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# Integrated Cropping Systems for Weed Management

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## Summary
Integrated cropping systems are gaining prominence on the Canadian Prairies. Research that documents weed management, crop production and economic benefits of single and combined optimal agronomic practices is on-going and is currently being adopted by forward-thinking and innovative growers. These weed management approaches have proven to be effective. There are however, plenty of opportunities to study and improve current systems at research and farm levels. The continued improvement, extension, uptake and feedback of these systems play a key role in increasing the viability, sustainability and competitiveness of our crop industry.

## Introduction
Weeds persist in all major world cropping systems. In Canada, the vast majority of major weed species are introduced aliens that arrived with those that settled and cropped the land. Techniques to manage these weeds have evolved from the drudgery of hand-hoeing to the relative ease of applying herbicides with GPS-guided sprayers covering 20 hectares per hour.

The introduction of herbicides was hailed as one of the most important advances in agriculture. Of the approximately 36 million hectares of cropped land in Canada, more than 25 million hectares receive annual herbicide applications (contrasted to < 3 million hectares which receive fungicides or insecticides)[22]. Herbicides typically comprise 20 to 30% of input costs in North American cropping systems[10]. However, despite widespread adoption of herbicide technology, there is ever-increasing interest in reducing herbicide use.

A key factor for successful weed establishment is soil disturbance[9]. Whether by tillage or grazing, weeds are more able to grow and proliferate at a site where native vegetation has been disturbed. Two other habitat traits that favour weed invasion are almost always present in modern crop landscapes; they are low species richness (crop monocultures) and high resource availability (sunlight, moisture, soil nutrients, fertilizer, etc.)[9]. Rapid response to high resource availability is a physiological attribute ofmost early succession plants (first invaders after disturbance) such as weeds.

There are many cultural weed management techniques that can lead to reduced herbicide dependence. The key to success in any cropping system is diversity. Successful cropping systems should promote increased levels of diversity in cropping species and planting and harvest dates. Additional practices such as direct-seeding, competitive varieties, increased seeding rates, strategic fertilizer placement, and growing silage, green manure and cover crops, all have excellent potential to suppress weed numbers. When optimal combinations of these practices are combined with judicious herbicide application into diverse cropping systems, significant reductions in weed populations can be achieved with long-term positive impacts on crop yields and net returns.

## Crop Rotation and Operational Diversity

Diverse crop rotations are the cornerstone of all sustainable pest management and crop production systems. Monoculture cropping facilitates an increase in weed species that are able to effectively compete with that crop or that are able to overcome competition through some avoidance mechanism. A greater variety of crops are now being grown on the Canadian Prairies with the inclusion of oilseed and pulse crops in our traditional cereal-based rotations. This is a positive step, but most of these crops are still spring-planted annual species. Despite steady improvements in herbicide efficacy over the last few decades, the predominance of summer-annual crops on the Canadian prairies aptly explains the continued dominance of three summer-annual weed species over the same time period: wild oat (*Avena fatua* L.), wild buckwheat (*Polygonum convolvulus* L.) , and green foxtail [*Setaria viridis* (L.) Beauv.][17]. Rotations could be improved by including fall-seeded (winter) crops and perennial forages such as alfalfa (*Medicago sativa* L.). Survey results indicate that 83% of farmers had lower weed densities after 2 to 4 years of forage production[11].

Crop diversification encourages operational diversity (diversity of practices) that in turn can aid weed management. Different crops are naturally planted and harvested at different times of the year; they may also require different herbicide timing and modes of action. If sufficient differences exist in germination requirements of crops and weeds then seeding date can be manipulated to benefit the crop. Early sown spring crops may out-compete weeds requiring warmer soil temperatures for germination [e.g., green foxtail, redroot pigweed (*Amaranthus retroflexus* L.)][3]. Conversely, delayed seeding can be used to manage early spring germinating weeds such as kochia [*Kochia scoparia* (L.) Schrad.]. The goal should be to vary seed dates and crop life cycle types in a field over years.

## No-Till Systems

No-till and direct-seeding can lead to shifts in weed species with an increase in some winter annual [e.g. narrowleaf hawksbeard (*Crepis tectorum* L.)] and perennial [e.g. dandelion (*Taraxacum officinale* Weber in Wiggers)] weeds being documented in western Canada[3,10]. Due to the protective stubble and associated increased snow cover in no-till systems, some annual species such as false cleavers (*Galium spurium* L.) have adopted a winter annual growth habit[10].

