Overcoming Weed Concerns in Conservation Tillage Systems

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Introduction

One of the primary reasons for tillage throughout history has been weed control. Annual weeds are usually well controlled with tillage but tillage can also stimulate another flush of weeds. Control of most perennial weeds with tillage is only partially effective as multiple passes are required to reduce energy reserves in the rhizome or root systems.

Despite the somewhat mixed success of using tillage to manage weeds, there was widespread concern about increasing weed populations and 'out-of-control' weeds if tillage was eliminated or even reduced. A second major concern revolved around the perceived need to increase herbicide use in conservation tillage systems. Farmers were worried about increased herbicide costs and environmentalists were concerned about greater potential impact on air and water quality.

Potential Tillage Intensity Effects on Weed Populations

Weed populations can readily adapt to new environments because of their diversity. Disturbance is a major habitat trait that favours weed invasion. Froud-Williams (1988) states "Arable land is characterized by regular, recurrent, and often highly predictable disturbance. The consequence of this disturbance is that weeds of cultivated land represent the most ephemeral of plant communities, completing their life cycles within a relatively short time and producing copious quantities of dormant seed of potentially long life span".

There always seems to be a weed species or biotype that can adapt to and thrive in the agricultural environments we create. Agricultural weeds are thought to have adapted to respond to cues associated with soil disturbance (Harker and Clayton 2004). Recently tilled land is often warmer, has greater diurnal temperature fluctuations, higher nitrate concentration, and increased aeration; all of these factors can stimulate weed germination.

Greater surface crop residues with conservation tillage can suppress weed establishment by altering environmental conditions related to germination, physically impeding seedling growth, and through allelopathic interactions (Blackshaw 2005). Weed seed dormancy, which allows weeds to persist in the soil for many years, is also reduced when weed seeds are not buried. Vertebrate and invertebrate seed predators have easier access to weed seeds left on the soil surface. In addition, weed seed predators occur in much greater numbers in zero tillage fields. Weed seeds left on the soil surface also experience greater mortality for at least two additional reasons: physiological aging and exhaustion of reserves through respiration and germination at soil positions and times of year that are not suitable for seedling emergence or survival.

Weed Population Shifts with Conservation Tillage

Several long-term studies were conducted in western Canada in the 1980s and 1990s to examine the effect of reduced tillage on soil quality and crop productivity. Fortunately, weed populations were also documented in many of these studies. Eleven field experiments ranging in duration of 4 to 12 years were included in a multi-site weed assessment study (Blackshaw 2005).

Of the 71 weed species enumerated, 56% were associated with minimum and/or zero tillage and 27% were associated with conventional tillage. Species ubiquitous across tillage systems represented the remaining 17%. Despite more than one-half of all weeds being associated with minimum-zero tillage, most of these weeds were not new weeds to these agricultural systems but they increased in density and distribution with the adoption of reduced tillage cropping practices.

All perennial species were more strongly associated with minimum-zero tillage than with conventional tillage. Canada thistle, perennial sowthistle and quackgrass were present in all tillage systems but their densities often increased with zero tillage. Others, such as dandelion and foxtail barley exhibited large increases in density with zero tillage. Biennial species were also associated with minimum-zero tillage and rarely occurred with conventional tillage.

Of the 39 annual weed species in these studies, 44% were associated with minimum-zero tillage, 33% with conventional tillage and 23% were ubiquitous across tillage systems. Many of the annual species associated with minimum-zero tillage have wind-disseminated seed capable of germinating on the soil surface; examples being annual sowthistle and prickly lettuce. Species such as stork's-bill and cleavers have taken on a winter annual growth habit with the insulating effect of greater snow cover with zero tillage.

Farmer experience has indicated that when direct-seeding is first adopted, given additional moisture at the soil surface as well as management adjustments to a new system, weed densities may increase for the first few years relative to weeds in tilled systems. However, after 5 to 10 years of zero tillage, overall weed densities are often lower than in tilled systems. In these situations there is potential for less herbicide use, perhaps even less than what was previously used in conventional tillage systems. Indeed, sales data indicate that herbicide use has remained relatively constant with widespread adoption of conservation tillage in western Canada.

Managing Weeds on Conservation Fallow

While fallow in now only practiced on 3 million ha annually on the Canadian prairies, it was a common practice on 10-14 million ha during the 1960s through 1980s. Farmers fallowed land mainly to conserve soil moisture but also to increase soil N levels and kill weeds. However, fallow maintained by tillage had the negative consequences of reduced soil organic matter, increased soil erosion, deterioration in soil structure, and increased salinity. Thus, developing alternative weed management methods on fallow was a high priority during the early days of conservation tillage.

Studies conducted at Lethbridge and Swift Current developed systems that employed a combination of wide-blade tillage and herbicides to control weeds on fallow (Blackshaw and Lindwall 1995a). Although not as effective in conserving surface crop residues as sole use of herbicides, the combined herbicide-tillage approach maintained sufficient crop residue to keep the risk of erosion low (Blackshaw and Lindwall 1995b). Soil water accumulation and following crop yields with the combined herbicide-tillage treatments were often superior to that with tillage only. Economics were favorable (Smith et al. 1996) and thus conservation fallow was rapidly adopted by growers. This was a major positive step in reducing soil erosion on the Canadian prairies.

