Seasonal Weed Response to Integrated Crop Management Systems

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Abstract

Weed plant density was monitored to determine the effect of various integrated crop management systems on weed population levels and evaluate the efficacy of the various management practices. The management systems studied primarily varied tillage and herbicide inputs. Weed plant density was determined in spring, prior to in-crop management and after in-crop management in each year of the study. Also, weeds were counted after in-crop management prior to the establishment of the management systems. Multivariate analyses were used to determine the response of the weed communities to the management systems. Principal response curves were used to illustrate seasonal fluctuations and trends in weed densities. Stinkweed, lamb's-quarters, wild buckwheat, redroot pigweed, wild mustard and Russian thistle are best controlled with in-crop herbicide applications. These species increased over time in the no herbicide high tillage system and low herbicide systems. Winter annuals, perennials and early spring annuals were found to increase in the lower herbicide zero-tillage systems. These species tended to be found in high densities in the spring and not effectively controlled in-crop.

Introduction

Tillage, herbicide use and crop competition are major factors determining weed community composition. Reduction of tillage and herbicide use may reduce the impact of agriculture on the environment; however, weed control in systems with lower levels of either tillage or herbicides is a limiting factor. The management systems included in this study enable the examination of the impact of reducing tillage and herbicides on weed communities. Seeding rate and seeding date are manipulated to enhance weed control in systems with lower inputs. This paper seeks to determine the effect of various integrated crop management systems on weed population levels and evaluate the efficacy of the various management practices.

Methods

Six integrated crop management systems were established in the fall of 1996 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).

Weeds were counted prior to spring treatments, prior to in-crop weed management and after in-crop weed management (residual counts) from 1998 to 2000. In 1997, weeds were only counted before and after in-crop management. In 1996, weeds were counted after in-crop management. This year was the site characterization year in which both sites were seeded to wheat and treated uniformly. At each assessment time, the weeds were identified and counted in twenty 0.5 m by 0.5 m quadrats in each of the 96 plots at each site. Five quadrats were placed randomly within each quarter of the plot.

Multivariate analyses were performed using the program CANOCO (ter Braak and Šmilauer 1998). Separate analyses were conducted for each site. All weed data were transformed by log density (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). 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, all subsequent analyses are based on redundancy analysis (RDA), a constrained form of principal components analysis (ter Braak 1995). In the RDA, weed species densities are constrained to be linear combinations of the interaction of cropping system and assessment date. Variation due to assessment date (year and time of count) is removed as a covariable. In order to create a traditional RDA based on a covariance matrix, the species were centred and the samples were neither centred nor standardized. In each analysis 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.

Table 1. Weed Species Included in Analyses of Each Site. Names from Darbyshire et al. 2000.

Common Name	Scientific Name	Kernen	Watrous
Absinth	*Artemisia absinthium* L.		x
Alsike clover	*Trifolium hybridum* L.	x	
American dragonhead	*Dracocephalum parviflorum* Nutt.		x
American vetch	*Vicia americana* Muhl. Ex. Willd.	x	x
Barnyard grass	*Echinochloa crusgalli* (L.) P. Beauv.		x
Bicknell's geranium	*Geranium bicknellii* Britton		x
Biennial wormwood	*Artemisia biennis* Willd.	x	x
Blue grass species	*Poa* spp.		x
Bluebur	*Lappula squarrosa* (Retz.) Dumort.	x	x
Borage	*Borago officinalis* L.	x	
Canada fleabane	*Conyza canadensis* (L.) Cronquist	x	x
Canada thistle	*Cirsium arvense* (L.) Scop.	x	x
Cleavers	*Galium aparine* L.	x	x
Common pepper-grass	*Lepidium densiflorum* Schrad.		x
Corn spurry	*Spergula arvensis* L.		x
Cow cockle	*Vaccaria hispanica* (Mill.) Rauschert	x	x
Dandelion	*Taraxacum officinale* G. H. Weber ex Wiggers	x	x
Flixweed	*Descurainia sophia* (L.) Webb ex Prantl	x	x

(Table continued on next page)

Table 1. Weed Species Included in Analyses of Each Site. Names from Darbyshire et al. 2000 *(continued)*.

