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Herbicides

Department of Primary Industries and Regional Development, Western Australia

Herbicides

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Herbicides play a vital role in integrated weed management programs. Knowledge of the mechanisms and activity of herbicides will improve the impact and sustainability of herbicides as a weed management tactic.

This fact sheet is a guide to the types of herbicides available and when and how they should be used.

Types of herbicides

Translocated herbicides

Translocated herbicides move to the site of action via the transport mechanisms within the plant xylem and phloem. The xylem transports water and nutrients from the soil to growth sites and the phloem transports products of photosynthesis (for instance, sugars) to growth and storage sites. It may take up to 2 weeks for symptoms to develop on the target weeds, depending on herbicide rate, conditions, and species.

Contact herbicides

Complete coverage of the target is critical because contact herbicides have limited movement within the plant. Compared to translocated herbicides (for example, glyphosate), contact herbicides (like paraquat, oxyfluorfen, diquat, and bromoxynil) tend to show symptoms rapidly; usually within 24 hours.

Selective herbicides

Selective herbicides will kill target weeds and not desired plants (like crop or pasture) when applied at a specified application rate.

Non-selective herbicides

Also called knockdown herbicides, non-selective herbicides such as glyphosate or paraquat will damage most plants.

Residual herbicides

Residual herbicides remain active in the soil for an extended time (months) and can act on successive weed germinations.

Non-residual herbicides

Non-residual herbicides, such as the non-selective paraquat and glyphosate, have little or no soil activity and are quickly deactivated in the soil. They are either broken down or bound to soil particles, becoming less available to growing plants. They also may have little or no ability to be absorbed by roots.

Post-emergent and pre-emergent

Post-emergent and pre-emergent are terms that refer to the target and timing of herbicide application. Post-emergent refers to foliar application of the herbicide after the target weeds have emerged from the soil, while pre-emergent refers to application of the herbicide to the soil before the weeds have emerged.

Herbicide mixtures and sequential applications

Herbicide mixtures and sequential applications involve the application of more than one herbicide, usually to increase the spectrum of weed species controlled and for resistance management.
A mixture involves the application of multiple products in a single application. Where herbicides are antagonistic and cannot be mixed in a single tank, they are applied sequentially.

Knockdown herbicides for fallow and pre-sowing control

Knockdown herbicides (or non-selective) kill all plants when used in sufficient quantities, under suitable environmental conditions.

Considerations

- Knockdown herbicides effectively kill weeds and are cost-effective.
- Use of knockdown herbicides can improve the timeliness of sowing.
- Use of knockdown herbicides rather than cultivation will reduce the risk of erosion, improve soil structure, and improve plant available soil water content.
- Consider the suitability of herbicide use for fallow or pre-sowing weed control by assessing environmental conditions.
- Stressed weeds will not be adequately controlled by knockdown herbicides.
- Overuse of knockdown herbicides will select for resistance.
- Suitable weather conditions for spraying can be limited, especially for weed control over the summer fallow.

Double knockdown

'Double knockdown' refers to the sequential application of 2 weed control tactics applied in such a way that the second tactic controls any survivors of the first tactic. A common combination is glyphosate followed by paraquat or paraquat/diquat.

Considerations

- Double knockdown delays or prevents the development of glyphosate resistance.
- Using a double knockdown strategy reduces the number of (potentially resistant) weeds to be controlled in crop.
- Excellent weed seedling control is achieved.
- Glyphosate should be applied first, followed by paraquat or paraquat/diquat.
- The timing between applications will vary depending on the main target weed species.
- Consider the main target weed species when choosing what herbicides to use in the double knockdown.

- Double knockdown is more expensive than a single herbicide application.
- Seasonal conditions will influence the scale of on-farm implementation (as a double knockdown takes more time than a single application).

Pre-emergent herbicides

These herbicides control weeds between radicle (root shoot) emergence from the seed and seedling emergence through the soil. Some pre-emergent herbicides may also provide post-emergent control.

