Technical Note TN580

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Crop Protection in Reduced Tillage Systems

SUMMARY

- **Changing tillage to reduced tillage systems has major implications for pest, weed and disease management.**
- **Grass weeds and volunteer crops are particular problems of reduced tillage systems, but broad-leaved weeds tend to reduce.**
- **Delaying sowing of autumn crops and stale seedbed options should be considered to help control grass weeds. Spring cropping, rotational ploughing and stubble burning where possible are alternative strategies.**
- **Grass weeds and volunteer cereals can act as green bridges for diseases and pests such as yellow rust and aphids.**
- **Take-all and common eyespot may reduce, but Fusarium and other foliage diseases may increase.**
- **Slugs increase in reduced tillage but so do predatory beetles and parasitic wasps.**

Introduction

Interest in non-ploughing tillage systems has increased because of the need to reduce costs, to establish winter crops timeously and because of perceived environmental benefits. Reduced costs include savings in time and machinery. Environmental benefits include reductions in soil erosion, nitrate leaching, fuel use, increased soil organic matter and activity of soil organisms. Where cultivations are undertaken, these are shallower, faster and often fewer than in plough systems. Such cultivations systems include direct drilling or no-tillage where cultivations are avoided altogether, minimum tillage which could be considered as disturbance to approximately 10cm depth and reduced tillage which also includes deeper cultivation but not to the plough depth. In the latter two cases the tillage will involve some mixing but not inversion of the soil layer. For the purposes of this Technical Note, the systems are grouped as reduced tillage. No-tillage systems prevent burial of straw and leave surface ash where stubble is burnt. The other systems bury straw and trash to varying degrees.

Reduced tillage systems are more frequently used in winter crop dominated rotations than spring crop, where there are concerns as to their suitability for spring barley, although there is some use and interest in resolving the problems in this crop. A detailed evaluation of reduced tillage systems is given in SAC Technical Note 553: 'Minimum tillage'.

Reduced Tillage and Weeds

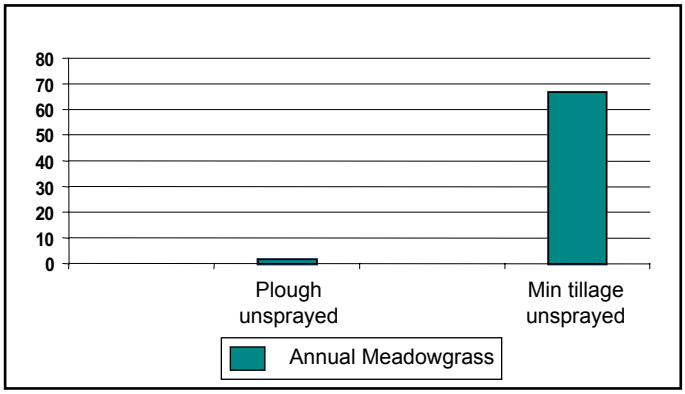
Table 1 shows the impact of reduced tillage on weeds in winter wheat in a SEERAD–funded reduced tillage trial in Midlothian. Annual meadow-grass increased whilst many broad-leaved weeds decreased in number compared with conventional ploughing. This appears to reflect what happens in practice; reduced tillage generally leads to increases

Table 1: Impact of reduced tillage treatment on weeds in winter wheat in trial in Midlothian. Not treated with herbicide. Weed number/m2 on 9 December 2002

	Annual meadow-grass	Volunteer oilseed rape	Common chickweed	Forget-me-not	Field pansy
Plough	548	24	44	4	36
Reduced tillage	1168	0	544	0	0

in grass weeds and volunteer cereals with some reductions in broad-leaved weeds. This has important consequences because grass weed control in cereals is more difficult than broad-leaved weed control in general, and volunteer cereal control can be impossible.

Fig 1: % Annual meadowgrass ground cover 8 March 2002 in winter wheat in trial in Midlothian



Weed seed behaviour

To understand the response of weeds to reduced tillage systems, some understanding of weed seed behaviour is needed.

