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Arable Extra

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Non-chemical weed management – stale and false seedbeds

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 Aotearoa-New Zealand. Globally, integrated weed management (IWM) is seen as the future of weed management. It is based on a whole-of-farm / system level approach [2]. Non-chemical approaches, such as stale and false seedbeds, are important IWM tools.

The use of stale and false seedbeds fell out of favour with the advent of herbicides. However, they are now a resurgent tool for weed management, often providing simple, effective and low cost weed control. The key difference between the use of these techniques historically and today, is that we now have a scientific understanding of how and why they work, and can use them in conjunction with other management methods.

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.
- Most of the weed seed bank is dormant, but a small fraction will germinate rapidly, in the right conditions.
- False and stale seedbeds are valuable IWM tools.

The science of weed seeds

The three key concepts underpinning false and stale seedbeds are dormancy, germination and maximum emergence depth.

Dormancy

Weed seeds can sit in the soil for years, even decades, doing nothing, then when conditions are right, they can rapidly jump into life. This ability is governed by dormancy. While the general concept of dormancy is well understood, scientifically our understanding is still developing because the processes that drive it are so complex. The key components of dormancy are illustrated in Figure 1.

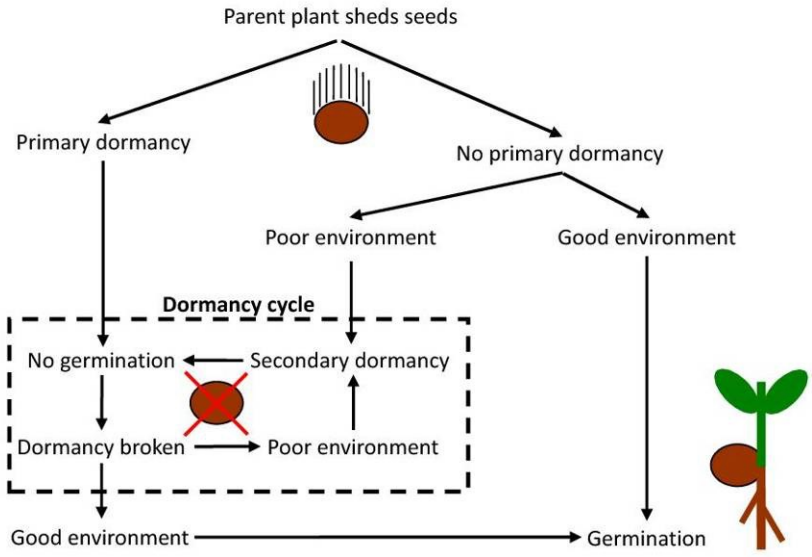

Figure 1. Dormancy mechanisms.

Seeds are shed from the parent plant either with, or without, primary dormancy. Primary dormancy means the seed is dormant when it is shed and will immediately enter the weed seedbank. Conversely, if seeds lack primary dormancy, then two things can happen: (1) under good conditions they will germinate rapidly, (2) under poor conditions, they won't germinate, and will typically enter secondary dormancy and join the weed seedbank.

Seeds with either primary or secondary dormancy enter the dormancy cycle (Figure 1). Seeds cycle in and out of dormancy, driven mostly by internal control mechanisms. When a seed is dormant it is incapable of germinating, even in optimum conditions. The seed will only emerge when dormancy is broken and the seed finds good germinating conditions. If dormancy breaks, but conditions are poor, then germination won't start, and the seed is likely to re-enter dormancy. This means that about 90% of weed seeds are dormant and cannot germinate, no matter how good the conditions are. This is why the weed seed bank is so persistent, and why weed seeds are often very difficult to germinate deliberately, much to the frustration of weed scientists! In comparison, many crop plants have no dormancy (either primary or secondary) because, even if their wild ancestor did have it, it has been bred out of them, so they will rapidly germinate when planted.

Dormancy is not an on or off condition, it is a continuum. Seeds can be partially dormant. Partially dormant seeds will only germinate when conditions are ideal, while if they were fully non-dormant, they would germinate even in marginal conditions. The time spans over which seeds cycle in and out of dormancy vary from weeks to years and are mostly driven by genetic factors.

