Weeds and Conservation Agriculture

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Summary

In crop production agriculture, tillage is used mainly for weed control. The advent of effective herbicides eliminated the need for wide crop rows to accommodate horse or tractor drawn cultivation equipment since herbicides can replace in-crop tillage and allow narrower row widths that maximize crop growth and yield. Until recently, the primary disadvantage of total no-till crop production was an increase in perennial weeds that required primary and seedbed tillage for control. Most herbicides used pre-emergent in crops only controlled germinating weed seeds and not established perennial plants. Most postemergent herbicides lacked selectivity for effective perennial weed control. Post harvest or before planting herbicide treatments for perennial weeds were limited because of possible soil residual or improper weed size for efficacy. The development of glyphosate tolerant crops and the use of pre and post-harvest glyphosate have essentially eliminated the perennial weed disadvantage for no-till agriculture. Glyphosate also controls annual weeds with excellent selectivity in tolerant crops. Glyphosate contributed to an estimated 60% no-till soybean production in Ohio and various herbicides allowed about 20% nottill corn production in Indiana, Illinois and Iowa in 2000. Herbicide usage increases with less tillage; but herbicides require far less energy in manufacture and use than tillage, an important benefit with increasing energy costs. This and other benefits of no-till crop production, such as reduced soil erosion and greater stored carbon, now can be achieved simply, effectively, and economically through herbicides that are safe to the user and the environment.

Key words: No-till, weeds.

Introduction

Reduced tillage that leaves a crop residual greatly reduces soil loss by wind or water erosion (Bilbro & Fryrear, 1994), sequesters carbon dioxide (Robertson et al., 2000), conserves energy for crop production (Retzlof, 1980), and retains soil moisture (Crutchfield, Wicks & Burnside, 1986). Crop yields are generally equal for conventional and no-till systems provided that weeds are controlled and proper crop stands obtained (Norwood, 1994; Miller & Nalewaja, 1985). Successful conservation agriculture, regardless of definition, is highly dependent upon effective weed control. Growers' respond to conservation practices provided production is maintained and the processes are compatible with individual operations. Today energy inputs in addition to soil conservation are of primary concern to both growers and society. In the past, attempts to implement reduced tillage conservation practices have often caused a loss in crop production because the reduced tillage did not adequately control weeds. The advent of effective herbicides provided the opportunity to reduce tillage as well as to plant crops in more narrow row widths for optimum plant growth and crop yield. Before the development of effective herbicides, crops were seeded in row widths that provided space for a horse or tractor drawn cultivator to control weeds. The recent development of highly active post-emergentapplied -herbicides and crops tolerant to broad-spectrum herbicides provide for simple effective weed control for conservation tillage practices. For these reasons, grower acceptance of conservation tillage practices will increase greatly in the near future.

The use of selective herbicides in the crop and non-selective herbicides in place of primary tillage was the impetus for conservation no-till agriculture. In the 1960s attempts were made using dalapon, 2,4-D, atrazine, trifluralin, and cyanazine in various combinations to control weeds in corn and fallow in the Great Plains of the United States. This was mainly to reduce the loss of soil by wind and to help conserve moisture during the fallow year. An ecofallow system using reduced tillage and atrazine was developed and used extensively in western Nebraska. The availability of glyphosate, RoundupR (Monsanto, 358.4 g ae/L) caused a large shift to no-till or reduced tillage fallow. Glyphosate has broadspectrum effectiveness and lacks soil residual to injure the following that made reduced-till fallow simple and hastened adaptation. However, most growers still conduct some primary tillage, usually chisel plowing prior to crop seeding, for no apparent reason other than tradition.

Recently no-till crop production has increased with the development of cultivars tolerant to herbicides or mixtures of herbicides with effectiveness for a wide spectrum of weed species. In 2000, 60% of the soybeans in Ohio were planted without tillage and no-till corn was planted to 24% in Ohio, 21% in Indiana, 18% in Iowa, and 17% in Illinois (Soybean Digest.com, January 2001). This relatively large area of no-till production was possible primarily because of Roundup ReadyR soybean varieties and various effective herbicide programs for weed control in corn.

Weeds and tillage

Weed seed distribution in the soil is greatly influence by the type of tillage. A survey of two fields, one moldboard plowed and the other chisel plowed for the previous 5 years, indicated that the chisel plow left 60% and plowing left 23% of the wild oat seed in the surface 2.5 cm of soil (Figure 1).