Considerations

- The residual activity of pre-emergent herbicides controls the first few flushes of germinating weeds while the crop or pasture is too small to compete.
- Good planning is needed to use pre-emergent herbicides as an effective tactic. It is necessary to consider weed species and density, crop or pasture type, soil condition and rotation of crop or pasture species.
- Soil activity and environmental conditions at the time of application play an important role in the availability, activity, and persistence of pre-emergent herbicides.
- Both the positive and negative aspects of using pre-emergent herbicides should be considered in the planning phase.

Selective post-emergent herbicides

These products control weeds that have emerged since crop or pasture establishment and can be applied with little damage to the crop or pasture plants.

Considerations

- Post-emergent herbicides give high levels of target weed control with the additional benefit of improved crop or pasture yield.
- Observations made just prior to application allow fine-tuning of herbicide selection to match weeds present in the paddock.
- Timing of application can be flexible to suit weed size, crop growth stage and environmental conditions.
- Some post-emergent herbicides have pre-emergent activity on subsequent weed germinations.
- Use careful consideration when selecting the best post-emergent herbicide to use in any one situation.
- Application of post-emergent herbicides to stressed crops and weeds can result in reduced levels of weed control and increased crop damage.
- Crop competition is important for effective weed control using selective post-emergent herbicides.
- The technique used for application must be suited for the situation to optimise control.
- Always use the correct adjuvant to ensure effective weed control.
- Selective post-emergent herbicides applied early and used as a stand-alone tactic have little impact on the weed seedbank.
- Choose the most suitable formulation of herbicide for each situation.
- The effectiveness of post-emergent herbicides is influenced by a range of plant and environmental factors.

Herbicide uptake by plants

Foliar applied herbicides

Effectiveness is influenced by the distribution/composition of the spray droplets and the characteristics of the leaf surface on which the spray is deposited.

Herbicides in the soil

Both foliar and soil applied herbicides may be present in the soil and absorbed through plant roots.

Root absorption

Water soluble herbicides are absorbed in water through root hairs and the area just behind the root tip.

Coleoptile and young shoot absorption

Some herbicides, such as triallate or trifluralin, act mainly through root uptake, with some shoot uptake. These products can be volatile and need to be absorbed quickly to be effective. Non-volatile shoot uptake herbicides (that is, diflufenican and metolachlor) rely on a moist soil surface for best efficacy.

Stressed weeds

Stressed weeds are harder to kill than healthy, actively growing weeds. Stress is caused by lack of moisture, lack of oxygen due to waterlogging, extremes of temperature, nutrient deficiencies, insect pests, disease, a sublethal dose of herbicide from prior applications or residues, and mechanical damage (that is, from tillage, slashing or grazing).

Once a weed has been subject to stress, it will not be adequately controlled by rates of herbicide that would otherwise be sufficient to control an unstressed weed, even after the stressed weed has apparently recovered from the stress. Additives may help control stressed weeds but can be unpredictable.

Movement of herbicides in the environment

Herbicides have the capacity to move in the environment away from the target area, and to cause damage to non-target plants and animals. There are management options to reduce the possibility of this happening.

Herbicides in plants

A certain proportion of any selective herbicide applied to a crop will be absorbed by crop plants and tolerant weeds rather than by those weeds that the herbicide is intended to control. These plants can tolerate the herbicides because various enzymes within them metabolise the chemical before it can cause permanent damage. Thus, this portion of the herbicide is removed from the environment and destroyed.

Susceptible weeds are not able to metabolise the herbicide quickly enough to avoid being killed. As the plant dies however, its cells rupture and release a range of oxidising enzymes. These enzymes destroy much of the plant tissue, and the herbicide. Thus, this fraction of the herbicide is also removed from the environment.

Herbicides in the atmosphere

Most herbicides get in the atmosphere from the drift and eventual evaporation of fine spray droplets that do not settle. All herbicides have the potential to do this. Some, like trifluralin and the volatile ester formulations of 2,4-D, are also sufficiently volatile to enter the atmosphere by evaporating (volatilising) from the surface of sprayed plants or the soil.

The potential danger that herbicides in the atmosphere pose to nearby plants is short term. Ultraviolet light striking a herbicide molecule has sufficient energy to disrupt some of the bonds between its constituent atoms, destroying the molecule. Rates of breakdown for any compound will depend on the intensity of sunlight.

