ORGANIC CROP PRODUCTION

AGRI-FOOD INNOVATION FUND

Canada Saskatchewan

9-1 Growing a competitive crop – first step in weed control

– B. Frick, E. Johnson - Scott Research Farm

Problem

Crops inevitably grow in relationship with weeds. Crops and weeds compete with each other for limited resources, such as nutrients, light, water, space. How can this competitive relationship be managed to give the advantage to the crop?

Background

Competitive ability can be viewed two different ways: ability to tolerate competition (maintain yield in the presence of weeds) and ability to suppress weeds. Studies indicate that the competitive aspects of tolerance and suppression may be correlated.[1] Factors that increase competitive ability include rapid germination, early emergence, seedling vigour, rapid leaf expansion, number of stomates, rapid canopy development, plant height, early root growth, and extensive root systems.[2,3,4]

Crops differ in competitive ability with weeds.[3,5] In general, barley is more competitive than spring rye. Both are more competitive than wheat or oat, and flax is less competitive. Durum wheats are less competitive than spring or winter wheat.[1] Wheat is considered more competitive than pea, and then in order of decreasing competitive ability, pea, potato, soybean, flax, and bean.[6] Most pulse crops, like lentil, are poor competitors. Canola offers poor competition to weeds in the seedling stage, but can compete well once it becomes established.[7]

Fall sown crops such as winter wheat and fall rye offer excellent early season competition, and do not require spring cultivation. These crops are especially effective at competing with spring germinating annual weeds such as wild oat or green foxtail. Fall sown crops also allow partial fallow after harvest, for further weed control. Greenfeed or silaging annual grain crops can be used as a partial fallow replacement.[8] Two years of harvesting barley for silage at an early stage (heads fully emerged) reduced wild oat densities to levels similar to wild oat herbicide applications.[9]

Perennial crops such as crested wheatgrass, brome, sweet clover and alfalfa can be very competitive with annual weeds by eliminating tillage's stimulatory effect on annual weed seeds. Perennial crops can also offer competition against perennial weeds that lasts beyond the annual crop season.[10,11] Crested wheatgrass is more competitive than other forages.[8]

Each crop has many different cultivars or cultivated varieties. Several major crops have trait variability that affect competitive ability.[2] In the past, crop breeding programs placed relatively little emphasis on developing superior cultivars for growth under weedy conditions,[12] but this is changing.

A test of 250 wheat varieties in Australia showed that old standard varieties (those released between 1880 and 1950) suppressed weeds more than most of the current varieties. Strongly competitive genotypes had high early biomass accumulation, large numbers of tillers, and were tall with extensive leaf display.[1] Yield differences in weedy conditions were not found when herbicides were used. Taller cultivars had fewer weeds than shorter cultivars. Cultivars also differed in the dormancy of wheat seeds and thus, in the number of volunteer wheat plants in subsequent years.[13]

In a study of eight wheat cultivars at Scott and Saskatoon, CDC Merlin, AC Minto and Columbus were found most competitive, and Genesis and Oslo least competitive with weeds. Spring spelt was the most competitive wheat in tests with model weeds (crop plants used to simulate weeds).[14]

Research indicates that long-vined, rapidly developing pea varieties were more competitive than shorter vined cultivars. Leaf type might be expected to make a difference, but studies at Morden did not find an advantage to leafier varieties competing with wild mustard.[8,15] Pea cultivar (tall, leafy Century; tall semi-leafless Tipu; short leafy Express) had no effect on grassy weed populations.[16]

Semidwarf winter wheat varieties resulted in a 14-30% greater yield reduction from downy brome (*Bromus tectorum*) than did taller cultivars.[7] Winter wheat was more effective in suppressing quack grass than tall or semi-dwarf spring wheats.[17] Research is currently underway at the University of Saskatchewan to develop oat cultivars with more weed competitiveness. Recently developed leafy forage oat genotypes have been found to be more competitive with wild oat than conventional milling or feed oat genotypes.[18]

Differences among cultivars depend on the entire cropping environment, not just the presence of weeds. For instance, in years with average or below average moisture, a semi-leafless pea cultivar seeded at reduced rates lost more to competition with wild mustard than did a leafy cultivar, and the semi-leafless cultivar lost more to competition when it was seeded at low rates than when it was seeded at high rates. Under drought conditions, wild mustard interference caused greater yield reductions in the leafy cultivar compared to the semi-leafless cultivar.[1 9]

Conclusions

Competitive ability varies among crops and among cultivars. Crops generally are most competitive if they have vigorous growth, especially at stages when weeds are emerging. Competitive ability is determined by characteristics of both crop and weed, and also by their environment.

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9-2 Using allelopathic and cover crops to suppress weeds

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Problem

How can allelopathy and cover crops be used to suppress weeds?

Background

Allelopathy in plants is the production of compounds that inhibit the growth of other plants. It may be direct, by living plants, or indirect through the products of plant decomposition. Allelopathy may be mediated by micro-organisms.[1] It is a challenge to separate the effects of resource competition and alleopathy. Resource competition occurs when one plant utilizes a necessary resource from a habitat, and excludes access from neighboring plants. In plant-plant interactions, allelopathy is generally used to denote the process by which plants release phtyotoxic compounds (allelochemicals) in the soil environment, resulting in a harmful effect on neighboring plants.[2]

Both crops and weeds have been found to contain compounds that can be considered allelopathic. These include crops such as barley, oat, wheat, rye, canola, mustard species, buckwheat, red clover, white clover, sweet-clover, hairy vetch, creeping red fescue, tall fescue, and perennial ryegrass.[1 3 4 5] These crops, in rotation, may suppress weeds in subsequent crops; however, these crops' weed suppression effects cannot be solely attributed to allelopathy. As with all other techniques, caution must be employed. Crops with allelopathic properties may suppress subsequent crop growth.

Cover crops may be sown to protect soil from erosion, for snow trapping or to increase soil organic matter. When the cover crop fixes nitrogen or otherwise improves soil properties, it is often referred to as a green manure. Both cover crops and green manures can have weed suppressing qualities. They may shade the ground, thus reducing temperature fluctuation and the weed seed germination that depends on it.[6] They may compete with weeds, and thus reduce their vigour, or they may have allelopathic properties. Cereal cover crops with a high C:N ratio may immobilize soil nitrogen allowing nitrogen-fixing crops to be more competitive. Tillage to kill the cover crop will also suppress weeds.

Cover crops can be sown into existing crops. If so, the timing should correspond to the time when weeds no longer cause yield losses (the end of the critical period).[7] Cover crops may also be sown after harvest, or in place of a fallow. Successfully established cover crops can develop sufficiently dense canopies in the fall to interfere with growth of perennial and winter annual weeds. Most tests of cover crops involve fall or winter cereals sown in the late summer and killed by herbicides the following spring.[8] Research at Lethbridge found that a well established, vigorous fall rye cover crop that was killed by herbicides or tillage in the spring suppressed weeds for the remainder of the fallow season.[9] The cover crop protected the soil from erosion and provided about a 50% reduction in weed biomass in the fall compared to bare fallow. The fall rye cover crop was particularly effective in reducing populations of dandelion and Canada thistle. Wheat yields following the cover crop were equal to yields obtained on bare fallow.

Fall seeded and spring tilled winter hardy rape substantially reduced lambs quarters and pigweed growth in a subsequent potato crop, and may have suppressed nematodes and diseases as well.[5] Another alternative is to use species that are not winter hardy. Tests with sorghum and oats showed weed suppression. These tests showed less effect than those where a winter hardy crop was killed chemically in the spring.[10] Winter-killed cover crops form a mulch in the spring that further suppresses weed establishment and growth.[7] Mulches may suppress weeds, but they are generally inadequate to control perennial weeds.[10] Crop suppression is generally less than that of weeds, in part because crops generally have larger seeds. Water use by the mulch crop is partially offset by greater snow-trapping.

Allelopathic mulches have potential problems as well as advantages. They may deplete moisture and immobilize nutrients, especially nitrogen. Including rapidly decomposing legume crops in the mix helps alleviate the latter problem.[3] The allelopathic effect may inhibit germination of small-seeded crops.[3] Cover crops may be more effective when you eliminate tillage, to concentrate residues more at the soil surface.[4]

Weed suppressing mulches need not be crop residues. Small areas of perennial weeds can be mulched with substances like manure. You need a substantial amount of manure for effective control - three feet or more deep, at least four feet beyond the patch. Other mulches: tar paper or black polyethylene, and mulched wood. Mulches must be maintained for at least one year for good weed suppression.[11] Check with a certifying agent which non-plant mulches are allowed.

Conclusions

Allelopathy is one plant's production of chemicals that suppress another. Cover crops are sown for the soil, and may have potential as a fallow substitute.

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9-3 Summerfallow as a weed management strategy – pros and cons

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Problem

Fallow has traditionally played a large part in weed control strategies. What are the advantages and disadvantages of this technique?

Background

Fallow can be used as a weed control method for both annual and perennial weeds. It can be used to reduce the weed seedbank by allowing weeds to germinate, then killing them before they set seed. This is especially effective on weeds with short dormancy periods, such as kochia, goat's beard, hare's ear mustard, Indian mustard, Russian thistle, cow cockle, green foxtail, downy brome, wild buckwheat or foxtail barley.[1] Some reduction is possible for weeds with longer dormancy, but some seeds will survive.

Three to six tillage operations may be required for effective annual weed control during the fallow year.[2] An early start is recommended for summerfallow tillage, perhaps by mid-May.[3] Tillage operations should be as shallow as possible to avoid bringing new weed seeds to the soil surface. The initial operation should always be the deepest with subsequent ones progressively shallower. Tillage is most effective when the soil surface is dry and air temperature high. Tilling small seedlings when the soil surface is moist will usually produce poor results, as many of the seedlings are transplanted rather than being killed.[4]

Fall tillage is an alternative to fallow tillage that can be used to destroy winter annual and biennial weeds. On weeds that over-winter, fall tillage is more effective than spring tillage. Fall tillage may encourage some summer annual weeds to germinate and most of these will be winter-killed. However, tillage also buries weed seeds that may become dormant, acting as a reserve for later years. Fall tillage should be shallow (less than four inches) to avoid deep burial of weed seeds.[4] Alternating intensive tillage during fallow years with cropping and spring and fall tillage can be used to reduce severe perennial weed problems.[5]

Fallow may also be used to control perennials such as Canada thistle and perennial sow-thistle.[6] With these species, the first tillage should be done at the bud stage. Food reserves are at a low at this time, and the tillage is most effective.[7] Once tillage begins, it should continue each time the plant reaches a height of about three inches, until freeze up. This approach will starve the root system and prevent it from forming any food reserves. The plants will enter winter in a very weakened state and many of them will not survive.[4]

This late season tillage for perennial weed control may be used after an early maturing crop, or in a partial fallow situation.[8] Appropriate crops include sweet clover, early maturing barley, fall rye, or oat cut for feed. Fall tillage after later maturing crops can also be effective against perennial weeds. Plants can be killed by exposing the roots, if freezing temperatures follow shortly after tillage.[4] Fall tillage reduces stubble and trash cover -- reducing snow trapping. It also accelerates soil erosion. So fall tillage should be approached cautiously.

Quackgrass problems should be handled differently. Tillage to control this weed depends on physically damaging the root system. In dry years, a cultivator with narrow spikes will be effective, as this drags roots and rhizomes to the surface where they dry out and die. In wet years or areas, the first tillage operation should be with a disc implement that cuts the rhizomes into small pieces. Each smaller rhizone section will try to establish a new plant, which in turn should be destroyed by subsequent tillage. New plant growth should not be allowed to grow taller than three inches before being tilled.[4] Tillage should be no deeper than required to do an effective job. Shallow tillage will concentrate rhizomes on or near the soil surface, resulting in a more uniform emergence and better control from future tillage.[4]

Tilled fallow is a management tool to be used with caution. Extensive fallow for weed control has probably led to the evolution of greater dormancy in some weed species. Weed communities adapt to whatever practices are applied consistently. Repeated cultivation is detrimental to the soil, and practices that reduce the intensity or extent of tillage should be considered.

Conclusions

Summerfallow tillage can be used to reduce the seedbanks of annual weeds, and to attack persistent perennial weed problems. Tillage and fallow should both be used cautiously, since they can result in severe soil and environmental degradation.

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9-4 Biological weed control

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Problem

Weeds are often introduced species in agricultural habitats. In their original habitats, they may have been less abundant, in part because their natural predators and diseases reduced their vigour and they were in competition with other species. How can we use these biological methods of weed control?

Background

Biocontrol of weeds is using living organisms to destroy weeds, or to inhibit their growth and ability to compete with crops. Biocontrol is often separated into two categories: introducing classical biocontrol agents, often insects, and the increase and inundative use of organisms, often disease agents.

Classical biocontrol introduces natural predators to weed populations. Classical biological weed control with insects involves introducing host-specific natural enemies from the target weed's native range. Classical biocontrol has had good long-term success in some instances, particularly in rangeland. It is less commonly used in cropped land. Generally, the target weed is a long-lived perennial species that is especially difficult to control by traditional means.

Nodding thistle is attacked by a weevil, *Rhinocyllus conicus* introduced to Saskatchewan in 1968.[1] Weevils may be gathered by collecting about 500 infected nodding thistle seed heads in mid-August, and placing them in new stands. Several years are required for the weevil population to become established so that it can effectively control the thistle.

Two insects, the black dot spurge beetle *Aphthona nigriscutis*, and the copper spurge beetle *Aphthona flava* can be used as biocontrol agents in leafy spurge. Larvae feed on spurge roots. The black dot spurge beetle is more effective on high, dry and exposed sites, on coarse soils. In Alberta, redistribution of beetles is about 65% successful. Redistribution is accomplished by collecting and releasing adult beetles.[2]

Toadflax seed predators *Brachypterolus pulicarius* and *Gymnaetron antirrhini* can be spread by placing infected toadflax stems among flower stems at the new site.[2] Additional agents being tested for toadflax control include the stem boring weevil *Mecinus janthinus*, the root boring moth *Eteobalea serratella* and the root galling weevil *Gymnetron linariae*. However, initial releases of *Mecinus janthinus* and *Eteobalea serratella* did not establish successfully in Saskatchewan.

The seed weevil *Apion hookeri* has successfully established on scentless chamomile after initial releases in 1992. The population is increasing over time and the weevil can reduce up to 40% of seed the plant produces. Other biocontrol agents released on scentless chamomile include a stem weevil *Microplontus edentulus* and a gall midge. Releases are currently being monitored for establishment success. Growers who want to obtain scentless chamomile seed weevils may contact Saskatchewan Agriculture and Food.

Inundative biocontrol involves applying large quantities of a control agent (such as a fungal pathogen) to weeds in much the same manner as a chemical herbicide. Once an inundative biocontrol agent is identified, its propagules (eg. spores, mycelium) can be produced in large quantities through fermentation techniques. The ... "commercial feasibility to mass-produce viable, infective and stable propagules of the pathogen is a major requirement for developing a bioherbicide".[4]

BioMal is a bioherbicide that contains viable spores of a fungus, *Colletotichum gloeosporoides f. sp. malvae,* that infects round-leaved mallow. Tests indicate that it can have a significant effect on the weed population. It currently is not available on the market.

