Organic Agronomy Training

Dr. Martin Entz – University of Manitoba

Lesson 2 | Part 2

Tillage and Weed Control

Organic Agronomy Training

This training was developed and delivered by Martin Entz, PhD, Department of Plant Science, University of Manitoba. It is intended for private and public sector agronomists who want to respond to the growing demand from producers for more information about organic grain production. Grain farmers considering a transition to organic or current organic practitioners who want to learn the theory and latest science will also find the course valuable. The course was designed with the Prairies in mind, however agronomists in other ecoregions will learn universal principles of organic production.

The training consisted of five 75 minute live online sessions over two weeks in January 2023:

- January 5: Designing Cropping Systems with a Focus on Nutrient Management
- January 6: Crop Establishment and Seeding Systems, Tillage and Weed Control
- January 10: Pest Management with a Focus on Disease, Insects (and Weeds)
- January 12: Soil Management for Organic Production: Putting Theory into Practice
- January 13: Question & Answers

All course content (lesson recordings, presentations and notes) can be accessed on pivotandgrow.com.

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Lesson 2, Part 2: Tillage and Weed Control

In this lesson, we will discuss ways of knowing and controlling weeds. This discussion will be followed by descriptions of the various weed control options using tillage. [1]

Resources – Organic Weed Management

To learn more about organic weed management:

- Manage Weeds On Your Farm - SARE - free, downloadable book
- Steel in the Field - SARE - free, downloadable book
- *Organic Field Crop Handbook* available from Canadian Organic Growers (https://cog-shop.myshopify.com/products/organic-field-crop-handbook-3rd-edition).
- 37-minute podcast by Manitoba Organic Alliance - Brenda Frick, an expert on weeds in organic cropping, talks about practical and helpful tips for managing weeds in organic cropping. With host Scott Beaton, she discusses how to prevent and manage tough weeds like Canada thistle and bindweed. https://manitobaorganicalliance.com/podcasts/season-1-episode-4-managing-weeds-in-organic-crops/.
- Article in which Steve Snider, Alberta farmer and Lena Syrovy, University of Saskatchewan, talk about weed control and tillage at Three ways to manage tough weeds on organic farms - Alberta Farmer Express Written by Jennifer Blair. March 2017.
- Manitoba weed info: Weeds - Agriculture and Weed Management in Organic Crop Systems
- Brenda Frick, LIVING WITH WEEDS Putting Weeds into Ecological Context

What we need to know about weeds

It is important to understand the biology and growth habits of the most common weeds on the farm. Are they annuals, winter annuals or perennials? Do they propagate by seed production only, or also by **rhizomes**? How long will the seeds remain viable in the soil?

Knowing what weeds are common on your farm will help to determine what lessons can be learned and what management strategies might be effective against them. To learn more go to: Weed Characteristics.

[1] Much of the information in this lesson was prepared by Dr. Brenda Frick, University of Saskatchewan. We are grateful for Brenda's in-depth knowledge of weed management in organic systems on the Prairies. Other information comes from the experiences of many organic farmers in Manitoba and beyond. We acknowledge their significant contribution.

Voices from the Field: G+G Farms

"Weeds are not always our enemy. Some weeds can be considered as friends. They tell you the story of your soil health. The type of weeds that are growing indicate what's going on below the ground," Garry Johnson says. For example, Canada thistle may indicate soil compaction or a mineral deficiency.

Weed management

Prevention

Preventing weed problems is critical. The most significant source of new weed species on organic grain farms is contaminated crop seed. Care should be taken to select sources of seed (and livestock feed) that are free of the types of weeds that aren't currently on the farm.

To eradicate a weed infestation in its early stages, you can:

- pull weeds (particularly simple taprooted plants),
- dig up perennial plant colonies by the roots,
- use solarization - lay clear plastic over an infested area to raise soil temperatures and kill all roots or seeds in the upper layer of soil, or
- apply mulch - lay down a barrier, often impermeable, to new plant growth in order to starve new shoots.

Once weed-infested areas become larger, mowing and tillage become more practical control methods.

Note that not all mulch or solarization materials are permitted in certified organic crop production and the use of certain mulches have restrictions. Check with the certifying body and the Permitted Substances Lists of the Canadian Organic Standards to ensure a material is permitted before you use it. [2]

[2] According to the Permitted Standards Lists of the 2020 Canadian Organic Standards, "Mulch: Biological materials from organic sources are permitted (e.g., straw, leaves, grass clippings, hay, wool or untreated burlap). If organic materials are not commercially available, non-organic, non-genetically engineered sources may be used provided that prohibited substances have not been used on these materials for at least 60 days before harvest. Prohibited mulch material includes, but is not limited to, sawdust, wood chips, bark and shavings that is treated or processed with Formulants used in crop production aids or with substances, such as herbicides, preservatives and glues, not listed in Table 4.2 (Column 1 or 2). Newspaper and paper mulch are permitted; glossy paper and coloured ink are prohibited. Plastic mulches: Non-biodegradable and semi-biodegradable materials shall not be incorporated into the soil or left in the field to decompose. Use of polyvinyl chloride as plastic mulch or row cover is prohibited. Biodegradable mulches: 100% of biodegradable mulch films shall be derived from bio-based sources. Formulants or ingredients shall be listed in Table 4.2 (Column 1 or 2). Biodegradable polymers and Carbon Black from GE or petroleum sources are not permitted."

Sanitation refers to the practice of minimizing the movement of weeds to other parts of the farm. The primary activities of sanitation involve keeping equipment free of seeds or other reproductive parts of weeds, and ensuring that field boundaries and other non-crop areas are kept free of weeds that are capable of reproducing. The spread or re-introduction of perennial weeds, such as quackgrass or Canada thistle, as a result of rhizomes or roots on tillage equipment, is an example of how equipment cleaning could prevent future weed problems.

Voices from the Field: Upland Organics

Cody Straza and Allison Squire of Upland Organics have eliminated all fall tillage except for spot-tilling patches of Canada thistle. Their work on soil health has led to a decline in annual weeds, but they still have problems with perennial weeds. Allison has realized that the soil biology differs between weedy and non-weedy areas. Their goal is to alter the soil life of the weedy patches with the goal of minimizing the vigour of the weeds.

Crop rotation

Crop rotation is critical for weed, disease and insect management. To design a crop rotation to provide weed control, consider the following:

- Alternating competitive crops, such as alfalfa or barley, with less competitive crops, such as flax or lentils. The most competitive crop is fall rye, followed closely by winter wheat, barley, oats, spring wheat, mustard, canola, peas, flax and, finally, low-lying crops such as lentil, chickpea and dry beans. Hemp is very competitive with weeds when it is seeded into warm soils.
- Alternating between broadleaf and grass crops in the rotation. Keep in mind that weeds are more competitive with crops to which they are most closely related.
- Varying seeding dates to prevent weeds from adapting to static management practices. See more information about this below. Alternating winter and summer crops within the rotation is the ultimate way to diversify seeding times.
- Using weed-suppressing cover crops, such as fall rye or sweetclover, wherever possible. (Learn more about this here).

Voices from the Field: Marshall Farms

"We're always looking for the fastest growing crops and ones that can compete with weeds, Larry Marshall explains. "Hands down, hemp is the best crop we've ever had."

As a pioneer in organic hemp (and a current director of the Canadian Hemp Trade Alliance), he has provided others with information based on his own experience.

"There are so many different varieties. Get the best one for your area," he advises. "One tall enough to compete with weeds but not so tall that you can't handle it."

Hemp is sensitive to daylength: the longer the days, the taller it grows. At their farm in northern Saskatchewan, they use a dwarf variety that grows 5-6 feet tall. Around Regina, 300-400 miles south, that variety grows two feet tall.