Germination

Unlike the dormancy continuum, germination is a yes or no option; there is no means of 'un-germinating'. Seeds have an impressive range of means of determining if conditions are conducive for them to grow and thrive once they have emerged: the right temperature, moisture, oxygen, nutrients (especially nitrate) and sometimes light. Through monitoring all these conditions seeds are able to sense how deeply they are buried in the soil. Factors such as low oxygen, low temperature, little diurnal temperature variation and no light, all signal that the seed is buried deeper in the soil. This is a key piece of information for a seed, because if it tries to germinate from too deep within the soil it will die due to running out of the limited amount of energy and nutrients stored within the seed.

Emergence depth

The maximum emergence depth for seeds is completely constrained by physics i.e. the amount of food and energy that a seed contains exactly determines how much soil a seedling can push up through before it dies of starvation. Most arable weeds can only emerge from a maximum depth of five centimetres (Figure 2). The majority of weedlings that successfully emerge come from seeds in the top two to three centimetres. This is the case even for larger seeded species, such as the knotweeds (*Polygonum* species).

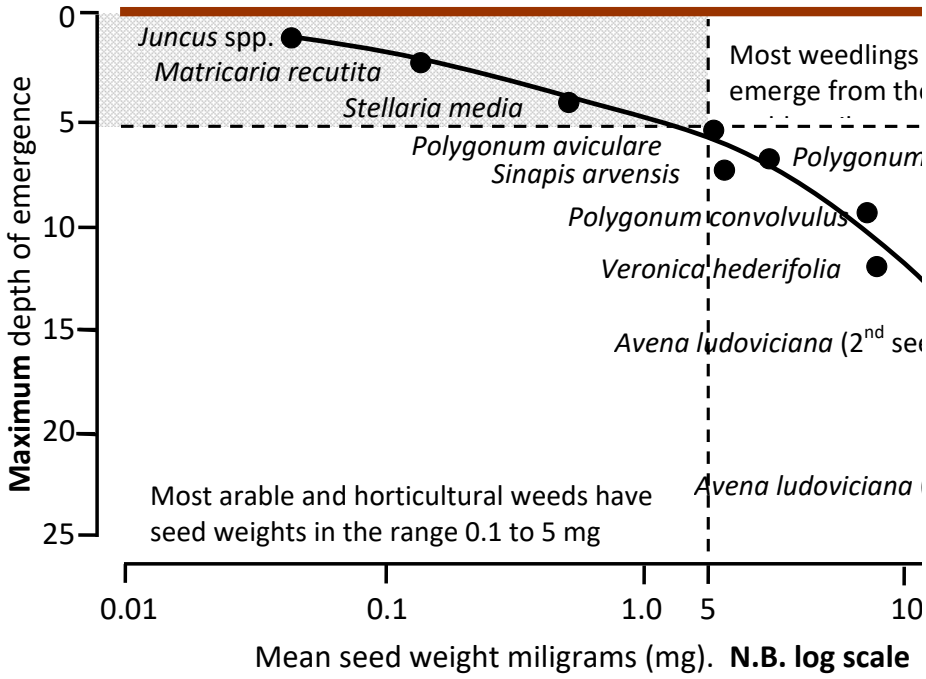

Figure 2. The maximum emergence depth of a range of weed seeds in relation to their weight. After Roberts, H. A., Ed. (1982). Weed Control Handbook.

Putting dormancy and emergence depth together on farm

The research findings outlined above identify three key factors related to weed emergence and the use of stale and false seedbeds.

- Most (90%) of the weed seed bank is dormant, but a small fraction will germinate rapidly, in the right conditions.
- Cultivation can create an ideal environment for weed seed germination.
- The vast majority of weeds emerge from seeds within a few centimetres of the soil surface.

Stale and false seedbeds

The terms stale and false seedbeds are often used interchangeably, but, in fact, they define two related, but different, techniques.

Stale seedbed

Figure 3 shows the principle of a stale seedbed and how some stages overlap; (a) the seedbed is prepared, (b-c) weed seeds germinate from the top 5 cm of soil (d) the crop is sown, (c-e) weed seedlings emerge (f) weed seedlings are killed (g), immediately prior to crop emergence.

The key advantage of the stale seedbed is that the weeds are killed without any soil disturbance, so the potential for bringing up new seeds, or for the germination requirements, (oxygen, temperature, light etc) to be increased is effectively zero. Stale seedbeds should therefore result in lower levels of weeds in the following crop. However, when a new germination stimulus is wanted, e.g. to aggressively flush out weed seeds, stale seedbeds may not be the best option.

