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Weed seedbank management and the influence of seed predators

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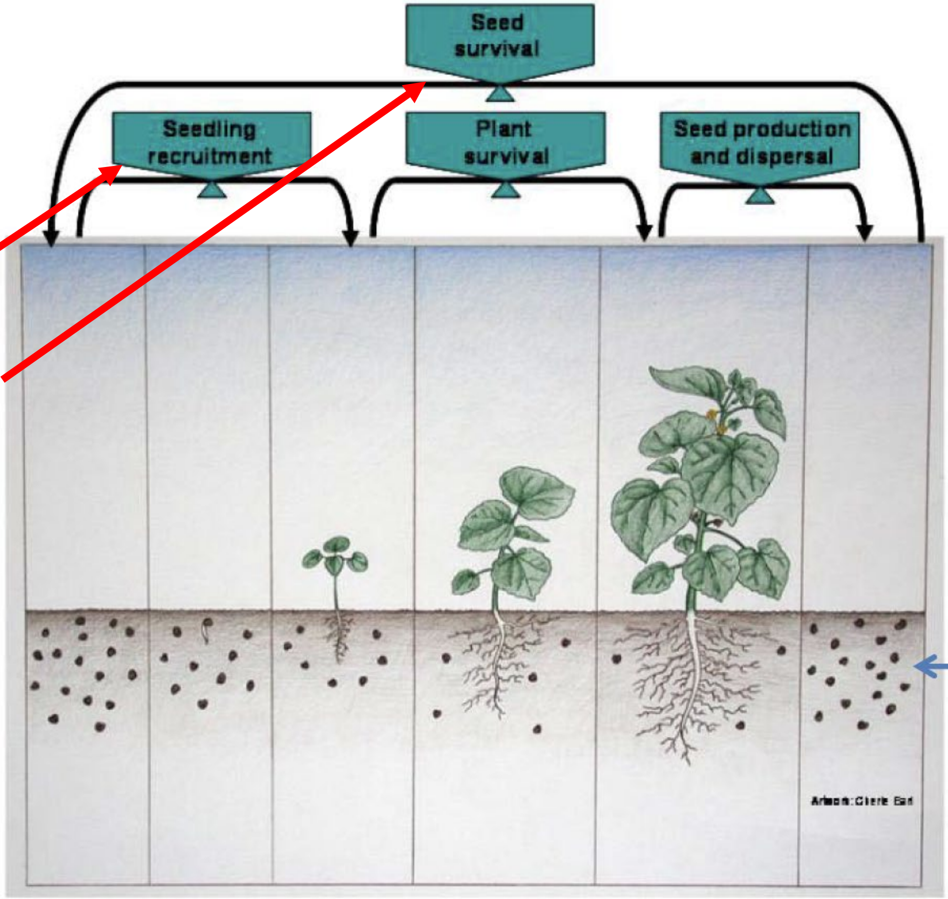
Outline

- What is the seedbank?
- Sources of seedbank inputs
- Considerations for managing the seedbank
- Control Methods
    - Chaff Collection
    - Seed Destructor
    - Seed Predators

Seedbank Formation



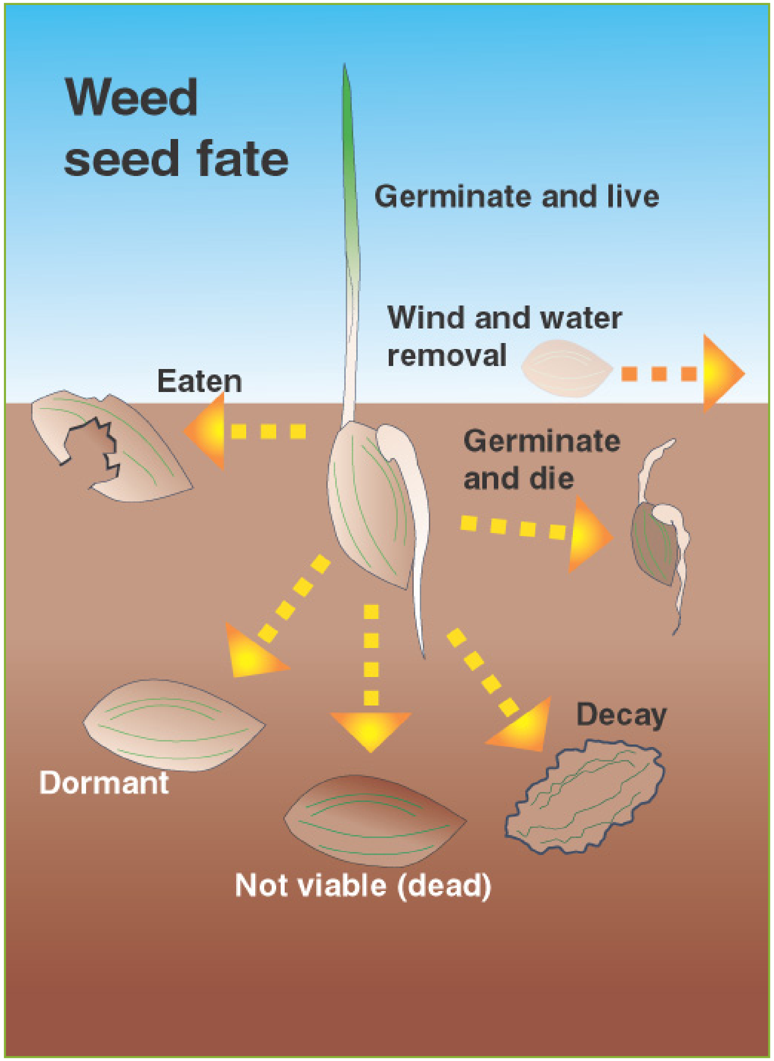
Critical to annual weed populations

weed seedbank

Artwork: Cherie Earle

Fate of Seeds

- Germinate
- Dormant
- Die (aging)
- Die (predators)



Questions for management

- How prevalent is weed seed return?
- Does it matter?
- What can we do about it?
    - management


Photo: Cress seeds

Photo: Breanne Tidemann

Seed Capacity/Production

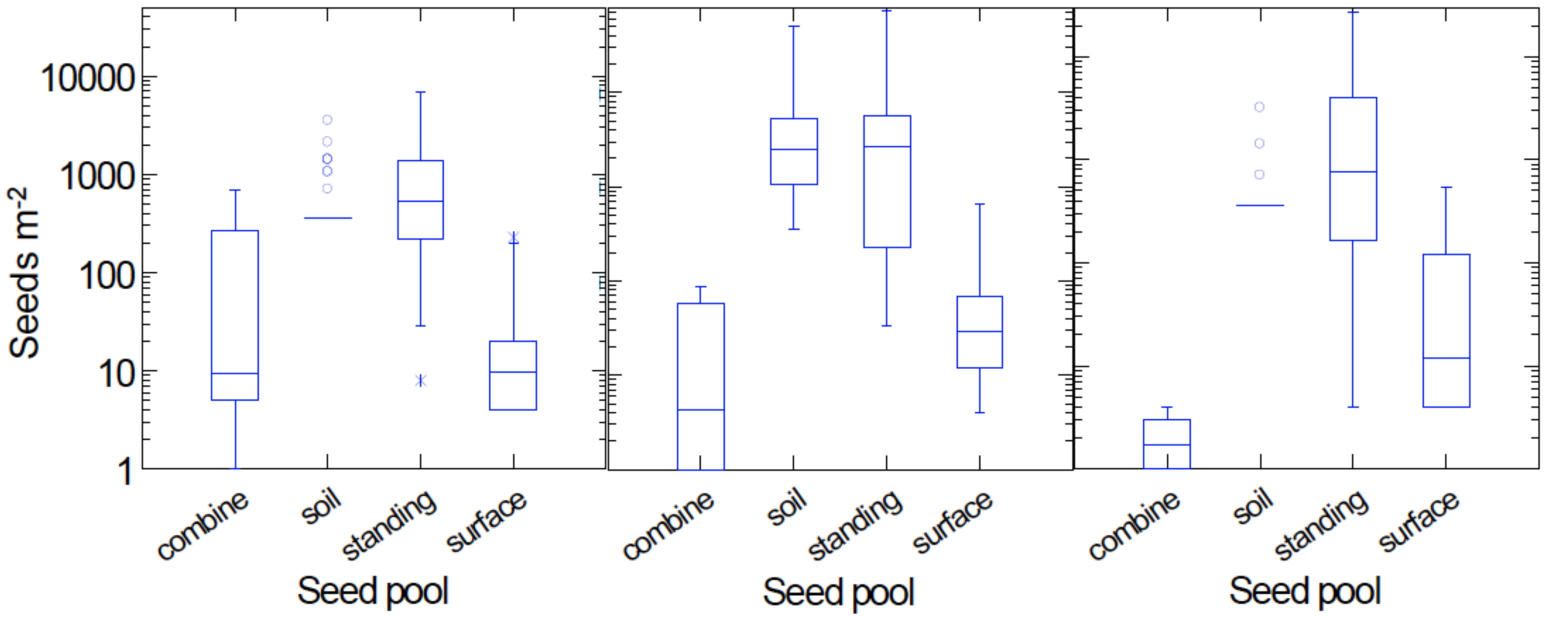
Species	Maximum	Minimum	Field Mean	
Quackgrass (seed)	400	15	50	Low
Volunteer wheat	250	10	100	
Foxtail barley	300	10	100	
Wild Oat	500	10	100	
Cleavers	3000	50	500	Med
Wild buckwheat	15000	100	500	
Volunteer canola	3000	50	750	
Chickweed	2500	500	1000	
Canada Thistle (seed)	5000	100	1000	
Curled dock	50000	100	2000	High
Wild mustard	5000	500	2000	
Dandelion	25000	1000	2500	
G. Foxtail	12000	500	2500	
P. sowthistle (seed)	50000	1000	3000	
Kochia	12000	1000	5000	
Lamb's quarters	100000	2000	7500	V. High
Redroot pigweed	100000	5000	10000	
Stinkweed	200000	2000	10000	

Van Acker and Bartlinski, 2006

giant foxtail

redroot pigweed

velvetleaf



26 species total

Davis (2008) Weed Sci.