The Saskatoon Research Center is a leader in research and developing inundative biocontrol agents. Several promising agents have been identified and are being developed to control weeds such as wild oat, green foxtail, dandelion, and scentless chamomile. Developing a bioherbicide is challenging since it is a living organism that must remain viable after application in order to be effective. Researchers at the Saskatoon Research Center are developing novel delivery systems for applying biocontrol agents.

Conclusions

Classical biocontrol agents are available for a few perennial weed species. Agents can be collected at previous release sites where they are already established. These agents offer the possibility of long-term, low-cost control. Inundative biocontrol agents have not yet reached the farm gate, but they have good potential.

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9-5 Tillage for weed control -- an introduction

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Problem

Tillage is often seen as the organic alternative to chemical weed control. Tillage can be very effective at reducing weed populations, but can it be embraced as the solution to the weed problem? What cautions are necessary?

Background

Tillage should be considered an external input – it requires the expenditure of fossil fuels. Reducing tillage reduces dependence on limited non-renewable resources. Spring tillage loosens and dries soil, thus warming it. Tillage can pulverize soil, making it more susceptible to erosion.[1] Tillage reduces stubble and trash cover, thus reduces snow trapping, and also accelerates soil erosion. Tillage also speeds decomposition and loss of organic matter, and increases salinization. It increases nitrogen volatilization to the atmosphere and potential for nitrate leaching.

Tillage also affects life within the soil. It can reduce the survival of beneficial invertebrates, soil microfauna and microflora.[2,3] Tillage reduces the populations of weed-seed eating carabid beetles and field crickets.[4]

Tillage exposes soil and weed seeds to the light. For some species, this triggers germination. When cultivation was performed at night or if the implement was covered, weed populations were reduced by up to 50%.[1,5] Tillage places weed seeds in better contact with the soil, also facilitating germination. In terms of weed control, deep tillage is a mixed blessing. It may bring up dormant seeds buried in the soil, and bury other seeds for later retrieval.[6]

Tillage equipment may spread perennial plant parts throughout the field. In this way, a small patch can become a general problem. Tillage favors some species over others, and thus is one of the management tools that can be used to alter weed communities.[5]

Tillage is not appropriate in some situations. Where risks of erosion or salinization are high, avoiding tillage is important. In other circumstances, tillage's negative effects can be limited by careful management, or seeking alternatives that reduce the need for tillage.

The type of tillage itself makes a difference. Some implements, such as the Noble or Victory blades, that leave stubble standing, will alleviate some fall tillage risk. These two equipment types are less effective in cool wet conditions. Tilling at slower speeds can reduce the erosion potential.

The amount of tillage can be lessened in various ways. You can leave uncultivated strips between cultivated areas. Leaving strips may also help trap snow. Tilling weedy patches rather than entire fields may also reduce risk. If erodible knolls have few weeds, leaving the knolls untilled will conserve residues and limit erosion. Where fallow tillage is planned, black summerfallow can be replaced with partial fallow, for instance, after plowdown of an underseeded crop, or mowing green feed.

Mowing, in place of tillage, can be an effective part of weed control where tillage is undesirable. Done early enough, mowing may prevent weed seed set. To be effective, mowing should be done before flowering, as many weeds can set seed very quickly after flowering, using the reserves left in the portion of cut stem that remains attached to the flowers.[7,8] Many weeds, such as wild oats or Russian thistle, can be used in green feed if cut before seed set. To control perennial weeds, mowing might be delayed until the onset of weed flowering when food reserves are at a low point. The weed will respond by sending up new stems, further depleting its reserves. Mowing at about three week intervals can severely weaken or even kill the weeds.[8]

Mowing is also important in conjunction with perennial forages. Mowing can be useful in giving an advantage to perennial forages over weeds. By preventing annual weeds' seed set, and depleting reserves of perennial weeds, mowing may be the most important component of weed control in perennial crops.

Mowing, like tilling, can interfere with beneficial creatures. Delaying mowing until mid to late July can reduce nesting birds' mortality.[9] This fits well with perennial weed control, but may compromise annual weed seed set prevention.

Conclusions

Every weed control technique has benefits and detriments. Non-chemical methods are not automat-ically environmentally friendly.[10] Techniques can sometimes be altered to reduce detriments without greatly reducing benefits. In developing effective and efficient weed management strategies, growers must consider advantages, disadvantages and limitations of all the tools available.

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9-6 Inter-row cultivation – effective weed control in field pea?

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Problem

Some growers in western Canada have considered using inter-row cultivation as an alternative to herbicides. There has been little research in western Canada on inter-row cultivation in our commonly grown field crops. This study's objective was to evaluate inter-row cultivation as an alternative weed management system in field pea.

Background

Inter-row cultivation is commonly used in row crop production in the United States.[1] It has been effective in corn and soybean when combined with a band of herbicide applied over the crop row.[2] Swanson and Jacobson[3] and Johnson[4] reported non-weed control benefits of inter-row cultivation such as improved soil aeration and reduced soil compaction. However, most benefits of inter-row cultivation are attributable to weed control.[5] Research on inter-row cultivation of field crops in Saskatchewan is very limited. Inter-row cultivation in cereal crops was investigated at the University of Saskatchewan in the 1920's.[6 7] The purpose of that research was primarily to reduce summerfallow and manage drought, and not to manage weeds. Two to three rows of wheat, oat, or barley (spaced 15 cm apart) were separated by a 90 cm spacing to facilitate cultivation. Barley and oats appeared to respond best to the treatment; however, there were no non-cultivated checks for comparison. Subsequent wheat crops yielded similar to wheat crops grown on fallow. These results were similar to the observations of Tull,[8] who stated that "the more successive crops are planted in wide intervals and often hoed, the better the ground does maintain them".

Study description

The study was conducted on cereal stubble at the Scott Research Farm in 1998 and 1999. Wild oat and wild mustard were seeded on the experimental area in early spring followed by a cultivation to distribute weed seeds. Field pea was seeded at a depth of 7.5 cm on May 12, 1998 and May 7, 1999. We used a hoe-drill plot seeder with adjustable row spacing and on-row packing. The crop was seeded in single rows spaced 33 cm apart to facilitate inter-row cultivation. Inter-row cultivation was conducted with a modified S-tine cultivator. Three tines were arranged in a delta formation and fitted with 10-cm sweeps to fit between the crop rows. Cultivation depth was 2.5 to 3.0 cm and was adjusted to ensure that crop rows were not covered by soil. Cultivation speed was 3.5 km/hr^{-1}. Experimental design was a randomized complete block with treatments consisting of sequential inter-row cultivations (1, 2, and 3 cultivations) and an untreated check. We cultivated at field pea's 6, 8, and 10-node stages. Inter-row cultivation before the six-node stage would have resulted in too much crop burial. A herbicide treated check was also included (seeded in 22 cm rows). Data collection included crop and weed density and biomass, and crop yield.

Major findings

Successive inter-row cultivation caused a linear reduction in wild mustard density in both years. Those wild mustard plants that remained produced as much biomass as plots where cultivation was not done. Many weed species exhibit morphological plasticity in response to environmental variation and density.[9] Weeds can compensate for density changes so that total biomass per unit area is held relatively constant. Inter-row cultivation had an erratic effect on grass weeds' density and biomass. Field pea yield showed a linear response to successive inter-row cultivation in both years. Response magnitude was greater under the more favorable growing conditions in 1999. Inter-row cultivation improved field pea yield by 33% and 78% for 1998 and 1999, respectively. However, herbicide application resulted in respective yield increases of 57 to 300%. Benefits from inter-row cultivation were limited due to in-row weed growth. Most uncontrolled weed growth occurred in the uncultivated area adjacent to and within the crop row. Results from this study are consistent with research conducted in other parts of the world. A standard cultivator was not effective in controlling weeds in field bean due to intra-row weed growth.[10] An in-row cultivator or rotary hoeing prior to inter-row cultivation was required to reduce weed populations to that achieved by a herbicide. Another study found satisfactory results with inter-row cultivation provided that weed populations are low.[11] Therefore, integration with other mechanical or cultural methods may be required for satisfactory results with inter-row cultivation.

Conclusions

Inter-row cultivation has potential as means of controlling late flushes of weeds. It should not be considered a stand-alone weed management technique since significant in-row weed growth may limit benefits. Future studies should investigate the potential of inter-row cultivation conducted on the same experimental area over a number of years to truly evaluate its potential.

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Table 1. Effect of inter-row cultivation on wild mustard density in field pea. Mean of two years (1998-99). Scott, SK.

Treatment	*Wild mustard density (plants/m^2)*
No inter-row cultivation	155
1 inter-row cultivation (6-node stage)	79
2 inter-row cultivations (6 + 8 node stages)	56
3 inter-row cultivations (6, 8 + 10 node stages)	60
Herbicide treatment	30
LSD$_{0.05}$	65

Table 2. Effect of inter-row cultivation on field pea yiels (kg/ha).

Treatment	*Field pea yield (bu/ac)*	
	1998	*1999*
No inter-row cultivation	15.8	14.9
1 inter-row cultivation (6-node stage)	18.2	20.3
2 inter-row cultivations (6 + 8 node stages)	19.3	26.5
3 inter-row cultivations (6, 8 + 10 node stages)	21.2	24.4
Herbicide treatment	24.8	47.0
LSD$_{0.05}$	3.1	6.6

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9-7 Post-emergence harrowing for weed control

– E. Johnson - Scott Research Farm

Problem

Organic crop production practices such as crop rotation, use of clean seed, careful use of tillage between crops, and good crop husbandry reduce problems with weeds. However, some weeds are likely to be found in the crop, and can cause yield loss if allowed to compete with the crop throughout the growing season. Can post-emergence harrowing be used to reduce these problems?

Background

Harrowing after seeding but before the crop emerges can be useful if weeds emerge before the crop. A rod weeder, cable weeder or flexible harrow may be used. Tillage with a drag or flex harrow after the crop emerges can also be effective. A rotary harrow can be used with an excess of trash, where a tine harrow would clog. Pre-seeding harrowing needs an aggressive angle, but post-emergence harrowing should disturb plants as little as possible. Harrowing may not kill all the weeds, but can damage them, to allow the crop a competitive advantage. Extra caution is needed if conditions are very dry.[1] Weeds such as Russian thistle, tumble mustard, wild buckwheat, stinkweed, green foxtail, lambs quarters and redroot pigweed can be controlled well.[2 3] Control of wild oat with post-emergent harrowing can be quite variable. Kirkland[4] reported that multiple post-emergence harrowing passes reduced wild oat panicles and fresh weight in spring wheat in two years out of a three-year study. However, spring wheat yield was improved in only one year of the study. Three to four passes were required to reduce wild oat fresh weight by 40 to 80%.

Crops are generally harrowed with the rows. Limited research done in western Canada and Europe indicates that harrow direction has little effect on selectivity (ratio of weed control to crop injury). Tables 1 and 2 discuss factors and timings for best results when harrowing post-emergence for weed control.

Table 1. Factors affecting the efficacy of post-emergence harrowing

Factors improving success	*Factors reducing success*
-- Harrow less than 2 inches deep	-- Large amounts of trash
-- Soil is dry	-- Compacted soil
-- Crop seeded heavy, deep	-- Weed seeds deep in soil
-- Cool wet conditions following harrowing to let crop recover	-- Poor growing conditions following harrowing

Table 2. Optimum timings for post-emergence harrowing for weed control

Recommended crop stages for harrowing

Crop	*Stage for harrowing*
Wheat	2 - 4 leaf
Barley	2 - 4 leaf, before tillering
Oat	not recommended
Sunflower	up to 6 leaf
Fababean	2 - 6 inches tall
Lentil	seedling less than 4" tall
Field pea	seedling less than 4" tall
Canola	not recommended
Flax	not recommended

Study description

Studies were conducted in 1998 and 1999. Wild mustard and wild oats were seeded as weeds. The experiment included field pea, canola, flax, lentil, and chickpea. Crops were harrowed at a combination of stages including emergence, three-, five- and seven-leaf stage. A check plot received no harrowing treatment. Harrowing was with a tine harrow, and was either a single or double pass at each timing. The experimental design was a split-plot with four replicates.

Major findings

Weed control in the study was erratic, however the study was very useful in determining the relative tolerance of crops to post-emergence harrowing. Crop injury was assessed by counting the number of crop plants remaining after the harrowing treatment. Field pea was very tolerant with 85 to 90% of the plants remaining after harrowing (Figure 1). Chickpea was also very tolerant; however, producers should be cautious with this practice since physical injury could make chickpea more susceptible to Ascochyta blight. Lentil showed intermediate tolerance to post-emergence harrowing, while canola and flax did not tolerate harrowing.

Conclusions

Post-emergence harrowing for weed control can be recommended in field pea. Harrowing should be approached cautiously for lentil and chickpea until more is known about the impact of harrowing on disease spread. Post-emergence harrowing is not recommended in either canola or flax.

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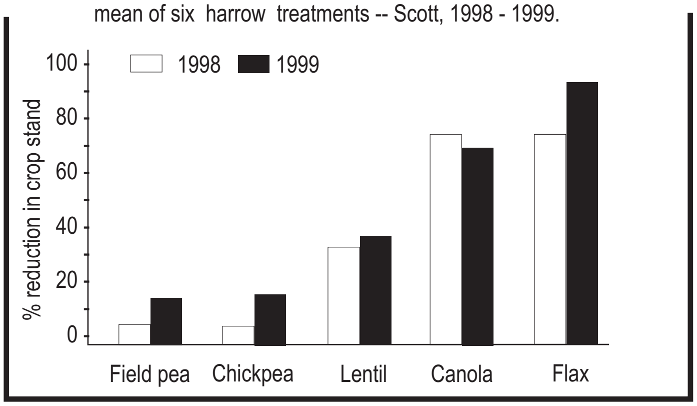
Figure 1. Percent reduction in plant stand due to post-emergence harrowing -- mean of six harrow treatments -- Scott, 1998 - 1999.



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9-8 Post-emergence field pea harrowing – rotary or tine?

– B. Frick, E. Johnson - Scott Research Farm

Problem

Post-emergence harrowing generally results in low selectivity, which is the ratio between weed control and crop injury.[1] Many organic growers have suggested that post-emergence harrowing's selectivity could be improved with changes in implement design. This study's objective was to determine if selectivity differed between a Phoenix rotary harrow and a tine harrow.

Background

The rotary harrow is manufactured in western Canada and is designed for granular herbicide incorporation and field leveling under high crop residues. The amount of soil disturbance caused by the rotary harrow is dependent on the angle of the harrow gangs in relation to the direction of travel. Soil disturbance is low when the harrow gangs are set perpendicular to the harrow hitch and increases as the angle approaches parallel.

