Tolerance of cereal crops to herbicides

D G. Bowran
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Ear deformity (missing spikelets, thinning of the rachis) caused by applying 2,4-D during ear development.

Tolerance of cereal crops to HERBICIDES

By D. G. Bowran, Research Officer, Weed Agronomy Branch

Herbicides have come to play an important role in the control of weeds in Western Australian cereal crops, with some estimates showing that sufficient herbicide was applied to treat every hectare of cereal grown in 1984. While the use of herbicides reduces competition from weeds, they may have a hidden cost. As chemicals which affect plants, herbicides may also affect and damage the crop which they are protecting. The crop may possibly fail to achieve its potential yield, and some or all of the economic benefits obtained from the chemical control of weeds may not be realised.

Crop tolerance and weed control

The removal of weeds from the crop so as to minimise competition for nutrients, water and light needs to be carried out at the earliest time and with the least cost for maximum weed control. Crop damage from herbicides can be significant. For example an infestation of 200 ryegrass plants per square metre will reduce the yield of wheat by about 25 per cent below its potential. If 20 grams per hectare of the herbicide Glean® were applied to a crop of Cranbrook wheat with this density of ryegrass, no yield increase would be likely as Glean® at this rate can depress yield of Cranbrook by about a quarter. The cost of the herbicide and its application would not be recouped, and its use would increase the cost of production with no added benefit.

Low levels of crop damage may be acceptable if large increases in yield are likely as a result of weed removal, but if only small yield increases are expected such levels of crop damage may be unacceptable. Before a decision can be made as to whether or not some crop damage is acceptable, and what are the alternatives if the damage is likely to be unacceptable, information is needed on weed densities at which spraying herbicides becomes economical, the likely effects of the herbicides on the crop, and whether environmental conditions will increase crop damage or reduce herbicide efficacy.

Plants can avoid herbicide damage in several ways:

- Plants may not be able to take up the herbicide.
- Plants may reduce uptake of the herbicide or, if herbicide is taken up, reduce movement in the plant.
- They may detoxify the herbicide before it causes injury.
• They may have a site of action of the herbicide which is not affected by the herbicide.

The degree to which herbicide damage is avoided depends on the crop type, species or variety, the environment and the herbicide used.

**Crop species**

Crops may differ in their sensitivity to herbicides. For example wheat and triticale are the most tolerant of the herbicide Glean®, followed by cereal rye and oats, with barley the least tolerant.

Varieties within a crop species are known to vary in their response to herbicides. The range of response may be from no effect to plant death, with reductions in yield and crop vigour being the more common effects. Such effects are strongly modified by the environment. For example Cranbrook wheat showed an average yield reduction* of 25 per cent in Department of Agriculture trials when treated with 20 g/ha of Glean® in 1984. Yet in 1985 a Cranbrook crop almost failed on a waterlogged site, while on a site with a well-drained soil with the same herbicide and amount almost no effect on the crop was seen.

Identification of crop varieties with an inbuilt sensitivity to particular herbicides is necessary to avoid such situations. Testing over a number of sites and seasons may be needed to provide this information. The table shows the yields obtained (as a percentage of weed-free control) when three wheat varieties were treated with 20 g/ha of Glean® at three sites in 1984.

Crop growth stage is important for the application of some herbicides, particularly the 'hormone-like' herbicides such as 2, 4-D, MCPA, dicamba, 2, 4-DB and MCPB. These can interfere with the processes of plant cell division which produce leaves, tillers, stems and ears. Application at the wrong time can result in leaf, stem and ear deformities and in reduced tillering.

Identification of the critical plant growth stage has been based on the tillering pattern of a cereal plant, and the assumption that a plant with two or more tillers is usually safe to spray with a high rate of these herbicides. It now appears that some varieties may have up to four tillers and still not be safe to spray.

To identify more accurately when cereal varieties are safe to spray with this group of herbicides, all the recommended wheat varieties for sowing in Western Australia were dissected in 1985 and their stage of ear development and Zadoks growth stage recorded. Despite a limited number of observations for some sites, the dissections indicated that with all wheat varieties except Cranbrook, Egret, Jacup and Miling spikelet formation was nearly completed by the time five leaves were fully emerged on the main stem (score Z15 on the Zadoks scale).

Application of 2, 4-D, MCPA and dicamba by themselves after this time would therefore be safe except on Cranbrook, Egret, Jacup and Miling. For these varieties application would need to be delayed until a further one leaf had emerged before the crop was safe (score Z16).

MCPA and 2, 4-D are often mixed with other herbicides for weed control and sprayed on the crop when plants have three to six leaves on the main stem (score Z13 to Z16). Although the rates of MCPA and 2, 4-D are only one-quarter to one-half those used at the later stages of growth, varieties that are more susceptible to these herbicides may suffer considerable damage as the herbicide is applied during critical growth stages. Jacup, Egret and Cranbrook are more susceptible than other varieties to low rates of these herbicides applied early.