When no-till is first adopted, given additional moisture and weed seeds at the soil surface, as well as management adjustments to a new system, weed densities may increase for the first few years relative to weed densities in tilled systems. However, after 5 to 10 years of no-till, overall weed densities are often lower than in tilled systems[2]. Over time, the elimination of tillage, and the associated costs of equipment and fuel, helps producers experience improved net returns.

Weed seed mortality tends to be greater when weed seeds are left on the soil surface (seed predators, environmental extremes, physical damage) compared to when buried in the soil with tillage (Figure 1)[18]. Additionally, crop residues on the soil surface reduce seed-soil contact and inhibit weed germination and growth through physical suppression and/or allelopathic interactions. Weed seed dormancy, which allows weeds to persist in the soil seed bank for many years, is also reduced when weed seeds are not buried. Reduced weed densities in long-term no-till systems have contributed greatly to successful use of other integrated weed management (IWM) practices on the Canadian Prairies.

Figure 1. Inter-row soil surface environment in a juvenile barley crop direct-seeded into canola stubble (AAFC, Lacombe Research Centre). Weed seed predators have greater access to seeds left on the soil surface. Weed seedling germination and survival is often less successful in the high surface-residue conditions depicted here. Relatively undisturbed residues from the previous canola crop reserve soil moisture and favour rapid crop emergence and early growth. Photo credit: K. Neil Harker

Pre-seed glyphosate is widely utilized for weed control in no-till systems because it is highly efficacious and economical. An innovative approach recently adopted by many farmers is to apply glyphosate 3 to 5 days after seeding (instead of 1 week before seeding) to better enable crops to gain a competitive advantage over weeds. Residual herbicides can also be tank mixed with pre-seed glyphosate to provide a few weeks of residual weed control during critical periods of early crop-weed competition. Effective weed control with these pre-seed herbicides contributes to reduced in-crop weed densities and facilitates successful use of other integrated management practices.

## Competitive Variety Selection

It is well known that some crops are more competitive than others with weeds, but perhaps more consideration should be given to selecting competitive varieties within a crop species. Tall barley varieties are usually more competitive than semi-dwarf varieties[20,24]. Hulled compared with hulless barley (*Hordeum vulgare* L.) varieties compete better with weeds due to faster emergence and more vigorous early growth[19]. Leafed field pea (*Pisum sativum* L.) varieties are more competitive than semi-leafless varieties due to increased shading of weeds[14]. Initially, open pollinated canola (*Brassica napus* L.) varieties were much less competitive than cereals. This has recently changed with the introduction of competitive hybrid varieties. Hybrid canola is now at least as competitive as spring wheat (*Triticum aestivum* L.) and can rival barley. Crop competitive ability with weeds is a trait that needs to be seriously considered (in addition to disease resistance, yield, and quality characteristics) in breeding programs and when growers choose new varieties.

## Optimizing Crop Seeding Rate and Plant Density

Establishing a dense, uniformly distributed crop will increase its ability to suppress weeds. One of the easiest and most consistent methods to accomplish this goal is to simply increase crop seeding rates[5]. However, there is some concern about adopting increased seeding rates in the driest regions of the Canadian prairies because of concerns about excessive vegetative growth and crops running out of water before grain fill. We have rarely been able to document this outcome in our research and only at cereal densities above 450 plants/m$^2$; much higher than the 225-300 plants/m$^2$ that are being recommended. Tiller production in cereals is thought to compensate for low seeding rates but tillers are the first to die with drought stress. During the severe drought conditions of 2001 and 2002, farmers generally experienced similar or greater crop yields with higher than currently recommended seed rates, especially in no-till systems. In addition to weed suppression, higher crop seed rates result in earlier and more uniform maturity, decreased green seed content in canola, and more uniform kernel size in cereals. It is noteworthy that many organic farmers have doubled, or even tripled, crop seeding rate as a weed management tool.

The benefits of higher crop seeding rates will only be realized with proper seeding operations. Healthy crop seed is required to optimize germination and emergence. Choosing the correct seeding depth and speed of seeding according to seed size, soil type, soil moisture, and seeding equipment are important factors affecting emergence and early crop vigour. For example, preliminary research at Lacombe indicates that canola emergence is reduced approximately 30% when seeding depth and speed are increased from 1 cm and 4 mph to 4 cm and 7 mph, respectively (Figure 2).