Having perennial forages in the crop rotation is the most effective way to control many problem weeds. The table below shows weed counts on 52 commercial conventional fields across Manitoba.[3] The 24 "C.C." fields were in continuous cereal production while the 28 "A.C." fields had 3-5 years of alfalfa followed by cereals. The scientists counted the weeds in spring, after crop emergence but before any in-crop herbicide application.

TABLE 2. Density, frequency, uniformity, and relative abundance values for *Medicago sativa*/cereal fields (A.C. Fields) and continuous cereal fields (C.C. Fields) in 1993.[a]

Species common name	Relative abundance		Density		Level of significance	Frequency		Uniformity	
	C.C. Fields	A.C. Fields	C.C. Fields	A.C. Fields	Log scale	C.C. Fields	A.C. Fields	C.C. Fields	A.C. Fields
			plants m^{-2}			%			
Wild oat	53.03	13.14	27.15	1.26	≤ 0.05	83.33	46.43	54.79	11.43
Green foxtail	44.63	23.86	22.32	2.66	≤ 0.01	75.00	64.29	45.83	26.25
Wild mustard	31.68	32.43	10.63	7.90	≤ 0.10	79.17	57.14	38.13	22.68
Wild buckwheat	31.38	39.71	9.15	6.10	NS	83.33	85.71	40.00	42.14
Annual smartweed spp.	20.85	16.59	6.78	1.80	NS	66.67	57.14	20.21	13.75
Quackgrass	19.79	19.09	7.58	3.70	NS	50.00	42.86	20.83	15.54
Common lambsquarters	15.47	28.99	3.16	5.70	NS	54.17	57.14	18.75	25.71
Canada thistle	13.69	2.52	2.33	0.27	≤ 0.01	54.17	7.14	15.63	2.68
Catchweed bedstraw	12.71	6.76	6.40	1.50	NS	20.83	10.71	13.13	6.07
Field pennycress	7.28	17.86	0.49	3.00	NS	41.67	46.43	5.63	14.46
Dandelion	1.98	28.34	0.08	4.35	≤ 0.01	12.50	64.29	1.25	28.93
Volunteer alfalfa	0.59	39.56	0.03	6.38	≤ 0.01	4.17	85.71	0.21	40.18
Redroot pigweed	3.55	5.32	0.26	0.51	NS	20.83	17.86	2.50	5.00
Perennial sowthistle	5.95	1.48	0.76	0.11	< 0.10	29.17	7.14	5.42	0.71
Persian darnel	4.54	0.00	2.88	0.00	NS	4.17	0.00	4.17	0.00

[a] Weed and crop species with (1) nonsignificant differences between field types or (2) population densities less than 1 m^{-2} are not included in this table.

[3] Ominski, P.D., Entz, M.H. and Kenkel, N., 1999. Weed suppression by Medicago sativa in subsequent cereal crops: a comparative survey. *Weed Science*, pp.282-290.

The weed density columns show that having perennial forages in the crop rotation significantly reduced Canada thistle and wild oat. Reductions in density were also observed for wild oat, green foxtail, smartweed, quackgrass, perennial sowthistle and other weeds.

How to increase the competitive advantage of a crop:

To increase the competitive advantage of a crop, consider:

- Seeding date
- Seeding rates and spacing
- Soil fertility
- Variety choice
- Using cover crops as nurse crops

Seeding date

The timing of weed emergence relative to crop emergence is critical. For example, for every day that wild oats emerge before a spring wheat or barley crop, yield losses increase by 3%. By the same logic, crop yield improves by 3% for each day wild oats emerge **after** the crop. At some point after the crop is well established, newly emerging weeds will not have a significant effect on crop yield. Growers can control the difference in emergence times of weeds and crops by adjusting the seeding date.

Seeding date is a major factor determining which weeds grow in a field. **For cereals, early seeding has consistently produced the most competitive crops with the highest yields.** However, as a general rule, non-cereal crops, such as flax, pulses, buckwheat and hemp, should not be seeded into cool soil. Under such conditions, the seedlings of these crops will be slow to develop and prone to disease, and will therefore not be competitive with weeds.

Voices from the Field: G+G Farms

Garry learned from his father, Ken, and uncle Norman, who in turn learned from their father, Frederik Johnson, an immigrant from Norway. He describes all three of them as "true stewards of the land."

*"They passed on the old ideas, like that the **soil will tell you what you need to know**, and to look at the indicators of nature," Garry says. For example, in the spring, they waited*

until the wild poplars budded out and then looked for wild oats. Once the wild oats emerged, they knew the soil was warm enough for seeding.

The weed that poses the greatest threat to their yields is wild oats. To control them, they wait for the wild oats to emerge before seeding so they can control the weed with the shovels on the air seeders.

But if you seed before the wild oats emerge, you will end up with a field infested with wild oats – something the Johnsons have learned the hard way. "It's always best if you can learn from your mistakes," Garry adds.

Delayed seeding can be an effective weed control practice by allowing for tillage before seeding. Tillage should begin early in an attempt to warm the soil and stimulate weed growth. The number of tillage operations that can be performed will depend on the soil type, moisture conditions, erosion concerns and the specific crop. Pre-emergent tillage can, for example, lead to greater than 80% wild oat control. Early-germinating broadleaf weeds, such as wild buckwheat and certain mustard species, may also be controlled using this approach. Delayed seeding may lead to better weed control, but producers need to consider the risk of delayed crop maturation and a potential reduction in crop quality and/or yield.

Vary seeding dates: by designing a crop rotation that uses different seeding dates from year to year, farmers can limit the ability of any one particular weed species to adapt and become problematic. Early-seeded crops should be well established before species like green foxtail emerge. Delayed seeding will allow, for example, the largest flush of wild oats to occur, providing an opportunity for tillage control before seeding. For optimal germination, green foxtail prefers higher soil temperatures than most cereals, while wild oats germinates well in cool soils.

Planting winter crops, such as fall rye or winter wheat, will help control spring annual weeds since they generally out-compete spring annual weeds. But these crops will become vulnerable to winter annual weeds like stinkweed, shepherd's-purse and flixweed. The fact that such fall-seeded crops are harvested early provides an opportunity to conduct a tillage program which will also help manage perennial weeds.

Should seeding be done early, before the flush of weeds in the spring, or should it be done after most weeds have germinated? Most organic farmers recommend to seed either very early or very late – not during the middle of the flush period.

Voices from the Field: Pristine Prairie Organics

"Unless your fields are prepared and in good shape, don't seed anything, because if you're organic, you don't get a chance to fix anything," suggests Bryce Lobreau of Pristine Prairie Organics.

If it's too late to seed or a field is weedy, "you might as well just change the plan and put a cover crop in. I've learned that myself the hard way.

"It's a different mindset if you're coming from a commodity setting to an organic setting. You can't cut corners. If you've got some weed patches and think you'll just seed through those, it'll be a disaster," Bryce says.

Seeding rate and spacing

Increasing seeding rates 20-50% above normal can increase the competitive ability of most crops. Increased seeding rates should also be used where either post-seeding or post-emergence tillage is planned to help compensate for any damage caused by the in-crop tillage. However, under certain environmental conditions, higher seeding rates may increase the disease incidence and result in higher lodging losses. Some Canadian prairie organic farmers are doubling seeding rates of wheat and other cereals and finding that this improves weed control.

Can large seed size compensate for deep seeding in organic barley and oat production?

"Greater seeding depths are often used in organic production to compensate for drier soil conditions caused by pre-seeding tillage. We hypothesized that reduced crop performance from deeper seeding could be compensated through larger seed. Field experiments were conducted in Carman, Manitoba, Canada in 2015 and 2016. Barley (*Hordeum vulgare*) and oat (*Avena sativa*) seed lots were sieved using standard industry sieves (from 0.08cm to >0.32cm x 1.91cm in barley seed lots and from 0.08cm to > 0.28cm x 1.91cm for the seed lots of oats) and classified into small, medium and large seed sizes for each seed lot. The proportion of small, medium and large seeds varied depending on farmer seed lot.

