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Non-chemical weed management - harvest and the weed seedbank

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 A-NZ. Globally, integrated weed management (IWM) is seen as the future of weed management. It is based on a whole-of-farm / system level approach [4]. Non-chemical approaches, such as managing weed seedbanks, are key IWM tools.

Minimising the return of weed seed to the soil - "weed seed rain" - and thus replenishing the weed seedbank is an increasingly important weed management technique. The message in the old adage - one year's seeding makes seven years' weeding - that it is better to minimise weed seed rain than try to control the resulting in-crop weed plants, is increasingly important. This is particularly true of herbicide resistant weeds. Fortunately, there are a growing range of techniques to reduce weed seed rain in arable systems. Maximising their value depends on understanding seed dormancy, germination and the role of the weed seedbank.

The weed seedbank is the heart of the annual weed challenge

The evolutionary strategy of annual and biennial weeds is to be a seed. The seeds are the permanent life stage; the plant is simply a mechanism to make more seeds, as quickly as possible. Therefore, minimising weed seed rain reduces the size of the weed seedbank, which gets to the heart of annual weed management.

Big seedbank = big weed populations

There is a 1:1 correlation between the size of the weed seedbank and the number of weeds that emerge in the crop [3]. So, a big seedbank means a lot of in-crop weeds which means a lot of in-crop weeding, and vice versa, small seedbanks mean fewer in-crop weeds, and much less in-crop weed management. Where in-crop weeding is effective, e.g. via effective herbicide use, then large weed populations are less of a problem; but where in-crop weeding is difficult, expensive, or kills a lower percentage of weed plants, then a small weed population can be the difference between crop success and failure.

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.
- Minimising the weed seed rain reduces the size of the weed seedbank and consequently the populations of in-crop weed plants.
- Understanding the behaviour of the weed seedbank, including its half-life and seed dispersal, is important.
- An increasing number of seed rain management tools are available for use pre- and post-harvest. These include:
  - Selective cutting of in-crop weeds.
  - Pre-harvest destruction of tall weeds' flower and seed heads.
  - Harvest weed seed control (HWSC).
- There is considerable potential for significant gains from existing weed seed rain management techniques, and new approaches continue to be developed and researched.

Longevity vs. survival

Research has shown that weed seeds can survive for decades or even centuries. However, a lot of this research is not representative of real-world conditions. For example, it may be based on seeds that were collected at the optimum time and carefully stored. Weed seeds in soil face a number of problems: their nutrients and energy are a

food source for everything from microbes to mice. Soil conditions are often hostile: abrasive and alternating between hot and cold, wet and dry. These and many other factors mean that seeds' potential longevity is generally many times higher than seeds' actual survival in the soil.

Seven years, as per the saying, is actually a long time for seeds to survive in soil. A large proportion of seeds are lost within a few months of being shed and most only survive for a few years. For example, most grass seeds will survive for five years at most as they lack the hard seed coat of broadleaf weeds. Seedbanks thus decline quite quickly when the weed seed rain is minimised, i.e., they undergo exponential decay. Consequently, the duration of the seedbank is best viewed through the concept of half-life. Typically, half the seeds are lost in a few years, while a few can last decades.

Dispersal

Another common misconception is that large numbers of weed seeds enter paddocks from outside the paddock or farm border. Weed seeds can disperse over large distances, but in reality, the vast majority only spread a few meters from the parent plant. Even weeds with airborne seed like thistles drop the majority of their seed close to the parent plant. This means that most weeds grow where their distant ancestors grew, with the seedbank forming the link in this chain of succession. The key exceptions to this are: farm machinery (mainly headers and other harvest equipment) which can disperse seed widely between paddocks and farms. However, the percentage of seed that is dispersed over longer distances can be important in introducing new weed species and herbicide resistance to a farm.

Putting it together

The number of annual and biennial weeds in a field is almost entirely due to the previous 1-5 years weed and weed seed rain management. Therefore, weed management needs to move beyond just focusing on killing weed plants growing among the crop to a whole of system approach, i.e., IWM, which includes managing the weed seed rain.

Weed seed rain and seed bank management

There are a growing number of approaches to managing the weed seed rain and therefore the weed seedbank. In tillage systems false seedbeds are a key technique and are covered in Arable Extra 136, 'Non-chemical weed management - stale and false seedbeds'. In-crop and harvest time options include:

- Selective cutting of thicker stemmed broadleaf weeds in thin stemmed crops.
- Pre-harvest destruction of flower and seed heads taller than the crop.
- Harvest weed seed control (HWSC).

Selective cutting of in-crop weeds

Combcut (lyckegard.com/en/products/combcut/) uses a series of dagger-like knives to cut thicker stemmed weeds, e.g., thistles, in thin stemmed crops, e.g., cereals, linseed and pasture. It can also be used to cut off weeds that are taller than the crop. It is typically used up to the point of stem elongation in cereals, as crop damage can occur past this stage. While cutting does not typically kill the weeds, it sets them back significantly and allows the crop to gain a competitive advantage. It can therefore significantly reduce flowering and thus seed production. Combcut is currently the only known machine cutting weeds within crops.

Pre-harvest destruction of tall weeds

There are a number of means of destroying weed flower and seed heads that are taller than the crop, e.g., wild oats and wild brassicas:

- Mowing systems that cut off / partly mulch the flower / seed heads.
- Cutting systems that cut and remove the flower / seed heads.
- Electrothermal weeders that kill weeds by boiling the water inside them.