Common Name	Scientific Name	Kernen	Watrous
Foxtail barley	*Hordeum jubatum* L.	x	x
Goat's-beard	*Tragopogon dubius* Scop.	x	
Green foxtail	*Setaria viridis* (L.) P. Beauv.	x	x
Hemp-nettle	*Galeopsis tetrahit* L.		x
Kochia	*Kochia scoparia* (L.) Schrad.	x	x
Lamb's-quarters	*Chenopodium album* L.	x	x
Narrow-leaved hawk's-beard	*Crepis tectorum* L.	x	x
Night-flowering catchfly	*Silene noctiflora* L.	x	x
Perennial sow-thistle	*Sonchus arvensis* L.	x	x
Prickly lettuce	*Lactuca serriola* L.	x	x
Prostrate knotweed	*Polygonum aviculare* L.	x	x
Prostrate pigweed	*Amaranthus blitoides* S. Watson	x	x
Purslane	*Portulaca oleracea* L.	x	
Pygmyflower	*Androsace septentrionalis* L.	x	x
Quack grass	*Elytrigia repens* (L.) Desv. ex B. D. Jacks	x	x
Redroot pigweed	*Amaranthus retroflexus* L.	x	x
Rose species	*Rosa* spp.	x	
Rough cinquefoil	*Potentilla norvegica* L.		x
Round-leaved mallow	*Malva pusilla* Sm.	x	
Russian thistle	*Salsola kali* L. subsp. *ruthenica* (Iljin) Soo	x	x
Shepherd's-purse	*Capsella bursa-pastoris* (L.) Medik.	x	x
Spear-leaved goosefoot	*Monolepis nuttalliana* (Schult.) Greene	x	
Spiny annual sow-thistle	*Sonchus asper* (L.) Hill	x	x
Stinkweed	*Thlaspi arvense* L.	x	x
Sunflower	*Helianthus annuus* L.	x	
Thyme-leaved spurge	*Euphorbia serpyllifolia* Pers.		x
Tumble pigweed	*Amaranthus albus* L.	x	x
Unknown grass species			x
Unknown weed species		x	x
Vetch species	*Vicia* spp.		x
Volunteer alfalfa	*Medicago sativa* L.	x	x
Volunteer barley	*Hordeum vulgare* L.	x	x
Volunteer canola	*Brassica napus* L. and *B. rapa* L.	x	x
Volunteer caraway	*Carum carvi* L.	x	
Volunteer fall rye	*Secale cereale* L.		x
Volunteer flax	*Linum usitatissimum* L.	x	x
Volunteer peas	*Pisum arvense* L.	x	x
Volunteer wheat	*Triticum aestivum* L.	x	x
White sweet-clover	*Melilotus albus* Medik.	x	
Wild buckwheat	*Polygonum convolvulus* L.	x	x
Wild mustard	*Sinapis arvensis* L.	x	x
Wild oats	*Avena fatua* L.	x	x
Wild tomato	*Solanum triflorum* Nutt.		x
Wood whitlow-grass	*Draba nemorosa* L.		x
Wormseed mustard	*Erysimum cheiranthoides* L.	x	x
Yellow sweet-clover	*Melilotus officinalis* (L.) Pall.	x	x

Weed assessments in systems that are closer together on the ordination have similar weed community composition; whereas, assessments in systems that are further apart were associated with different weed communities. Species vectors point toward assessment dates in systems that have the highest densities of those species. The length of the species vector is proportional to the variation in species density. The change in the weed community over time is illustrated by connecting the centroids for each system.

