Ecologically Based Weed Management

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Weeds remain a problem for both conventional and organic farmers

- Herbicide resistance
- Off-site movement of herbicides in air and water
- Incomplete control with cultivation
- Complications due to weather

Weed control efficacy with a rotary hoe and interrow cultivator in corn and soybean (multiple passes)

Gunsolus (1990): 92%
Renner & Woods (1998): 83%
Mohler et al. (1997): 68%

Weed control efficacy with pre- and post-emergence tine harrowing in cereals

Kolb et al. (2010): 40%

Steerage hoe, Switzerland

Cultivating carrots, Switzerland

Steerage hoe in spring wheat, Maine

(Source: E. Gallandt)

System Cameleon
Farmer and researcher tour
Östergötland, Sweden, April 2016

(Source: E. Gallandt)

Cultivation is important, but durable improvements in weed management are based on:

- Understanding ecological principles and processes
- Learning the life history characteristics of problematic weed species
- Carefully considering and comparing management options

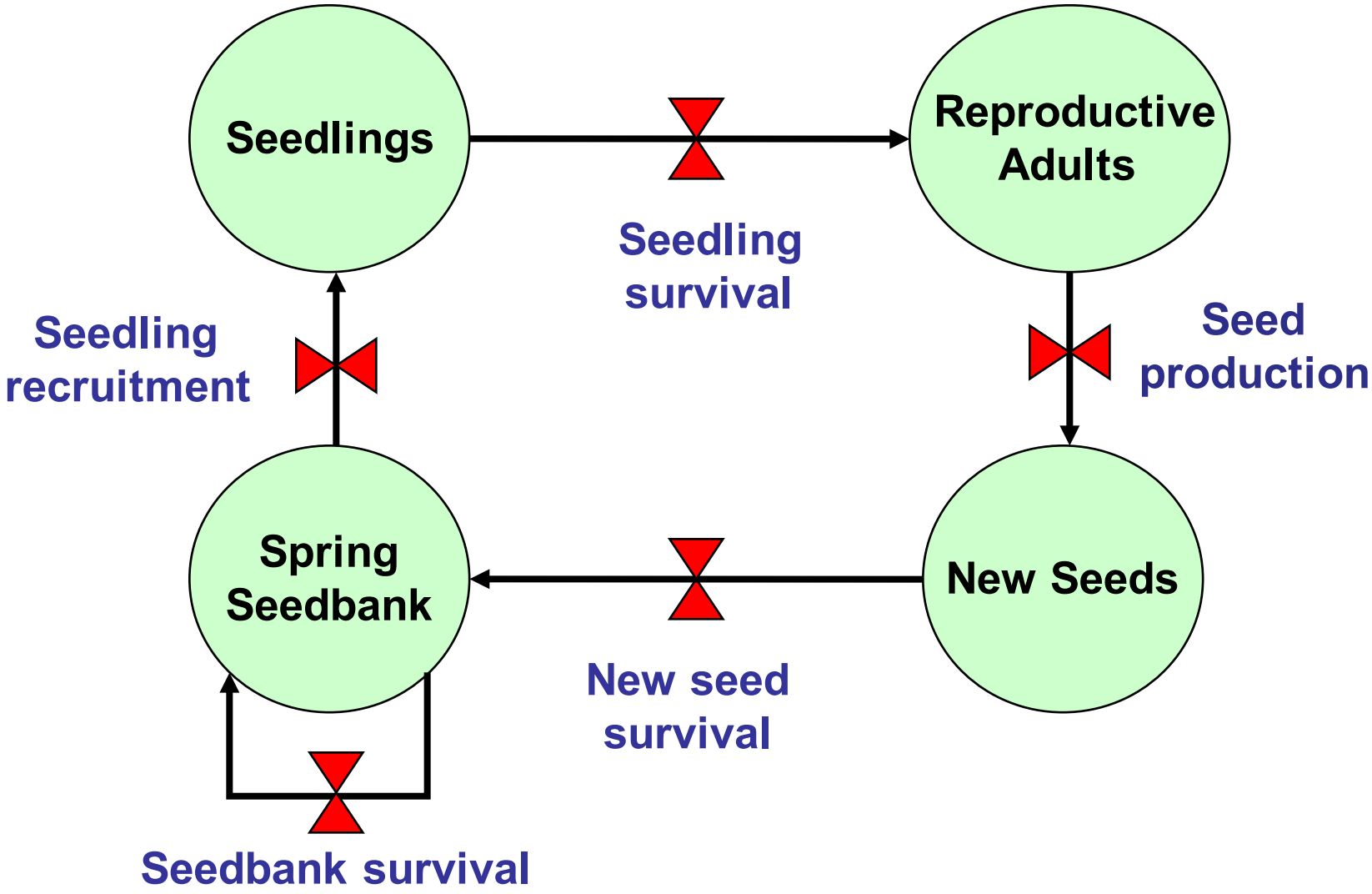
Weed population dynamics

Population dynamics equation

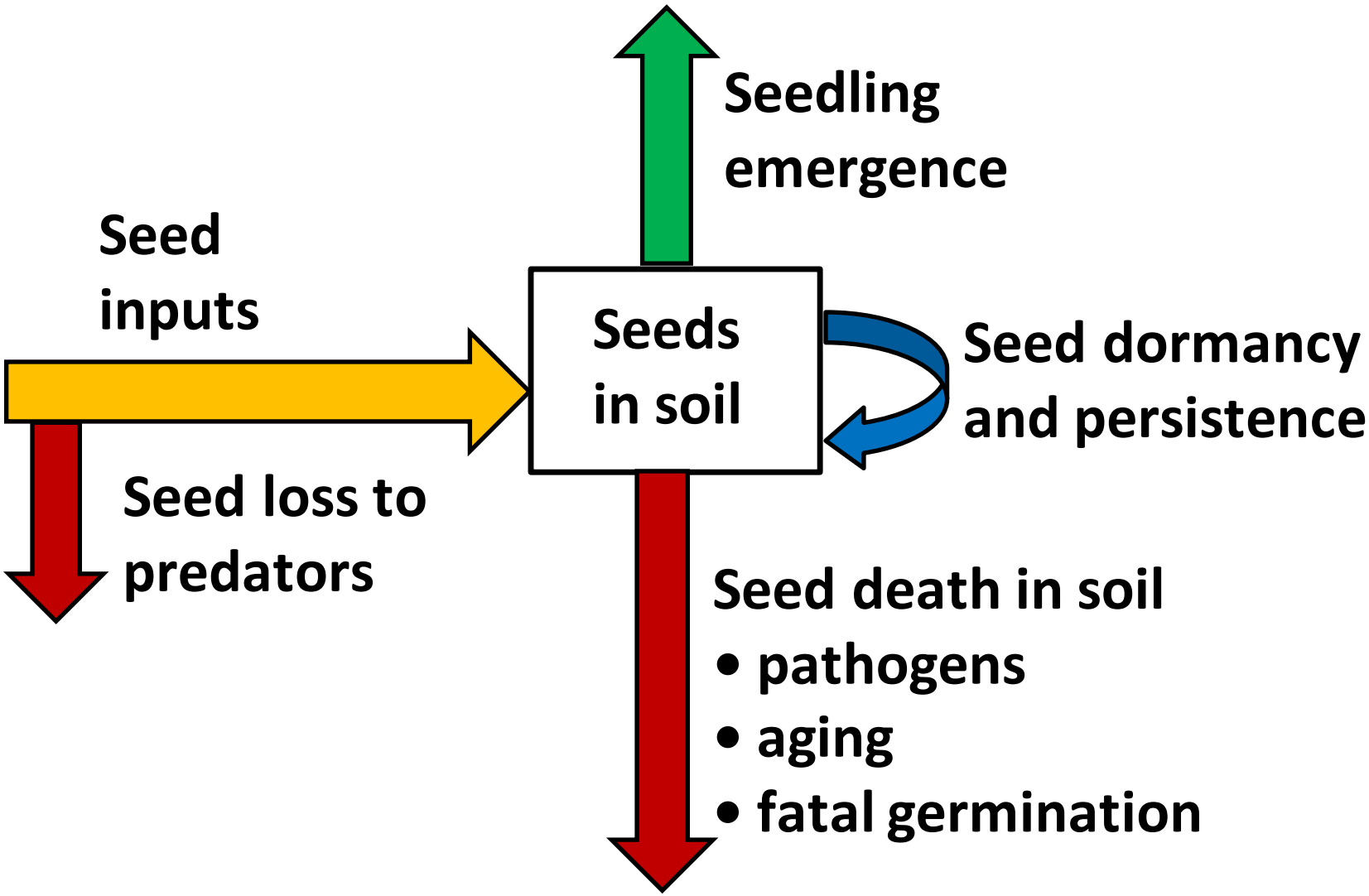
$$N_t = N_{t-1} + B - D + I - E$$

- N_t: the number of organisms at time t
- N_{t-1}: the previous number of organisms
- B: births
- D: deaths
- I: immigrants
- E: emigrants

