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Simazine and other triazines

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One of the most successful examples of breeding for herbicide resistance is the development of triazine resistant canola varieties. Now we are trying to select for triazine tolerance in lupins, Agriculture Western Australia's breeding and testing program is now carried out with a basal treatment of simazine. Terry Piper outlines the chemistry and action of these widely used herbicides and points to reason why they can sometimes fail.
Soil moisture requirements
Triazines are absorbed from soil by the plants' roots, and must be dissolved in the soil water for this to happen. Thus they work best under conditions of high soil moisture. Simazine in particular is noted for its poor weed control in seasons where the rainfall is intermittent. As the surface soil dries out, the amount of simazine in solution becomes less and less, and the weeds receive a much reduced dose. Sandy soils need a water content of at least 5 per cent before enough simazine will be absorbed by weeds, while for heavy clay soils the figure will be 10-15 per cent.

Simazine has virtually no leaf uptake. The other three products (atrazine, cyanazine and terbutryn) will enter plants through the leaves, and indeed terbutryn is used primarily in this way in Western Australia. Atrazine can be used post-emergence in triazine tolerant (TT) canola varieties, but must be mixed with a spraying oil to increase leaf uptake to the level necessary for weed control. The oil aids penetration of the chemical through the waxy leaf surface.

Brief chemistry, solubility, formulation
Simazine belongs to the group of herbicides known as the s-triazines. Also in this group are atrazine, terbutryn (Igran® etc), and cyanazine (Bladex®). The common chemical feature of this group is a central ring structure of 3 carbon and 3 nitrogen atoms. The name comes from a combination of the Latin tri-, meaning three, and the French for nitrogen, azote. Thus three nitrogens.

The triazines as a group are relatively insoluble in water (simazine 5 parts/million, atrazine 33 ppm, terbutryn 58 ppm, cyanazine 171 ppm). Nor are they soluble in organic solvents. They must therefore be formulated as flowable suspensions or as dispersible powders or granules. They do not leach appreciably except with very heavy rainfall and light soils. Even then, leaching is usually minor.

If oil based herbicides such as grass selectives (Hoegrass®, Fusilade®, Verdict® etc) are mixed with the other triazine herbicides (Igran®, Bladex®) they will also increase leaf uptake, often to the point where crop tolerance is exceeded. This is the reason why Igran®/Hoegrass® mixes cannot be used safely in wheat, and Bladex®/Fusilade®, Verdict® etc) combinations will damage peas.

Mode of action and entry into plants
The triazines act on the photosynthetic processes within plants, specifically the Hill reaction where water is split to form oxygen. They have also been shown to have some growth regulating effects, stimulating growth and greening plants at sub-lethal doses. Because the herbicide acts by restricting the plant's ability to create its own food, it cannot begin to slow growth until the reserves in the seed are exhausted. Weed seedlings therefore will emerge and grow on until they have 1 to 3 leaves, the exact size being directly related to the seed size. They then begin to go pale and/or yellow and the leaves may become flaccid with watery blotches. Grasses often appear burnt at the tips.

if crops treated with pre-emergence triazine appear to be excessively weedy at first, a follow-up treatment should not be applied straight away. The weeds may die in a week or so anyway, and while they are stressed from the triazine, any further treatments will be less effective. This caution applies particularly when conditions are dry, and the triazine is relatively inactive. The next rain will freshen up the weeds and reactivate the chemical. Weed control can then be spectacular.

Plant tolerance, activity range
Crop plants tolerate triazines due to a variety of different mechanisms.
Maize and sorghum have the ability to metabolise the chemical rapidly. Any that enters these plants is broken down before it can reach the photosynthesis sites and cause any damage. These crops suffer no damage at all from triazines.

Triazine tolerant (TT) canola, and most weeds that have developed resistance to triazines, have a modified photosynthetic pathway. The chemical processes involved in photosynthesis have been changed in such a way that triazines are no longer able to disrupt them. The plants can tolerate massive rates of triazines, but their altered photosynthesis is not as efficient as the original, and they grow slightly slower than their susceptible counterparts. Thus there is a yield penalty in using such crops, but this is more than offset if the area has high levels of otherwise uncontrollable weeds.

Other plants, and lupins are probably in this category, tolerate moderate rates of triazines because their roots are inefficient.
Seeding machines that leave the soil ridged or cloddy are often associated with poor simazine performance. On the other hand, poor incorporation is another factor contributing to weed escapes. Simazine works best on small weeds so each seedling needs to pick up its dose soon after germinating. If the simazine distribution through the soil is patchy, some weeds will germinate in untreated soil. Under dry conditions, they will put most of their root growth straight down chasing moisture, rather than sideways to where the next patch of simazine lies. By the time some of their roots reach any simazine they will be too big to be fully controlled.