Organic growers commonly use post-emergence harrowing for weed control; however it is not a practice commonly used by conventional growers. Fifty-two percent of organic growers surveyed in Saskatchewan used post-emergence harrowing as a weed control practice.[2]

There are very few published papers on post-emergence harrowing in western Canada. The results of a 12-year study at Indian Head showed that the yield of barley and spring wheat grown under weed-free conditions was not reduced by a single harrow pass conducted at emergence, the 1.5 or 2.5 leaf stage.[3] Kirkland[4] reported that multiple post-emergence harrowing passes reduced wild oat panicles and fresh weight in spring wheat in two years out of a three-year study. However, spring wheat yield was improved in only one year of the study. Three to four passes were required in order to obtain a reduction in wild oat fresh weight of 40 to 80%.

Studies have shown that field pea can tolerate post-emergence tillage performed with a harrow or rotary hoe.[5,6] Yield responses from post-emergence tillage in field pea have ranged from 0 to 18%.[5,6,7]

Study description

The experiment was conducted on spring wheat stubble in 1998 and 1999 at the Scott Research Farm. Weeds were seeded in the early spring followed by a shallow cultivation to distribute weed seeds and crop residue. Field peas (*cv.* Grande) were seeded on May 13, 1998 and May 5, 1999. We used a hoe-opener plot seeder (22 cm row space) equipped with on-row packing. The experimental design was a randomized complete block and the treatment design was a 2x2x2 factorial. Factors included harrow type (rotary, tine), setting (low and high soil disturbance) and number of passes (single, double). Low and high soil disturbance settings are illustrated in Figure 1. Our experiment included two checks -- one untreated, one herbicide treated.

Harrow treatments were carried out at field pea's four - five node stage. The single pass harrowing operation was done in the same direction as the crop rows. In the double pass treatment, the second harrow pass was done in the opposite direction to the first. Harrowing speed was 6 km/hr^{-1}. Plot size was 4x5 meters and each treatment was replicated four times. Crop burial was visually estimated on a scale of 0-100 per cent immediately after harrowing was done. We collected data on crop and weed density and biomass, and crop yield.

Major findings

The tine harrow buried more crop than the rotary harrow in both years, particularly when harrows were set at high soil disturbance level. The rotary harrow's high disturbance setting and the tine harrow's low disturbance setting (tines set at an angle of 45° backwards) buried similar amounts of crop.

Post-emergence harrowing had significant effects on field pea density in both years. In both years, the tine harrow's high disturbance setting reduced field pea density more than its low disturbance setting and both rotary harrow settings (Table 1). The tine harrow's high disturbance setting resulted in a 25% (1998) and 35% (1999) decline in field pea density. The tine harrow's low disturbance setting resulted in fewer problems with crop residue plugging than did the high disturbance setting. Residue attached to the bottom of the tines on the high disturbance setting caused more plant uprooting. The rotary harrow is designed to distribute crop residue and this may account for its lack of crop injury.

In both years, harrow type had a significant effect on wild mustard density (Table 2). The tine harrow was more effective in reducing wild mustard density in both years. Harrow type had no effect on wild oat density in 1998; however, in 1999 the tine harrow's high disturbance setting resulted in higher wild oat density and biomass, due to greater crop injury (Table 3). Increased plant covering effects from the tine harrow's high disturbance setting was more effective in controlling wild mustard density but this was offset by higher crop injury.

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This agrees with Rasmuusen's findings[8] – that a flexible chain harrow was a more efficient weed killer than a spring-tine harrow but it also caused more crop damage in field pea and spring wheat. He concluded that similar results could be obtained with all harrow types, if their settings are adjusted to give similar plant covering effects.

In 1998, there was no significant increase in crop yield due to post-emergence harrowing. In 1999, the highest yields were obtained with the tine harrow's low disturbance setting and the rotary harrow's high disturbance setting (Table 3). The rotary harrow's low disturbance setting did not improve crop yield since it didn't effectively control broadleaf weeds.

Conclusions

Selectivity did not vary with harrow type. There was opportunity to improve selectivity within both harrow types by adjusting the level of soil disturbance and crop burial caused by the harrow. A high level of soil disturbance and crop burial was counter-productive as significant crop injury offset any improvements in weed control. Since the tine harrow's low disturbance setting resulted in lower crop injury without sacrificing weed control, producers would be advised to set their harrow tines at a 45° angle backwards. On the rotary harrow, a 45° angle provided both satisfactory weed control and crop tolerance.

Table 1. Effect of harrow type and disturbance setting on field pea density. -- Scott, SK -- 1998 - 1999.

	Field pea density (plants/m^2)	
Harrow/setting	*1998*	*1999*
Tine / low	62	66
Tine / high	52	50
Rotary / low	65	64
Rotary / high	60	73
Untreated	66	74
LSD$_{0.05}$	7	10

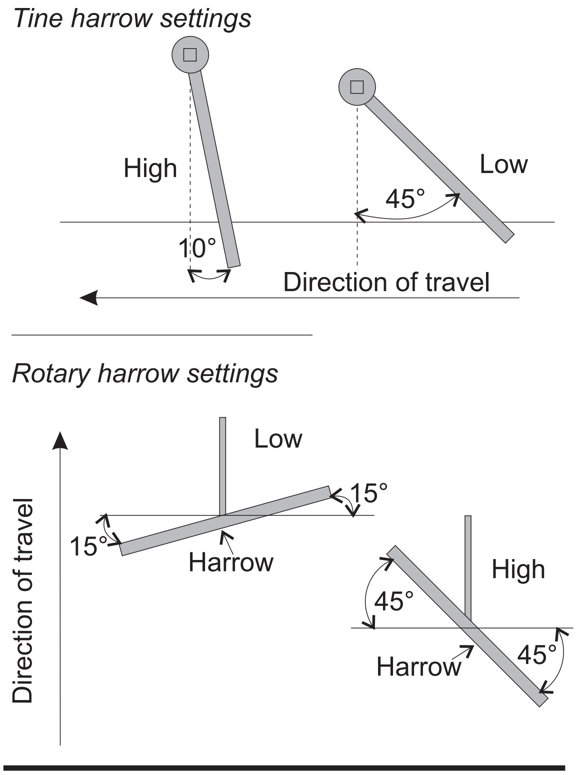
Table 2. Effect of harrow type on wild mustard density -- means of two disturbance settins for each harrow type -- Scott, SK -- 1998 - 1999.

	Wild mustard density (plants/m^2)	
Harrow	*1998*	*1999*
Tine	25	46
Rotary	45	119
Untreated	42	235
LSD$_{0.05}$	14	25

Table 3. Effect of harrow type and disturbance setting on wild oat biomass and field pea yield -- Scott, SK -- 1999.

	1999	
Harrow/setting	*Wild oat biomass (g/m^2)*	*Field pea yield (bu/ac)*
Tine / low	247	35.2
Tine / high	506	27.2
Rotary / low	216	28.4
Rotary / high	234	32.4
Untreated	223	26.1
LSD$_{0.05}$	204	5

Figure 1. Soil disturbance settings for tine and rotary harrows.


Tine harrow settings

Rotary harrow settings

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9-9 Weeds -- when are they a good thing?

– B. Frick, E. Johnson - Scott Research Farm

Problem

Weeds are often defined as plants growing where they are unwanted. The definition reflects our attitude, but doesn't help us understand the roles these plants play in managed ecosystems.

Background

In natural environments, weeds are the first species to colonize disturbed habitats. Many weeds are well adapted to survive and reproduce where other plants can not – often in conditions of low fertility or frequent disturbance. Weeds can modify these habitats in ways that make them more hospitable for other species. Weeds shade the soil surface – reducing evaporation and the sun's harmful effects. They can reduce wind speeds at the soil surface. In winter, they trap snow, adding to soil moisture. Weeds can be important agents of soil conservation. Weed roots can stabilize erodible soil and provide channels for the movement of water and air in the soil. They contribute to soil tilth.

Some weed roots penetrate so deeply that they tap nutrients unavailable to crop plants. The weeds bring these nutrients to the surface as the plant grows new shoots or shallow roots. When weeds die and decompose, those nutrients become available in the soil's surface layers. Weeds can also add substantial organic matter to the soil.

Weeds may indicate soil or management conditions. Redroot pigweed and wild mustard, for instance, do well only when phosphorous levels are relatively high,[1] and thus they indicate adequate phosphorous when they are abundant. Lamb's quarters, on the other hand, is more common in phosphorous deficient soils,[2] and thus may indicate a problem. Dandelions do poorly in soils low in potassium.[3] Other weeds, such as foxtail barley, may indicate salt accumulations. Thus weeds can signal the astute manager that management changes are required.

Some weeds are highly nutritious, as human food, or animal feed. They can be harvested, cut for feed, grazed, or left for wildlife. Lamb's quarters, dandelion, common chickweed, and redroot pigweed can be used in salad or as cooked greens. Stinkweed seeds add flavour to salad dressings. Dandelion roots can be used as a coffee substitute.[4] Wild oats, kochia and quack grass make nutritious forage if cut early. Weeds that emerge late in the season may cause little crop loss in that year. If the field is fenced, they might provide suitable grazing after harvest.

Weeds can harbour beneficial insects, *mychorrizae*, birds, etc. Weed seeds at soil surface may be an important food source for insects. Weeds with a shallow nectar source are particularly important as food sources for predatory wasps, hoverflies and other desirable predatory insects.[5]

Even in a crop, weeds are not always a problem. Volunteer pea in a wheat field may be of more value than the wheat crop if it can be separated after harvest. A few weeds in a bean or pea field may reduce wind damage and help raise the pods higher off the ground, making them easier to harvest. In a wet year, weeds in a lentil field might stress the crop into flowering, rather than producing only vegetative matter.

Conclusions

Weeds are signs of life in otherwise inhospitable habitats. They play a role in both natural and managed ecosystems. They alter the environment in ways that can be beneficial.

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9-10 Livestock and other beneficial organisms for weed management

– *B. Frick, E. Johnson - Scott Research Farm*

Problem

Many plants considered weeds in agricultural crops are actually highly nutritious and palatable plants. Can livestock use weeds? Can we integrate livestock and other weed eating animals into a weed control strategy?

Background

On mixed farms, livestock may be used directly to graze weeds, or consume mown weeds, chaff, and screenings. Goats are browsers, and are especially good at controlling woody plants, such as aspen or rose. Goats also eat thistles.[1] Sheep can effectively control leafy spurge. Once they acquire a taste for it, sheep consume large quantities of spurge, which gives them nutritious forage.[2] Sheep are especially good for weed control, as they graze close to the ground, and will readily eat thistles.[2] In legume crops, sheep will graze out grassy weeds.[3] Geese have been used in garden plots to control grassy weeds.[2] Weeder geese can be used (at five to six geese/hectare) after crops grow too large for birds to eat. Hogs, at 24 animals/hectare, can control perennial weeds between cropping seasons in fenced fields. Cattle and sheep can be used for early grazing to prevent weed growth. Weed regrowth faces strong competition from legumes and grasses in pasture.[4] If livestock are used to graze mature weeds, or to dispose of screenings or chaff, digestion will destroy many, but not all, weed seeds.[2]

Livestock also have indirect benefits in a weed management system. Livestock reclaim otherwise-useless things like screenings, chaff, patches mown for weed control, and these practices become more viable for the producer.

Long-term rotations that include a perennial offer distinct benefits to soil quality and weed management. Currently, the usual way to get alfalfa or another perennial legume back into the rotation is to include livestock as part of the production system.[5,6] Options that generate the ‘livestock advantage’ without livestock might also be pursued. For instance, dehy and seed alfalfa producers might develop partnerships with livestock producers.

Beneficial creatures other than livestock may also be important in weed management. They can be encouraged by maintaining habitat for them. This might include reducing tillage, maintaining shelterbelts and wooded refuges, sloughs, or borders, and leaving unbroken native land. Blind use of refuge habitats is risky, because it is difficult to determine, at first, if creatures harbored this way are beneficial or harmful. However, careful observation should help make that decision. Our usual habit of viewing all non-domesticated creatures as pests may be cautious, but it is unwarranted.

Biological agents in the soil can also affect competitive relationships among crops and weeds. Some biological agents are available to improve crop growth, such as the rhizobial inoculants used with legumes to support nodulation or the fungal organism of *Penicllium billai* to solubilize inorganic phosphorus in the soil. Arbuscular mycorrhizae (AM) can benefit plants by facilitating nutrient uptake and improve growth and yield.[7] These mycorrhizae benefit some species such as cereals and legumes over species that do not associate with them,[7] such as wild mustard, lamb’s quarters, wild buckwheat, tame mustard, canola and quinoa.

Other soil organisms can be directly detrimental to weeds. Seed-borne bacteria may effectively reduce dormant weed seed populations. Rhizobacteria have potential to reduce the vigor of grass weeds in cereal crops. Applying microbial agents to control weeds may prove useful in the future. Reducing tillage might foster growth of these bacteria, which actively grow on crop residues, and are favored by the cooler, moister environment the residues generate.[8]

Helpful insects can be encouraged by providing habitat, such as shelterbelts and ground cover. Increased weed seed predation has been observed with cover crops. Reader[9] reported that ground-cover restricted seedling emergence by providing a habitat for seed predators. High numbers of insects, snails, slugs, and voles were reported in heavy residues of rye and hairy vetch and it was felt that these organisms’ feeding decreased the number of weed seedlings.[10] Some carabid insects show a preference for species of foxtail.[9]

Conclusions

Livestock can be useful in weed management both as direct consumers of weeds, and because livestock provide cost recovery for some weed management practices such as chaff collection or mowing. Other beneficial organisms can be encouraged by leaving natural environments within the farm ecosystem, by reducing tillage, and by using chemicals judiciously.

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9-11 Weeds on organic farms

– B. Frick, E. Johnson - Scott Research Farm

Problem

Are the weeds on organic farms different from those on neighboring farms?

Background

Weeds, like all plants, live in the context of their environment, the history of the land and the random workings of chance. Some of the most important factors that make up the environment are beyond a farmer's control, such as climate. Some factors important to weed development, like soil temperature and moisture, reflect both the local climate and specific farm management. Farm management on organic farms is often different from neighboring farms, and thus weed communities might be expected to be different.

One study in Saskatchewan indicated that organic systems had more weed species and more individual weed plants than conventional systems. Wild mustard, lamb's quarters and Canada thistle especially were more abundant in organic systems. Wild oats were relatively less of a problem. In that study, differences among years were greater than differences between organic and conventional systems.[1]

A second study compared larger numbers of Saskatchewan organic and non-organic farms. It concluded that cropping system, especially if the farm had a history of perennial forage crops, had a greater influence on the weed community than whether the farm was managed organically or not. Perennial forages tended to encourage perennial and biennial weeds, while annual cropping systems encouraged annual weeds. Organic fields had greater numbers of weed species most susceptible to herbicides -- wild mustard, lamb's quarters and bluebur (Table 1).[2] Organic fields had more individual weeds, on average, and greater numbers of weed species than neighboring fields.[3]

In a Manitoba study, organic producers reported problems with wild mustard, Canada thistle, red root pigweed, green foxtail and wild oats. Wild mustard was much more of a problem for organic producers than their conventional counterparts (Table 2).[4]

In experimental comparisons of organic and conventional systems in South Dakota, annual broad-leaved weeds were not consistently different in organic systems than in conventional systems. Grassy weed numbers, mostly green and yellow foxtail, were substantially higher after six years in organic cereals than they were in conventional cereals. They were not consistently higher in organic soybeans.[6]

Conclusions

Weed communities vary because of many factors. Factors such as cropping system, year and region can be more important than whether farms are managed organically or not. Organic farms will likely have more wild mustard, lamb's quarters, Canada thistle, bluebur and redroot pigweed than will conventional farms.

