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Mechanical weed management

Introduction

Herbicide based weed management is facing increasing challenges. Herbicide resistance in New Zealand is more prevalent than previously thought and is likely to continue to increase [1]. Existing herbicides are being lost due to regulations and market demands. Almost no new modes of action are coming to market internationally and due to the small market size and difficulty of registration these may not be available in NZ. Globally, integrated weed management (IWM) is seen as the future of weed management. IWM is based on a whole-of-farm / system level approach [4]. Non-chemical approaches, such as mechanical weeding, are key IWM tools.

Before the advent of herbicides, mechanical weeding, e.g. interrow hoeing, was a key means of controlling in-crop weeds. Many of these approaches were highly effective, but by current standards, their work rate is unacceptable. With more than half a century of mechanical weeding development in organic farming, and more recently with the use of artificial intelligence (AI), modern mechanical weeding is highly effective and has good work rates. Unlike herbicides, where new modes of action are few, new types of mechanical weeder continue to be developed and techniques improved and refined.

Key points

- Herbicide resistance, reducing herbicide options and market demands are driving a move towards understanding non-chemical weed management options and developing integrated weed management (IWM) systems.
- Physical weeding can be used as a replacement for herbicide applications.
- There are two main classes of physical weeders: contiguous weeders that weed the whole field surface, and incontiguous weeders that treat the intrarow and interrow with different weeding tools.
- Contiguous weeders include spring tine weeders, spoon weeders, Einböck Aerostar-Rotation, Combcut and electrothermal.
- Incontiguous weeders are mostly interrow hoes, though these have evolved to the point that they weed both the interrow and intrarow.

Contiguous and incontiguous weeders

Mechanical weeders are divided into two main types:

- Contiguous weeders which uniformly weed the entire field surface irrespective of the location of the crop, and
- Incontiguous weeders where the interrow (between crop rows) is weeded with different tools to the intrarow (the crop row).

There are five main types of contiguous weeders:

- Spring tine harrows (also called tine weeders and other names).
- Spoon weeders (also called rotary hoes in North America).
- Einböck Aerostar-Rotation.
- Combcut.
- Electrothermal.

Incontiguous weeders suitable for arable crops are mostly modular parallelogram based ‘interrow’ hoes. The term ‘interrow hoe’ is however increasingly a misnomer as they now often carry tools for weeding the intrarow as well as the interrow. There are many dozens of parallelogram hoe manufacturers so there are weeder designs to suit any crop.

As contiguous weeders don’t need to follow the crop rows they don’t require guidance systems. They also work on regular and narrow crop rows, and even crops with non-standard planting patterns, e.g., checkerboard. They are available in small to large widths, e.g., 3 to 20 m and depending on the situation can be used at higher speeds so they can have high work rates. However, for the soil engaging weeders (spring tine harrows, spoon weeder and Aerostar-Rotation) they can only be used on more robust crops that can survive the weeding action, e.g. cereals, peas and beans. Because the weeding action has to be gentle enough not to kill the crop, their action is less aggressive than incontiguous weeders, so they work best on small weeds, and won’t kill bigger weeds.

Incontiguous weeders must accurately follow the crop rows as the interrow weeding tools will kill the crop plants, so some form of steering / guidance system is essential, e.g., RTK GPS autosteer or computer vision systems. As the interrow weeding tools are more aggressive they can kill larger tougher weeds.

The different weeder types are often complementary, for example they could be viewed as having different modes of action, like herbicides. Growers focusing on mechanical weeding, such as organic farmers, may have several machines, both contiguous and incontiguous, so they have the right tool for different crop-weed scenarios.

For soil-engaging weeders, timing is critical and should be based on the size of the weeds not crop stage as is often the case with herbicides. Even for the more aggressive weeders, weeds should be targeted at the cotyledon stage, i.e., newly emerged. As weeds get bigger, weeding effectiveness declines, and in the case of the less aggressive contiguous weeders it declines very quickly as weeds grow.

Contiguous weeders

Spring tine harrows

Spring tine harrows are the dominant contiguous weeder, especially in arable crops and are the best starting point when getting into mechanical weeding. Developed over 50 years ago, there are many manufacturers of them, with some machines having unique features. They are based on flexible steel rods, around 5 mm in diameter that ‘comb’ through the soil surface breaking and burying weeds (Figure 1).