Seed longevity

- Beal’s experiment initiated in 1879 – 3 of 21 species remained viable after 100 years
- Duvel’s experiment initiated in 1902 – 36 of 107 species viable after 39 years.
- These are extremes; under normal conditions most seeds lose viability in 2-10 years.

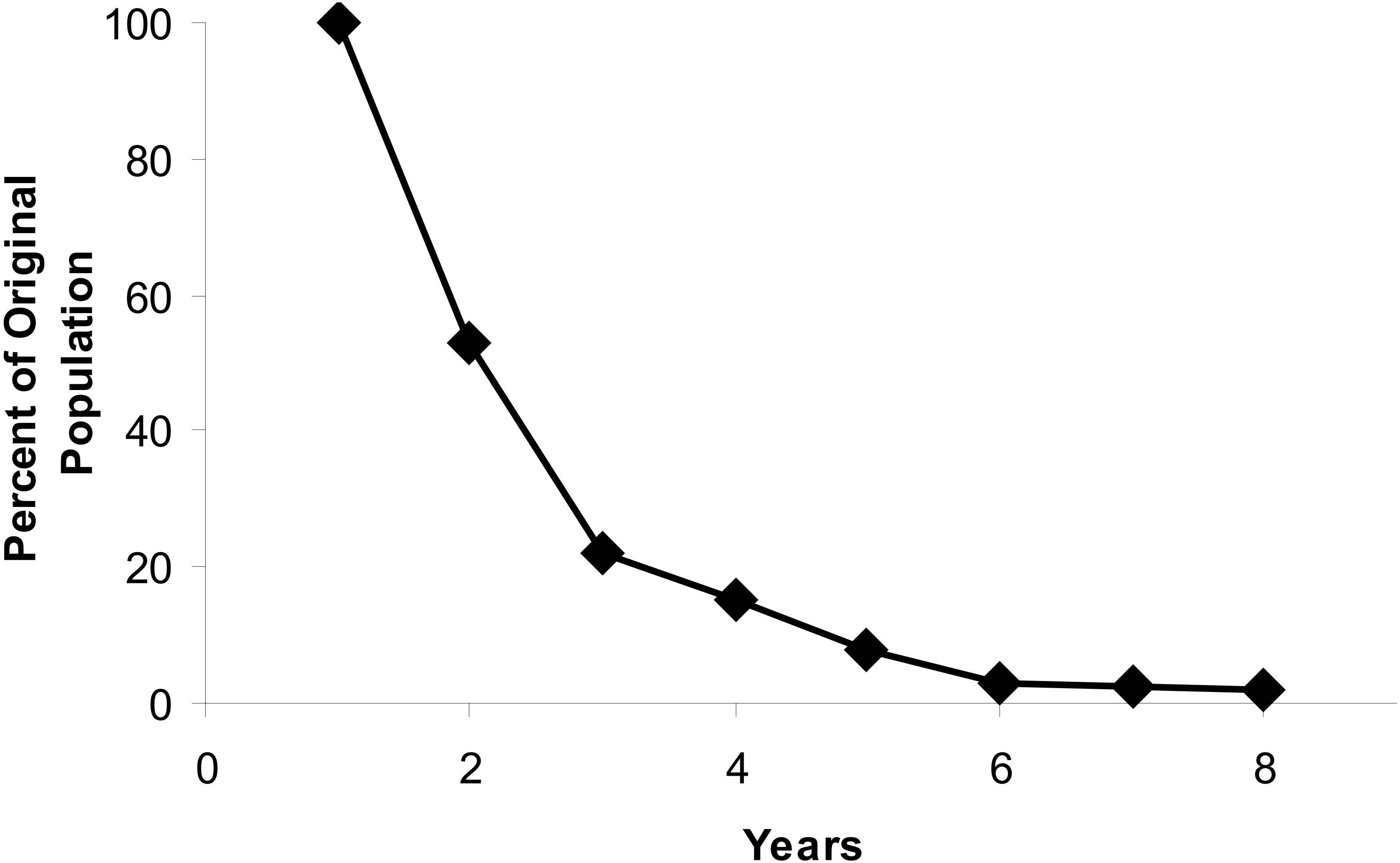
Seed bank Longevity – does it matter?

Species	Maximum	Minimum	Practical	
Kochia	2 yrs	0 yr	0-2 yrs	**Short**
Volunteer wheat	3 yrs	0 yr	0-2 yrs	
Foxtail barley	7 yrs	1 yr	1-2 yrs	
Canada Thistle (roots)	2 yrs	1 yr	1-2 yrs	
Dandelion	2 yrs	1 yr	1-2 yrs	
Quackgrass (seed)	4 yrs	1 yr	1-3 yrs	
Cleavers	5 yrs	1 yr	1-3 yrs	
Annual sowthistle	5 yrs	1 yr	1-4 yrs	
Canada Thistle (seed)	21 yrs	1 yr	2-3 yrs	**Med**
Perennial sowthistle (seed)	5 yrs	2 yrs	2-5 yrs	
Volunteer canola	14 yrs	1 yr	3-5 yrs	
Wild Oat	7-9 yrs	3 yrs	4-5 yrs	
Chickweed	10 yrs	6 yrs	5-10 yrs	**Long**
Wild buckwheat	>6yrs	6 yrs	6-10 yrs	
G. Foxtail	30 yrs	4-5 yrs	5-15 yrs	
Lamb's quarters	39 yrs	6-8 yrs	8-20 yrs	
Redroot pigweed	40 yrs	10 yrs	10-20 yrs	**V. Long**
Stinkweed	30 yrs	8 yrs	10-20 yrs	
Curled dock	80 yrs	10yrs	10-30 yrs	
Wild mustard	60 yrs	20 yrs	20-30 yrs	

Van Acker and Bartlinski, 2006

Rate of Decline in Seed Viability With Time (Wild Mustard)

(Warnes and Andersen 1984)



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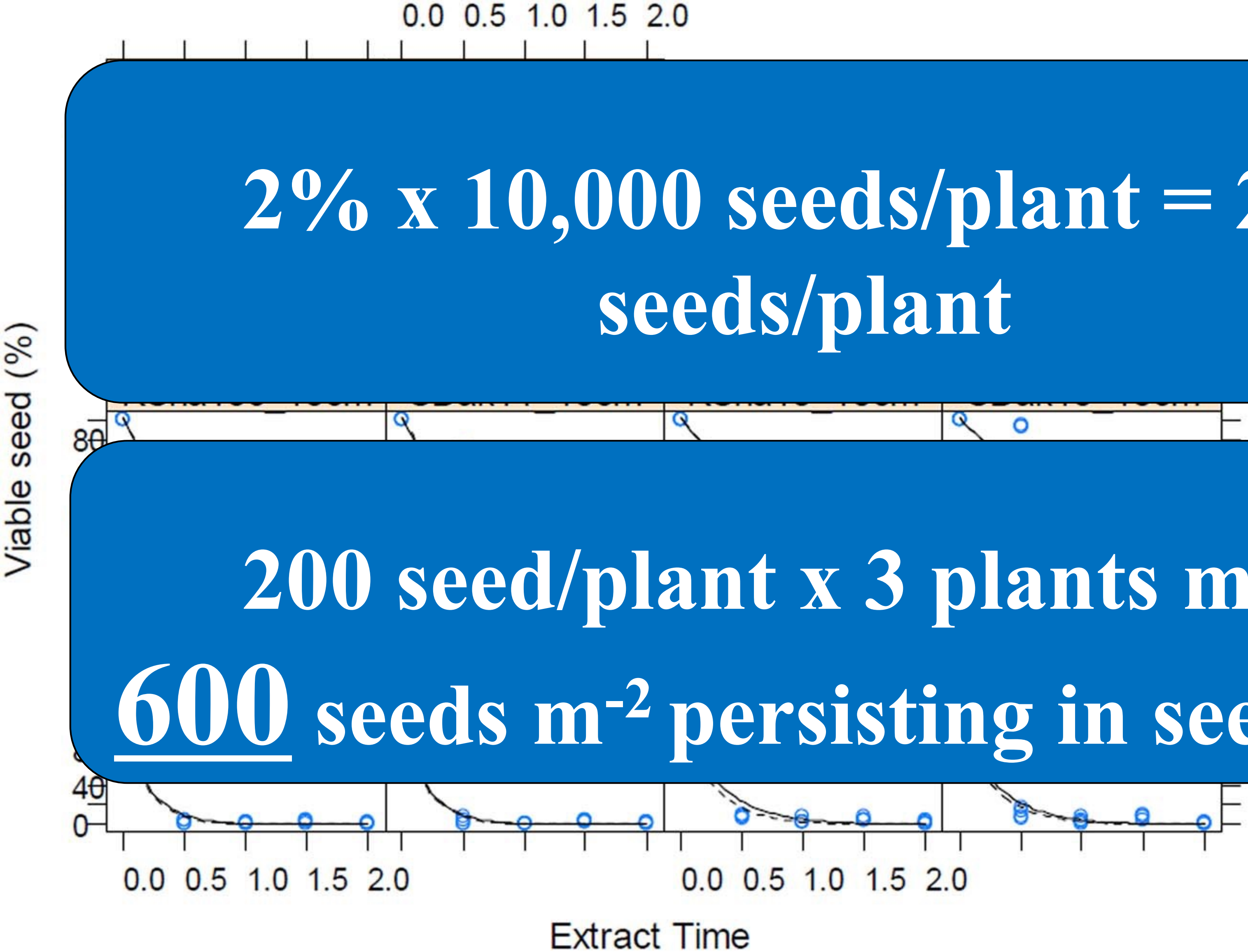
Kochia seed decline (5 US States)



2% x 10,000 seeds/plant = 200 seeds/plant

200 seed/plant x 3 plants m^{-2} = <u>600</u> seeds m^{-2} persisting in seedbank

Managing seed viability pre-harvest

Table 4.1 Mean comparisons of kochia seed time to 50% emergence, final emergence percentage, and plant biomass using seed collected from pre-harvest herbicide studies conducted at Saskatoon and Scott, SK from 2012 to 2014. Estimate statements represent pre-planned comparisons between glyphosate rates, glyphosate with contact herbicides, and tank-mix rates.