Table 1. Comparison of weed density (#/m^2) in different cropping systems* and in organic systems relative to those with moderate levels of chemical inputs (Mod).

	Fallow		*Annual crops*		*Annual and perennial crops*	
Head	*Mod*	*Organic*	*Mod*	*Organic*	*Mod*	*Organic*
Stinkweed	16.2	44.1	13.4	40.3	11.9	21.2
Green foxtail	17.4	45.3	10.1	85.3	1.9	30.4
Wild buckwheat	1.7	6.1	4.7	9.3	5.0	24.1
Lamb's-quarters	0.6	75.7	1.0	52.8	4.4	24.7
Wild oats	0.9	19.3	9.5	4.6	0.3	0.7
Narrow-leaved hawk's-beard	0.6	0.9	2.9	1.6	34.5	24.9
Quack grass	1.0	0.9	1.3	0.7	23.3	31.5
Russian thistle	2.6	4.3	1.3	8.5	1.1	1.2
Shepherd's purse	< 0.1	1.1	4.3	5.4	0.8	18.7
Canada thistle	< 0.1	1.5	1.6	1.4	0.3	1.5
Wild mustard		52.3	0.5	6.3	< 0.1	0.1
Dandelion	< 0.1	1.3	0.2	0.2	16.1	4.6
Perennial sow-thistle	< 0.1	0.8	0.7	0.6	1.1	2.0
Field horsetail		0.5	0.3	2.8	1.1	3.0
Volunteer canola	0.9	0.7	2.3	0.2	< 0.1	
Volunteer wheat	0.2	0.3	1.0	0.5	< 0.1	
Kochia	1.6	3.0	< 0.1	0.1	22.4	0.1
Flixweed	0.7	0.8	< 0.1	0.2	6.8	1.1
Bluebur	< 0.1	1.5	< 0.1	1.8	0.4	1.3
Cleavers		< 0.1	2.1	< 0.1		

* Fallow systems include fallow; annual and perennial cropping systems includ perennial crops; annual cropping systems do neither of the above.

Table 2. Comparison of weed problems reported by Manitoba organic producers[4] and weed numbers found on Manitoba farms (mostly not farmed organically)[5]

Weed species	*Organic producers Relative importance**	*Other producers Relative importance**
Wild mustard	21	4
Canada thistle	18	6
Redroot pigweed	14	4
Green foxtail	13	28
Wild oats	12	11
Wild buckwheat	5	9
Quack grass	4	3
Perennial sow thistle	4	3
Lamb's-quarters	3	3
Curled dock	2	0

* Importance is equal to the number of reports for a given species, expressed as a percentage of all species reports (i.e. larger numbers indicate greater importance)

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9-12 Weeds - when are they a problem?

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Problem

Weeds are often defined as plants growing where they are unwanted. What makes these plants so undesirable? What sort of problems can weeds cause?

Background

Farmers are often concerned that weeds may reduce crop yields. Weeds use the same nutrients that crop plants use, often in very similar proportions. They also use resources such as water, sunshine and space that might have gone to crops. The more similar the weed and crop requirements, the more they will compete for those resources. Weeds that compete aggressively with crops reduce their yield. Weeds are most damaging to crop yields if they have some advantage over the crop. Four factors are especially important: density, timing, size and chemistry.

More weeds are generally a larger problem than few weeds, but weed density is not the only concern.[2] For instance, at very high densities, green foxtail plants tend to compete strongly with each other and thus remain very small. These small plants probably have little competitive effect on the crop even when there are many of them. At medium densities, green foxtail plants grow larger and can severely reduce crop yields. In this example, a reduction in weed numbers may actually increase the weed problem.

Timing of weed-crop competition is important. Ecologists have defined a critical period of weed competition. This is the time when the weed reduces crop yield. Weeds that are removed before the critical period, or that emerge after the critical period do not cause any appreciable yield loss. The exact timing of this period is not an "inherent property of the crop"[3] and varies for different crops, for different weed species, and under different conditions such as year or location.[4] In general, weeds should be removed at early crop growth stages. Early weed removal was found necessary to protect field pea yield.[5]

Relative timing of crop and weed emergence is very important in determining the magnitude of yield loss from weed competition. When it comes to plant competition, generally the first one out of the ground wins. Competition from wild oat resulted in a 17% yield loss in barley when it emerged five days before the crop compared to a 3% yield loss when wild oat emerged five days after crop emergence.[6]

Weed size is partly a matter of timing. Weeds that emerge before the crop are generally larger and better established than those that emerge after the crop. This gives them greater access to soil and spatial resources, and thus they do more damage to crop yield. Size also varies among species. For instance, three Canada thistle plants are naturally much larger, and likely to cause more yield loss, than three thyme-leaved spurge plants. Size also depends on plant nutrition, disease, and pests.

Some weeds may limit crop development through chemical means, or allelopathy, either while they are alive, or as they decompose. Some weeds, for example Canada thistle or quack grass, release chemicals that inhibit their neighbors. This affects their competitive relationships.

Weeds can cause problems other than crop yield loss. Some weeds are poisonous and can taint food and feed crops. For example, wild mustard seed cannot readily be removed from canola, and can flavor the resulting canola oil if crushed with the crop seed. Stinkweed in feed for dairy cattle produces off-flavors in milk.

Weeds that remain green at harvest, especially those with fibrous stems, can interfere with harvest. The problem varies with both the crop and the weed. A low-growing weed like wild tomato causes very little problem in a cereal crop because most of the plants are below swath height. In a crop like lentil, chickpea, or bean, severe harvest difficulties may occur. The low cut means that wild tomatoes are harvested with the crop, and they can stain the pulse and clog the machinery.[7] Weeds like wild buckwheat, that twine through a crop can also be problematic.

Weeds can harbour problem insects and crop diseases. For instance, mustard-family weeds can carry over canola diseases, making rotation a less effective tool for disease management.

Immature weeds can interfere with harvesting operations. Weed seeds in harvested crops cause dockage and increase risk of spoilage. This can reduce crop value, or increase shipping costs.

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Weeds in grasslands are generally those that are less palatable. They increase with grazing, because the livestock graze them less than the more palatable plants. Over time, this reduces range productivity for livestock.[1] Weeds such as smooth brome or purple loosestrife can compete aggressively with native vegetation, and replace it.

Conclusions

Weeds cause many problems. Most importantly, weeds can reduce crop yield. Weeds cause greater crop losses if they occur in large numbers, if they get a head start on the crop, if they are especially vigorous, or if they produce allelopathic substances. Other problems weeds cause include dockage, tainted products such as feed or food, increased numbers of harmful insects or diseases, and more difficult harvest.

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9-13 Crop husbandry for weed management

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Problem

What is crop husbandry? How is it important for weed management?

Background

One of the most effective weed management tools is good crop husbandry.[1] A strong and competitive crop offers less opportunity for weeds. All crop management techniques that contribute to good growth can be considered weed management tools. Crops can compete well with weeds if they establish quickly and uniformly, are vigorous, and well nourished.[2]

Agronomic recommendations are often assembled from results obtained in virtually weed free experimental plots. A combination of sowing time, crop genotype, crop planting arrangement, crop density and fertilizer input that's optimal under weed free circumstances is not necessarily optimal in weedy fields. Moreover, desirable husbandry practices can contribute considerably to weed control at very little extra cost.[3]

Two primary principles of crop husbandry relate to weed management:

- vary farm practice to avoid having weeds adapt to it
- whenever possible, give advantage to the crop, not the weed.

●

Varying farm practice prevents weeds that prosper in one system from gaining too strong an advantage. Many factors can be varied to 'confuse' the weeds. These include:

- extensive and varied crop rotations
- alternating timing of operations such as seeding and harvest
- varying tillage amount and timing
- modifying soil fertility through green manures, livestock manures and other soil amendments, and using crops that deplete nutrients to a greater or lesser extent.

Slight alterations of existing practices are often enough to change their relative advantage. For instance, on-row packing, rather than packing the entire field may give an advantage to the crop relative to most of the weeds. Banding liquid manures near the crop row, rather than across rows may mean a relatively greater share of them goes to the crop.

Seeding rates and patterns can also have an effect on how well a crop competes. High seeding rates and narrow row spacing decrease the distance between crop plants, and the canopy closes sooner. This reduces weed seedling germination, and gives the crop an edge in early competition. The disadvantages are increased seed costs, and less-feasible inter-row cultivation.

High seeding rates are especially helpful on weedy land. On weed-free land, high seeding rates offer no advantages over recommended seeding rates.[4][5] Green feed and silage crops can be seeded at higher rates to increase crop competition and feed quality. Increased seeding rates should also be used if either postseeding or postemergence tillage is planned. This will help compensate for any damage caused by in-crop tillage. An increase of 25% above normal is often recommended. High seeding rates may be advantageous in a dry year if seedlings more effectively cover the soil and reduce evaporation from the soil surface. If there is enough moisture, high seeding rates will speed maturity (two to three days), and result in shorter plants with fewer tillers. Under certain environmental conditions, higher seeding rates may increase disease incidence or may result in higher lodging losses.

In one Saskatchewan study, increasing peas' seeding rate reduced weed numbers; high pea populations competed well with weeds.[6] In another study at Scott, barley yielded the most at narrow row spacing and increased seeding rate. Weed biomass was reduced by both narrower row spacing and increased seeding rate.[7]

Narrow row spacing allows crops to fill the available space more completely, leaving less space for weeds. Cross-seeding is another alternative that needs no machinery modification, but has much the same effect.

Conclusions

Good crop husbandry is an effective weed management system. Two primary principles of crop husbandry relate to weed management:

- vary farm practice to avoid having weeds adapt to it
- whenever possible, give the advantage to the crop, not the weed.

Practices recommended for weed-free conditions may need to be altered for weedy conditions. High seeding rates, and close planting patterns leave less opportunity for weeds.

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9-14 Crop rotations for organic systems

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Problem

Crop rotations are considered the key to sound organic farming practice. Why are crop rotations important? What is a good organic crop rotation?

Background

Crop rotation is a planned sequence of different crop types, such as spring-seeded cereals, fall-seeded cereals, oilseeds, pulses, perennial legumes and other perennial species. Rotations also include alternating crop types, for instance between barley and wheat, or flax and canola; or alternating cultivars within a crop species, for instance, between Harrington and Brier barley.

Crop rotation is a central component of all sustainable farming systems. Crop rotation offers the most effective, indirect method of minimizing pest, disease and weed problems and maintaining and enhancing soil structure and fertility.[1] Crop rotations can limit build-up of weeds that are favored in a single crop environment.[2] Crop rotations have many benefits, including increased soil microbial activity, which may increase nutrient availability, including phosphorus. When crops are rotated, yields are usually 10 to 15% higher than when grown in monoculture.[3]

Each crop has unique characteristics, and thus requires different kinds of disturbances, such as different seeding times, different tolerance to practices such as post-emergence harrowing, etc. Crop rotation dictates the pattern of these disturbances, that ultimately change weed species' composition within agroecosystems.[4] Thus, in spring-sown crops there is selection against autumn-germinating weed species while the opposite is true of autumn-sown crops.[5] There has been evidence since at least the 1800s that weed incidence varies with crop rotation.[6] An extensive literature survey of over 200 references indicated that weed number, biomass and seed production are reduced in rotations and intercropping situations compared to monoculture.[7]

The greater the differences between crops in a rotational sequence, the better cultural control of pests can be expected.[8] In a Saskatchewan study, the presence of winter wheat in a rotation was the factor with the largest impact on quackgrass growth. When winter wheat established well with adequate moisture, it suppressed quackgrass.[9]

Including alfalfa or other perennial legumes in rotations may be especially helpful in managing weed problems.[3] This solution is limited, in part, by the small number of farms with livestock.[10] This problem might be overcome through creative marketing (to livestock producers or the dehy industry), in the use of alfalfa grown for seed, and of short-term plow-downs when seed prices are favorable. A further constraint results from perennial legumes' high moisture requirement resulting in severe soil drying. For this reason, introducing perennial legumes should be done cautiously, with on-farm feasibility testing.

Using legumes in rotation began to decline when synthetic nitrogen was introduced in the 1940's.[11] Making rotations shorter (not including perennials, pastures, green manures and increased summerfallow) has reduced soil organic matter, degraded soil physical properties, and increased erosion and external inputs.[8] Once established, forage grasses and legumes within rotations are very effective in suppressing growth of some annual weeds. This is a consequence of leaving the soil surface undisturbed, providing dense crop canopy cover and root development, and mowing. Mowing affects annual weed growth much more severely than it affects forage grasses and legumes.[2]

A Saskatchewan study indicated that weed populations were affected more by frequency of perennial forages in rotation than by any other management factor studied. When forage crops' frequency within a rotation increased, there were more perennial or winter annual weeds such as dandelion, smooth brome, quack grass and narrow-leaved hawks-beard -- and fewer annual species. Other factors influencing weed communities less than rotation were the number of tillage passes and fallow frequency. Both tillage and fallow encouraged annual weed growth, but discouraged both perennials and winter annuals.[12]

A good crop rotation is dependent on the site, the manager, field history and the rest of the farm operation, but a guideline for weed management is to include as much diversity as you are comfortable with. Crop rotations can vary timing of disturbances (such as early seeded, late seeded, winter crops, biennials, perennials, and green manures). Crop rotations can account for differences in nutrient requirements. For instance, a three year alfalfa crop might be followed by wheat (which will use nitrogen from alfalfa breakdown), a legume (that would not require a high

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nitrogen level and would fix atmospheric nitrogen more effectively at low soil nitrogen levels), wheat again, and then oats (with a small nutrient requirement).[3] Rotating crops for disease and insect management can contribute to a healthy crop with less opportunity for weed growth. Crops can be rotated according to competitive ability. For instance, competitive crops such as barley or alfalfa could be grown before less competitive crops such as flax or lentil to start the less competitive crops in as clean a field as possible. Using a competitive crop, or several competitive crops following a less competitive crop may be used for clean up. Weed suppressing cover crops such as fall rye or sweet-clover can replace some of the summerfallow land.

Conclusion

A good crop rotation is important in reducing weeds, diseases, nutrient depletion and in improving crop vigour. An ideal rotation balances requirements of crops and soil, disturbance timing and farmer comfort.

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9-15 Soil fertility affects weed and crop competition

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Problem

Making nutrients available to the crop generally means making nutrients available to weeds. Crops and weeds have the same basic nutrient requirements. How can soil fertility be managed to give the greatest advantage to the crop?

