Section 5: Implementing an IWM program using tactic groups

Implementing integrated weed management plans

Successful integrated weed management (IWM) depends on having:

- clear weed management objectives
- a well-defined plan.

In general, the key weed management objective will be to reduce both weed numbers and the size of the weed seedbank in the soil. There may also be specific objectives for each farm business, or each paddock within a farm business. For example, managing a herbicide resistant weed population may be a specific objective within one paddock, while avoiding the introduction (or spread) of a specific weed may be an objective in another paddock.

A plan should be developed for each paddock or management zone based on the following five steps:

1. Review past actions.
2. Assess the current weed status.
3. Identify weed management opportunities within the cropping system.
4. Match opportunities and weeds with suitable and effective tactics.
5. Combine ideas using a rotational planner.

Use *Section 6: Profiles of common weeds of cropping* (and other resources) to develop a full understanding of the target weed. Then use *Section 4: Tactics for managing weed populations* (and other resources) to research the weed management tactics available and the likely benefits, impacts and limitations of each tactic, including those not directly related to weed management. Match the tactics to the weed and the farm business. Consider fine-tuning agronomic practices (see *Section 3: Agronomy to enhance the implementation and benefits of weed management tactics*) to enhance the impact of the weed management tactics being used.

The IWM plan should be:

- flexible – able to respond to seasonal conditions
- based on a good understanding of the life cycle and characteristics of the target weed
- based on thorough knowledge of the farm – climate, soil and history
- linked to long-term goals of the farm business
- cost-effective in the medium to long term.

Step 1 Review past actions

History of herbicide use

Managing herbicide resistance evolution in weed populations requires a good knowledge of past herbicide use. A record of all herbicides previously applied will flag any herbicide groups and weeds that may be at high risk of developing resistance.

Collate herbicide use information on a paddock-by-paddock basis for as many years as records are available.

When there are greater than acceptable numbers of survivors from an application of herbicide (taking into consideration the meteorological conditions when it was applied), good records can help identify whether resistance is a likely cause.

The history of herbicide use information can then be used to:

- prioritise weed management tactics so as to avoid the use of high-risk herbicide mode-of-action (MOA) groups in paddocks with high application rates in the past
- identify those paddocks at risk, where weed populations can be prioritised for resistance testing, and for more detailed monitoring of weed numbers and distribution.

Information on the effectiveness of herbicides applied can be used to save time and money by highlighting potential herbicide resistant populations. Where control has been unsatisfactory, make a record of the target weed and the situation in which it is growing, the growth stage and health of the weed and any possible explanation as to why the tactic failed, eg incorrect use of the tactic, poor application technique or timing, adverse weather conditions.

History of non-herbicide tactic use

Gather as much information as possible on any non-herbicide tactics that have been used in the past, whether or not they were targeting weed management, and an indication of how effective they were at reducing weed numbers. Record, for each paddock, events such as:

- cultivation, including 'light' cultivations
- residue burning
- slashing/mowing
- silage and hay cuts
- rotational changes such as pasture production.

Step 2 Assess the current weed status

Record the key weed species (see *Section 6: Profiles of common weeds of cropping*), including in-crop and fallow weeds, and the distribution and density of each. Always note the date when making paddock assessments.

When recording the **distribution** of each weed across the paddock, observe if it is:

- widespread and scattered at low plant density
- widespread and at high plant density
- in a small localised area and, if so, where
- in high density patches and, if so, where.

When recording the **plant density** of each weed, observe the distribution of the weed across the paddock. If the weed is distributed uniformly, estimate the average density. If it occurs in patches, assess the average density within those discrete areas (see *Assessing weed population density* in this section).

Together, distribution and density give a clear picture of the weed status at a given time. Thorough and repeated (perhaps annual) weed assessment records effectively identify changes in weed species and distribution within a paddock and across the farm. While conducting these observations new weed introductions will also be identified.

A global positioning system (GPS) or physical markers can be used to map the location of isolated weed incursions or weed patches so they can be tracked and managed from year to year.

Current herbicide resistance status of weed populations

To ensure effective and economical management decision-making in the future, it is essential to determine why weeds survive an application of herbicide. If the reason for herbicide failure cannot be clearly and confidently determined, the weed population should be tested for herbicide resistance (see *Assessing herbicide performance* in this section).

A positive test result confirms the need for alternative tactics or herbicides. An incorrect assumption about the herbicide resistance or cross-resistance status of a weed population can be very expensive. Further application of an inappropriate herbicide will only lead to a build-up of the herbicide resistant weed seed levels in the seedbank, increasing the magnitude of the problem (see *Herbicide resistance testing* in this section and *Section 2: Herbicide resistance*).