Managing Weeds in Direct Seeding Systems

Early questions included how to effectively and economically control weeds prior to seeding plus those troublesome weeds (often perennials) that tended to be greater problems with conservation tillage. Paraquat and glyphosate were widely evaluated for these purposes. Paraquat was cheaper than glyphosate in the 1970s and 1980s but due to its contact mode of action it often provided poor control of grass species (e.g., wild oat and volunteer cereals) at seeding time and only provided topgrowth control of perennial weeds. Glyphosate moves throughout plants and thus was a far more effective herbicide than paraquat. However, it was not until the price of glyphosate was reduced in the late 1980s and early 1990s that it became widely used in direct-seeding systems. Glyphosate is now used preseed to control emerged weeds, preharvest to control perennial weeds, and postharvest to control perennial weeds plus fall emerging winter annual weeds. Recently, herbicides such as florasulam and carfentrazone have been tank-mixed with preseed glyphosate to provide improved control of weeds such as dandelion and narrowleaf hawksbeard.

Specific research was conducted to control troublesome perennial weeds such as foxtail barley (Blackshaw et al. 1999) and Canada thistle (O'Donovan et al. 2001) in zero tillage systems. Herbicides were identified to control these species but more importantly integrated multi-year management programs were developed for these weeds.

Adoption of direct-seeding techniques has allowed farmers to grow a greater variety of crops. Snow trapping and reduced evaporative losses with zero tillage have increased soil moisture levels in the Brown and Dark Brown soils of the prairies. This has allowed producers to grow oilseed and pulse crops in these regions where previously only cereals were grown and where fallow was extensively practiced. The net result of this has been a 70% decrease in fallow, 60% increase in canola, and 250% increase in pulse crops on the Canadian prairies (Blackshaw et al. 2008). Crop diversification is a cornerstone of all sustainable pest management and crop production systems (Derksen et al. 2002).

Diverse Cropping Systems

Weeds fortunate enough to grow in simple, repeated cropping systems will continue to have little difficulty adapting and thriving in those systems. Liebman and Staver (2001) state “Continuous production of a single crop and short sequences of crops with similar management practices promote the increase of weed species adapted to conditions similar to those used for producing the crops….In contrast,…employing crops with different planting and harvest dates, different growth habits and residue characteristics, weeds can be challenged with a wide range of stresses and mortality risks, and given few consistent opportunities for unchecked growth and reproduction”.

Two things govern the successful utilization of crop diversity in weed management systems: the life cycle of the most dominant weed(s) and the life cycle of the rotational crops. Many crop rotations involve substantial crop species diversity but lack crop life cycle diversity. For example, if wild oat is the dominant weed species, crop producers must employ something other than just summer-annual crops in their rotation. Accordingly, in winter wheat, winter-annual downy brome is easily managed when the crop rotation involves a summer-annual crop (Blackshaw 1994).

Using crop rotations with varying crop life cycles is not the only way of introducing diversity into a cropping system. Diversity can also be introduced by varying crop seeding date (Clayton et al. 2004), or by varying the date of crop harvest (Harker et al. 2003).

Integrated Weed and Crop Management

Other cultural weed management techniques have been extensively researched and are slowly but surely being adopted by farmers (Blackshaw et al. 2008). These IWM practices include higher crop seeding rates, altered seeding dates, competitive cultivars, strategic fertilization, and growing silage, green manure and cover crops. These weed management practices can be effective on their own but far greater impact is realized when they are combined within a systems approach conducted over several years.

A multi-year study conducted at Lethbridge, Lacombe and Scott found that the combination of early seed date, higher crop seeding rate, and spring-applied subsurface-banded fertilizer resulted in the most competitive cropping system (Blackshaw et al. 2008). Weeds were well controlled with this IWM approach and it is notable that the weed seedbank was not greater after four continuous years of using 50% herbicide rates within a competitive cropping system at two of three sites.

Another multi-year study conducted at four locations, where practices were repeated over several years, illustrates well the importance of combining optimal practices in an integrated crop management system (Harker et al. 2009). Wild oat seed production at the quarter herbicide rate was reduced by 91, 95, and 97% in 2001, 2003, and 2005, respectively, when tall barley cultivars at double seeding rates were rotated with canola and field pea (high management) compared to short barley cultivars at normal seeding rates continuously planted to barley (low management). Combinations of favorable cultural practices interacted synergistically to reduce wild oat emergence, biomass and seed production, and to increase barley yield. For example, at the quarter herbicide rate, wild oat biomass was reduced two- to three-, six-to seven- or 19-fold when optimal single-, double-, or triple-treatments were combined, respectively. Notably, high management at low herbicide rates often had higher barley yields than low management in higher herbicide rate regimes.

Concluding Remarks

Farmers should not be deterred from adopting conservation tillage practices because of concerns of increased weed control problems but rather be aware of potential changes in weed communities and how they may be managed. Over the last two decades, there is good evidence on the Canadian Prairies to suggest that we have reduced weed density and species numbers via the management practices that have been employed. Effective and economical weed management programs are now available for successful implementation and continuation of conservation tillage cropping systems in western Canada.

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