Impacts of Direct Seeding -Weed Dynamics

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INTRODUCTION

The acreage of fields managed by reduced- and zero-tillage systems has been increasing in the Canadian Prairie Provinces in the past decade, with highest use of these practices in Saskatchewan (Statistics Canada. 2007). Several studies have been conducted to determine the influence of tillage systems on weed species, sometimes producing inconsistent results (Thomas et al. 2004). This paper uses survey data from Saskatchewan to determine if tillage systems are associated with other management practices, total weed density and relative abundance of weed species.

MATERIALS AND METHODS

Saskatchewan Weed Survey

In 2003, weed surveys were conducted on 2046 fields in Saskatchewan after in-crop management in July or August (Leeson et al. 2003). The surveyed crops were the most common annual cereal, oilseed and pulse crops: spring wheat, barley, durum, oats, canary seed, canola, flax, mustard, field peas, lentils and chickpeas. These fields were selected using a stratified random sample based on the proportion of the surveyed crops in each ecodistrict. The weeds were counted in twenty 0.5 m by 0.5 m quadrats placed in an inverted W-pattern within each field. In conjunction with the survey, producers were asked to fill out a management questionnaire detailing practices used on the surveyed field. 1010 questionnaires were returned with complete information about tillage, fertilizer and seeding practices.

Tillage Definitions used in the Analysis

Tillage systems are defined by the total soil disturbance occurring during the crop year including: the preceding fallow (if applicable), after harvest in the preceding year, in the spring prior to seeding, during the seeding operation and after seeding (Table 1). The zero-tillage system did not include any significant preseeding tillage; however, the use of packers, harrows and harrowpackers were allowed. Also, heavy harrows could be used once at any time during the crop year. At the time of seeding, smooth coulters, on-row packing, tine harrows and harrow packers were allowed but rotary harrows and fluted coulters were not allowed. The zero-tillage system did not use any tillage on fallow in the previous year. A single separate fertilizer application before seeding may occur if it would cause less than 33% soil disturbance, i.e. a single deep banding or injection operation. When a separate fertilizer application was made, the seeding operation was only allowed to cause up to 33% soil disturbance based on opener width and row spacing. If there were no separate fertilizer or manure applications that involve soil disturbance, the seeding operation may cause up to 40% soil disturbance based on opener width and row spacing. Both scenarios were grouped in the analyses to create the zero-tillage system.

Systems with high-disturbance seeding operations, but with soil disturbance equivalent to the zero-tillage system at all other times would technically qualify as reduced tillage; however, they were placed in a separate high-disturbance direct-seeded category for this paper (Table 1). This

category includes all direct-seeded systems where the soil disturbance at seeding exceeds 40%. All fields direct seeded with discers or sweep openers would be classified as using a high-disturbance direct-seeded system.

Table 1. Maximum tillage allowed at various times in each tillage system. A field may be classified as belonging to the zero-tillage system if it follows one of two different scenarios based on the presence or absence of a single low-disturbance fertilizer operation. Fields following both zero-tillage scenarios are grouped in all analyses.

	Zero-Tillage (ZT)		High-Disturbance Direct-Seeded	Reduced-Tillage	High-Tillage
Time of tillage	Scenario 1	Scenario 2	(HDDS)	(RT)	(HT)
Summer fallow	none	none	none	tillage and chemical	No restriction
Fall (after harvest)	1 heavy harrow pass *or*	<33% disturbance *or*	<33% disturbance *or*	<33% disturbance	No restriction
Spring (before seeding)	1 heavy harrow pass	<33% disturbance	<33% disturbance	1 cultivator pass	No restriction
At seeding	<40% disturbance	<33% disturbance	No restriction	No restriction	No restriction
After seeding	harrow	harrow	harrow	No restriction	No restriction

In the reduced-tillage system, fall tillage may include unrestricted used of heavy harrows as well as harrows, packers and anhydrous knives (Table 1). Spring tillage may also include one pass with a cultivator, rodweeder and/or rotary harrow. If the preceding crop was fallow, weed control must not be entirely achieved by tillage.

Systems with more intensive tillage were classified as high tillage (Table 1). This term is used to avoid the regional connotations associated with conventional tillage. While higher levels of tillage are considered conventional in the northern areas of the Prairies, actual rather than relative tillage intensity is more likely to effect weed populations.

Analysis

Tillage data were weighted by the proportion of acres in each ecodistrict with the surveyed crops, to account for non-response. Data summarized by tillage system were also weighted by proportion of acres in each ecodistrict with the surveyed crops; accounting for both non-response and the unequal adoption of tillage systems across the province.

