Crop –Weed Interactions under Diverse Cropping Systems in the Canadian Prairies

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Abstract

Diverse cropping systems with different input levels and crop diversities can alter weed community dynamics (abundance and crop-weed competition). Organic systems believed to have greater heterogeneity in soil resources which can sustain more competition form weeds compared to conventional systems. However, direct evaluation of competitiveness among the two systems under wide range of crop diversities has not being tested. Therefore, a study was carried out within a long-term cropping systems study at Scott, Saskatchewan to compare weed dynamics. The main experiment consists of three input levels; high, reduced, and organic and three diversity levels; low, diversified annuals, diversified annual perennials. A micro-plot study was carried out within the main experiment with four weed control treatments applied in the wheat phase of reduced and organic systems. The treatments were 1.weed free treatment, 2. weedy treatment, 3. standard weed control and 4. pseudo weed established at 1:1 ratio with the crop. Within organic crop rotations weed density was high in diversified annual perennial system while in reduced systems it was high in diversified annual grain rotations. Overall, diversified annual perennial system had low weed biomass compared to low diversity rotation. There was no difference in weed biomass between organic and reduced systems. There was no difference between organic and reduced systems for yield loss. Grain yield was greater in reduced compared to organic systems. Even under weed-free conditions grain yield was low in organic systems indicating weeds are not the major yield limiting factor in Saskatchewan organic cropping systems.

Key words- weed competition, organic systems, conventional systems, yield loss.

Introduction

Continuous adoption of high input conventional cropping practices have caused cropping systems to be less diverse and increased reliance on synthetic inputs to control weeds and to enhance soil fertility (Liebman and Stavers 2001). Apart from impact to the surrounding environment, the long-term practice of high input crop production negatively affect agro-ecosystem itself by reducing the amount of soil organic matter (Matson et al. 1997), accelerating the development of herbicide resistance against weeds (Powles et al. 1997), and reducing the diversity of crops (Brush 1989) and weeds (Andreasen et al. 1996). The growing awareness of the negative impacts of conventional cropping systems had caused to adopt alternative crop production practices throughout the world.

The adoption of alternative cropping systems is gaining interest due to the economic and environmental sustainability (Robertson and Swinton 2005). Organic crop production systems are gaining interest as an alternative for conventional cropping systems due to the lower input cost, increased grower independence, environmental stewardship, and emergence of organic markets (Entz et al. 2001; Ngouajio and McGiffen 2000). Yet, these alternative cropping systems have being dealt with the challenge of meeting high yields compared to conventional systems. At present the conventional cropping systems heavily rely upon synthetic inputs such as fertilizers and pesticides for optimum yields and replacing those synthetic inputs without losing crop yields is challenging for alternative cropping systems (Robertson and Swinton 2005).Therefore, increased weed pressure and soil nutrient deficiencies are more common in organic and in low-input systems, which may or may not lead to crop yield reductions (Waldon et al. 1998; Clark et al. 1999; Ryan et al. 2004).

Improved grain yields are a reflection of the adequacy of weed control and nutrient management in cropping systems. However, it has been the major challenge in organic cropping systems. The yield comparisons between organic and conventional systems have shown mixed results. Some studies identified low yield in organic compared to conventional systems (Entz et al. 2001; Ryan et al. 2004; Welsh et al. 2009). Soil nutrient deficiencies (Waldon et al. 1998; Barberi 2002) and high weed density (Posner et al. 2008; Entz et al. 2001) associated with organic systems could be the main reasons for low yields. In contrast, Davis et al. (2005), Delate and Cambardella (2004), Ryan et al. (2009), and Hiltbrunner (2008) reported either similar or substantially higher grain yield despite the high weed density in organic cropping systems.

Improved soil conditions (Bauer and Black 1994; Liebman and Davis 2000) and altered nutrient dynamics due to different sources of Nitrogen (Dyck et al.1995) under organically managed soils would be able to sustain greater weed density without sacrificing crop yield. Organic systems can provide greater long-term soil benefits by enhance C and N than conventional systems. Improved soil quality due to the high organic matter in organic cropping systems believed to play an important role mediating the mineralization (Baur et al. 1991; Manlay et al. 2007) and buffering the yield at excessive or limited rainfall conditions (Gallandt et al.1998; Mallroy and Potter 2007).