Degradation of herbicides in soil

Many herbicides that are used in one year of a typical cropping rotation have the potential to damage crops grown in other years of that rotation. Fortunately, in an average year these herbicides are broken down (degraded) into harmless compounds by a combination of biological and chemical processes, and do not cause any problems for the crops.

From the moment an herbicide enters the soil system, it begins to break down. Most of this degradation is due to the action of microscopic living organisms which break down the organic material in the soil to provide the energy they need to live (it is their food supply).

Some herbicides are also prone to chemical reactions that alter their structure and render them non-phytotoxic. These degradation processes depend on soil temperature and moisture levels. Degradation begins when the moisture level rises above the wilting point and increases in direct proportion to soil temperature. Extra moisture increases the rate of degradation but not by as much as higher temperatures.

Triazines (atrazine and simazine), sulfonyl ureas (chlorsulfuron, triasulfuron etcetera), and imidazolinones are all candidates for carryover. All other things being equal, imidazolinones will be more persistent on acid soils and sulphonyl ureas on alkaline soils. Triazines are slightly more persistent on alkaline soils.

Paddocks should be regarded as having potentially damaging levels of residues if these products were applied in June or later (especially in a year with low rainfall after application), or if earlier applications were followed by significant periods when the soil surface was dry.

Movement of herbicides by soil or leaching

- If wind or water moves soil that is left bare from cultivation for cropping, or destruction of vegetation by herbicides on firebreaks and roaded catchments, any herbicides in the soil will also be moved and may damage desirable vegetation wherever it settles.
- As rainwater moves from the surface down the soil profile, herbicides in the soil will move with it, to some extent. This leaching is a dynamic process, whereby the herbicide alternates between being dissolved in the water and therefore moving with it and being adsorbed onto soil particles and therefore immobile. The rate of movement of any herbicide down the soil profile therefore depends on its solubility in water and the strength with which it absorbs onto soil particles.
- Later in the season, when there is reverse water flow net back toward the drying surface soil, it is possible for previously leached herbicide to move up from sub-soil with the water.

Residue effects

Triazine residues will vary in the damage they cause according to seasonal conditions.
Residue effects will be reduced when the season start is uniform and rainy, compared to dry.
Root disease will exacerbate the effect of triazine residues, as the young seedlings cannot grow away from the residues that are concentrated in the cultivation layer.

Sulfonyl urea and imidazolinone residues are more soluble and therefore less affected by soil moisture. The first effect of the sulfonyl ureas is to prune roots. Be careful in duplex soils with sand, rather than alkaline clay, because the sulfonyl ureas can leach down to the clay where they will be more persistent due to the high pH.

Herbicide drift

Herbicide drift is the movement of pesticide away from the target area in the atmosphere.
The 3 main forms of drift are droplet drift, vapour drift, and particulate drift, with droplet drift being the main cause of off-target damage.

Spray emerging from a boom breaks up into droplets of varying size. Larger droplets fall onto the target area, while the smallest droplets may remain in the air.

Because droplet drift usually disperses as it moves away from the sprayed area, the type of crop damage it causes in adjoining areas is easily recognised. That part of the sensitive crop that is closest to the sprayed area is severely damaged, but damage decreases with distance away from the severe zone.

Vapour is produced by evaporation from the droplets when they leave the boom and the target surface after spraying.

Like droplets, vapour disperses rapidly as it is carried away from the target area. Vapour will remain suspended in the air unless the contaminated air is forced back to ground level where it may damage growing plants.

Vapour can drift for long distances, and the characteristic feature of vapour drift damage is that no clear damage gradients can be seen. Damage, which is generally mild but widespread, is usually caused by a large body of contaminated air that is several square kilometres in size.

To understand damage caused by drift of herbicides, the following 4 key aspects require understanding:

1. Production of driftable sized particles

Most agricultural herbicides are applied as fine droplets in the 150 to 300 µm range, produced by hydraulic nozzles on boom sprays. Droplets from 100 to 200 µm in diameter usually stick to the first surface they encounter but droplets larger than 500 µm are likely to bounce off leaves and end up on the soil or lower canopy. Droplets smaller than 50 µm are likely to float around the target plant and drift off.

