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Arable Extra

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Non-chemical weed management - mechanical weeding

Introduction

Following a recent review of FAR's weed management research programme, three key priorities were identified for future research and extension investments in this area. In addition to continued testing of herbicide strategies, herbicide resistance management and biosecurity, non-chemical weed control was identified as being of primary importance for the long term sustainability of weed control programmes in the cropping sector. Non-chemical weed control embodies a wide range of farming system factors which, combined with greater knowledge of weed seed biology, can be used to enhance, and more importantly maintain, herbicide activity.

This FAR Arable Extra is the first in a series of three that will discuss alternative methods of controlling weeds. While this may not immediately result in a change of practice, or be applicable to all growers, the series aims to promote greater awareness of the need to broaden the range of weed control tools, in order to maintain the efficacy of current herbicides and reduce the impacts of issues such as resistance or herbicide degradation. This edition examines the role of mechanical weeding and how it can be integrated into a cropping system, either as direct substitute for, or alongside herbicide applications.

Before the advent of herbicides, mechanical weeding, e.g. interrow hoeing, was a key means of controlling weeds in crops. While many of these approaches were very effective, by modern standards, their work rate is unacceptable. Fortunately, many old techniques have been fully updated so that work rates are comparable to other field operations e.g. spraying, and new machines have considerably broadened the weeding approaches that can be used.

Spring tine harrows vs. interrow hoes

The use of mechanical weeders are divided into two approaches: (1) contiguous weeders which uniformly weed the entire field surface irrespective of the location of the crop, and (2) non-contiguous weeders where only the interrow (between crop rows) is weeded and/or different tools are used to weed the interrow and intrarow (weeds between plants down the crop row). There are only two types of contiguous weeders: the spring tine harrow (tine weeder) and rotary spoon weeder (rotary hoe) (Figure 1), whereas there are a considerable number of non-contiguous weeder designs.

The advantages of contiguous weeders are they don't need to follow the crop rows, are often large / wide, can be used at higher speeds so have high work rates, and width-for-width are cheaper than non-contiguous weeders. However, they can only be used on more robust crops that can survive the weeding action, e.g. cereals, peas and

Key points

- Modern mechanical weeding work rates are on a par with other field operations, such as spraying.
- There are two main approaches: spring tine harrows that weed the whole field surface, and interrow hoes, that only weed the interrow area, but with a much more aggressive action than harrows.
- Spring tine harrows can achieve weed control on a par with herbicides giving significant e.g. 10%, yield increases, in robust crops such as cereals and beans, providing they are used when the weeds are small and in dry conditions. Caveats are that they are more effective against broad-leaf weeds than grasses and don't work so well in coarse or stony soils.
- Interrow hoes are better suited to more delicate crops, e.g. vegetable seed, and more challenging soils (hard / stony). They kill more weeds in the interrow, but they need guidance systems, such as RTK GPS, or computer vision to keep them on line. Of the two, GPS autosteer has a clear edge in terms of availability and ease of use.
- Both spring tine harrows and interrow hoes can be substituted for herbicide applications and they can also be used synergistically with herbicides, e.g. band spraying the crop row and mechanically weeding the interrow.

beans, and because the weeding action has to be gentle enough not to kill the crop, their weed kill is lower than that of non-contiguous machines.

Non-contiguous weeders such as interrow hoes, have to follow the crop rows as the weeding tools will kill the crop, so some form of guidance is essential, meaning these tools are generally more expensive and have lower work rates. However, as they are much more aggressive in their weeding action they kill more weeds including harder to kill weeds, such as larger weeds, and weeds with woody stems. In short it's a case of horses for courses: of matching the weeder to the crop, soil type, weeds and climate.