"Seed lots were sown at shallow (2.5 cm) and deep (6.4 cm) depths in organic fields. Deeper seeding and use of small seed size resulted in decreased grain yield and increased weed biomass. This trend occurred in both years, but was only significant in 2015. No seed size by seeding depth interactions were observed for crop emergence, weed biomass, grain yield or dockage for oat or barley over the 2 year study. In two instances, crop biomass was greater with larger compared with smaller seed at shallow seeding depths. This research indicated that large seed did not compensate for lower crop productivity and higher weed biomass owing to deep seeding, but that large seed and shallow seeding independently led to more positive outcomes for organic barley and oat production….

"Using larger seeds means using a larger volume of seed per unit area of land during planting. One question therefore regards the economics of planting a larger volume of seed compared with a smaller volume of seed. Results from our study could be used to test the economic implication of increasing seed volume per hectare through the use of larger seeds. For example with barley, an investment in an extra 65 or 43 kg/ha of seed (2015 and 2016, respectively) resulted in a grain yield increase of 871 and 339 kg/ha for the two years. For oats, an investment of an extra 56 and 47 kg ha of seed (2015 and 2016, respectively) resulted in grain yield increases of 607 and 277 kg/ha for the two years. **Therefore, averaged across years and crops, our results show that for each 1 kg/ha invested in seed, the return was 10 kg/ha of grain; a 10 to 1 return on investment.**[4]"

[4] Stanley, K.A. and Entz, M.H., 2019. Can large seed size compensate for deep seeding in organic barley (Hordeum vulgare) and oat (Avena sativa) production? An assessment of farm-saved seed. Organic Agriculture, 9(4), pp.373-381.

Using narrow row spacing in cereal, pulse and most oilseed crops generally offers the best competitive advantage against weeds. From a crop-weed perspective, any system that places seeds equal distances apart in all directions is the ideal arrangement. Less competitive crops, such as lentils, will tend to benefit most from narrow rows.

Photo credit: Brenda Frick

Intercropping

Dr. Martin Entz and his team have recently conducted an intercropping study with organic peas.[5] Because field peas are poor competitors with weeds, organic pea production can be challenging. They experimented with using peas seeded at a full seeding rate along with three intercrop partners – barley, oats and mustard. The intercrops reduced weed biomass 17% to 44% with barley and oats being more suppressive than mustard.

The study's economic analysis considered the cost of production, pea yield loss from intercropping and the cost of separating peas from the different intercrops. Results showed that under low weed pressure (1150 kg/ha weed biomass at maturity) and earlier seeding, oat intercrops reduced net return. However, under weedy conditions (2649 kg/ha weed biomass) and later seeding, field pea-oat intercrops significantly increased net return.

Soil fertility

The level of soil fertility changes the relative competitiveness between the crop and weeds. At Glenlea, MB, problems with Canada thistle are most severe in the P-deficient system. Where manure is added regularly to supply P, thistle is much less of a problem. In organic soybean production in Manitoba, it was observed that the greatest factor determining crop yield was soil N status at time of soybean planting. When levels of soil

[5] Bailey-Elkin, W., Carkner, M. and Entz, M.H., 2021. Intercropping organic field peas with barley, oats, and mustard improves weed control but has variable effects on grain yield and net returns. Canadian Journal of Plant Science, pp.1-14.

nitrogen were low, organic soybeans had a competitive advantage over weeds because the soybean plants could supply their own N. But as soil N increased, soybean grain yield decreased.[6]

Variety choice

Varieties that achieve canopy closure early or have a more competitive architecture (taller and/or have more tillers) are more competitive. For example, semi-dwarf cereal varieties are less competitive than taller lines. Studies have found that using semi-dwarf winter wheat varieties resulted in a 14-30% greater yield reduction from downy brome, compared to taller cultivars.

Voices from the Field: G+G Farms

In a research trial, Garry and Geri Johnson seeded AAC Oravena, an oat variety developed specifically for organic production. They were greatly impressed and are growing 300 acres of Oravena for seed in 2022.

"Oravena had very strong germination and it covered the ground very quickly," Garry says. "Unfortunately, I don't think we've seen it in its full potential [given the drought] but it has the potential to be a very good milling oat."

Garry recalls a talk Dr. Martin Entz gave 25 years ago about wheat varieties. "Of the 25-30 most common varieties, he said only three would work well in organic agronomic conditions and one of those will be a shining star."

Since then, more varieties have been developed for organic production, such as AAC Kingsore oat. This variety provides higher yields than AAC Oravena but lower levels of beta-glucan, the soluble fibre that gives oats its heart health designation. However, the vast majority of seeds are developed for non-organic production.

"The seed is the most important thing," Garry says. "If you don't have a good solid seed that's willing to participate in your agronomic environment, you have nothing."

Cover crops

To help small-seeded crops, such as forages, become established, farmers can use a nurse crop to help control weeds. For example, oats seeded at a reduced seeding rate

[6] Carkner, M.K. and Entz, M.H., 2017. Growing environment contributes more to soybean yield than cultivar under organic management. *Field Crops Research*, *207*, pp.42-51.

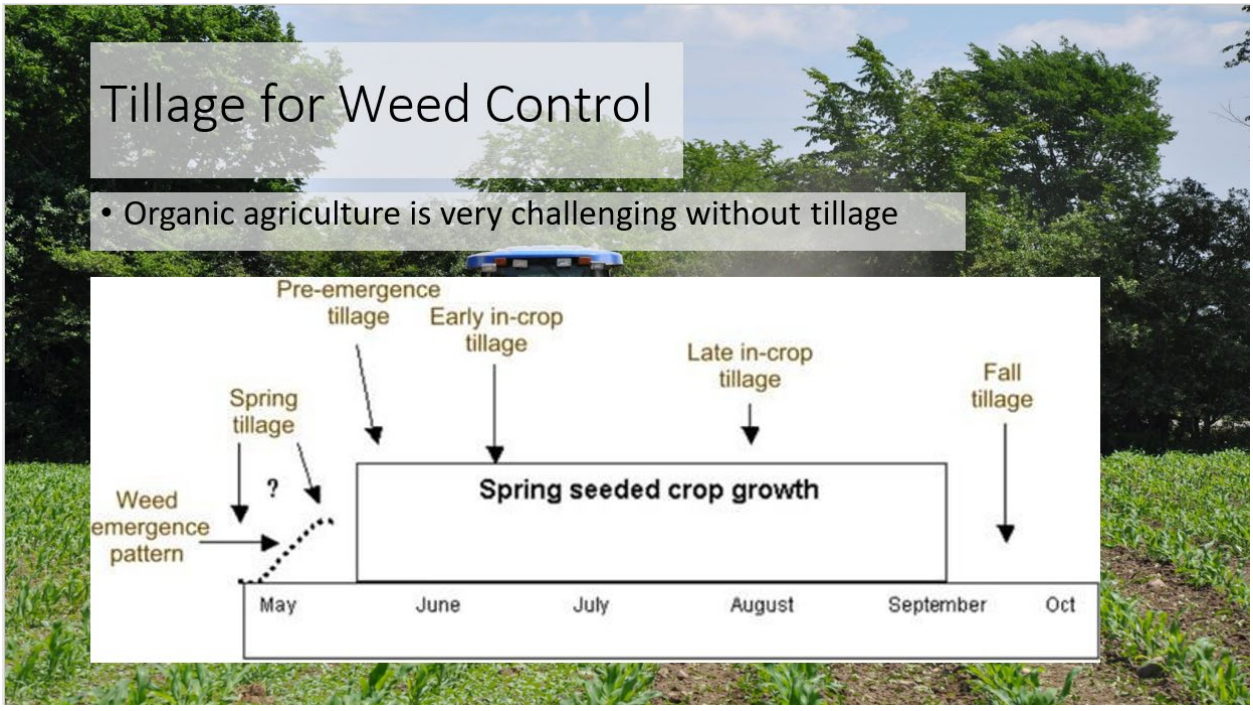
act as a nurse crop for alfalfa or clover. For details on the many ways to use cover crops to control weeds, check out Module 4 of the Green Manure Tool Kit here.