Herbicide	Rate	ET_{50} Emergence	Final Emergence	Above-ground Biomass
	(g a.i./a.e. ha^{-1})	Thermal Hours	%	g
Untreated	0	1944 C	44.5 A	74 A
Glyphosate	450	2081 A-C	12.7 BC	27 A-D
Glyphosate	900	2141 AB	9.1 BC	14 CD
Pyraflufen-ethyl‡	20	2030 A-C	24.4 AB	50 A-C
Pyraflufen-ethyl + Glyphosate‡	20 + 450	2021 A-C	15.1 BC	29 A-D
Pyraflufen-ethyl + Glyphosate‡	20 + 900	2050 A-C	17.4 BC	27 A-D
Glufosinate	600	2174 A	6.3 C	13 CD
Glufosinate + Glyphosate	600 + 450	2172 A	13.2 BC	25 B-D
Glufosinate + Glyphosate	600 + 900	2088 A-C	5.0 C	8 D

Bertholet and Willenborg, 2019

Species	Seed Longevity Rating	Seed Production Rating	Problem Rating	
Quackgrass (seed)	L	L	1	V. Low
Volunteer wheat	L	L	1	
Foxtail barley	L	L	1	
Wild Oat	M	L	2	L. Low
Cleavers	L	M	2	
Canada Thistle (seed)	M	M	3	Low
Kochia	L	H	3	
Volunteer canola	M	M	3	
Dandelion	L	H	3	
P. sowthistle (seed)	M	H	4	Med
Wild buckwheat	H	M	4	
Chickweed	H	M	4	
G. Foxtail	H	H	5	M. High
Curled dock	VH	H	6	High
Wild mustard	VH	H	6	
Lamb's quarters	H	VH	6	
Redroot pigweed	VH	VH	7	V. High
Stinkweed	VH	VH	7	

Van Acker and Bartlinski, 2006

Additional Considerations

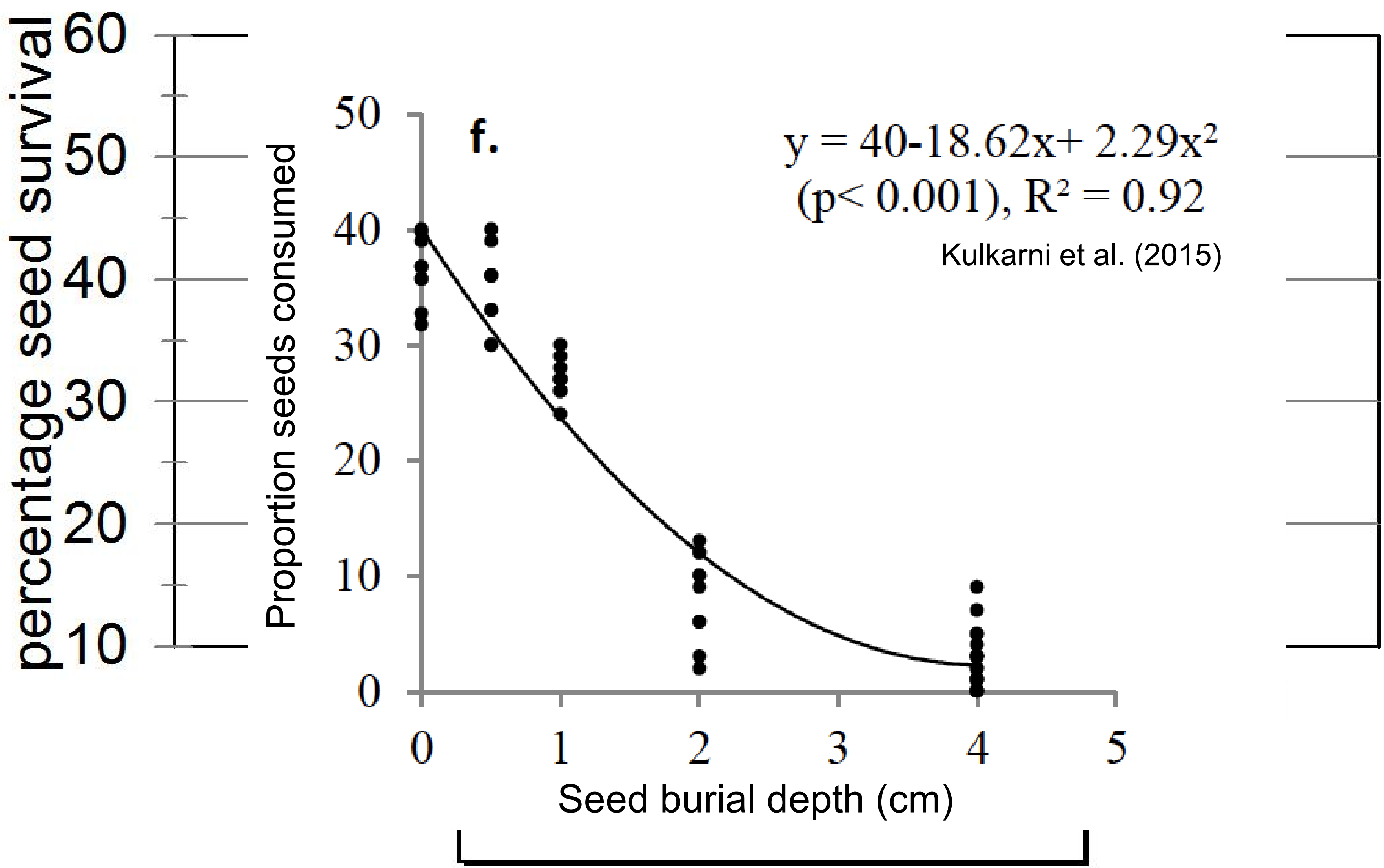
- New weed?
- Tough to control weed?
- Herbicide Resistant?
- Dispersal?

Additional Considerations

- New weed?
- Tough to control weed?
- Herbicide Resistant?
- Dispersal?
- Seed burial?

Wild oat seed survival

Sagar and Mortimer 1976

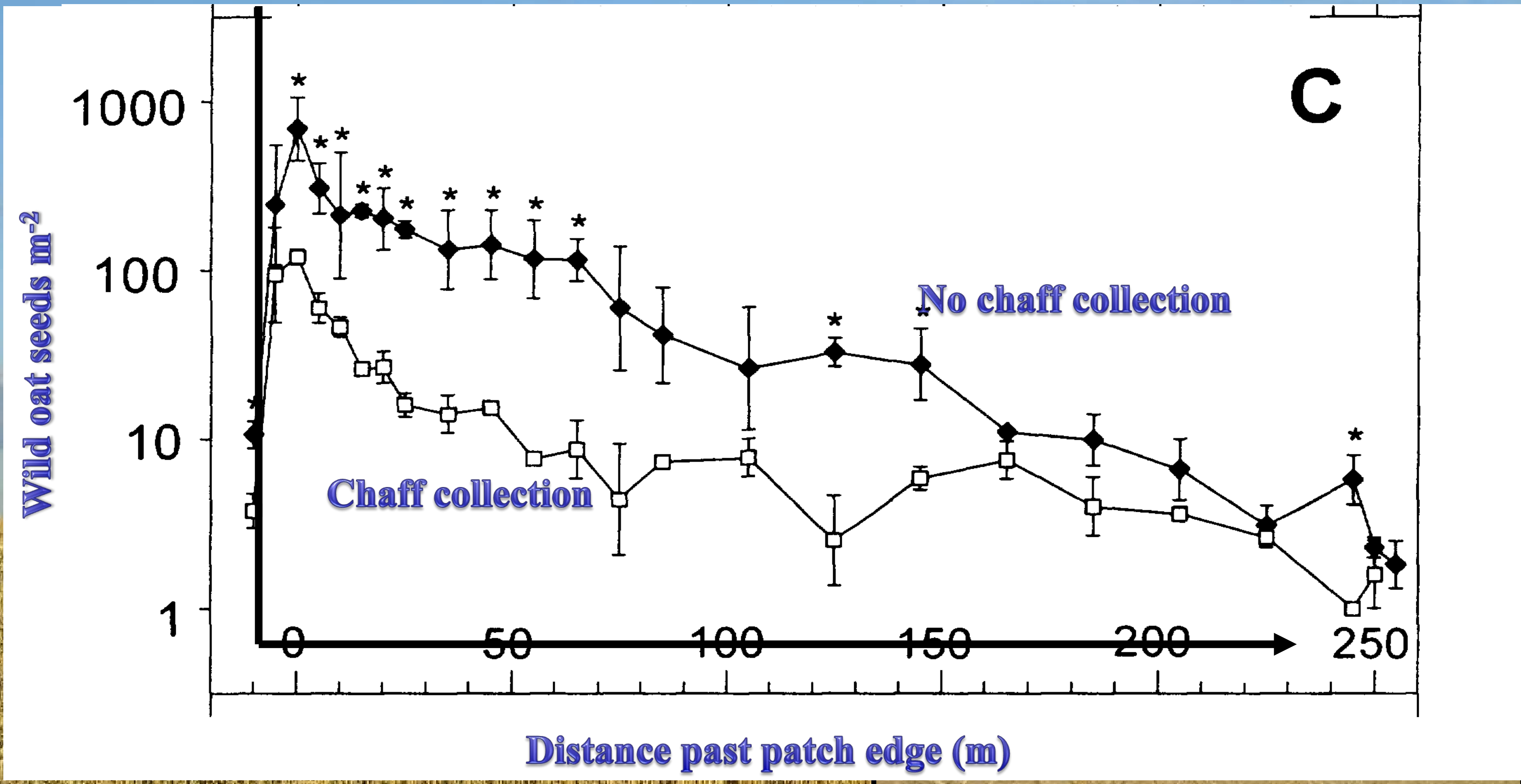


Managing the seedbank (non-chemical)