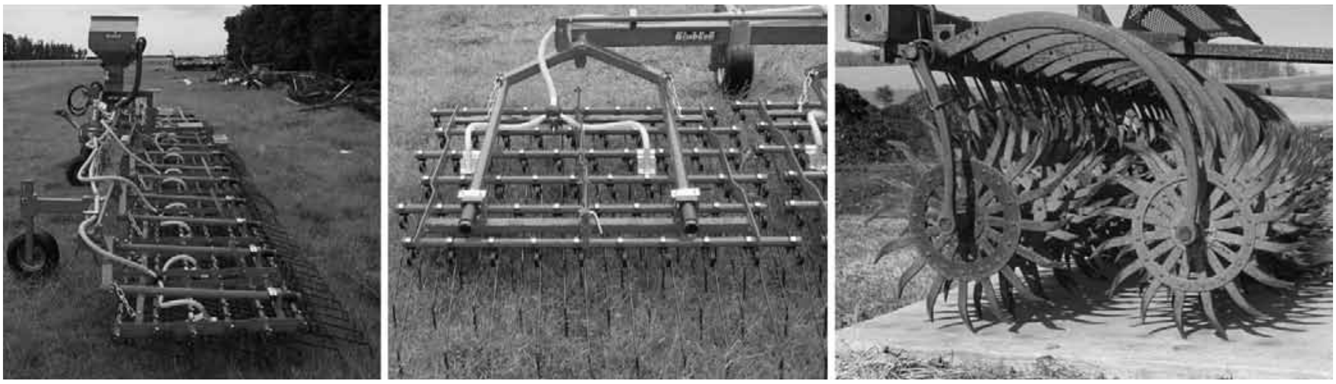

Figure 1. Left and center: spring tine weeder with pneumatic seeder, right: rotary spoon weeder

Spring tine harrows

Of the contiguous weeders, the rotary spoon weeder is uncommon outside the USA, and while a good machine, has a number of limitations. Accordingly, spring tine harrows are the preferred option for most farmers.

Spring tine harrows are very flexible tools that can weed a wide range of arable/combinable crops. Their ability to be either aggressive or gentle in their weeding action means that they can also be used for light secondary tillage, and when fitted with pneumatic seeders, can also be used for broadcast sowing a wide range of small seeded crops, especially pasture. They also come in very large widths, up to 15 metres or more, and, (depending on conditions) can be used at high speeds, e.g. 15 kph, so work rates can be very high. These attributes mean the spring tine harrow is the first choice for arable farmers looking for a mechanical in-crop weeding tool.

Spring tine harrows can work on a range of crop sizes up to about 20 cm high depending on crop type, however, they work best on small weeds, from white thread to around two true leaves, so it is the weed size, rather than crop size, that is the guide for when to weed. They are more effective against broad leaf weeds (dicots) than grass weeds (monocots) and they need a loose, fine, dry tilth to work best. Hard, cloddy, stony and wet soils can significantly reduce their effectiveness, because wet soils cling to the tines reducing their ability to bury and uproot weeds and allowing uprooted weeds to re-establish. Clods and stones can also cause the tines to ride up and out of the soil, reducing the amount of soil contact and therefore the number of weeds controlled.

Most research into optimising spring tine harrows has focused on selectivity, i.e. understanding how the weeders kill weeds and how the crop survives, which determines the 'selectivity' of the weeder, in the same way that selective herbicides kill weeds but not the crop. Weeds are killed by uprooting and burial, with 20 to 50% of weeds killed by uprooting, with great numbers of smaller weeds, especially at the white thread stage, being killed via uprooting, and more killed with deeper working and higher speeds (Kurstjens, Perdok et al., 2000).

On the crop side, there are two key determinants of survival, 'resistance' which is the ability of the crop to resist being covered by soil or uprooted, and 'recovery' which is how well the crop can recover from being covered by soil. Resistance and recovery added together determine how 'tolerant' the crop is to weeding, i.e. resistance + recovery = tolerance. For example, some crops are hard to bury but don't survive burial very well, while others can almost completely disappear under the soil after weeding, but, they have very high recovery, so burial has little effect. Research has shown that the most tolerant cereal crop is triticale, followed by wheat, barley and oats, with the differences mostly due to an ability to recover from burial (Rasmussen, Nielsen et al., 2009). The lesson is that you can bury triticale and it will come back, but oats will suffer more.