Background

All plants require the same basic nutrients but plants differ in the way they respond to nutrient availability. They differ in their ability to access nutrients because of differences in their root structures or mycorrhizal associations. They also can differ in their ability to tolerate nutrient imbalances, or in their efficiency at converting nutrients into growth. Maintaining or improving soil fertility is thus an element of weed management.

There is an advantage in placing nutrients where they are more readily accessed by the crop than by weeds. Although crop competitiveness may improve with improved nutrient status, some weeds are more effective at utilizing excess resources than are crops.[1] Nutrient levels are generally recommended on the assumption that herbicides will be used, and that weeds are not an important consideration. Lower nutrient availability means less available for weed growth as well as for crop growth.

Higher nutrient levels stimulate the competitive ability of wild oats, green foxtail and barnyard grass.[2] Other weeds might be limited by nutrient levels that are adequate for crop growth. Redroot pigweed, for instance, is especially sensitive to low phosphorous levels, and will not grow well if phosphorous is depleted.[3] Wild mustard is also sensitive to low phosphorous levels,[4] but lamb's quarters may be more abundant in soils with phosphorous deficiencies.[5] One author claimed, after reviewing numerous research reports on fertilization's effect on weeds, that "weeds are capable of absorbing nutrients faster and in relatively bigger amounts than crop plants and thus profit more from fertilization. In the presence of a high weed population density, fertilizer application may stimulate weed growth so greatly that the crop plants will be overgrown and suppressed."[6]

Wild oat-wheat competition experiments showed that wild oats were better able to compete with wheat at higher nitrogen levels. Wild oat seed production increased with nitrogen, while wheat yield decreased. Wheat yield increased with added nitrogen only if wild oats plants were less than 2% of the total plant counts.[7] In another study, total weed density (several species) was highest at lowest nitrogen level in cereal crops.[8] Therefore, results from experiments investigating nitrogen effects on weed competition have been contradictory. The effect of fertilizer nitrogen on weed-crop competition is largely dependent on fertilizer placement.[9] Generally, in studies where weed growth has been favoured over crop growth, the nitrogen has been broadcast. Banding nitrogen close to the seed-row allows the crop roots to use applied fertilizer more efficiently than weeds. A number of studies have been conducted which show that banding nitrogen can favor the crop over weeds.[10,11,12]

Phosphate fertilizers applied at seeding have been shown to increase crop competitiveness.[13] Long-term application of manure or other phosphate sources may have similar effects. Manure should be composted to kill most weed seeds. Use soil tests to determine appropriate amounts to add. In one study where herbicides were not used, researchers found that soil amendments (cattle manure and potato compost and alternating years of legume green manure) substantially reduced the weed biomass, possibly by improving crop competitiveness.[14]

Conclusions

Competition between crops and weeds for nutrients, and for other factors (light, space, water) at different nutrient levels, are complex interactions that depend on many factors - crop species, weed species, moisture, nutrient release timing, nutrients' positional availability, nutrient ratios, etc. Actions that alter nutrient availability will affect the weed community and the crop's competitive ability.

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9-16 Weed characteristics

– B. Frick. E. Johnson - Scott Research Farm

Problem

Knowing what weeds are common on a particular farm will help to determine what lessons can be learned and what management strategies might be effective against them. What can we learn about common weeds to help with weed management?

Background

Most weeds have some characteristics in common. Weeds generally produce large numbers of seeds. Weed seeds can often germinate under a variety of conditions, but some portion of the seed population remains dormant. Dormant weed seeds are insurance against conditions that might destroy growing plants. Even though 95% of the weed seeds in the soil 'seed bank' may be lost to germination or death, the seed bank can often recover in a single year.[1] Many weeds develop rapidly, are able to self-pollinate, disperse widely and tolerate a wide range of environmental conditions.[2] A study in 1980 indicated that despite enormous effort, weeds have steadily increased from 1900 to 1980.[3] This trend probably continues.

Weeds have characteristics unique to each species, so recognizing weed species can be important. Many sources are available to help with weed identification.[4 5 6]

Several weed characteristics have been summarized in Table 1. Let's compare wild oats and green foxtail as an example of what we can learn from these characteristics.

Green foxtail (commonly known as wild millet or pigeon grass) is an annual grass with small seeds that birds seem to love. As with most weeds, seed production can be prolific. Seeds that germinate on the soil surface, or in surface chaff, often have trouble rooting, so these species can be less abundant in zero-tillage systems. Root development, even within the soil is not extensive. Therefore, harrowing is often an effective means of control. Green foxtail is a warm season grass. It germinates more quickly and is more competitive at higher temperatures. Thus, it is more aggressive in late-seeded crops, common in organic systems, and is less vigorous in cooler situations such as in zero-till, or early seeding. Mature plants vary in size from one inch to three feet. Large plants can be quite competitive. Small, very dense plants can reduce surface moisture supplies.

Wild oat is an annual cool season grass. It has larger seeds, and thus is less prolific. Because the seeds are large, they tend to dry out on the soil surface, making wild oats more common in wet areas, or low spots. Wild oat germinates quickly in cool soils, and is more competitive at lower temperatures. Thus, it can emerge before the crop and become very competitive. Pre-seeding tillage will remove many early germinating plants. Later seeded crops may be relatively free of wild oats. Wild oats can be quite competitive. Seeds can remain dormant for long periods, making wild oat management a perennial task.

Conclusions

Weed management can be made easier and more effective by considering the characteristics of the most common weeds.

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Table 1. Some characteristics of the most common weeds in Saskatchewan. [7, 8 9 10, 11]

Weed	*Life * history*	*Seeds/ plant*	*Germination*	*Dormancy*	*Maturity*	*Preference*	*Yield ** losses*	*Management*
Wild oats	A	250	Early	Long	Medium	Wet or low spots	10% for 10	Delayed seeding
Green foxtail	A	5,000	Late	Short	Early	Cultivated areas	Varies with size	No-till, early seeding harrowing
Wild buckwheat	A	1,200	Early	Medium	Medium	---	22% for 30	Delayed seeding
Stinkweed	A, W	15,000	Spring / fall	Medium	Medium to long	---	20% for 750	Fall/spring tillage
Canada thistle	P	700	Medium	Medium	Late	Field edges	38% for 14 shoots	Fall tillage, mowing
Lamb's quarters	A	72,000	Early	Long	Late	Organic soils	25% for 200 in barley	Harrowiing
Perennial sow-thistle	P	10,000	---	---	---	Moist, fertile	No estimate	Mowing, tillage
Russian thistle	A	---	Early	Medium	Mid to late	Drier sites	No estimate	Strong competition
Wild mustard	A	3,500	Early, continual	Very long	Early to late	Cool, moist	35% for 100	---
Redroot pigweed	A	---	Late, warm	Long	Late	Fertile soil	No estimate	Establish crop early
Shepherd's purse	A, W	38,500	Spring / fall	Medium to long	Early	---	No estimate	Fall/spring tillage
Kochia	A	14,600	Early	Short	---	---	No estimate	Delayed seeding
Dandelion	P	---	---	---	---	Field edges	No estimate	Tillage deeper than 2 inches
Quack grass	P	---	---	---	---	---	10% for 100 shoots	Tillage, mowing spring/fall

* A = annual, W = winter annual, P = perennial

** Yield loss estimates for weed number per metre squared in wheat. Example: 10 wild oats per metre squared caused a wheat yield loss of 10%. For perennial plants, losses are expressed per shoot rather than per plant, because it is difficult to recognize distinct plants in the field.

9-17 Field pea – manage seeding for best pre-emergence weed control

– E. Johnson - Scott Research Farm

Problem

It is recommended that field pea be seeded early and at a depth of 5 - 7.5 cm. Organic producers often delay seeding and use pre- or post-seeding tillage to remove germinated weeds. Crops that emerge before weed emergence are more competitive than crops emerging at the same time or after weed emergence. Delayed seeding to control late-emerging weeds and seeding at shallower depths to promote rapid crop emergence may be an alternative weed management strategy. What combination of seeding date, seed depth, and pre-emergence weed control optimizes field pea yield when grown without herbicide use?

Background

Organic producers use several cultural and mechanical methods to manage weeds.[1] Prior to introduction of selective herbicides, secondary tillage combined with delayed seeding was commonly recommended to control wild oat.[2] Research conducted from 1952 to 1957 at seven locations in western Canada found that tillage and delayed seeding controlled greater than 70% of wild oat in wheat and barley.[3] A Minnesota study found that pre-plant tillage just prior to delayed soybean planting resulted in reduced weed populations.[4] Delayed seeding may be effective in controlling some weed species, but it normally results in lower yields for many crops.[5] Field pea production has been shown to be viable in the brown and dark brown soil zone of Saskatchewan, provided that seeding is completed before mid-May.[6] In British Columbia, delayed seeding reduced processing pea yield at a location where the mean maximum growing season air temperature exceeded 21° C, but had no effect at location with lower air temperatures.[7] Delayed seeding and secondary tillage is commonly used by organic growers in spite of the potential yield decline.[1] Most weed seeds emerge from shallow depths (< 2 cm) and large seeded crops can be seeded deep allowing for selective mechanical weed control between seeding time and crop emergence.[8,9] Pavylchenko[10] observed that pre-emergence tillage gave crops about a ten-day weed free period.

Study description

Our field experiment was conducted on cultivated cereal crop stubble at the Scott Research Farm from 1999 to 2001. Treatments of seeding date (early May, mid-May and late May), seed depth (2.5 cm and 7.5 cm) and weed control (none, pre-emergence tillage, and herbicide) were applied in a split-plot experimental design. Each treatment was replicated four times. Wild oats and wild mustard were seeded just before the earliest seeding date followed by a shallow cultivation to distribute weed seeds and manage crop residue. We seeded field pea (*cv* Grande) at a target plant density of 80 pea plants m^{-2} with a narrow opener hoe-drill equipped with on-row packing. We did pre-emergence tillage about three to five days after seeding, but the second tillage sometimes had to be delayed up to 10 days depending on weather conditions. Pre-emergence tillage was accomplished in the shallow seeded plots (2.5 cm) with a tine harrow while a rod-weeder was used for the deep seeded plots (7.5 cm). Data collection included field pea density, weed density, weed biomass, and crop yield.

Major findings

Crop establishment was very good in all years with plant densities exceeding 70 plants/m^{-2} (data not shown). Overall, seeding date and seeding depth did not have an effect on crop establishment. Field pea was not damaged by pre-emergence tillage as the treatments did not reduce field pea density. In some cases, deep seeding delayed crop emergence (date at which distinct crop rows were visible) by one day. However, emergence differences did not affect time to crop maturity.

Pre-emergence tillage did not result in a detectable reduction in weed biomass at the early May seeding date since very few weeds had emerged (Table 1). Herbicides effectively reduced weed biomass at all seed dates. Pre-emergence tillage was effective in reducing weed biomass at the delayed seeding dates, with the pre-emergence rod-weed treatment resulting in weed fresh weight reductions similar to herbicide treatments. Pre-emergence harrowing was not as effective as pre-emergence rod-weeding in reducing weed biomass at delayed seeding dates. Deep seeding provided some weed control effect at the late May seeding date since the seeding implement was able to uproot and bury more weeds when set at a 7.5 cm depth.

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Seeding delayed until late May resulted in yield declines of up to 37% (Table 2). Previous research has shown that seeding field pea in late May compresses the flowering period resulting in lower yields.[6]

Pre-emergence tillage resulted in small crop yield increases at the early May seeding date; however, it provided yields equivalent to herbicides at the mid-May seeding date. At the mid-May seeding date, yields achieved by pre-emergence tillage resulted in 80% of the highest yield achieved with early seeding and herbicide application. At the late May seeding date, pre-emergence tillage improved field pea yields by 30 to 35% with pre-emergence rod-weeding providing higher yields than pre-emergence harrowing.

Though pre-emergence tillage improved field pea yield at the late May seeding date, these yields were still lower than the untreated checks seeded in early May. Shallow seeding did not improve field pea competitiveness at any seed date. Deep seeding resulted in higher yields at both the early and late May seeding date, but not at the mid-May seeding date.

We don't fully understand the reason for higher yields with deep seeding at the early seed date. However, we believe that deep seeding may provide a better environment for *Rhizobium* bacteria survival, resulting in improved nitrogen fixation. Improved yield from deep seeding at the late May date is likely due to the weed control effect described earlier. Organic growers may be able to achieve adequate weed control and satisfactory yields with a slight delay in seeding date followed by pre-emergence tillage, but a long delay in seeding is counter-productive.

Conclusions

Pre-emergence tillage between seeding time and crop emergence can be very effective in reducing weed density and preventing yield loss provided there is adequate weed growth at tillage time. A strategy for producers who choose not to use herbicides would be to conduct early spring tillage to stimulate weed emergence, wait 10 - 12 days and then seed at a 7.5 cm depth. Follow this with pre-emergence rod-weeding five to seven days after seeding.

Table 1. Interaction effects of field pea seeding date, seed depth, and weed control system on weed biomass at Scott -- 1999-2001.

		Weed biomass *(grams/m^2)*		
Depth	*Treatment*	*Early May* *May 2-6*	*Mid May* *May 14 - 18*	*Late May* *May 30 - June 1*
2.5 cm	Untreated	714	707	933
	Pre-emerge harrow	622	478	567
	Herbicide	99	186	209
7.5 cm	Untreated	749	781	656
	Pre-emerge rod-weed	656	183	315
	Herbicide	31	183	314
LSD			*195**	

* LSD (P=0.05) to separate weed control means within hte same seed depth and seeding date.

Table 2. Interaction effects of field pea seeding date, seed depth, and weed control system on field pea yield at Scott -- 1999-2001.

		Crop yield *(kg/ha)*		
Depth	*Treatment*	*Early May* *May 2-6*	*Mid May* *May 14 - 18*	*Late May* *May 30 - June 1*
2.5 cm	Untreated	1758	2076	1103
	Pre-emerge harrow	1933	2738	1437
	Herbicide	2930	2719	2032
7.5 cm	Untreated	2163	2059	1340
	Pre-emerge rod-weed	2214	2737	1795
	Herbicide	3363	2729	1807
Seeding date means		*2393*	*2510*	*1585*
LSD		*146**	*242***	

* LSD (P=0.05) to separate seeding date means

** LSD (P=0.05) to separate weed control means within the same seed depth and seeding date.

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9-18 Selectivity - an important concept in mechanical weed control

– E. Johnson - Scott Research Farm

Problem

Some form of mechanical weed control is generally used by most organic producers. Post-emergence weed control with an implement such as a harrow or a rotary hoe may control weeds, but does not always improve crop yields. If weed interference is reduced, then why aren't crop yields always improved?

Background

Selectivity is defined as the ratio between weed control and crop injury.[1] In general, mechanical weed control is most selective when the crops differ from weeds in growth habit, emergence time and maturity time.[2] Weeds with a short specific germination period are more easily controlled mechanically than weeds that germinate over a long time period.[2] Large seeded crops can be seeded deep which allows highly selective mechanical weed control between seeding time and crop emergence.[3] Most weed seeds emerge from the top two cm of soil with the maximum emergence depth at six cm.[4] This technique can provide effective weed control and give the crop a competitive advantage.[5,6] Pavlychenko[7] observed that pre-emergence tillage provided the emerged crop with about a ten-day weed free period.

