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Weed problems in various tillage systems in the Nordic countries

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Abstract
There is an increasing use of various forms of reduced tillage or no-tillage in the Nordic countries. This will favour the growth of grass weed species and perennial species. Perennial creeping weeds like *Elymus repens*, *Cirsium arvense*, and *Sonchus arvensis* are important in all Nordic countries. Stationary weeds such as *Taraxacum* spp., *Artemisia vulgaris* and volunteer grassland species increase in areas with reduced tillage and especially no-tillage systems. Winter annual and biennial species such as *Matricaria perforata*, *Poa annua*, *Alopecurus geniculatus* and *Stellaria media* are frequently occurring weeds in reduced tillage systems in all countries, while *Alopecurus myosuroides* and *Apera spica-venti* are problems in Denmark and Southern parts of Sweden and Finland. The effect of tillage on the abundance of summer annual weeds varies according to the individual species. Volunteer oats can increase in reduced tillage. Non-inversion tillage systems strongly depend on glyphosate usage for cleansing the land prior to crop sowing, but more selective post-emergence herbicides should follow this treatment for attaining satisfactory control. Especially, the timing of the glyphosate treatment is an important issue for the success of weed control at non-inversion tillage.

Keywords: Weeds, reduced tillage, no-tillage, cereals.

1. Introduction

Traditionally, inverting tillage by the mouldboard plough is intended for weed control, seedbed preparation and incorporation of straw residues into the soil. Reduced tillage or no-tillage omitting the plough for small grain cereals has increased in the Nordic countries in order to reduce erosion, nutrient leaching, soil compaction and to save operational and machinery costs for tillage. In reduced tillage systems cultivation by different types of harrows/cultivators often occurs only in spring or in autumn and spring. In so called no-tillage the only disturbance of the soil is from the drilling machine. The interest in reduced tillage or no-tillage mainly applies to spring cereals, but in recent years ploughless tillage in winter cereals has received more attention.

In principal, tillage buries weed seeds and plant parts, but also transfer some parts to the soil surface. Plant parts like propagating roots and rhizomes may be cut into smaller pieces. Harrowing will not cause so deep burial as the plough with more seeds occurring in the upper 10 cm soil layer (e.g. Tørresen et al. 2003). The reaction of the different weed species depend on their properties (see below). Deep burial stimulates induction of dormancy in weed seeds. Soil tillage may stimulate germination by giving the weed seeds the light signal to break dormancy, a looser soil structure and give more oxygen to the soil and seeds (e.g. Håkansson 2003, pp. 56-59 + 160-162).

Traditionally, the weed species occurring in arable crops differ from the weed species in perennial crops like grasslands and pastures. Species that germinate from seeds in spring are adapted to spring sown crops, while species that are able to germinate also in autumn together with autumn sown crops are frequent in such crops. In grasslands more perennial stationary weeds occur. Perennial creeping weeds propagating by roots or rhizomes may become a problem in all type of crops. When omitting the plough, the cropping situation may be more like a perennial one. The availability of effective herbicides in the crop or crop rotation against the weed species strongly influences if weeds become a large problem (cf. Håkansson, 2003, pp. 20-55).

A lot of experiments have been done to study weeds under various tillage systems in the Nordic countries. Since growing of crops in the Nordic countries is performed at its Northern limits, various tillage systems in these countries may face problems and weed species different from those in more Southern parts of Europe.

This presentation will focus on common weed problems associated with various tillage systems in the cereal production in the Nordic countries as illustrated by some case studies. We will mainly focus on what happens when omitting the mouldboard plough in conventional farming.

2. Methods

The methods differ in the different studies. In most of the studies tillage has been included and herbicides have been given according to requirement; thus, the herbicide glyphosate has often been used to compensate for the plough (Skuterud et al. 1996; Jalli et al., 2006). In a few cases, multi-factorial treatments with tillage and herbicides have been performed (Hallgren, 1987; Tørresen & Skuterud, 2002; Tørresen et al., 2003). Other types of information come from interviews with farmers (Lätti, 2002), studies of herbicide usage and the area of land omitting autumn ploughing or performing only light autumn cultivating/harrowing.