Life history of an annual weed



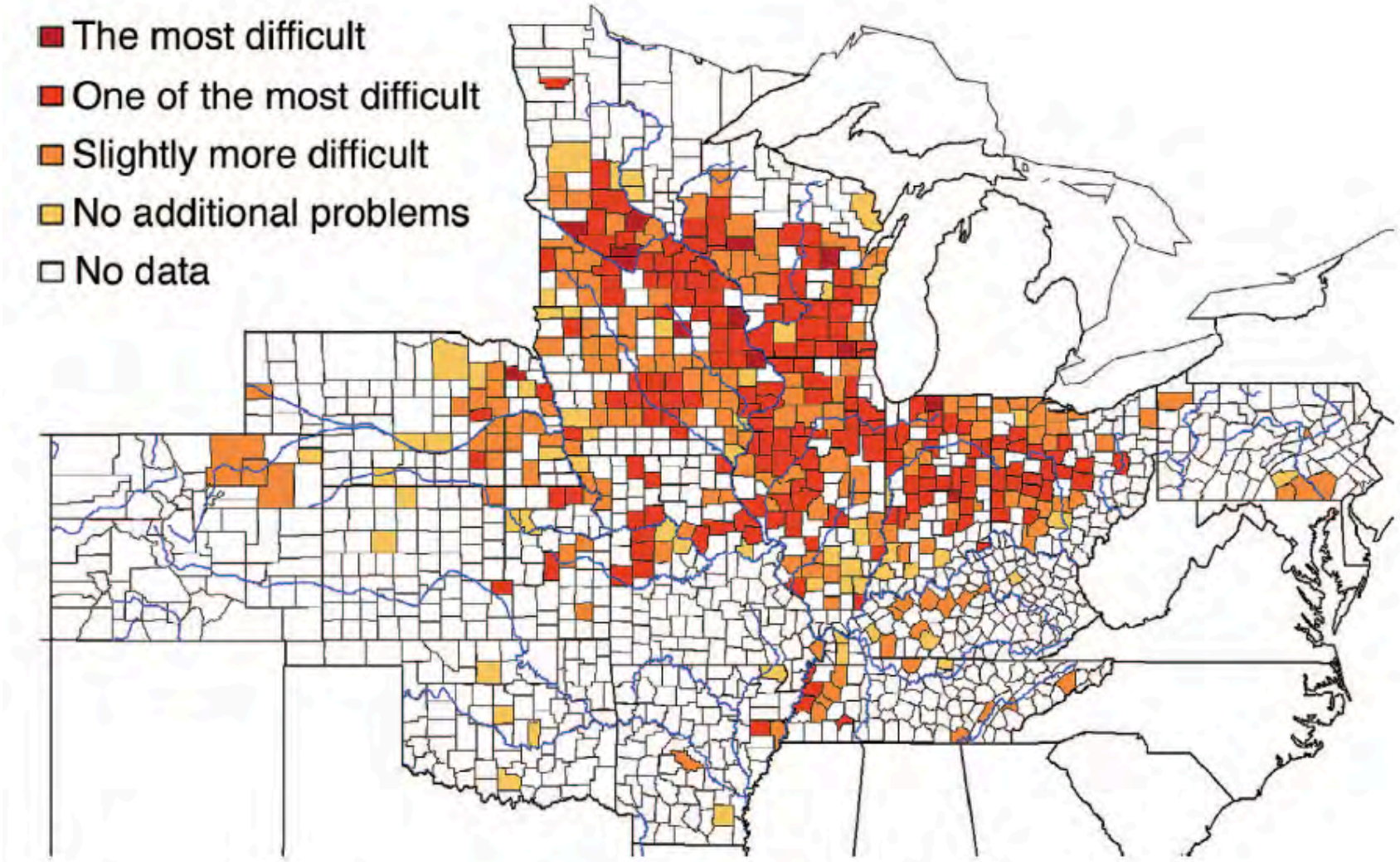
Weed seedbank dynamics


Seedling
emergence
Seed
inputs
Seeds
in soil
Seed dormancy
and persistence
Seed loss to
predators
Seed death in soil
• pathogens
• aging
• fatal germination

A case study: giant ragweed


Giant ragweed
Ambrosia trifida
University of Illinois Extension photo/Lyle Paul

Results of Survey of Certified Crop Advisors in the Corn Belt Regarding Difficulty of Managing Giant Ragweed



Source: Regnier et al. 2016

Key characteristics of giant ragweed contributing to its success in agroecosystems (with an emphasis on organic systems)