Figure 1. Spring tine weeder with pneumatic seeder.

Some machines can also integrate a pneumatic seeder so they can be used for crop (including cover crops) and pasture establishment as well as weeding. Their weeding action can be adjusted from very delicate to sufficiently aggressive to be used for cultivation (tillage). The main adjustments are the angle of the tines, the down pressure and forward speed.

Spoon weeders

Spoon weeders are known as rotary hoes in North America where they were invented and are much more common. They consist of multiple spoked wheels with the ends of the spokes flattened into a spoon shape and angled, so that they enter the soil nearly vertically, and exit more horizontally, thus picking up a small amount of soil and flinging it into the air (Figure 2).

Figure 2. Spoon weeder (rotary hoe), left high residue original N. American design, right new European design. Right photo Einböck GmbH.

While originating in America, a number of European manufacturers now also produce spoon weeders with a range of improvements, e.g., better depth control. As there is less soil surface directly impacted by the spoon tips compared with a spring tine weeder, the spoon weeder relies on the soil thrown in the air to bury and break weeds as it lands. It therefore only effectively kills cotyledon stage weeds. Conversely it is highly effective at breaking soil caps and will work in soil that is too hard for a spring tine weeder to work in. It also works when soil is covered by crop residue, while all other soil engaging contiguous weeders require bare soil.

Einböck Aerostar-Rotation

The Aerostar-Rotation is a patented design unique to Einböck (www.einboeck.at/en/products/crop-care/weeding-technology/aerostar-rotation). It also consists of multiple spoked wheels, but, unlike the spoon weeder the spokes are simple round steel rods, and the wheels are angled to the direction of travel forcing the spokes to scuff through the soil. It's weeding action is therefore much more like the spring tine harrow than a spoon weeder. It is also considerably more aggressive than a spring tine harrow.

Figure 3. Einböck Aerostar-Rotation. Photos Einböck GmbH.

Combcut

Combcut (lyckegard.com/en/products/combcut/) is another unique weeder invented by Jonas Carlsson, a Swedish organic farmer. It consists of a series of dagger-like knives with narrow gaps between them that allow thin stemmed crop plants such as cereals, linseed, pasture, to slide between them but that will cut off thick stemmed weeds, e.g., thistles (Figure 4).

Figure 4. Combcut showing whole machine (top) weeds being cut (bottom left) adjustable knives (bottom right). Photos LyckeGård Group AB.

Combcut differs from the previous contiguous weeders in several ways. It is not soil engaging, so is not limited by soil conditions, especially moisture. It is aimed to be used when the crop and weeders are larger, typically up to stem elongation in cereals. It typically does not kill the weeds as it cuts them above ground level, rather it aims to set the weeds back to give the crop a competitive advantage and to reduce seeding. It can also be used above the crop to cut tall weeds, again to minimise seed rain. This makes Combcut highly complementary to the previous weeders, e.g., it can cut weeds that escaped previous soil engaging weeders.

Electrothermal

Electrothermal weeders use high voltage electricity to boil the water inside weeds, destroying them from the inside out. As the electricity is applied to the weeds' foliage and returns via the soil (the earth) it has a systemic weed kill for any plant that is unable to regenerate from underground organs, e.g. creeping roots. While it is currently cutting-edge technology with machine design still evolving, independent research is mostly confirming its considerable theoretical potential. There are currently four manufacturers, zasso.com, rootwave.com, crop.zone and theweedzapper.com. They all have different approaches / systems for applying the electricity to the plants. Weed Zapper has a simple horizontal bar that is designed to kill weeds overtopping the crop. Crop.Zone and Zasso apply the electricity to plants on the ground, e.g. to dehaulm potatoes and kill off pasture. Rootwave have a hand applied and perennial crop weeders.

Incontiguous weeders - parallelogram hoe

While interrow hoes date from before the herbicide age, and there are now dozens of manufacturers, their design has converged to independent parallelogram units which carry the weeding tools, which in turn are mounted onto a toolbar (Figure 5). This allows machines to be very wide e.g., > 20 metres.

Figure 5. Parallelogram hoe consisting of a number of independent parallelogram units mounted on a toolbar. Right photo Garford Farm Machinery Ltd.

