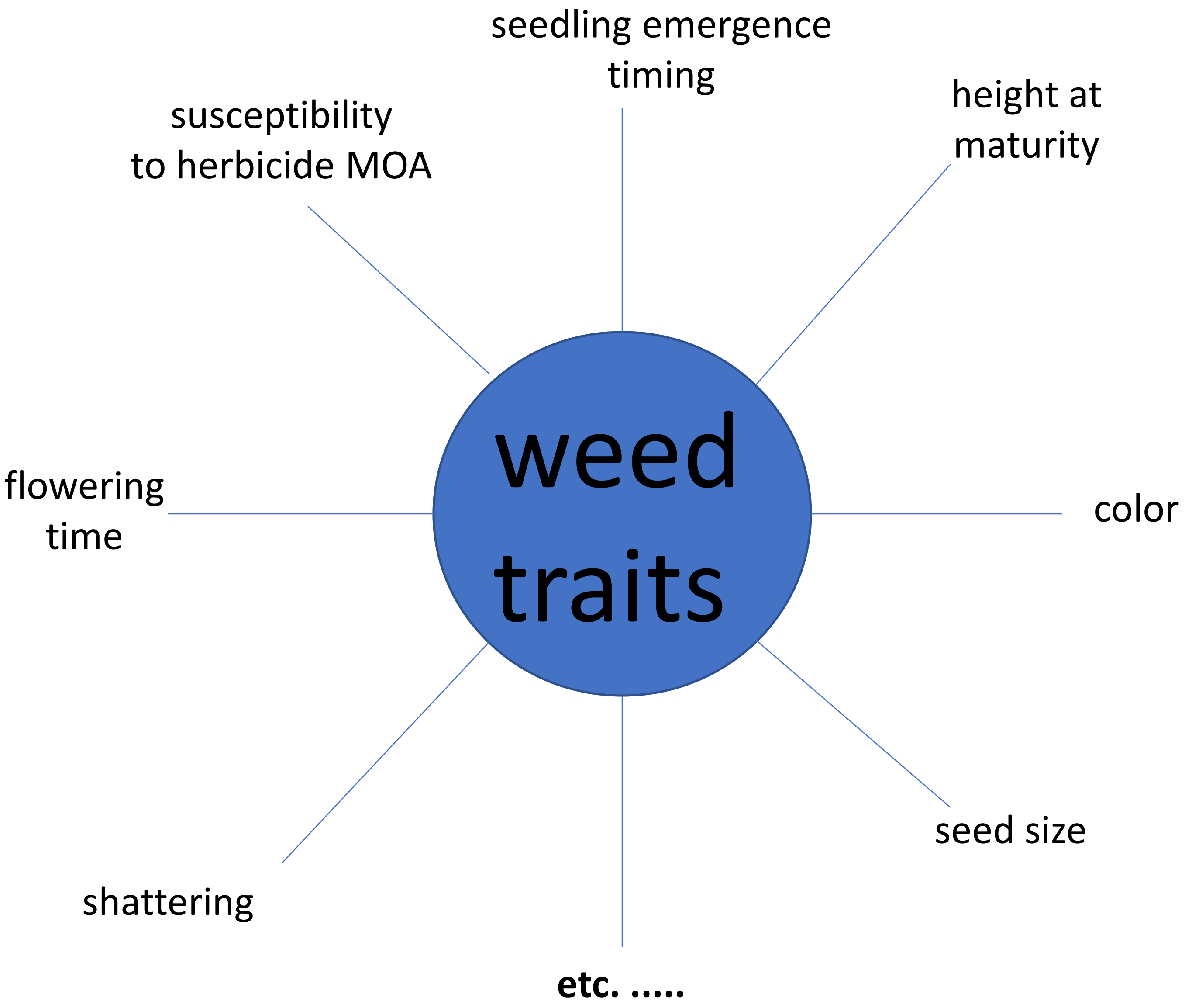
When a strong selection pressure is applied consistently, nature evolves rapidly away.




1996
2005



Seedling emergence (%)
0
10
20
30
40
Day of year
60
70
80
90
100
110
120
130
140
150
160
ACCESSION
ORG FARM
RIVER


weed traits
seedling emergence timing
height at maturity
color
seed size
etc. .....
shattering
flowering time
susceptibility to herbicide MOA

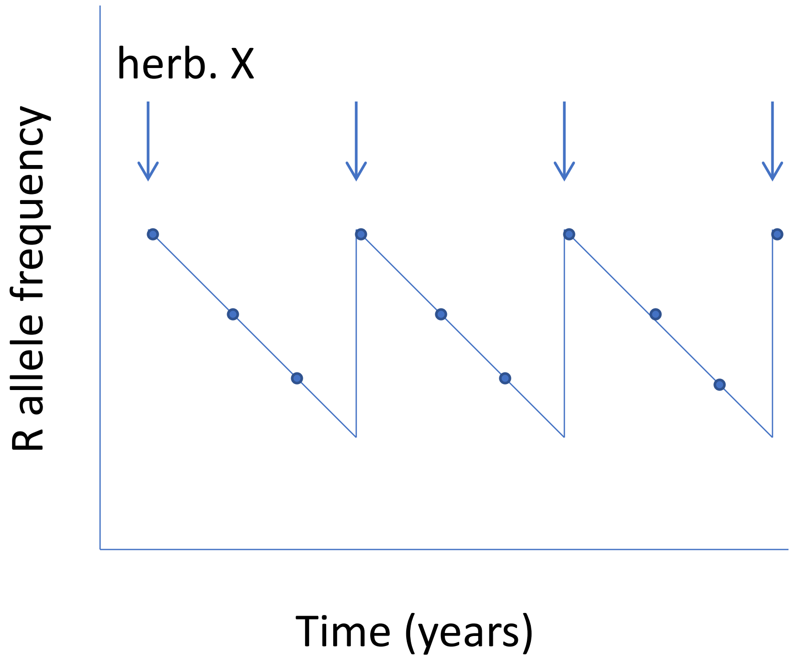
Slowing weed evolution: heterogeneous environments

- Can we manage the field environment so that we provide contrasting, diverse selection pressures on weed populations?

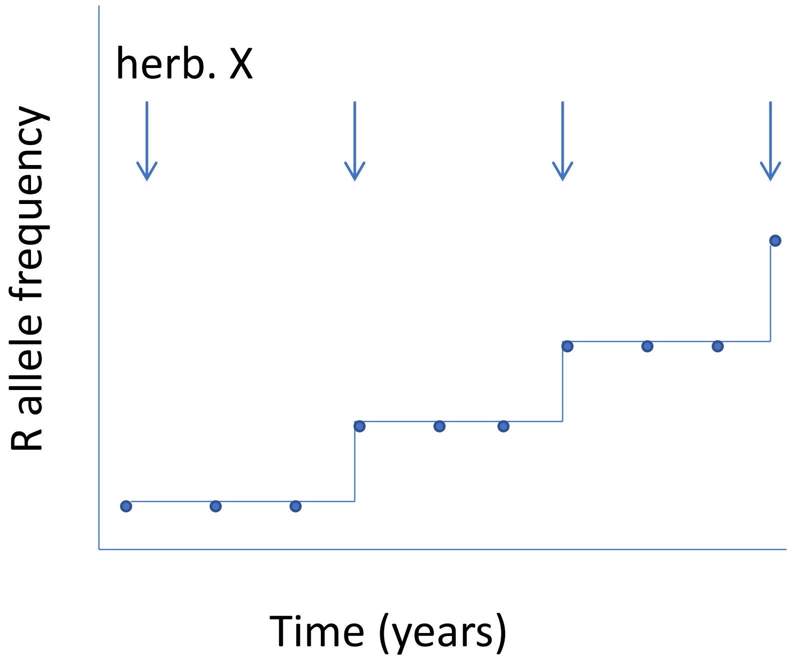
  - Vary selection pressures over time

  - Combine selection pressures simultaneously

HR Strategy A: rotate MOA over time

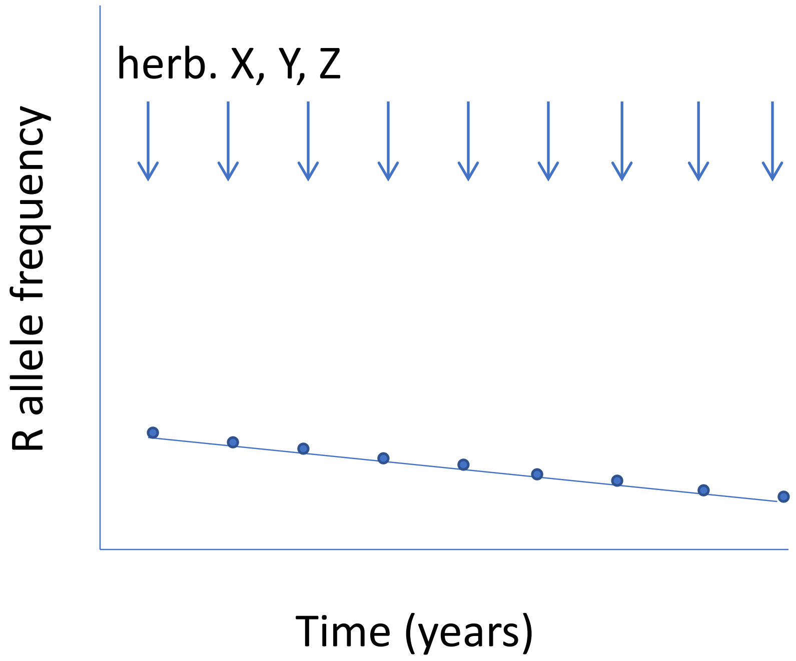


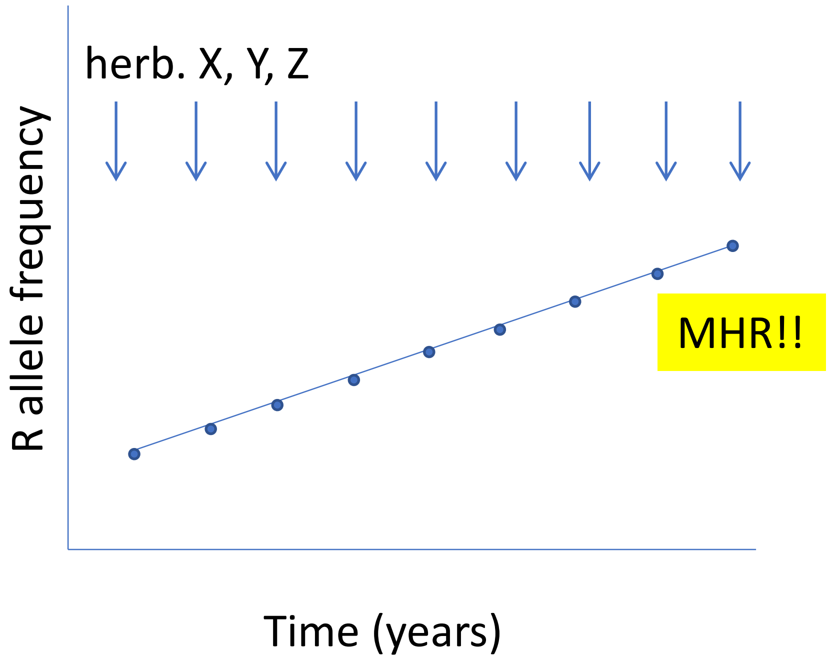
high fitness cost



no (low) fitness cost

HR Strategy B: apply multiple MOA simultaneously (tank-mix)



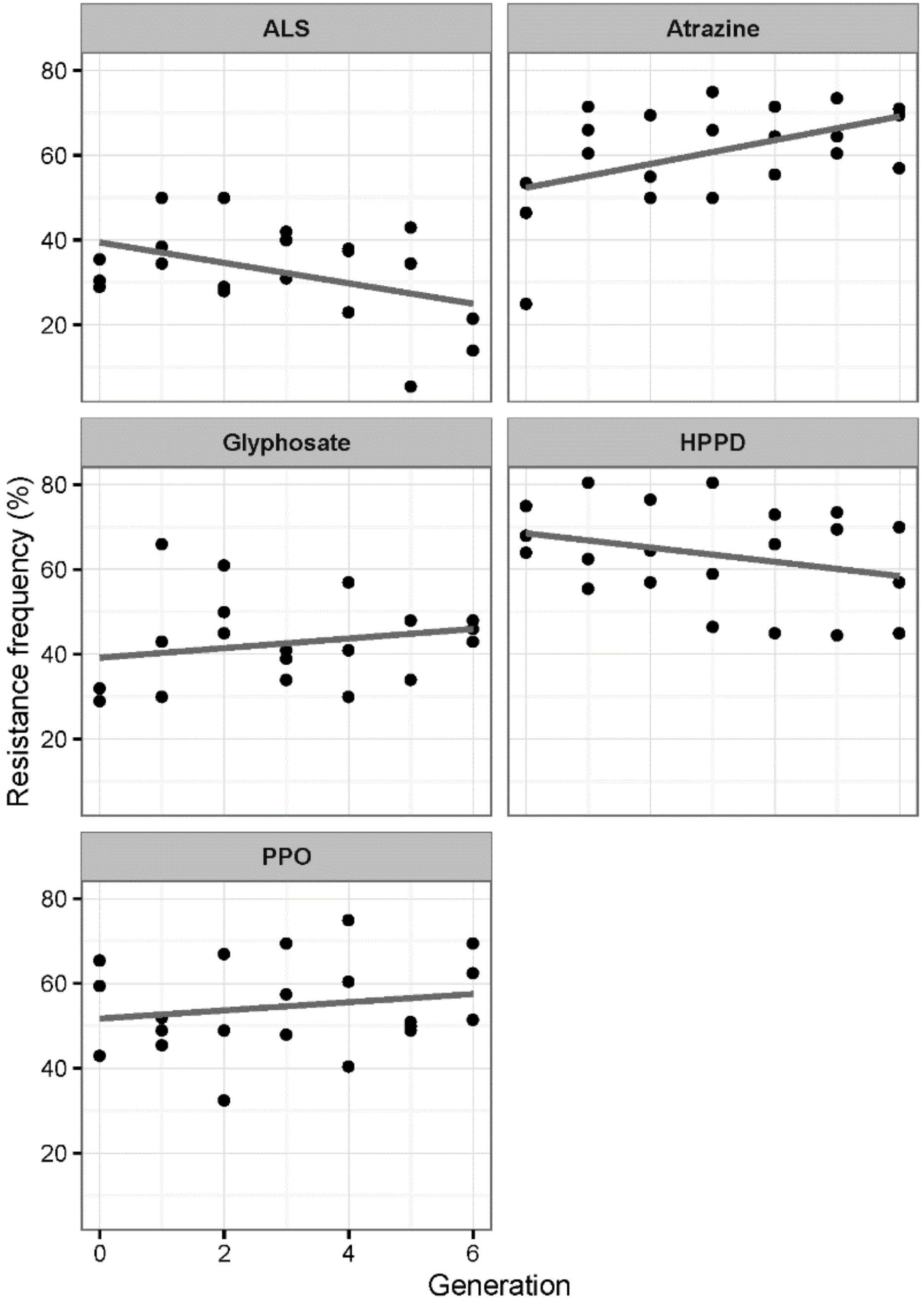


high mortality/ fitness cost

low mortality/ fitness cost

Multiple herbicide-resistant
Amaranthus tuberculatus
in east-central Illinois (CHR)

<u>R sites of action:</u>
ALS-inhibitors
HPPD-inhibitors
Growth regulators
PPO-inhibitors
PSII inhibitors
(+VLCFA, ‘22)

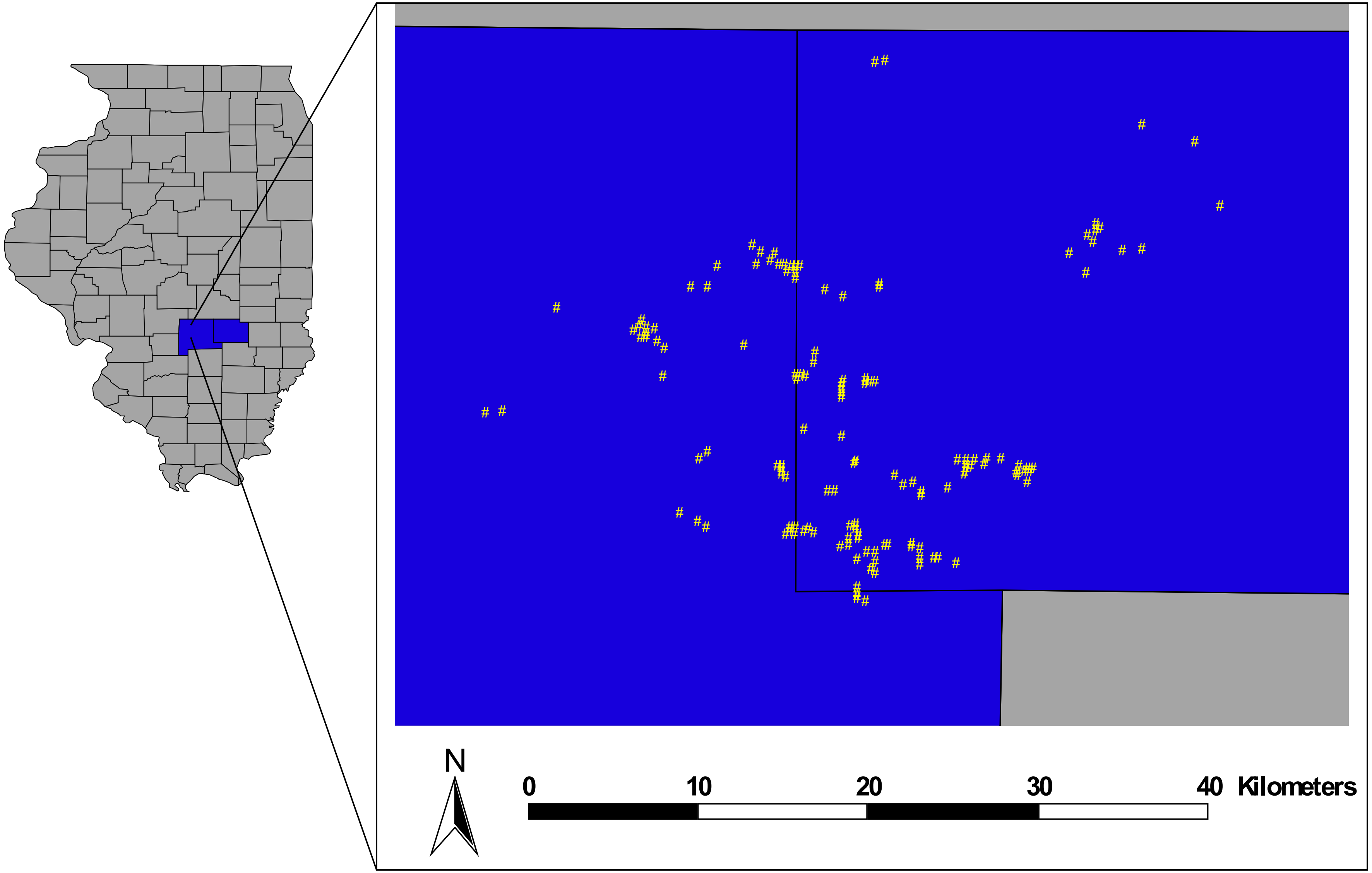


There were **no** fitness costs for 4 of 5 resistances found in synthetic population of common waterhemp.