Large seeds with substantial energy reserves

https://www.agry.purdue.edu/courses/agry105/common/giantragweed.htm

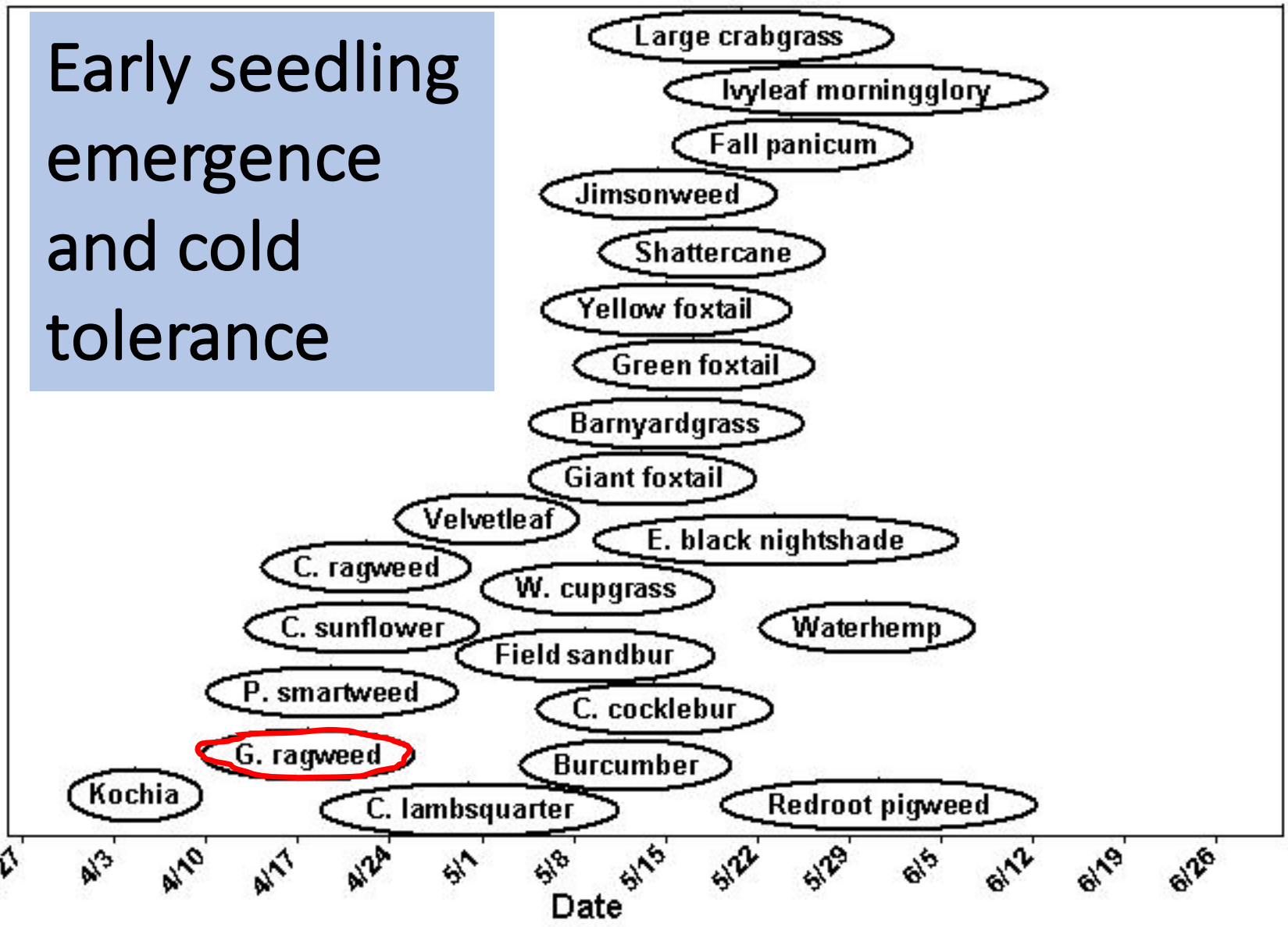

Large cotyledons
http://www.msuweeds.com/worst-weeds/giant-ragweed/

Rapid leaf production and growth

https://nature.mdc.mo.gov/discover-nature/field-guide/giant-ragweed-horse-weed-great-ragweed-buffalo-weed


Capable of overtopping crops
07/18/2015
Courtesy of D. Weisberger

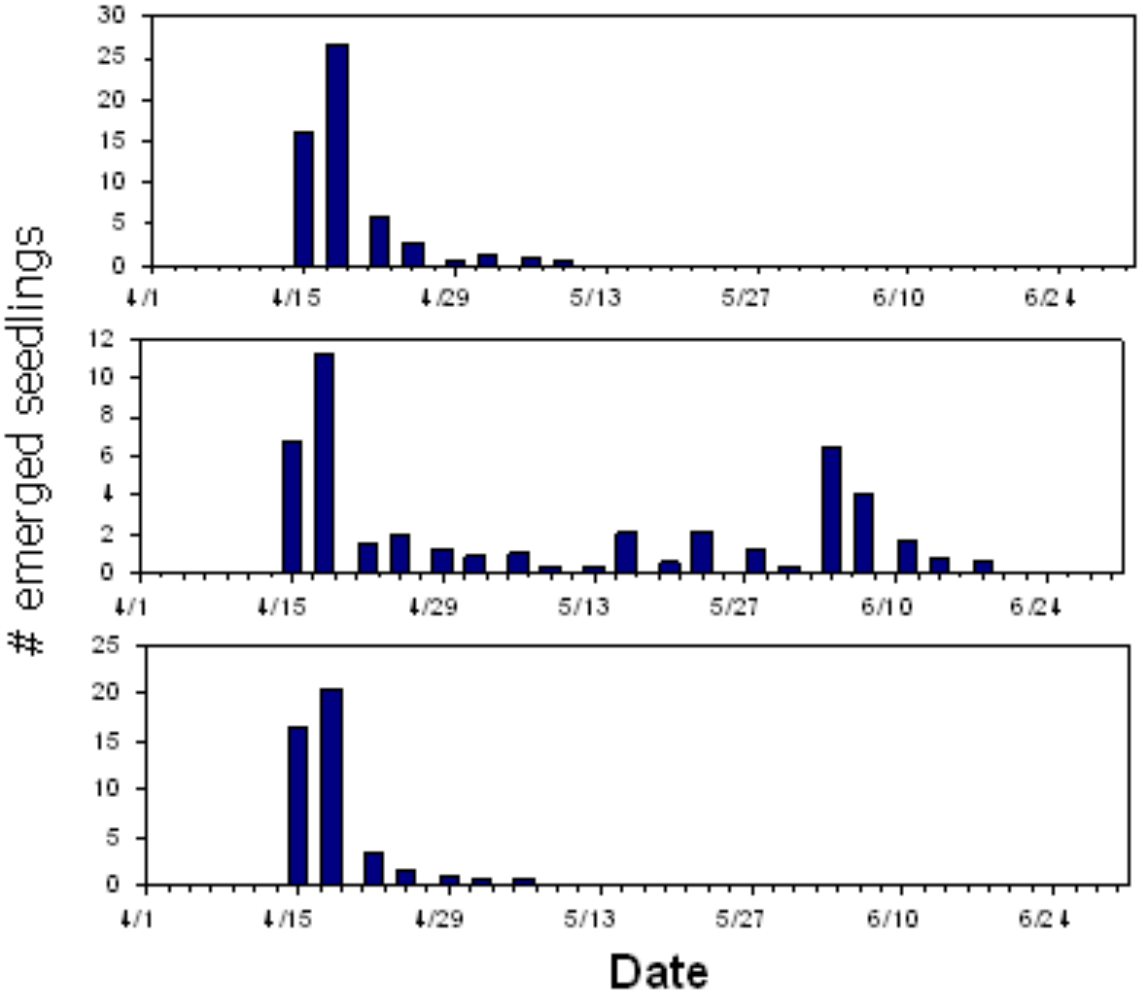
Figure 1. Weed emergence profiles. 1997-98. Hartzler, Buhler, and Sandell. Iowa State Univ.



Source: Hartzler 2000

Giant ragweed seedling emergence patterns differ among locations and populations

Figure 3. Emergence patterns of three giant ragweed biotypes.