Step 3 Identify weed management opportunities within the cropping system

Weed management tactics need to complement the farming system and business goals. Ensure that proposed changes to the system are suited to the land, infrastructure and management resources, and that the inclusion of weed management tactics is practically, environmentally and economically sound. Be aware of likely constraints to implementing weed management tactics such as:

- enterprises within the business that limit the use of some tactics (eg canola and some soil residual herbicides)
- the farming system employed (eg cropping only)
- personal preferences (eg no-till, aversion to change, preference for livestock)
- financial situations or poor availability of contractors or markets
- soil types and/or environment.

Identification of constraints helps define opportunities for controlling weeds and the available weed control tactics. Discussing such issues with the grower will help ensure that later advice meets the needs of the farm business.

Sometimes the use of a weed management tactic may provide an opening for a new enterprise. For example, production of high-value legume silage may represent a profitable new enterprise as well as being a valuable tool to manage weed seedbanks.

Weed management plans should be flexible. Regular reviewing ensures that tactics can be added or removed as needed.

Step 4 Match opportunities and weeds with suitable and effective tactics

Tactic groups

Just as herbicides can be grouped by mode of action, tactics for weed control can also be assigned to one of five groups (Table I1). Each tactic group provides a key opportunity for weed control and is dependent on the management objectives and the target weed's stage of growth.

Table I1 Tactic groups used to aid weed management planning

Tactic group	Opportunity/timing	Weed impact	Tactic	
TG 1				
Deplete weed seed in the target area soil seedbank	Fallow Stubble Pre-sowing Pasture phase	Encourage germination of weed seeds (subsequently killing them)	Tactic 1.4 Tactic 1.5	Autumn tickle Delayed sowing (seeding)
		Reduce viability of weed seed in the seedbank	Tactic 1.1 Tactic 1.3 Tactic 4.2*	Burning residues Inversion ploughing Grazing crop residues
		Removal of weed seeds from the seedbank	Tactic 4.2* Tactic 3.5* Tactic 1.2	Grazing crop residues Grazing – actively managing weeds in pastures Encouraging insect predation of seed
TG 2				
Kill weed(s) (seedlings) in the target area	Fallow Pre-sowing Early post-emergent Pasture phase	Kill weeds, particularly seedling weeds	Tactic 2.1 Tactic 1.1* Tactic 2.2a Tactic 2.2b Tactic 2.2c Tactic 2.2d Tactic 2.3a Tactic 2.3b Tactic 2.4	Fallow and pre-sowing cultivation Burning residues Knockdown (non-selective) herbicides for fallow and pre-sowing control Double knockdown or 'double knock' Pre-emergent herbicides Selective post-emergent herbicides Inter-row shielded spraying and crop row band spraying Inter-row cultivation Spot spraying, chipping, hand roguing and wiper technologies
TG 3				
Stop weed seed-set	Pasture phase Late fallow Late stubble In-crop	Controlling weed seed-set while maintaining yield	Tactic 3.1a Tactic 3.1b Tactic 3.1c Tactic 3.1d Tactic 3.2 Tactic 3.5 Tactic 2.4* Tactic 3.3	Spray-topping with selective herbicides Crop-topping with non-selective herbicides Wiper technology Crop desiccation and windrowing Pasture spray-topping Grazing – actively managing weeds in pastures Spot spraying, chipping, hand roguing and wiper technologies Silage and hay – crops and pastures
		Controlling weed seed-set while sacrificing yield	Tactic 3.4	Renovation crops and pastures – green manuring, brown manuring, mulching and hay freezing
TG 4				
Prevent viable weed seeds within the target area being added to the soil seedbank	Pasture phase Late crop salvage Harvest	Physical removal of viable seed from paddock	Tactic 3.3* Tactic 4.1 Tactic 3.1d* Tactic 1.1* Tactic 4.2	Silage and hay – crops and pastures Weed seed collection at harvest Crop desiccation and windrowing Burning residues Grazing crop residues

Tactic group	Opportunity/timing	Weed impact	Tactic	
TG 5				
Prevent introduction of viable weed seed from external sources	Sowing	Whole-farm hygiene	Tactic 5.1a	Sow weed-free seed
	Fallow		Tactic 5.1b	Manage weeds in non-crop areas
	Stubble		Tactic 5.1c	Clean farm machinery and vehicles
	In-crop		Tactic 5.1d	Manage livestock feeding and movement
	Pasture phase			
	Farm operations			
	Livestock feeding			

Note: *Tactic used outside of their main tactic group, support the primary ones within that group

Step 5 Combine ideas using a rotational planner

A rotational planner is a useful and simple way to pull together an IWM plan. It needs to be drafted for each paddock and should include details such as:

- key weeds
- soil type(s)
- soil pH
- management issues and resistance issues (current and/or future)
- key weed management objectives that need to be addressed
- crop and pasture rotations
- selected weed management tactics from the different tactic groups
- plans for herbicide use (in-crop and fallow).