Wu et al. 2017

Lessons learned about factors driving evolution of HR in common waterhemp in IL soybean

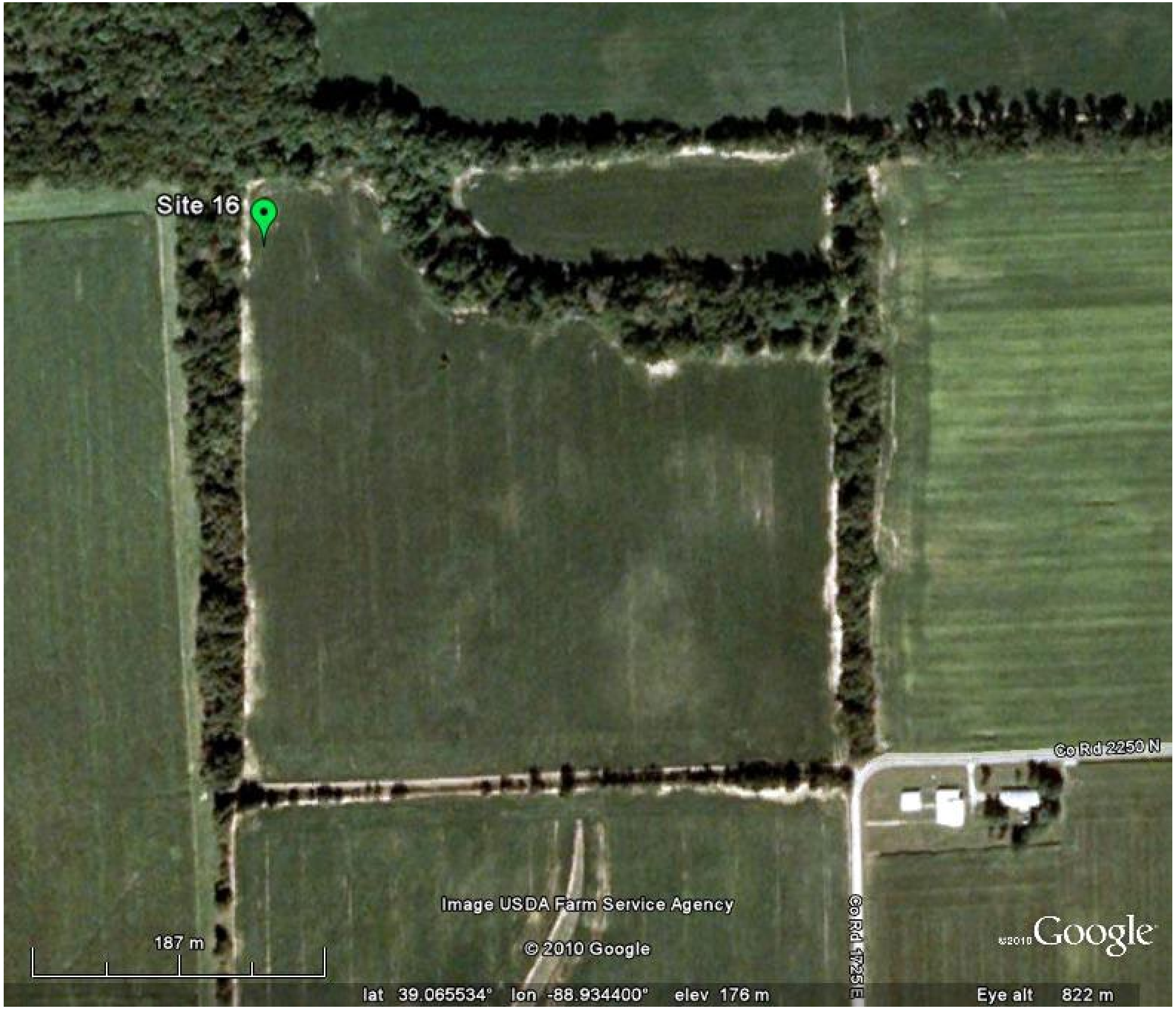
Field locations

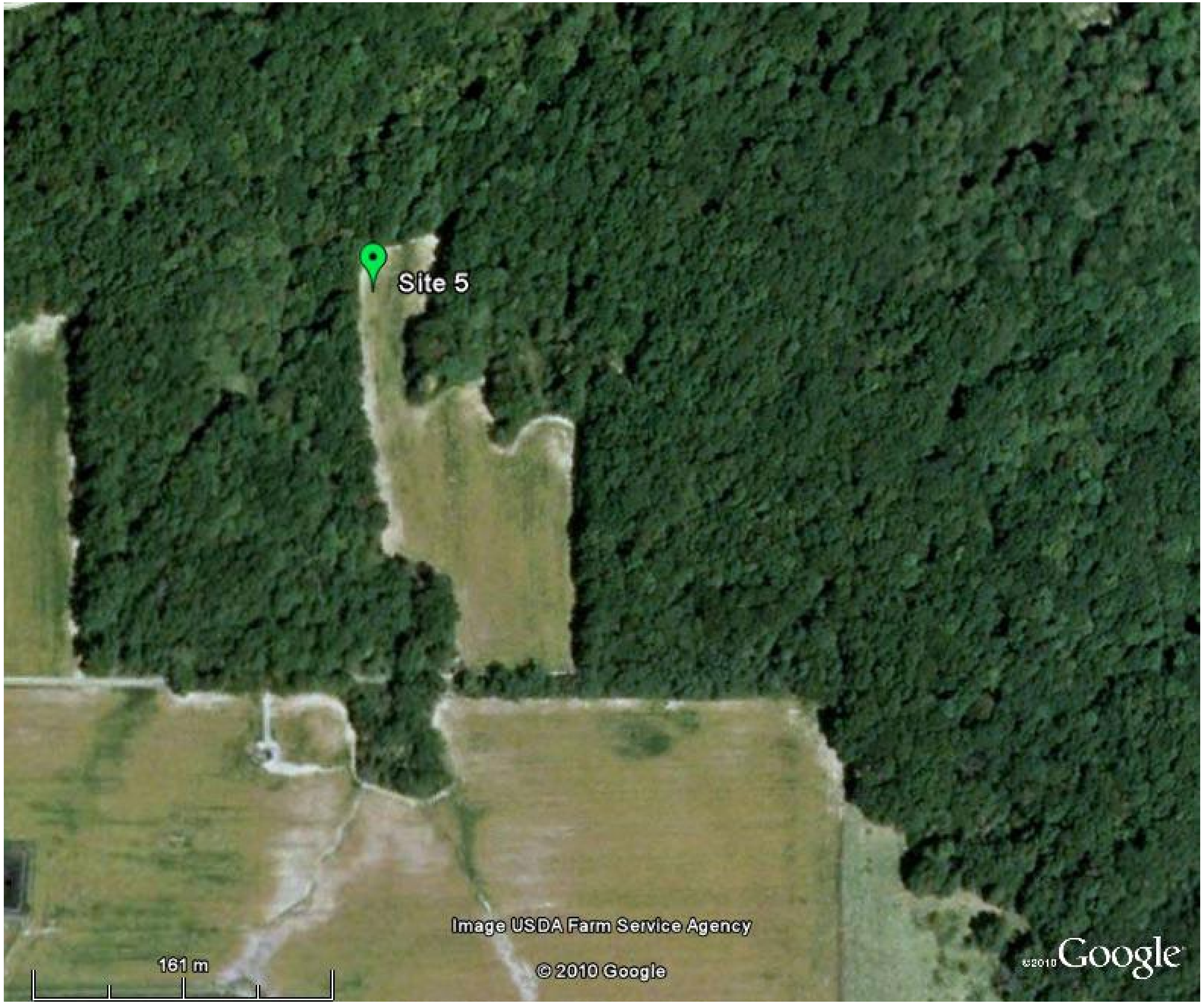


Epidemiology of R_{gly} in waterhemp

- Landscape
  - Proximity to other infected fields
  - Water
  - Topography
  - Land use, landscape complexity
- Management History (2004-2010, 141 fields)
  - Cropping system
  - Herbicide program
  - Animals
  - Machinery

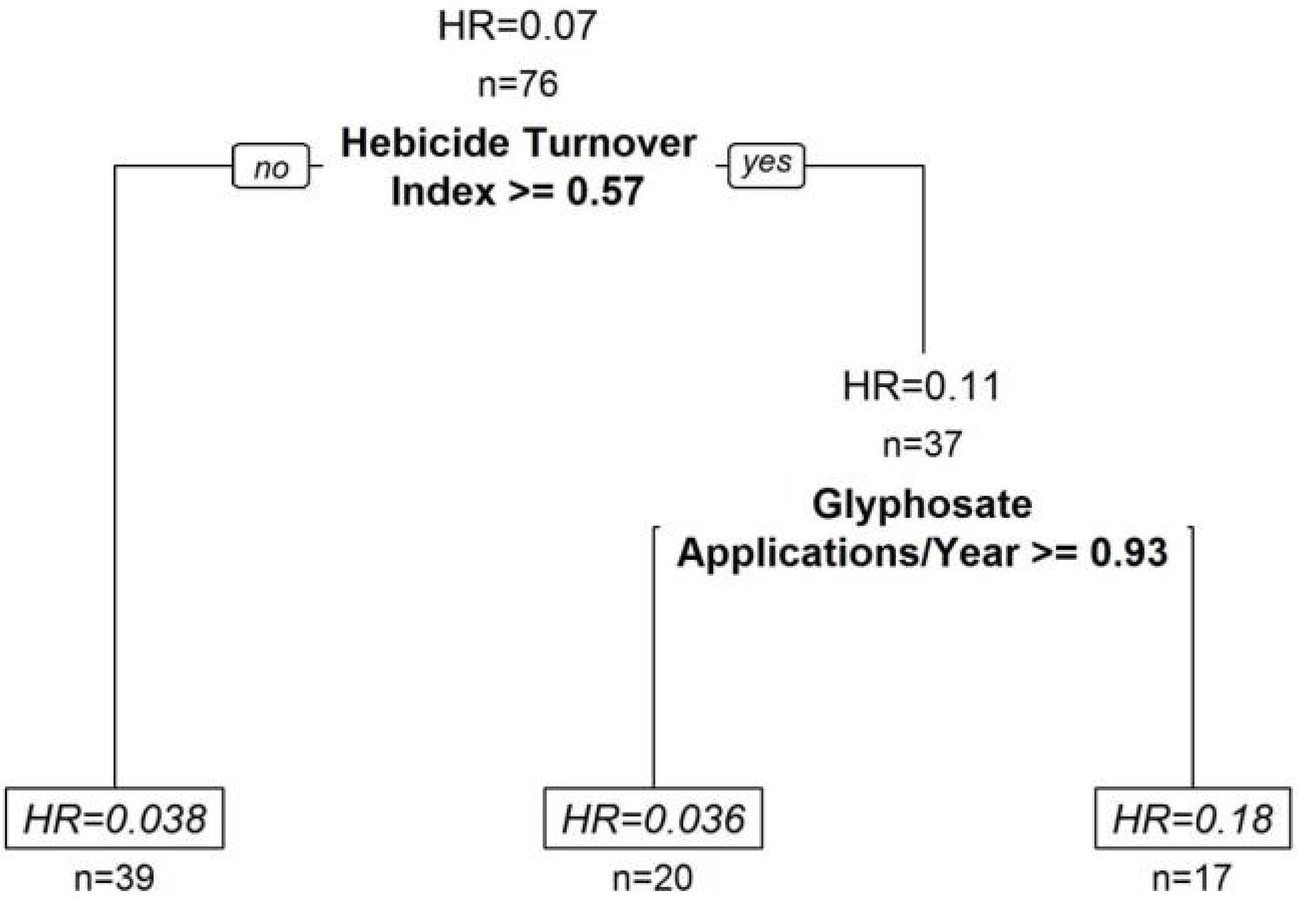

Site 117
Site 116
E 400th Ave
N 100th St
Image USDA Farm Service Agency
© 2010 Google
251 m
©2010 Google


Site 16
Co Rd 2250 N
Co Rd 1725 E
Image USDA Farm Service Agency
© 2010 Google
187 m
©2010 Google
lat 39.065534° lon -88.934400° elev 176 m
Eye alt 822 m


Site 5
Image USDA Farm Service Agency
© 2010 Google
161 m
©2010 Google

Resistance screening

Did herbicide rotation help delay gly-R?



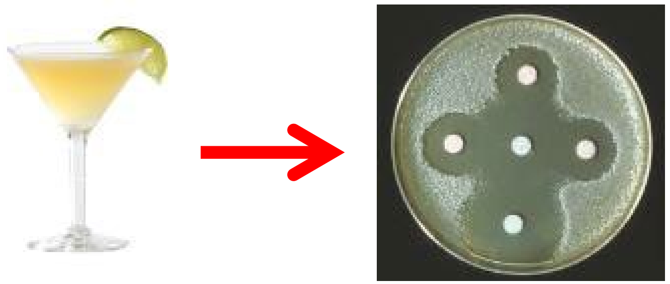
No.

Greater amount of herbicide MOA turnover was associated with more resistance evolution from 2004-2010. So was heavy glyphosate use.

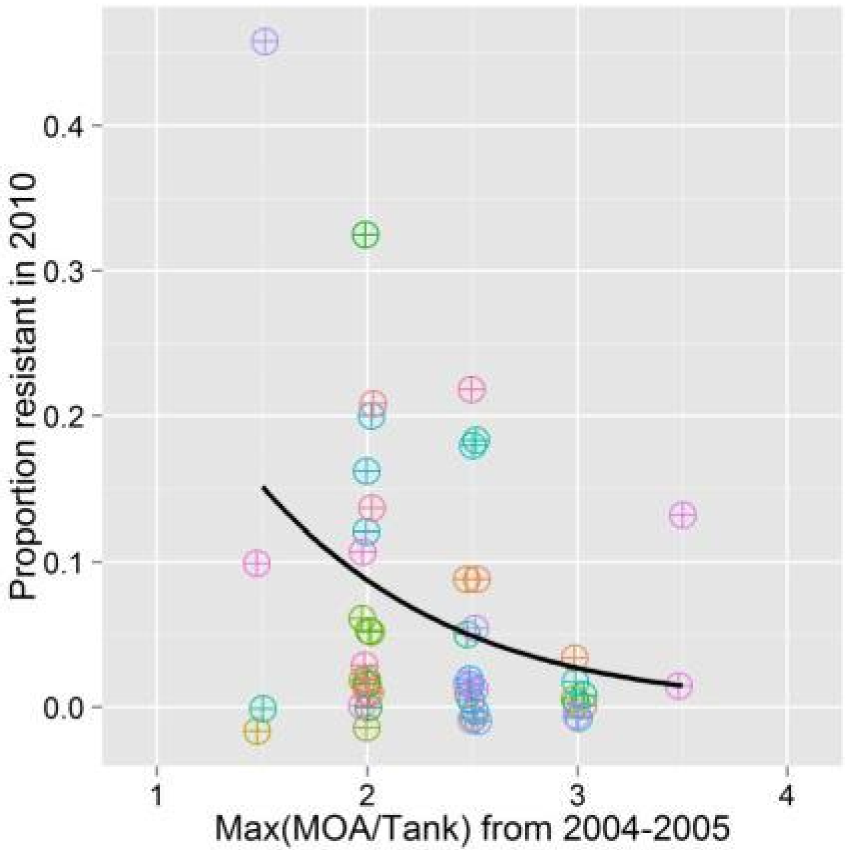
Evans et al. 2016

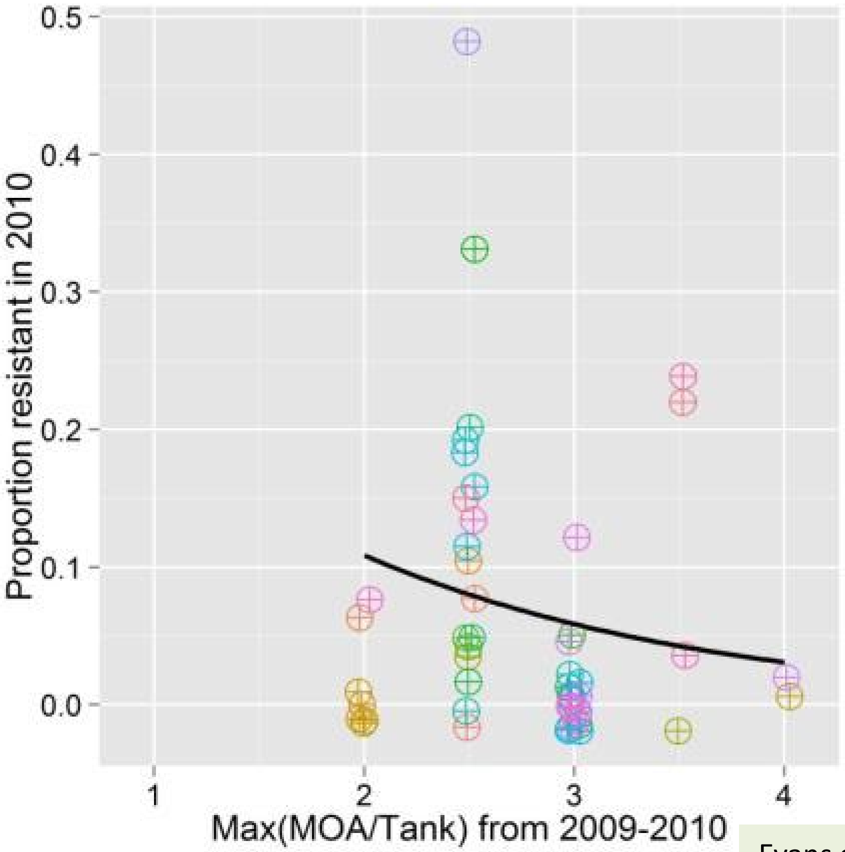
Did tank-mixing help delay gly-R?

Yes!



Cocktails with more MOA were associated with **less** resistance evolution from 2004-2010.





Evans et al. 2016

Are you doomed to HR if your neighbor is a lousy weed manager?

Mgt (MOA complexity)

-0.44 ***

GR

0.03 ns

Neighbors

NO!

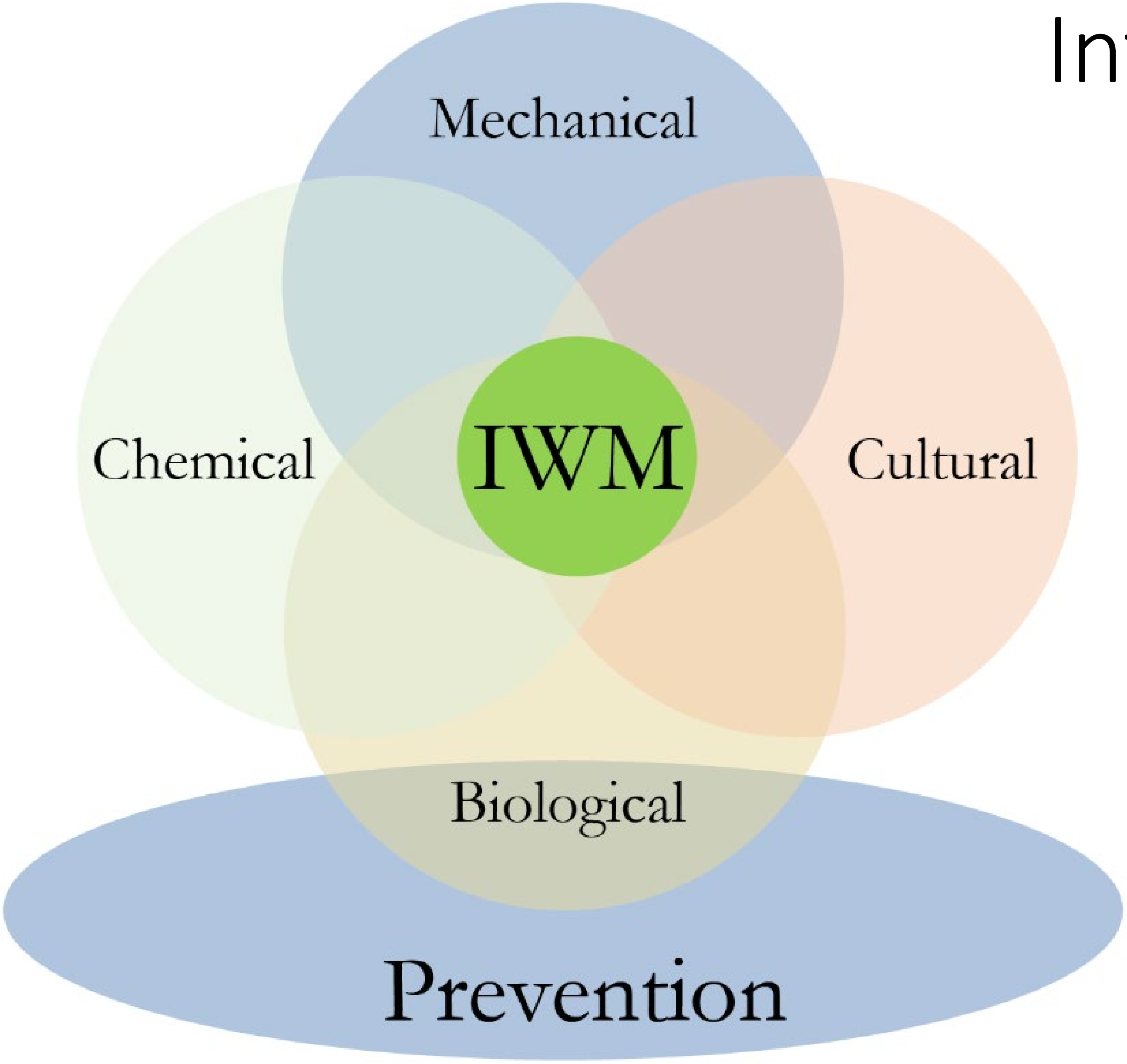
We saw **no** influence of proximity to infected neighbors on the rate of evolution of glyphosate resistance.

Evans et al. 2016

Lessons learned

1) Herbicide rotation doesn’t help delay glyphosate resistance evolution (may work for other MOA) => Fitness cost of gly-R is **low**
2) MOA cocktails can help delay gly-R, **for a while....**
3) What you do on **your** fields matters
4) Any weed management program relying only on herbicides will encounter resistance problems. Need to **diversify practices.**

Long-term solutions to managing weeds must go **beyond tactics** to system-level thinking



Integrated weed mgt.