Wild oat can emerge from greater depths than most other weed species but pre-emergence tillage can still be effective. Wild oat has a mesocotyl that extends the growing point meristem away from the seed to near the soil surface.[8] In cereal crops, the mesocotyl remains close to the seed, protecting the growing point from mechanical injury.

Fifty-two percent of organic growers surveyed in Saskatchewan use post-emergence harrowing as a weed control practice.[9] Post-emergence tillage generally has low selectivity as the negative crop covering effect can offset the positive weed killing effect.[10]

Studies in Europe show that the primary action with post-emergence harrowing is burying plants with soil and less than 25% of the weeds are uprooted by the treatment.[11] The amount of soil burial required to control many weed species varies between two and three cm.[12,13] This may be difficult to achieve in the field as it was found that less than 10% of harrowed plants were buried deeper than 1.5 cm.[11] Partially buried plants generally survive,[13] although dry soil conditions may increase the mortality of partially buried plants.[14]

Sensitivity to soil burial is related to seed size.[13] Small-seeded plants exhibit greater mortality when buried, particularly in early growth stages. The small seeded plants rely heavily on photosynthesis to supply their energy needs, while large-seeded plants can draw on seed reserves in early growth stages.[3,15]

Weed burial effectiveness depends on soil texture, weed growth stage, plant architecture, harrowing speed and depth, harrow setting, soil moisture and number of passes. Fine-textured soils have a higher mechanical resistance than coarse-textured soils, which impedes recovery of buried plants.[16,13] The plant's ability to resist bending is important in tolerating post-emergence harrowing as bent plants are more easily buried.[14,13,11] Therefore, plants in advanced growth stages tolerate post-emergence harrowing better than seedlings. Weeds that form a rosette with their meristem close to the soil surface are more sensitive to burial than erect weeds with their meristems above ground level.[13]

Soil coverage increases in proportion to harrowing depth.[17] Weed control due to harrowing will be spatially variable in a field, as working depth and soil cover will fluctuate in response to soil conditions. Weed burial by a tine implement may vary due to ridges formed by the back row of tines. Kurstjens and Perdok[11] reported that up to 80% of weeds were covered by ridges between the tines; however, the trench left by the tine covered less than 30% of weeds. This may be why multiple passes tend to result in more efficacious weed control as subsequent harrow passes may fill the trenches with soil.

The amount of soil disturbance a harrow causes is controlled by the angle of the harrow tine in relation to the soil surface. A forward pointing tine was found to cause 42% more horizontal transport of soil than a backward pointing tine.[18] The distance soil aggregates move is proportional to the square of the tool velocity. Therefore, increased harrow speeds result in more uniform soil covering of weeds but do not necessarily increase burial depth.[19] Faster harrow speeds do not improve selectivity as they increase soil burial of both weeds and crop.[1]

Soil moisture's effect on post-emergence mechanical tillage efficacy is not clear. In controlled environment studies, moisture content did not affect survival of four weed species if they were completely buried.[14]

Dry conditions were very effective in improving mortality if plants were pulled from the soil and the roots were re-buried. Good soil moisture conditions might have resulted in the differential ability of spring wheat and wild oat to recover from harrowing.[20] Above-normal precipitation and good soil moisture conditions at and following harrowing were reported in the one year where harrowing improved spring wheat yield. The effect of soil moisture on harrowing efficacy may also be dependent on the weed species.[11]

Multiple harrow passes may be required to achieve some level of weed control.[20,21,22] A model developed by Rasmussen[23] suggested that up to three harrow passes provided the optimum level of weed control and yield response in field pea. Four to five consecutive harrow passes in winter wheat were required to achieve up to 95% weed control.[24] Three passes reduced weed biomass by about 75% in spring barley.[22]

Deep harrowing, high soil disturbance, and multiple passes may cause more weed burial; however, selectivity is not necessarily improved as there is generally a proportional increase in crop burial.[10] Under low weed populations, increased crop covering due to consecutive harrow passes resulted in a decline in spring barley yields of 0.12 to 0.15% for every unit percentage of crop cover. To minimize crop injury, it is usually recommended that harrowing be conducted in the same direction as crop rows.[25] However, Wilson *et al.*[21] found that harrowing direction had no impact on weed control or crop injury in winter wheat.

Harrowing may be more selective at the crop's later growth stages, provided the weeds are in early developmental stages.[24] Four passes with a flex-tine harrow resulted in up to 90% control of small broadleaf weeds with no damage to winter wheat when it was harrowed at a height of 20 to 25 cm. The established crop was able to push the tines sideways where inter-row weeds were controlled. Wilson *et al.*[21] also reported that winter wheat tolerated harrowing in the spring, but autumn harrowing caused severe crop injury.

Overall, yield responses to post-emergence harrowing have been modest due to low crop-weed selectivity. Kirkland[20] reported a 19% spring wheat yield increase in one year of a three-year study. In Denmark, post-emergence harrowing resulted in spring wheat yields ranging from 91 to 118% of the untreated check.[26] Yield response in winter wheat has ranged from 0 to 10%.[21,24] A model for harrowing in field pea suggested yield responses in the range of 0 to 5% corresponding to 0 to 70% weed control.[23] However, Al-Khatib *et al.*[27] reported that post-emergence cultivation with a finger weeder resulted in an 18% yield increase in field pea. Weed control levels in harrowed spring barley averaged about 75%; however, yield responses did not exceed 10%.[22] Models developed by Rasmussen[10] suggest that crop yield response will be greater under high weed pressure, as the positive weed-killing effect will outweigh the negative crop damage.

Conclusions

Organic growers who use mechanical weed control techniques should time their operations to maximize selectivity. Pre-emergence tillage in deep seeded crops can result in highly selective weed control. Post-emergence harrowing has low selectivity, therefore organic growers need to scout their fields to determine if the practice is justified. If post-emergence harrowing is warranted, every attempt should be made to minimize crop injury.

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9-19 Evaluating *Interceptor* – an organic herbicide

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Problem

Organic producers are not allowed to use synthetic pesticides in their production system. However, herbicides derived from natural sources may be allowable. Interceptor is a herbicide registered and certified for organic production in New Zealand. A non-selective organic herbicide could be very useful in replacing pre-seeding or pre-emergence tillage. This study's objectives were: 1) to evaluate Interceptor's efficacy in controlling annual indicator weeds, and 2) to define application parameters that may improve Interceptor's efficacy.

Background

Interceptor is a non-selective, contact herbicide derived from an extract of pine oil. Since the herbicide kills by contact, uniform spray deposition on the target plant is required for maximum efficacy. We did preliminary greenhouse and field studies to evaluate Interceptor's efficacy in organic field crop production, using canola and tame oat as indicator 'weeds' in both studies. Preliminary greenhouse studies were done at the Scott Research Farm. Interceptor application resulted in quick desiccation of canola plants but had little activity on oat plants in the greenhouse studies. This is likely due to the contrasting leaf orientations of canola and oat. Canola's broader leaves are horizontally oriented, while oat has thin, vertically oriented leaves. Broad, horizontal leaves receive more spray droplets and the spray is more likely to be retained on the leaf. Greenhouse studies also suggested that weed control with Interceptor could be improved by increasing carrier volume from 10 gpa to 20 gpa.

Study description

Field studies were conducted at all SPOKE sites plus the Kernen Crop Research Farm at Saskatoon. Canola and oat were seeded at target densities of 150 and 200 plants m^{-2} respectively. Plot size varied by location. Interceptor was applied at three rates: 10%, 20% and 30% v/v concentration. Included in the study were an untreated check and an industry standard (glyphosate). Glyphosate rates were 0.25, 0.50 and 0.75 liters/acre. Interceptor was applied with standard spraying equipment using a carrier volume of 20 gpa. Glyphosate was applied at 5 to 10 gpa. Herbicides were applied when the plants were in the three-to-five leaf stage. Experimental design was a randomized complete block.

Visual control ratings (0 to 100% control) were taken three, seven, and 14 days after application. Plant biomass data were collected 14 to 21 days after seeding.

Major findings

Trends were similar for all locations -- we combined data. Interceptor caused some leaf burn on oats, but control ratings averaged less than 10% (Table 1). There was no significant reduction in wild oat biomass from Interceptor treatments at all rates. Since Interceptor is strictly a contact herbicide, spray coverage is critical. Oat has a narrow leaf with a vertical orientation, therefore spray retention is generally low. Interceptor gave slightly better results on canola, but overall control was still not satisfactory (Table 2). Interceptor was very fast acting on canola -- symptoms appeared within a few hours. Initial control ratings for Interceptor were higher than for glyphosate. However, significant regrowth occurred one to two weeks after Interceptor application. Final control ratings for Interceptor ranged from 10 to 26% depending on rate. The 30% Interceptor rate resulted in about a 22% reduction in canola fresh weight, relative to the untreated check. Glyphosate application at rates above 0.50 liter/acre resulted in a 99% reduction in both oat and canola fresh weight.

Conclusions

Interceptor herbicide is not effective as a non-selective herbicide using conventional field application technology. Control may be slightly improved with flooding type nozzles that improves spray coverage; however, it is doubtful that small changes in application technology would result in an acceptable level of weed control. High rates of active ingredient are required with Interceptor, which would further reduce its applicability in extensive field crop production.

In spite of its limitations for field crop production, Interceptor herbicide may have potential as a herbicide for the domestic market. Many urban municipalities are restricting the use of pesticides. In an urban situation, the high concentration required is not an issue due to the small areas usually treated. Since domestic application is usually done with a hand sprayer, spray coverage may be improved. Homeowners who wish to use a herbicide derived from a natural source may find the fast acting nature of the herbicide appealing -- symptoms appear in hours.

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Table 1. Efficacy of Interceptor and Glyphosate in the control of tame oat. Mean of eight Saskatchewan locations -- 2001.

Treatment	*% Visual Control 3 DAT*	*% Visual Control 7 DAT*	*% Visual Control 14 DAT*	*Weed biomass g/m^2*
Check - untreated	0.0	0.0	0.0	538.4
Interceptor 10%	4.4	2.4	3.2	535.7
Interceptor 20%	6.6	5.1	5.4	511.3
Interceptor 30%	15.9	9.8	9.6	519.9
Glyphosate 0.25 L/acre	8.4	67.1	87.6	2.7
Glyphosate 0.50 L/acre	13.8	86.4	95.5	1.5
Glyphosate 0.75 L/acre	18.1	91.3	99.5	2.8
			LSD$_{0.05}$	71

Table 2. Efficacy of Interceptor and Glyphosate in the control of canola. Mean of eight Saskatchewan locations -- 2001.

Treatment	*% Visual Control 3 DAT*	*% Visual Control 7 DAT*	*% Visual Control 14 DAT*	*Weed biomass g/m^2*
Check - untreated	0.0	0.0	0.0	497.2
Interceptor 10%	13.1	14.6	9.8	558.2
Interceptor 20%	33.1	30.5	20.2	435.4
Interceptor 30%	49.7	36.4	26.6	388.7
Glyphosate 0.25 L/acre	10.3	51.4	72.3	47.7
Glyphosate 0.50 L/acre	14.1	75.5	88.1	0.7
Glyphosate 0.75 L/acre	18.8	79.9	91.8	0.3
			LSD$_{0.05}$	94

9-20 Organic lentil production – optimum seeding rate, row spacing

– E. Johnson - Scott Research Farm

Problem

Pulse crops such as lentils compete poorly with weeds. Post-emergence harrowing may be used; however, this can cause damage and result in higher levels of disease such as Ascochyta blight. This study's objective was to assess various row spacings (11, 22, 33, and 44 cm) and seeding rates (30, 60, 120, and 240 kg ha^{-1}) to improve competitiveness of organically grown lentil.

Background

Farmers attempting to minimize negative effects of uncontrolled weeds often consider using narrower row spacings and higher seeding rates. Spring barley seeded in 33 cm rows and not treated with herbicides had 46% and 55% higher wild mustard biomass compared to barley seeded in 11 and 22 cm rows, respectively.[1] Increasing barley seed rate from 85 kg ha^{-1} to 200 kg ha^{-1} reduced wild oat dry matter and seed production.[2] Increasing field pea seeding rate reduced weed densities and improved crop yield at Melfort.[3] Research conducted in Alberta shows that increased canola seeding rates can reduce the competitive effect of tartary buckwheat.[4] We anticipate that narrower row spacings and higher seeding rates will improve the yield of organically grown lentil.

Study description

The study was conducted in both 2000 and 2001 on a tilled fallow site that received an early spring cultivation. Glamis lentil was seeded with a hoe-drill plot seeder equipped with on-row packing. In the 2000 trial, weeds were seeded into the test area prior to seeding lentil. In 2001, lentil was seeded into a location known for its high natural density of annual weeds. Wild oat, wild mustard, lambs quarters and stinkweed made up most of the weed population in both years. The experiment was conducted according to a split plot design with row spacings (11, 22, 33, and 44 cm) as the main plot factor and seeding rate (30, 60, 120, and 240 kg ha^{-1}) as the subplot factor. Treatments were replicated four times. Subplot size was 2 m x 5 m. No post-emergence herbicides were applied. Data collected included only lentil seed yield.

Major findings

Extremely high weed populations severely reduced lentil yield in 2000, while 2001 yields were much better under natural weed populations. In spite of low yields in 2000, yield trends were similar for both years and data were combined. Lentil yield increased as seeding rate increased at the 11, 22 and 33 cm row spacings (Figure 1). At the 44 cm row spacing, increased seeding rate above 60 kg ha^{-1} had no effect. Optimum seed rate for lentil grown in the presence of weeds approached 150 to 200 kg ha^{-1}.

Conclusion

Organic producers should consider seeding in a narrow row spacing combined with increased seeding rates. If narrow rows are not practical, then producers should use a seeding implement that distributes seed in a wide row band.

Optimum seed rate for lentil under weedy conditions was approximately 1.5 - 2.0 times the current recommended seeding rate for conventional producers.