Danjo lupin was damaged or killed by all rates of soil applied atrazine (plants at left edge of tray received no herbicide). Gungurru (below) was not damaged, even at the highest rate of atrazine.

Except for the truly tolerant crop species, the triazines do not have a wide activity range; they are relatively non-selective toward seedling plants. Although 1 litre per hectare will control sensitive weeds like silver grass or doublegee, and 2 to 3 litres per hectare is needed for the more tolerant ryegrass or radish, compare this with chlorosulfuron (e.g. Glean®) where 20 grams per hectare is needed to control ryegrass or capeweed, while 1 gram per hectare will control clovers or medics.

**Development as a lupin herbicide**

There is no doubt that simazine has been responsible for the growth of the Western Australian lupin industry, especially the tendency to dry seeding. It provides control of almost all weeds, and can be applied pre-plant (even several weeks before seeding) when time pressures are less. Although crops often appear weedy and farmers believe the simazine has done little, an inspection of unsprayed headlands usually shows that substantial control has occurred. Simazine requires moist soil to be effective and our soils often go through dry periods, especially early in the season. If an opening rain is followed by a 2 to 3 week dry spell, the soil surface will dry out. There may be plenty of moisture below 10 centimetres, and the crop and weed seedlings will survive and grow well, but the simazine is sitting in dry soil from where it cannot be extracted by roots. The weeds may be slowed by any simazine they have already absorbed, and they will be stunted further when the surface next rewets, but total control will usually not be achieved.

In contrast, those crops that are sown into moist soil 2 to 3 weeks after the break are often completely weed free. The soil has fully wetted and conditions may be slightly cooler. The soil surface stays moist for longer and simazine can work to its full potential.

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applied post-emergence, with an admixture of spraying oil, will give much better control of all brassicas and most other weeds.

Degradation processes, half life, residues

In the soil, triazines are broken down mainly by microbial action. Fungi, bacteria and other organisms use them as a source of food nitrogen. There is also some degradation by chemical hydrolysis, whereby the molecules react with water. The new molecule formed has very low plant toxicity, and remains in the soil doing nothing to plants until it is eventually consumed by microbes.

Simazine has a half life in Western Australian soils of 3 to 6 weeks during winter. That is, in 3 to 6 weeks, half of an applied dose will have degraded, and half of the remaining half will degrade in the next 3 to 6 weeks. Over an average winter, at least 95 per cent of an application will have degraded by the end of the season. Any remaining chemical will have no effect on following crops.

However, if the season is appreciably drier than normal there is a danger that residues will remain at levels that could damage cereal crops. (Appreciably drier than normal' is a loose term, but it is difficult to be specific. Much will depend on the nature of the soil and the patterns of rainfall. The comments earlier regarding triazine availability to weeds also apply to triazine availability to degrading processes. Any time the surface soil moisture falls below wilting point, degradation will slow or stop.)

Crop damage also depends on a number of factors. Soil moisture is the most important. If the season is wet, last year’s residues will be more damaging as they are more active in the moist soil. Ironically, if the second season is dry, any carryover residues will do much less harm.

Crop variety is also important. Some wheats are much more sensitive than others. Machete for example is particularly sensitive while Cascades seems relatively tolerant. Research in this area is ongoing, and we still have much to learn. Eradu and Cadoux, for example, have shown both high and low tolerance at different sites, so the variety also may exhibit soil type differences.

Finally, root diseases seem to exacerbate the effect of residues. Many cases have been recorded where residue damage manifested itself as circular patches resembling root disease such as Eradu patch or rhizoctonia. But the plant symptoms were those of triazine damage.

We think that the presence of disease fungi may slow root development, not to the point that would cause permanent damage to the crop in itself, but just enough to mean the young seedling must draw most of its supplies from the surface soil, where the triazine residues are. This is enough to raise its triazine uptake above the point of no return. Elsewhere in the paddock, the seedlings can grow away from any transient damage.

If residues are suspected, affected paddocks should be sown at the end of the cropping program rather than at the beginning to allow as much time for degradation as possible to take place after the break. It is also an advantage to sow at the end of a rainy period rather than at the beginning. This will mean the wheat seedlings are emerging as the surface soil is drying out. The simazine in this soil will then be less available to those seedlings, which will survive and grow using sub-soil moisture. If they can attain a reasonable size before another rain re-wets the surface, they have a better chance of overcoming the simazine.

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