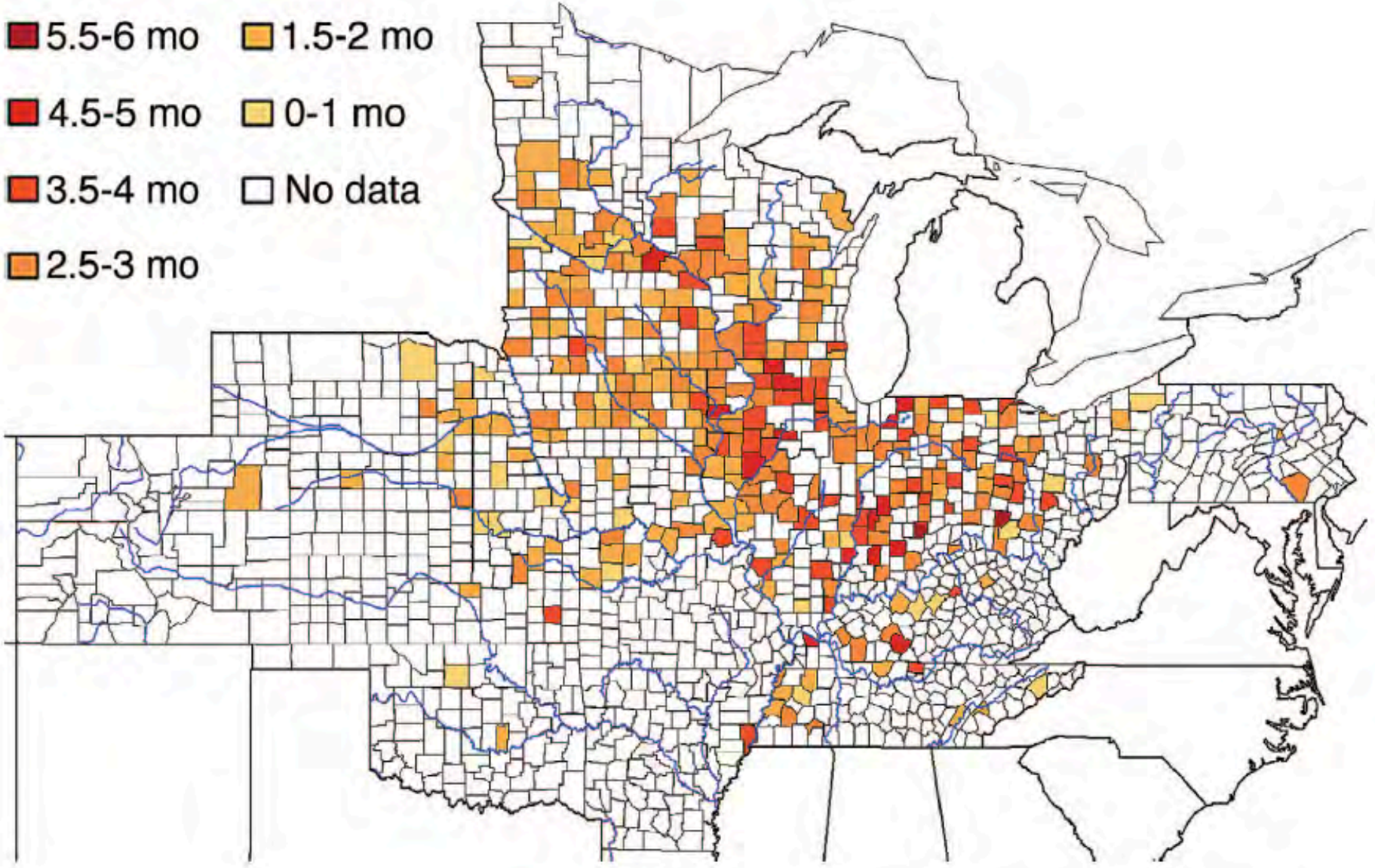
Iowa agricultural field

Ohio agricultural field

Iowa non-agricultural field (flood plain)

Source: Hartzler 2003

Distribution of emergence period of giant ragweed, in months



Source: Regnier et al. 2016

Extended periods of seedling emergence make giant ragweed control more challenging.

But giant ragweed has several vulnerabilities….

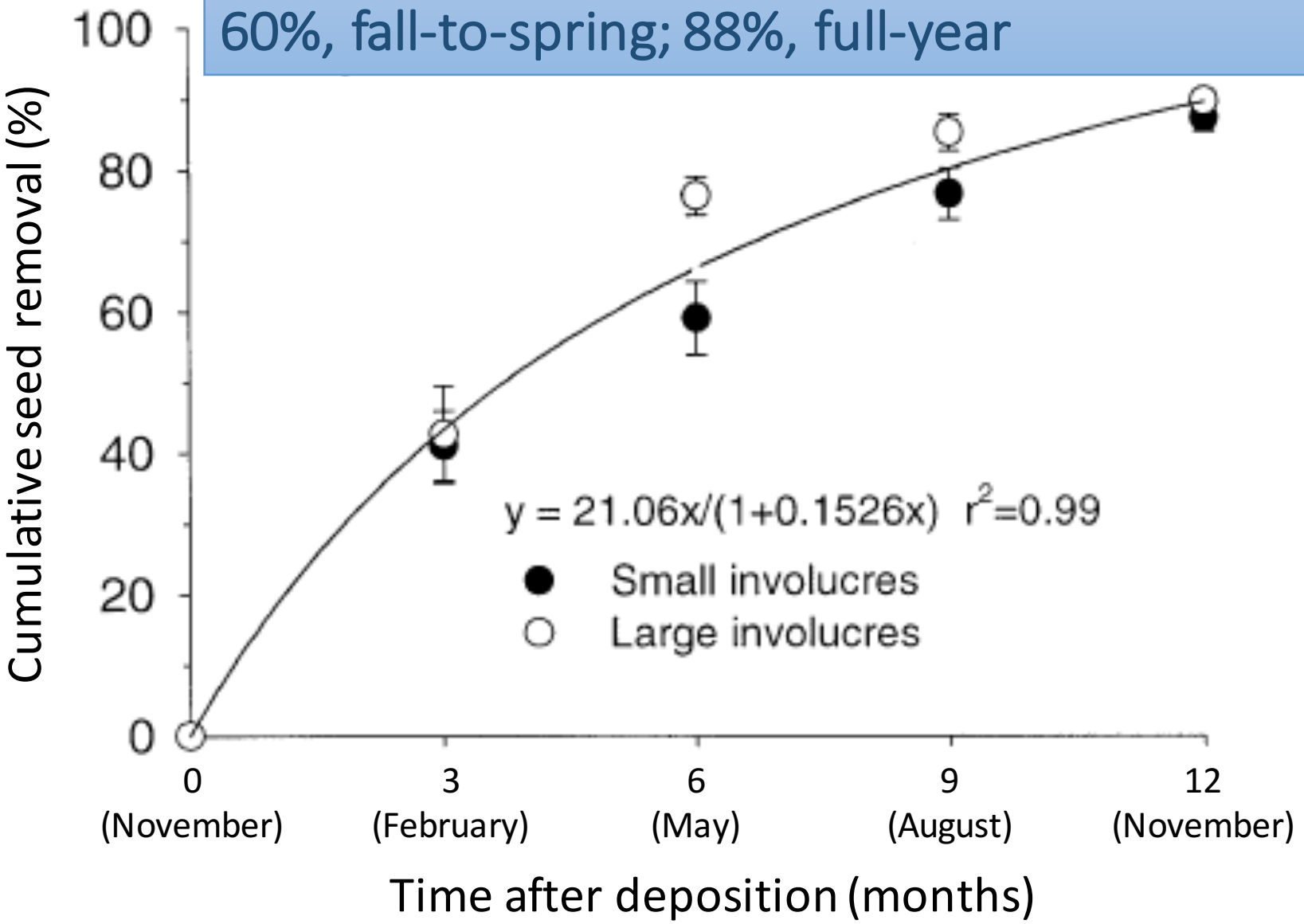
- High rates of seed consumption by predators (e.g., rodents, invertebrates, and birds)
- Short lifetime of seeds in and on the soil (i.e., it has a transient seedbank rather than a persistent seedbank)
- Relatively low rates of seed production (1,000s rather than 10,000s or 100,000s)