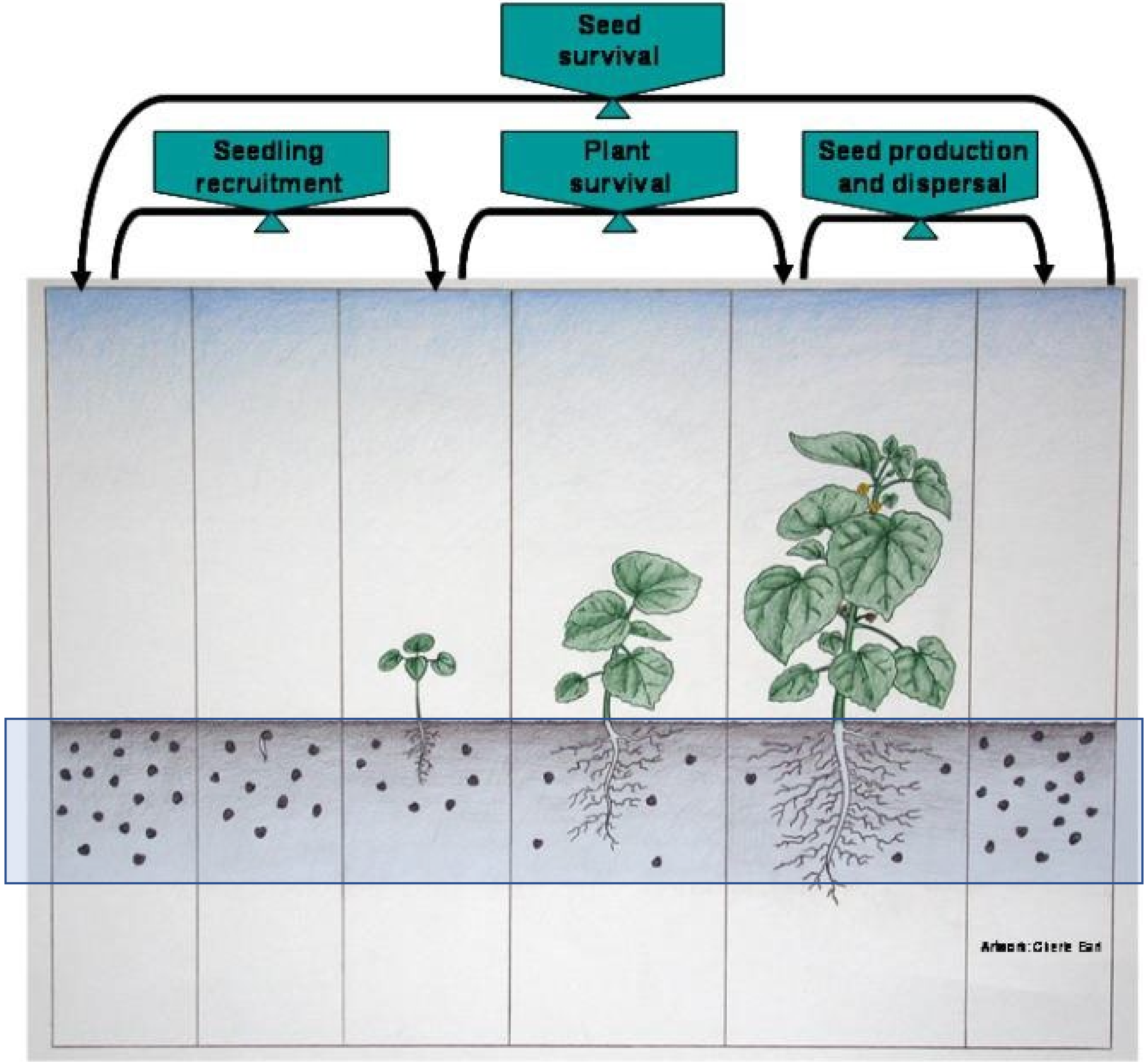
- Not just a set of tools
- Need to know your weeds
- Choose appropriate tactics
- Spread tactics throughout weed life cycles
- Manage for the long-term
- Build weed suppressive cropping systems
- Begin with prevention

Drawing by Annie Klodd https://integratedweedmanagement.org/

Weed-suppressive cropping systems...

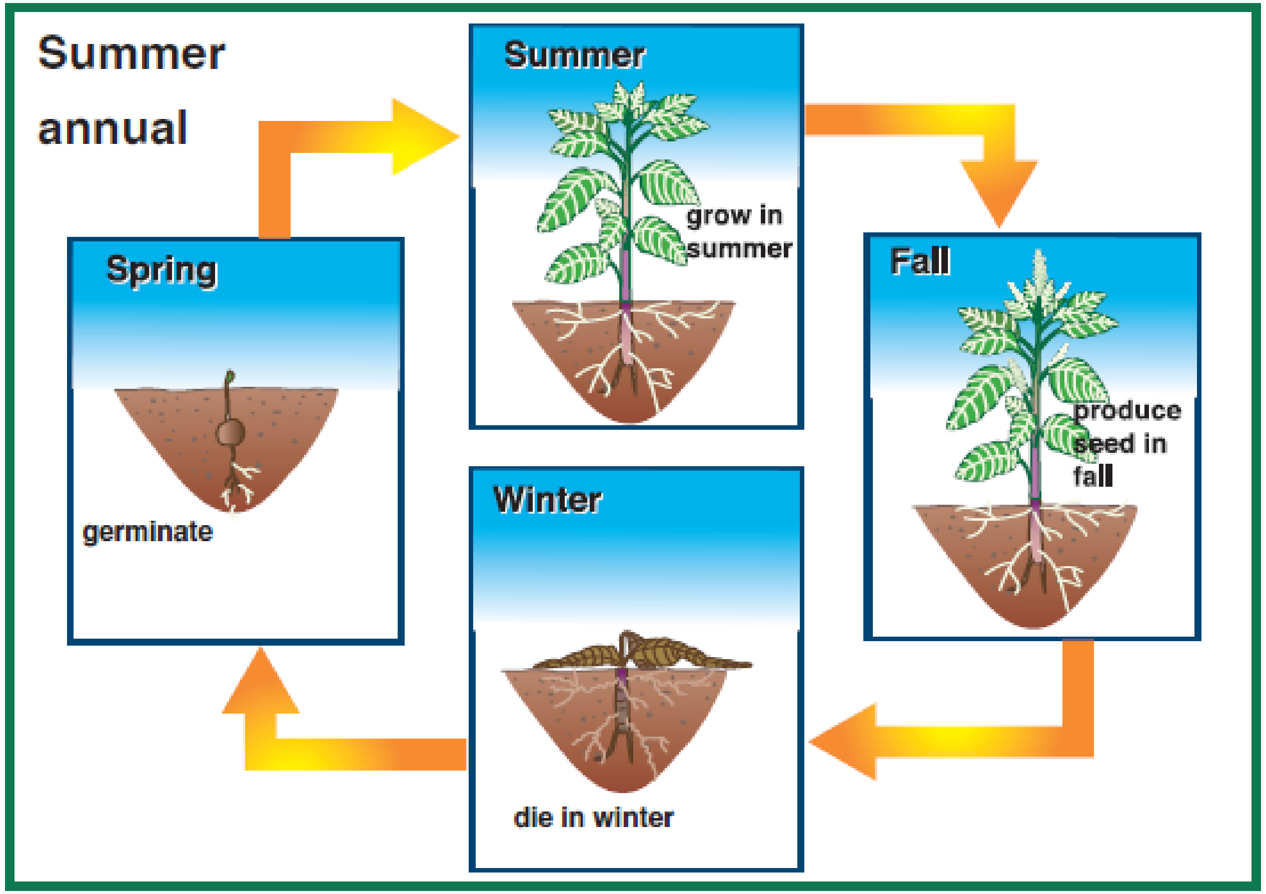
- Prevent germination
- Prevent seedling establishment
- Reduce weed competition
- Reduce seedbanks
  - Reduce seed production
  - Prevent seed return
  - increase seed predation
  - increase seed decay

Know your weeds: life history



Artwork: Cherie Earle

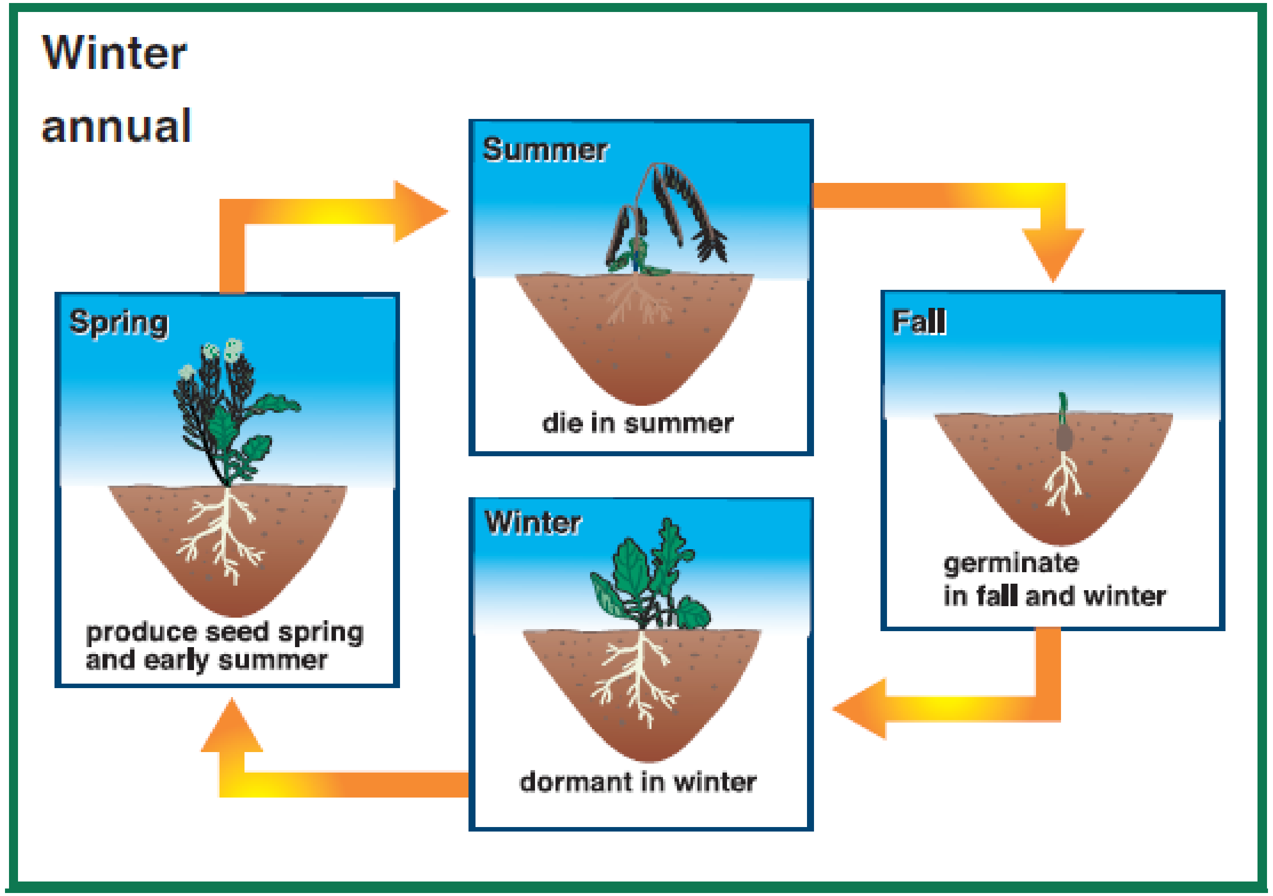
Weed life history: I. summer annuals



tall waterhemp
(*Amaranthus tuberculatus*)

Source: Cavigelli et al. 2000

Weed life history: II. winter annuals

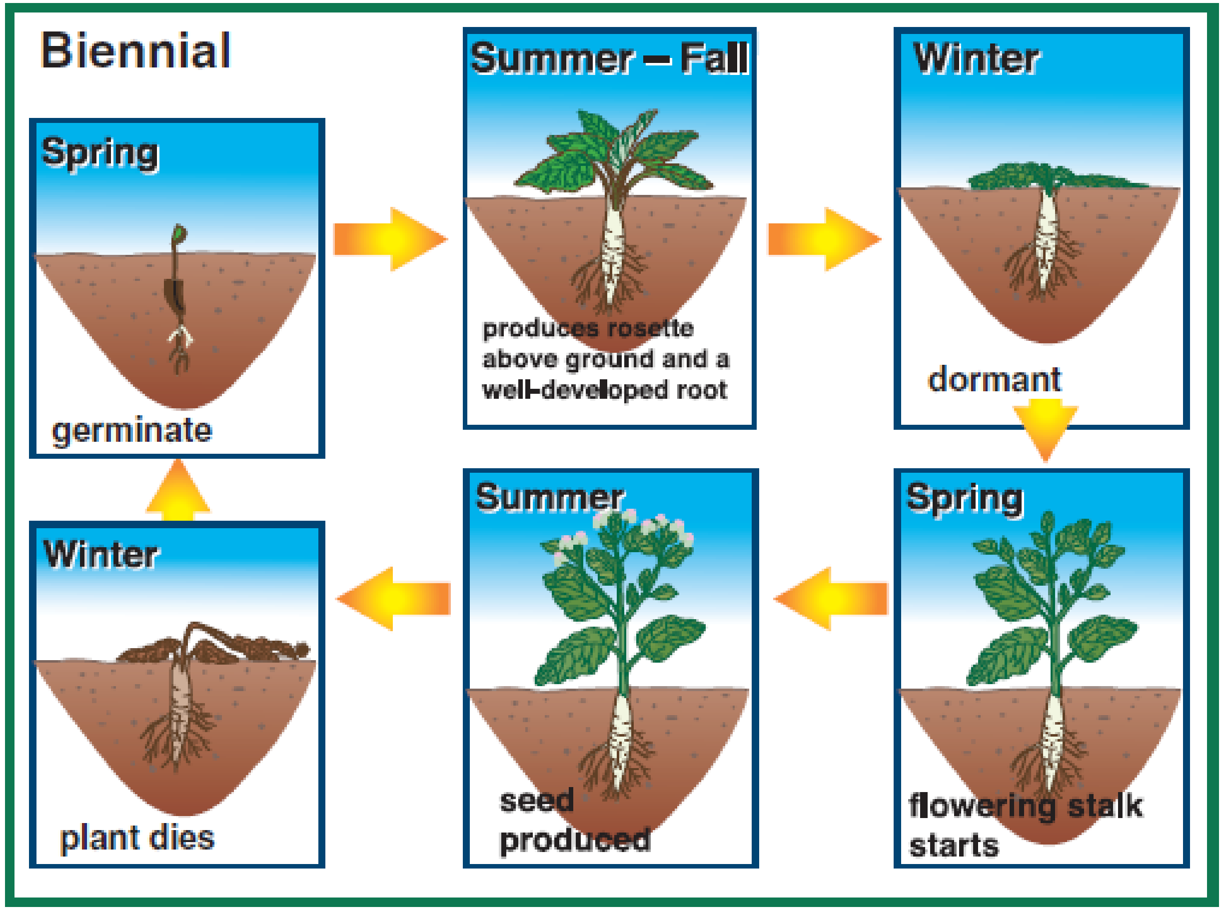


Source: Cavigelli et al. 2000

marestail (*Conyza canadensis*)

Image source: B. Hartzler, ISU

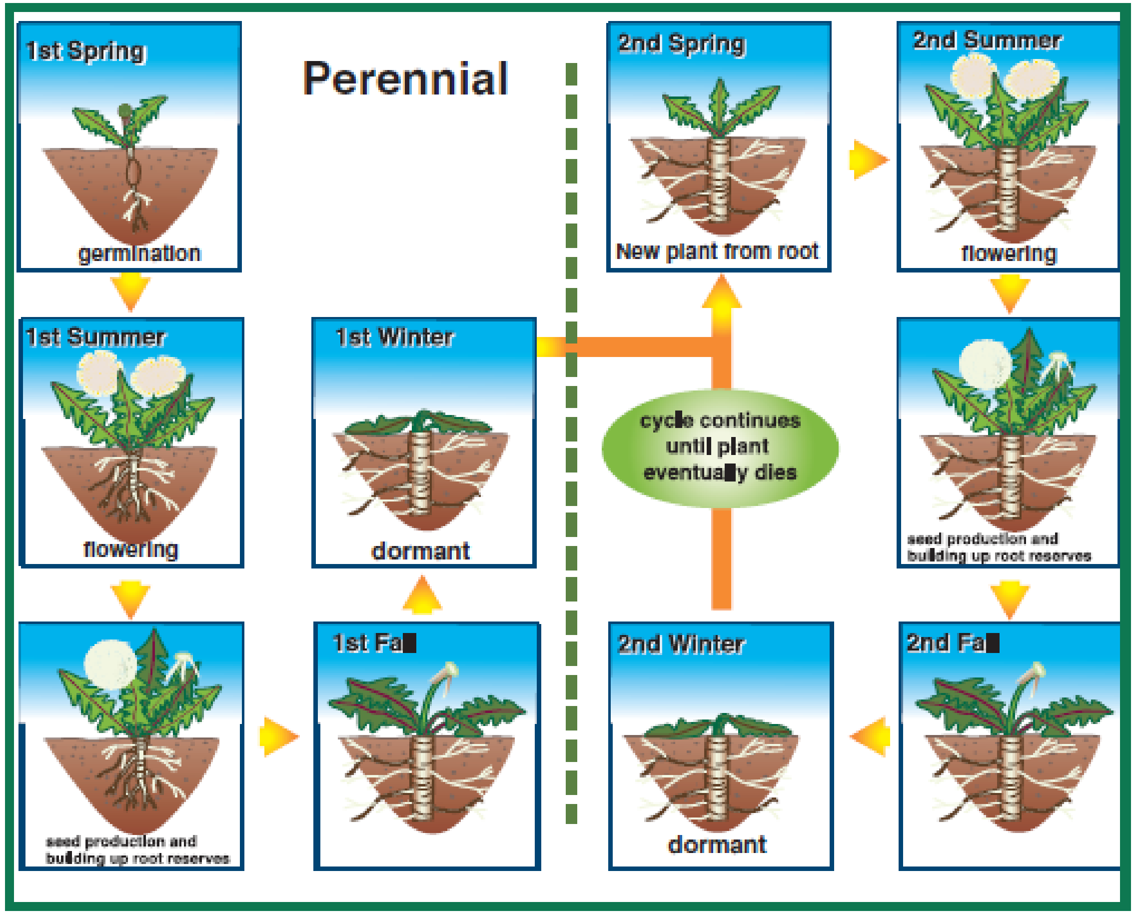
Weed life history: III. biennials



wild carrot (*Daucus carota*)

Source: Cavigelli et al. 2000

Weed life history: IV. perennials



Canada thistle (*Cirsium arvense*)