- Weeds need moisture, oxygen and, in many cases, at least a brief flash of light to germinate. Disturbing the soil exposes the seed to these factors, so any disturbance encourages germination. Reducing disturbance tends to reduce germination of buried seeds.
- Some weeds need very little burial and will germinate on the surface where they have shed, so long as there is sufficient moisture; grass weeds and volunteer crops are particularly able to do this.
- Only a small proportion of the broad-leaved weed seed bank is able to germinate and respond to soil disturbance at any one time; most of it contains dormant seed able to emerge in future years. In reduced tillage, germination of seeds near the surface is encouraged, but in no-till systems such seeds are discouraged from germinating.
- With most grass weeds, volunteer cereals and oilseed rape there is very little dormancy, if any, and they readily emerge in reduced tillage systems. Some cereals and grasses can however persist in the seedbank for 1-3 years, black-grass 2-3 years, wild-oats for over 12 years and oilseed rape for 9+ years as dormancy develops in response rapid burial after harvest. So ploughing may increase the persistence of these weeds. On the other hand sterile brome does not persist for more than year, and ploughing is therefore a good method of control.
- The depth at which seeds can germinate and emerge is another key factor. Most weeds germinate from 1-5cm but some can emerge from lower depths and are less affected by the type of cultivation: volunteer crops, wild-oats and cleavers can probably emerge from 10-15cm or more, and not mind if the soil is disturbed or not.

Specific effects of cultivations

The behaviour of weeds seed will be different in response to cultivation system. If there is a no-tillage system, some weeds will readily germinate, others will be dormant and not germinate. If the soil is disturbed, letting in air and light, weed seed may break dormancy and germinate.

- Most grass weeds and volunteer crops will readily germinate in reduced tillage systems as soon as moisture and temperature conditions allow. However, if the seed is ploughed down soon after harvest, many will persist in the seed bank. If the land is ploughed again in the subsequent year, it will bring up those seeds, which may then germinate. However, over that year the seed bank has degraded, so fewer emerge.

  Consequently a ploughed rotation tends to have less of certain grass weeds such as black-grass, rye-grass and bromes, that do not persist for long. There are exceptions: for example, wild-oats and volunteer rape because of their ability to persist for longer and to germinate from depth, are not discouraged by ploughing.
- Leaving many grass seeds, shed cereal grain and particularly oilseed rape on the soil surface after harvest reduces their chances of becoming persistant weeds. They readily germinate then or are predated. If time is left before sowing for such germination, then the emerged weeds can be killed, and the seed is not available to come up in the following crop. This is a stale seedbed approach. The later sowing is left the less of these weeds that will emerge in the crop.
- Most broad-leaved weeds have some dormancy. If ploughed down they form part of the seed bank which may germinate when ploughed back up again. In the case of these weeds, long-term reduced tillage through the rotation will deplete the near-to-surface seed bank as the available seed gradually breaks dormancy, so long as good weed control is maintained in the crop. In practice this appears to be true, with broad-leaved weeds in general being less of a problem in reduced tillage systems.

Perennial weeds

Perennial weeds such as common couch-grass and creeping thistle rely on underground rhizomes or stolons for spread. These weeds may be encouraged by reduced cultivation.

Impact on herbicide resistance weeds

Reduced tillage tends to encourage the rapid development of weed resistance near the soil surface in susceptible species, whilst ploughing mixes the seed bank, which dilutes the resistant gene pool.

Cultural Management of Weeds

Understanding the behaviour of weed seeds in response to conditions and cultivations allows the development of strategies of cultural management that reduces the dependency on herbicides. This is important not only for cost and environmental impact benefits but also because for many weeds, herbicides can give inadequate levels of control. In wheat, full control of weeds such as brome, black-grass and rye-grass is difficult to achieve with herbicides, and in the case of black-grass and rye-grass, herbicide resistance has a serious impact on herbicide use.

