Seedbank Response to Integrated Crop Management Systems

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Abstract

Six integrated crop management systems varying primarily in terms of tillage and herbicide inputs were maintained for four years at two locations in the Moist Mixed Grassland ecoregion in Saskatchewan. The seedbank was sampled in each plot in the spring of 1997 prior to the initiation of the experiment and the spring of 2001 following the completion of the experiment to determine if cropping system had changed seedbank composition. Redundancy Analysis (RDA) was used to directly quantify the change in weed seedbank attributable to cropping system at each location. The RDA was constrained by cropping system for the 2001 data and year for the 1997 data. Initial spatial variation observed in the 1997 weed seedbank was removed from the analysis by using plot number and replicate block as binary covariables. The majority of species increased in the seedbank in all systems studied at both locations. The seedbank from the no herbicide high tillage systems was distinguishable from the other systems by large increases in lamb's-quarters and stinkweed at both locations. While similar species tended to increase in all the systems with herbicides, the systems with lower levels of herbicides applied had larger increases in the seedbank than those with high herbicide inputs.

Introduction

Weed seedbanks are expected to reflect effectiveness of past weed control. A comparison of the seedbank prior to the establishment of the integrated management systems with the seedbank four years later enables an evaluation of the ability of the management systems to prevent weed seeds from maturing. The seeds represent the potential for the establishment of future weed communities under ideal conditions. Species that are allowed to build up in the seedbank may threaten the future sustainability of the systems. This paper seeks to determine the effect of various integrated crop management systems on weed seedbank composition.

Methods

Six integrated crop management systems were established in 1997 varying primarily in terms of tillage and herbicide levels: High Herbicide/Zero Tillage, Medium Herbicide/Zero Tillage, Low Herbicide/Zero Tillage, Low Herbicide/Low Tillage, Medium Herbicide/Medium Tillage and No Herbicide/High Tillage (Thomas et al 2002). Each system completed a four-year crop rotation of wheat-canola-barley-pea. Each crop was present in each year from 1997 to 2000. There were four replicates at Saskatoon (Kernen Crop Research Farm, University of Saskatchewan) and Watrous (Agricultural Research and Development Farm, Saskatchewan Wheat Pool).

In the spring of 1997 and 2001, twenty soil cores (11 cm deep, 4.5 cm diameter) were taken in each of the 96 plots at each site. Five samples were placed randomly within each quarter of the plot.

The seeds in each soil core were grown out in the greenhouse. The soil cores were covered with vermiculite to reduce water loss and watered daily. Weed seedlings were identified, tallied and removed weekly. When germination ceased (approximately four weeks), the samples were frozen (-15^{o}C) for at least two weeks to break dormancy of any remaining seed and then allowed to grow out in the greenhouse a second time.

Multivariate analyses were performed on the data from each site using the program CANOCO (ter Braak and Šmilauer 1998). All weed data were transformed by log abundance (log x+1) prior to analysis to reduce the influence of plots with species found in relatively high densities. Only species that occurred more than once were included in the analyses (Table 1).

Table 1. Species Identified at Each Site in the Seedbank. Species marked with a “p” were present in the analyses, while those marked with a “r” were rare and excluded from the analyses. Common and scientific names are from Darbyshire et al. 2000.

Common Name	Scientific Name	Kernen	Watrous
American stinging nettle	*Urtica dioica* L. subsp. *gracilis* (Aiton) Selander	r	p
Balsam poplar	*Populus balsamifera* L. subsp *balsamifera*		p
Barnyard grass	*Echinochloa crusgalli* (L.) P. Beauv.	p	p
Biennial wormwood	*Artemisia biennis* Willd.		p
Canada fleabane	*Conyza canadensis* (L.) Cronquist	p	
Canada thistle	*Cirsium arvense* (L.) Scop.	p	p
Cattail	*Typha latifolia* L.	p	r
Cleavers	*Galium aparine* L.	p	
Common groundsel	*Senecio vulgaris* L.	p	p
Common pepper-grass	*Lepidium densiflorum* Schrad.	p	p
Cow cockle	*Vaccaria hispanica* (Mill.) Rauschert	r	
Dandelion	*Taraxacum officinale* G. H. Weber ex Wiggers	p	p
Flixweed	*Descurainia sophia* (L.) Webb ex Prantl	p	p
Foxtail barley	*Hordeum jubatum* L.	p	p
Green foxtail	*Setaria viridis* (L.) P. Beauv.	p	p
Kochia	*Kochia scoparia* (L.) Schrad.	p	p
Lamb's-quarters	*Chenopodium album* L.	p	p
Narrow-leaved hawk's-beard	*Crepis tectorum* L.	p	p
Night-flowering catchfly	*Silene noctiflora* L.		p
Perennial sow-thistle	*Sonchus arvensis* L.	p	r
Prostrate knotweed	*Polygonum aviculare* L.	p	p
Prostrate pigweed	*Amaranthus blitoides* S. Watson	p*	p*
Purslane speedwell	*Veronica peregrina* L.		p
Pygmyflower	*Androsace septentrionalis* L.		r
Quack grass	*Elytrigia repens* (L.) Desv. ex B. D. Jacks	r	
Rayless aster	*Brachyactis ciliata* (Ledeb.) Ledeb. subsp. *angusta* (Lindl.) A.G. Jones		r
Redroot pigweed	*Amaranthus retroflexus* L.	p*	p*