Tillage

Tillage options for weed management in organic agriculture on the Prairies

Caution: Extensive tillage should always be approached with caution. It can create serious soil erosion and soil health problems, particularly if it is done on a large area. Where soil erosion is a problem, tillage should be integrated with other methods to protect the soil.

The two main purposes of tillage in organic systems are controlling weeds and incorporating green manure legumes and other cover crops.
Secondary uses of tillage include seedbed preparation and incorporation of crop residues; however, these have become less critical due to new equipment such as no-till drills.



Voices from the Field: Mill Creek Organics

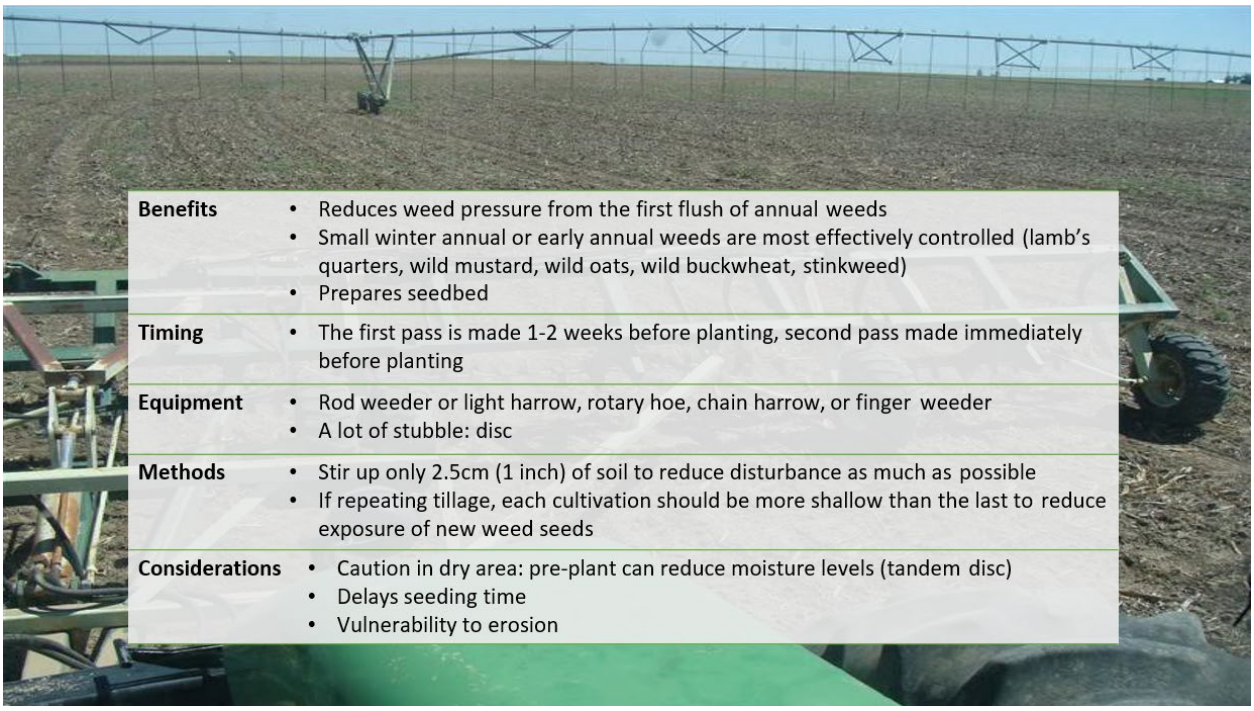
Alex Boersch of Mill Creek Organics has reseeded crops that had poor establishment or were weedy.

"We've learned the hard way," he states, ***"if you think a field is mediocre, do not hesitate to take it out and seed something else****. We found that, compared to conventional, there's less of a yield loss to seeding late in organic production. If I see there's too much wild oats coming, I won't hesitate to take it out and start over again, even if that means seeding in June."*