- Chaff collection
- Seed destructors
- Seed predators

Chaff management

Combine Harvester Dispersal of Wild Oat with and without Chaff Collection

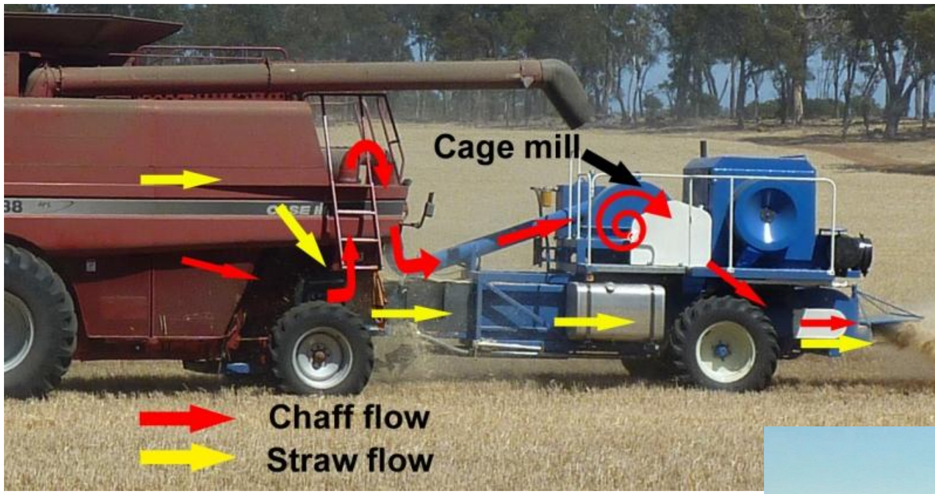


Shirtliffe, S.J. and M.H. Entz. 2005. Weed Sci. 53: 465-470.

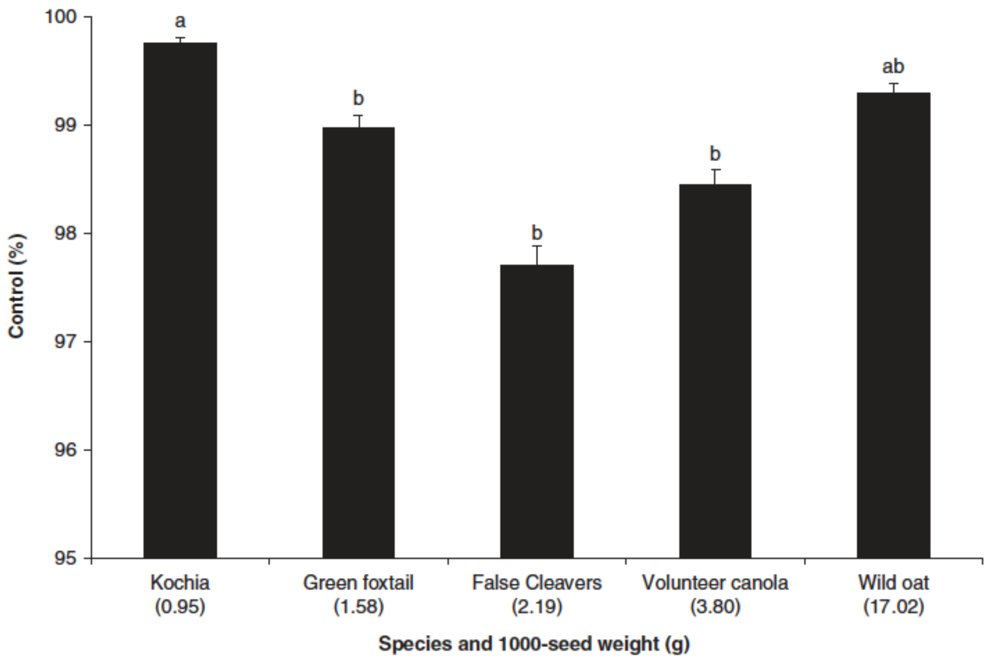
Grazing Crop Residues

Photos: Bart Lardner

Chaff management



Harrington Seed Destructor



Tideman et al. (2017). Weed Sci. 65:650-658

Concerns

- Cost?

Ultimately, weed seeds will still fall to ground!

    - Height

- Weed Evolution?

Seed Shatter

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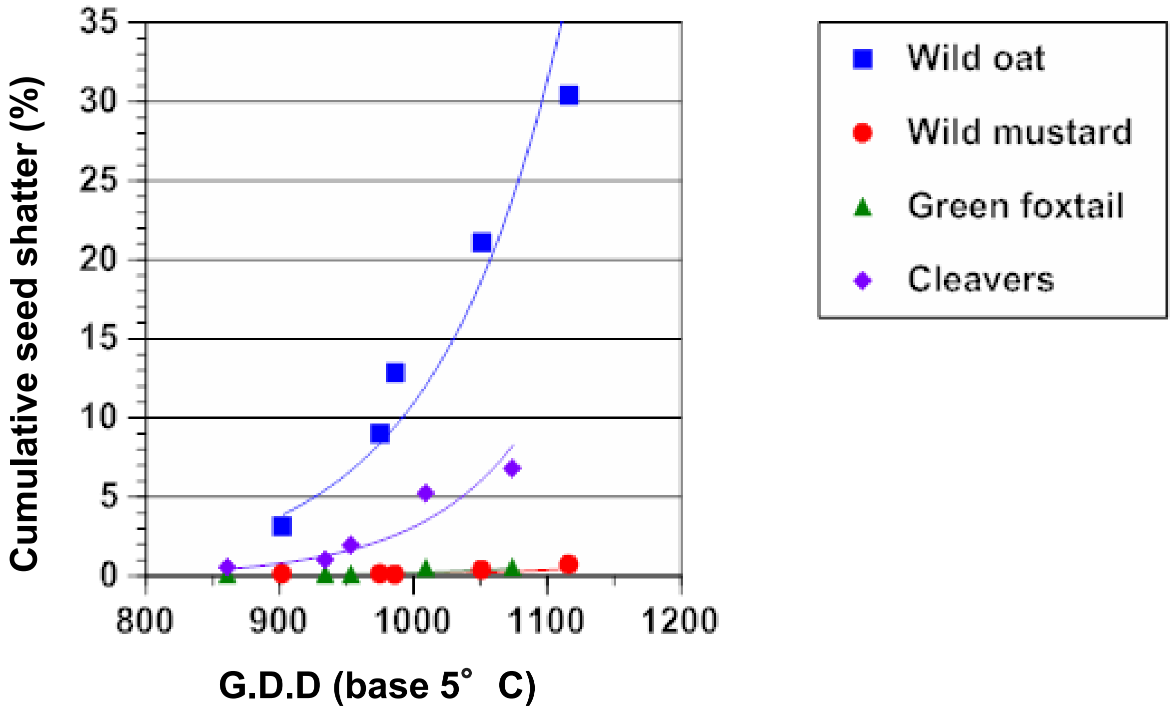


Burton et al. (2017).

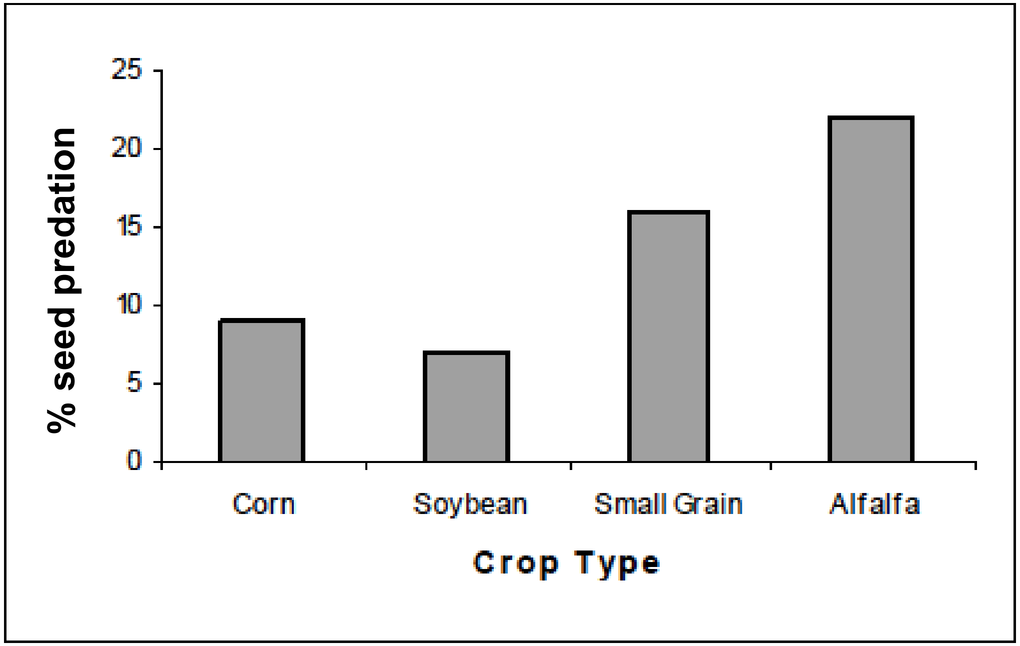
Table 5. Weed seed shatter (± SE) in spring wheat at Scott, SK, in 2014 and 2015 (data combined across years).