In barley, herbicide use is more limited than in wheat, and in oats it is very limited; serious doubt should be placed on growing oats in reduced tillage systems. In broad-leaved crops, grass weed herbicides tend to be more effective. Control of weeds is covered in other technical notes. However, integrated cultural control is critical and the following strategies should be considered in reduced tillage systems:

a) Delaying sowing to allow a stale seed bed strategy has a major impact on grass weed and volunteer crop populations in the following crop. The stale seed bed technique can be used in spring, but is perhaps most useful in winter cereals. The technique requires about a 4 week gap after harvest to allow the weeds to germinate, along with adequate moisture. The weeds are most cost effectively killed with a low dose of glyphosate. Unfortunately this can present serious problems in many parts of Scotland where harvests are generally later; especially as one of the key reasons for reduced tillage is to allow earlier sowing of the winter crop.

Early emerging weeds that are most reduced by delayed sowing/stale seedbed techniques

Meadow-grasses	Italian rye-grass
Barren or sterile brome	Volunteer cereals and rape
Black-grass	

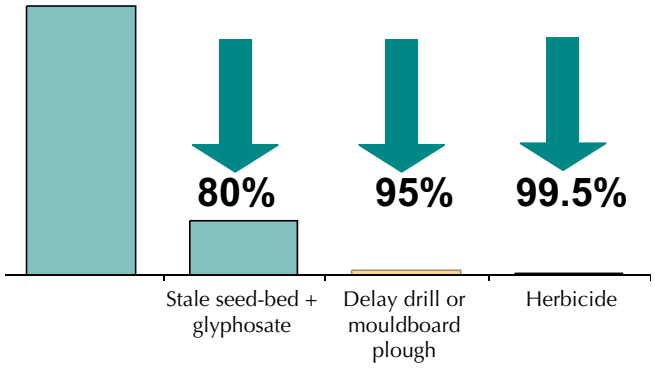
b) A non-tillage set-aside/ fallow break will reduce problems from shallow emerging weeds. Slight surface disturbance in early autumn will encourage grass weed and volunteer crop emergence; spray with glyphosate in spring before the grass weeds flower.

c) In winter crop rotations, oilseed rape and beans offer alternative herbicide strategies that can help grass weed management, and beans are later sown so allowing a stale seed bed approach. Otherwise spring cropping in the rotations reduces most grass weeds.

d) Where grass weeds start to get out of control consider a rotational ploughing strategy. This is used in areas with severe black-grass, with perhaps a 3-4year rotation. Although this reduces some of the advantages of reduced tillage, it has been considered worth doing when grass weed populations are high.

e) Burning straw and stubble is still possible in Scotland and can be very helpful in killing cereal grain and grass seed. Removing straw otherwise will assist weed control; some grass weeds may be encouraged by straw covering into delayed or secondary dormancy, which reduces the effectiveness of the stale seed bed approach.

Fig 2: An example of potential cumulative benefit of cultural control: sterile brome



Reduced Tillage and Disease

Reduced tillage can have an impact on the types of disease and the severity of disease compared to traditional ploughing. This is mostly due to the impact of reduced tillage on the soil structure, the amount of crop trash and fungal bodies on the soil surface, and also the presence of cereal volunteers in a field.

Take-all

Changes in soil structure are important for disease, since a good structure is ideal for healthy root development, allowing a crop to grow away from disease. If the soil is wet or compacted, it can limit root development and allow root diseases such as take-all to attack the roots. Take-all is however influenced most by crop rotation and is best controlled by ensuring there is a break from cereals between wheat crops. Assuming the soil structure is good in a reduced tillage crop, and there is not an increase in cereal volunteers, SAC research has shown the severity of take-all is lower under reduced tillage.

Obviously if reduced tillage soils become compacted and grass weeds are not controlled, take-all will become a major problem in second cereal crops.