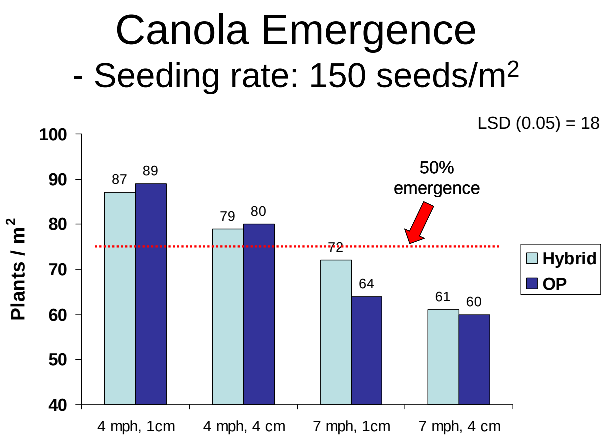


Figure 2. Canola emergence response to seeding depth and seeding speed. Hybrid cultivar = 71-45RR, Open pollinated cultivar

While it seems relatively apparent that decreasing row spacing should increase crop competition with weeds, there is little consistent evidence to support this conjecture when crops are already seeded in relatively narrow rows between 8” to 12” (20 to 30 cm).

Additionally, growth and competitive ability of many weed species is enhanced by higher soil nutrient levels.

Much research has gone into manipulating fertilizer timing and placement to reduce weed interference in crops. Spring compared with fall-applied fertilizer often reduces weed biomass and increases yield of spring-planted wheat, barley, canola and field pea[4,7]. An even more consistent approach to reduce weed growth and improve crop yield is to apply fertilizer in subsurface bands rather than surface broadcasting (Figure 3)[6]. No-till enhances the benefits of subsurface banded fertilizer because germinating weed seeds are concentrated on the soil surface away from banded fertilizer.

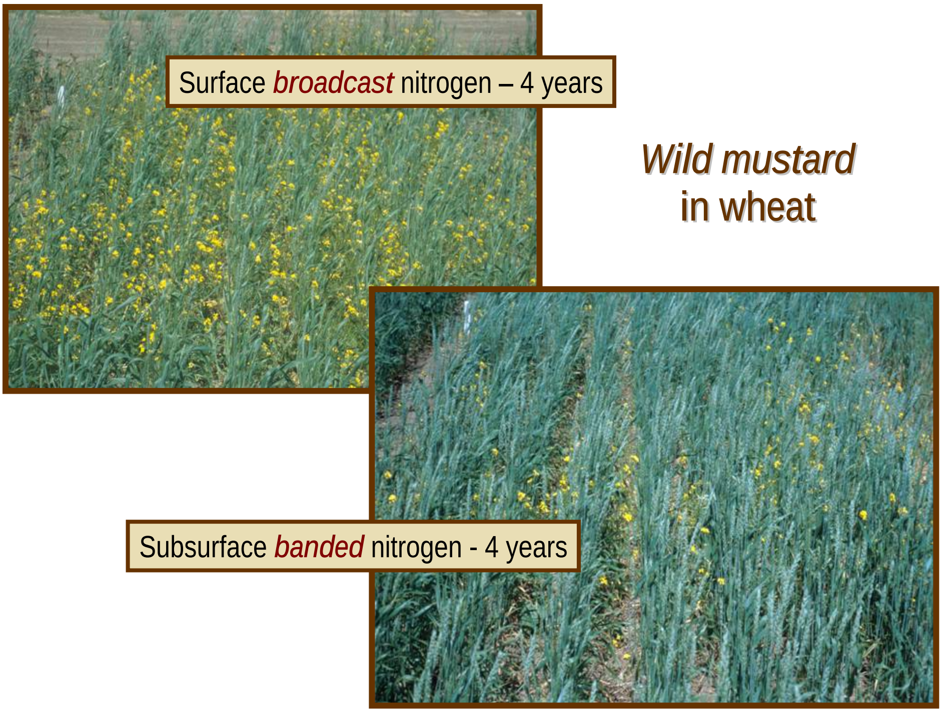


Figure 3. Wild mustard response to broadcast vs. banded N fertilizer applied in four consecutive years (AAFC, Lethbridge Research Centre).

## Silage, Green Manure and Cover Crops

Silage crops are harvested before many weeds produce mature seed, thus limiting viable seed return to the soil. Silage production for 2 to 3 consecutive years can be more effective than herbicides in reducing the weed seedbank[15]. Thus,
silage crops can be a good long-term management tool for most weeds but can be even a more valuable option when trying to control herbicide-resistant weed populations. The real key to delaying the occurrence of herbicide resistant weeds is to apply herbicides less often.