Source: Cavigelli et al. 2000

Highest priority management targets, by life history

annual

seeds

biennial

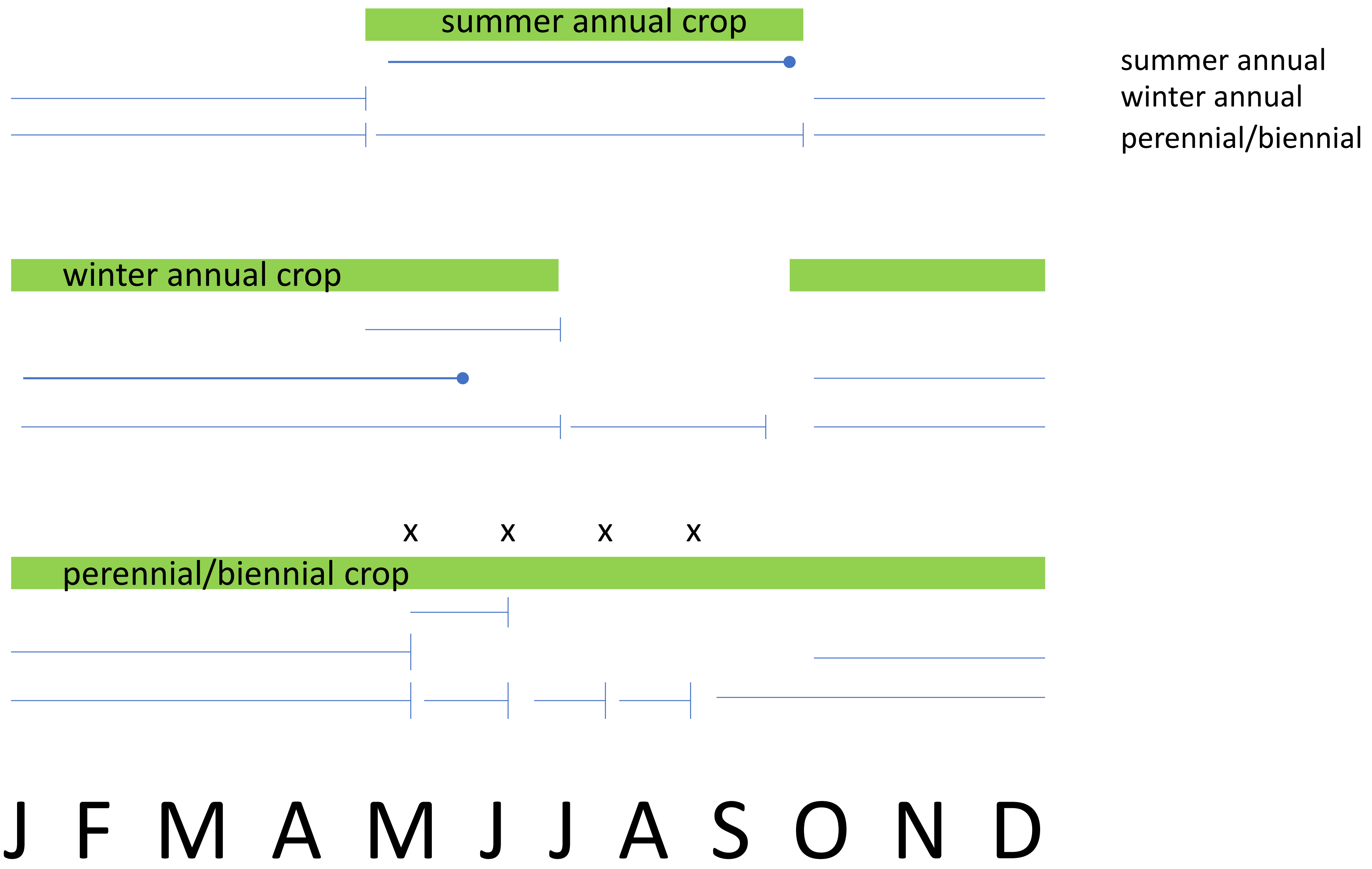
rosettes, seedlings > seeds

perennial

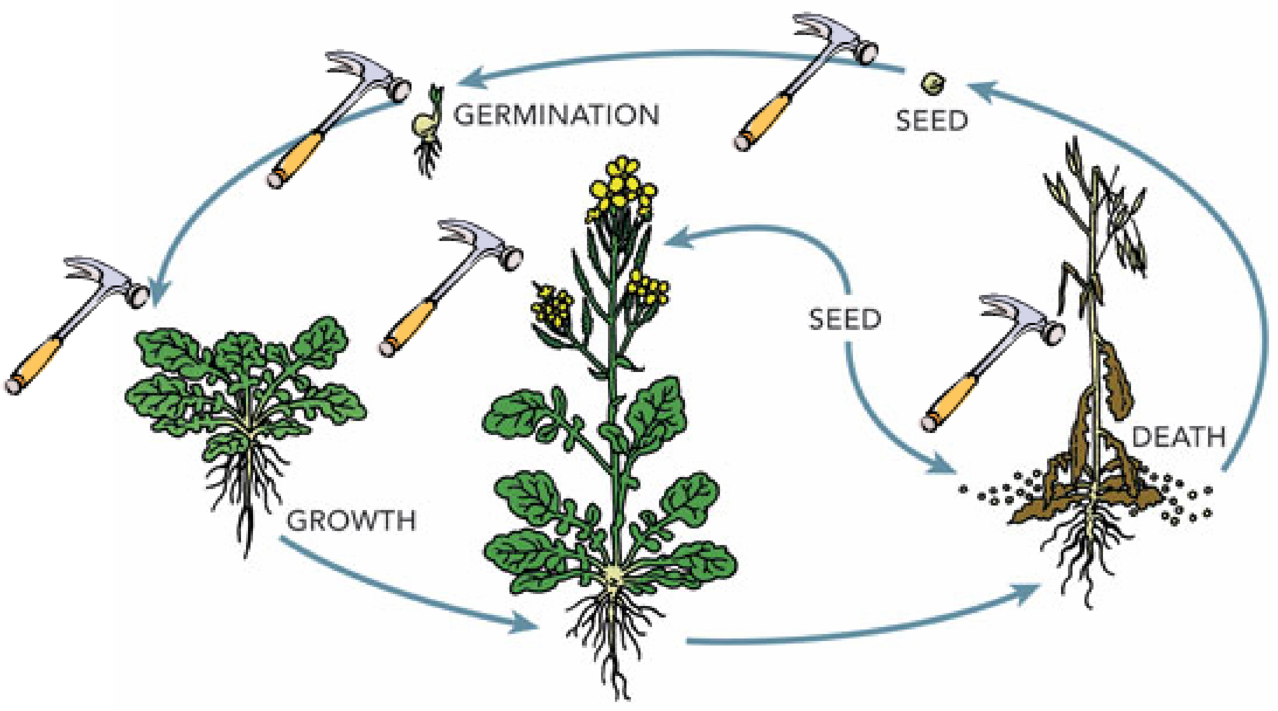
rosettes > seedlings > adults > seeds

Davis. 2006. Weed Sci. 54: 558-565

Plan rotation phases to disrupt weed life cycles

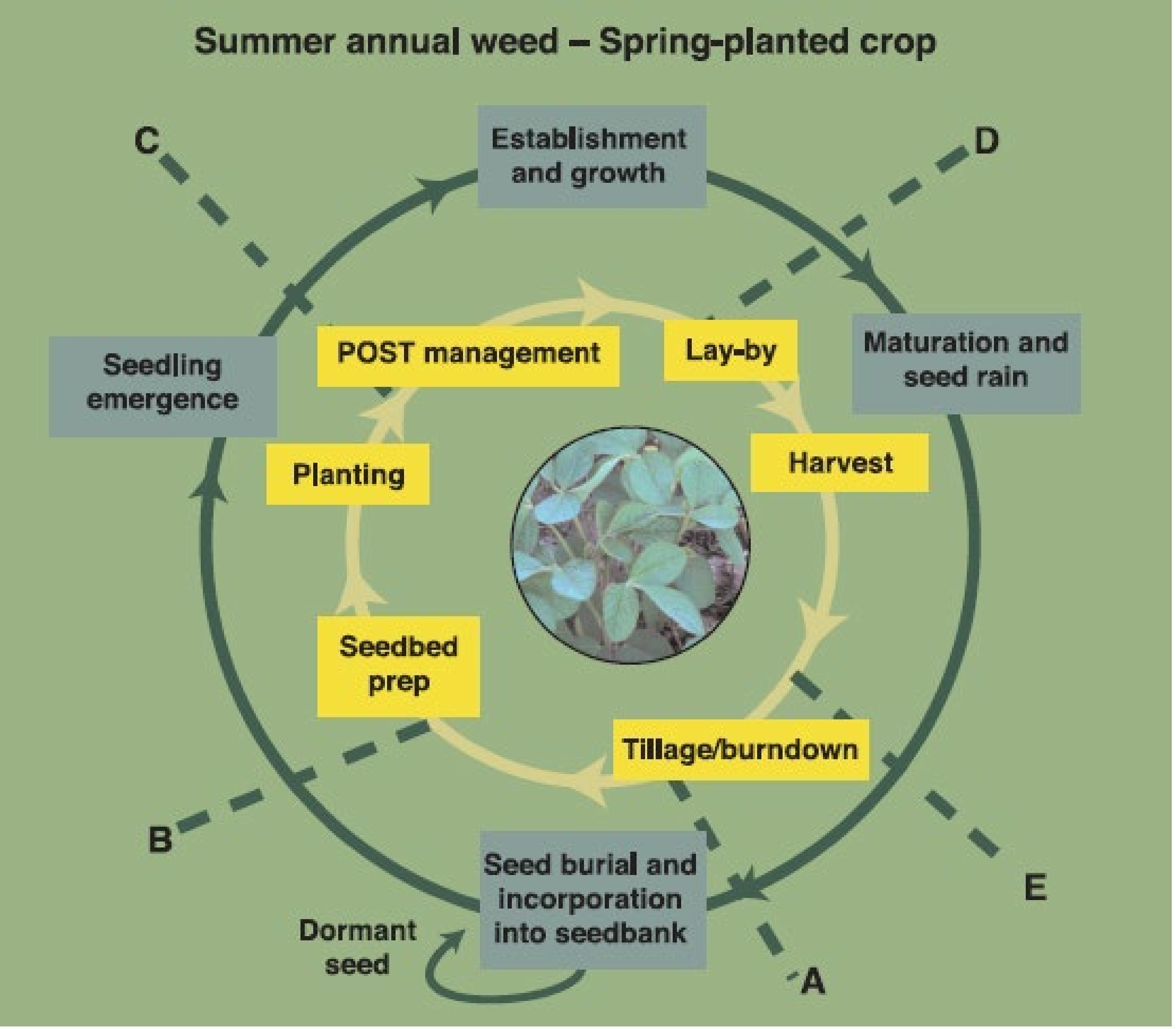


Target **all** stages of life cycle

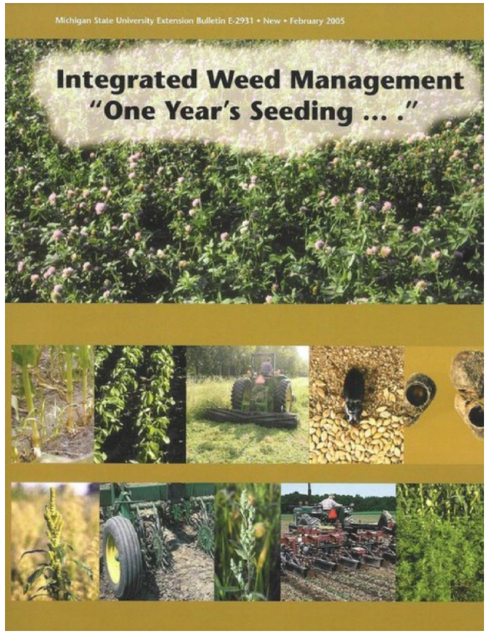


‘Many little hammers’ (Liebman and Gallandt, 1997)

Artwork: Rich Smith



Davis et al. (2005) Integrated weed management



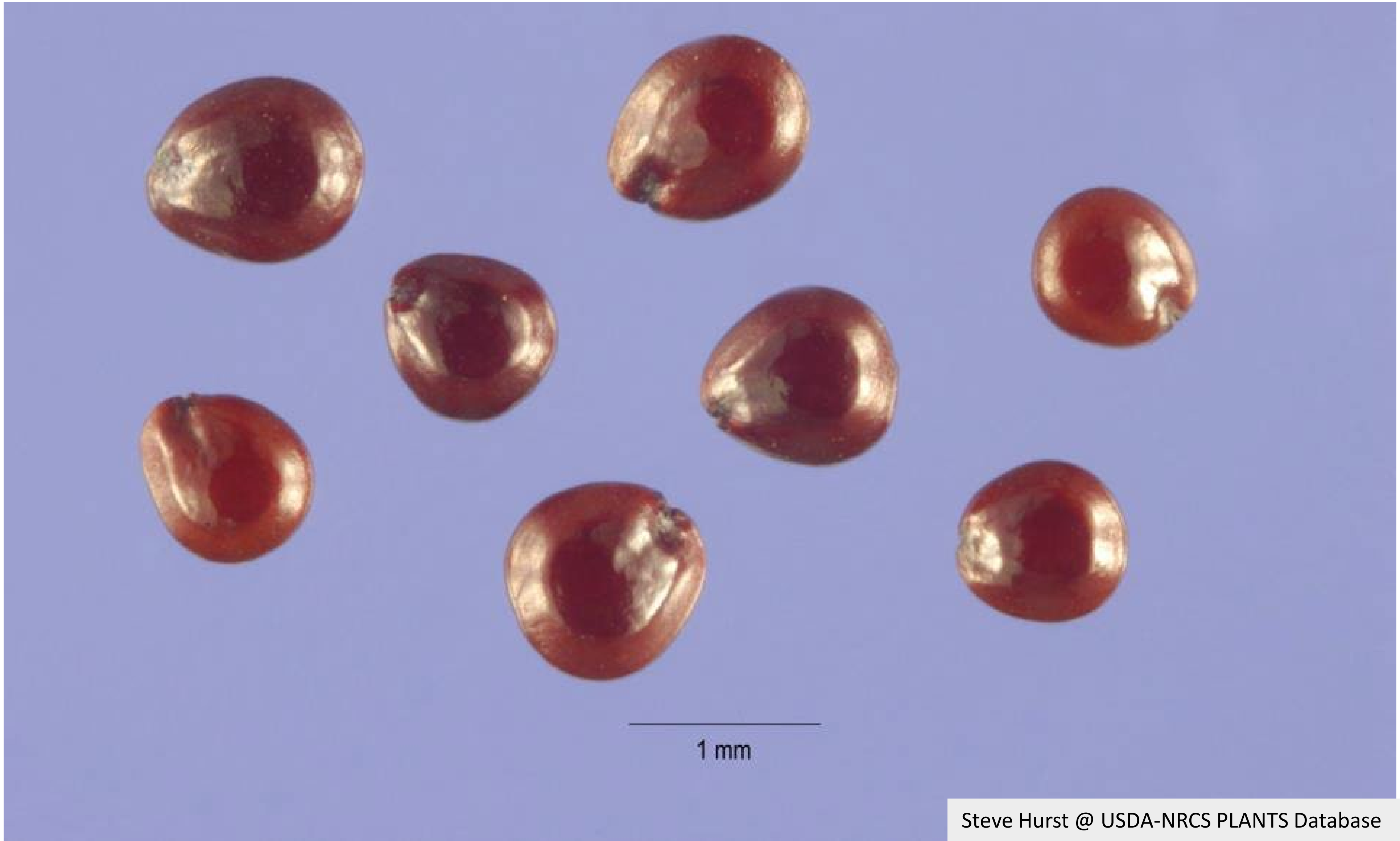
https://drive.google.com/file/d/1tWeFijBdw47KvFdmcuKyJWC3ZrEtBwK5/view

Figure 1. The relationship between field operations for a spring-planted crop (yellow) and life cycle of a summer annual weed (green). Dotted lines show weed management opportunities throughout the year. Source: Adam Davis.

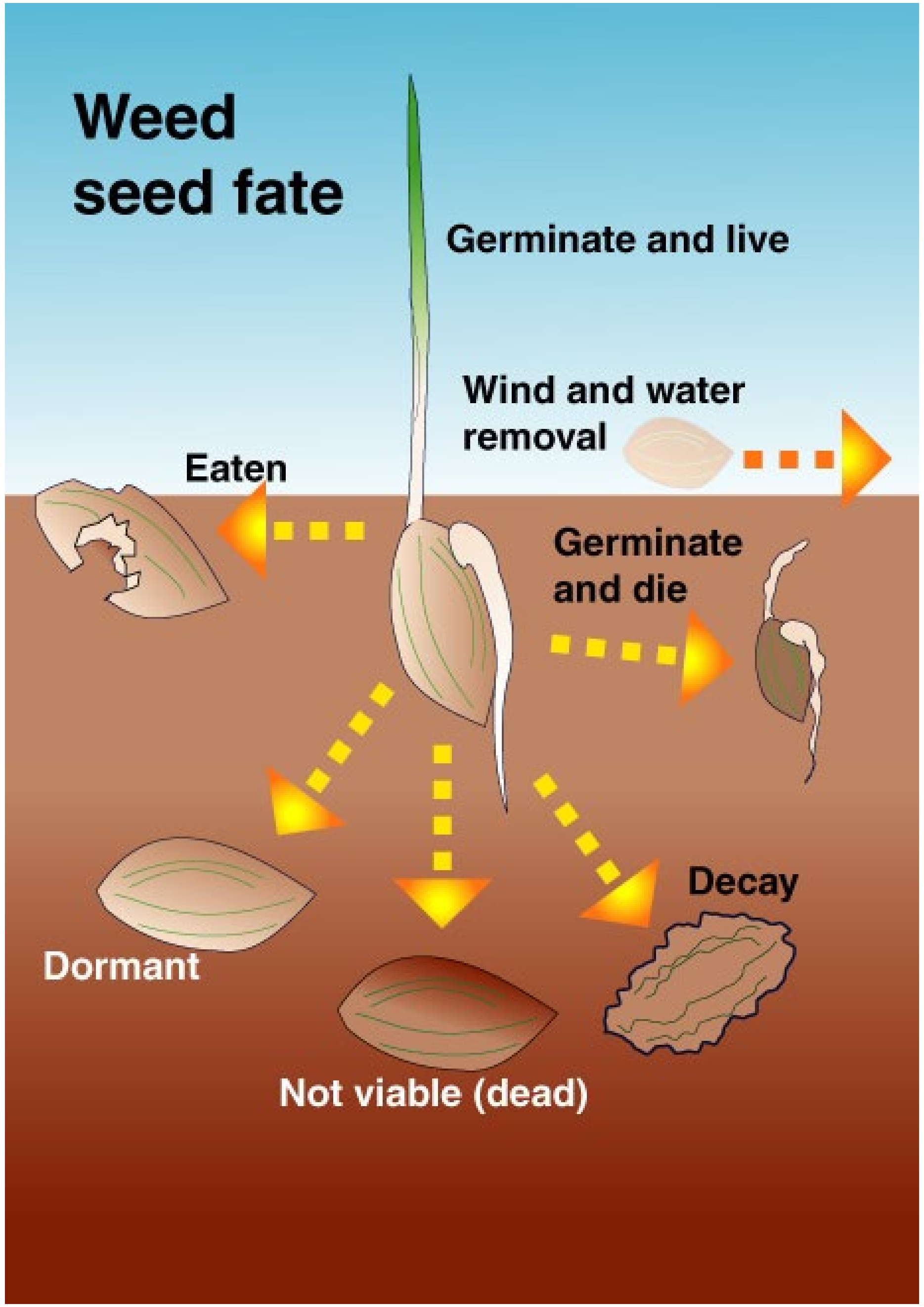
Stage	Potential sources of weed management benefits
A	seed decay (Ch. 9), seed predation (Ch. 9), seed aging (Ch. 1), depth placement of seeds (Ch. 4), loss of seed dormancy (Ch. 1)
B	fatal germination (Ch. 1), allelopathy (Ch. 3), stale seedbed (Ch. 7), mulch/cover crop (Ch. 3), seed-soil contact (Ch. 2), PRE herbicide (Ch. 8),
C	physical control (Ch. 7), POST herbicide (Ch. 8), crop competition (Ch. 5)
D	hand weeding (Ch. 7), swathing (Ch. 7), herbivory (Ch. 9), crop competition (Ch. 5)
E	seed predation (Ch. 9), seed removal with chaff (Ch. 10), mowing (Ch. 7), stubble burning (Ch. 7), sanitation (Ch. 10), fencerow maintenance (Ch. 10)

Use a **diverse** set of tools

Manage weed seedbanks



Steve Hurst @ USDA-NRCS PLANTS Database



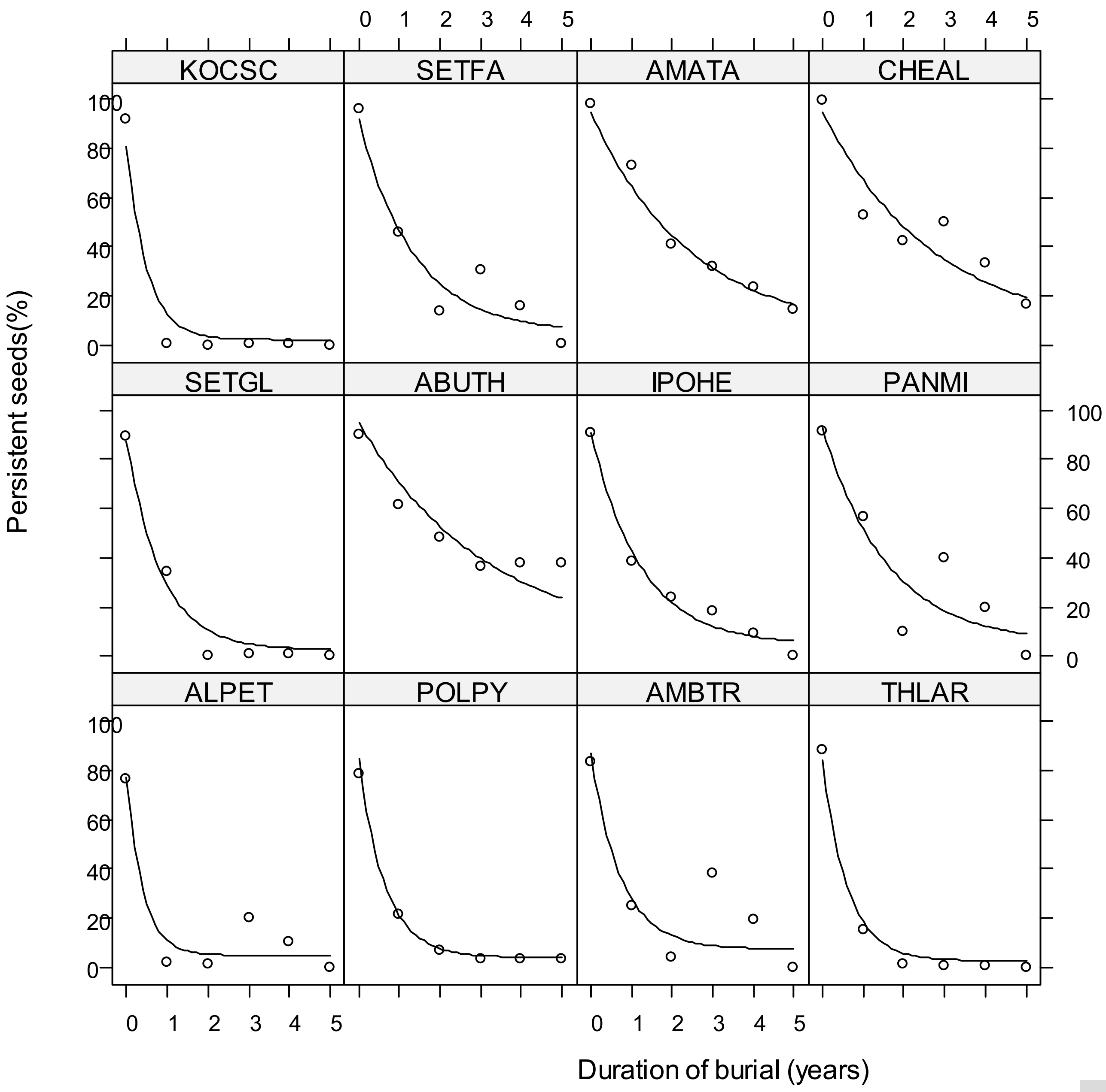
Davis et al. (2005) Integrated weed management

Weed seedbank is persistent, but don’t give up!

Weed species	Years for 50% reduction in seedbank (Burnside et al. 1996)	Years for 50 % reduction in seedbank (Davis et al. 2016)
common lambsquarters	12	2
velvetleaf	8	2.4
smartweed	4	0.5
redroot pigweed	4	1.8
common ragweed	2.5	0.7
giant foxtail	< 1	1
kochia	< 1	0.12

The way these data were estimated was biased towards longevity (stored in glass jars).