3. Results and discussion

Development of weed species with various tillage systems

In multi-factorial studies with tillage and herbicide treatments, herbicide and tillage effects can be separated. In Sweden, Hallgren (1987) studied the effect of no-tillage (direct-drilling) and conventional seedbed preparation including the mouldboard plough in combination with treatment with 1.44 kg/ha glyphosate in fields with the occurrence of *E. repens* and some broadleaved annual weed species in winter cereals and spring cereals. In his study, *E. repens* increased in plots with no glyphosate and no-tillage. Thus, the omission of glyphosate resulted in a substantial decrease in grain yield in no-tilled plots. However, a larger number of broadleaved annual species occurred after conventional tillage than after no-tillage, while the opposite was true for the weed biomass. *M. perforata* was abundant in no-tillage plots and the effect of glyphosate on this species was substantial.

The results of the study of Hallgren (1987) are in agreement with studies in Norway (Tørresen & Skuterud, 2002; Tørresen et al., 2003). In the Norwegian studies, tillage was combined with glyphosate treatment (0.5 kg a.i./ha, in the stubble in autumn or spring or in ripe barley) and post-emergence herbicides (normal dose rates, in early summer) in growing spring cereals for four or seven years. The tillage treatments included autumn ploughing + spring harrowing, spring ploughing + spring harrowing, autumn harrowing + spring harrowing, spring harrowing and no-tillage. They showed that overwintering species became more abundant at reduced- or no-tillage than at ploughing. There were less weeds after autumn harrowing than after only spring harrowing, while the largest weed abundance were present at no-tillage. Spring ploughing caused only slightly more weeds than autumn ploughing.

Winter annual and biennial species increased rapidly during the first years, but the occurrence was stabilized after few years. The most important winter annuals and biennials were *M. perforata*, *P. annua*, *A. geniculatus* and *S. media* both as number of plants in early summer and as biomass before harvest. All of them, except for *S. media*, which reacted inconsistently, increased with decreased tillage intensity. Some species of the same group were abundant in number of plants, but with little biomass at harvest. They were *Capsella bursa-pastoris*, *Lamium purpureum*, *Myosotis arvensis* and *Senecio vulgaris*. For some of the species this corresponds to the results obtained by Boström & Fogelfors (1999), who found that *M. perforata*, *M. arvensis* and *S. media* increased at autumn stubble cultivation without ploughing when compared with systems including autumn mouldboard ploughing. This corresponds also with Danish results concerning *P. annua*, *S. vulgaris*, *M. arvensis* and *S. media* (Nielsen & Pinnerup, 1982).

Perennial species increased steadily with years (Tørresen et al. 2003). This was evident for both creeping perennial weeds, like *E. repens* (4 fields), *Cirsium arvense* (4 fields), *Sonchus arvensis* (1 field), *Stachys palustris* (1 field) and *Agrostis gigantea* (1 field) and stationary perennial weeds, such as *Taraxacum* spp., *Trifolium* spp., *Phleum pratense* and *Phalaris arundinacea*. The stationary species were especially abundant in no-tillage plots.

There was also a slight increase in the summer annual species at reduced tillage or no-tillage. In this group, the different species reacted differently to tillage intensity either by number of plants in early summer and in some cases also by biomass before harvest (Tørresen & Skuterud, 2002). *Spergula arvensis*, *Galium aparine* and *Sonchus asper* increased at less intensive tillage. This was also evident for volunteer oats (*Avena sativa*) when a dormant cultivar had been grown the previous year. *Chenopodium album*, *Fumaria officinalis*, *Viola arvensis* and *Galeopsis* spp. were favoured by autumn ploughing and/or spring ploughing. This corresponds to results obtained by Boström & Fogelfors (1999) for *Spergula arvensis* and *G. aparine* and by Nielsen & Pinnerup (1982) for *C. album*, *V. arvensis* and *Sonchus* spp.