The preliminary rotational planner can be reviewed and improved from both weed management and economic perspectives by asking questions such as:

- Will this plan be effective in reducing the weed seedbank of key target weeds?
- Is the plan likely to lead to economical and sustainable crop production?
- Are there significant areas of risk if aberrant seasonal conditions or other unexpected events occur?
- Is there flexibility within the plan?

Review the results

The plan should be reviewed to assess its impact on the target weed(s). Monitor outcomes to determine the effectiveness of each tactic and the combination of tactics for each paddock. Decide which tactics had the biggest impact on weed numbers (and why) and which tactics were disappointing (and why).

Adapt the rotational plan as needed depending on seasonal conditions and results achieved. Always be open to new ideas and practices.

Useful skills

Weed identification

Correct weed identification is critical to the selection of appropriate control tactics. Resources to assist with weed identification include: the *Ute Guides*, websites, reference books, agronomists, local council weeds officers and the herbariums located within each state. A weed identification course will help identify the key features of plants used to distinguish one from another.

Collecting and submitting plant samples for identification

If taking weed samples to assist with identification, a few basic collection principles need to be observed:

- Submit fresh samples – collect as close to the time of identification as possible and store in a plastic bag in the refrigerator. If practical, an alternative is to plant the weed in a pot. When collecting and transporting weeds, ensure that the plant and accompanying soil are contained so there is no risk of spread.
- Submit as much of the plant as possible including the underground parts. Dig up the plant and shake off the loose soil surrounding the root system. Gently washing the roots in a bucket of water is also helpful but take care, as the original seed (point of germination) may still be attached and could assist identification.
- Where possible provide flowers, seeds or fruit, as these are the most distinctive features for identification. Failure to provide these parts may prevent successful identification.
- If a range of growth stages or plant health states are present, it is essential to provide representative plants from each.
- Provide the following information:
  - name, address and contact details
  - the situation in which the plant is growing, including location, soil type and distribution (eg scattered, clumps, single)

An example of a good weed photograph, showing the whole plant, with good detail of leaves and stems to aid identification.
Photo: Andrew Storrie

– any information that may assist with identification: Is the weed growing where imported fodder has been fed out? Have particular weed management tactics been used in the current season? When did you first notice the weed?

Digital photos can sometimes be useful for weed identification. Useful features to include are:

- the whole plant, showing architecture: is it prostrate, erect, a bush, a vine etc? Include an object such as a coin or ruler to indicate size
- the key parts of the plant including leaf shape and colour, flowers, fruit, seeds and underground parts such as bulbs.

When taking digital photos be sure that the weed can be distinguished from the background (eg other plants, soil) and ensure that shadows do not obliterate the weed, especially its key features.

Assessing weed population density

The most accurate way to estimate the population of a weed in a paddock is to count the number of plants in an area of known size at a number of locations. Weed plant counts should be done using a quadrant, which may be square or circular. The number and location of counts needed to estimate the population will vary depending on the distribution pattern.

How big should the quadrant be?

The size of the quadrant will depend on the density of the weeds. Small quadrants ($0.1m^2$) are adequate for weed populations greater than 200 plants per m^2. This would equate to counts above 20 plants per quadrant. For lower weed densities increase the quadrant size (up to $1m^2$) so that you are counting between 5 and 50 plants per count.

1. If the weed is in distinct patches across the paddock:
- Conduct plant counts within the patches only.
- Do at least 5 counts within each of at least four patches, giving 20 counts for the paddock. The more counts carried out, the more accurate the assessment.

2. If weeds are relatively uniformly distributed across the paddock:
- Conduct a transect. Walk in a line across the paddock taking a set number of steps, then do a plant count (for example, walk in a 'W' path as in the diagram and do a count at each 'x'). The most important thing is to do at least 20 counts ensuring you have covered the majority of the paddock. DO NOT concentrate your counts in one corner of the paddock.

Record the plant count for each weed species being monitored.