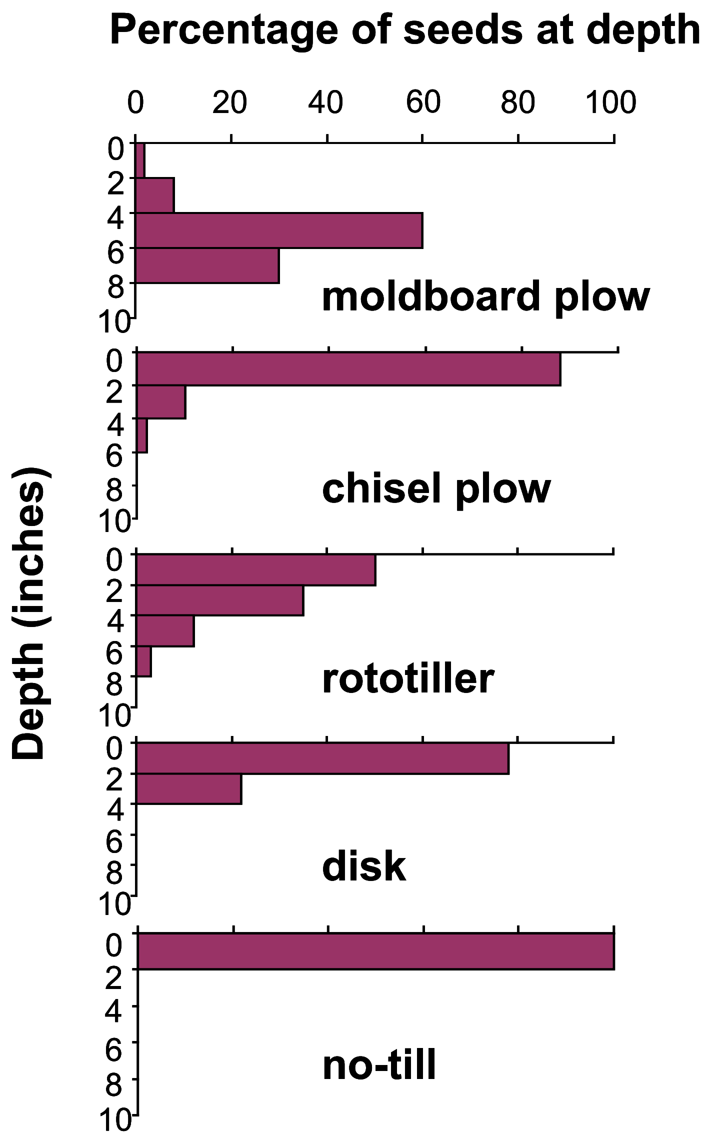
I have more confidence in these numbers (seeds allowed to germinate and exposed to predators).



Davis et al. 2016

Tillage as one-time rescue for massive seed input

Photo: Adam Davis



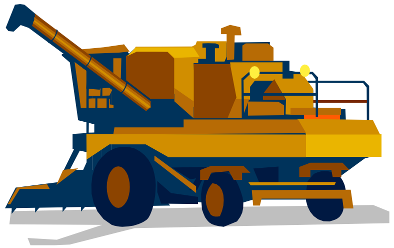
Percentage of seeds at depth
0
20
40
60
80
100
Depth (inches)
0
2
4
6
8
10
moldboard plow
chisel plow
rototiller
disk
no-till

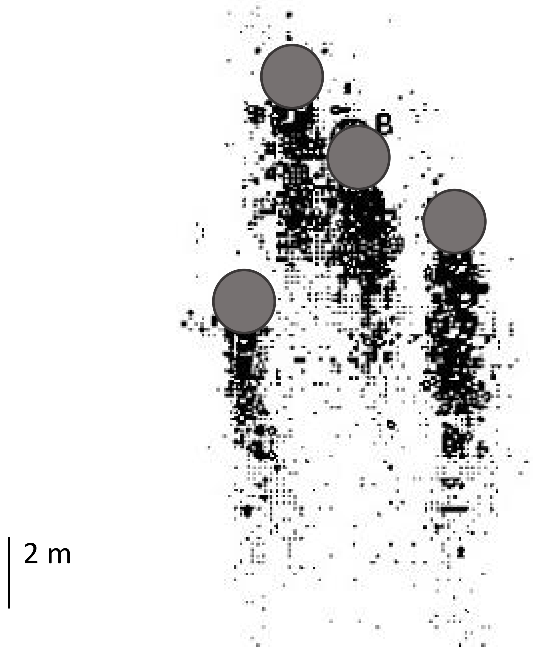
Mohler (2001)


JAN 27 2005

Need for Harvest Weed Seed Control

Combine harvesters are one of the most efficient **weed seed dispersal** devices ever invented.





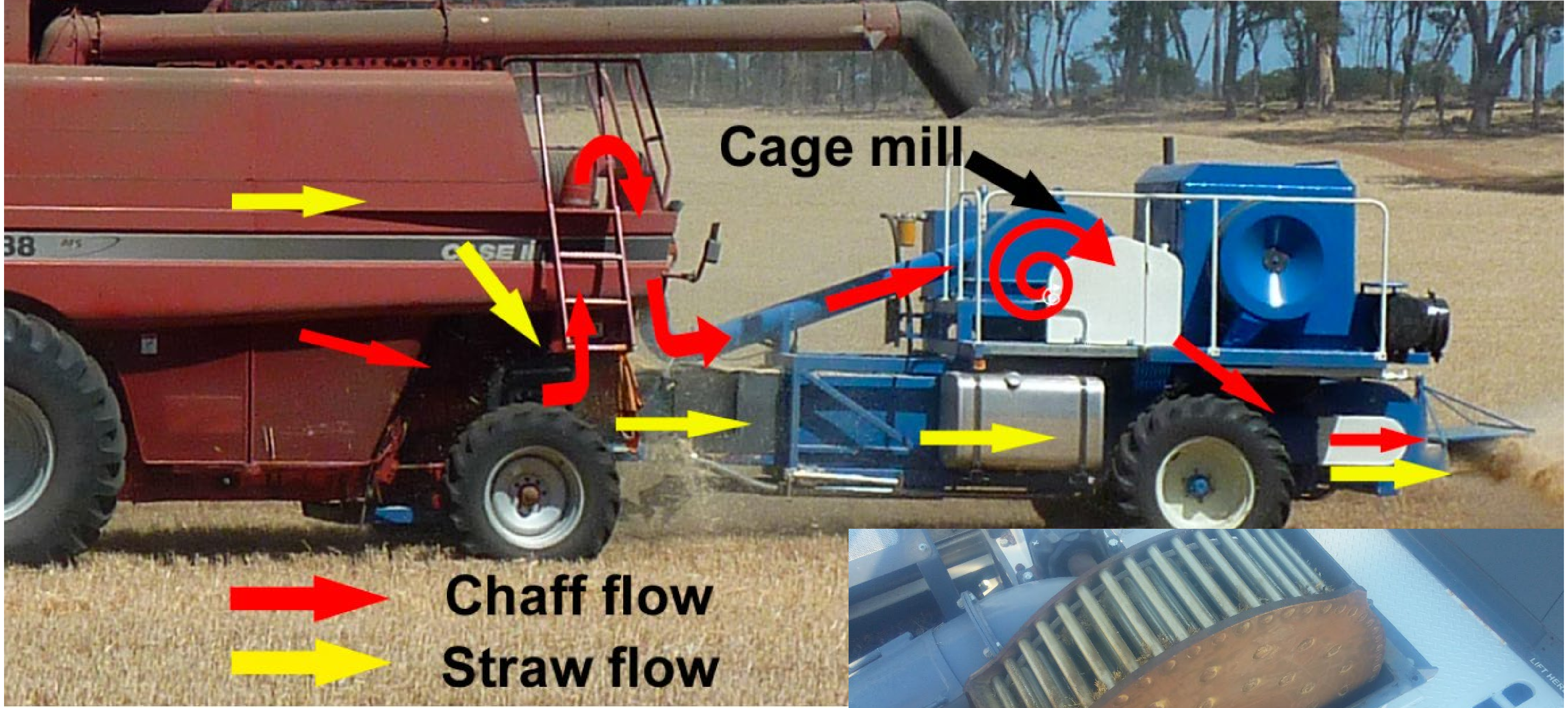
= standing weeds with undispersed seed

Cousens and Croft, 2001

The Harrington “Seed destroyer”: will it work here too?

https://will.illinois.edu/agriculture/note/42130

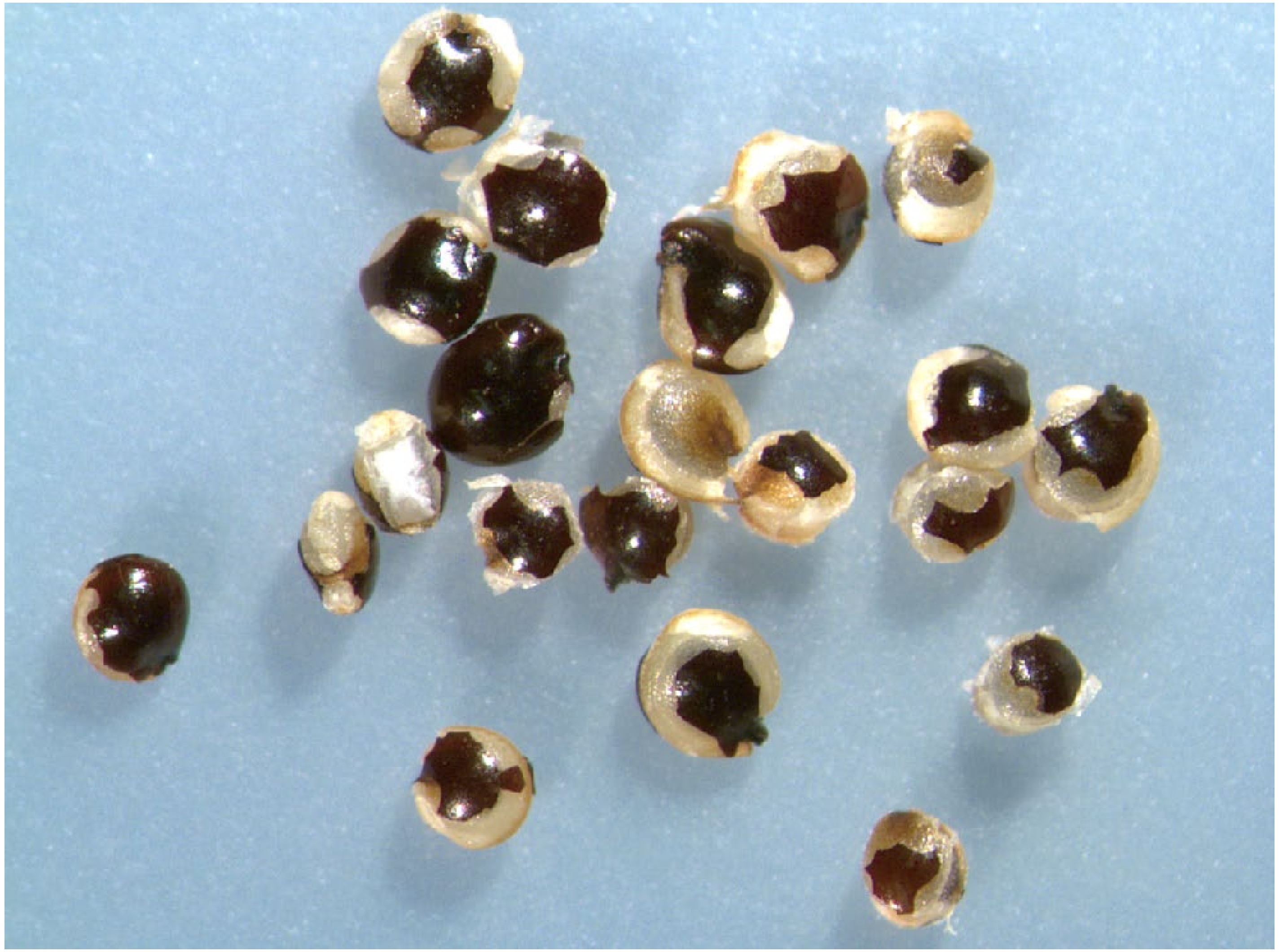
Harrington Seed Destructor



Walsh et al. (2012)

Fuel use/hr: +0.5 gal (combine); 6-8 gal (HSD)
Weight: 12,000 lbs; tow hitch wt: 992 lbs
Engine: Cummins QSB6.7, 205 hp @ 1800 rpm
Cage mill: 188 hp @ 1400 rpm
Harvest speed: no restriction
Source: DeBruin Engineering, Australia

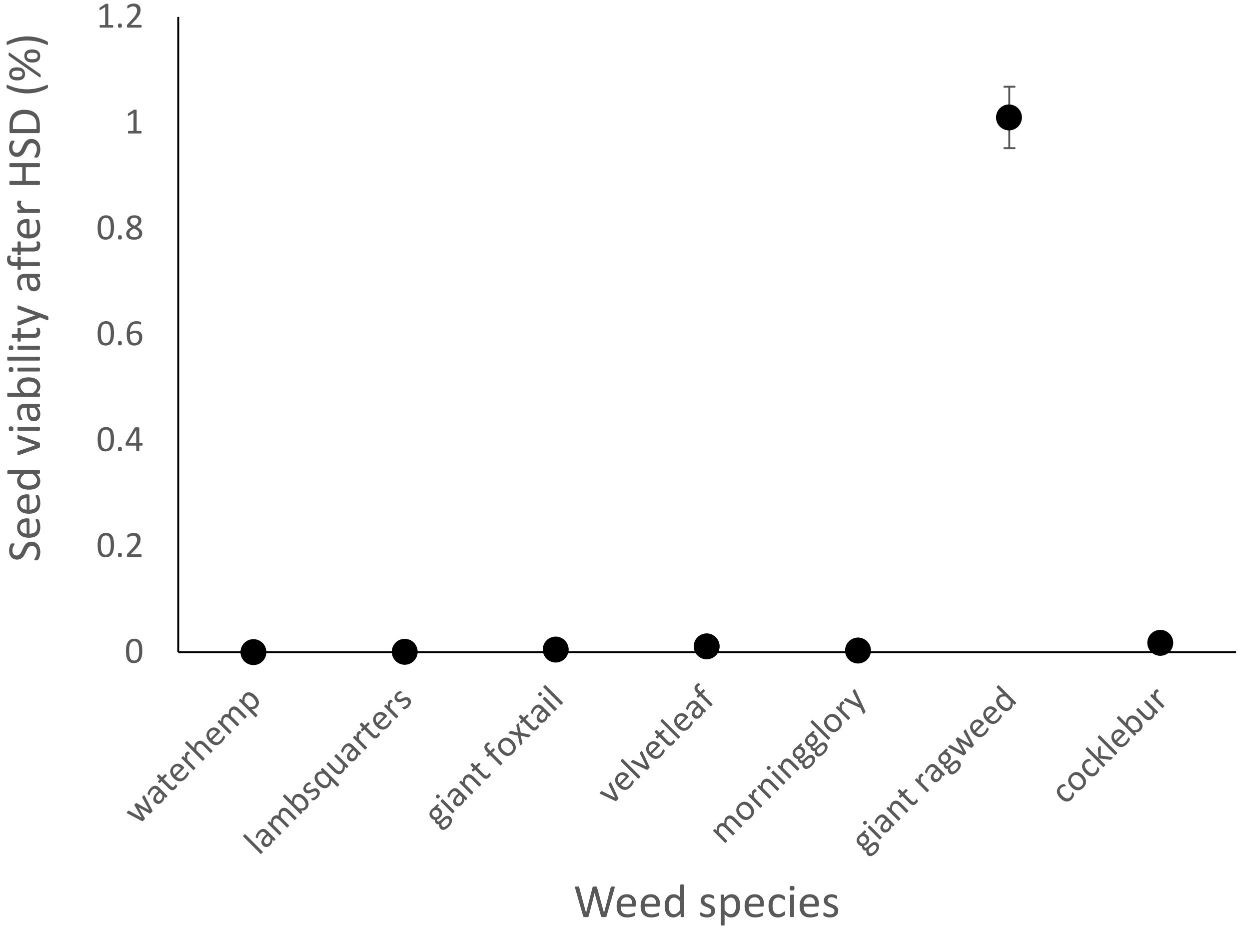
www.debruinengineering.com.au



Waterhemp (*Amaranthus tuberculatus*) seed after HSD treatment

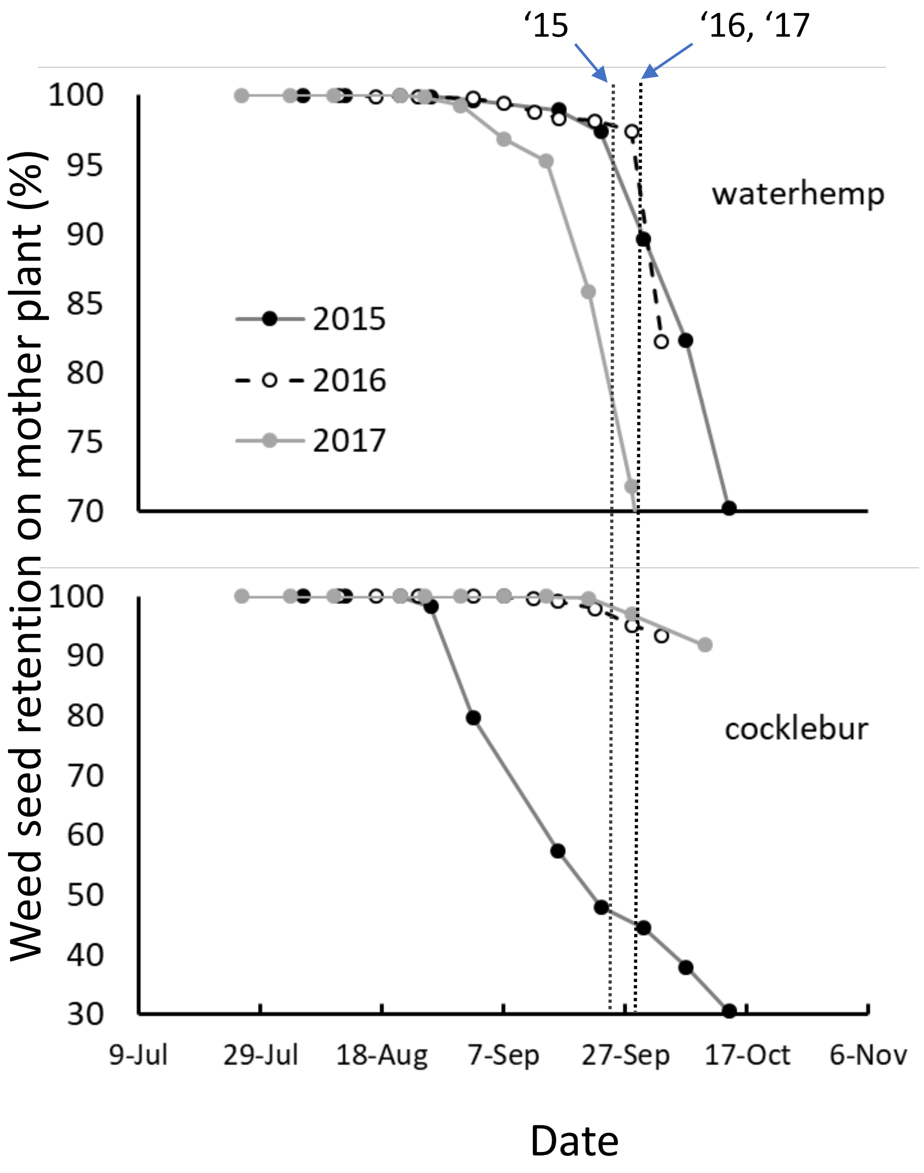
Photo: Nick Hausman

In stationary trials, the HSD reduced weed seed viability by ≥ 99%



Shergill et al. 2020

Weed seed capture varies by species, year, harvest date



Reduction in seed return: 70 to 80%

Reduction in seedlings: ~ 70%

Lazaro et al. in press

What weed traits is the HSD likely to select on?

- shattering: earlier seed dispersal
- flowering time: earlier seed formation
- seed size?
- seed coat strength?
- dormancy?