Apart from the direct effects of the altered nutrient dynamics, the differences in crop-weed competition due to greater tolerance or enhanced crop competitiveness to weeds could be one of the main reasons for greater yield observed under high weed pressure in organic systems. According to Smith et al. (2009), the greater diversity in soil resources in organic systems would have reduce the competition of weeds by allowing greater niche differentiation. At present Saskatchewan has the largest organic crop production in Canada accounting for 54% of cultivated organic land (Canadian Organic Growers 2010). Therefore at present, cropping systems in Saskatchewan prairies can be broadly grouped as organic, low-input, or high-input farms based on input use with wide cropping diversity. Long-term weed dynamics and their effect on crop yield under these cropping systems are not well known. Therefore, a study was carried to understand weed dynamics (abundance and crop-weed competition) under organic and conventional (no-till) cropping systems in Saskatchewan Prairies.

Materials and Methods

A field study was carried within the long-term alternative cropping systems (ACS) study at Scott, Saskatchewan in 2011 and 2012. Alternative Cropping systems study established to evaluate different cropping systems with three input levels (high, reduced and organic) and three crop diversity levels (low, diversified annual grains, diversified annual perennial). Experimental design is a four replicate split-split plot design. For further details of the experiment can be found in Brandt et al. (2010). The current study was carried out as a micro-plot study within ACS. The experimental design was a split-split plot with four replicates. Four sub-sub-plots were established within the wheat phase in all rotations (sub-plot factor) in both RED (conventional) and ORG input systems (main plot factor). Four treatments 1.weedy (no weed control), 2.weed free (hand weeded), 3.standard weed control practices, 4. weed mimic (tame oat seeded at 1:1 ratio with wheat-seeding rate) were randomly allocated into sub-sub plots with 2 x 3 m dimensions in all the four replicates in ACS trial.

The four sub-sub plots were seeded with the same wheat crop at the time of seeding the wheat crop in the wheat phase of the particular rotation in the main experiment. The weed mimic treatment was established by seeding tame oat variety (CDC Dancer) at 300 plants m-2 after wheat crop has emerged. The oat was seeded using double disk cone seeder in between wheat rows. All the weeds were continuously hand removed in both weed free treatment and in weed mimic treatment in order to have weed-free plots. At the time of the standard weed control practices carried out in the wheat crop in organic and reduced systems in the main experiment, same practices were carried out into the standard weed control treatments in micro-plot experiment. When herbicides were applied to the standard treatment, a polythene cover was laid over the rest of the sub-sub plots in order to intercept herbicides. When harrowing was carried out in organic standard treatment, the tractor drove through the rest of the plots with harrower lifted up in order to impose similar tractor effect on all other sub-sub plots.

Crop plant counts were taken after emergence using two $0.25 m^2$ quadrats placed randomly at front and back of each sub-sub plot. Quadrats were placed in order to include three wheat rows. Similarly, oat plant counts were measured in the weed mimic treatment. Weed counts of weedy and standard treatments were measured after one week from the application of particular standard weed control treatments. Weed counts were taken using four $0.25\ m^2$ from both front and back of each plot. Quadrats were placed in order to include three wheat rows. Weeds were identified to species level and counts were taken. After maturity, crop shoot biomass was sampled from all the sub-sub-plots using two $0.25 m^2$ quadrats placed at front and back of each plot. Similarly, weed shoot biomass were sampled to species level in weedy and standard treatments. In the weed mimic treatment, oat biomass was sampled. Crop, weed, and oat biomass were bagged separately and were taken to the lab and kept for 2-3 days in the oven at 60-70oC. After drying, the dry biomass weights were recorded. At the time of harvest, wheat crop were hand harvested using two 0.25 m2 quadrats placed at front and back of each sub-sub-plot. Wheat was threshed using the combined harvester and cleaned using dockage tester and the final grain weight were measured.

The total weed density, total weed biomass, oat biomass, crop biomass, and wheat grain yield data were tested for assumptions of ANOVA. Appropriate transformations were carried out to meet the assumptions of ANOVA. All the data then were analysed using MIXED models in SAS 9.3 as a split-split plot design.

Results and Discussion

Average weed density was 346 plants m-2 in ORG systems and 141 plants m-2 in RED systems. The weed density was affected (P = 0.048) by input, rotation, and weed control interaction (Table 1). Due to high variation in weed density among the two years weed density results were analysed and presented separately for the two years (Figure 2).