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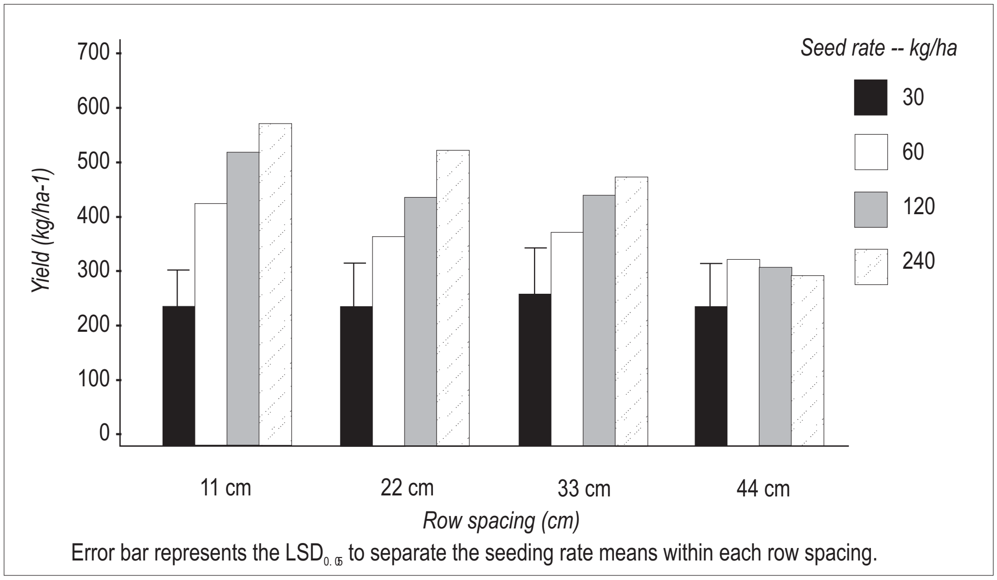

Figure 1. Mean lentil yield response to effects of row spacing and seeding rate -- lentil growing under weedy conditions -- Scott -- 2000 - 2001.

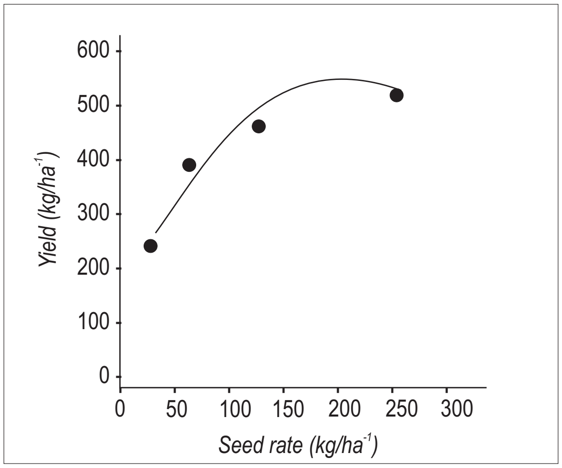

Figure 2. Effect of seed rate on lentil yield (kg/ha) grown in weedy conditions. Seed rate means are the mean of two years of data and three row spacings (11, 22, 33 cm) where row spacing had an effect.
Scott -- 2000 - 2001

9-21 Clipping weeds above a crop canopy

– E. Johnson - Scott Research Farm
– G.E. Hultgreen - Prairie Agricultural Machinery Institute, Humboldt

Problem
Weed control is a challenge for organic growers. Organic producers rely on crop rotation, cultural practices, and mechanical means to control weeds. Weeds in short stature crops such as flax and lentil can be particularly problematic. This study's objectives were: 1) to develop or modify field equipment that could clip weeds above the crop canopy, 2) to determine if weed clipping improves crop yield, and 3) to determine if weed clipping influences weed seedling densities in the subsequent growing season.

Background
Some organic producers have experimented with clipping weeds above the canopy of short stature crops such as lentil or flax. While clipping weeds may provide some aesthetic value, it is not known whether the practice will affect crop yield or weed seed return to the soil seed bank. A project was initiated in 1999 to develop or modify equipment for weed clipping and to evaluate whether the practice improved crop yield and/or reduced weed seedling recruitment the following growing season. At Scott, a field experiment was conducted over two years where clipping at various stages of weed development was evaluated. Clipping was done above a lentil crop canopy with a gas-powered hedge trimmer. The Prairie Agriculture Machinery Institute (PAMI) at Humboldt modified the cutting component of a self-propelled swather and carried out field trials on four farm fields.

Study description
Scott experiment
- Conducted in 1999 and 2000
- Experimental design: RCBD
- CDC Glamis lentils seeded on May 18, 1999 and May 8, 2000
- Lentil seeded in 22 cm rows at a rate of 130 kg/ha^{-1}
- Wild oat and wild mustard seeded at a density of 100 seeds/m^{-2} between the crop rows
- Clipping done at these timings:
- -- 1 -- Wild mustard in full flower/ Wild oat in boot stage;
- -- 2 -- Wild mustard podded/ Wild oat headed;
- -- 3 -- Wild mustard seed watery-ripe/ Wild oat mid-dough stage;
- Herbicide and unclipped weedy checks were included.
- Herbicide treatment: post-emergence sequential application of metribuzin (212 g ai/ha^{-1}) sethoxydim (212 g ai/ha^{-1}).

Data collection included crop yield and wild mustard and wild oat seedling emergence the following spring (plants m^{-2}) prior to seeding. In the spring of 2001, lambs quarters (*Chenopodium album* L) emergence was also recorded.

PAMI field trials
Fields were clipped above a lentil or flax crop with a modified swather. Each field also had an unclipped check strip.

Major findings
Scott experiment
Weed clipping did not result in a detectable lentil yield increase in either year (Figure 1). Clipping must be postponed until the weeds elongate above the crop canopy. Most of the yield loss associated with weed competition occurs in early crop development stages.

Although variable, clipping reduced subsequent weed seedling emergence. Clipping in 1999 reduced wild oat emergence the following spring if the clipping occurred after wild oat heading (Figure 2). In the 2000 - 2001 study, wild oat populations were low and clipping did not cause a significant reduction in emergence.

There was no detectable difference in wild mustard recruitment in the 1999 - 2000 study, but there was a trend towards lower densities when the wild mustard was clipped at the podding stage (Figure 3). Many of the pods formed below the crop canopy in the first year of the study, which reduced the efficacy of clipping. Clipping at anyy weed stage was effective in reducing wild mustardd recruitment in the 2000 - 2001 study (Figure 3). Recruitment of lambs quarters showed similar results (Figure 4).

PAMI field trials
Field studies conducted by PAMI showed similar trends to the Scott trials (Table 1).

Conclusions

While results are preliminary, weed clipping may have potential as a means of reducing weed seed return following a short stature non-competitive crop. Further study is warranted to define optimum timing for clipping and to improve consistency of results.

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Table 1. Effect of weed clipping on subsequent wild oat and wild mustard density (plants/m^2). Mean of four field trials conducted by PAMI. Fields used as replicates to determine LSD. Assessments done in spring of 2001.

	Wild oat density (plants/m^2)	*Wild mustard density (plants/m^2)*
Unclipped	29	17
Clipped	6	6
$LSD_{0.05}$	22	21

Figure 4. Effect of weed clipping on subsequent lambs quarters density -- Scott -- 1999 - 2000. Error bar represents $LSD_{0.05}$.

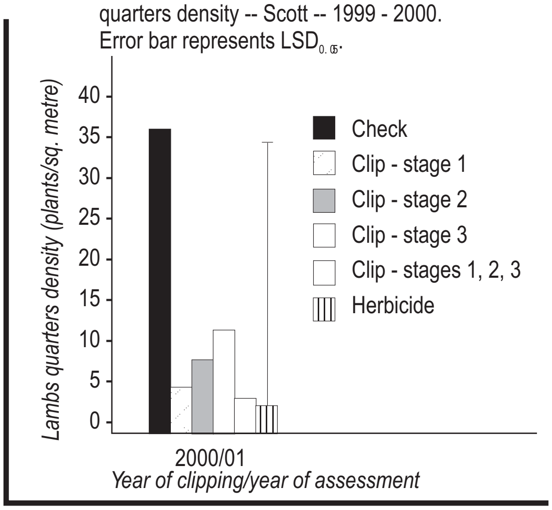


Figure 1. Effect of weed clipping on lentil yield -- Scott -- 1999 - 2000. Error bars represent the $LSD_{0.05}$ within years.

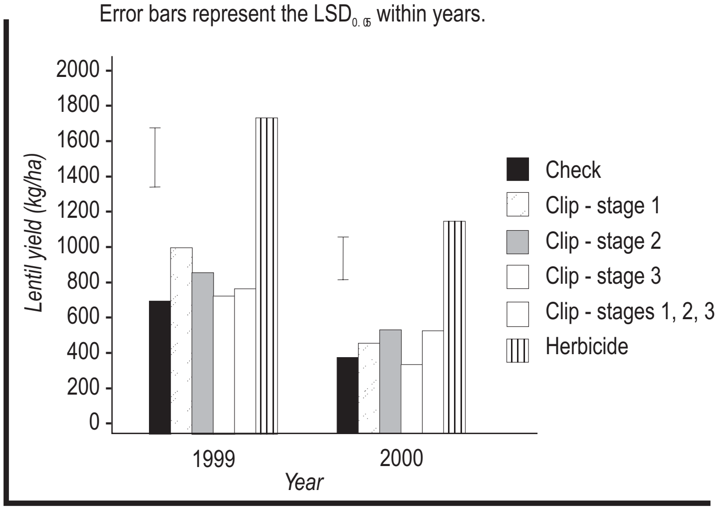


Figure 2. Effect of weed clipping on subsequent wild oat density -- Scott -- 1999 - 2000. Error bars represent $LSD_{0.05}$ within years.

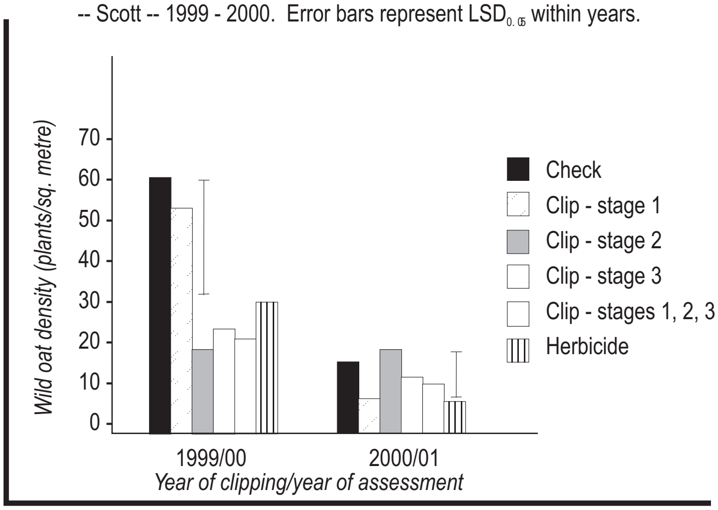
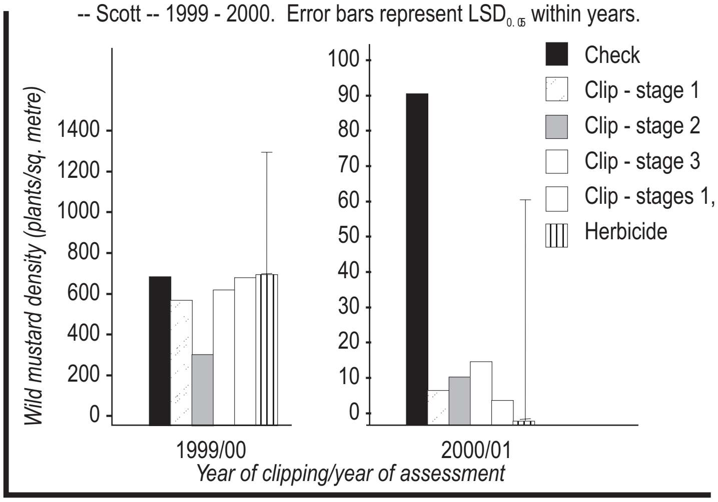


Figure 3. Effect of weed clipping on subsequent wild mustard density -- Scott -- 1999 - 2000. Error bars represent $LSD_{0.05}$ within years.



9-22 Photocontrol – tilling in the dark?

– E. Johnson - Scott Research Farm

Problem

Many buried weed species develop a light-dependent stimulus for germination. This led to the concept of photocontrol, (excluding light during tillage), as a potential way to reduce weed seed germination. Much research has been conducted on photocontrol in Europe and South America, but very little has been done in western Canada. We examined the potential of photocontrol in western Canada with an extensive literature review to indicate whether further research is warranted.

Background

The soil contains a massive amount of weed seeds with estimates as high as 137,000 seeds per square meter.[1] The density and composition of the seed bank is very heterogeneous within a landscape[2,3] and is closely linked to the land's cropping history[4,5] but will also be influenced by tillage practices,[6,7] soil water,[5] and soil type.[2]

In temperate climates most seeds are dispersed near the end of the growing season.[8] Spring annual weed seeds must avoid germination before entering the winter. Late summer germination is avoided by seeds' primary dormancy, light induced dormancy, and normally, low amounts of available water. As autumn progresses low temperatures additionally inhibit germination.

Seeds can become light-dependent for germination upon burial in the soil.[9] The first plants to emerge after disturbance of natural vegetation or perennial cover arise from dormant seed in the soil rather than from freshly dispersed seed.[10] Large populations of viable buried weed seeds were found in soil that had been in pasture for six years.[11] Soil cultivation produced a large flush of germination during the subsequent four weeks. Exhumed seeds had low germination levels in the dark but a 90-second light flash was enough to cause germination of a large proportion of the seeds.

Light stimulus from soil disturbance is an important evolutionary survival mechanism.[8] Soil disturbance will reduce competition from established plants, thereby improving the seedling's chance of survival. Light requirement can be a signal that the seed is close enough to the soil surface so it has a high probability of successful emergence. The light stimulus is mediated by a sophisticated photoreceptor in plants known as phytochrome that is extremely sensitive to fluctuations in light intensity and light quality.[12] Phytochrome functions at all stages of the plant's life cycle, acquiring information on the light environment, and giving the plant the capacity to adapt to light fluctuations.

Studies have shown that excluding light during tillage can reduce weed seed germination.[13,14,15,16,17,18,19] Photocontrol has been accomplished by tilling at night or covering the tillage implement with a light-proof cover. Weed emergence from light-induced tillage is the result of the light flash experienced during tillage and not from light that may reach the seed after emergence.[19] Experiments where tillage was conducted in the dark and the area covered with opaque plastic sheets had similar emergence to plots tilled in the dark and not covered.

Light-excluded tillage has generally caused a greater reduction in the number of dicots emerging, with less impact on grasses.[15] Emergence of small seeded broadleaf weed species such as lambs quarters, pigweeds, and wild mustard were reduced with night tillage, but there was no effect on large seeded broadleaf species like velvetleaf.[16] However, another study found no relationship between seed size and light-induced germination.[20]

Jensen[16] found that weed emergence from daytime tillage was due to an increased emergence of weed seeds from deep levels where light could not normally penetrate. Night tillage may also slow weed seeds' germination rates, thus allowing a seeded crop a chance to emerge before weed emergence.[15,20] Time of season can influence the success of photocontrol since many species have seasonal dormancy periods.[19] A study in southern Sweden found that night tillage was most effective in May, less effective in April and August, and ineffective in October.[18] Reduction in weed emergence from nighttime tillage was quite small in this study, ranging from 5 to 30%.

Success with photocontrol may be dependent on the type of tillage implement used. Nighttime tillage was effective in reducing seedling emergence when a moldboard plow was used, but was ineffective when a chisel plow was used.[19] Moldboard plowing may have moved a higher percentage of deeply buried, light sensitive weed seeds to the surface than the chisel plow.