- ALL TOOLS WILL BREAK IF OVER-USED
  - Many Little Hammers

Cultural control

Cropping system diversification to build weed suppressive cropping systems

Crop rotation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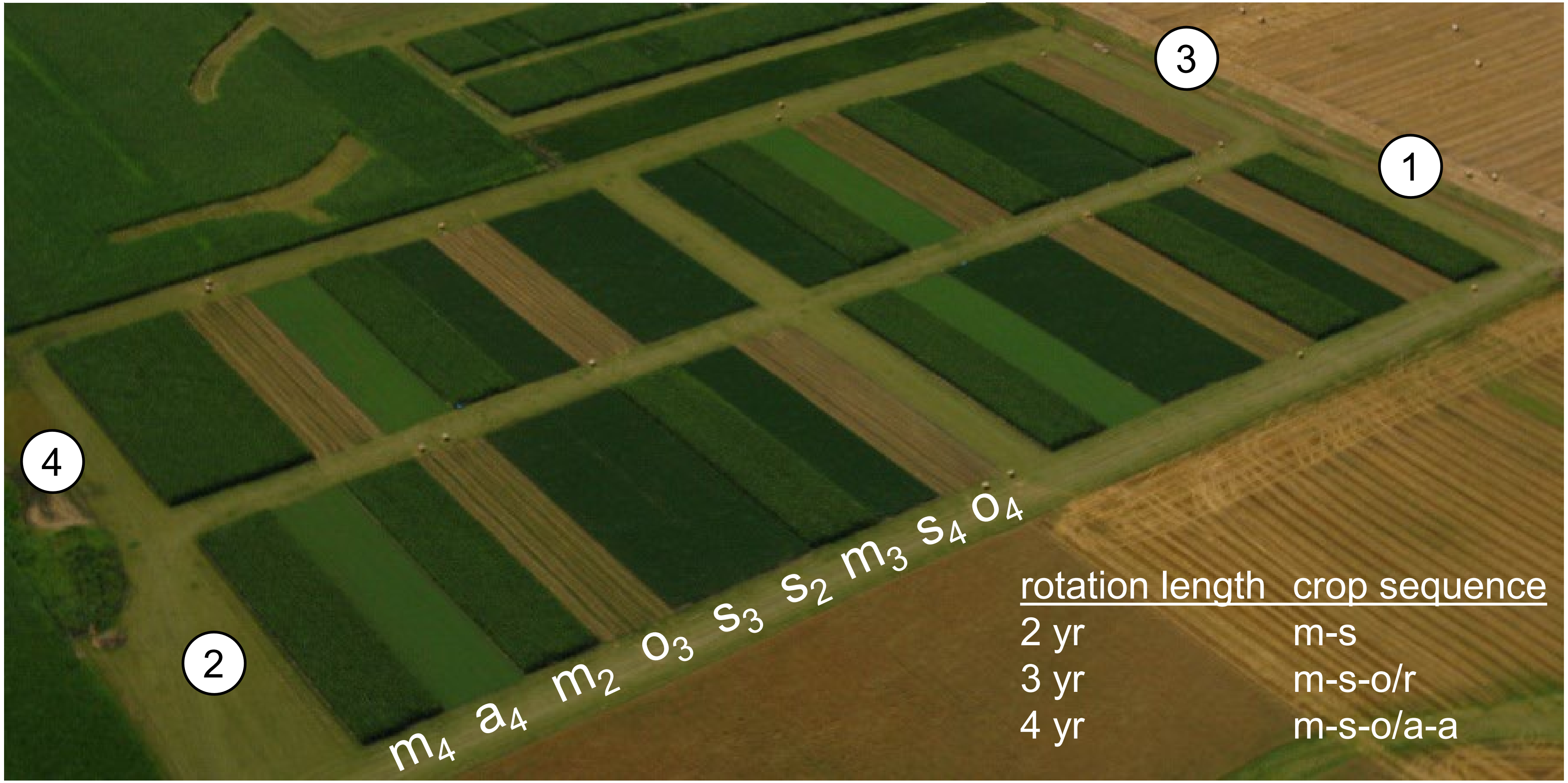
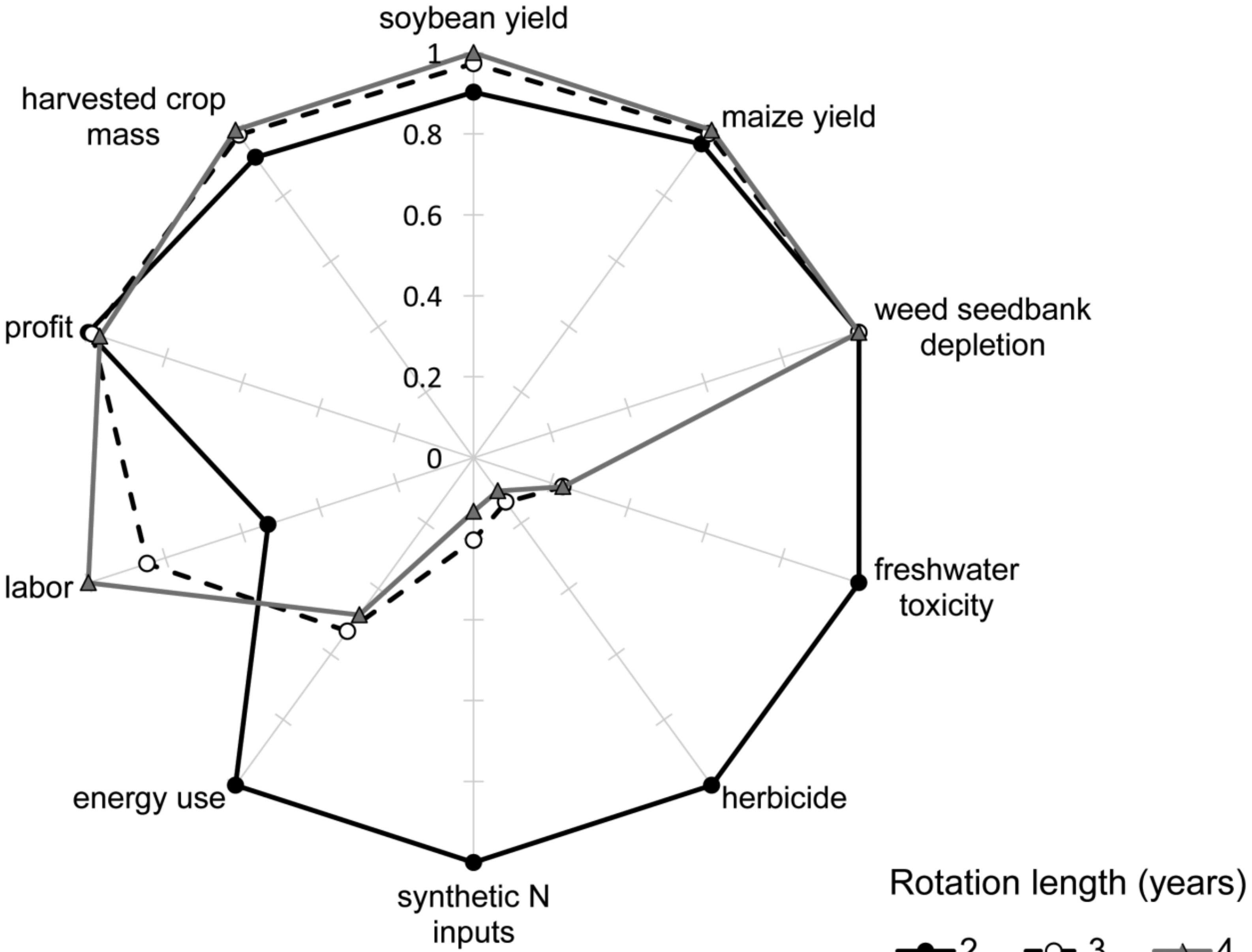
RESEARCH ARTICLE OPEN ACCESS

Increasing Cropping System Diversity Balances Productivity, Profitability and Environmental Health

Marsden Farm
Boone, IA
Dr. Matt Liebman, PI



Davis et al. 2012 PLOS ONE 7(10): e47149



Davis et al. 2012 PLOS ONE 7(10): e47149

Marsden Farm
Boone, IA

small grain underseeded
with red clover, early fall
after summer's growth

Forage legumes for allelopathy

incorporation of
legume green manure

increase of phenolic
acids in aqueous sol'n
in soil

increased leakiness in root
membranes, fungal pathogens follow
trail of exudates via chemotaxis

weed seeds suppressed
(chemical & fungal)

crop seeds unharmed

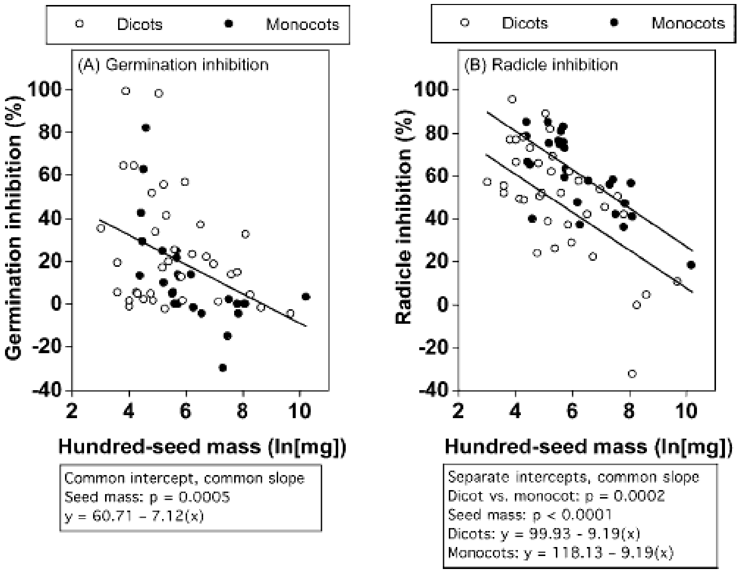
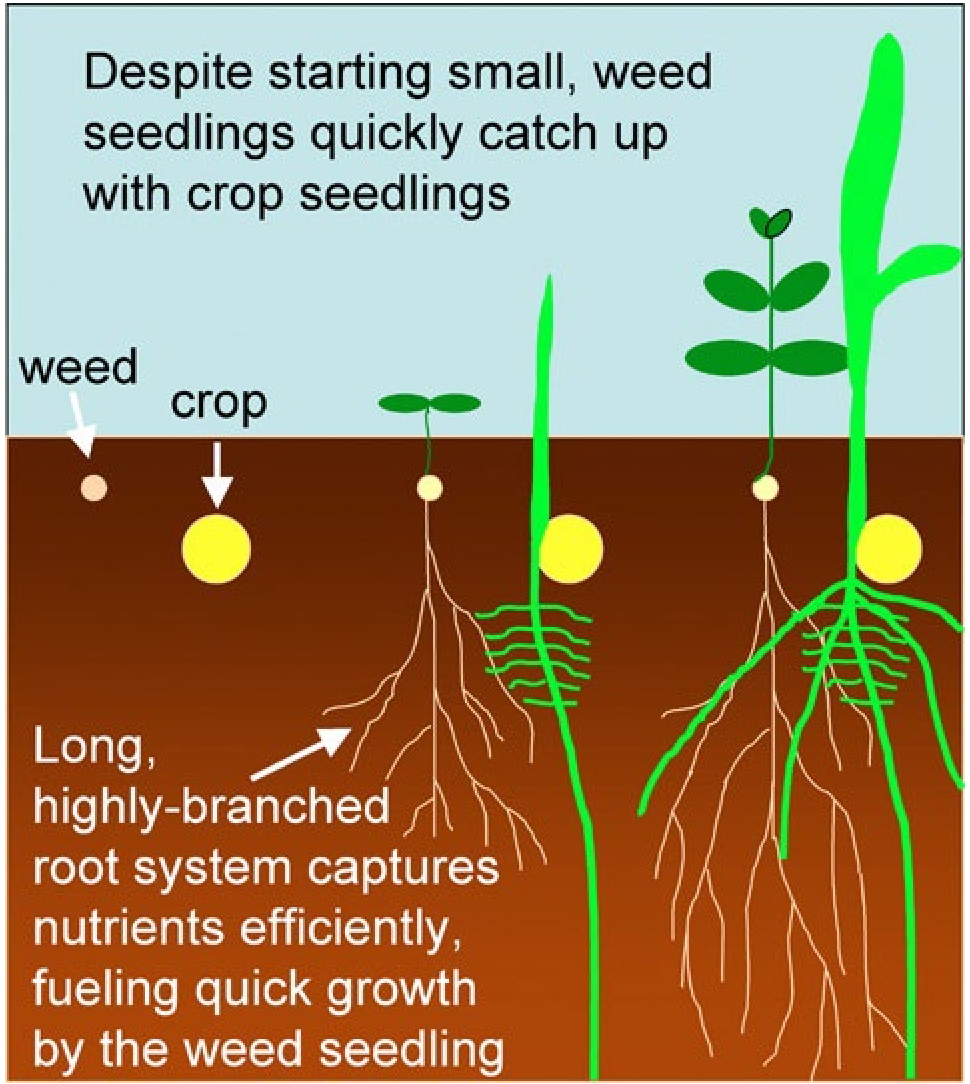


FIGURE 1. Germination inhibition (A) and radicle inhibition (B) of seeds in Experiment 1 as a function of seed mass and taxonomic class (monocot vs. dicot). Eighteen weed and 44 crop accessions were exposed to a 2% aqueous extract of Marathon red clover or distilled water. See text for methods of calculating germination inhibition and radicle inhibition.

Conklin et al. 2002. Plant & Soil. 238: 245-256
Liebman & Sundberg. 2006. Weed Sci. 54:340-345.

Crop-centric fertility



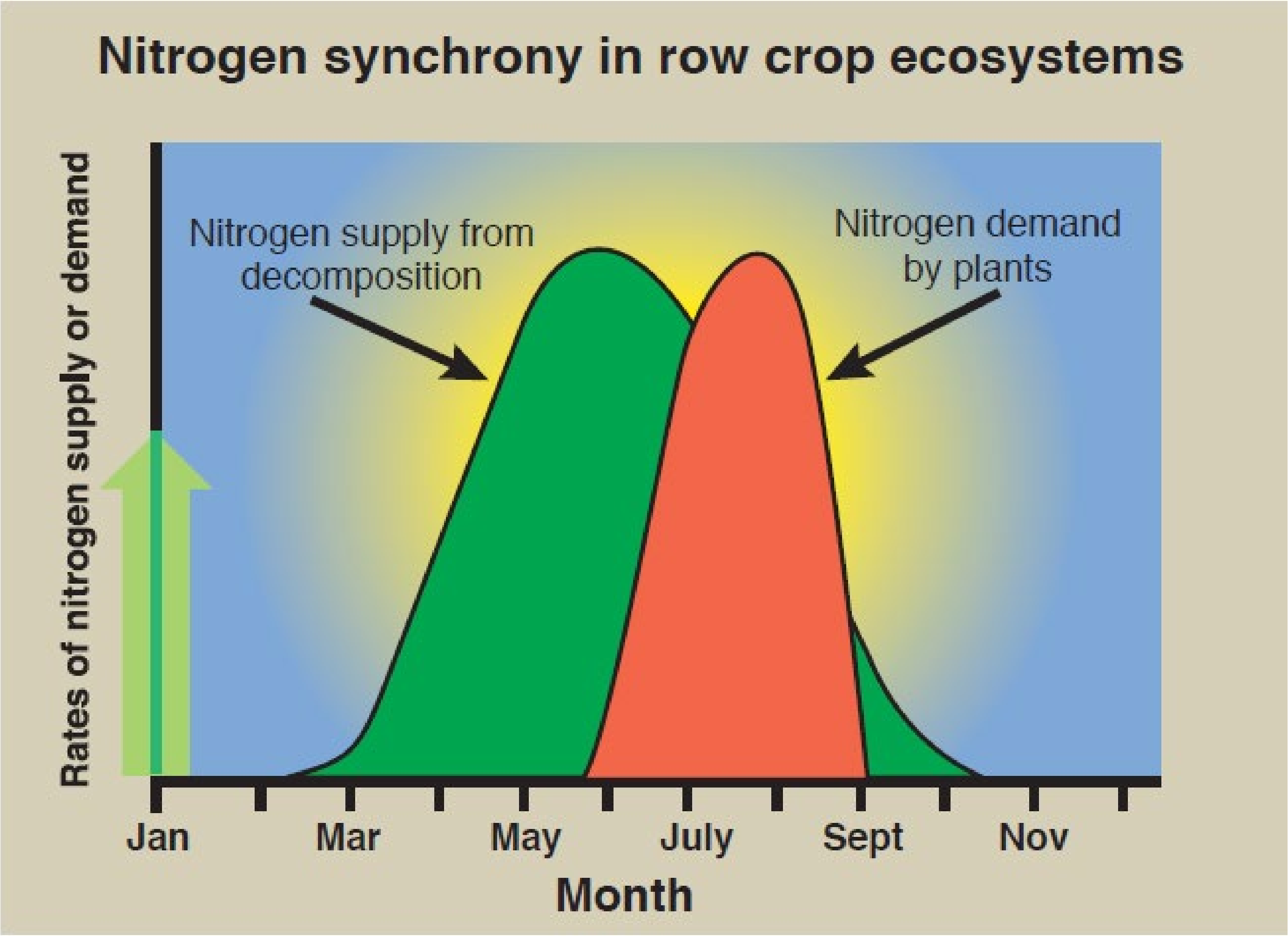
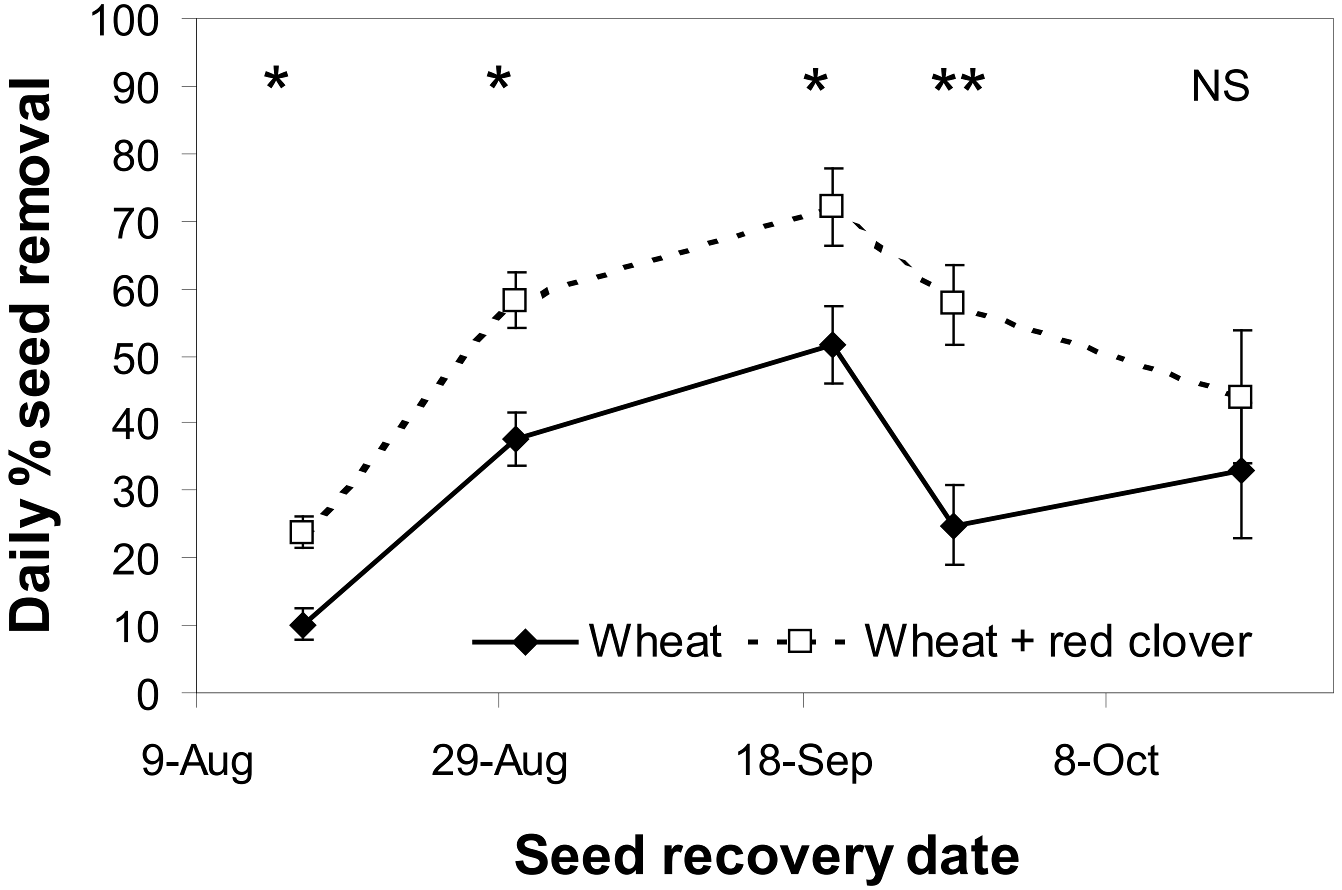


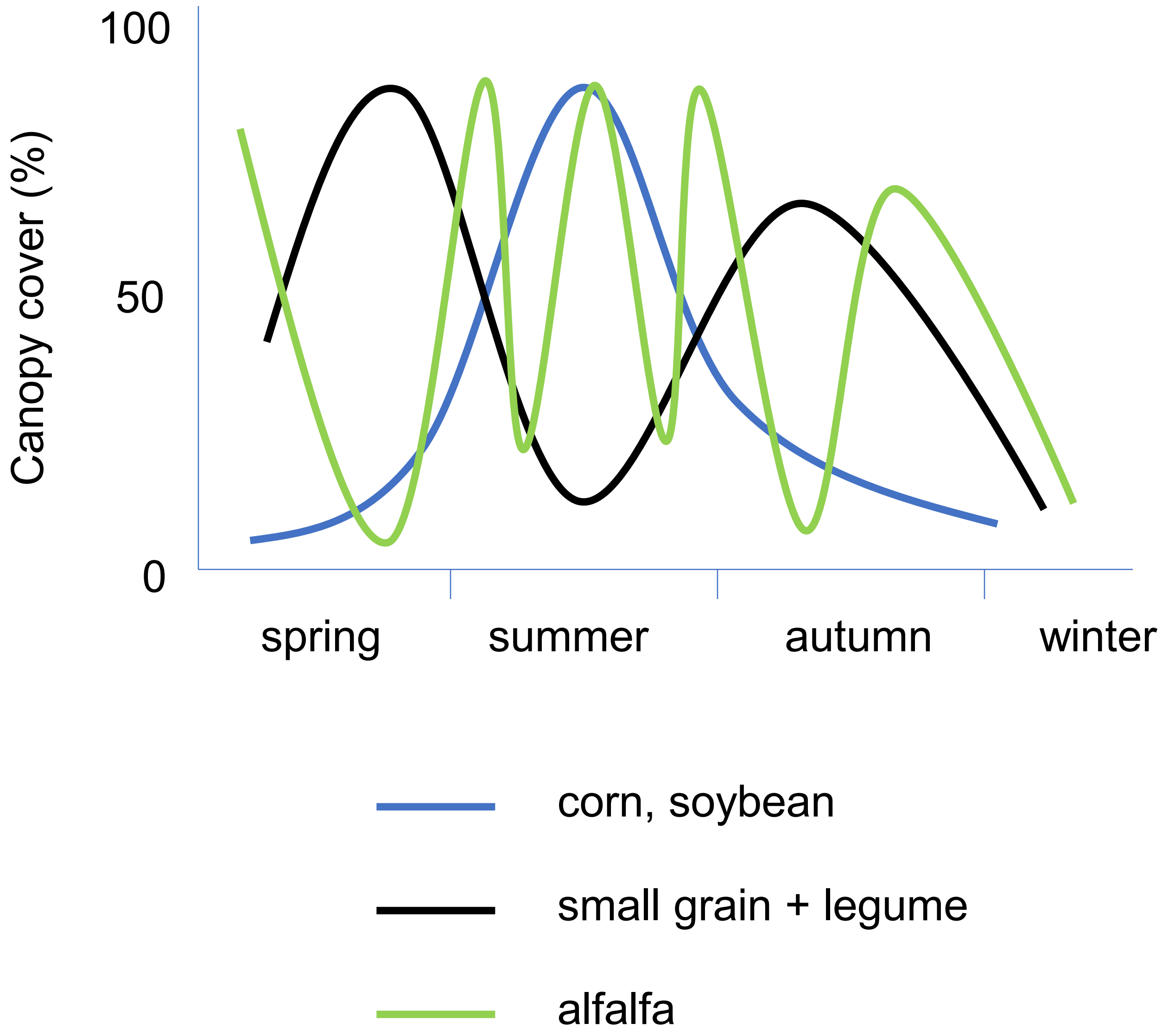
Figure 4. Nitrogen synchrony in row crop ecosystems. Source: Cavigelli et al., 1998.