Table 1. ANOVA for the effect of input, rotation, and weed control on weed density, weed biomass, grain yield, and yield loss assessed at Scott in 2011 and 2012.

Treatment	Weed Density±	Weed BM±	Crop BM	Yield	Yield Loss
Input	0.002	0.7775	0.0001	0.001	0.5626
Rotation	<.0002	0.002	0.2277	0.634	0.7712
Weed control	<.0001	0.0003	0.0086	0.0078	NA
Input x Rotation	<.0001	0.3119	0.0004	0.0044	0.5975
Input x Weed control	0.0613	0.0011	0.0001	0.0071	NA
Rotation x Weed control	0.7909	0.8031	0.0308	0.8573	NA
Input x Rotation x Weed control	0.0448	0.8124	0.5373	0.789	NA

± denotes data log transformed before analysis.

NA denotes not applicable.

BM denotes biomass.

As observed in combined data for the two years, similar input by rotation by weed control interaction was identified for the two years when analysed separately (data not shown). Under the standard conditions, ORG systems had greater weed densities in DAP rotations while RED systems had greater weed densities in DAG rotations in both years (Figure 1A and 2B). Similar pattern can be observed under weedy conditions except in 2011 where in ORG weedy treatment DAG and DAP had similar weed densities.

Under weedy conditions RED-DAG systems had high weed density in both years and are similar to weed densities in ORG-DAP. This suggests that even chemical weed control is being carried out for 17 years in RED-DAG systems it was unable to reduce weed population over time. Still, in-season chemical weed control is effective as it was able to reduce weed densities significantly in both years (Figure 2A and 2B) compared to weedy conditions. However, high weed densities observed in ORG-DAP was not effectively controlled by standard weed control practices (post-emergence harrowing) used (Figure 2A and 2B). Still, standard weed control practices were able to reduce weed density in ORG-DAG rotation and importantly there was no difference that with RED-DAG system.

Overall, results suggest that in both ORG and RED input systems crop diversity level has a great effect on weed densities. Furthermore, the effectiveness of harrowing in ORG systems depends on the type of crop rotation but in RED systems chemical weed control is effective for all crop diversity levels studied. Inability to effectively reduce weed densities by post-emergence harrowing in ORG-DAP systems could be due to differences in weed species, high weed density, or due to differences in soil conditions compared to DAG and LOW diversity systems.

The weed biomass was affected by the interaction between input and weed control treatments (Table 1). Despite there were differences in weed densities between input levels there was no difference in weed biomass between ORG and RED systems (Figure 2). Also there was no difference in weed biomass between weedy and standard weed control treatments in ORG systems. Under RED systems weedy treatments had greater weed biomass than standard weed control treatments implying the effectiveness of herbicides.