No-tillage obviously would leave all the seed on or near the soil surface. Without tillage, weed seeds may still be protected from depredation by insects, animals, and birds because of self-burial as soils expand and crack with changes in moisture (Somody, Nalewaja & Miller, 1985) thus, allowing weeds to grow from seed without tillage. A portion of the seed of most weed species remain viable when buried in soil and will germinate and infest the field when brought to the surface with subsequent tillage.

Most weed seeds can survive in the soil for at least 17 years (Burnside, Wilson, Weisberg & Hubbard, 1996) or even longer (Klingman, 1961). However, some species, e.g., downey brome (Bromus tectorium L.), kochia (Kochia scoparia L.) and Russian thistle (Salsoa iberica) rapidly lost viability. Moldboard plowing has been used effectively to control downey brome because the seed viability is lost before being brought to the surface by subsequent tillage. The longevity of wild oat seed viability generally increases as burial depth increases. The seed within the top 4 cm had about half the viability of seed buried 24 to 28cm deep after 7 months (Table 1)(Miller & Nalewaja, 1990). Thus, the long-term seed reserve should be less with no tillage or tillage that keeps the seed near the soil surface. The viable seed emerging from near the soil surface would be soon depleted if in-crop control was complete. This seed viability information indicates that, except for species with a short viability when buried deep in the soil, chisel plowed or moldboard plowed fields would have weed infestations similar to no-till fields in the short term. In the long term, effective weed management that prevents new weed seed and production systems that do not bring old viable seed to the surface would reduce weed infestations.

Table 1. Viable wild oat seed in the soil as influenced by time and depth of burial (Miller & Nalewaja,1990).

	Months			
Depth, cm	7	33	60	168
0-4	15	6	2	0
12-16	25	15	9	0
24-28	29	23	15	1

However, conservation agriculture, and no-till, maintain a crop residue on the soil surface that keeps the soil cooler and moister increasing survival of germinating small seeded weeds as compared to conventional tillage.

A chisel plow production system increased total weeds by about five times compared to a moldboard system over five years and three cropping systems (Ball & Miller, 1993). A no- till system was not included, but the three weed control input levels indicated that the increased weeds from reduced tillage would be overcome by increased control inputs. These results indicated that tillage systems that increase weeds need not cause yield-reducing losses, but greater herbicide or other control inputs may be needed. In Western Canada, herbicides eliminated weed changes caused by tillage but did not greatly change the species diversity (Derksen et al., 1995). The herbicides usually were directed at the major species to prevent yield loss. Since herbicides used in conventional cultivars do not control all weeds the uncontrolled minor species may become a major problem and use of another herbicide would be needed for control.

The above research indicated that no-till increased the number of annual weeds but not the number of species. However, other research has indicated a weed species shift, most commonly to more perennial weeds with reduced or no-till systems (Miller & Nalewaja, 1985; Mulugeta, Stoltenberg & Boerboom, 2001; Derksen et al., 1995). The disruption of perennial plant roots by moldboard plowing prevented the establishment of Canada thistle, but chisel plowing was no more effective than no-till (Table 2). Several perennial weed species increased with zero tillage (Derksen et al., 1995). However, another report indicated that perennial weeds were eliminated by both chisel and moldboard plowing, the species were not indicated (Mulugeta et al., 2001). Thus, the effectiveness of the chisel plow in controlling perennial weeds may depend on the prevailing species. No-till, the most conserving system, promotes development of perennial weeds. Perennial weeds are severe competitors with crops and more difficult to control than annual weeds. Control of perennial weeds in crops was limited before the development of Roundup ReadyR crops.

Weeds respond to environment and no-till greatly reduces root and seed disruption, increases soil moisture, and decreases soil temperature. All of these conditions will influence the number and the type of weed species. Thus, effective weed control for various species is essential for successful long-term conservation agriculture. Herbicides are logical for no-till, as effective biological control methods are not available and tillage is not soil or energy conserving. Further, in-crop control is essential because control by non-selective means when the crop is not growing is not timely for control of many problem weeds.