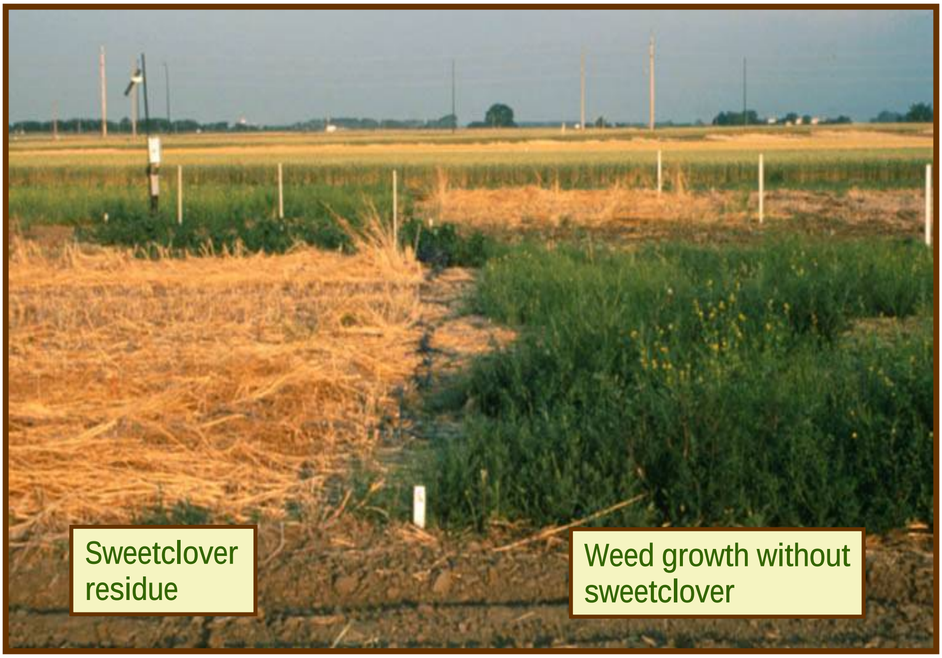


Figure 4. Sweetclover residues inhibiting weed growth due to surface mulch and release of allelochemicals. Photo was taken six weeks after terminating sweetclover growth (AAFC, Lethbridge Research Centre).

Green manure and cover crops are widely used by organic farmers but adoption by non-organic farmers is only just begining. Sweetclover (*Melilotus spp*.) in the drier regions and red clover (*Trifolium pratense* L.) in the wetter regions of the Canadian Prairies are the green manure crops of choice. In addition to their nitrogen fixing ability, both species are strong competitors with weeds and decaying sweetclover residues are known to release allelochemicals that inhibit weed growth (Figure 4). Winter rye (*Secale cereale* L.) is the main cereal cover crop utilized in Canada. Its vigorous growth suppresses weeds and decaying residues release weed-inhibiting allelochemicals.

## Single Components versus a Systems Approach

The weed management practices outlined above can be effective on their own, but far greater impact is realized when they are combined within a systems approach conducted over several years[1, 13].

Foxtail barley (*Hordeum jubatum* L.) is one weed species that became a greater problem with the adoption of no-till in brown and dark-brown soil zones of western Canada. Research showed that combining several factors such as crop rotation, higher crop seeding rates, sub-surface banded N fertilizer, and timely herbicide use in a multi-year approach gave excellent control of this species[8]. Adoption of an IWM system for foxtail barley was one of the first success stories and it occurred in part because the need was so great. New practices will be adopted when there is a perceived need and when those practices are effective and affordable.

Another multi-year no-till study conducted at Lethbridge, Lacombe and Scott (23 site-years of data) assessed the merits of combining several crop production practices to manage weeds in the context of full or reduced herbicide rates[4,7]. Factors included in the study were crop rotation, seed date, seed rate, fertilizer timing, and herbicide rate. Treatments were applied in four consecutive years to assess annual and cumulative effects. The combination of early seed date, higher crop seed rate, and spring-applied subsurface-banded fertilizer resulted in the most competitive cropping system within this study. 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. These IWM systems were consistent in performance, effective and economical[21].

In another multi-site study, use of a competitive hybrid canola variety, higher seeding rates, and early weed removal resulted in superior weed management and a 41% increase in canola yield compared with less-optimal agronomic practices[12]. The economics of adopting such practices were again shown to be positive[23].