Data from the weed survey were summarized in terms of frequency, field uniformity, density, and relative abundance index (RAI) as described in Thomas (1985) for each tillage system. Frequency is the number of fields in which a particular weed species occurred, expressed as a percentage of the total number of fields surveyed. Field uniformity is the number of quadrats in which a particular weed species occurred, expressed as a percentage of all the quadrats surveyed. Field density is a measure of the number of plants of a weed species counted in a quadrat

averaged over all fields surveyed. RAI is a combination of the frequency, field uniformity, and field density values for each weed species. Each of the component values is expressed as a percentage of the total for all weed species and summed, such that the total of the RAI values for all weed species equals 300.

The Kruskal-Wallis one-way analysis of variance by ranks was used to determine if significant differences existed between tillage systems in weed density (Sokal and Rohlf 1995). This analysis was chosen because the data do not meet the assumption of normality. Multiple comparison tests were performed following Siegel and Castellan (1988). Boxplots are used to illustrate differences in weed densities between systems (Sokal and Rohlf 1995).

RESULTS AND DISCUSSION

Classification of Saskatchewan Producers in 2003

Zero-tillage was the most common system in all ecoregions (Table 2). The use of the high-disturbance direct-seeded system was most common the Moist Mixed Grassland and Aspen Parkland. If the high-disturbance direct-seeded system is considered a sub-set of the reduced tillage system, the high-tillage system was least common system in all ecoregions.

Table 2. Percentage of area in each ecoregion using each tillage system.

Ecoregion	ZT	HDDS	RT	HT
		%		
Mixed Grassland	49.5	10.2	20.2	20.1
Moist Mixed Grassland	53.2	19.9	13.6	13.3
Aspen Parkland	42.8	18.3	20.9	18.0
Boreal Transition	50.7	8.2	22.9	18.2
Saskatchewan	48.6	15.2	19.0	17.2

Management Practices associated with Tillage

Use of herbicides and time of herbicide application were related to tillage system (Table 3). Systems with higher tillage use were less likely to use herbicides at each of the application times. 21% of area with the high-tillage system did not use herbicides at any time for the 2003 crop. Less than 1% of zero-tillage production area did not receive at least one herbicide application.

Table 3. Percentage of area in each tillage system using herbicides at various times during crop year.

Time	ZT	HDDS	RT	HT
		%		
Pre-harvest (2002)	13.7	10.7	6.4	3.2
After harvest (2002)	6.8	5.2	6.9	2.5
Before crop emergence (2003)	82.1	37.1	20.9	24.0
After crop emergence (2003)	93.1	93.3	88.4	64.4
At least one of above times	99.6	97.9	96.7	78.9

Cropping diversity was also related to tillage system (Table 4). Summer fallow was more common in systems with more tillage; it was included in rotations in 80% of the area in the high-tillage system and only 31% of the area in the zero-tillage system. Hay was most often included

in the high-tillage system (11%). In these cases, tillage may have been necessary to break the perennial crop. Conversely, oilseed and pulse crops were more often included in rotations on land where zero tillage was practiced. The association of pulse crops and conservation seeding systems has previously been shown (Haak 2003). Overall, 34% of the high-tillage area had only one crop type (cereals) planted in six years while only 5% of zero-tillage area had comparably low crop diversity (Table 5). Only 16% of the area in high- and reduced-tillage systems had three or more crop types included in the rotation, as compared to 34% in the high-disturbance direct-seeded and 47% in zero-tillage systems.

Table 4. Percent of area in each tillage system including summer fallow and various crop types in a six-year period.

Crop type	ZT	HDDS	RT	HT
		%		
Summer fallow	30.5	46.8	69.5	79.5
Cereal	100	100	99.4	99.7
Oilseed	80.5	70.1	63.1	51.8
Pulse	60.3	48.7	31.5	17.9
Hay	1.9	2.1	0.7	10.6
Specialty	0.3	1.6	0.7	1.5

Table 5. Percent of area in each tillage system including a diversity of crop types in a six-year period.

Number of crop types	ZT	HDDS	RT	HT
		%		
1	4.6	11.4	21.2	34.0
2	48.2	54.7	62.8	50.5
3+	47.2	33.9	16.0	15.6

Total Weed Density

Most producers, regardless of tillage system, were able to successfully control their weed populations (Figure 1). In all tillage systems, some fields did not have any weeds detected in the surveys. These weed-free fields accounted for at least 4% of the area in each system and 7% of the area in the zero-tillage system. At least a quarter of the area in all systems had residual weed densities of less than 3.5 plants per metre square. In the zero- and reduced-tillage systems, half of the area had a weed density of less than 8 plants per metre square. In the high-tillage and high-disturbance direct-seeded systems, half the area had a weed density of 9 and 12 plants per metre square or less, respectively.