(Table continued on next page)

Table 1. Species Identified at Each Site in the Seedbank. Species marked with a "p" were present in the analyses, while those marked with a "r" were rare and excluded from the analyses. Common and scientific names are from Darbyshire et al. 2000 *(continued)*.

Common Name	Scientific Name	Kernen	Watrous
Rough cinquefoil	*Potentilla norvegica* L.	p	p
Round-leaved mallow	*Malva pusilla* Sm.	r	
Russian thistle	*Salsola kali* L. subsp. *ruthenica* (Iljin) Soo	p	p
Shepherd's-purse	*Capsella bursa-pastoris* (L.) Medik.	p	p
Spear-leaved goosefoot	*Monolepis nuttalliana* (Schult.) Greene	p	
Spiny annual sow-thistle	*Sonchus asper* (L.) Hill	p	p
Sticky willowherb	*Epilobium ciliatum* Raf.	p	r
Stinkweed	*Thlaspi arvense* L.	p	p
Thyme-leaved spurge	*Euphorbia serpyllifolia* Pers.		p
Tumble pigweed	*Amaranthus albus* L.	p*	p*
Volunteer alfalfa	*Medicago sativa* L.	r	
Volunteer barley	*Hordeum vulgare* L.	r	r
Volunteer canola	*Brassica napus* L. and *B. rapa* L.	p**	p**
Volunteer flax	*Linum usitatissimum* L.	r	
Volunteer wheat	*Triticum aestivum* L.	p	p
Wild buckwheat	*Polygonum convolvulus* L.	p	p
Wild mustard	*Sinapis arvensis* L.	p**	p**
Wild oats	*Avena fatua* L.	p	p
Wild tomato	*Solanum triflorum* Nutt.		p
Wood whitlow-grass	*Draba nemorosa* L.	p	p
Yellow evening-primrose	*Oenothera biennis* L.		r
Yellow lavauxia	*Oenothera flava* (A. Nelson) Garrett	r	
Yellow sweet-clover	*Melilotus officinalis* (L.) Pall.	p	

*Prostrate, redroot and tumble pigweed were not distinguished in 1997 seedbank counts; therefore, these species were combined for analyses of seedbank data as pigweed species
**Wild mustard and volunteer canola were not distinguished in 1997 seedbank counts; therefore, these species were combined for analyses of seedbank data as Brassica species

Detrended Correspondence Analysis (DCA) of each data set resulted in a gradient length less than four standard deviations, indicating a linear response of species to environmental gradients (ter Braak and Šmilauer 1998). Therefore, subsequent analyses were based on redundancy analysis (RDA), a constrained form of principal components analysis (ter Braak 1995). To directly quantify the change in weed seedbank from the baseline 1997 to 2001 attributable to cropping system, weed species densities were constrained by cropping system for the 2001 data and year for the 1997 data. Initial spatial variation observed in the 1997 weed seedbank was removed from the analysis by using plot number and rep as binary covariables. In order to create a traditional RDA based on a covariance matrix, the species were centred and the samples were neither centred nor standardized. The environmental variables are nominal; therefore, the ordinations were scaled to emphasize inter-sample relationships enabling the interpretation of distances between groups. Species scores were not transformed after the analysis was complete leaving the scores proportional to the standard deviation of the species.

Reduced model Monte Carlo permutation tests were carried out to determine whether the RDA axes explained more variance than expected by chance. For each Monte Carlo test, the treatments were randomly assigned to the weed data for each plot 1000 times and the analysis was rerun each time to determine the probability of a random version of the data explaining more variance than the original data. In all analyses, permutations were restricted to amongst subplots to reflect the experimental structure.

The ordination of the seedbank data can be interpreted using biplot rules (ter Braak 1994). The magnitude of change in seedbank composition from the start to end of the study in each cropping system is proportional to the distance between the centroid for 1997 and centroids for each system in 2001. Systems that are closer together were associated with similar changes in the seedbank; whereas, systems that are further apart were associated different changes in the seedbank. The length of the species vector is proportional to the change in species density. The relative change in species density in any system may be determined by perpendicularly projecting the system centroid to the species vector.