Western Canadian crop producers spend approximately $500 million on wild oat herbicides every year. In an integrated crop management study conducted at four western Canada locations over five years, we compared wild oat management in optimal versus low management systems. The low management system was continuous, short-statured barley seeded at 200 seeds/$m^2$. The optimal management system was tall-statured barley seeded at 400 seeds/$m^2$ and rotated in alternate years with canola and field peas. In the spring of 2005, after five years of ¼ herbicide rates, wild oat emergence densities were 311 plants/$m^2$ in the low management treatment and 8 plants/$m^2$ in the optimal management treatment at Lacombe (Figure 5). After five years across all locations, wild oat populations and biomass were similar in systems with optimal management and ¼ herbicide rates to systems with low management with full herbicide rates. Barley yields in year five were often greater in the optimal system with ¼ herbicide rates than in the low management system with full herbicide rates. Weed control is more about crop management than herbicide application.

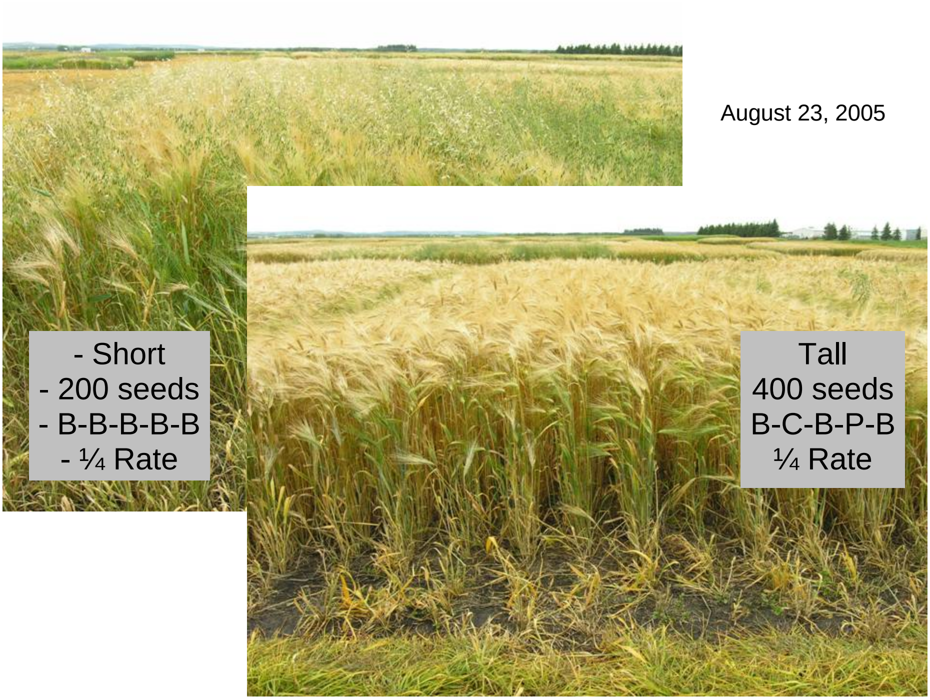


Figure 5. Barley with associated wild oat after five years of low (top) and optimal (bottom) management (AAFC, Lacombe Research Centre). Both plots received ¼ rates of recommended wild oat herbicides for five successive years (2001-2005). The low management system was continuous short-statured barley seeded at 200 seeds/$m^2$. The optimal management system was tall-statured barley seeded at 400 seeds/$m^2$ and rotated in alternate years with canola and field peas. Photo of Lacombe site in Harker et al. 2009 study.

Finally, weed management will not be successful if weeds and weed control are the exclusive focus[13]. For example, when crop health is compromised by nutrient deficiency, weed management will be compromised. When crop disease or insect pests above threshold levels are ignored, weed management will be reduced. When the crop is seeded too fast or too deep, weed management will suffer. Indeed, successful integrated cropping systems for weed management are highly dependent on crop health.

## Concluding Remarks

Much research is being conducted and progress is being made on developing biologically and economically sound integrated weed management systems. As technologies such as site-specific weed management (seeding rates as well as herbicides), variable-rate fertilizer application, or weed seed destruction in the combine become more practical, they can be employed by growers in integrated cropping systems. Useful weed management practices must be put together into workable systems at the farm level. Once viable systems are developed they must be demonstrated at the field level and a consistent message must be given by multiple people at multiple forums over multiple years. Patience is required by all involved as meaningful change is usually a slow process.

Sustainable production practices such as diversified rotations, higher crop seed rates, competitive varieties, sub-surface banded fertilizer, and silage or cover crops are slowly but surely being adopted by farmers. More importantly, farmers are devising viable systems that work on their individual farms. Despite these successes there is no room for complacency. There remains much work to be done by all members of the agricultural community to develop, refine, and facilitate adoption of these improved weed management and crop production systems.

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