	Total seed shatter[a,b]					
	Swathing stage			Direct-harvest stage		
Weed species	g m^{-2}	no m^{-2}	% of retained	g m^{-2}	no m^{-2}	% of retained
Wild oat	4.82 a (1.04)	299 (67)	19.3 (4.3)	6.51 a (1.18)	389 (75)	28.0 a (3.6)
Wild mustard	0.31 b (0.09)	132 (41)	1.73 (0.84)	0.56 b (0.14)	228 (57)	1.79 bc (0.62)
Green foxtail	0.01 b (0.01)	21 (8)	0.61 (0.22)	0.10 b (0.03)	46 (15)	0.78 c (0.33)
Cleavers	0.08 b (0.03)	37 (10)	3.73 (1.99)	0.21 b (0.08)	68 (23)	5.15 b (1.90)

Seed Predators

Seed Predators

- Seed predation can be responsible for up to 90% seed loss (Honek et al. (2005)
  - Ground beetles and crickets greatest sources of loss in fields



Westerman et al. (2005). Weed Res.

University of Saskatchewan

Seed Predators

- Earthworms also may be important
    - Earthworms collected seeds of giant ragweed (Regnier et al. 2008)
        - reduced seedling emergence

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Earthworms as seedling predators: Importance of seeds and seedlings for earthworm nutrition

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Stable isotope analysis

ABSTRACT

Anecic earthworms have been shown to collect, concentrate and bury seeds in their burrows. Moreover, recent studies suggest that earthworms function as granivores and seedling herbivores thereby directly impacting plant community assembly. However, this has not been proven unequivocally. Further, it remains unclear if earthworms benefit from seed ingestion, i.e., if they assimilate seed carbon. We set up a series of three laboratory experiments in order to test the following hypotheses: (1) anecic earthworms (*Lumbricus terrestris* L.) not only ingest seeds but also seedlings, (2) ingestion of seedlings is lower than that of seeds due to a 'size refuge' of seedlings (i.e., they are too big to be swallowed), and (3) seeds and seedlings contribute to earthworm nutrition. *L. terrestris* readily consumed legume seedlings in the radicle stage, whereas legume seeds and seedlings in the cotyledon stage, and grass seeds and seedlings in the radicle and cotyledon stage were ingested in similar but lower amounts. Importantly, ingestion of seedlings, in contrast to seeds, was lethal for all plant species. Moreover, earthworm weight change varied with the functional identity and vitality of seeds and natural ^{15}N signatures in earthworm body tissue underlined the importance of seedlings for earthworm nutrition. The results indicate that the anecic earthworm *L. terrestris* indeed functions as a granivore and seedling herbivore. The selectivity in seedling ingestion points at the potential of direct earthworm effects on plant community assembly. Further, seeds and seedlings most likely contribute significantly to earthworm nutrition potentially explaining the collection and concentration of seeds by *L. terrestris* in its middens and burrows; however, the present results call for experiments under more natural conditions.

1. Introduction

Post-dispersal seed predation is a key factor for demographic changes in plant communities and plant community assembly (Hulme, 1998), with its effect on seed survival exceeding that of pre-dispersal predation (Moles et al., 2003). It is increasingly recognized that the selective feeding of earthworms on seeds, which has been shown for *Lumbricus terrestris* L. to depend on seed size (Shumway and Koide, 1994; Smith et al., 2005; Eisenhauer et al., 2009a), shape (McRill and Sagar, 1973; Eisenhauer et al., 2009a) and surface structure (Shumway and Koide, 1994), is likely to impact plant community invasibility and assembly (Eisenhauer and Scheu, 2008; Eisenhauer et al., 2008a, 2009b). Anecic earthworms (earthworms that live in permanent vertical burrows primarily feeding on

(Willems and Huijsmans, 1994; Decaens et al., 2003; Milcu et al., 2006; Eisenhauer and Scheu, 2008; Eisenhauer et al., 2008b). Thereby, anecic earthworms have been shown to concentrate seeds in their burrows and incorporate them into deeper soil layers (Regnier et al., 2008) suggesting that earthworms feed on collected and buried seeds and germinating seedlings in their burrows (Eisenhauer and Scheu, 2008). However, interactions between earthworms and seeds are manifold and idiosyncratic. First, seeds might benefit from displacement and burial enhancing seed survival by reducing exposure of seeds to aboveground seed predators (Heithaus, 1981), whereas on the other hand seeds buried below some critical depth may fail to emerge (Traba et al., 1998). Second, while seed ingestion by earthworms have been shown to be detrimental for some plant species, others benefit from earthworm

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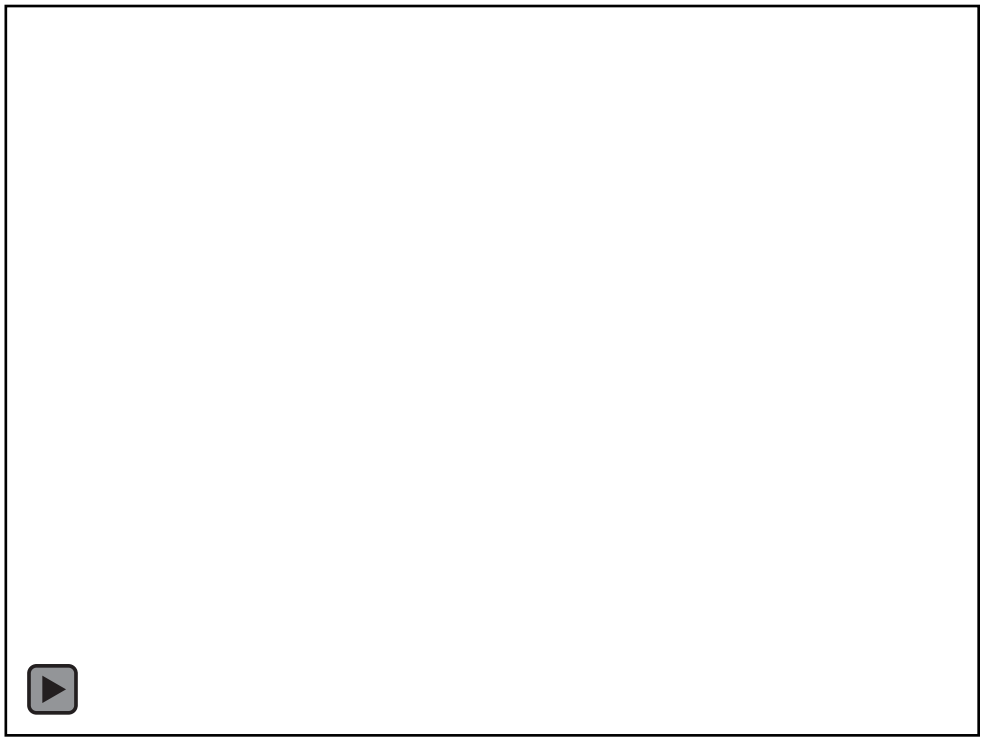
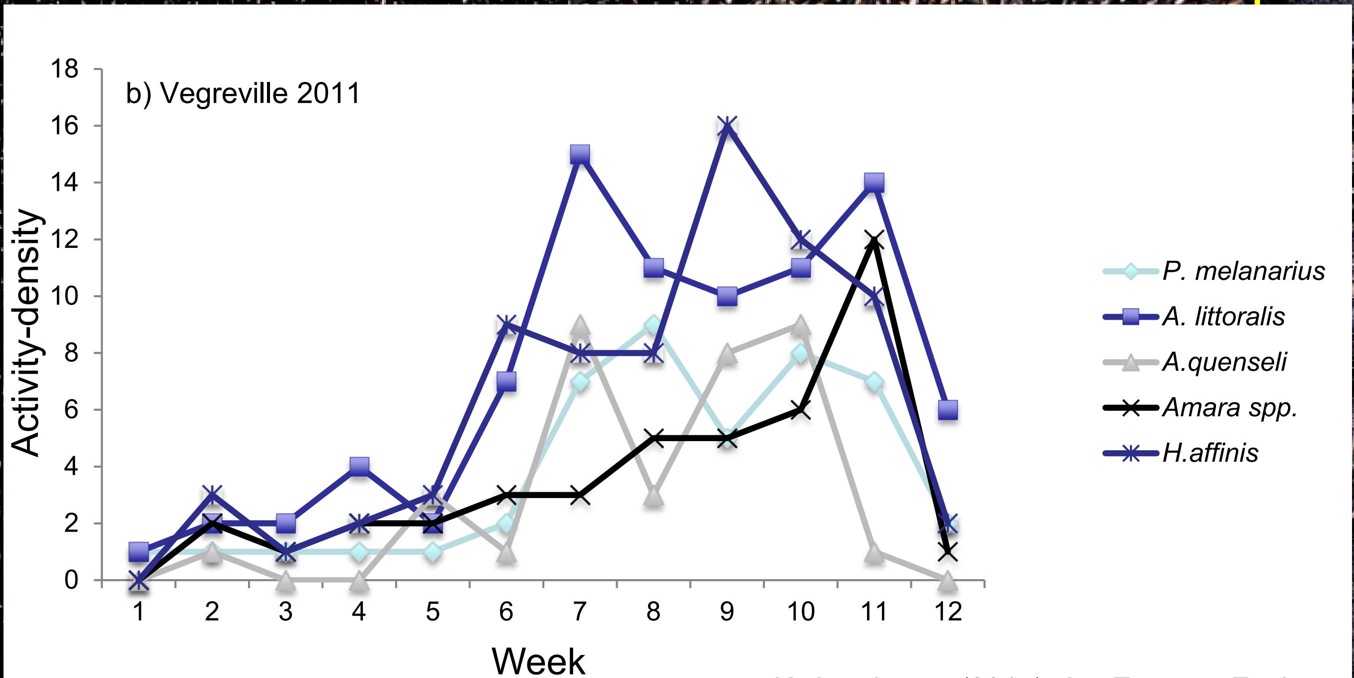
Earthworm seed collection



Kent Harrison, Ohio State

Outbreaks of Amara

Floate and Spence (2015)



Kulkarni et al. (2017). Ag. Ecosyst. Environ.