Results from photocontrol have been inconsistent with germination reductions ranging from no effect[19] to as high as a four-fold decrease in some cases.[15] In other cases, a decrease in relative emergence of many annual species has been reported but absolute weed numbers in light-excluded plots were still unacceptably high.[14,15]

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The inconsistent response to photocontrol is likely due to the complexity of the seed germination process. In addition to light, weed seed dormancy can also be broken by fluctuating soil temperatures,[21] and soil nitrate level.[22] Also, some weed seeds can lose their light dependency over time[22] and there can be considerable genetic variation within a weed species in their response to light.[20]

Conclusions

Weed seed-bank dynamics are affected by agronomic practices and environmental and soil conditions. Tilling in the dark has shown potential in some experiments; however, results have been inconsistent. Organic producers may want to evaluate this practice on their own farms; however, they should not have high expectations of success.

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9-23 Weed control – false seed bed technique

– *E. Johnson - Scott Research Farm*

Problem

Organic producers often use spring cultivation to stimulate weed populations to germinate. Once weeds have emerged, they can be controlled before or as the crop is seeded. Seeding is delayed to allow time for weed germination and tillage. How long should the farmer wait between final tillage and seeding the crop?

Background

Spring tillage can be used for weed control as well as to prepare the seedbed. Shallow pre-seeding tillage (less than three inches) in early spring can aerate and warm the soil, thus stimulating weed seedling germination. Harrow-packing following spring cultivation firms the soil and further encourages weed seed germination. The tillage operation should destroy weed growth while conserving as much soil moisture and crop residue as possible.[1] The second tillage operation is delayed until weeds have emerged.[2] Seeding can then be conducted after the second tillage operation. This practice can be especially successful at reducing the weed seedbank of winter annual and early emerging species, such as stinkweed,[3] knotweed, Russian pigweed, Russian thistle, lambs quarters, wild mustard,[4] wild oats, and wild buckwheat. Weed control can be very successful with delayed seeding, but the practice may reduce crop yields either because of increased losses due to delayed harvest, or from reduced moisture in tilled soils.[5 6 7] Seeding should only be delayed long enough to let weeds emerge.

Study description

The study was conducted at Scott from 1997 to 1999 and at Melfort from 1997 to 2000. Both grass and broad-leaved weeds were seeded in the early spring, and were then cultivated and harrow packed. Field pea, lentil, canola and flax were sown the same day, and one, two, three, four or five days later.

Our experimental design was a randomized complete block with four replications.

Major findings

Pre-seeding tillage timing did not always have an impact on weed density or crop yield. When it was important, it was generally better to seed as close to tillage as possible. Pre-seeding tillage timing appeared to have more effect under the higher moisture conditions experienced at Melfort. However, pea yields were improved at Scott in 1998 if seeding was conducted soon after tilling (Table 1). At Melfort, flax yield declined as seeding was delayed (Table 1) with field pea and canola yields showing similar trends. Overall yields were low at Melfort in 1999 but flax showed similar yield responses to pre-seeding tillage timing with highest yields occurring when seeding was conducted within one day of the final tillage operation (data not shown with this article).

Table 1. Delaying seeding after tillage -- effect on field pea and flax yield at Scott and Melfort, respectively -- 1998.

Days between tillage and seeding	*Field pea yield Scott, 1998 kg/ha^{-1}*	*Flax yield Melfort, 1998 kg/ha^{-1}*
5	1335.8	194
4	1383.2	479
3	1345.3	784
2	1428.9	893
1	1488.2	1032
0	1492.9	1168

Conclusions

There may be yield benefits to seeding soon after the final pre-seeding tillage operation. Whether these benefits materialize or not probably depends on the timing of moisture availability for weed germination prior to seeding crop, and on conditions that permit adequate crop growth.

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9-24 Weeds – how to prevent new problems

– B. Frick, E. Johnson - Scott Research Farm

Problem

Weeds enter farms and fields in various ways. Historically, most of our weeds were introduced from Europe and other areas as a result of human immigration to the prairies. On individual farms, weeds are introduced from neighbouring farms, from suppliers, from road margin to field and from field to field. How can we prevent new weeds establishing on farms?

Background

Introduction of weeds onto the farm can be slowed, but not halted, by careful prevention and sanitation. Some seed movement is inevitable, due to birds, mammals, movement during snow melt, etc.

The first step in preventing weed introduction is to sow clean seed. Weed seeds are found as contaminants in the seed from other farms,[1] or in seed cleaned at grain elevators.[2] Weed seeds and vegetative parts can be transported on equipment. It is a sound practice to thoroughly clean equipment that moves between fields or beyond weed patches. This is especially important if custom work is done. A tarp over grain, soil or feed being transported will prevent contamination along roads or in yards.

It is often recommended that weeds be removed along fence lines, shelterbelts, road allowances or in other non-crop areas to prevent them from spreading to fields. However, only a few weeds on field margins pose a real threat of spreading into adjacent fields.[3] Complete elimination of field margin weeds may damage beneficial insects that require weeds as host species. If non-crop areas are especially weedy, they can be seeded to competitive native grasses. Movement of Canada thistle into fields is reduced by having the field margin sown to native species, rather than having an unsown border.[4] If these areas are mowed, delaying operations until late July will allow ground nesting birds to raise their broods.[5]

A chaff saver behind the combine can collect weed seeds. It is especially good at collecting crop seeds that blow over and cause volunteer problems in following years. It is also effective at removing large numbers of seeds of later maturing weeds. This practice prevents some weed movement within a field and provides useful livestock feed. Weed seeds should be cooked, ground or pelleted before using as feed. Chickens are especially good at destroying weed seed viability. Sheep, horses, swine and cattle are progressively less effective at destroying weed seed viability.[6] If green feed contains weed seeds, it can be made into silage to destroy them. Properly composting livestock manure should kill most weed seeds.[7]

Conclusions

Weed movement onto farms and among fields can be slowed. Importing weeds can be reduced by sowing clean seed, by purchasing only clean plant material such as hay, and by cleaning equipment traveling among fields. Careful management of non-crop areas can reduce weed movement into fields. Chaff collection can reduce future weed problems.

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9-25 Field pea harrowing – flex-tine weeder or tine harrow?

– *E. Johnson - Scott Research Farm*

Problem

Post-emergence harrowing generally results in low selectivity, which is the ratio between weed control and crop injury.[1] Many organic growers have suggested that selectivity of post-emergence harrowing could be improved with changes in implement design. This study's objectives were to determine if selectivity differed between a Lely Flex-tine harrow and a tine harrow; and to determine whether multiple passes will optimize weed control in field pea.

Background

The flex-tine weeder is a common implement used in Europe by organic growers in crops such as sugar beets[2] and potatoes. The flex-tine harrow is also referred to as a finger weeder.[3] The springy tines of the flex-tine harrow are gentle enough not to harm the crop while uprooting or covering small weeds. The long, thin spring-tines may be pushed aside by a well-established crop, allowing for selective weed control between rows. The amount of soil disturbance caused by the flex-tine harrow can be adjusted by adjusting the angle of the tine relative to the soil surface.

Fifty-two percent of organic growers surveyed in Saskatchewan use post-emergence harrowing as a weed control practice.[4] There are very few published papers on post-emergence harrowing in western Canada. Results of a 12-year study at Indian Head showed that yield of barley and spring wheat grown under weed-free conditions was not reduced by a single harrow pass conducted at emergence, the 1.5 or 2.5 leaf stage.[5] Kirkland[6] reported that multiple post-emergence harrowing passes reduced wild oat panicles and fresh weight in spring wheat in two years out of a three-year study. However, spring wheat yield was improved in only one year of the study. Three to four passes were required in order to obtain a 40 to 80% reduction in wild oat fresh weight.

Studies have shown that field pea can tolerate post-emergence tillage performed with a harrow or rotary hoe.[7,8] Yield responses from post-emergence tillage in field pea have ranged from 0 to 18%.[8,9,10]

Study description

The study was conducted on wheat stubble from 1999-2001. An early spring cultivation was performed on the experimental area. Wild oat and wild mustard were seeded across the plots at a target density of 100 plants/m^{-2} for each species. A second shallow cultivation was done immediately after weed seeding to uniformly distribute the weed seeds.

Field pea (*cv.* Grande) was seeded in early May at a rate of 220 kg/ha^{-1} (80 viable seeds/m^{-2}) with a hoe-drill plot seeder (22cm row-space) according to the treatment design. Field pea was inoculated with 5.6 kg/ha^{-1} of granular inoculant applied in the seed row. The experiment was conducted according to a randomized complete block design.

Treatments included a factorial combination of harrow type (tine and flex tine), levels of flex tine soil disturbance (low, moderate, and high), and number of operations (one - four passes). Settings for the flex-tine harrows are illustrated in Figure 1.

Our strategy for multiple harrow passes was: one pass = single harrowing at crop's three to four node stage; two passes = single harrowing at crop's three to four node stage and a single harrowing one week later; three passes = double harrowing at crop's three to four node stage and a single harrowing one week later; and four passes = double harrowing at crops' three to four node stage and a double harrowing one week later.

Untreated and herbicide (imazamox + imazethapyr 50:50 applied at a rate of 30 g ai/ha^{-1}) checks also were included in addition to the factorial arrangement of harrow type and passes. Treatments were replicated four times. Subsubplots were 2 m x 5 m. Data collected included field pea density, total weed density and fresh weight, and seed yield.

Major findings

The tine harrow and moderate and high disturbance settings of the flex-tine harrow caused a decline in field pea density as the frequency of harrowing increased (Figure 2). The flex-tine harrow's low disturbance setting resulted in minimal crop injury with plant densities similar to the herbicide treatment and the untreated check.

Highest weed densities were recorded with the flex-tine harrow at the low disturbance setting (Table 1). All other harrow types and settings resulted in similar weed densities. Two or more harrow passes resulted in the lowest weed densities for all the harrow types and settings.

We found no significant difference in weed fresh weight between harrow types or disturbance settings (Table 2). Although the flex-tine harrow's low disturbance setting resulted in the highest weed densities, maintaining sufficient plant populations allowed the crop to compete more effectively with weeds. Three or more passes resulted in up to a 40% decline in weed fresh weight (relative to the untreated check), independent of harrow type or setting.

All harrow types and settings resulted in similar field pea yields (Table 3). Highest yields were obtained with the three pass system which resulted in approximately 20% higher crop yield than the untreated check. Herbicides improved crop yield by 60%.

Results from this study are consistent with other studies comparing harrow types. A tine harrow was more effective in reducing broadleaf weed numbers than a rotary harrow, however it caused more crop injury.[11] Rasmuusen[10] reported that a flexible chain harrow was a more efficient weed killer than a spring-tine harrow but it also caused more crop damage in field pea and spring wheat. He concluded that similar results could be obtained with all harrow types, if their settings are adjusted to give similar plant covering effects.

Conclusions

Crop injury could be reduced by using a low disturbance setting on the flex-tine harrow. The flex-tine harrow can be easily adjusted to vary the amount of soil disturbance and crop covering. The harrow should be set to minimize a reduction in plant density. High levels of soil disturbance did not result in improved weed control. The three-pass system employed in this study resulted in a 50% reduction in weed biomass and a 20% increase in field pea yield.

Figure 1. Settings for flex-tine harrow experiment. Scott -- 1999 - 2001.

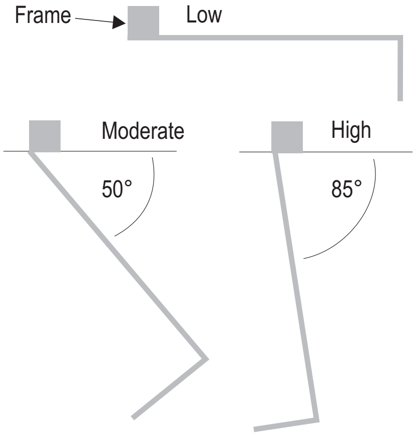

Table 1. Tine harrow, flex-tine harrow setting, and number of post-emergence passes -- effect on weed density (plants/m^2). Scott, SK. 1999-2001.

Factor	*Weed density (plants/m^2)*
Harrow	
Tine	55
Flex-tine - Low disturbance	93
Flex-tine - Moderate disturbance	68
Flex-tine - High disturbance	57
LSD ($P=_{0.05}$)	*19*
Number of passes	
One	85
Two	66
Three	62
Four	59
LSD ($P=_{0.05}$)	*19*
Checks	
Untreated	107
Herbicide	26

Table 2. Tine harrow, flex-tine harrow setting, and number of post-emergence passes -- effect on weed fresh weight (g/m^2). Scott, SK. 1999-2001.

Factor	*Weed fresh weight (g/m^2)*
Harrow	
Tine	315
Flex-tine - Low disturbance	375
Flex-tine - Moderate disturbance	338
Flex-tine - High disturbance	307
LSD ($P=_{0.05}$)	*NS**
Number of passes	
One	395
Two	373
Three	271
Four	296
LSD ($P=_{0.05}$)	*71*
Checks	
Untreated	441
Herbicide	30

* *NS* = Differences between means are not significant

Figure 2. Tine harrow, flex-tine harrow setting, and number of post-emergence passes -- effect on field pea density (plants/m^{-2}) -- Scott -- 1999 - 2001.

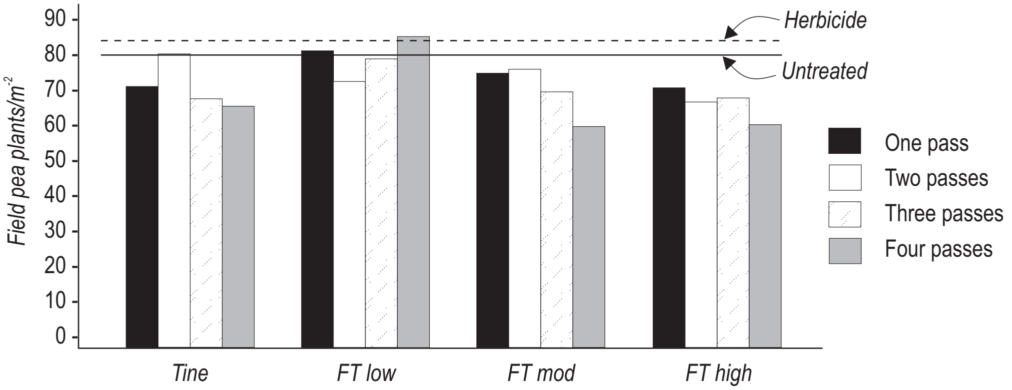

Table 3. Tine harrow, flex-tine harrow setting, and number of post-emergence passes -- effect on field pea yield (kg/ha). Scott, SK. 1999-2001.

Factor	*Field pea yield (kg/ha)*
Harrow	
Tine	2306
Flex-tine - Low disturbance	2334
Flex-tine - Moderate disturbance	2203
Flex-tine - High disturbance	2301
LSD ($P=_{0.05}$)	*NS**
Number of passes	
One	2182
Two	2261
Three	2342
Four	2358
LSD ($P=_{0.05}$)	*170*
Checks	
Untreated	1989
Herbicide	3185

* *NS* = Differences between means are not significant

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