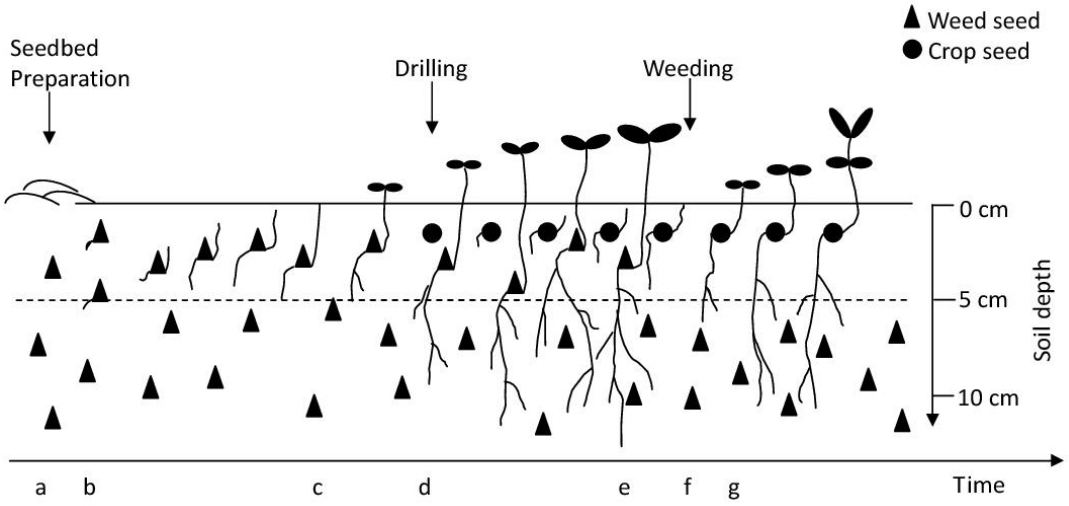

Figure 3. Illustrative scheme of a stale seedbed.

False seedbed

Figure 4 shows how a false seedbed works. The seedbed is prepared the same as for a stale seedbed (a), weed seeds in top 5 cm of soil germinate (b-c) and then emerge (c-d), the soil is then re-cultivated with the minimum disturbance necessary to kill weed seedlings(e), the crop is then sown (f) germinates and emerges (g).

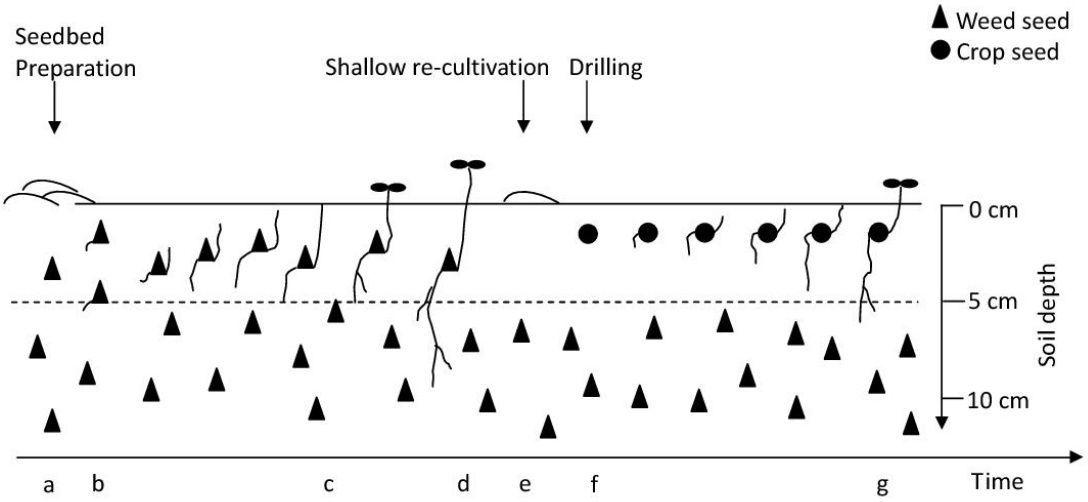

Figure 4. Illustrative scheme of a false seedbed.

The key to false seedbeds is that recultivation must be as shallow as possible, i.e., within the 5 cm and ideally 3 cm depth from which most weeds emerge. If cultivation is deeper than this, then it will bring up non-dormant but ungerminated seeds from below the emergence layer, which will then emerge in the crop. The deeper the recultivation, the more new weed seeds it will bring up, so that when recultivation is more than 10 cm deep the entire effect of the false seedbed is lost.