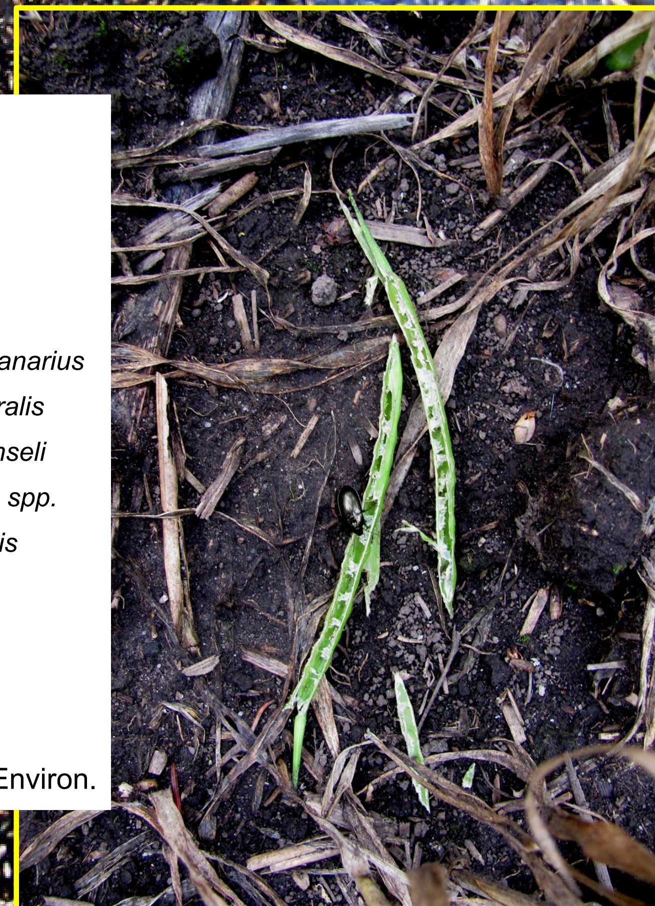
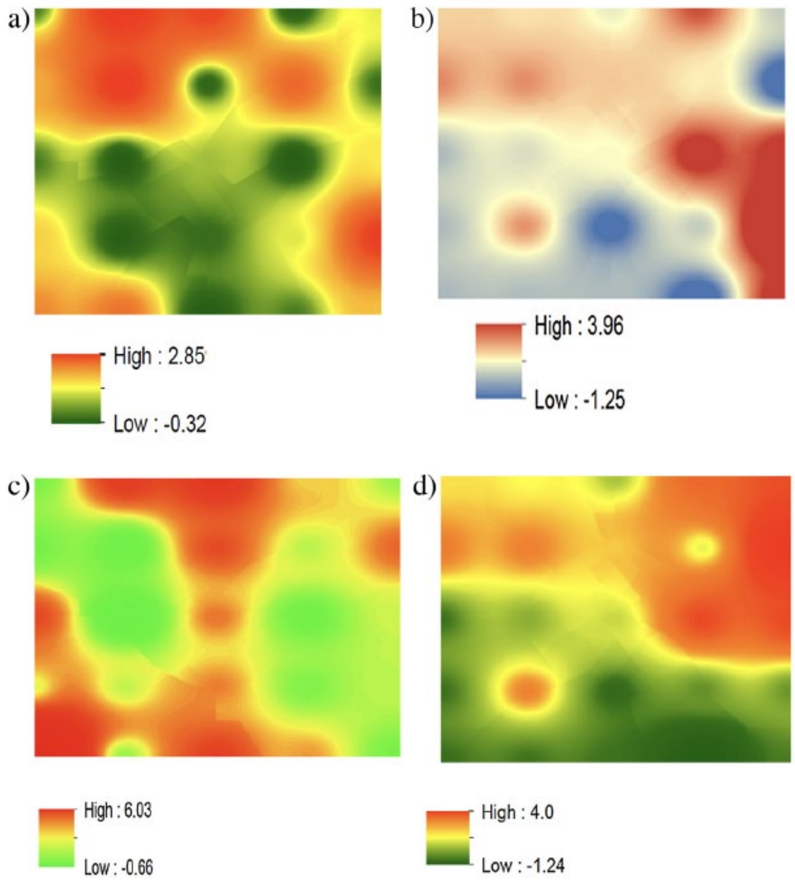


Photo Courtesy: B. Berry

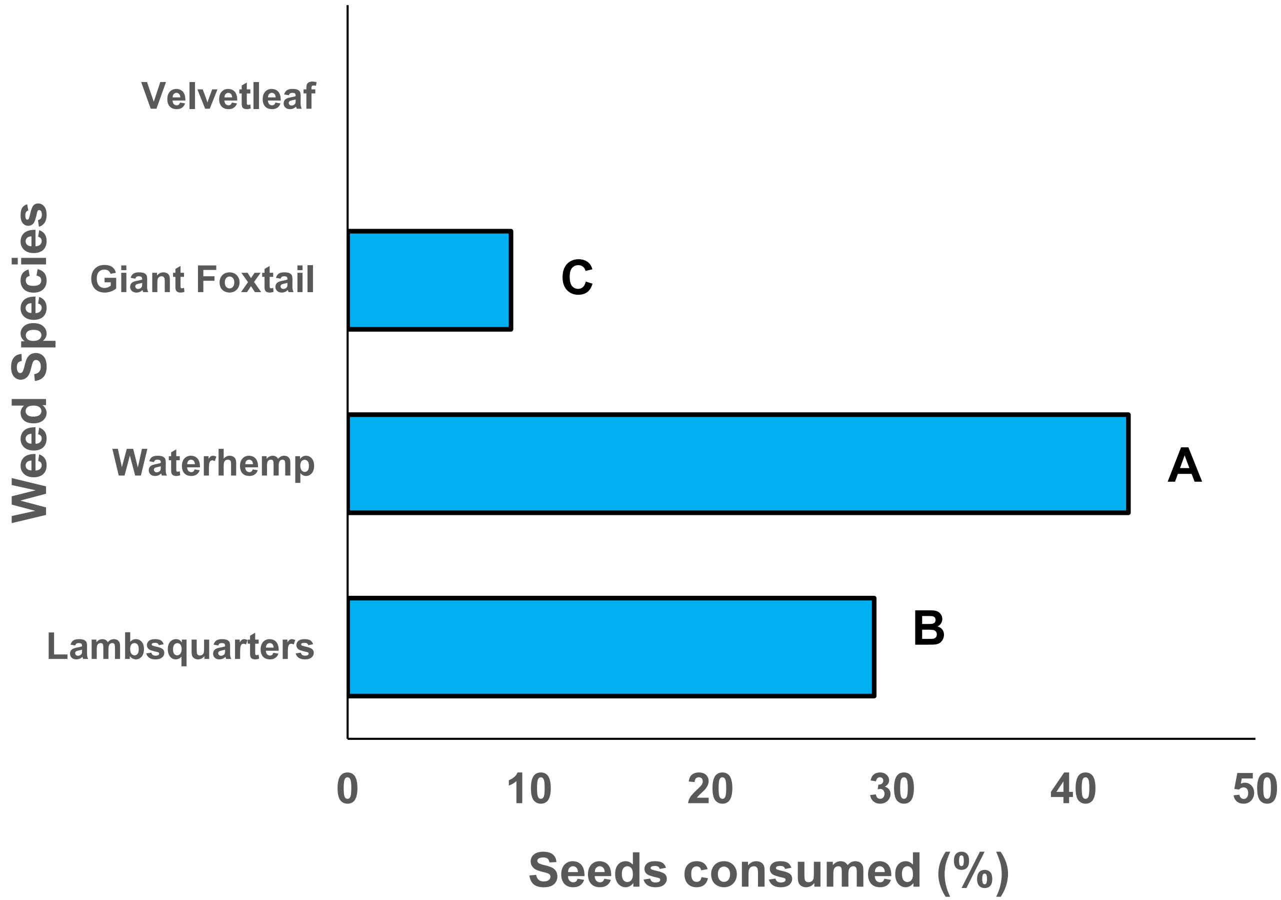
Seed Predators - carabids



Index of Association X_k Seedling density	Seed density
0.56*	0.30
0.41*	0.25
0.72*	0.23
0.70*	0.32
0.73*	0.42
0.71*	0.30
0.40*	0.27
0.45*	0.18