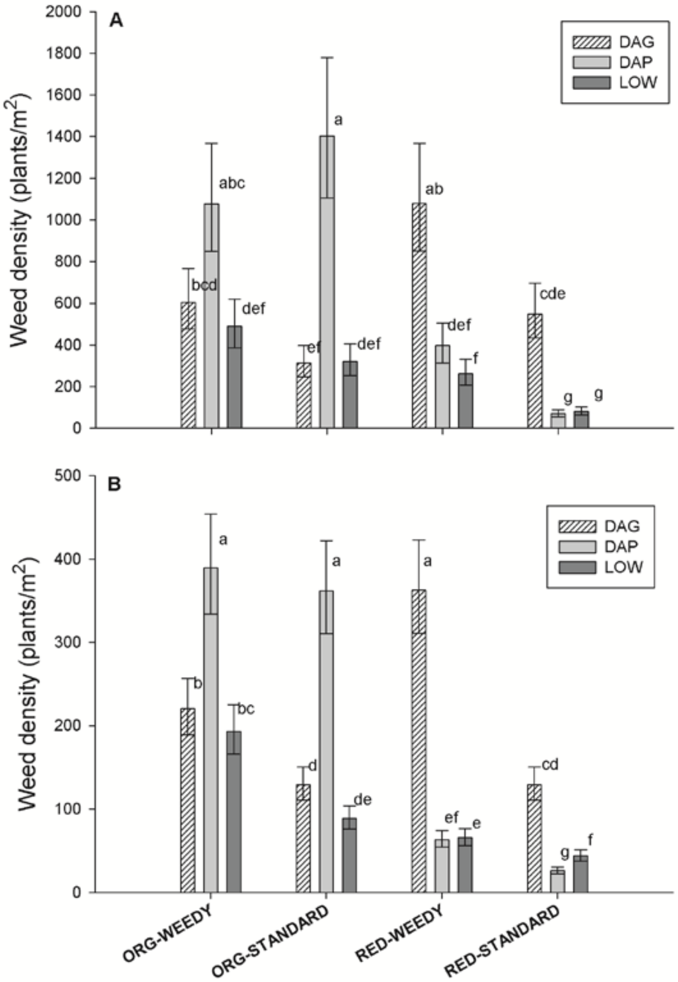

Figure 1. Weed density as affected by input, rotation, and weed control assessed at Scott in 2011 (A) and 2012 (B). Weedy- no weed control, Standard- standard weed control practices.

Overall, crop rotations had significant effect (P = 0.002) on weed biomass regardless of input or weed control (Table 1). The LOW diversity rotations had greater weed biomass than DAP rotations. The diversified annual grains rotation had medium weed biomass compared to LOW and DAP (Figure 3). Although weed biomass expected to be greater in DAP for ORG systems and DAG for RED systems due to greater weed densities compared to other systems, weed biomass was mainly affected by overall crop rotations than by input level by rotation interaction.

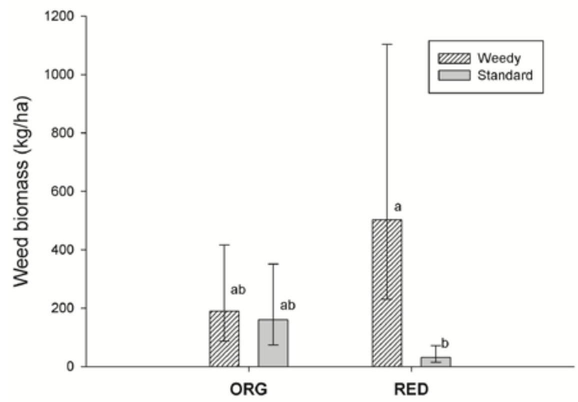

Figure 2. Effect of input and weed control on weed biomass assessed at Scott in 2011 and 2012.

Also it indicates that differences in weed densities at early crop stages among cropping systems may not reflect weed competition at later stages of the crop. Therefore, it can be speculated that different crop rotations had different capacities to suppress weeds regardless of initial weed densities within the season. Low weed biomass in DAP can be either due to greater weed suppressive ability of the wheat crop in that rotation by enhanced crop growth or lower growth of weeds due to nutrient deficiency due to having a perennial crop in the rotation. Since there was no rotation effect on crop biomass (Table 1) the former argument can be excluded.

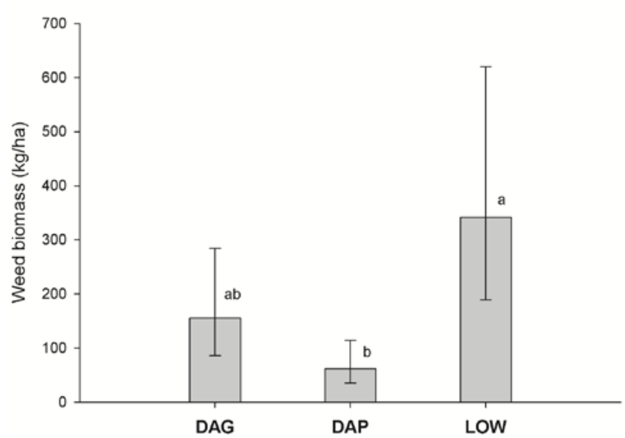

Figure 3. Effect of crop rotation on weed biomass assessed at Scott in 2011 and 2012.

The grain yield was affected by the interaction between input level and crop diversity level (P = 0.0044) (Table 1). The three organic crop rotations had less yield compared to the three RED rotations (Figure 4). There was no difference in grain yield among organic rotations but under reduced systems DAP rotation had greater yield compared to LOW and DAG rotations.