Results and Discussion

At Saskatoon, all species with exception of volunteer wheat increased in the seedbank from 1997 to 2001 in all systems (Fig. 1, Table 2). The entire area was cropped to wheat the year before the initiation of the experiment, whereas only a quarter of the area was cropped to wheat in the next four years. The higher species densities in 2001 in all systems may be partially attributable to favourable timing of precipitation in 2000, facilitating weed seed production. The smallest change in the seedbank was associated with the high and medium herbicide systems, while the largest change in seedbank was associated with the no herbicide high tillage system. The high herbicide no tillage system was associated with a unique weed community comprised of the highest populations of pigweed species, *Brassica* species, Canada thistle, lamb's-quarters and stinkweed and the lowest populations of flixweed, dandelion and kochia. The other systems were more similar to each other than to the no herbicide high tillage system. However, the low herbicide reduced tillage systems tended to have higher weed populations than systems with higher amounts of herbicides.

The trends observed at Watrous were similar to those at Saskatoon, although some of the species involved in the differentiation of systems varied between sites (Fig. 2, Table 3). The no herbicide zero-tillage system was distinguished from the other systems by having the highest levels of lamb's-quarters, stinkweed, wild buckwheat, green foxtail, Russian thistle and pigweed species and the lowest levels of *Brassica* species. The association of the Brassica species with different systems at Saskatoon and Watrous reflects a difference in the relative amounts of wild mustard and volunteer canola at the two sites. In 2001, 53% and 10% of the group was wild mustard at Saskatoon and Watrous, respectively. This suggests that, while closely related, these two species react quite differently to the cropping systems studied. At Watrous, the separation between the management systems with herbicides applied was less than Kernen, however, the ordination indicates that the low herbicide zero-tillage system generally has highest weed densities. This trend may be partially attributable to the high density of narrow-leaved hawk's-beard. As seen at Kernen, narrow-leaved hawk's-beard densities decreased with either high herbicide or tillage levels.

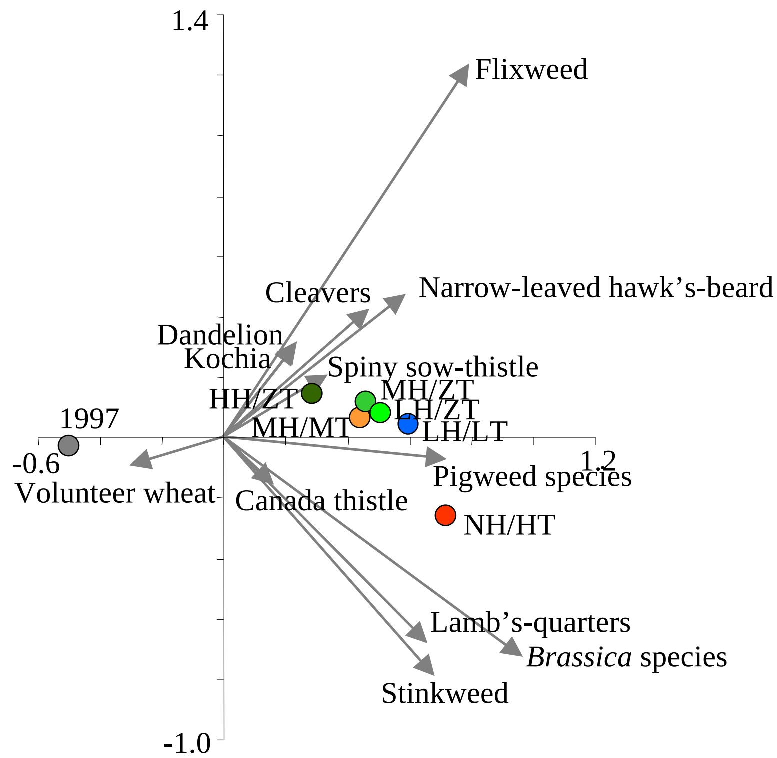

Figure 1. RDA ordination of changes in weed seedbank at Kernen constrained by cropping system using year, crop, replicate block and plot as covariables. Weed species with the greatest amount of explained variance on the first two axes are displayed. Axis one and two account for 84.6% and 7.1% of the explained variance in the species data, respectively ($P \leq 0.001$).

Table 2. Seedbank (per metre square) of Weed Species Identified as Changing over Time by the RDA of Kernen.