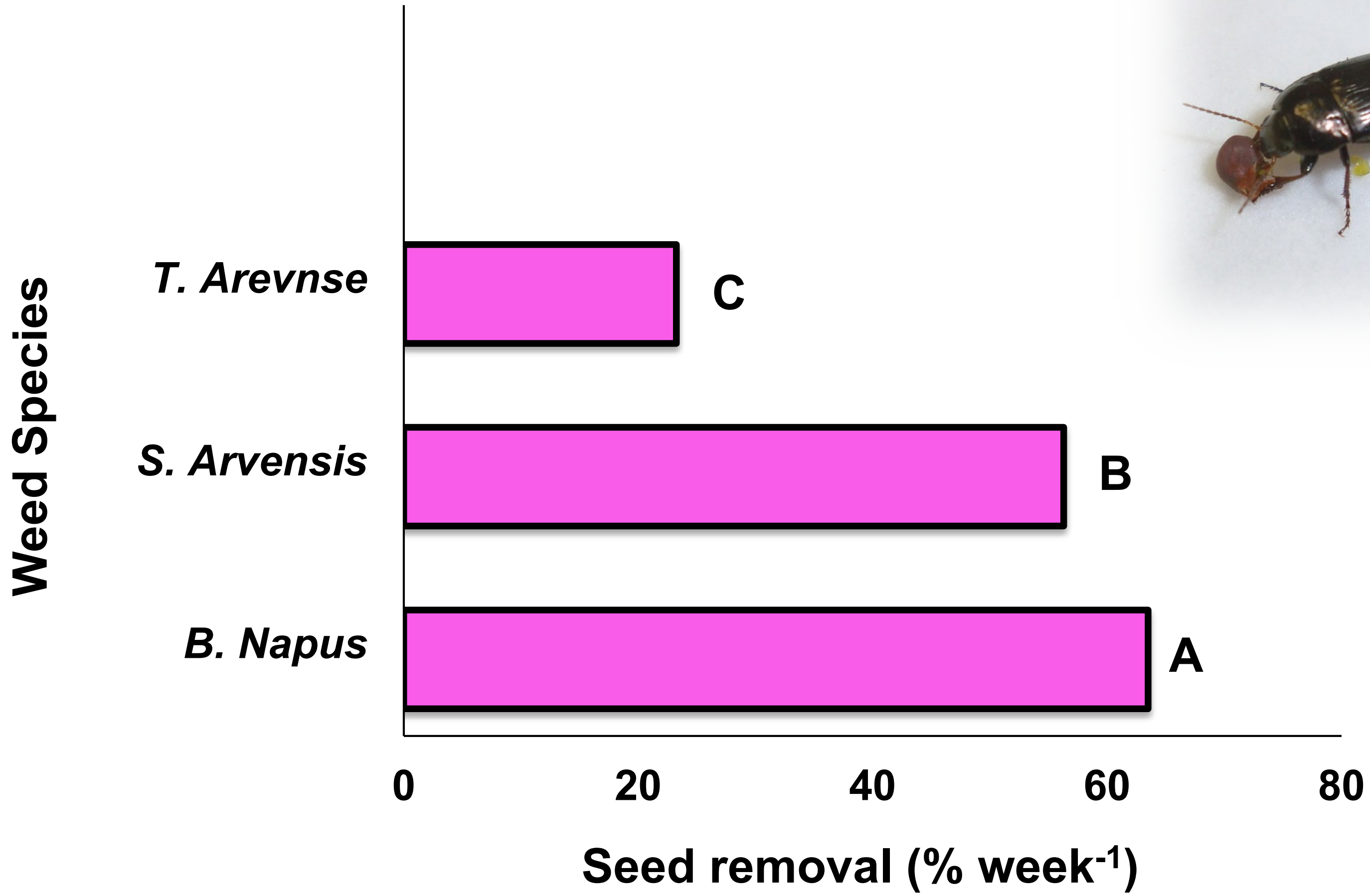
Kulkarni et al. (2017). Ag. Ecosyst. Environ.

Seed Preferences



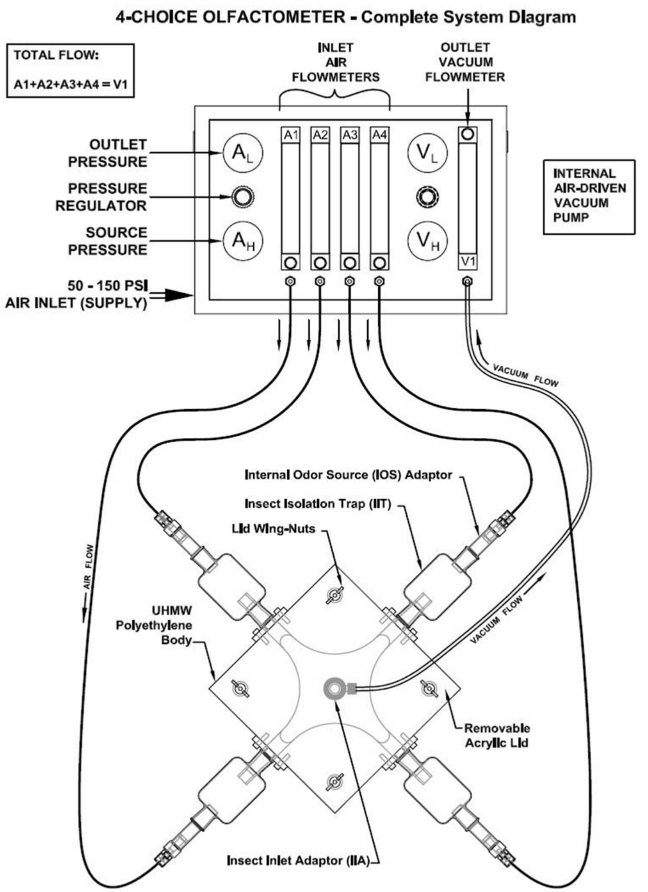
Van der Laat et al. (2015). Weed Science

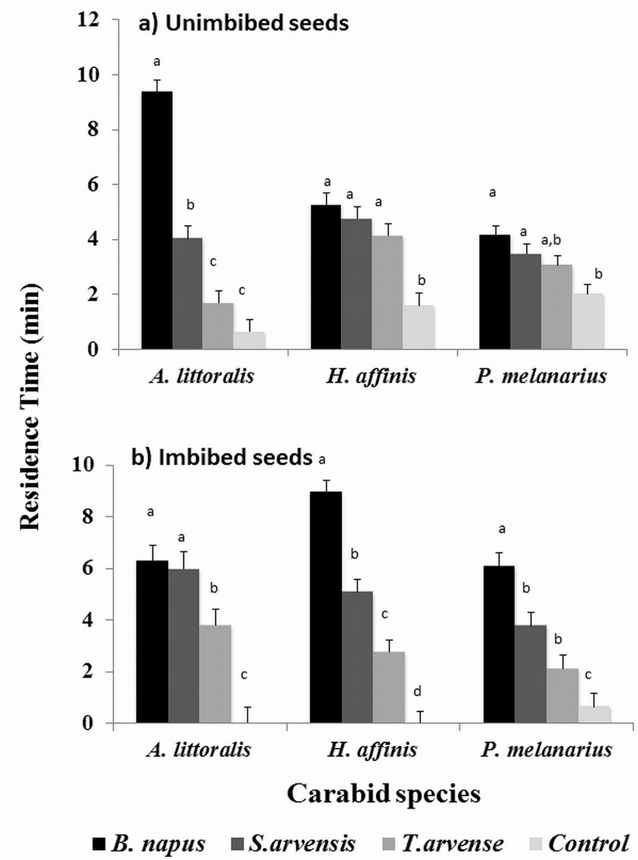
Seed Preferences



Kulkarni et al. (2016). Weed Science

Seed Preferences

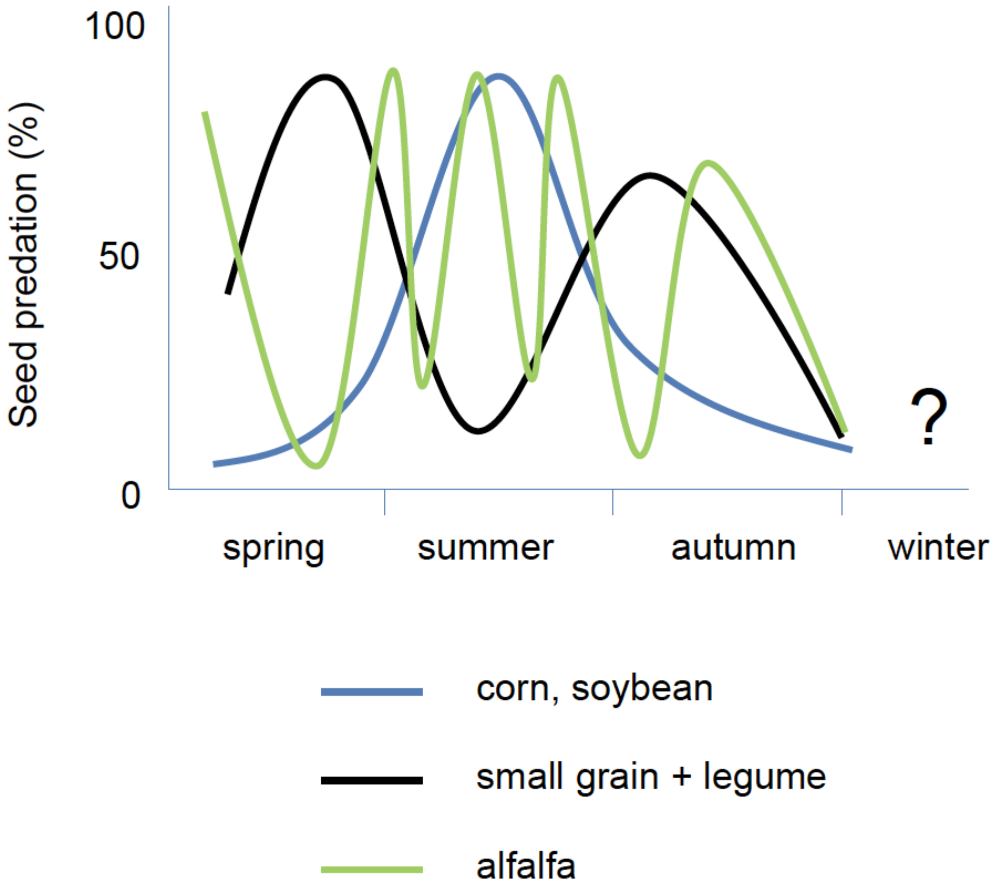




Strategies to Enhance Seed Predation

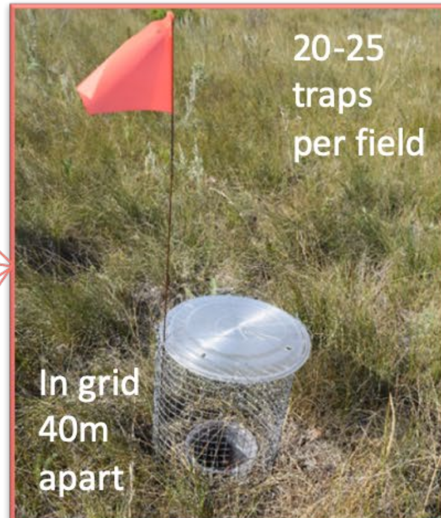
Encouraging Seed Predators

1. Diversified Crop Rotations

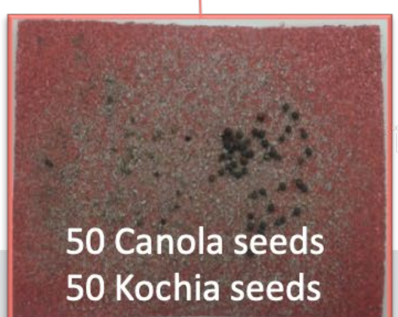


Heggenstaller et al. (2006). J. Appl. Ecol.