In summary, it is difficult to make hard generalisations about optimising selectivity, due to the considerable variation among crops, weeds and soils, but, selectivity is less affected by row spacing and the direction of weeding in relation to the row, and more affected by the intensity of treatment, i.e. the depth and speed of the weeder.

The other significant research focus in this area is on pre and post crop emergence harrowing, i.e. timing of weeding in relation to crop stage. In general, weed size not crop size should determine when to weed, as the effectiveness of the weeders rapidly decreases with increasing weed size, while the tolerance of the crops varies much less at different sizes, although there are exceptions. In general, combining pre and post emergent weeding has a cumulative effect, not a synergistic one (Table 1).

Table 1. The effect of pre, post and combined (pre + post) crop emergence spring tine harrowing on weed biomass and yield (BrandsÆTer, Mangerud et al. 2012).

Time of weeding	Weed biomass reduction	Yield increase
Pre emergence	22%	6.2%
Post emergence	41%	4.0%
Pre + post emergence	54%	10.0%

In cereals, weed control and yield increases have often been found to be comparable to using herbicides (Rueda-Ayala, Rasmussen et al., 2011; Armengot, José-María et al., 2012).

Interrow hoes

When contiguous weeders are not sufficient, e.g. in more delicate crops such as vegetable seed, harder soils or tougher weeds, interrow hoes are the principal alternative. While there are dozens of manufacturers, the design of interrow hoes has converged on the parallelogram and toolbar design (Figure 2). This allows machines to be very wide (10+ metres), and be adapted to all crop types, from cereals to vegetables.

Figure 2. Typical interrow hoe consisting of a number of independent parallelogram units mounted on a toolbar.

The key issue with interrow hoes is the need for guidance, which has now been effectively solved using RTK GPS autosteer systems, especially those using ‘double steer’ where both tractor and implement are independently steered. There are also computer vision systems, although these are more complex to set up due to the need to ‘train’ the systems to identify the crop correctly. Such computer guidance systems have created a paradigm change for interrow hoeing, turning an often difficult job needing specialist tractors, into ‘just’ another field operation with high forward speeds, e.g. > 10 kph. While, both approaches have significant price tags, the growing use, and decreasing cost of GPS autosteer, means that interrow hoeing is an increasingly realistic option.

Interrow hoes can be used on any row crop, and can work in tall crops, e.g. 1 metre high maize, though this depends on the hoe’s design. They will also kill weeds at later growth stages, e.g. 10 cm, although the percentage kill still declines as weeds get bigger. Interrow hoes can also effectively work in a wide range of soil types and conditions, e.g. stony and wet, depending on the type of weeding tools used, e.g. cultivator points vs. L blade hoes.

There has been less research into the practicalities of interrow hoeing compared with spring tine harrows, however, there is a publicly available review (Welsh, Tillett et al., 2002) that is a helpful introduction and still mostly current with the exception of guidance systems.

There many different manufacturers of interrow hoes, and like much agricultural machinery, there are machines which are well designed and built, and those that are not. The same applies to spring tine harrows. It is therefore essential to get expert advice on the different types and makes of machines that are suited to your farm system.

Integrating mechanical weeding with herbicides

Both spring tine harrows and interrow hoes are easy to integrate with herbicides, as they can substitute for a herbicide application. However, just as there are lots of herbicides with different modes of action, deciding exactly when and where to substitute requires consideration of the specifics. For example, spring tine harrows are more effective against dicots, so they are a good choice in crops where herbicide options for dicots are limited or there are concerns about resistance.

Interrow hoes are very aggressive and can kill a very wide range of weeds, but they don't touch weeds in the intrarow, so using a more effective but expensive herbicide down the row and mechanically weeding the interrow, ideally in one pass, can provide a great synergy between the two approaches. For example, Buhler, Doll et al. (1995) found that integrating interrow cultivation with reduced levels of herbicide by banding, maintained weed control and corn yield compared with the full-rate treatment and was an effective weed management option.

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