The direction of change of the weed communities in each of the six systems is compared using principal response curves (Van den Brink and ter Braak 1997). This variation on traditional RDA allows a clearer representation of change due to cropping system over time. The analysis is conducted in a similar manner to the previous RDA; however, the interactions between assessment date and the medium herbicide medium tillage system are not included as constraints in the analysis, allowing this system to be used as a reference point. Therefore, change in weed communities in each system is compared against the change observed in the medium herbicide medium tillage system.

A principal response curve is a graph of canonical coefficients for one axis of the RDA versus time. The canonical coefficients are a measure of the deviation of the weed community from the reference system. The species scores, presented to the right of the principal response curve, enable the reader to determine the relative influence of each species on the principal response curve. Species with the highest absolute values have the largest influence on the trends illustrated in the principal response curve. Species with absolute values less than one are not included on the diagrams in this paper. The log-difference between the weed densities in the control and each system in each year can be determined for each species by multiplying the species score by the desired canonical coefficient.

Reduced model Monte Carlo permutation tests were carried out to determine whether the 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. Permutations were restricted to amongst subplots to reflect the experimental structure.

Results and Discussion

The weed communities at Watrous and Kernen differed before the establishment of the study. Residual weed densities were much higher at the initiation of the experiment at Kernen than at Watrous (Fig. 1). Kernen was dominated by wild buckwheat and redroot pigweed, while stinkweed was the major weed at Watrous. Only three species, redroot pigweed, wild buckwheat and dandelion, were found in the top ten species at both sites.

The RDA of Kernen indicates that the weed community in the no herbicide high tillage system tended to have more summer annuals (wild buckwheat, wild mustard, stinkweed, lamb's-quarters and redroot pigweed) than the systems with herbicide applied (Fig. 2). The systems with reduced tillage and low herbicides were associated with higher densities of perennials (Canada thistle, quack grass and dandelion), winter annuals (flixweed and narrow-leaved hawk's-beard) and some annuals (cleavers and kochia). The change in weed communities over time as illustrated on the ordination is not intuitively clear, indicating the need for a better method of displaying this data.

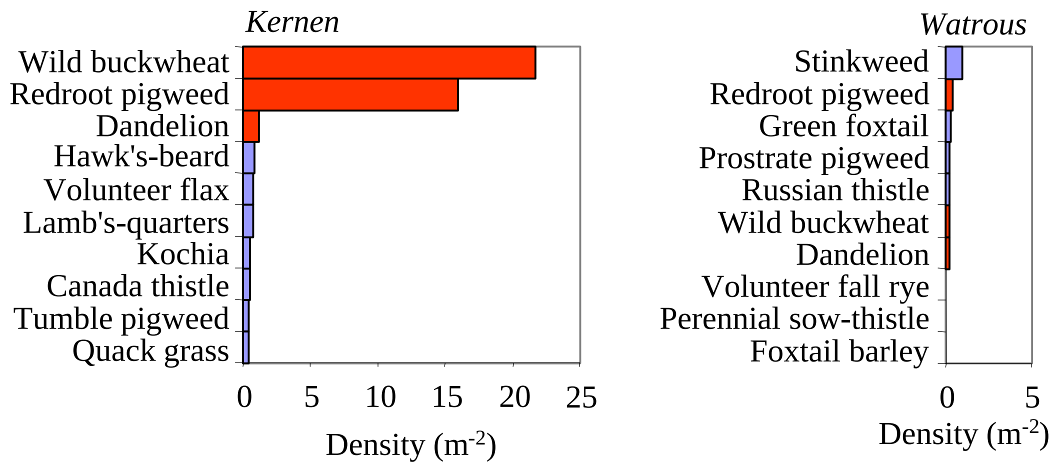

Figure 1. Residual weed densities at Kernen and Watrous in 1996 prior to the establishment of the management systems.