Possibilities and limitations of weed control

There is usually an increased need for use of herbicides at reduced tillage. For the farmer, the weed problems are closely related to the availability of herbicides with good efficacy on the weeds that are favoured by reduced tillage or no-tillage. In an early phase, many farmers may give up the omission of ploughing due to problems with weeds (Skuterud et al., 1996). There seems to be a learning period for farmers of how to manage weeds at ploughless tillage systems. In Norwegian studies overwintering weeds in most cases could be controlled by a combination of stubble treatment with glyphosate and post-emergence herbicides in early summer (Tørresen & Skuterud, 2002; Tørresen et al. 2003). This was also true for species like *C. arvense* and *Sonchus arvensis*. Glyphosate has also a good effect on seed-propagated species like *P. annua* and *M. perforata*. Two problems were revealed in the studies: volunteer oats and *E. repens*. It is also found that grass weeds seemed to be more difficult to control than broadleaved weeds in Finland (Jalli et al., 2006) and Denmark (Melander, 1994).

The most important grass weed in all Nordic countries is *E. repens* (Melander, 1994; Håkansson, 2003, pp. 193-196; Tørresen et al. 2003; Jalli pers. comm.). At higher latitudes at least in some years with late harvest of spring cereals there are problems for *E. repens* to grow enough to ensure a good control with glyphosate, especially in combination with autumn harrowing. *E. repens* preferably should have more than 3-4 leaves at the time of spraying. Spraying too early results in poor control. Treatment in spring or in ripe barley is an alternative for better control of *E. repens* when harvest is late (Tørresen et al. 2003). Growing winter cereals in northern parts of the Nordic area makes it extremely difficult to have enough time to get a proper control of *E. repens*. In these areas winter wheat should be sown before 15 September. In more southern areas there is more time for controlling *E. repens*. The best option in such case is to use a pre-crop with possibilities to control *E. repens*, e.g. barley (glyphosate in ripe barley), potatoes, oilseed rape and other broadleaved crops. However, monocropping of cereals is very common in large parts of the Nordic countries.

It has been questioned if *E. repens* will be resistant to glyphosate at frequent use in reduced tillage systems. Studies in Norway have shown that various ecotypes of *E. repens* responded differently to reduced dose rates of glyphosate, but development of resistance has not been indicated (Tørresen & Skuterud, 2004). Even though there was no evidence of resistance, the risk of being dependent on one single herbicide should not be neglected as frequent use of a herbicide may result in resistance. There are now possibilities to control *E. repens* with sulfosulfuron in a growing wheat crop in Sweden and Finland, but for long term control glyphosate still gives the best effect.

In addition to *E. repens*, other grass weeds such as *Alopecurus myosuroides*, *Apera spica-venti* and *P. annua*, are seen as problems in Danish non-inverting tillage systems (Melander, 1994). Lätti (2002) interviewed no-till farmers and they stated that they had had problems with weeds like *P. pratense*, *Alopecurus* spp. and *Poa* spp. Jalli et al. (2006) also observed that grass weeds, such as *P. pratense*, *Alopecurus* spp., *Poa* spp. and *Festuca* spp., increased at no-tillage systems when compared to systems with ploughing. In addition to the above-mentioned studies in Norway, there are observations of *Poa trivialis* being frequent in reduced tillage systems.

There are opportunities to control new emerging plants of grass weeds in autumn (winter cereals) and spring (autumn and spring cereals). Resistance in some species (*A. myosuroides*, *A. spica-venti*) to several graminicides (e.g. isoproturon) in Europe has been reported (www. weedscience.org). For more established grasses and perennial grasses, glyphosate is then an alternative.