Seed Predators

Peromyscus maniculatus

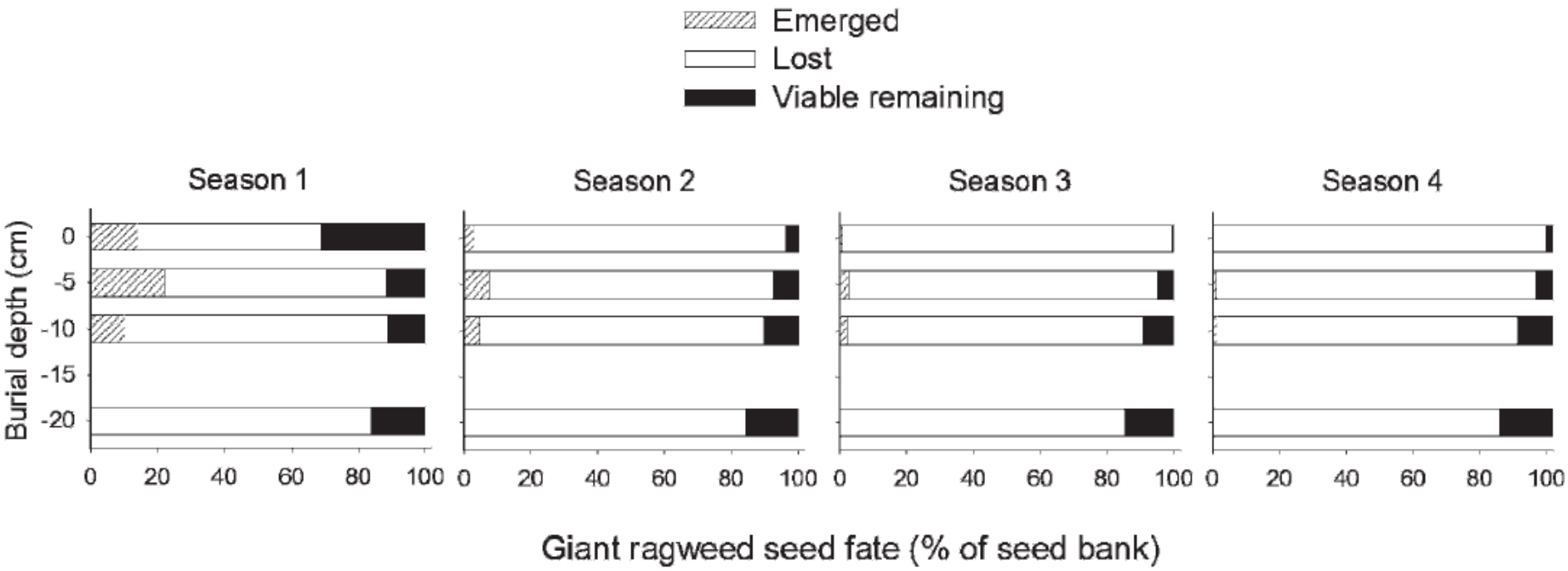
Gryllus pennsylvanicus

Removal of giant ragweed seeds by predators: 60%, fall-to-spring; 88%, full-year



Source: Harrison et al., 2003

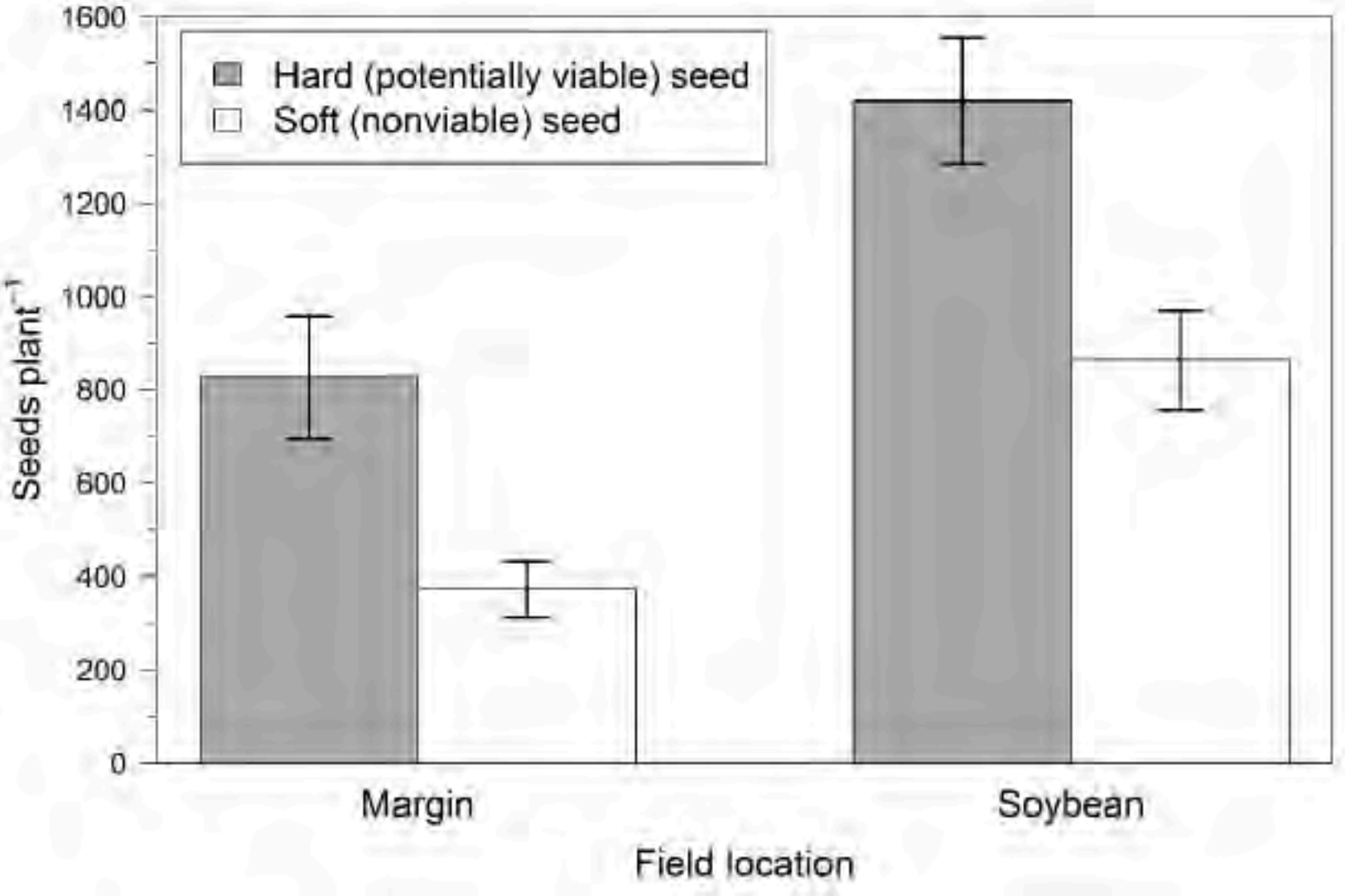
Fates of giant ragweed seeds buried at different depths over a four-year period



- Most seedling emergence occurred within the first two years.
- About 90% of seeds buried in the top 10 cm (four inches) of soil were eliminated after two years.

Source: Harrison et al. 2007

Giant ragweed seed production on field edges and in soybean



Source: Goplen et al. (2016)

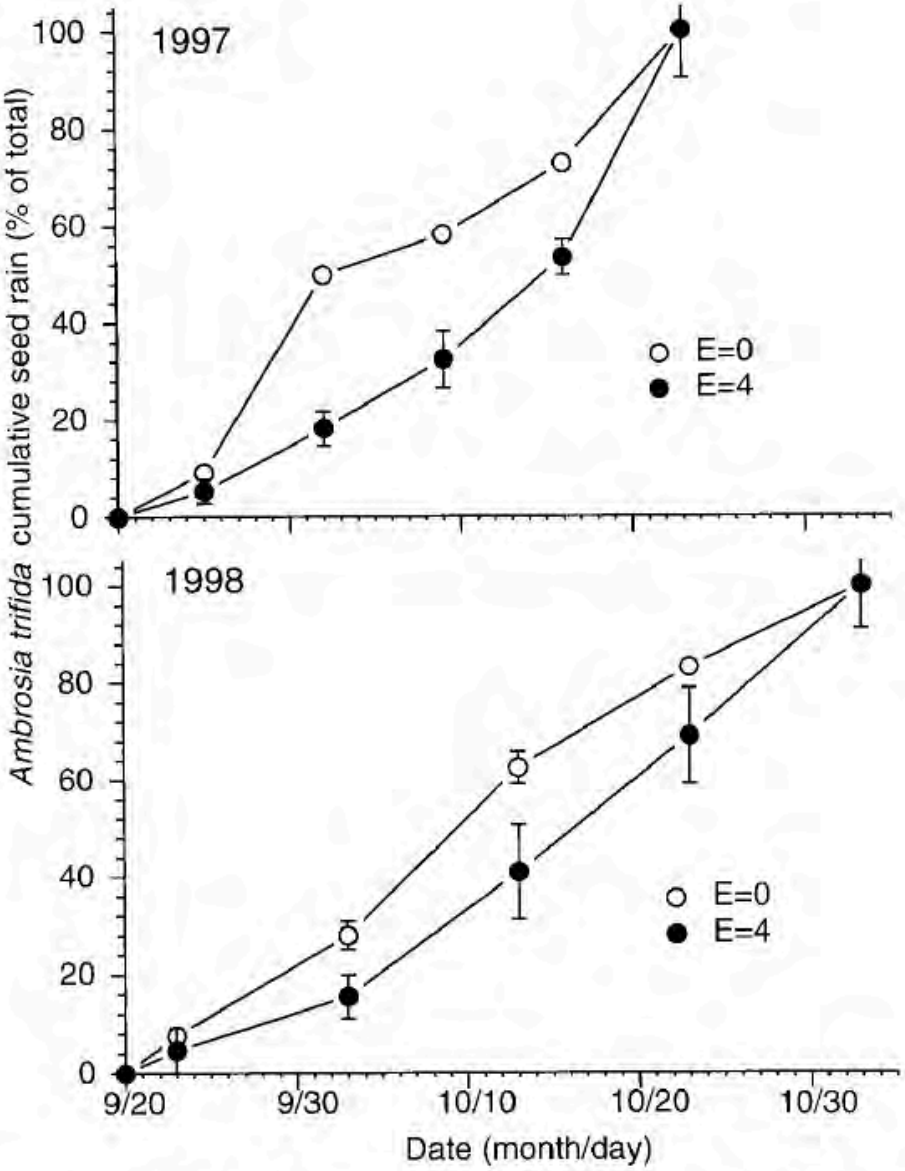


FIGURE 5. Effect of weed emergence time on cumulative seed rain of giant ragweed (*Ambrosia trifida*) in corn *Zea mays* in 2 yr. E = 0 designates simultaneous emergence of crop and weeds; E = 4 designates weed emergence 4 wk after crop emergence. Data points shown represent means of four replications. Vertical bars represent standard errors of the means.