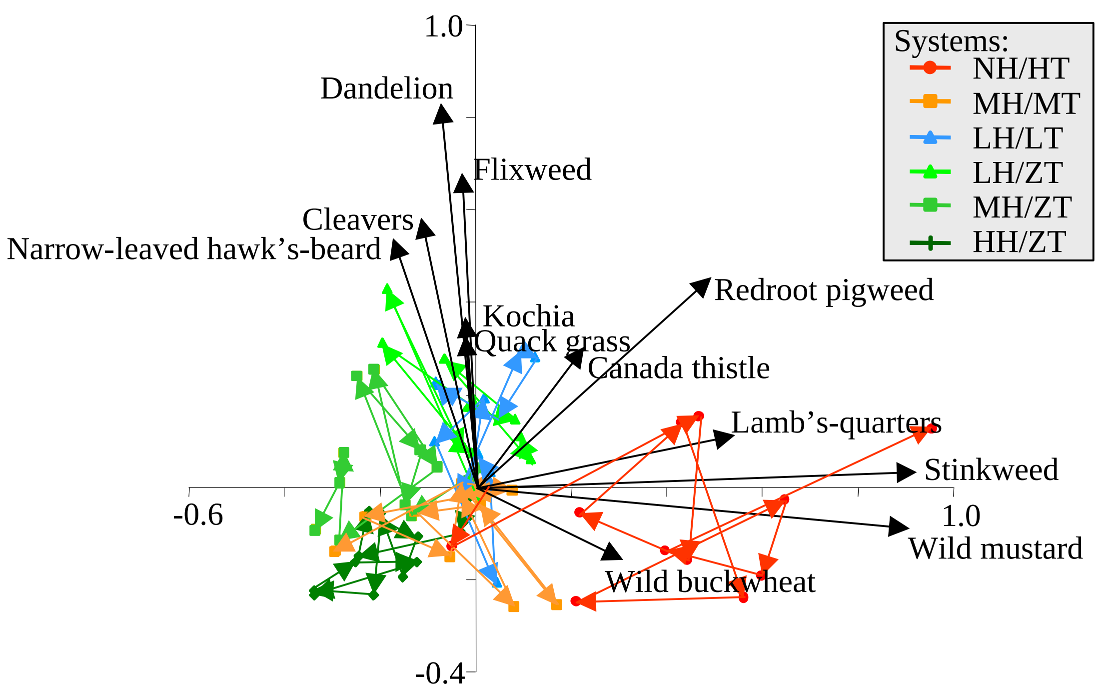

Figure 2. RDA ordination of Kernen species constrained by cropping system at each assessment date. Species with the greatest amount of explained variance on the first two axes are displayed. System counts are joined by arrows to indicate change through time. Axis one and two account for 48% and 20% of the explained variance in the species data, respectively ($P \leq 0.001$).

The RDA of the Watrous data showed very similar trends as observed at Kernen (Fig. 3). Four of the five species associated with the no herbicide high tillage system were the same at both sites. Russian thistle, a summer annual, was associated with this system as Watorus, but not at Kernen. The low herbicide zero-tillage system was associated with species following perennial (dandelion and foxtail barley) and winter annual (narrow-leaved hawk's-beard and shepherd's-purse) life cycles as observed at Kernen. Interpretation of the change in weed communities through time on the ordination of the Watrous data is not intuitively clear, as seen with the Kernen ordination.