The Kruskal-Wallis one-way analysis of variance indicated that the high- and zero-tillage systems had significantly different weed densities from each other ($P<0.01$). The weed densities in the other systems were intermediate. The boxplots (Figure 1) illustrate a greater dispersion of densities in the high- than zero-tillage systems. The differences related to tillage intensity were evident at higher weed densities. A larger percentage of the area in the high-tillage system had high weed densities. A quarter of the area in the zero-tillage system had weed densities greater than 20 plants per metre square; while over 34% of the area in the high-tillage system had weed densities greater than 20 plants per metre square. A quarter of the area in the high-tillage system

had weed densities greater than 29 plants per metre square; while only 14% of the area in the zero-tillage system had weed densities greater than this level. While three zero-tillage fields had more than 250 plants per metre square, the chance of this occurring in reduced- and high-tillage systems was more than double that of the zero-tillage system. The larger percentage of area in the high-tillage system with high weed densities may be attributable to the larger percentage of area in this system not using herbicides in comparison to the zero-tillage system (Table 3).

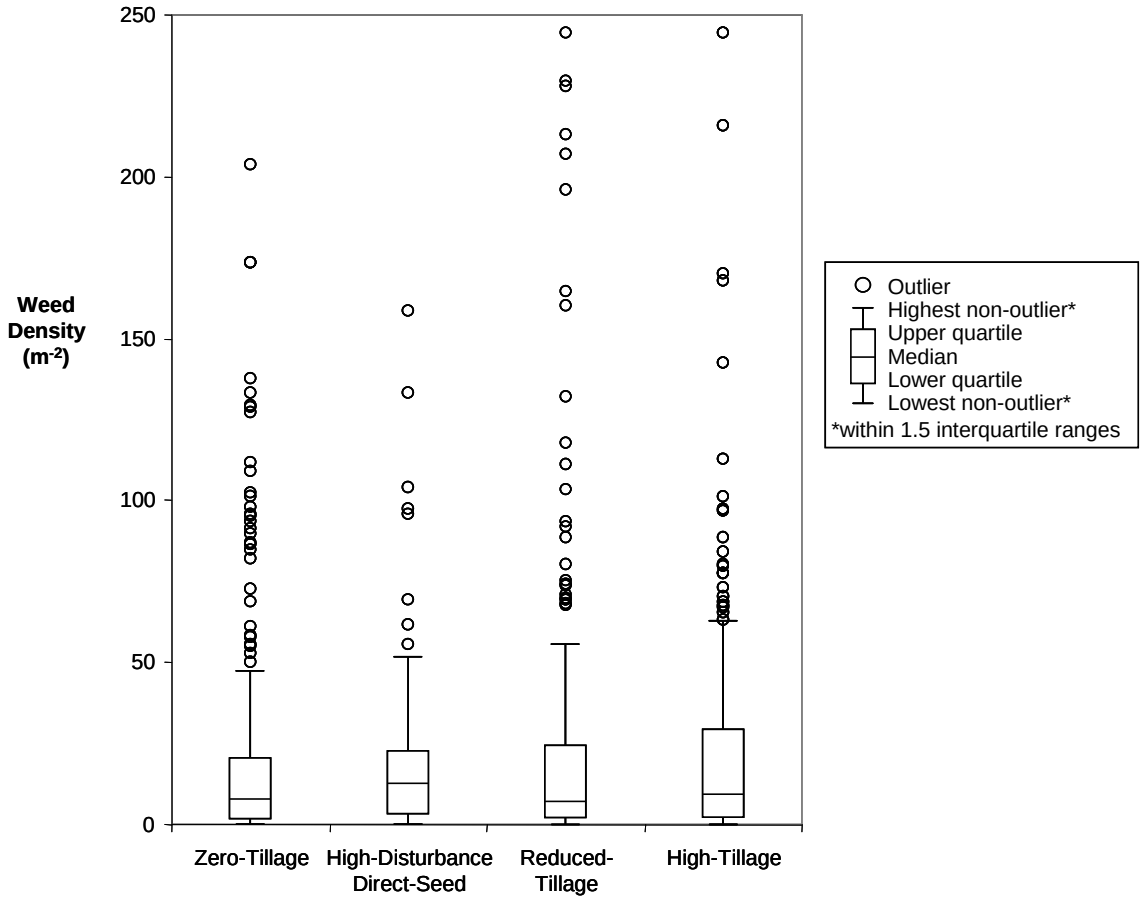

Figure 1. Boxplots of total weed densities in each tillage system. The plot is truncated; the high-, reduced- and zero-tillage systems each had three sites with densities higher than 250 plants per m^2.