The design has therefore moved from just hoeing the interrow to being a platform on which a highly diverse range of weeding tools are mounted which can weed both the interrow and intrarow - hence the change of name to parallelogram hoes. This makes them highly adaptable with weeding tools that can weed delicate crops, e.g., direct sown vegetables, to robust crops such as cereals. The interrow weeding tools are commonly based around horizontal knife blades which have an aggressive weeding actions that can cut through larger weeds, including perennials like Californian thistle.

The key issue with parallelogram hoes is the need to accurately follow the crop rows. This is now solved using RTK GPS autosteer systems, especially those using ‘double steer’ where both tractor and implement are independently steered, as well as computer vision systems.

Another key issue for parallelogram hoes is the need to match the drill / planter to the hoe. With the computer steering systems achieving accuracy at centimetre level, allowing hoeing very close to the crop row, drill coulter and hoe crop gaps need to match down to millimetre level. There is also a limit to crop row spacings. While the guidance systems can work with very narrow rows, there is a practical limit in that when the rows are very close the area of interrow is so small that the field is almost entirely intrarow. As intrarow weeding techniques are generally less aggressive / effective than interrow weeding, overall weeding efficacy is reduced. At 15 cm row spacings and a 4 cm intrarow / crop gap, 73% of the field surface is interrow, at 10 cm spacings that drops to 60%, and 20% at 5 cm.

Robotic weeders

There have been profound advances in robotic weeders in the last few years, due to the huge gains in artificial intelligence systems, such as Google DeepMind [3]. Currently the technology is still bleeding edge, and is almost entirely focused on vegetable crops. However, the speed of advances means that it may be a viable option in arable crops in a handful of years. This may not be able to do all the weeding, for example they may initially be valuable in ‘mopping up’ uncontrolled weeds after other faster cheaper weeding techniques, e.g., spring tine weeder. They may also be valuable for managing herbicide resistant weeds, e.g., scouting and mapping fields for weeds surviving herbicide applications, so the appearance of resistant weeds can be spotted sooner, allowing more effective management.

Integrating mechanical weeding with herbicides

Contiguous weeders are simple to integrate into existing herbicide based cropping systems as there is no need to match or follow crop rows. The spring tine weeder, spoon weeder and Aerostar-Rotation can be direct drop-in replacements for individual herbicide applications both pre- and post-crop emergence.

Introducing a parallelogram hoe requires more thought and planning, due to the need to match to match the drill / planter and the parallelogram hoe, plus potentially increasing row spacings, and the need for guidance systems.
Another option is to mix interrow hoeing with intrarow banded herbicides, ideally in one pass. This is particularly valuable for more expensive herbicides that achieve better weed control.

Conclusions

There is a large diversity of physical weeders with different mode of actions. Some can be directly integrated into farm systems without making any changes, others require modifications, e.g., row spacing. Like herbicides, different modes of action work best or achieve specific outcomes at different points over the crop's life.

References

1. Ghanizadeh, H. and Harrington, K.C., Herbicide resistant weeds in New Zealand: state of knowledge. New Zealand Journal of Agricultural Research, 2021. 64(4): p. 471-482. https://www.tandfonline.com/doi/full/10.1080/00288233.2019.1705863 DOI:10.1080/00288233.2019.1705863

2. Liebman, M. and Gallandt, E.R., Many little hammers: ecological management of crop-weed interactions, in Ecology in Agriculture, Jackson, L.E., Editor. 1997, Academic Press: San Diego, CA. ISBN 978-0123782601. https://www.sciencedirect.com/science/article/pii/B9780123782601500105

3. Merfield, C.N., Could the dawn of Level 4 robotic weeders facilitate a revolution in ecological weed management? Weed Research, 2023. 63(2): p. 83-87. https://onlinelibrary.wiley.com/share/author/SDVNYVQKUI5IMKRZVPQD?target=10.1111/wre.12570 DOI:10.1111/wre.12570

4. Riemens, M., Sønderskov, M., Moonen, A.-C., Storkey, J., and Kudsk, P., An integrated weed management framework: A pan-European perspective. European Journal of Agronomy, 2022. 133: p. 126443. https://www.sciencedirect.com/science/article/pii/S1161030121002148 DOI:10.1016/j.eja.2021.126443

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