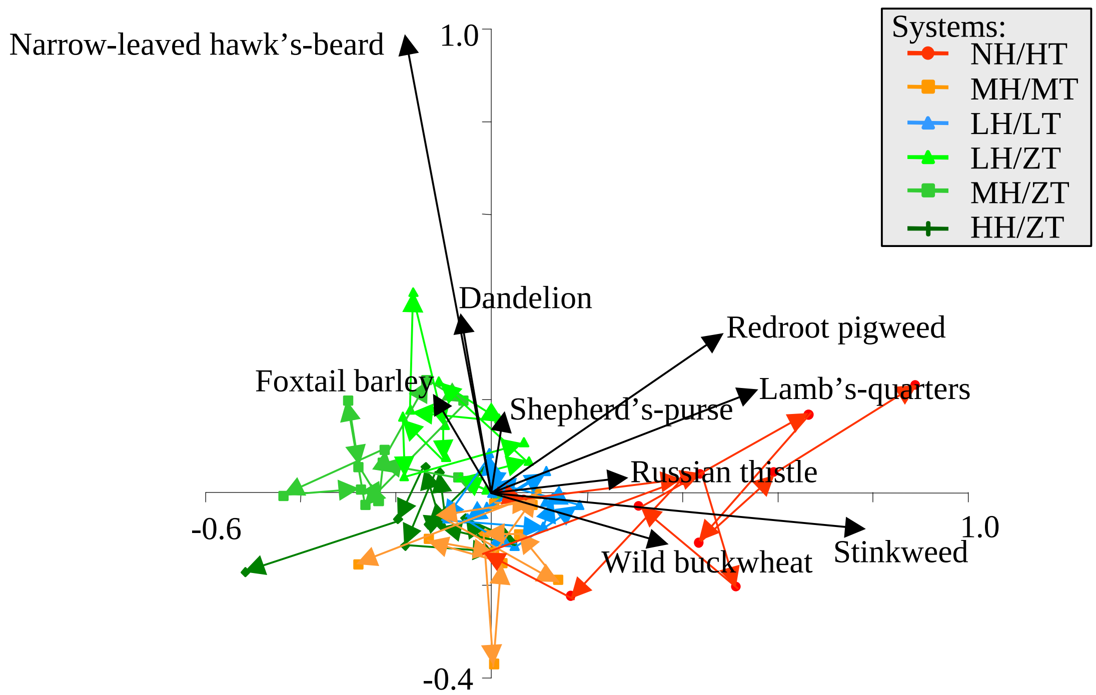

Figure 3. RDA ordination of Watrous species constrained by system at each assessment date. Species with the greatest amount of explained variance on the first two axes are displayed. System counts are joined by arrows to indicate change through time. Axis one and two account for 54% and 15% of the explained variance in the species data, respectively ($P \leq 0.001$).

The PRC of the first axis of the Kernen site indicates a gradual build up of stinkweed, wild mustard, lamb's-quarters, redroot pigweed and wild buckwheat in the no herbicide high tillage system (Fig. 4). The comparatively steep slope between the pre-treatment and residual counts in this system indicates that these species are not as well controlled in-crop by this system in comparison to the other systems. Late seeding of both wheat and canola in the no herbicide high tillage system allows a higher level of control of weeds at this time than in the other systems. Both of the low herbicide systems also appear to be building up populations of these species, although at a slower rate than in the no herbicide high tillage system. The medium and high herbicide zero-tillage systems appear to be maintaining populations of these species slightly lower than observed in the medium herbicide medium tillage system.