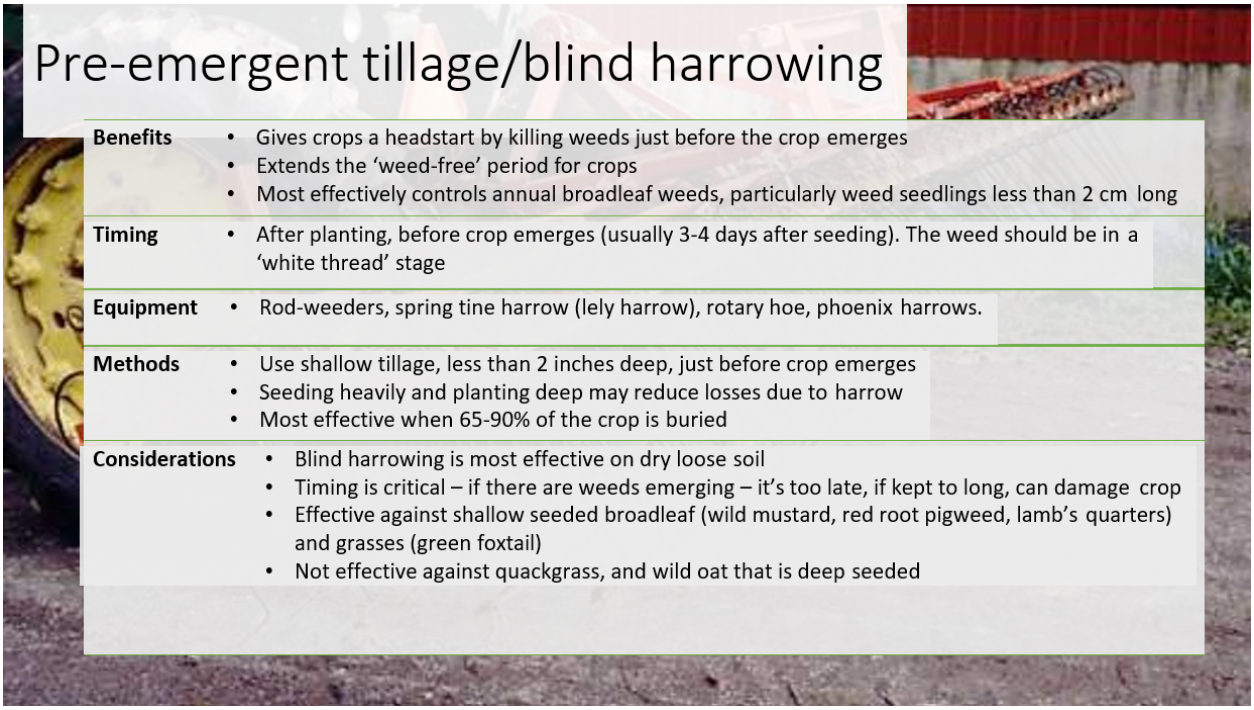
Tillage

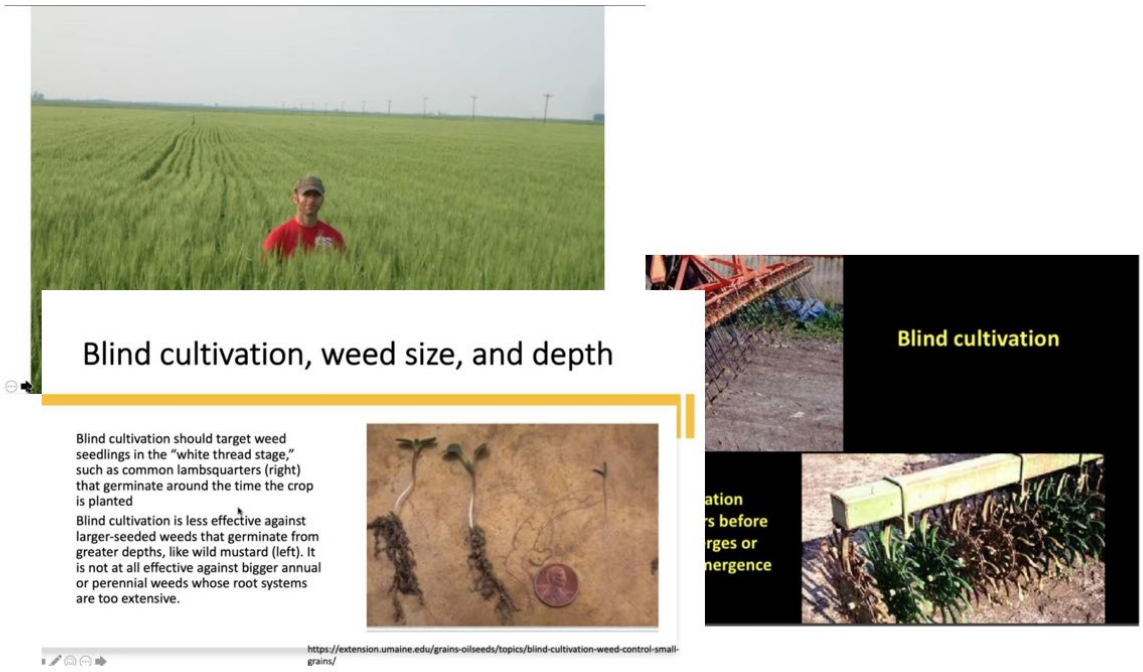
Pre-seeding tillage is used to prepare the seedbed to (1) control weeds that have germinated prior to seeding and (2) allow seeding to occur at a uniform depth.

Although having multiple tillage operations before seeding is generally discouraged because this can reduce soil moisture levels, leave the soil vulnerable to erosion and reduce overall soil health, if a number of pre-seeding tillage operations are planned, the first operation should be the deepest, with each successive one shallower. The first operation can aerate and warm the soil, or in many cases, expose small weed seeds to light in order to stimulate weed growth. The following operations should destroy weed growth while conserving as much soil moisture as possible. The loss of soil moisture due to tillage can be a critical problem, hindering successful crop establishment. Delayed seeding can also cause difficulties in areas with short growing seasons. It is important to balance these negative aspects against the advantages of weed control.

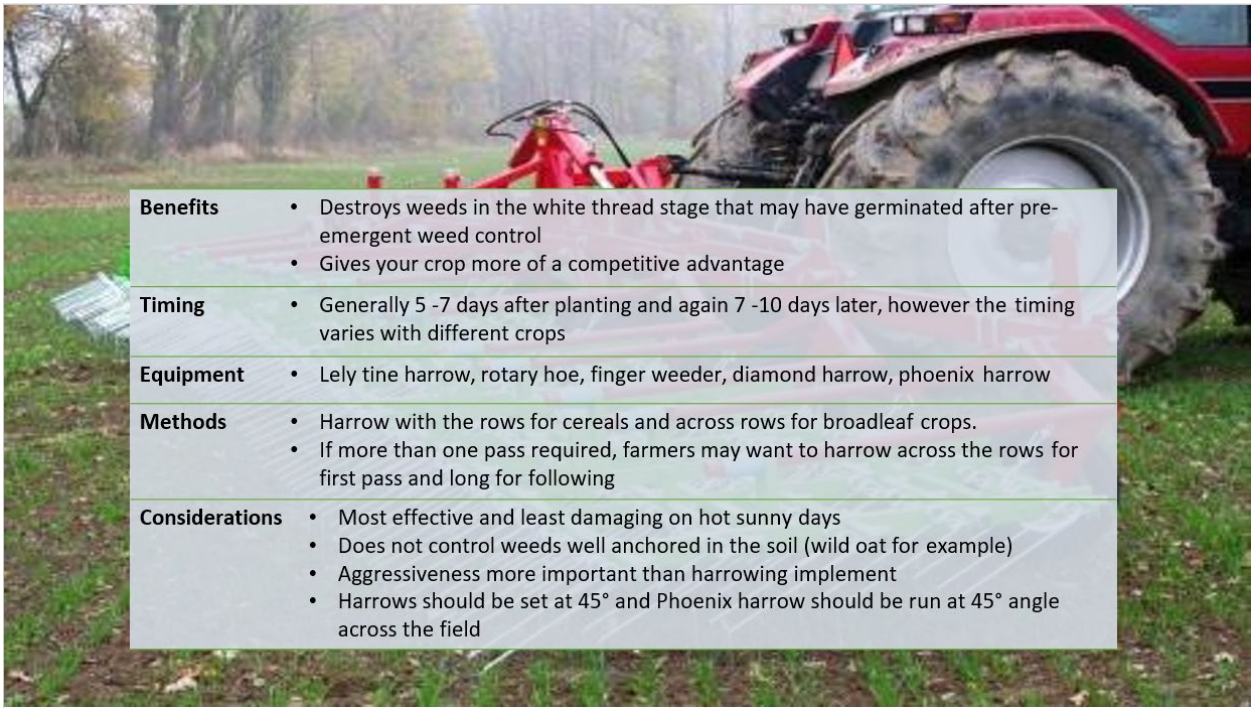


Pre-emergent tillage (blind cultivation) is conducted after seeding but before or just shortly after the crop emerges. It can be done by harrowing, rotary hoeing or using a rod-weeder. Best results will be obtained on a warm, sunny day when the soil surface is dry.





Post-emergence tillage may be done on weeds that emerge shortly after the crop emerges. This can be done with a harrow or rotary hoe. This provides good control of small-seeded species, such as green foxtail, lamb's-quarters and redroot pigweed, which usually emerge from shallow depths.



Benefits	• Destroys weeds in the white thread stage that may have germinated after pre-emergent weed control • Gives your crop more of a competitive advantage
Timing	• Generally 5 -7 days after planting and again 7 -10 days later, however the timing varies with different crops
Equipment	• Lely tine harrow, rotary hoe, finger weeder, diamond harrow, phoenix harrow
Methods	• Harrow with the rows for cereals and across rows for broadleaf crops. • If more than one pass required, farmers may want to harrow across the rows for first pass and long for following
Considerations	• Most effective and least damaging on hot sunny days • Does not control weeds well anchored in the soil (wild oat for example) • Aggressiveness more important than harrowing implement • Harrows should be set at 45° and Phoenix harrow should be run at 45° angle across the field

The effectiveness of post-emergence tillage depends on many factors:

- competitive ability of the crop,
- seeding depth,
- crop stage,
- weather and soil conditions, and
- implement and tractor speed.

A certain amount of crop damage is likely to occur; therefore, seeding rates should be increased to compensate for the damage. Wild oats can germinate from deep in the soil and post-emergence tillage is rarely effective in its control. A field inspection of weeds and the depth from which they are emerging should be done prior to any post-emergent tillage.

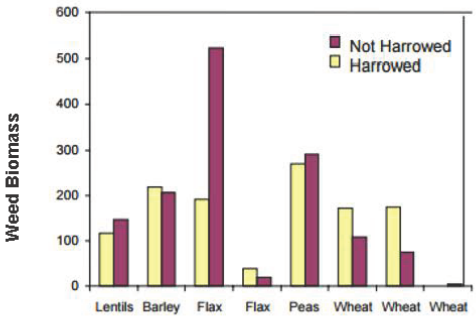
Post-emergence tillage is most successful when soil surface conditions are dry, and the weather is warm and windy. It is generally recommended that the harrowing operation should be in the direction of the rows. However, recent research indicates that the direction is not as important as once thought.