Giant ragweed seeds are not dispersed from parent plants until late summer and fall

Source: Harrison et al. 2001

Situation analysis

Giant ragweed seed population density in the soil of a field in Minnesota

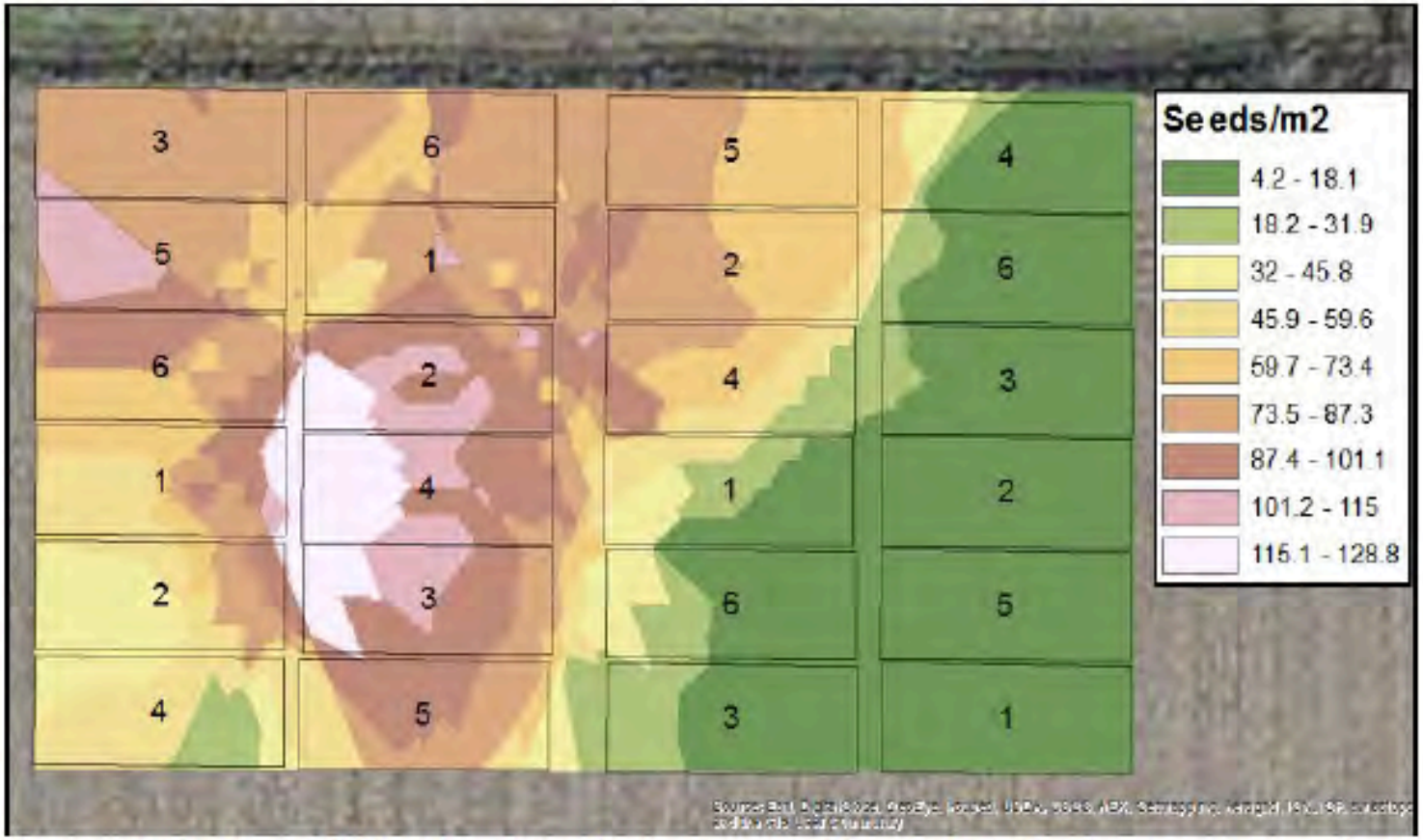


Figure A-2. Spatial distribution of starting seed bank density in experiment 1 at Rochester, MN taken in 2012. The krigging method of spatial interpolation was used to interpolate data and produce the seed density map.

100 seeds/m^2 = 404,686 seeds/acre

Goplen, 2015

It can be hard to beat the numbers

- 100 seeds per square meter in the soil seedbank = 404,686 seeds/acre
- 30% of the seeds germinate and emerge → 121,406 seedlings/acre
- 90% effectiveness in cultivation → 12,140 plants/acre
- 1,400 seeds produced per plant → 16,996,812 seeds/acre
- 60% seed loss to predators → 6,798,725 seeds/acre added to the soil seedbank

Cropping systems and weed management

Consider two kinds of crops

(1) Row crops that can be cultivated, sprayed, and/or hand-weeded. Weed control may be less than 100% effective.

(2) Solid seeded crops that are harvested in mid-summer, mowed, and/or removed for fodder. ***Cutting these crops in a timely manner can prevent reproduction by giant ragweed.***

No-till seeding of a winter cereal crop into soybean residue


Winter triticale in April, Boone Co., IA

Winter cereals mature in mid-summer

Winter triticale harvest in July

Alfalfa

Key questions for giant ragweed management

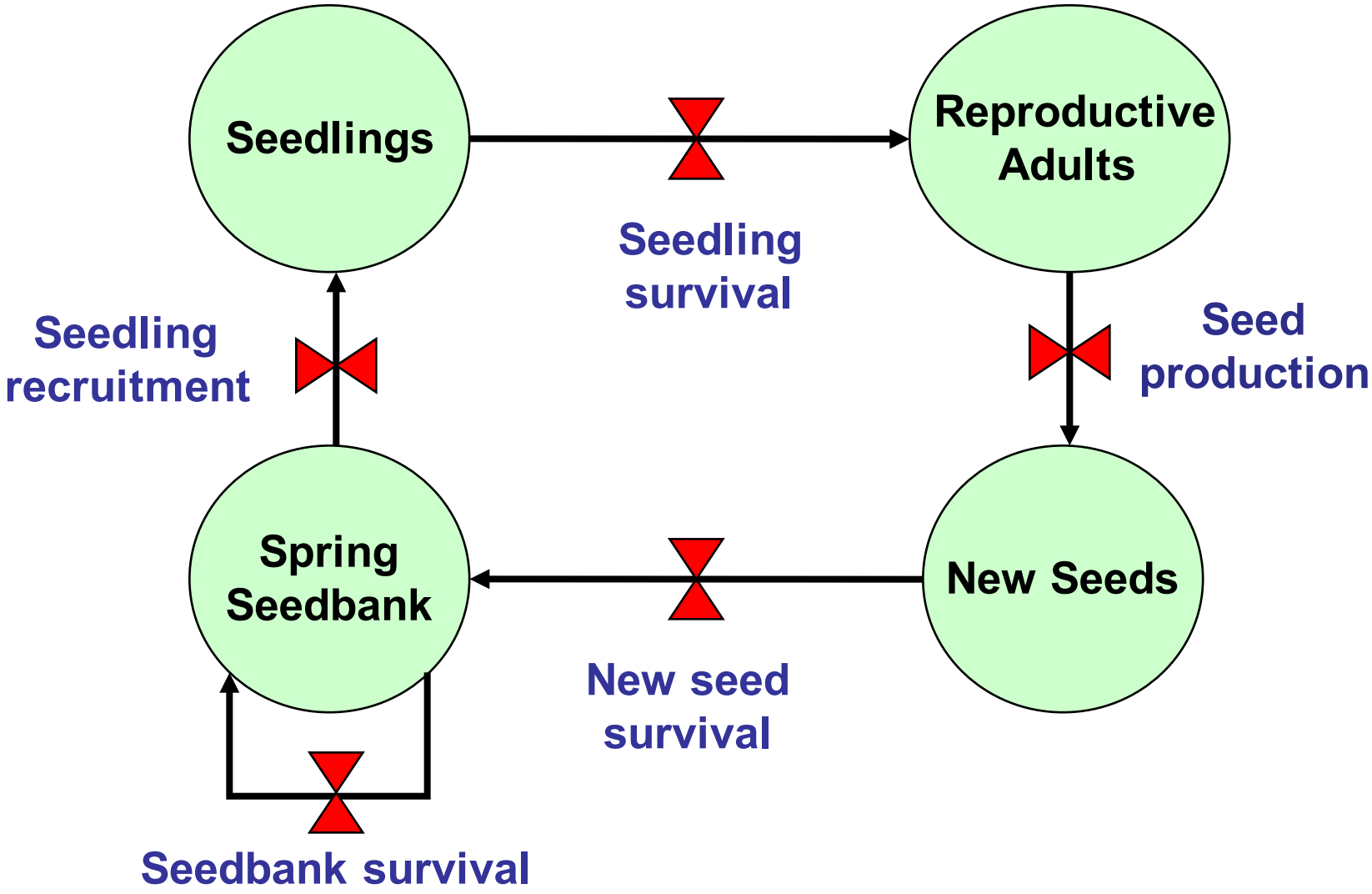
- How effective does control need to be to prevent infestations from getting worse?
- Is the length of a crop sequence important?
- Is the sequence of crops within a given rotation important?
- How can hand-weeding supplement cultivation?