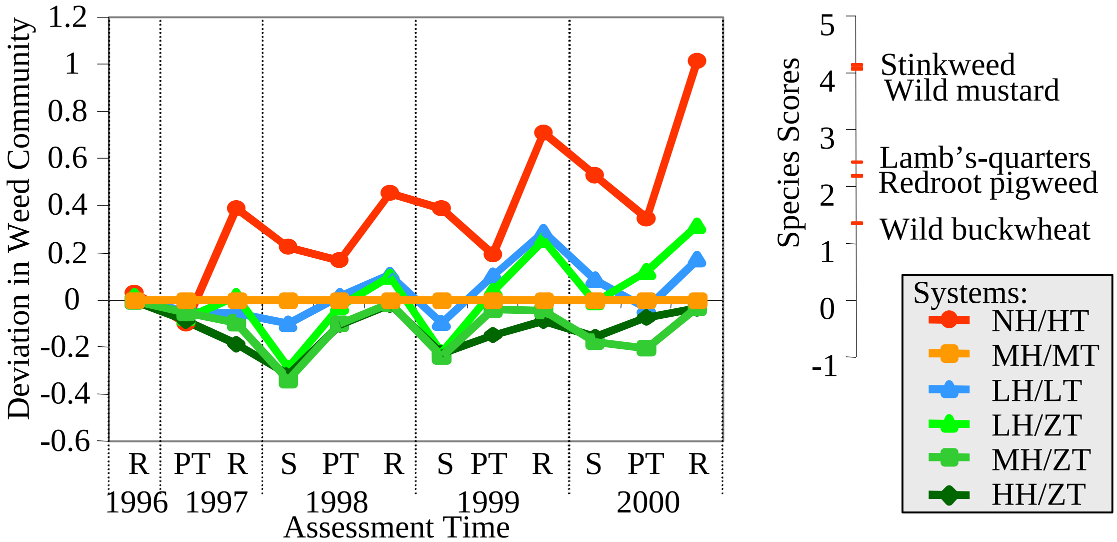

Figure 4. PRC of first axis of Kernen data. This axis accounts for 48% of the variance in the species data due to management system ($P \leq 0.001$).

The first PCR of the Watrous site shows similar trends leading to the increase of stinkweed, lamb's-quarters, redroot pigweed, wild buckwheat and Russian thistle in the no herbicide high tillage system (Fig. 5). These species did not appear to increase in the low herbicide systems at Watrous until 2000. As the densities of weeds at Watrous were initially much lower than at Kernen, it might be expected to take longer for the systems to differentiate. The medium and high herbicide zero tillage systems at Watrous maintained levels of these species at or below those in the reference system, as observed at Kernen.

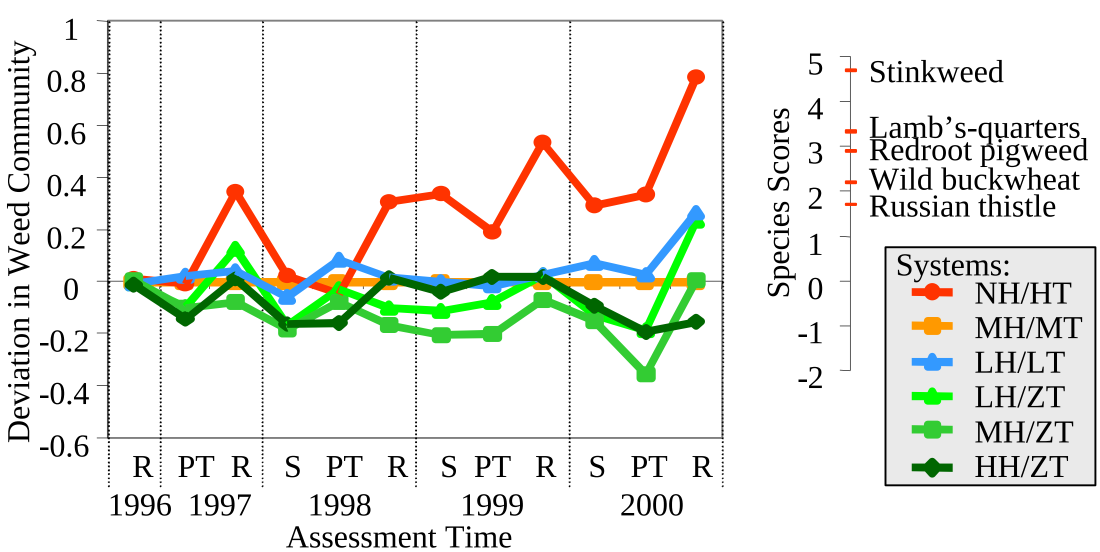

Figure 5. PRC of first axis of Watrous data. This axis accounts for 54% of the variance in the species data due to management system ($P \leq 0.001$).