Plant counting is an opportune time to make notes on different aspects of the weeds and the crop. Consider whether plants appear small and stunted, or affected by insects or disease. Make observations on their distribution, such as whether they are all growing in the furrow with no weeds in the inter-row, or if the density is higher in the header trails.

Also take note of other weeds present. Records should be able to be interrogated to show changes in weed density and spectrum over time. These records can be an early warning of an emerging problem.

Estimating potential weed population density

Potential weed population density can be estimated in a number of ways:

- When weeds are setting seed, count the number of seed heads or pods, and the number of seeds per pod or seed head, from a given sample area. This will give an estimate of the total number of seeds produced.
- A more complex but accurate method is to take soil cores, sieve and wash them, and count the seeds in those samples. This technique is often limited to use as a research tool as it is time consuming and dependent on seed identification skills.
- Water small areas in the paddock and identify and count the germinating weeds. This can be done in the autumn but does not always provide a realistic guide to the potential weediness due to the complex nature of seed dormancy.
- Use paddock records from past monitoring to give an estimate of aspects such as weed species, density, seed-set and location. It allows you to monitor changes through time.

Assessing herbicide performance

Understanding how different herbicides work helps when assessing herbicide performance. It is important to remember that the rate at which plants die after the application of herbicide depends on the product and rate applied as well as the weather conditions following application. For example, the effect of paraquat/diquat on weeds can be observed shortly after spraying, with initial effects being observed within hours in bright sunlight and significant effects evident in a few days. Herbicides such as the sulfonylureas, however, are slower acting and it may be up to 6 weeks after application before final assessments of their effectiveness can be made.

In addition, it is important to understand the 'claims' made by the herbicide manufacturer. Some products registered for the control of weeds do not claim to kill the weed but, rather, 'suppress' growth, reducing seed-set and competition against the crop.

Herbicide failures occur for numerous reasons, including application error, adverse environmental conditions, plant stress and herbicide resistance. Spray and paddock records play an integral role in the effective assessment of herbicide performance.

Evaluate the likelihood of application error by asking:

- Has the target weed been accurately identified?
- What product was used, and was it a correct choice for the target weed?
- Was the correct product rate used for the weed growth stages present?
- Were appropriate adjuvants used at the correct rates?
- Did the product reach the target? Certain herbicides may be intercepted and bound to other plant material (eg stubble) or soil and thus not reach the target weed.
- Was the product measured accurately when making up the spray tank mix?
- Was the quality of the water used satisfactory? The performance of some pesticides is affected by water quality characteristics such as hardness, pH, salinity and clay content.
- Was the water volume per hectare appropriate?
- Was the boomspray accurately calibrated?
- Were there equipment problems, eg blocked nozzles, erratic pump performance?
- Were the correct nozzles, pressure settings, boom height and boom speed used to achieve the desired uniform coverage?
- Were label directions regarding environmental spray conditions observed?
- What else was added to the tank mix? Some pesticide mixtures, while being physically compatible (ie can mix together), may be biologically incompatible. Biological incompatibility can result in reduced weed control and/or increased crop damage. Performance may also be reduced if insufficient time has been left between separate applications of antagonistic products.
- Was the tank solution mixed properly and was agitation adequate to keep it mixed?

Environmental factors or conditions at the time of spraying can influence the performance of herbicides. When assessing performance problems, good records of the conditions at the time of spraying are critical.

Herbicide labels provide some guidance as to desired conditions or, alternatively, conditions to avoid when spraying weeds. Unfortunately, due to the nature of weather, the number of 'ideal' spray days in a season is limited. Critical environmental factors to consider include:

- the time of day applied
- the presence of heavy dew
- the temperature at time of application and up to 10 days before or after application
- clear skies versus heavy clouds / overcast conditions
- rainfall events, eg whether rainfall has occurred after application and before the rain-fast period of the post-emergent herbicide has elapsed. Heavy rain shortly after use of soil-applied herbicides can move them into the crop root zone, increasing crop damage

- stressed weeds due to many factors, including:
  - too dry or wet, or frosts before or after application
  - poor nutrition
  - disease or insect attack
  - competition from other weeds or the crop
- soil pH affecting herbicide availability to weeds or the crop
- whether the product leached or was otherwise destroyed so that uptake by the target weed was limited.

Once again, good records help determine the reason for herbicide failures. Their importance cannot be emphasised enough. If no reason can be found for a spray failure and herbicide application records indicate that resistance is likely, confirm suspicions and conduct some form of herbicide resistance test (see below).