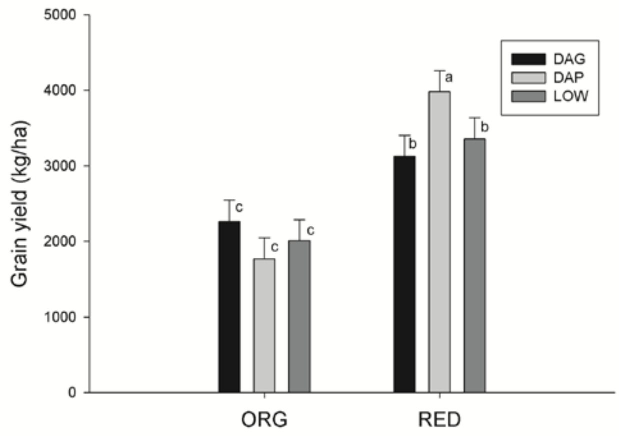

Figure 4. Effect of input and crop diversity on grain yield assessed in Scott 2011 and 2012.

There was an interaction between input level and weed competition on grain yield (Table 1). Either in weedy, weed-free, or standard weed control conditions grain yield was low in ORG systems compared to RED systems (Figure 5). Significant differences in ORG and RED systems even under weed free conditions suggests that low yield potentials in ORG rotations is not mainly due to high weed densities or inadequate weed control but can be due to other soil related factors. No differences between weed-mimic (similar weed density) treatments between ORG and RED rotations (Figure 5) suggests that even the grain yield potential is high in RED systems when subjected to high weed competition the yield loss is greater (56%) for RED systems compared to 41% in ORG.

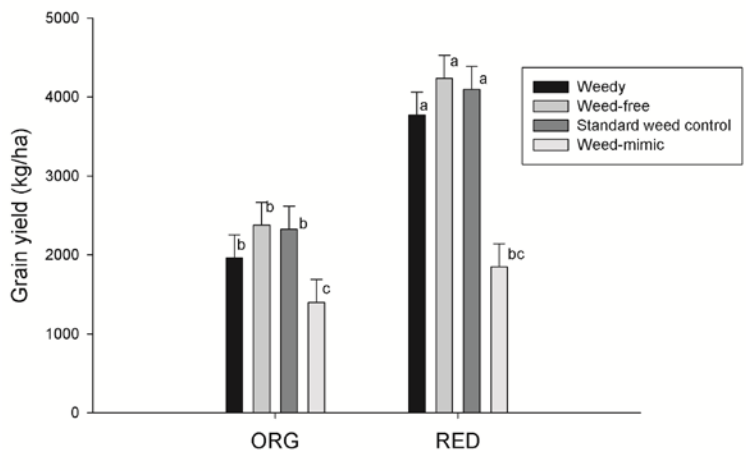

Figure 5. Effect of input level and weed competition on grain yield.

Relative yield loss (ratio between weedy and weed free yield) is an indication of the crops ability to withstand weed competition. When the two cropping systems were compared for percentage yield loss no difference was observed (Table 1). Thus, indicates that organic systems do not have a better capacity to withstand weed competition more than conventional systems.

Conclusions

Within organic crop rotations weed density was high in diversified annual perennial system. In reduced systems weed density was high in diversified annual grain rotations under standard weed control conditions. Weed biomass mainly affected by overall crop rotation where diversified annual perennial system had low weed biomass compared to low diversity rotation. There was no difference in weed biomass between organic and reduced systems. There was no difference between organic and reduced systems for crop tolerance. Grain yield was greater in reduced compared to organic systems. Even under weed-free conditions grain yield was low in organic systems indicating weeds are not the major yield limiting factor in Saskatchewan organic cropping systems.

Acknowledgement

The authors gratefully acknowledge the Agri-Food Agriculture Canada (AAFC) for giving access to the alternative cropping systems trial at Scott Saskatchewan and allowing carrying out this experiment. Special thanks should go to Eric Johnson (officer in charge), and Arlen Kapaniac (research technician) in Scott research station for providing full support to carry out this project. We would also wish to thank Julia Leeson (weed biologist at AAFC) for providing the transport facilities. Also we would like to thank Shaun Campbell (Research technician) and the staff in agronomy lab in Kernen research farm and the grad students in the department of plant science, University of Saskatchewan for their great support. Finally we would like to thank Organic Agriculture Centre for Canada (AAFC) for funding the project.

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