The second axis of the PRC from Kernen illustrates the seasonal fluctuations of several winter annuals and perennials; dandelion, flixweed, narrow-leaved hawk's-beard, quackgrass and Canada thistle (Fig. 6). Cleavers and kochia also followed similar patterns. Both of these annuals tended to germinate early in the spring at this site. The species represented by the second axis tend to be found in the highest densities in the spring counts within the zero tillage systems. In each year, the in-crop control of flixweed, kochia, cleavers, Canada thistle and redroot pigweed was less effective in the low herbicide zero-tillage system than the other zero-tillage systems leading to a gradual increases in the residual populations over time in the low herbicide zero-tillage system (Fig. 6). The residual counts of dandelion, narrow-leaved hawk's-beard and quackgrass increased over time in the low herbicide low tillage system, ending at higher densities than the low herbicide zero-tillage system. In the low herbicide low tillage system, the populations of these species were not controlled as effectively at seeding as in the zero-tillage systems, in addition to in-crop control comparable to the other low-herbicide system. At the time of the residual counts, the species on the second PRC were found in levels similar to the reference system in the medium herbicide zero-tillage systems and less than the reference system in the high herbicide zero-tillage system. The no herbicide high tillage system tends to have the lowest densities of these species at the time of the spring counts. Although spring control of these species is relatively good, in-crop control is least effective in this system, often leading to relatively high residual counts.

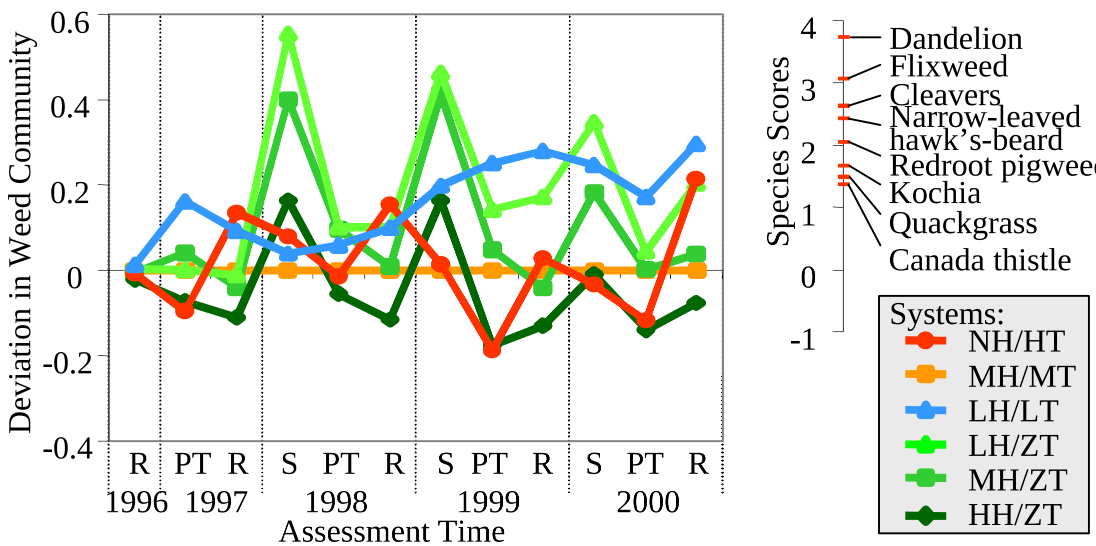

Figure 6. PRC of second axis of Kernen data. This axis accounts for 19% of the variance in the species data due to management system ($P \leq 0.001$).

Redroot pigweed, a late germinating annual, would not be expected to react in a similar manner to the other species on the second PRC axis. This species has high scores on both PRC axes, therefore, the response is a combination of the two axes weighted by the scores on each axis (Figs. 4 & 6). Redroot pigweed, found in the highest densities in the no-herbicide high tillage plots, is a late germinating annual species not present at the time of spring counts thus following the pattern of low spring counts observed in this system on the second PRC.