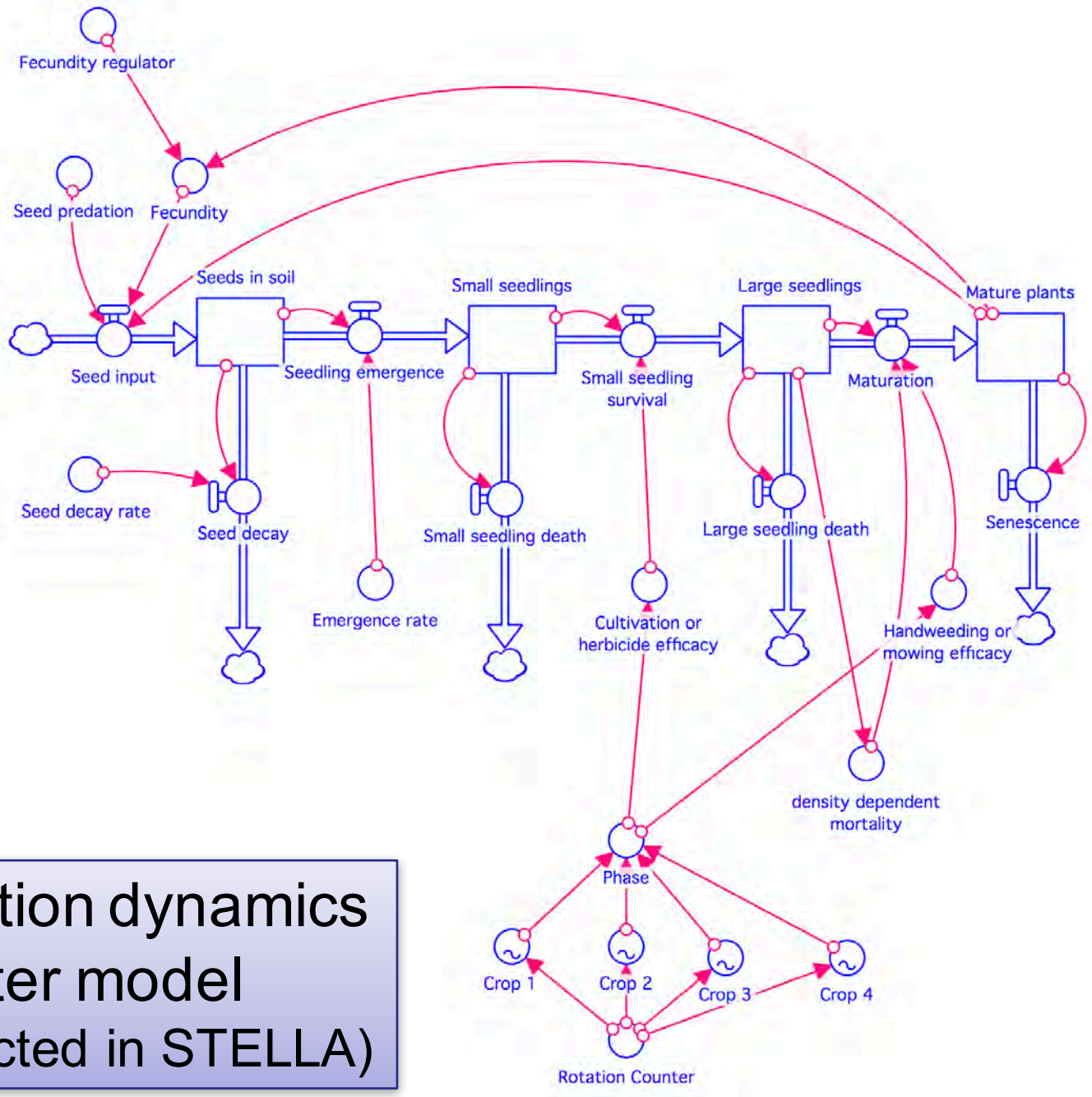
Key performance indicators

- Weed seed population density in soil
- Weed plant density

Consideration of weed management options using models

Life history of an annual weed

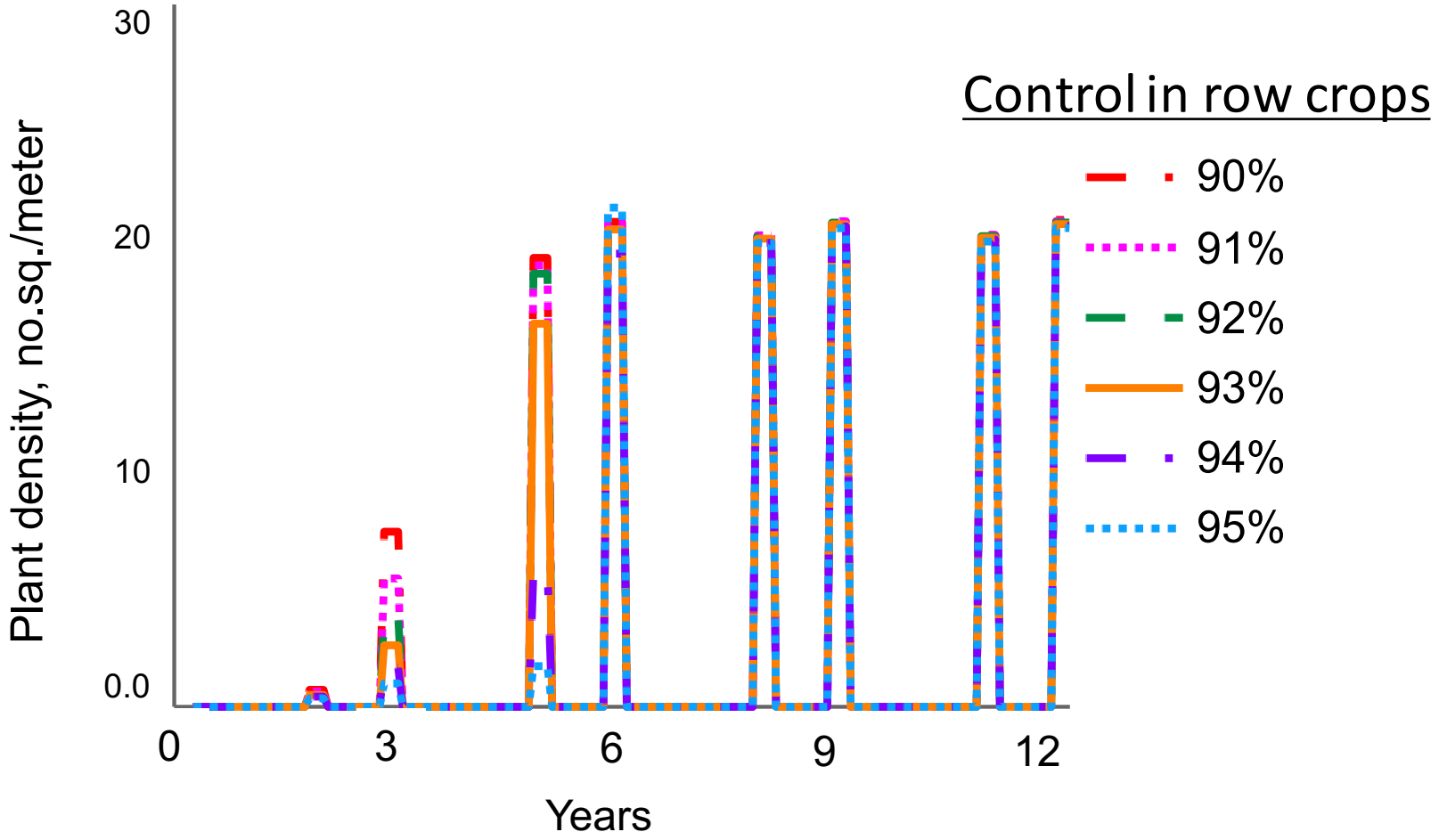




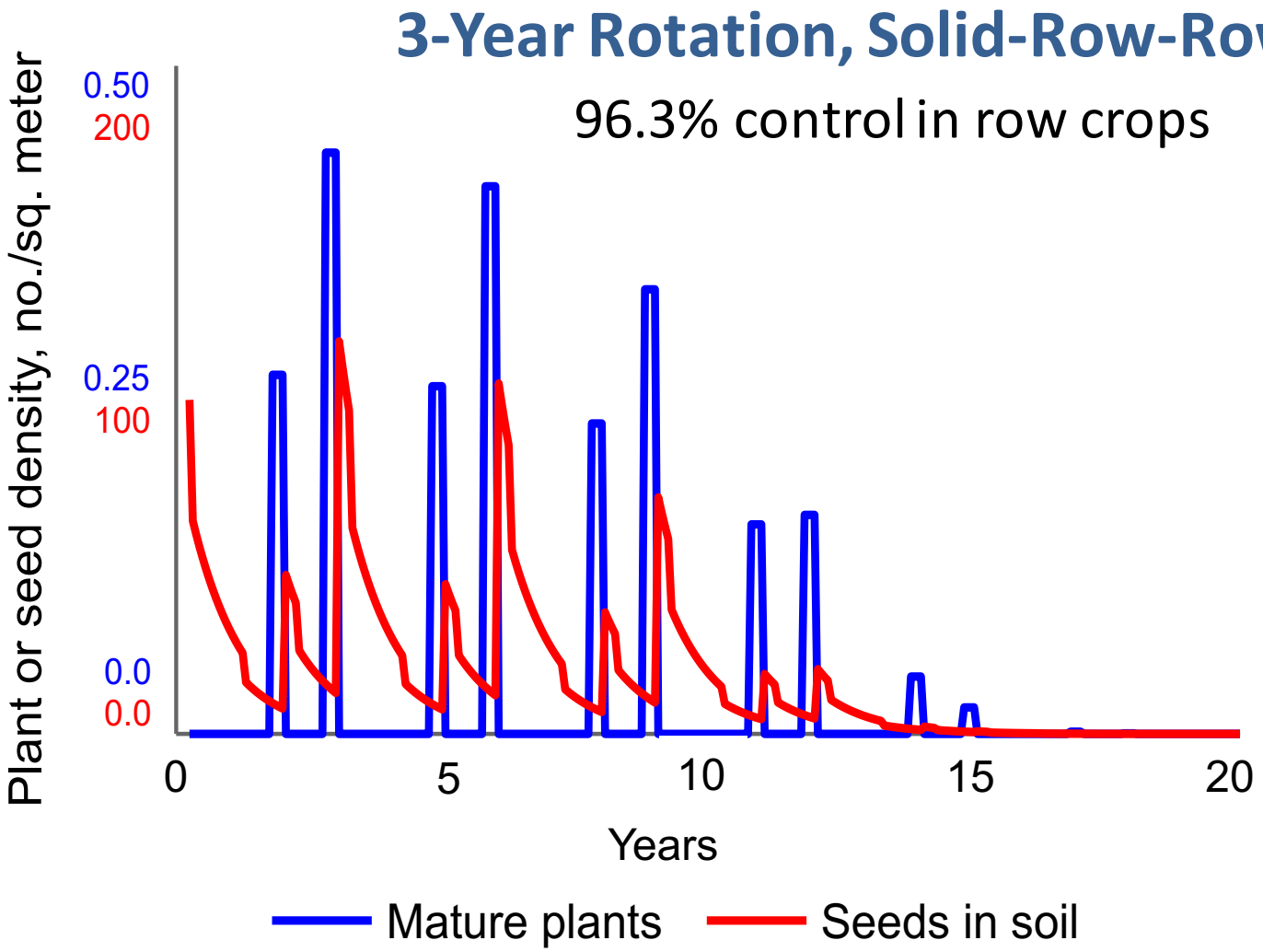
Population dynamics computer model (constructed in STELLA)

How effective does giant ragweed control need to be?

3-Year Rotation, Solid-Row-Row



How effective does control need to be?



Is the length of a crop sequence important?

Rotation length	Control required in row crops to prevent giant ragweed population increase
3-year: Solid-Row-Row	96.3%
4-year: Solid-Solid-Row-Row	90.2%

Is the sequence of crops within a given rotation important?

Sequence	Control required in row crops to prevent giant ragweed population increase
Solid-Solid-Row-Row	90.2%
Row-Row-Solid-Solid	97.7%

How can hand-weeding supplement cultivation?

(solid-solid-row-row sequence)

Control strategy	Control required in row crops to prevent giant ragweed population increase	
	Cultivation	Hand-weeding
Cultivate only	90.2%	0%
Cultivate + hand-weeding	80.0%	50.7%

Meanwhile, back in the real world…

Hybrid winter rye & Tom Frantzen
Frantzen Farm, New Hampton, IA

Some points to remember

- Certain crops and management activities can minimize weed seed inputs.