Crop row spacing

Certain crops have been traditionally planted in rows to facilitate in-between row cultivation for weed control as proposed by Jethro Tull (1731), author of Horse Hoeing Husbandry. With the discovery of selective herbicides, weeds could be controlled between crop rows as well as within the rows without cultivation. This reduced the need for wide rows to provide room for a horse or tractor drawn cultivator. Selecting a row width to maximize crop yields and eliminate erosion-causing tillage is now possible. Narrower rows provide more uniform distribution of the crop over the area reducing within crop competition and increasing the ability of the crop to compete with weeds (Bilbro & Fryrear, 1994). Yields have generally been increased by the narrower rows when moisture and fertility are adequate (Figure 2) and (Boerma & Ashley, 1982).

The narrow rows alone did not provide adequate weed control as yields without herbicides were only about 45% that of the weed free soybeans regardless of row width (Wiesbrook et al., 2001). Narrow rows increased weed control with herbicides through increased competition with weeds. Thus, the use of herbicides makes possible narrow row crop production and the narrow rows also are beneficial to herbicide performance.

Herbicides and conservation tillage

The development of selective postemergent herbicides (applied to emerged weeds) greatly increased the potential for conservation no-till agriculture. The earlier developed pre-emergent herbicides (applied to the soil surface) only controlled germinating weed seeds or required a timely rain for efficacy. Some also required incorporation for efficacy and those that did not require incorporation often gave more consistent efficacy when incorporated. Obviously, soil incorporation of a herbicide is not consistent with no-till crop production. The availability of postemergent herbicides made possible application of specific herbicides according to the weeds present. Selective herbicides, by definition, control weeds in crops without injury to the crops. However, variation in herbicide tolerance among cultivars has restricted the use of some herbicides to certain cultivars. A single selective herbicide often controls some grasses or broadleaf weeds and various herbicide combinations are used depending on the weed species. However, no-till requires consistent efficacy for a broadspectrum of weeds because the crop residue prevents supplemental cultivation. The availability of postemergent herbicides did not stimulate extensive no-till crop production because available herbicides or combinations of herbicides did not control enough weeds, especially perennials common in no-till production. The development of crop cultivars tolerant to herbicides with broad-spectrum efficacy in various environments greatly simplifies and assures effective no-till crop production. Specifically, cultivars with tolerance to glyphosate allowed use of a herbicide that provided excellent crop safety and broadspectrum annual and perennial weed control with one or two in-crop treatments. The large increase in no-till soybean in the USA is because of Roundup Ready$_{R}$ cultivars. In corn and wheat, the need for glyphosate tolerance was less essential to no-till production because more effective postemergent herbicides are available for conventional hybrids and cultivars and hybrids are available with resistance to several effective herbicides or herbicide combinations (Table 3). Even with the availability of effective weed control treatments for corn and wheat, no-till is still not as common as with soybean. No-till corn production will increase as glyphosate tolerant corn becomes more accepted in the market, because of the simplicity of glyphosate for weed control. No-till wheat production will increase as Roundup Ready wheat becomes available and growers become familiar with the system.

Growers are highly interested in producing no-till sunflower, but available herbicides are too limited to control all weeds. Cultivars soon will be available with tolerance to imidazolinone and a specific sulfonylurea herbicide (tribenuron). These will be the first postemergent herbicides for broadleaf weed control in sunflower, in the USA. The imidazolinone will provide a rather broad spectrum of grass and broadleaf control and broadleaf weed control from the sulfonylurea plus a graminicide will provide a wide weed control spectrum. However, weeds are known with resistance to imidazolinones and sulfonylureas. Control of the resistant weeds will require continued use of a preemergent herbicide, such as sulfentrazone for control of ALS resistant kochia.

Effective postemergence herbicides are available for use in canola. In North Dakota about 80% of the canola is Roundup Ready$_{R}$ and no-till canola production will increase. The firm moist soil with no-till is positive to canola establishment and the canola residue does not interfere with subsequent crop seeding. Sugarbeet may have potential for no-till or strip tillage should the glyphosate or glufosinate resistant hybrids be commercialized. With effective weed control, most crops are adaptable to some form of conservation tillage production with proper crop rotations to reduce diseases and insects.