Weed Community Composition

The top three most abundant species were green foxtail, wild oat and wild buckwheat in all tillage systems (Table 6). All the species that ranked relatively high in the zero-tillage system also ranked relatively high in the high-disturbance direct-seeded system. Eight species were in the top ten in both the high- and zero-tillage systems. Volunteer wheat ranked seventh in all tillage systems except the high-tillage system where it ranked eighteenth. Volunteer canola ranked in the top ten in the zero-tillage and direct-seeded systems; however, it ranked 22nd in the high-tillage system and 27th in the reduced-tillage system. Similarly volunteer flax only ranked in the top 20 in the direct-seeded and zero-tillage systems. The higher abundance of volunteer flax and canola in the zero-tillage system may be attributable to the more frequent inclusion of oilseeds in this system (Table 4). While cereals were more common in the high-tillage system, it

is difficult to identify volunteer wheat in a wheat crop, probably contributing to the lower relative abundance of volunteer wheat in the high-tillage system. Narrow-leaved hawk's-beard and foxtail barley also placed 11 ranks higher in the zero-tillage than high-tillage systems (Table 6). These species were also more common in the high-disturbance direct-seeded system. Quack grass also ranked much higher in the zero-tillage than high-tillage system. Species that are more abundant in the high-tillage system than the reduced-tillage systems include: wild mustard, perennial sow-thistle, cow cockle, volunteer alfalfa, bluebur and volunteer mustard. The high abundance of volunteer alfalfa in the high-tillage system may be attributable to the more frequent inclusion of hay in this system.

Table 6. Relative abundance ranks of top 25 species in either the high- or zero-tillage systems. Species order is based on difference in rank between the high- and zero-tillage systems.

Species	ZT	HDDS	RT	HT	ZT vs. HT
	—— Relative Abundance Rank ——				Difference in Rank
Volunteer flax	13	10	29	27	14
Volunteer canola/rapeseed	10	8	27	22	12
Volunteer wheat	7	7	7	18	11
Narrow-leaved hawk's-beard	18	19	32	29	11
Foxtail barley	23	24	44	34	11
Quack grass	22	27	20	30	8
Cleavers	12	9	14	16	4
Barnyard grass	14	16	8	17	3
Canada thistle	4	4	4	6	2
Flixweed	24	14	16	24	0
Kochia	8	5	15	8	0
Green foxtail	1	1	1	1	0
Wild oats	2	2	2	2	0
Wild buckwheat	3	3	3	3	0
Lamb's-quarters	5	11	6	5	0
Dandelion	11	17	11	11	0
Persian darnel	25	46	40	25	0
Redroot pigweed	9	13	10	7	-2
Stinkweed	6	12	5	4	-2
Pale smartweed	21	31	21	19	-2
Field horsetail	16	18	13	12	-4
Shepherd's-purse	19	21	19	14	-5
Russian thistle	15	6	9	9	-6
Wild mustard	17	15	12	10	-7
Perennial sow-thistle	20	22	17	13	-7
Cow cockle	32	32	25	21	-11
Volunteer alfalfa	36	49	46	23	-13
Bluebur	31	28	34	15	-16
Volunteer mustard	42	---	26	20	-22

SUMMARY AND DISCUSSION

The choice of tillage is just part of an entire management system. This is emphasized in this paper by comparing residual weed populations that represent the cumulative effect of all management decisions, not just tillage system. In general, these weed populations were similar in all tillage systems indicating most producers were able to successfully manage their weeds. The timing of the weed counts enabled the producers to treat any individual problems prior to the weed assessment; therefore, weed populations may be expected to be the lowest at this time of year, possibly masking some tillage effects.

Differences in residual weed populations between tillage systems may also be partially attributable to management decisions other than tillage system. For example, more common use of herbicides in the zero-tillage system may be expected to contribute to lower weed densities in this system. Conversely, producers using direct-seeded systems tend to include a higher diversity of crops in their rotations, leading to a larger presence of volunteers.

Other weed species that are more abundant in zero-tillage than high-tillage systems include the perennial grass species, foxtail barley and quack grass, as well as the winter annual, narrow-leaved hawk's-beard. Producers should be aware that these species can be more troublesome in direct-seeded systems, particularly if the weeds are not controlled at early stages of infestation.

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