This technique should only be considered for use during the following stages of crop development:

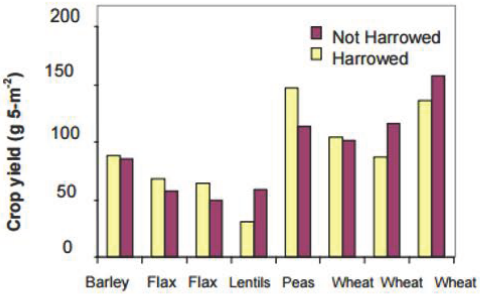
- Wheat - From the two-to four-leaf stage.
- Barley - From the two-to four-leaf stage (before tillering). Barley is more sensitive than wheat.
- Oats – Some research has shown oats to be more susceptible than wheat or barley to damage, however recent work in Saskatchewan and Europe demonstrated that oats have good tolerance to post-emergent harrowing. Oats at the 5-leaf stage appear more tolerant; younger seedlings are quite susceptible to harrowing.
- Sunflower - Safe up to the six-leaf stage. Harrow across the rows. Adjust the seeding rate to make up for the approximately 5,000 plants/acre that will be lost each time the crop is harrowed.
- Faba bean - Harrow across the rows when the crop is 5-15 cm tall and the plants are dry.
- Lentils, Field peas - Harrow in the seedling stage (no more than 10 cm tall). The crop must be dry to minimize the spread of disease. Use tine harrows only. Lentils are more sensitive to damage than peas.
- Hemp – Hemp agronomists do not recommend post-emergence tillage for hemp because the crop is very sensitive to disturbance and mechanical damage in the early stages of growth. Hemp is very sensitive until 30 cm tall and then takes off. If there is significant weed pressure before this, growers will need to replant or be set up with inter-row cultivation.

Effectiveness

- University of Saskatchewan worked with organic farms to evaluate
  - How effective harrowing was on certain crops



Weed biomass in harrowed and unharrowed fields for several crops, 2005



Crop yield for harrowed and unharrowed fields for several crops, 2005

Frick, 2005

Samurai Weed-Eater

- Jeff Moyer at the Rodale Institute made modifications to his Rotary Hoe
- Chains attached to the back roll roots onto the soil surface to help dry them out in wetter conditions

Seeding cover crops with in-crop tillage

When the crop is at the 2-leaf to 4-leaf stage, there is an opportunity to harrow in cover crops. Seeding at this time means the cover crop will pose less competition to the main crop. Some farmers have attached weeding harrows to air-seeding units.

Dr. Martin Entz and his colleagues have studied the new Einböck rotation harrow and camera-guided weed control.[7] They concluded:

- The mechanical treatments resulted in significantly less weed biomass (in only wide-row production) and significantly more crop biomass (in both narrow- and wide-row production) compared to the weedy control.
- Dry bean yield was increased compared with the weedy control with mechanical treatments in all cases, though yields were similar to the full herbicide treatment only for the 2X enhanced cultivation in wide-row production.
- The one-time study demonstrated the potential of adding finger weeders to camera-guided inter-row cultivation in wide-row bean production. A companion study demonstrated high tolerance of dry beans to the Einböck rotary weeder.

Find out more about seeding cover crops and using cover crops to control weeds in Modules 3 and 4 of the Green Manure Tool Kit.

Voices from the Field: Haywire Farms

At Haywire Farms, the hard red spring is underseeded with cover crops at a cost of about $10-$15/acre (seeding rate: 2-2.5lbs/ac). At first, the farmers seeded cover crops with an air seeder set at 1⁄2-inch deep a few days after wheat. Lately, they have been using post-emergent harrowing before broadcasting phacelia and Dutch white clover and harrowing again three or four days later. After swathing the wheat, the cover crops take off. The clover fixes nitrogen and the phacelia improves the soil.

Row-crop tillage

Up until recently, row-crop tillage was practiced only on wide-row production systems for crops such as dry beans, corn, potatoes and vegetables. With the development of camera-guidance, inter-row cultivation is now possible in narrow-row crops such as wheat, barley, flax, hemp and peas. While inter-row tillage does a good job of controlling weeds between the rows, the weeds growing in the rows (e.g., wild oats and wild mustard) may just compensate and end up producing just as much biomass and seed as areas that were not tilled.

[7] Stanley, K.A. and Entz, M.H., 2022. New tools for mechanical weed control in low-input dry bean (Phaseolus vulgaris) production. Canadian Journal of Plant Science.

Because tillage can stimulate weed seeds to germinate, several passes through the field may be necessary to manage the resulting flushes. Seeding and tillage passes need to be highly accurate to prevent damage to the crop.

Row Crop Tillage

Voices from the Field: Penny Lane Organic Farms

Voices from the On Penny Lane Organic Farms, Stewart Wells and Terry Toews control annual weeds in organic cereals and pulses using a camera-guided cultivator with four-inch sweeps that tills the soil between crop rows (which are nine inches apart). By controlling weeds throughout the season, they can reduce the number of weeds that mature. This cuts down on the weed seedbank and conserves a lot of water. On the test plots Stewart has established around the farm, he's noticed that since using the new cultivator, wild oat numbers are "way down and the crops look very clean."

It is important in row-crop systems for tillage equipment to match seeding equipment widths or for tillage implements to be a simple fraction (i.e., 1/2, 1/3 or 1/4) of the seeder so that rows remain constant. Row-crop tillage equipment can be quite specialized with shrouds to protect the crop and sensors to make fine adjustments to the path of the implement. This allows for tillage as close to the row as possible without damage to the crop.