Herbicide resistance testing

There are a number of different methods of testing for herbicide resistance. Resistance testing can be conducted on-farm or by a commercial resistance testing service. Tests can be performed in situ (in the paddock during the growing season), on seed collected from the suspect areas, or by sending live plant samples to a testing service.

In-situ testing

An in-situ test can be performed following herbicide failure in a paddock. The test should be done at the earliest opportunity, remembering that the weeds will be larger than when the initial herbicide was applied. Test strips should be applied using herbicide rates appropriate to the current crop growth stage and weed size, plus a double rate. The test strips should only be applied if the weeds are stress free and actively growing. To more accurately assess the level of control, conduct weed plant counts before and after application. Green or dry plant weights can be calculated for more accurate results.

When testing for resistance it is useful to understand the resistance profile of the weed population: ask which herbicides from which groups don't work? When conducting resistance tests use a range of products from different MOA groups and subgroups. This is of particular value when dealing with weed species known to develop cross-resistance (see *Section 2: Herbicide resistance*).

In order to test a number of herbicides in situ a small motorbike boom or firebreak boom is more suitable, as long as it can be accurately calibrated.

Elders Ltd has developed an in-situ resistance testing boom. Offered as a fee-for-service operation to clients, Elders will spray resistance test strips in the paddock, enabling results to be observed firsthand.

Due to the often late timing of in-situ testing, results must be carefully interpreted, preferably with the help of a more experienced agronomist.

Herbicide resistance seed tests

Seed tests require collection of suspect weed seed from the paddock at the end of the season. This seed is generally submitted to a commercial testing service. It is possible to conduct your own pot tests at home, but this can be a difficult task due to the complex seed dormancy mechanisms of some weed species, the challenge of applying product at accurate rates, and the difficulty of maintaining reasonable growing conditions for the weeds in pots.

The turnaround time for seed tests is generally several months due to the need to break dormancy. This can mean that results are received very close to the start of the following growing season.

Approximately 3,000 seeds of each weed (an A4-sized envelope full of good seed heads) is required for a multiple resistance test. This equates to about one cup of annual ryegrass seed or six cups of wild radish pods.

Consult the testing service for more details on seed collection for herbicide resistance testing.

Syngenta herbicide resistance Quick-Test™

The Syngenta herbicide resistance Quick-Test™ (QT) uses whole plants collected from a paddock rather than seeds, eliminating the problem of seed dormancy and enabling a far more rapid turnaround time. In addition, the tests are conducted during the growing season rather than out of season over the summer. A resistance status result for a weed sample is possible within 4–6 weeks. The QT, which was developed by Dr Peter Boutsalis while working for Syngenta in Switzerland, is patented in Australia.

For each herbicide to be tested, 50 plants are required. To reduce postage costs, plants can be trimmed to remove excess roots and shoots.

The QT is a **whole plant test**. Weeds (ranging in size from 2-leaf to late-tillering – Zadoks decimal code 12 to 16) are collected and sent to the testing service by mail. In some cases even plants at the early flowering stage can be tested using the QT methodology.

Upon arrival at the testing service, plants are carefully trimmed to produce cuttings and transplanted into pots. After appearance of new leaves (normally 5–7 days), plants are treated with herbicide in a spray cabinet. The entire procedure, from paddock sampling to reporting results, takes between 4 and 6 weeks, depending on postage time and the herbicides being tested.

Unlike paddock tests, the QT is performed under controlled conditions so it is not affected by adverse weather conditions. The age of the plants is also less critical to the testing procedure. The trimming of the plants prior to herbicide application means that herbicides are applied to actively growing leaves, thus mimicking chemical application to young seedlings. The Quick-Test™ has been used to test resistance in both grass and broad-leaf weed species. During testing, both known sensitive and resistant biotypes are included for comparison.

Collecting seed and plant samples for resistance testing

The area to be tested may be as large as a paddock or only a small problem spot. In large paddocks you may want to consider submitting a few samples, for example from different management zones or soil types within the one paddock.

Draw a mud map of the collection points or area, or use a GPS to record locations. Avoid producing a sample dominated by seed from only a few plants by collecting just one seed head from any individual plant. The aim is to provide the most representative sample possible. Collect enough seed to fill an A4 envelope, or sufficient plants to cover the range of herbicides to be tested under a Quick-Test™.

When sampling patches of weeds, following a herbicide application failure, only collect seed or plants from these patches as you wish to know whether the cause of these patches is herbicide resistance.

In a large area collect seed or plant samples every 10–20 m along a 'W' shaped transact (see *Assessing weed population density* in this section). Avoid headlands or areas where there may have been spray misses or where the application rate is questionable.

Contributors

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Further reading

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