Mowing systems that cut and partly mulch the flowers and seed heads must be used before seeds are ripe (or able to ripen off the plant) otherwise they won't reduce the weed seed rain. However, if they are used too early, the weeds can regrow and produce new flowers and seeds. Getting the timing right is therefore critical. One example of this approach is the Weed Surfer, Figure 1 (www.ctmrootcropsystems.co.uk/products/weed-surfer/).

Cutting and removing flowers and seed heads means that timing is less critical than mowing systems, as they can be used just before harvest to maximise seed capture, and minimise regrowth. Cutting must, however, be done before seeds start to be shed, or seed heads become ripe enough to shatter when cut. An example of cut and remove systems is Zürn Top Cut Collect (www.zuern.de/en/cutting-platforms/products/econventional/top-cut-collect/)

Figure 1. The Weed Surfer. Photo CTM Harpley Engineering Ltd.

Figure 2. Zürn Top Cut Collect. Photo Zürn Harvesting GmbH & Co.

Electrothermal weeders kill plants by using high voltage electricity to boil the water inside plants, destroying them. One machine, the Weed Zapper from the USA (theweedzapper.com), is primarily being used to kill weeds overtopping crops. Like mowing, the weeds need to be treated before they produce viable seeds as it is unlikely the electricity will flow through the seeds themselves, so while the plant may be killed the seeds would still contribute to the seed rain.

Harvest weed seed control

Harvest weed seed control (HWSC) was developed in Australia over two decades ago. When weed seeds that travelled through the header were prevented from returning to the soil, very large reductions of in-crop weeds were achieved. For example, in-crop annual ryegrass emergence was reduced by 90% in just four years [2]. HWSC is now a maturing technology in Australia, and is being investigated in both Europe and USA. FAR will conduct trials on HWSC in the 2024/25 season. The main challenge is considered to be the much larger volumes of straw in New Zealand compared with Australia.

The core of HWSC is that most of the weed seeds are in the chaff, so the chaff is kept separate from the straw, and then treated to manage the weed seeds in it.

There are multiple HWSC approaches:

- Chaff lining and burning.
- Chaff carts.
- Bale direct.
- Impact mills.
- Chaff tramlining / chaff decks.

Chaff lining and burning involves a simple funnel system which puts the chaff in a line down the center of the header, where it is burnt. While effective, the issues around burning limit its use.

Chaff carts are large carts towed behind the header which collect the chaff. It is then dumped in piles, which can be burnt or eaten by stock. The chaff can also be collected and sold off-farm.

Bale direct feeds both straw and chaff into a bailer towed behind the header.

Impact mills grind up both the chaff and weed seeds, killing them.

Chaff tramlining / chaff decks are used in control traffic farming (CTF) systems, where the chaff is put onto the tramlines / wheelings, concentrating the weeds into narrow strips. This helps firm the tramlines up, the anaerobic conditions in the chaff kills some of the seeds, particularly grasses, and if the weeds do germinate they are driven over.

There are pros and cons to consider for all techniques; these include the cost of the extra machinery, ease of header modifications, running costs / power requirements (especially of on-header cage mills), and the removal of nutrients and organic matter (via residue) from paddocks.

There is extensive information on HWSC on the Australian 'Weed Smart' website (www.weedsmart.org.au/big-6/harvest-weed-seed-control).

Stubble management

Established approaches such as stubble burning have long been recognised by farmers for their potential to control weeds, especially grasses. FAR trials, conducted as part of the non-inversion agronomy project (2003 – 2008), illustrated that burning cereal crop residues played a key role in brome control for the following crop (Table 1).

Table 1. Influence of burning on grass weed control in barley (assessed as plants/m^2, 15 March and 29 April)1 and seed head numbers/m^2 (5 January)^2. (F. Dastgheib & N. Poole 2005 – NZ Plant Protection Proceedings 2010).

	Ripgut brome			Soft brome		
Treatment	**15 March**	**29 April**	**5 January**	**15 March**	**29 April**	**5 January**
Burning	4.5	12.0	0.1	6.0	45.7	0.1
Early Till	44.8	40.2	0.5	29.8	35.0	0.1
Late Till	36.5	0.0	0.5	148.9	1.7	0.1
No Till	40.4	15.5	9.0	209.5	42.2	7.8
LSD 0.05	**29.0**	**21.50**	**3.7**	**93.6**	**ns**	**3.2**

[1] Average of eight 0.1 m^2- quadrats per plot.
[2] Average of six readings of 1m^2 quadrats per plots.
Notes: Late till treatment cultivated 11 April.
Notes: All treatments glyphosate treated after March assessment and April assessment.
All treatments received uniform application of in-crop herbicides following treatments outlined, crop sown 7 June.

Conclusions

It was a wise farmer who first noted that one year's seeding makes seven years' weeding. A growing body of research and practical experience now shows that managing the weed seed rain, and therefore the weed seedbank, through techniques such as in-crop weed cutting, mechanical flower and seed head topping and post-harvest seed destruction, can be just as, or even more, effective for long term weed management than just spraying in-crop weed plants. These techniques are also increasingly important for the management of herbicide resistant weeds by limiting their seeding and spread.

References

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