Equipment

As noted above, re-cultivation depth is critical to the success of false seed beds. It must be less than 5 cm deep and kill 100% of emerged weeds. This need for shallowness and 100% weed seedling kill is beyond the ability of most common cultivators. Harrows and stubble cultivators can do an adequate job, but they tend to go deeper than ideal and/or fail to achieve sufficient weed kill. Where false seedbeds are being used as a regular component of weed management, and/or they are being used in critical situations, e.g. before vegetable seed crops, then using more specialist machines can pay considerable dividends.

In terms of off-the-shelf equipment, spring-tine-harrows are a leading tool (see Arable Extra 134), with the benefit that they have a wide range of other uses on-farm. However, even when used aggressively, they may not achieve 100% weed kill, and more than one pass may be required. Incomplete weed kill may not be a problem in competitive crops such as cereals, but in less competitive crops, such as vegetable seeds, it becomes an issue. Where 100% weed kill and very shallow cultivation is essential, there are two main approaches: 1) horizontal rotating rods, that have evolved from American rod-weeders, or 2), gangs of flat, A-blade sweeps, typically used on interrow hoes. Figure 5 shows an original rod weeder from the USA, a rod incorporated into a spring tine cultivator, and an A blade sweep cultivator.

Figure 5. American rod weeder (left), false seedbed cultivator using rod weeder (middle), A-blade sweeps (right).

For stale seedbeds, either flame, steam and electrothermal weeders can be used for non-chemical approaches. Flame and steam are equivalent to a contact herbicide, not a systemic one, so they are most effective against small weeds and dicots. Electrothermal has a systemic effect, and, depending on plant morphology, can kill larger weeds.

Regardless of whether a false or stale seedbed is used, or the type of machinery, if the seedbed is not in optimum condition, e.g. too dry or cloddy, then germination will be reduced, and weeds are then likely to emerge later in the crop. Therefore, the golden rule is that the original seedbed must be of the best quality possible, and if conditions are dry and irrigation is available, then the soil should be moistened.

When to use false and stale seedbeds

Harvest

One of the main uses for false seedbeds is at harvest to manage weed seeds shed in the crop and also volunteer seed crops, e.g. oil seed rape. In terms of volunteers, as noted above, most crops don't have dormancy, so, if they find good germination conditions after release from the parent plant, they will germinate readily. A very shallow cultivation, e.g. via harrowing, and/or rolling, after harvest can trigger germination and the seedlings can then be killed with further shallow cultivation or herbicide. Conversely, if the seed is cultivated into the soil (buried), especially by ploughing, then it will not germinate, and if it has some dormancy capability, is likely to enter the seed bank and become dormant. Therefore, using a false seedbed at harvest can eliminate considerable numbers of recently shed crop seeds, while ploughing them under can result in volunteers coming up for many years.

An important difference between the grasses / monocots and dicots (both weeds and crops) is that grasses generally have short lived seeds (no hard seed coats). Consequently, ploughing grass seeds under and then not re-inverting the soil for several years will result in the majority of seeds dying. This is a well-established technique for grass weed management. The same does not generally provide the same level of seed death for dicots. Many dicots will return to the surface and germinate with future cultivations.

Sowing

The other main use of false and stale seedbeds is prior to sowing, especially in the spring, to help combat the spring weed flush. Figure 6 shows crops of direct-drilled carrots and silverbeet which have received mechanical inter-row weeding rather than herbicides. The high level of intrarow weed control is due to false and stale seedbeds. Specialist false seedbed cultivators are essential to achieve such high levels of weed control.

Figure 6. High levels of weed control achieved using false and stale seedbeds in direct-drilled ware carrots and silverbeet. The 'token' fat hen plant in the left photo was the only one in 200 m of bed.

Conclusions

False and stale seedbeds can be highly effective and inexpensive ways of reducing the non-dormant weed seedbanks in the emergence zone. Weeds that could have infested the crop are grown and killed before, or as part of, crop establishment. When used as part of a whole-system approach to weed management, false and stale seedbeds can achieve very high levels of weed control, making subsequent weeding operations, both chemical and non-chemical, more effective, easier and often cheaper.

Further reading

False and Stale Seedbeds: The most effective non-chemical weed management tools for cropping and pasture establishment. The FFC Bulletin, 2015-V4, 25. www.bhu.org.nz/future-farming-centre/information/bulletin/2015-v4/false-and-stale-seedbeds-the-most-effective-non-chemical-weed-management-tools-for-cropping-and-pasture-establishment.

References

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2. 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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