In Finland, Vanhala & Pietola (2003) report that volunteer oats may increase with reduced tillage (various autumn stubble cultivation systems) compared with autumn mouldboard ploughing, which agrees with observations at various forms of reduced tillage in Norway (Tørresen et al., 2003). Volunteer oats emerging after spring tillage could not be controlled by the post-emergence herbicides used. This is a problem in cereals grown for seed production and also in wheat for food production at abundant occurrence of volunteer oats. Later on, however, other herbicides have been registered, which have effect both on broadleaved weeds and grass weeds. These herbicides have been tested with regard to the control of volunteer oats; they retarded the growth but did not give full control and made them difficult to see when inspecting the field for impurities (Tørresen unpublished results). An (expensive) alternative is to apply herbicides registered for the control of wild oats (in Norway on dispensation in seed production) when there are problems with volunteer oats. However, the best option is to grow a less dormant oat cultivar.

Another problem concerns perennial dicotyledonous species and an increased use of phenoxy herbicides (MCPA, mecoprop-p), e.g in Finland (Jalli pers. comm.). *C. arvense* and *Sonchus arvensis* are the most common problems in this respect according to Lätti (2002) who interviewed Finnish no-till farmers. They told that these weeds were harmful in addition to the above mentioned grass species.

More *Artemisia vulgaris* than before have been observed in cereal fields in Norway, probably because of more reduced tillage and use of early applied sulfonylurea herbicides. The same is hypothesized in Finland for *C. arvense* and *Sonchus arvensis* as a result of the use of sulfonylureas and earlier treatments (Jalli, pers. comm..). However, no evidence on this was found in the national weed survey of spring cereals in Finland in 1997-1999 (Salonen & Hyvönen, 2002).

In no-till oats (1 exp.), good control was achieved because *C. arvense* and *Sonchus arvensis* had the opportunity to grow and produce leaves and stems and even buds before the treatment. At late treatment, *C. arvense* could be easily controlled with phenoxy herbicides and sulfonylureas in direct-seeded fields, while *Sonchus arvensis* is a little more difficult according to former experiments (Jalli pers.comm.).

4. Conclusion

Less tillage obviously means more weeds, particularly more winter annual, biennial and perennial weeds. Weed species that may become more abundant in non-inversive tillage are summarized in Table 1. This list can be longer and represent some frequent seen problems with reduced tillage or no-tillage systems. In general, ploughless tillage has resulted in increased use of both glyphosate and more selective post-emergence herbicides (including treatments against dicotyledonous perennials). Species with increasing abundance in the southern parts of the Nordic region are *A. myosuroides* and *A. spica-venti*. Much of the situation in each country reflects the possibilities of using herbicides in the tillage system. Many grass weeds and some perennial broadleaved weeds may be difficult to control in reduced tillage or no-tillage.

Table 1. Species that have shown to increase in reduced tillage or no-tillage systems compared to systems including mouldboard ploughing in the Nordic countries (mentioned in alphabetical order). Species that may be difficult to control with herbicides are given in bold italics.

Weed species	Summer annual species	Winter annual + biennial species	Perennial creeping species	Perennial stationary species
Monocotyle-donous species	***Avena sativa***	***Alopecurus geniculatus***	***Agrostis gigantea***	***Festuca* spp.**
		Alopecurus myosuroides*	***Elymus repens***	*Phleum pratense*
		Apera spica-venti*		***Poa trivialis***
		Poa annua		
Dicotyledon-ous species	*Galium aparine*	*Capsella bursa-pastoris*	*Cirsium arvense*	***Artemisia vulgaris***
	Galium spurium	*Lamium purpureum*	***Sonchus arvensis***	*Taraxacum* spp.
	Spergula arvensis	*Lapsana communis*		*Trifolium* spp.
	Sonchus asper	*Matricaria perforata*		
		Myosotis arvensis		
		Senecio vulgaris		
		Stellaria media		

*only abundant in Denmark and southern parts of Finland and Sweden.

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