	1997	2001					
Species	ALL	HH/ZT	MH/ZT	LH/ZT	LH/LT	MH/MT	NH/HT
Volunteer wheat	40	6	8	14	6	4	4
Flixweed	5	151	256	204	340	116	85
Dandelion	4	26	26	41	22	28	18
Kochia	1	37	26	26	39	39	18
Cleavers	<0.1	43	65	59	155	57	47
Narrow-leaved hawk's-beard	5	77	102	472	411	151	100
Spiny annual sow-thistle	2	31	20	47	53	29	53
Pigweed species	536	885	1060	1673	2463	1526	2697
Brassica species	47	401	466	493	399	554	2713
Canada thistle	<0.1	6	4	12	22	14	35
Lamb's-quarters	51	88	120	226	301	90	576
Stinkweed	374	509	594	1349	1769	523	4569
All species	1346	2632	3299	5153	6493	3468	11371

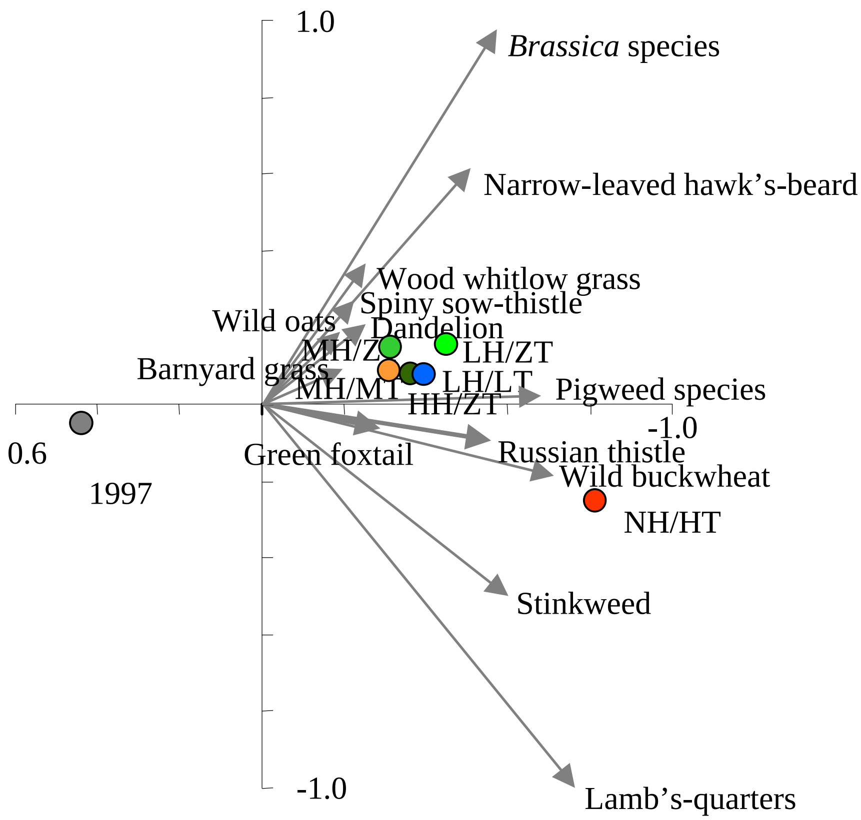

Figure 2. RDA ordination of changes in weed seedbank at Watrous constrained by cropping system using year, crop, replicate block and plot as covariables. Weed species with the greatest amount of explained variance on the first two axes are displayed. Axis one and two account for 87.5% and 8.6% of the explained variance in the species data, respectively ($P \leq 0.001$).

Table 3. Seedbank (per metre square) of Weed Species Identified as Changing over Time by the RDA of Watrous.

	1997	2001					
Species	ALL	HH/ZT	MH/ZT	LH/ZT	LH/LT	MH/MT	NH/HT
Brassica species	5	358	259	356	185	142	77
Wood whitlow-grass	<0.1	20	31	31	53	28	33
Narrow-leaved hawk's-beard	1	85	149	372	55	31	98
Spiny annual sow-thistle	<0.1	45	18	24	14	28	24
Wild oats	1	18	83	51	10	20	26
Dandelion	<0.1	33	16	20	26	45	35
Barnyard grass	<0.1	8	35	18	18	108	75
Pigweed species	229	478	499	729	543	521	3238
Russian thistle	5	37	18	33	33	22	144
Green foxtail	17	86	75	155	240	499	560
Wild buckwheat	9	86	92	106	136	185	1467
Stinkweed	532	1018	812	1107	1451	535	5426
Lamb's-quarters	35	126	67	128	214	116	2076
All species	869	2475	2845	3739	3157	2387	13476

Summary

Better weed management is necessary in systems relying entirely on tillage for annual weeds including lamb's-quarters, stinkweed, pigweed species, wild mustard, wild buckwheat, Russian thistle and green foxtail. Reduction of tillage may lead to increased seedbanks of flixweed, dandelion, kochia, cleavers, narrow-leaved hawk's-beard, spiny sow-thistle and wood whitlow grass, particularly if herbicides are also reduced. These results concur with trends observed in weed counts conducted throughout the study (Leeson et al 2002).

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