The smaller droplets provide better coverage, which is important when the target plant is small, the herbicide is poorly translocated, or when low carrier volumes are used. Larger droplets result in greater interception or less drift, but the poorer coverage may need to be compensated for by using translocated herbicides or higher carrier volumes.

Most commercially available nozzles produce a range of droplet sizes, so there is usually a proportion of very fine droplets that may drift. For emulsifiable concentrate sprays, drift reducing agents may reduce drift. For aqueous sprays, the addition of a drift reducing agent may increase the production of droplets less than 100 µm diameter and cause greater drift. Shear stresses in recirculating pumps, especially centrifugal pumps, can reduce the effect of polymer drift reducing agents.

2. Transport of herbicide away from the target area

Under the influence of gravity, all droplets fall at a speed called sedimentation rate. Large droplets fall faster than small droplets. Within a few centimetres of the nozzle, the movement of most droplets is determined by gravity, their buoyancy, and wind. The higher the droplet is released, the further it will move away from the target area because the wind speed is slower close to the ground and there is more time for the wind to move the droplet before it lands. Therefore, the amount of pesticide that drifts off target is closely related to the boom or flying height. Halving the height of the boom above the target will reduce drift by about 60%. In situations where drift can cause problems (for example, susceptible crops growing down wind, water catchments and residential areas nearby), the boom should be operated at the lowest height possible for the nozzles and spacing.

Decreasing the nozzle spacing will allow the boom to be operated at a lower height. Large droplets contain more herbicide, but tend to land close by, while small droplets contain less herbicide but are moved over greater distances by the wind and are more likely to be affected by turbulence that may carry them upwards.

The amount of driftable droplets that form varies with the formulation of herbicide applied and method of application. About 2 to 10% of spray volume of aqueous formulations will be in drift-prone droplets (droplets less than 100 µm diameter) when using normal flat fan or cone nozzles on an aircraft. The proportion of drift-prone droplets is even less when using these nozzle types on a boom spray. Emulsifiable formulations of herbicides will produce about twice as many droplets in this size range with the same equipment.

The size of the area sprayed also affects the amount of herbicide leaving the target area because successive runs contribute to drift. As small droplets drift away from the sprayed area, they normally disperse to non-toxic concentrations within 100 to 200 metres downwind. Under low level temperature inversion conditions, the droplets may be trapped in a layer of cool air close to the ground and move greater distances at higher concentrations. These conditions are most likely to occur when there is little or no wind, clear skies, the weather is influenced by a high-pressure system, and the ground is cooler that the surrounding air in the evening. These conditions may last until the sun warms the ground the following day or the wind speed increases. Most insurance claims for drift damage are associated with inversions, which can be made worse by valleys that can channel drift laden air for a kilometre or more.

3. Interception or absorption of the transported herbicide by the off-target species

As droplets leave the target area, they usually decrease in size as the carrier evaporates. This affects the deposition on off-target plants and generally reduces the damage that would otherwise be predicted by drift.

Damage is a function of the number of droplets impacting the plant, multiplied by the concentration of herbicide in the droplet. Small droplets produced by the evaporation of large droplets carry more herbicide than small droplets produced at the nozzle.

4. Dose response curve of the herbicide for the affected species

The dose response curve for many plants to herbicides is a logistic curve as shown in Figure 1, below. At very low doses, there is no significant effect on the plant. As the dose of herbicide increases, the amount of damage increases until, at high doses, the plant dies and more increases of dose will have no further effect.