Source: Emilie Regnier, OSU



Davis et al. (2003)

Diverse crops can provide year-long cover to seed predators



Heggenstaller et al. (2006)

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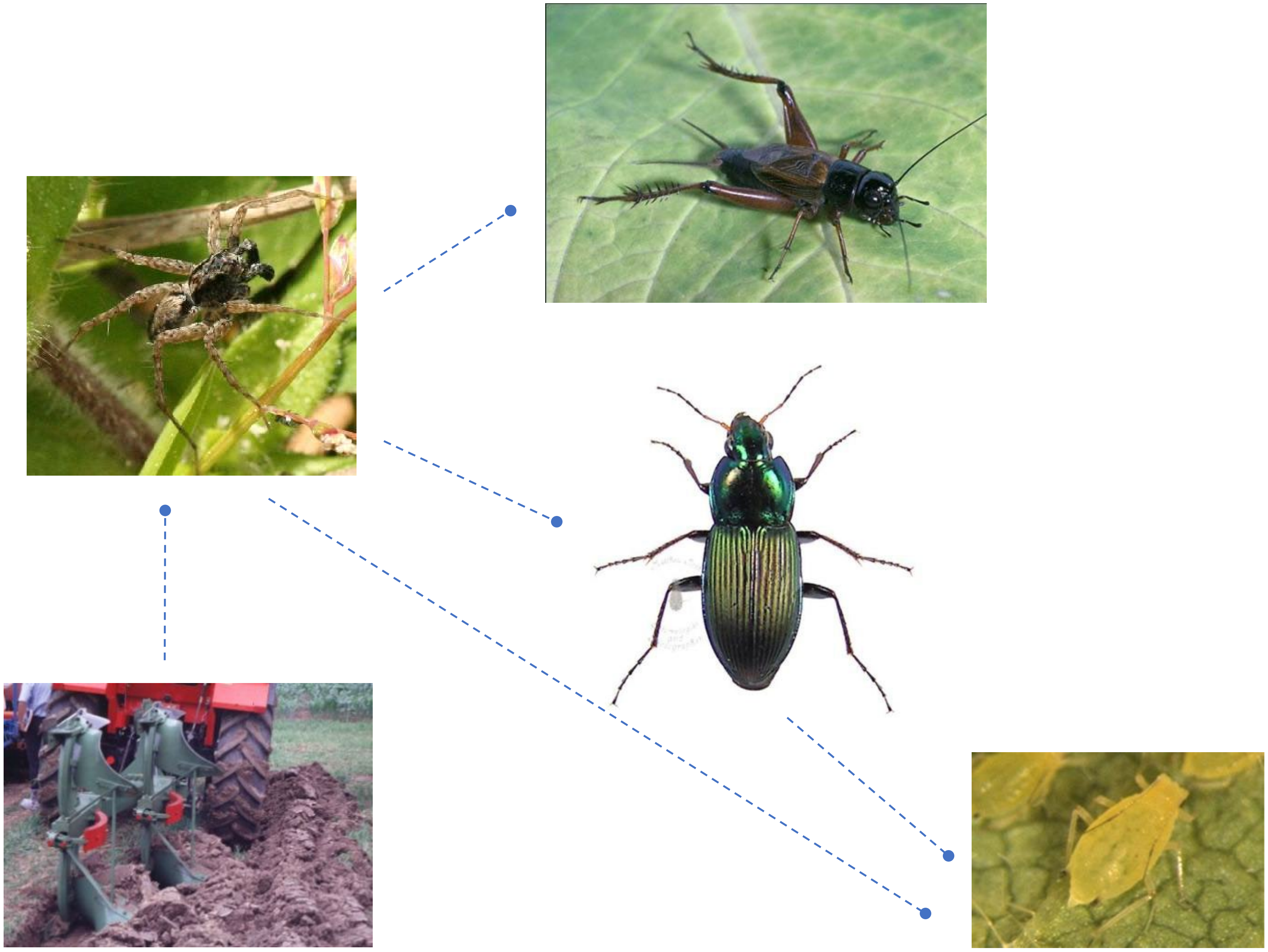
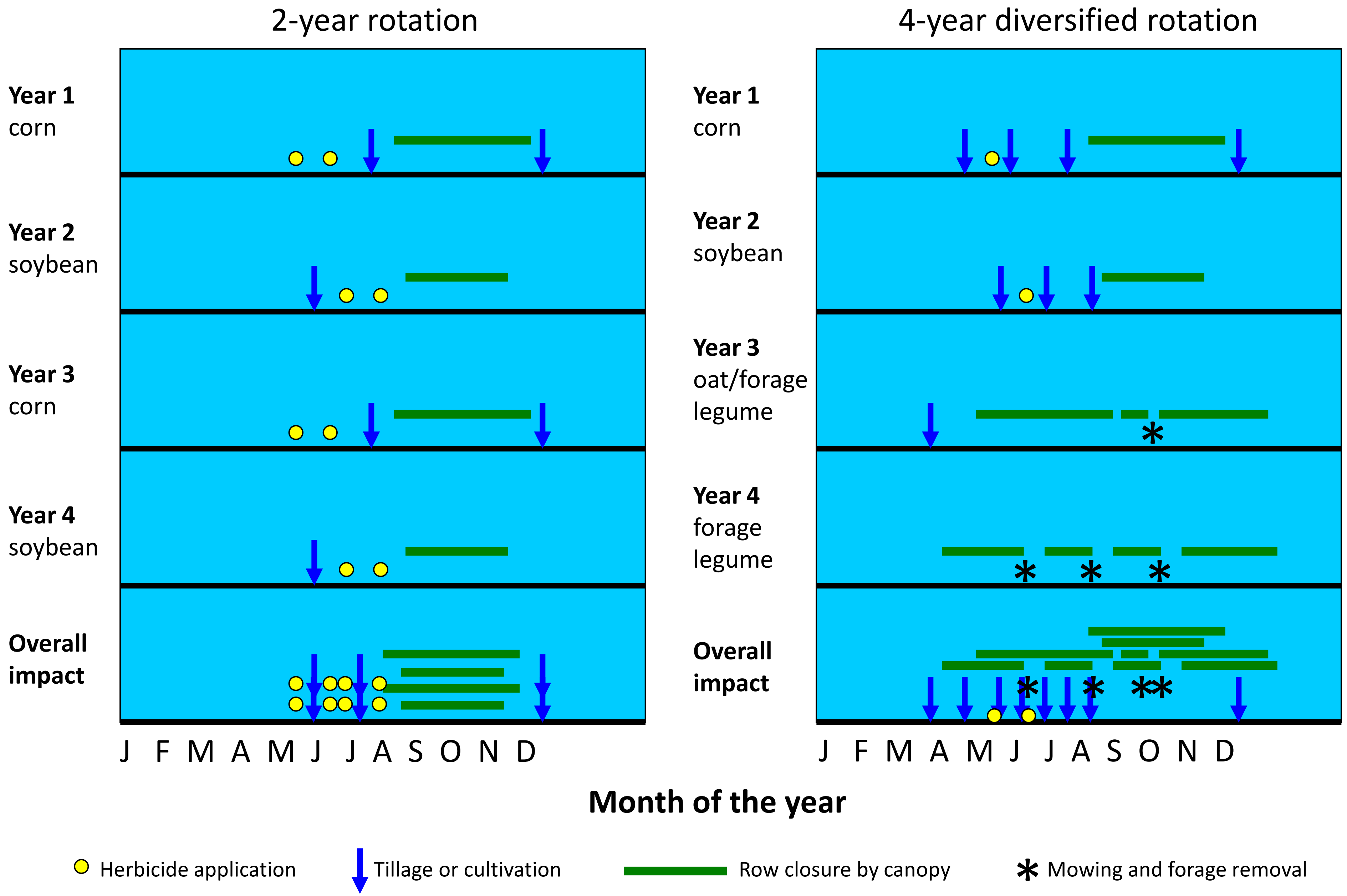
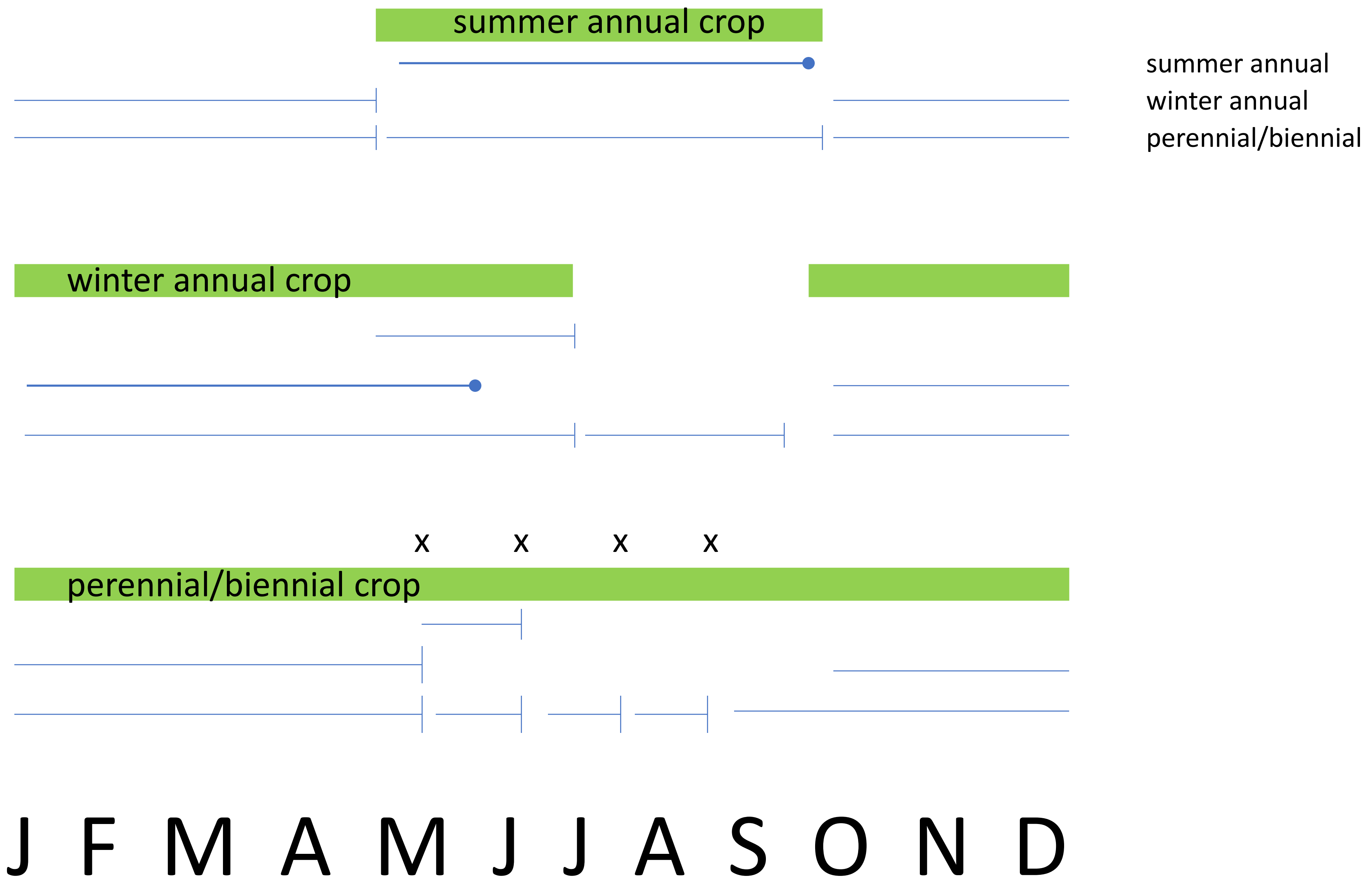




after Liebman and Staver, 2001

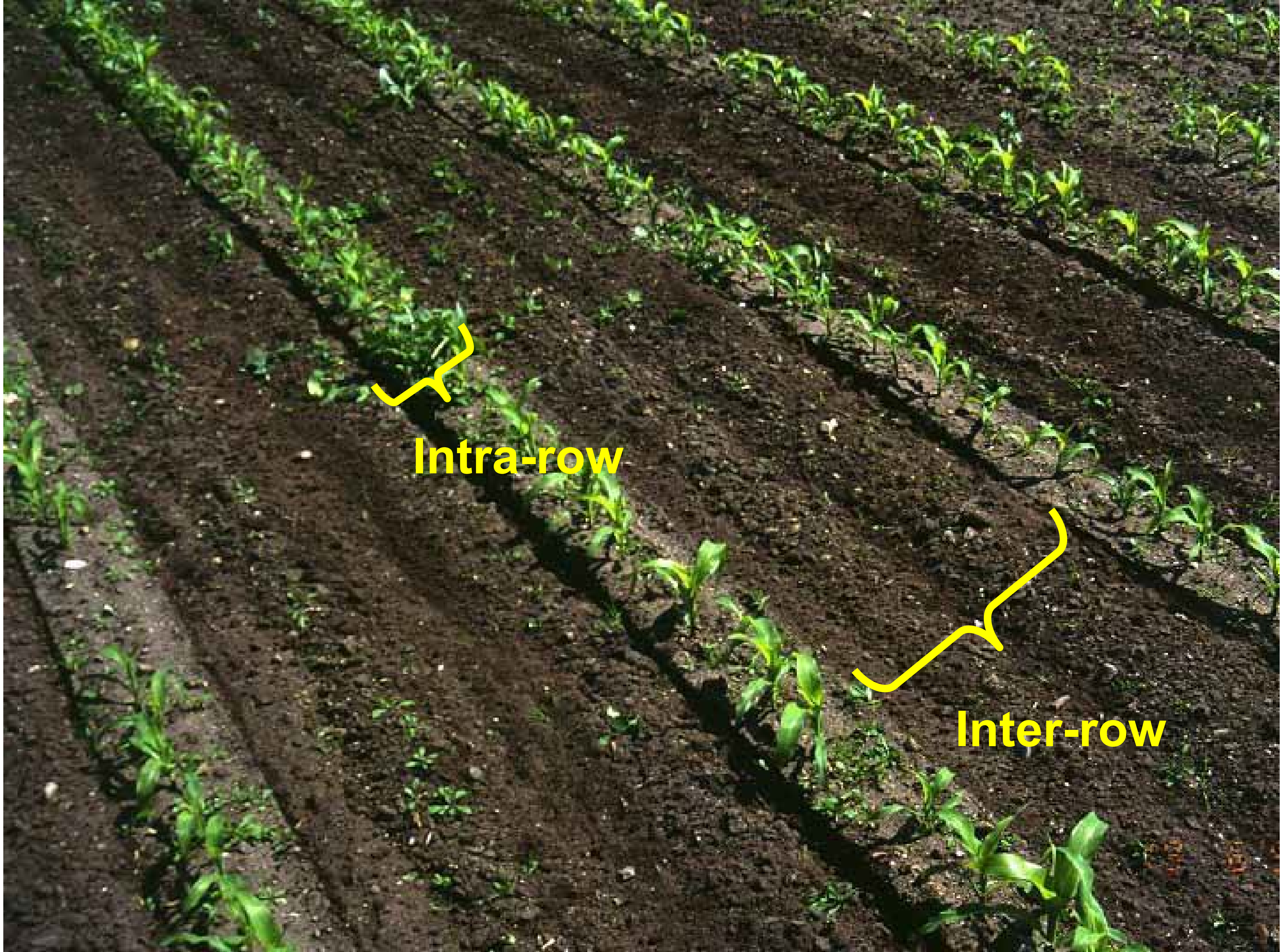
Disruption of weed life cycles



Use herbicides to **tune**, rather than **drive**, weed management system

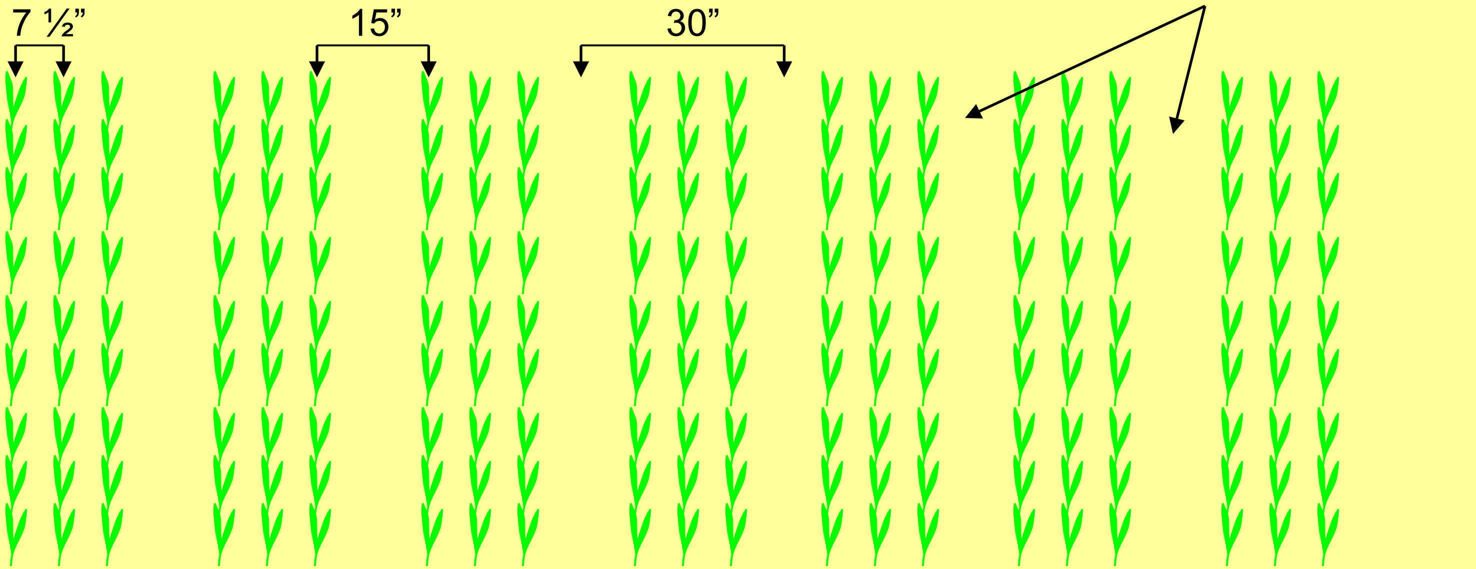
Davis et al. 2012

Physical control

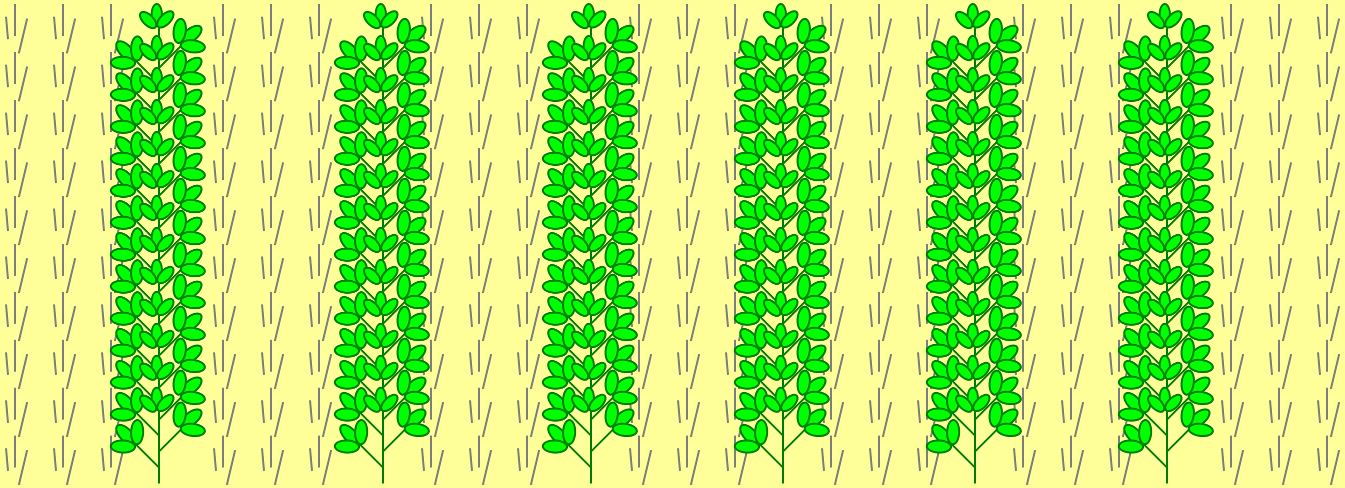

Intra-row
Inter-row

Adding sunflowers into a crop rotation can help clean up a weed field because sunflowers can be cultivated very aggressively.