Table 2: % take all on roots in three seasons

Year	2002	2003	2004	Average
Reduced tillage	47	55	9	37
Ploughed	56	60	10	42

Common eyespot

The stem base disease common eyespot, is primarily spread through crop trash from previous crops. We would therefore expect higher levels of disease in reduced tillage crops, where there is more trash on the soil surface. The opposite was observed over three seasons in Scottish trials, and a similar observation was seen throughout the UK. This observation suggests that crop debris on the surface is not enough to increase the risk. It is possible antagonists to common eyespot are also greater where there is a high level of trash. Alternatively, partially inverted trash may allow the eyespot fungus to overwinter more than eyespot fungus present on the surface.

Table 3: % Eyespot on stem base

Year	2002	2003	2004	Average
Reduced tillage	41.7	30.6	20.3	31
Ploughed	39.0	35.6	32.6	37

This observation has been used as part of a new eyespot risk assessment, where reduced tillage is a lower risk factor in reduced tillage crops. It may also be one of the reasons why crop yields were higher in the reduced tillage areas. Details of the risk assessment are available in technical note on Wheat Diseases: TN569.

Table 4: Impact of reduced tillage on crop yields (t/ha)

Year	2002	2003	2004	Average
Reduced tillage	10.4	8.9	9.5	9.6
Ploughed	8.9	9.1	8.2	8.7

Fusarium

Other stem base problems are however likely to increase under reduced tillage. Fusarium is a common soil fungus which can attack the stems and also infect the ears, leading to potential mycotoxin issues. In Germany, the high risk factors have been reduced tillage and maize in a crop rotation. The SAC research confirmed that reduced tillage did lead to an increase in stem base Fusarium in 2002 where disease levels were highest. Levels of head Fusarium were low, but more attention will be needed to ensure good control of head Fusarium under reduced tillage. Although maize is not a major crop in Scotland, any change in cropping rotations to include maize will lead to a higher risk of Fusarium.

Table 5: % Fusarium on stem base

Year	2002	2003	2004	Average
Reduced tillage	17.7	11.5	6.0	12
Ploughed	10.6	9.9	9.0	10

Volunteers and disease

Some diseases survive periods between crops via volunteers. This is sometimes called the "green bridge effect", where disease from one season's crops infect later developing volunteers and subsequently the disease can then be transmitted from the volunteers to the next season's crop. Since volunteers are more likely to occur in reduced tillage situation, it can be expected that crops grown under reduced tillage and crops in close rotations will be at risk from early attacks of yellow rust and powdery mildew. There is no evidence that the risk is higher, but certainly controlling volunteers is an important method of preventing yellow rust, powdery mildew and net blotch from spreading.

Cephalosporium leaf stripe

There are some diseases that are rare under traditional cultivation, which can become a major problem in wheat under reduced tillage and close crop rotations.

In the majority of cases, the disease is no more than a curiosity, but there are cases in Scotland under reduced tillage, where yield losses can be excessive. These cases tend to be heavy clay continuous wheat fields where the trash is incorporated into the field. This is not surprising given the fungus is a slow growing fungus which carries over in trash. As such, there are usually warning signs of a serious problem developing in a field over 2-3 years. The yield loss is predominately due to excessive number of small tillers which die early, hence having poor grain fill.

A complete break from wheat (and preferably barley, oats, grasses and volunteers) for at least two years and in severe cases three years, is the best way to get disease levels back under control. There is evidence in the USA and also Scotland that a single year break is insufficient time to eradicate the problem.

Seed treatments are not known to prevent the problem. This is not surprising for a soilborne disease. Again in the USA there are indications of varietal differences, but there is insufficient information on the susceptibility of UK varieties.

Removing straw, ploughing and, where permitted, burning are the most effective ways to prevent a build up of the problem. The literature states that barley may carry the disease over, but symptoms are not obvious in this crop.