Seed Predators in pulse crops



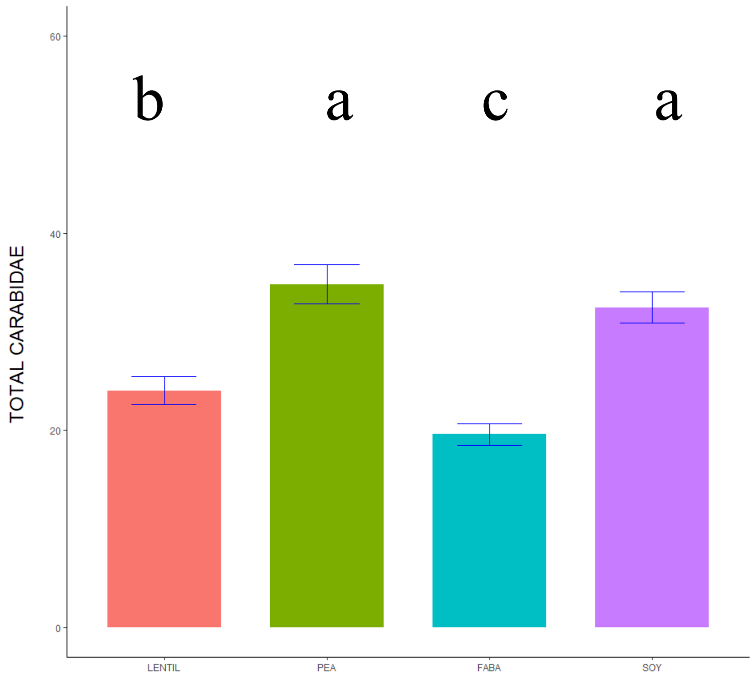
x15 weeks in 2017
x18 weeks in 2018

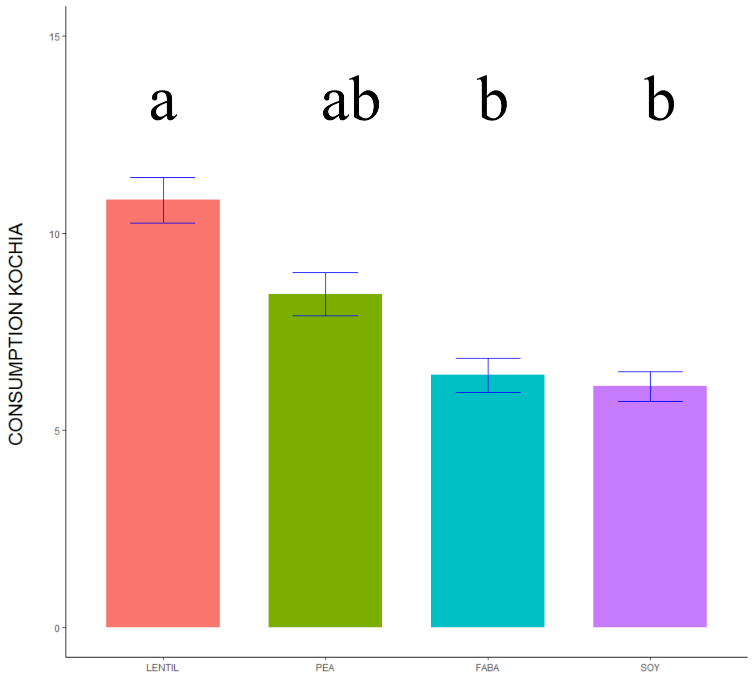


Insect group	Total catch
Silphidae	75127
Amara	33451
Pterostichus	24920
Caelifera	14497
Agonum	12663
Grillidae	7035
Poecilius	6922
Carabini	3624
Harpalus	2833
Elateridae	1672
Carabidae other	1224
Histeridae	1151
Scarabaeidae	1142
Conccinellidae	633
Raphidophoridae	247
Meloidae	81

De Heij and Willenborg, unpublished

Predation in Pulse Crops 2017





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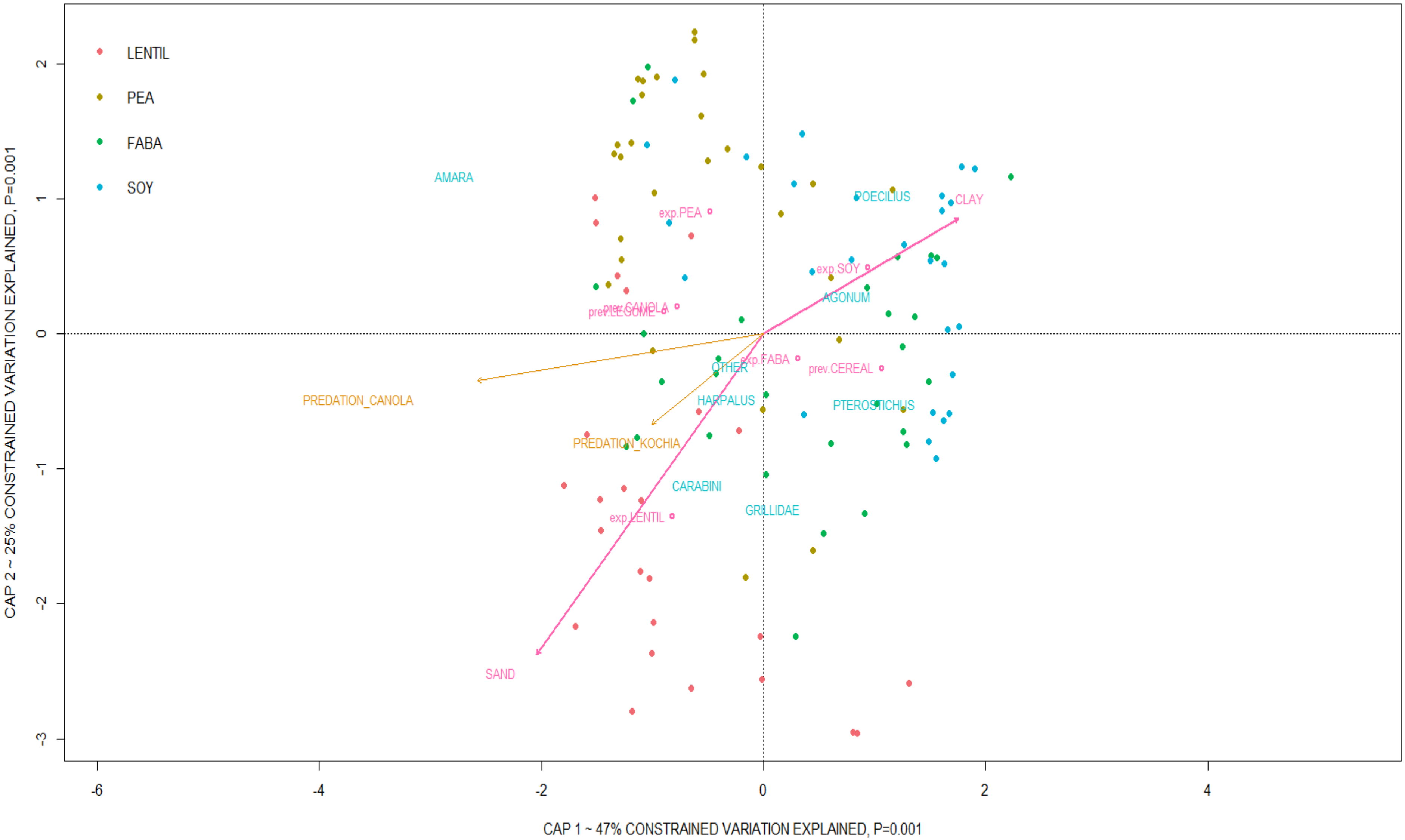
Relationship between factors



Encouraging Seed Predators

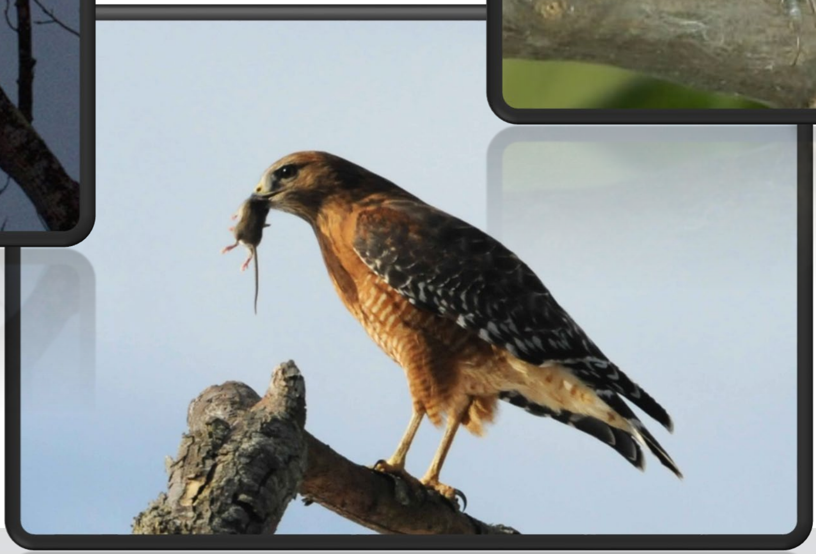
MacLeod et al. (2004). Agric Forest Entol.

Encouraging Seed Predators

3. Cover Crops

Legumes to fill niches in grain-based cropping system

Seed Predators are prey



Encouraging Seed Predators

4. Decrease Tillage

Seed predators require:

- -food
- -water
- -overwintering habitat
- -shelter from adversity

Encouraging Seed Predators

5. Canopy Closure

Row Spacing

Spatial Arrangement

Acknowledgements

SASKATCHEWAN pulse Growers

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ALBERTA Canola PRODUCERS COMMISSION