Year 1: drill small grain, skipping every 4th row

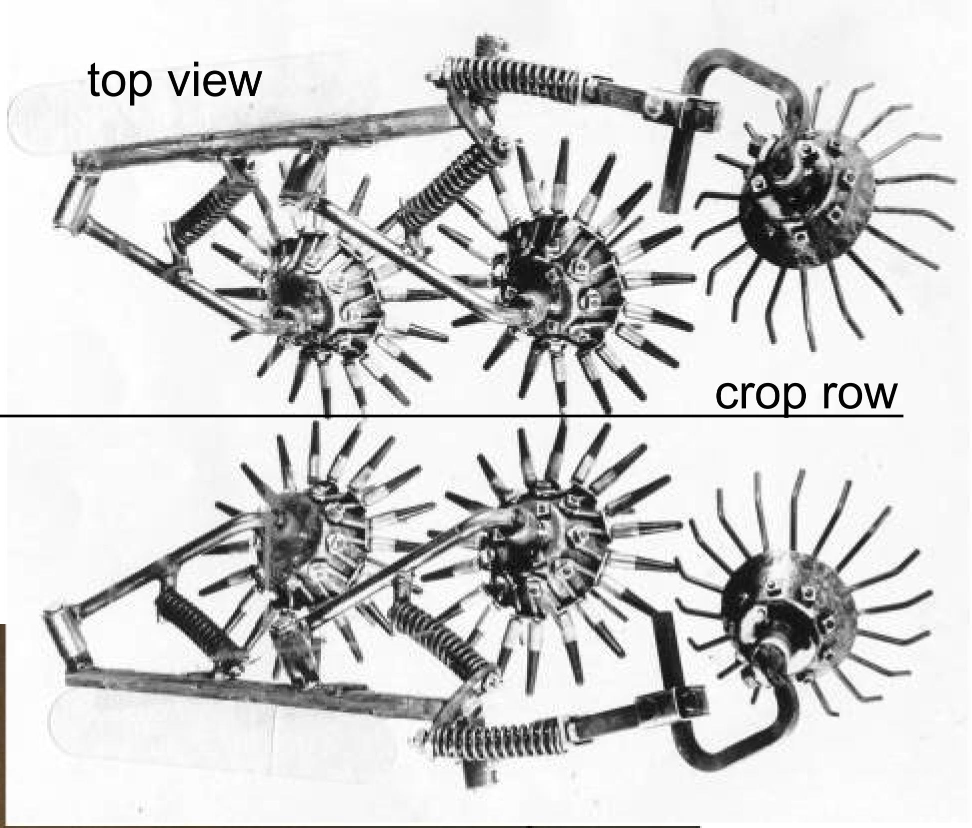


Year 2: plant corn or soybean into clean rows

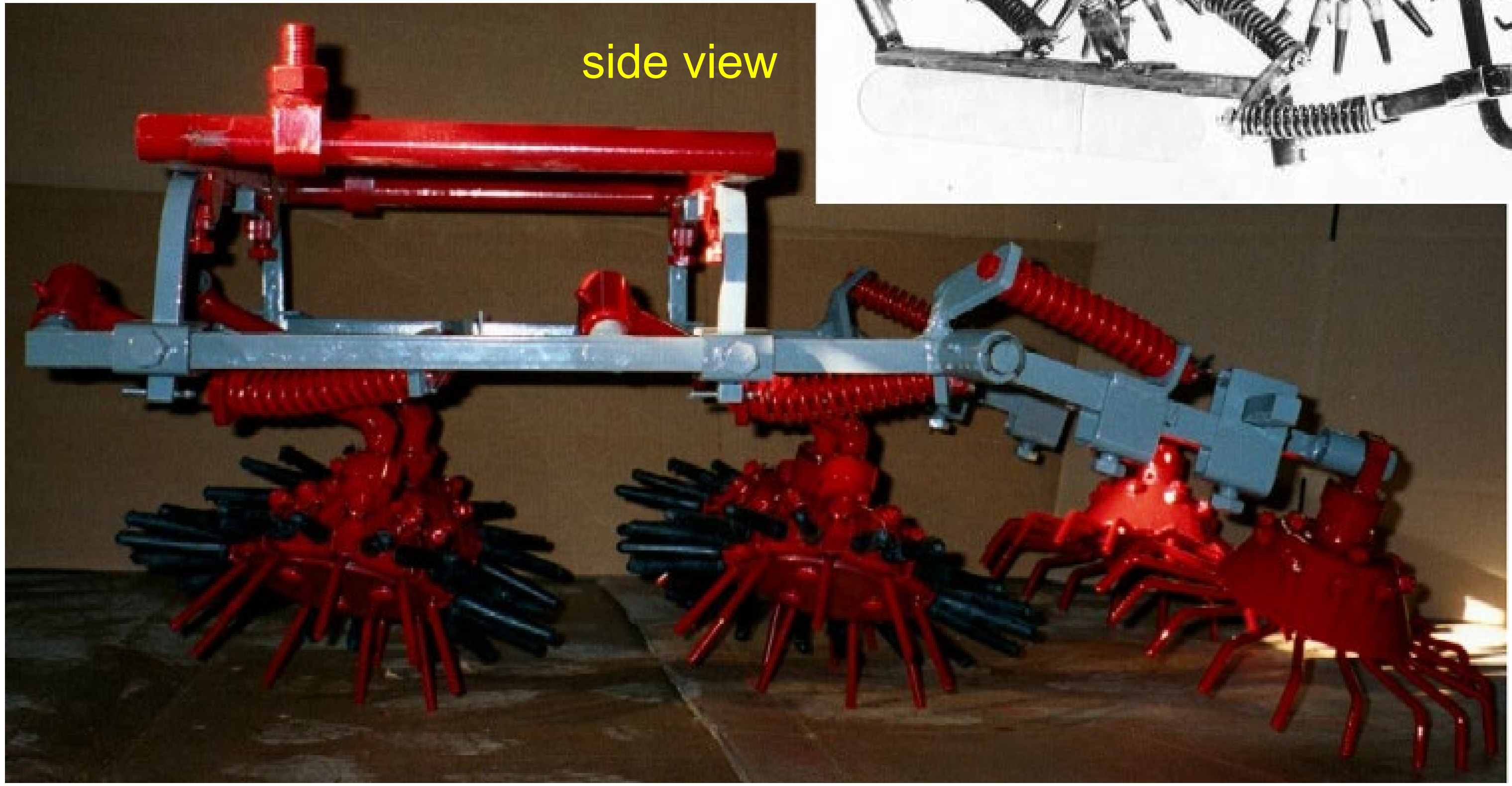


Source: Melander and Rasmussen, 2000

Buddingh finger weeder

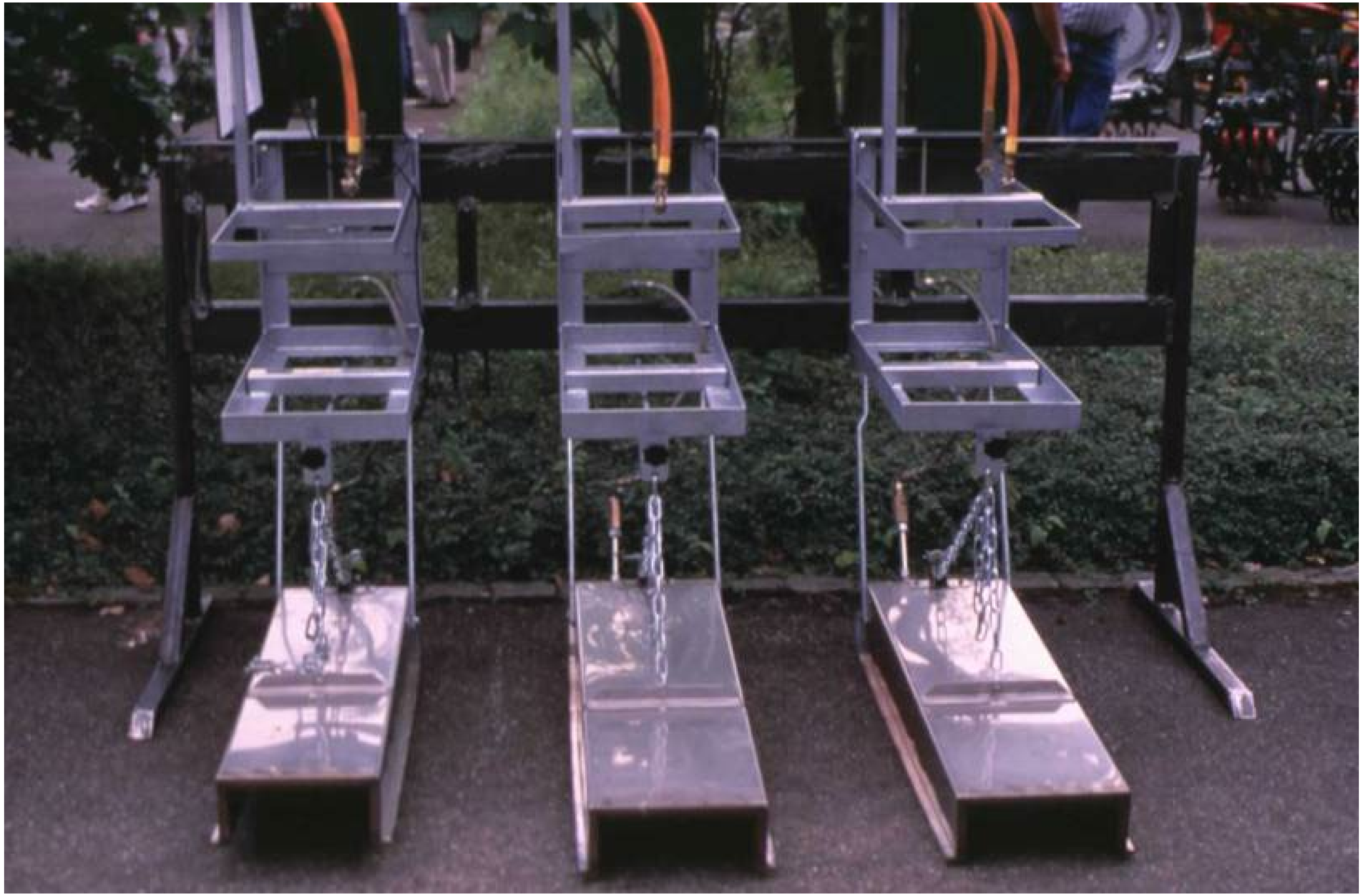


direction of
travel



Source: Phil Sarver

Flame-weeder with tent shields to concentrate heat

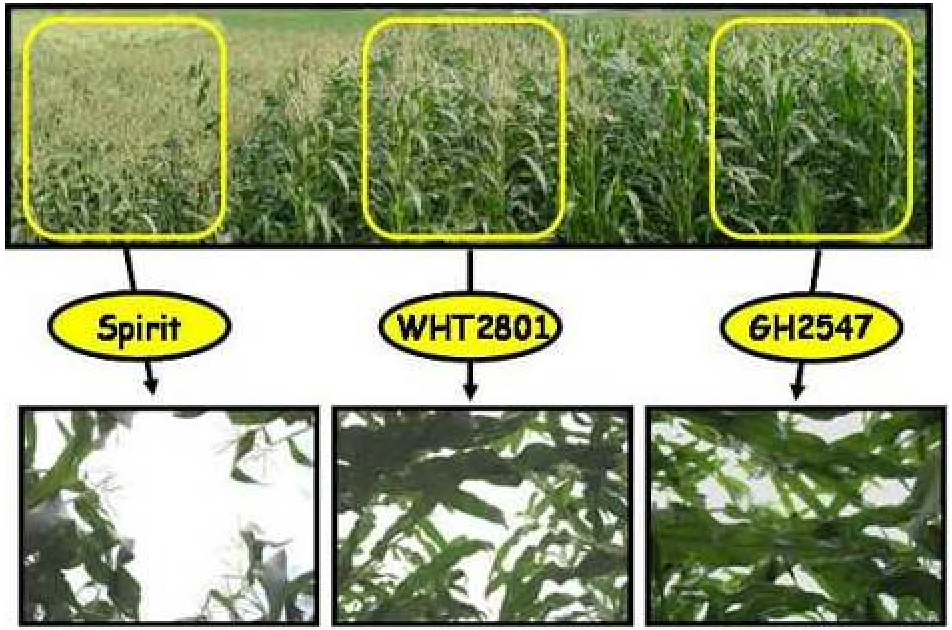


Source: Adam Davis

Left: band-steamer. Right: sugar beets emerging in row cleaned by pre-emergence band-steaming.

Source: Bo Melander

Competitive crop cultivars

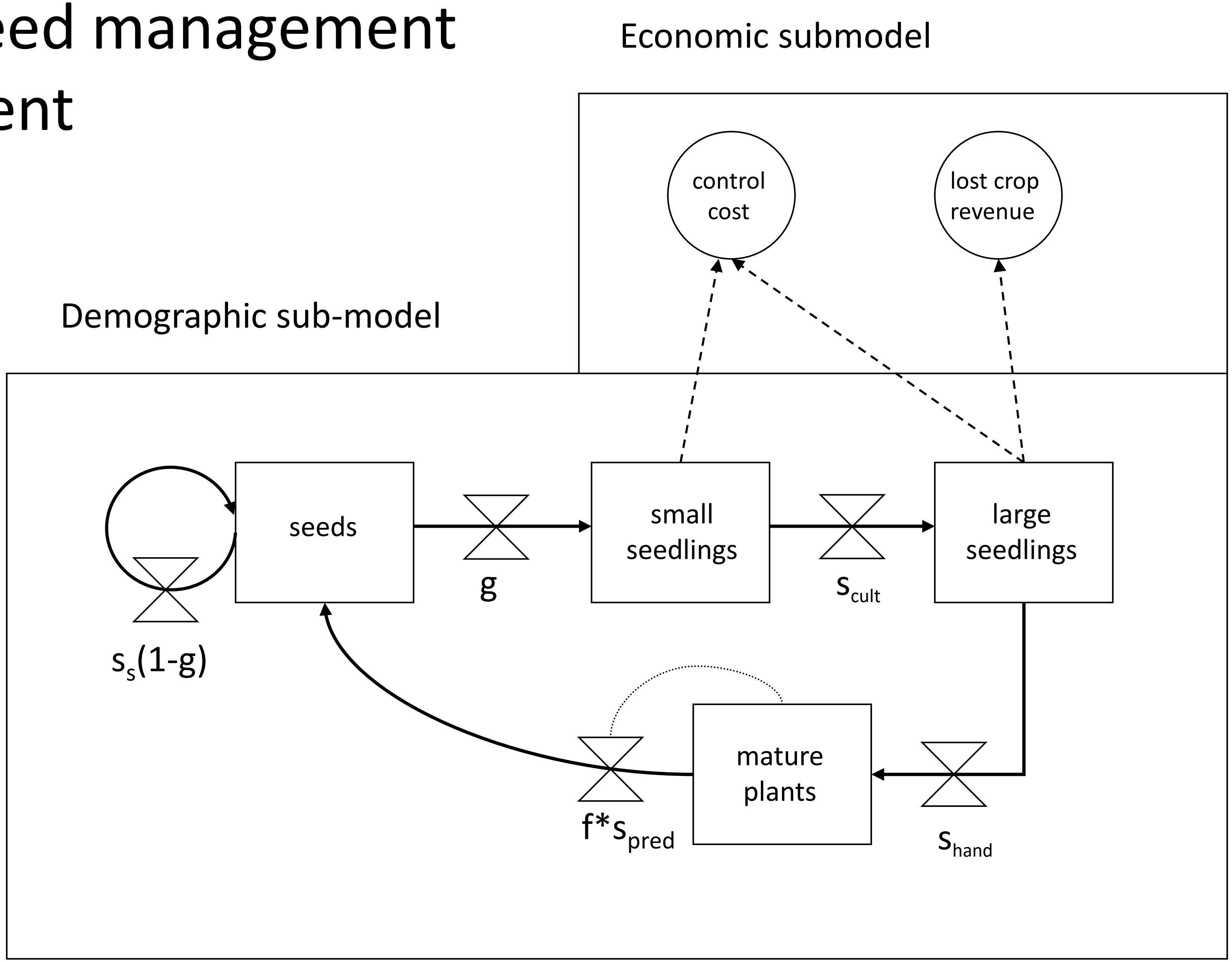


crop yield loss:

weed seeds:

Williams et al. 2008

Integrated weed management
Is an investment



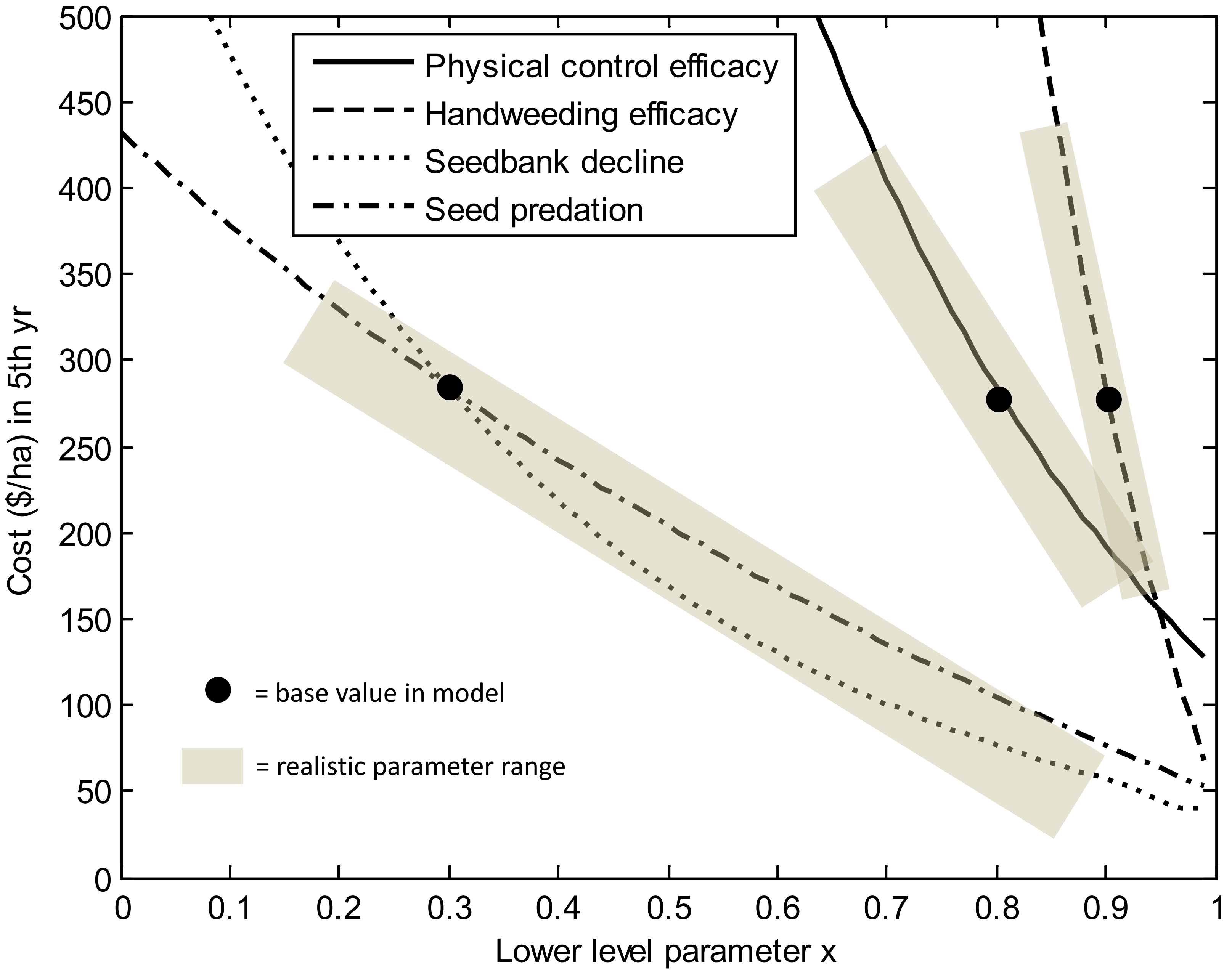
Liebman and Davis (2009)

Hand weeding intra-row weeds:

200-500 hours per hectare in carrot and direct sown onion and leek

Melander and Rasmussen, 2001

DIAS



Liebman and Davis (2009)

The most important weed management tool on your farm

Thoughtful weed management

- Weed community
  - biology of dominant species
  - spatial distribution on farm, population densities
- How are weeds defeating current mgt. system?
  - emergence timing
  - resistance
  - overwhelming seedbank
  - competition
- What individual tools have an effect on problem weeds?
- How can these tools be combined, and varied over time, to be effective for years to come?
  - Use cultivation to tune, not drive, weed management system
  - De-emphasize ‘big-hammer’ approaches
- Pay attention, and adjust strategy: **adaptive management**