Environmental conditions can modify such a response, and even relatively tolerant varieties may show some damage at some times.

Seeding rate may affect the degree of crop damage. Lemerle *et al.* (1981) showed that a wheat-crop sown at lower rates of seeding (15 to 30 kilograms per hectare) produced significantly more tillers than a crop sown at lower rates of seeding (15 to 30 kilograms per hectare).
The effect of applying a sulfonyl urea herbicide (similar to Glean®) on three wheat varieties two weeks after application at Z13.
The weed-free control area is the dark green strip between the two pegs, with the herbicide treated area immediately in front.
The variety in the centre showed a 15% reduction in yield on these plots, while the varieties on either side showed no yield reduction.

higher rates of seeding (60 to 120 kg/ha), but damage caused by 2, 4-D was greater at earlier application times in the crop with the lower rates of seeding. This was because ears in the later tillers were less developed than those of the early tillers, and they were more likely to be at a critical stage for 2, 4-D application.

Environmental conditions
The environmental conditions under which a crop is growing before, at or after herbicide application can modify the amount of crop damage. Conditions which increase plant stress are more likely to increase the level of crop damage by a herbicide. Significant predisposing causes of damage under Western Australian conditions are waterlogging, nutrition, temperature and soil pH.

Waterlogging can increase plant stress, making plants less able to detoxify a herbicide. It may also increase the availability of a herbicide by keeping it in solution. As it is not always possible to predict when a particular crop is likely to be waterlogged, planting susceptible crops or varieties in areas where a waterlogging problem is likely to develop should be avoided. Herbicides which may cause crop damage should not be used where there is a risk of waterlogging.

Plant nutrient deficiencies may be increased by the use of some herbicides, especially those which can reduce root growth. Such deficiencies are more likely where the nutrient is at a marginally deficient level in the soil, or where the nutrient is in a particular soil zone but the roots are restricted from growing there by the herbicide. Copper deficiency has been seen in wheat crops treated with Glean®, and zinc deficiency has been seen in cereal crops sprayed with Hoegrass®. Correcting potential soil nutrient deficiencies before they occur will help to reduce possible herbicide/nutrient interactions.

Temperature can affect a crop’s reaction to herbicides, mainly by modifying a plant’s ability to detoxify a herbicide. Low night air temperatures at spraying, especially frost conditions, can increase damage from herbicides such as 2, 4-D, dicamba and MCPA.

Soil pH, soil compaction layers, soil type and organic matter content may alter the level of crop damage, depending on the herbicide used. A herbicide which is absorbed by the roots is more likely to be affected. Depth of planting of seed and the evenness of incorporation of a herbicide into the soil can also modify the level of crop damage sustained. Where any of these factors are suspect, herbicide label recommendations often indicate their relative importance.

Type of herbicide
The activity of a herbicide depends on its chemical structure. The ‘hormone-like’ herbicides tend to cause the greatest damage to cereals, with MCPA less damaging than 2, 4-D amine and 2, 4-D ester causing more damage. The herbicides 2, 4-DB and MCPB are less damaging to the crop than 2, 4-D or MCPA respectively because the plant cannot convert the 2, 4-DB or MCPB to either 2, 4-D or MCPA.

Lower rates of herbicides are generally less damaging to a crop than higher rates, but this depends on the sensitivity of the crop or variety as well as the environmental conditions.

Herbicides may be mixed with other herbicides or chemicals to increase the effectiveness of weed control, or with
insecticides, fungicides and fertilisers. Some chemicals in the mixtures will not interact with one another or the crop, while others may increase crop damage. There is often no information available as to how particular combinations will affect a crop. Unless there are recommendations or sound reasons for mixing two or more chemicals this should not be done.

The tolerance of a cereal crop to herbicides is a complex matter as usually more than one of the factors mentioned is operating at the same time. To what extent combinations of factors can increase crop damage is not known, but additive effects can occur. The environment itself may cause crop damage, and care should be taken when interpreting any interactions between herbicides and the environment.

Most herbicides are applied during early crop growth. Although crop growth may also be reduced at that time, a crop's ability to compensate for such reductions can mean that under good growing conditions overall yield may not be affected. A reduction in the number of tillers produced often results in increased grain set and grain weight of the remaining tillers with no overall net loss in yield.

Future research

In the short term, Department of Agriculture research will aim to identify adverse herbicide/crop variety combinations, especially as new varieties and herbicides become available. It will also investigate in more detail how adverse environmental conditions can affect a crop's response to herbicides, and identify the relative importance of time of application and variety susceptibility for herbicides such as 2, 4-D.

Longer term research may study the breeding of herbicide tolerance into crop varieties so that new crop/herbicide combinations are available, such as Hoegrass® tolerance of oats. It may also be possible to enhance the existing level of tolerance in crops so that the environment and timing of application have less potential for causing crop damage.

References