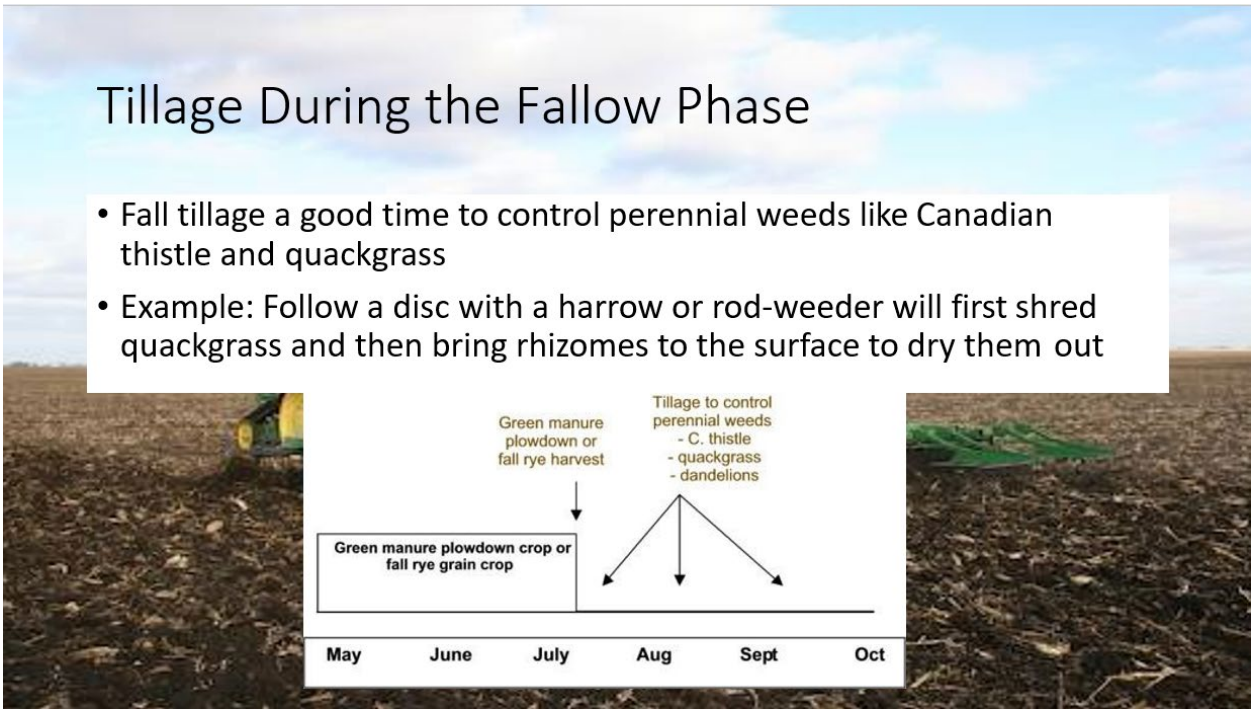
In Row Tillage

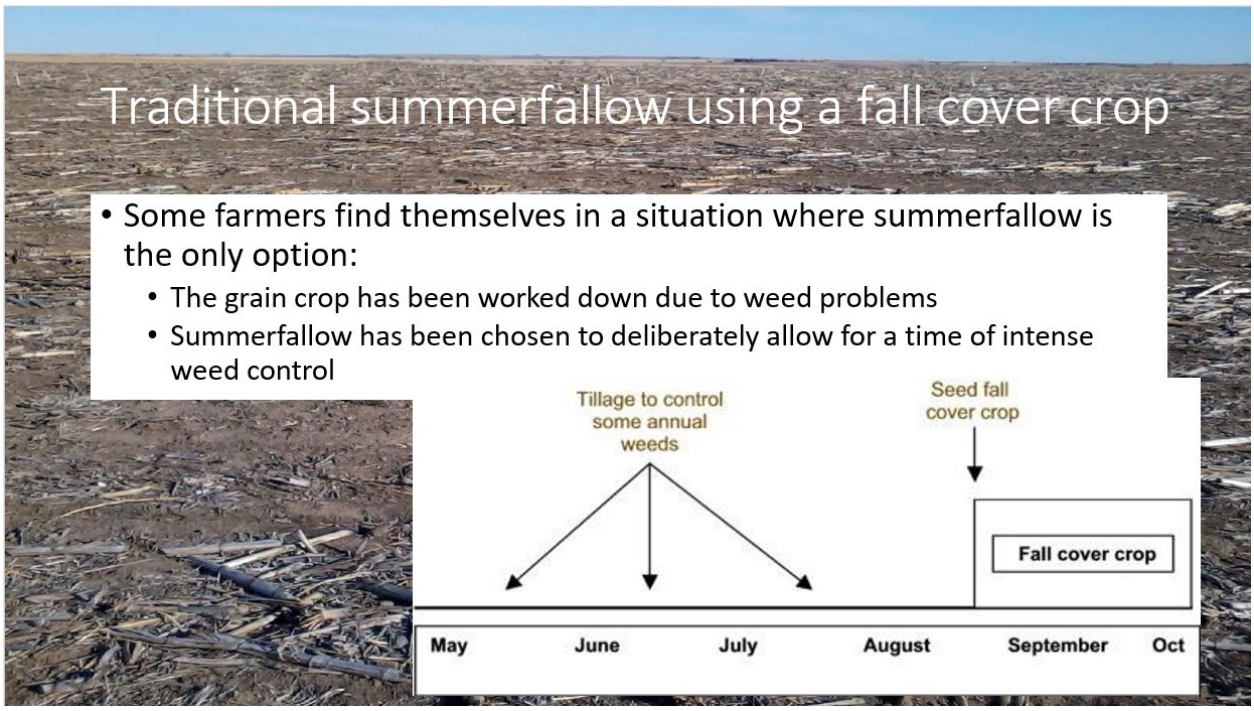
Post-harvest tillage

Post-harvest tillage is effective in controlling winter annual and biennial weeds. Tillage should be shallow (less than 10 cm deep) to avoid burying weed seeds in the soil – unless fields are plowed once every 7-10 years. Quackgrass and Canada thistle may be better controlled if the tillage operation is soon followed by freezing temperatures.

Summerfallow tillage

Summerfallow tillage is particularly effective for the control of perennials such as Canada thistle, quackgrass, sow thistle and field bindweed. If these weeds occur in patches, the patches should be worked separately to avoid spreading the weed over the entire field, as well as to avoid excessive and unnecessary tillage. Canada thistle is best left undisturbed until it reaches the green bud or early flower stage. The plant is weakest at this stage of growth, and thus most vulnerable to tillage. Once tillage begins, it should be repeated each time Canada thistle reaches the bud stage until August 1, then again each time the plant reaches a height of about 7.5 cm, until freeze-up. This approach will starve the root system and prevent it from forming any food reserves. It will enter winter in a very weakened state, and many plants will not survive.





L: wide blade cultivator used for summer fallow tillage; leaves residue on surface.
R: field bindweed.

For field bindweed, experiments conducted in Kansas found that repeated tillage 12 days after the emergence of new shoots controlled established plants within two fallow seasons.[8] Furthermore, the experiments also showed that this strategy required the fewest number of tillage operations over that two-year period to completely eliminate the perennial root. Note, however, that summer fallow with repeated tillage is not recommended because of its many negative effects on soil health. However, given that field bindweed is so challenging for organic farmers, one option is to isolate the bindweed patches and intensively till only in those areas.

[8] Research by Phillips and Timmons between 1936 and 1943.

Tillage to control quackgrass depends on physically damaging the weed's root system. In dry years, a cultivator with narrow spikes will be effective; this will drag roots and rhizomes to the surface where they will dry out and die. In wet years or wet areas, the first tillage operation should be with a disc implement that cuts the rhizomes into small pieces. Each of these smaller sections of rhizome will try to establish a new plant, which in turn has to be destroyed by subsequent tillage. New plant growth should not be allowed to get taller than 7.5 cm before being tilled. Tillage should not be any deeper than what is required to do an effective job. Shallow tillage will concentrate the rhizomes on or near the soil surface, resulting in a more uniform emergence and better control from future tillage operations.

Reducing tillage in the green manure year

Achieving optimum weed control in organic farming with less tillage is an important goal. How to Make Organic No-till Work for Field Crops in Southern Manitoba shows some of the research conducted on reduced tillage organic green manure management in Manitoba.

Other methods of weed control

Using an inter-row roller crimper for inter-row weed management. Details on this Australian invention can be found here.

Weed clipping involves cutting weed growth above short-stature crops. This does not usually prevent yield losses in the year of clipping, but reduces the production of seed and subsequent emergence of weeds in following years. Clipping should be done after weeds have flowered, but prior to seed set. Note that some indeterminate weeds may continue to flower below the cut line and produce significant amounts of seed. A video of clipping above organic lentils is shown here.

In-crop weed clipping

- Modifications need to be made to the swather to prevent
  - Residue build up over top of the main crop in windrows
  - Keep weed heads from being built-up on the table braces
- More effective catching wild mustard than wild oat

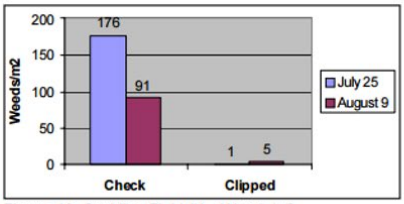


Figure 10. Spalding Field #1 - Weeds/m².