- Starting new rotation sequences with weed suppressive crops is useful.
- Weed emergence without subsequent reproduction depletes the seedbank.
- Leaving weed seeds on the soil surface for as long as possible maximizes seed predation.

And now, the test…


Sharon & Dick Thompson
Boone, Iowa
Thompson
Research Farm

Table 3. Weed density prior to crop harvest near Boone, IA.

Year	Crop	Weed density		
		Common waterhemp	Foxtail species	Other species[a]
		Plants/10 m²		
1994	Hay	350	410	280
1995	Corn	6	2	4
1996	Soybean	1	0	0
1997	Corn	1	4	1
1998	Oat	750	510	80

[a] Included common lambsquarters, Pennsylvania smartweed, and velvetleaf.

Buhler et al., 2001

Table 2. Density of viable weed seeds of the upper 20 cm of a Nicollet loam soil near Boone, IA. Samples were collected in October of each year.

		Weed seed density[a] (seeds/m^2)			
Year	Crop	Common waterhemp	Foxtail species	Other species[b]	All species
1994	Hay	27,880 b	4,840 b	8,650 a	41,370 b
1995	Corn	13,750 c	510 c	1,780 b	16,040 c
1996	Soybean	7,260 d	130 c	630 c	8,020 d
1997	Corn	1,910 e	500 c	400 cd	2,810 d
1998	Oat	64,160 a	6,490 a	130 d	70,780 a

[a] Means within a column followed by the same letter are not significantly different according to Fisher's LSD ($\alpha = 0.05$).

[b] Included common lambsquarters, Pennsylvania smartweed, and velvetleaf.

Buhler et al., 2001