Herbicides and energy conservation

No-till crop production also conserves fossil fuel energy in addition to conserving soil. Herbicides are now effective at low rates/ha. A gram of herbicide requires an estimated 25 kcal of petroleum energy for production. One litre of diesel contains 9320 kcal. Tillage operations of one moldboard plowing plus three cultivations requires 307,560 kcal/ha or 33.64 L/ha diesel (Retzlaff, 1980). (Table 4). Thus, the petroleum energy used in tillage would produce 12.3 kilograms of herbicide. The energy to apply the herbicide is 8760 kcal/ha per application. The recently developed herbicides often require less than a total of 0.1 kg/ha in two applications. Glyphosate is normally applied at from 0.3 to 0.8 kg/ha. With two applications the maximum usage would be 1.6 kg/ha or only 40,000 kcal/ha. The energy requirements for herbicides and applications can be further reduced with proper application techniques. Glyphosate at a half rate gave efficacy similar to a full rate when spray volume was reduced from 90 to 23 L/ha (Ramsdale & Messersmith, 2000).

The lower volume not only would allow less herbicide use, but also the smaller sprayer load would also reduce energy for application.

For imidazolinone or sulfonylurea herbicides, the required amount per treatment is from 0.074 to 0.170 kg/ha. However, these herbicides require an adjuvant for efficacy that would also require energy for production. Again since adjuvants are usually used as a percentage of the spray volume the input could be reduced in half if the equally or more effective 23 L/ha were used instead of 45 L/ha or the label requirement of 90 L/ha (Nalewaja & Ahrens, 1998). The potential benefits from no-till crop production are becoming very attractive economically and user friendly with development of new highly active and effective herbicides. This is evident from the extensive no-till soybean production in Ohio as mentioned above. The author has successfully grown Roundup Ready$_R$ soybean no-till for the past two years on a field heavily infested with many species of annual, biennial, and perennial weeds. Because of the high population and several species of weeds, three applications of glyphosate were required the first year, but the total rate was about 1 kg/ha. Glyphosate was mixed for 200 g/ha in 30 L/ha spray volume, but speed was reduced for patches of perennial weeds to increase application rate. Weeds were less abundant in the second year because of effective control the first year and only two applications were used. Because of the low glyphosate rate and water known to be high in minerals, an adjuvant that provided 0.25% surfactant plus ammonium sulphate was included in the spray. The low spray volume minimized the amount of adjuvant and allowed use of a small spray tank and a small fuel efficient spray tractor.

Potential problems

In the long-term, weeds may either develop resistance to herbicides or species naturally tolerant to herbicides may increase. This is especially important with no-till as effective herbicides are essential to successful conservation agriculture. The tillage alternative for weed control is contradictory to no-till. In practice, herbicides did not change weed diversity mainly because herbicide use changed to control the major competitive species (Derksen *et al*., 1995). However, continued usage of glyphosate or other herbicide treatment with broad-spectrum effectiveness could cause new resistant weeds to develop in these fields. In the author’s soybean example, hoary alyssum (*Berterda ubcaba* (L.)DC.) appeared tolerant to glyphosate. Plants were sparse and limited to only about two hectares. Hand spraying with 2,4-D was used and this is expected to prevent further infestation.

Thus, in order to maintain the use of an effective herbicide, growers will need to make an intensive effort to detect resistant or tolerant weeds and prevent their development. This means that methods such as hand pulling or spot treatments with non-selective herbicides would be essential immediately upon detection of a weed with resistance. The 2,4-D used for hoary alyssum was not selective, but loss of soybean plants was minimal with the hand application. Had more plants been present, a second herbicide selective in soybean would be an option, if effective for the specific weed.

Growing crops with tolerance to a herbicide will prevent that herbicide from controlling volunteers in the subsequent crop. Thus, another herbicide effective on the crop would be needed the following year. Crops tolerant to glufosinate, a non-residual herbicide with broad-spectrum effectiveness and a mode of action different from glyphosate, provide an option to control glyphosate tolerant crops and weeds. The rotation of glyphosate with glufosinate or other herbicide would provide for control of crop volunteers as well as reduce the development of weed resistance.

Soils in no-till production remain cooler in the spring and this may adversely influence warm season crops. Strip tillage in the crop row has been an adaptation to overcome cool soils. Often this has been in conjunction with a cover crop that is seeded with conventional tillage. However, the concept could be applied to no-till. It was suggested that this might have potential in sugarbeets (Dexter, North Dakota University, Fargo). Such systems would have weeds adapted to no-till in-between the rows and those adapted to tillage in the rows. The areas could change from year to year. Never the less, sugarbeet with tolerance to broad spectrum glyphosate or glufosinate would easily make the system possible.