The PRC of the second axis from the Watrous site shows similar seasonal fluctuations of populations of narrow-leaved hawk's-beard, dandelion, redroot pigweed, lamb's-quarters, foxtail barley and shepherd's-purse within the zero-tillage systems (Fig. 7). At Watrous, the medium herbicide zero-tillage system had higher levels of these species than the medium herbicide medium tillage reference system; while the high herbicide zero-tillage system had similar numbers to those found in the reference system. The low herbicide low tillage system did not appear to increase as much at Watrous as at Kernen, attributable in part to the good control in this system in 1998 and 1999. As seen on the first PCR, the densities of lamb's-quarters and redroot pigweed in the no herbicide high tillage system appeared to steadily increase over the experimental period at Watrous (Table 3).
However, these species followed the annual fluctuations illustrated in the no herbicide high tillage system on the second PRC. This is expected as redroot pigweed is a late germinating annual and late flushes of lamb's-quarters may be stimulated by rainfall (unpublished data).

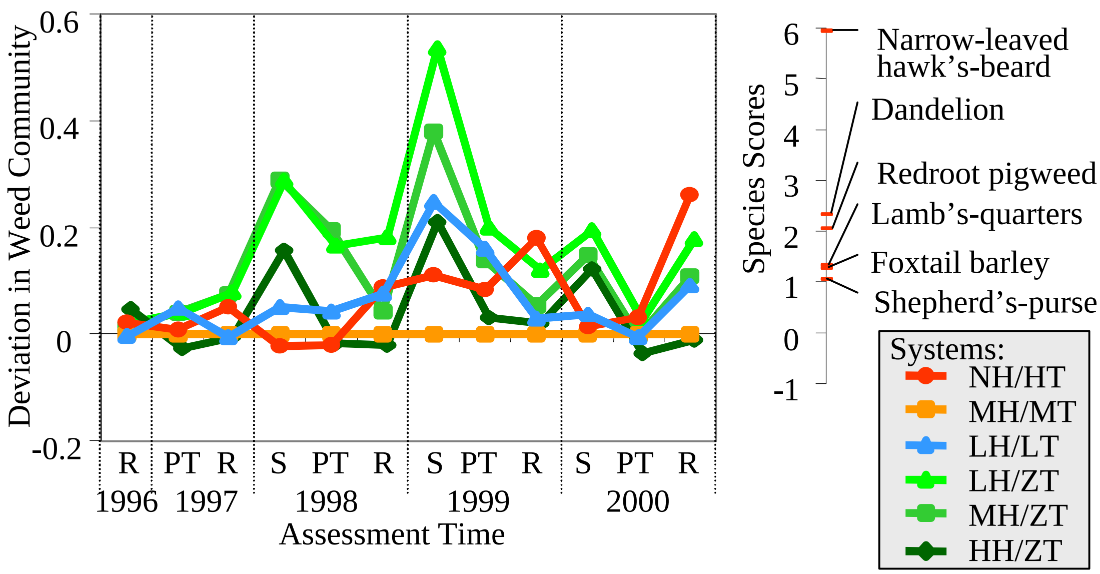

Figure 7. PRC of second axis of Watrous data. This axis accounts for 16% of the variance in the species data due to management system ($P \leq 0.001$).

Summary

Stinkweed, lamb's-quarters, wild buckwheat, redroot pigweed, wild mustard and Russian thistle are best controlled with in-crop herbicide applications. These species all increased over time in the no herbicide high tillage system and low herbicide systems. Delayed seeding and seedbed preparation was able to provide some control of these weed populations in the no herbicide high tillage system; however, more research is necessary to optimize in-crop control in these systems.

Winter annuals, perennials and early spring annuals were found to increase in the lower herbicide zero-tillage systems. These species tended to be found in high densities in the spring and not effectively controlled in-crop. These species were steadily increasing throughout the duration of the experiment. These species need to be monitored in low herbicide zero-tillage systems.

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