Ergot

Ergot is a disease which can attack a wide range of grasses. It is a problem, because the fungal bodies which develop on the heads and which are harvested with the grain are poisonous. Previous outbreaks tend to be associated with open flowering varieties of triticale, rye, wheat and barley. Where the weather is cool at flowering, it can prolong the flowering period, increasing the risk of infection. Ergots which fall to the ground generally survive no more than one year. Where they are buried by ploughing, they will not be a source of disease. In a reduced tillage situation, ergots will remain on or near the surface, so there is a greater risk of infection in a second year. A greater increase in cereal volunteers may also increase the risk of carry over between cereal crops. Where disease levels become high, ploughing will need to be considered to bury the ergots on the surface.

Reduced Tillage and Pests

One of the benefits from reduced tillage is the increase in populations of beneficial insects such as predatory ground beetles and parasitic wasps over several seasons' use. Ploughing tends to kill a proportion of beneficial insects that overwinter in the soil, whereas adoption of reduced tillage allows a greater degree of survival, and leads to a higher level of natural control of pests such as slugs and aphids. Recent research at SAC and elsewhere in the UK has demonstrated significant benefits in pest management by natural enemies, with long term adoption of reduced tillage techniques in conjunction with targeted insecticide use.

One potential downside of reduced tillage is a tendency for slug populations to increase, as ploughing often kills slugs and slug eggs to some extent. However, the increase in slug populations is overcome to varying degrees by the build up of ground beetle populations that will prey on slugs, and by the provision of alternative food sources such as weeds and volunteers. Use of slug traps to gauge slug populations is recommended, coupled with the use of metaldehyde slug pellets where necessary to ensure that the newly sown crop does not get checked by slugs.

Aphids, and particularly the threat of barley yellow dwarf virus (BYDV) in cereals, may be increased if volunteer cereals and grass weeds are left unchecked, as these will harbour aphids (and possibly BYDV), and provide a 'green bridge' between the previous crop and the next. Consequently weed control either prior to sowing, or post-emergence may be necessary to reduce the risk of aphids and BYDV in cereals. In some circumstances, an aphicide application in the autumn, through the use of treated seed or a spray may be necessary depending on the level of weeds/volunteers present, aphid presence on the newly emerging crop, and the migration of flying aphids into the crop.

Once crops have established in reduced tillage systems, pest pressure is comparable to that of conventional cropping, although continual reduced tillage within a field over several seasons may lead to a reduction in some pests through an increase in natural control.

Table 6: Impact of cultural management on pests, weeds and diseases of cereals (- decrease, + increase, o little or no effect)

	Grass weeds (excl. Wild-oat)	Wild-oats seedbank	Volunteer crops	Broad-leaved weeds (excl. cleavers)	Cleaver seedbank	Perennial weeds	Herbicide resistant grass weeds	Take-all	Common eyespot	Fusarium	Cephalosporium leaf stripe	Yellow rust	Powdery mildew	Net blotch	Ergot	Slugs	Aphids	Predatory ground beetles
Plough	– – –	o	–	++	o	– / +	– –	+ +	+ +	–	–					–	–	– –
No-till	++	–	++	– –	o	+ +	+ + +	–	–	+	++					+[2]	+	+++
Reduced tillage	+++	o	+++	–	o	++	+++	–	–	+	++					+[2]	+	++
Plough straight after harvest	– / +	++	– / +	++	+	o	– –											
Straw remova[l]	–	–	–	o	–	o	– –											
Stubble burn	– –	–	– – –	o	o	o	– –											
Stale seedbed[1]	– – –	_	– – –	_	o	o	– –											
Delayed sowing[1]	– – –	o	– –	–	–	o	–											
Overwintered stubble[1]	– –	–	– –	–	– –	o	– –											
Presence of grass weeds and volunteer cereals	o	o	o	o	o	o	o					+	+	+	+++			
Spring non-cereal crop break	– –	o	–	– / +	– –	– / +	– –				o							
Poor soil structure	o	o	o	o	o	o	o	+++										

[1] In conjunction with herbicide treatment; [2] In conjunction with increased predation by ground beetles

– / + Depends on weed species; o No or neutral effect

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