In the example of glyphosate resistant hoary alyssum in Roundup Ready soybean, information on effectiveness of various herbicides for hoary alyssum was not found. No-till agriculture causes development of many uncommon weeds that could soon reduce the effectiveness of successful weed control systems. Weed scientists must be proactive in determining potential weeds and their control for long-term successful no-till crop production. The development of herbicide resistant crops used in conjunction with methods to prevent weed resistance will allow for large long-term increases in conservation agriculture.

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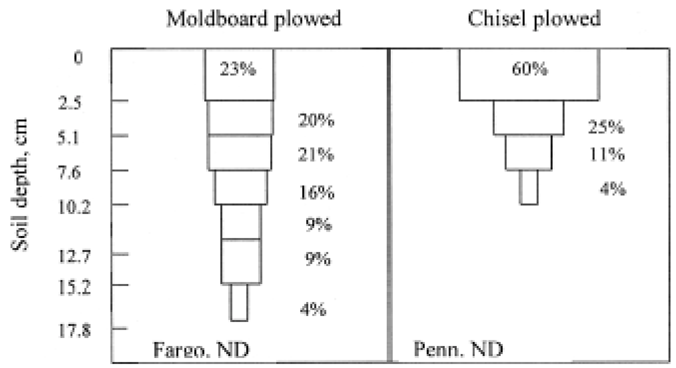

Figure 1. Distribution of wild oat seed in the soil after 5 years of moldboard or chisel plowing.

Table 1. *Viable wild oat seed in the soil as* influenced by time and depth of burial (Miller & Nalewaja,1990).

	Months			
Depth, cm	**7**	**33**	**60**	**168**
0-4	15	6	2	0
12-16	25	15	9	0
24-28	29	23	15	1

Table 2. Weeds after 6 years in continuous wheat with various tillage without herbicides and average wheat yield with and without herbicides (Miller and Nalewaja,1985)

	Weeds[a]						
	AVEFA		**KCHSC**		**CIRA**	**Wheat yield[a], g/m^2**	
Tillage	**No.**	**% of C**	**No.**	**% of C**	**No.**	**Not treated**	**Treated**
No-till	1016	75	208	158	88	10.0	21.3
Chisel plow	1887	140	363	277	44	7.5	19.4
Moldboard plow	1350	100	131	100	00	12.5	21.9

[a] No. = plants/0.4 ha x 1000, % of C = % of conventional, and treatment was diclofop plus 2,4-D. AVEFA = wild oat, KCHSC=kochia, CIRA=Canada thistle.

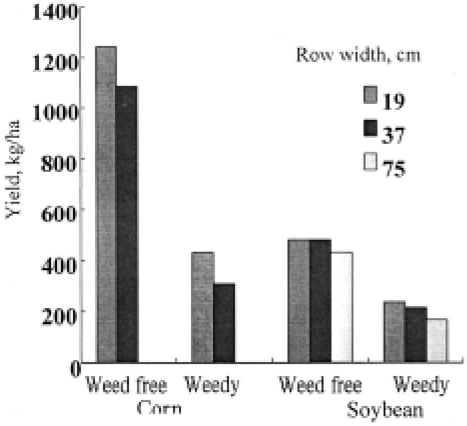

Figure 2. Influenced of row spacing on weed free and weedy corn and soybean. Weed free was Roundup® at 2.25 kg/ha plus 2% ammonium sulfate.

	Herbicides					
Crops	Glyphosate	Glufosinate	Imidazolinone	Sulfonylurea	Sethoxydim	Bromoxynil
Soybean	X	X		X		
Corn	X	X	X		X	
Canola	X	X	X			
Cotton	X					X
Flax				X		
Sunflower			X	X		
Wheat	X			X		

[a] With some herbicide groups the crop only had tolerance to specific members in the group and the new cultivar or hybrid allowed for the use of more effective herbicides in the group and in other cases crop tolerance provided for use of certain members of the group (sulfonylurea sunflower and flax).

Table 4. Litres per hectare and kcal energy for various weed control practices(Nebraska and North Dakota on-farm fuel use surveys and calculations).

Operation	**Litres/hectare**	**kca/hectare**
Moldboard plow	16.81	256669
Field cultivator	5.61	52285
Disc	6.55	61046
Chisel plow	8.89	82855
Harrow	3.27	30476
Sprayer	0.94	8761