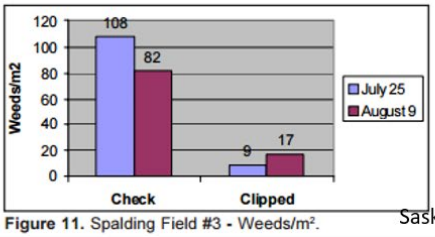


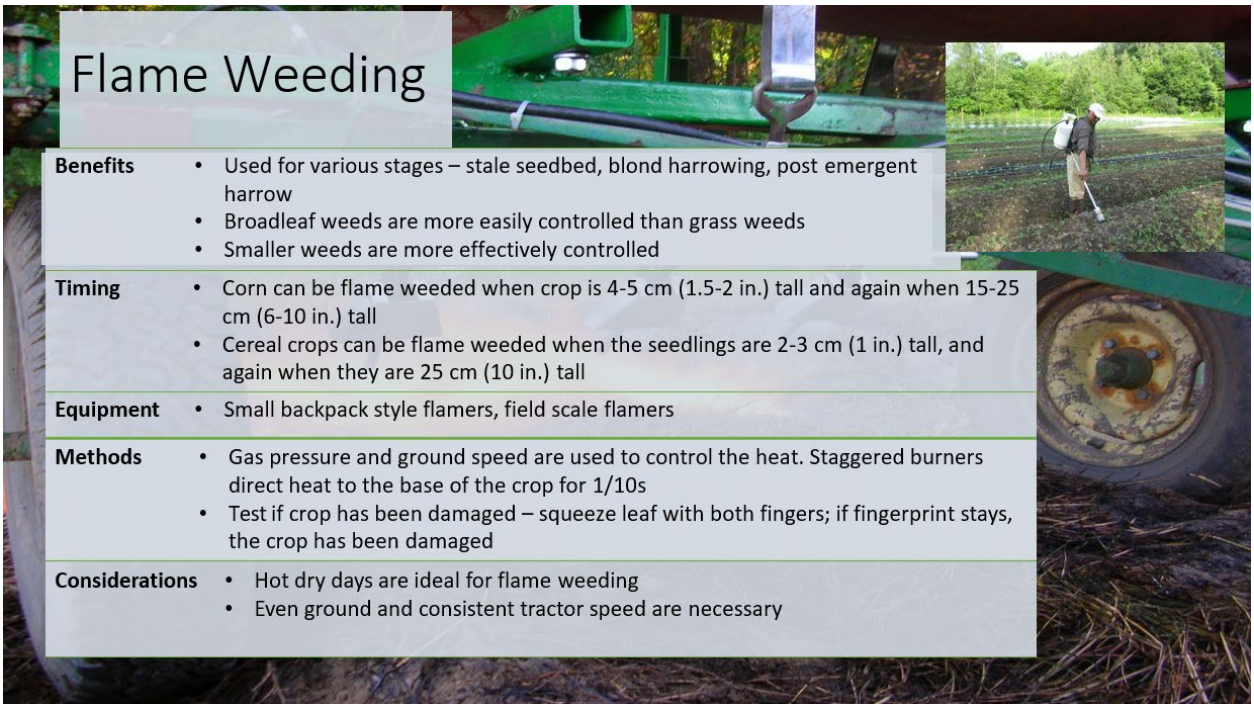
Figure 11. Spalding Field #3 - Weeds/m².

Saskatchewan Agr. 2001

Combcut is a Swedish machine that clips the hollow-stemmed weeds that grow in the canopy of cereal/grass crops. It is important to keep knives sharp to maintain cutting effectiveness. A video on the use of the combcut in Manitoba is here.

- In cereals, Combcut in crop canopy
- In pulses, Combcut must be (mostly) above canopy

Flaming is an effective way to kill small weeds. This technique is used as a pre-seed burnoff (literally) in small-scale production (e.g., vegetables) and also in row-cropped corn production. Search flaming and weed control in YouTube to find videos of the process.



Allelopathy occurs when chemicals released by one plant suppresses the germination or growth of another plant. Fall rye, for example, is an allelopathic plant. The living rye plants (including seedlings), as well as the rye crop residue, have been shown to inhibit a number of weed species, including wild oats. Research in Manitoba showed that fall rye seedlings (at the 4-leaf stage) produced toxins that reduced germination of broadleaved weeds.[9] For weed control, producers can seed fall rye in the fall and incorporate it the following spring (this will also help protect the soil over the winter).

Sweetclover is another allelopathic green manure crop. Also, surface residues of immature cereals appear to be particularly inhibitory to the emergence of annuals, including lamb's quarters, purslane and redroot pigweed.

Harvest management Reducing the number of weed seeds that are returned to the soil before and during harvesting will have a significant impact on weed pressure in future years. Many combine harvester models can be fitted with a chaff collection system that

[9] Flood, H. and M.H. Entz. 2009. Effects of wheat, triticale and rye plant extracts on germination of navy bean (*Phaseolus vulgaris*) and selected weed species. *Canadian Journal of Plant Science*. 89: 999-1002.

captures the material that is too small to be collected in the grain and is normally blown out the back of the combine as waste. This small lightweight material usually contains a large number of weed seeds. A chaff collector captures this material and either blows it into a trailing wagon or deposits it on top of a straw swath for baling later. Swathing enhances this process by cutting many weeds before they have shed seed and allowing them to dry so that seed is collected in the chaff rather than shattering to the ground prior to harvest, or at the cutter-bar.

More recently, "weed destructors" that fit onto combine harvesters have been developed. These machines collect the chaff and crush weeds seeds before depositing the chaff back onto the soil surface. The example below is from Germany.

But weeds are sneaky. Research in Western Australia shows that if chaff collectors and weed destructors are used, the weed population shifts and many weeds start dropping their seeds earlier in the season. This is an example of natural selection responding to a management practice.

Voices from the Field: Haywire Farms

"One of our weed management strategies is that every weed comes off the field with the harvest," explains Trevor Riehl of Haywire Farms, "whereas with the conventional mindset, your combine is your primary seed cleaner. It would be set to blow out all the light weeds and light kernels so the crop is 90% clean coming off the field."

In contrast, the Haywire farmers keep the combine fan turned "way down." Their crop might have 40% dockage but this is beneficial because they are harvesting weed seeds. An early step in their transition was buying a seed cleaner. This saves them having to transport grain to a seed cleaning plant. The screenings are fed to their grain-finished livestock.

Biological weed control

Classical biological control involves using a parasite or predator (such as a microorganism or insect) from the weed's place of origin to regulate a weed population. Classical biological control has good potential, and at present it has been most successful in rangeland. Nodding thistle (*Carduus nutans*) and scentless chamomile (*Matricaria perforatum*) are being controlled with good success, while there is moderate success in controlling leafy spurge (*Euphorbia esula*).

Terminating perennial crops in organic production

Organic options for terminating perennial crops, such as alfalfa, alfalfa/grass mixtures and grasses, include discing and plowing. New disc designs do a more thorough job of perennial crop termination. Plows, if used once every 7-10 years, have the advantage of burying weed seeds and crop residue deeper in the soil. Plowing more effectively buries weed seeds in sandy soil than in clay soil.[10]

After intensive tillage to terminate perennial crops, producers can seed cover crops to reduce the risk of soil erosion and help restore soil health.

[10] Swanton, C.J., Shrestha, A., Knezevic, S.Z., Roy, R.C. and Ball-Coelho, B.R., 2000. Influence of tillage type on vertical weed seedbank distribution in a sandy soil. *Canadian Journal of Plant Science*, *80*(2), pp.455-457.

Conservation Tillage	Description
Mulch tillage	• Crop residue is almost always present on the soil surface • 30% of crop resident covers the soil
Ridge Tillage	• Ridges are made and crop is planted into the ridges continuously each year • Crop residue on the ridges reduces erosion
Killed Mulches	• Plant material grown for purpose to being killed for mulch <u>Techniques:</u> • Mowing • Undercutting • Rolling • Weather killing
Living Mulches	• Plants that grow in the understory as well as before and after grain crops <u>Examples:</u> • Black medic • Undersown forage

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The Prairie Organic Development Fund (PODF) is an investment platform established to develop organic agriculture and marketing in the Canadian Prairies. PODF builds resilience by investing in organic provincial associations (Capacity Fund) and high impact programs (Innovation Fund) related to marketing, research, policy, education and capacity development that have broad public benefit to the organic sector. The fund is directed by a board made up of organic producers, grain buyers, organic brands, researchers and provincial organizations.

The **Canadian Organic Ingredient Strategy (COIS)** provides farmers with tools and support to incorporate organic farming practices that help meet the growing demand for organic foods in Canada. The tools developed as part of this project will help Canadian farmers benefit from increased knowledge and skills in organic farming methods, which can improve soil health and boost farm resilience in the face of changing markets and climate change.

Visit www.pivotandgrow.com to learn more about the tools created as part of COIS.