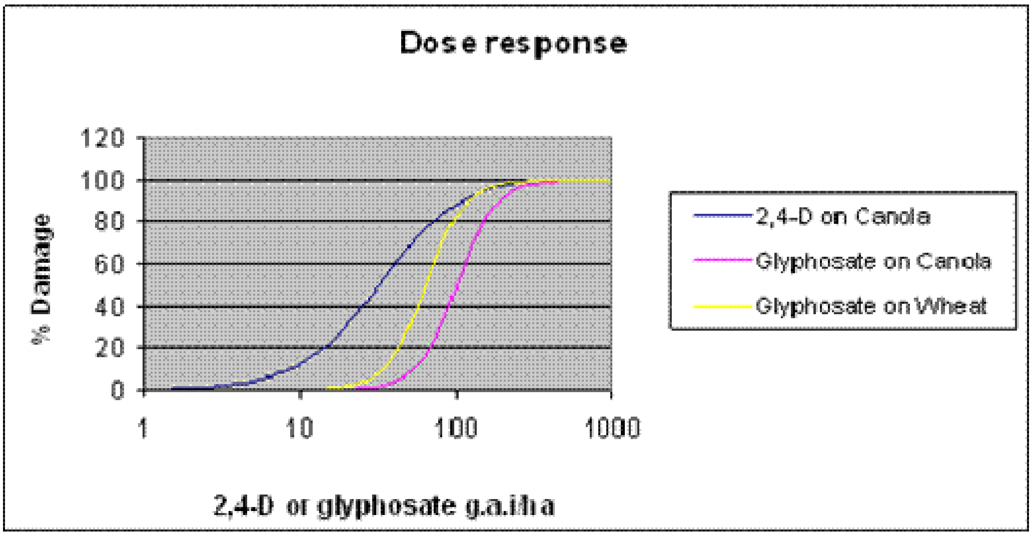

Figure 1 Dose response curve of the herbicide for the affected species

Figure 1 shows that wheat is damaged more than canola by low doses of glyphosate.
The no-effect-level (NOEL) is around 10 grams of active ingredient per hectare (g.a.i/ha) for wheat, and 25 g.a.i./ha for canola.

The dose of glyphosate and 2,4-D required to kill canola is similar. However, because the slope of the dose response curve for 2,4-D is less that for glyphosate, the NOEL for 2,4-D on canola is much less that the NOEL for glyphosate. This means that canola crops are more tolerant to glyphosate drift than they are to 2,4-D drift.

Drift can be reduced by increasing the droplet size, reducing boom height, and application at reduced wind speeds.

Effect of environmental conditions and windspeeds on spraying operations

The effectiveness of the spraying operation will be influenced by the following environmental conditions at the time of spraying:

Weather

High temperatures, low humidity, high delta T (delta T is a measure of evaporation), and wind speeds less than 3 km/h or greater than 15 km/h may result in loss of herbicide through drift or evaporation.

Plant stress

Lower levels of control often occur when weeds are under environmental stress when sprayed. For example, for glyphosate to work, it must be translocated around the plant to its site of action, and the weeds need to be actively growing (not stressed) to maximise the uptake and translocation. Plant stress may be caused by environmental conditions such as drought, waterlogging, and frost.

Rainfall

Rainfall shortly after spraying may wash herbicide off the plants before it has had time to act.

Wind speed is the main factor to be considered when spraying for winter crops. In windy conditions, follow the advice below:

- Read the herbicide label or seek advice from an agronomist. Take note of the toxicity of the herbicide and any adverse effects it will have on other crops, trees, wildlife, or human health.
- Assess the potential for damage downwind from the paddock to be sprayed. An advantage of spraying in high wind speeds is that you know the direction in which the spray will drift. However, drift can also be a problem in very light winds, particularly if there is a temperature inversion.
- Reduce the risk of drift by using low pressure nozzles or low nozzle height. Remember that no current method eliminates drift.
- Assess the risks and decide if they are worth taking. For example, if you are spraying a selective herbicide in wheat and there are wheat crops downwind, you may be safe to spray in a strong wind. However, if you are spraying knockdowns and you are trying to establish a belt of new trees downwind, wait for more favourable spraying conditions.
- Do not spray if the maximum wind speed is greater than the speed at which you are spraying because when spraying with the wind behind, you risk spray drift contact.

Invest in the purchase of a small hand-held anemometer to measure wind speed when spraying. Wind speed is variable, so when deciding whether to spray, read the maximum wind speed during a wind gust. The average wind speed will be lower than this figure, so allow a margin of safety. Wind speed and direction should be recorded for all spraying.

Contact us

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More information

Refer to the department website at dpird.wa.gov.au for more information about the following:

- Crop weeds
- Competitive crop weeds
- Integrated weed management tactics to manage crop weeds
- Summer weeds and their management
- Herbicide application
- Factors affecting herbicide application
- Residual herbicides – carryover and behaviour in dry conditions

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