HERBICIDES AND LIFE IN THE SOIL

Land & Water Resources Research & Development Corporation

By V.V.S.R Gupta, CSIRO Land & Water

Pesticides are an essential in modern agriculture. In Australia over $800 million is spent each year on pesticides, with 65% of this expenditure on herbicides.

Many herbicides are applied directly to the soil which has lead to questions about their impact on the soil biota - the Life in Soil.

A diverse range of organism types and species carry out one function

Soil biota consist of a diverse range of organisms; both flora (microorganisms) and fauna (animals). These organisms carry out key soil functions and are grouped by both body size and function (See figure 1) For example the function of nutrient cycling is carried out by microflora, e.g. bacteria, microfauna e.g. protozoa and mesofauna e.g. collembola (springtails).

All the organisms involved in a specific function are grouped and termed a functional group, eg. nitrification is carried out by nitrifying microorganisms.

Agronomic practices which interfere with specific organisms may reduce the output of a functional group but may not cause it to cease. However, this may result in a new population balance which could lead to plant pathogenic organisms becoming dominant.

An understanding of the impact of different herbicides on various soil functions will help farmers work in harmony with the soil biota and minimise the impact of herbicides on these functions.

Please note:

- The following information draws on Australian and international research.
- A majority of herbicide research is laboratory based. This is because field fluctuations in temperature and moisture and the variability in physical and chemical properties of soil may influence the soil organisms to a greater extent than the application of a pesticide. Direct transfer of results from lab research to field situations may not be appropriate.

Physical versus chemical weed control

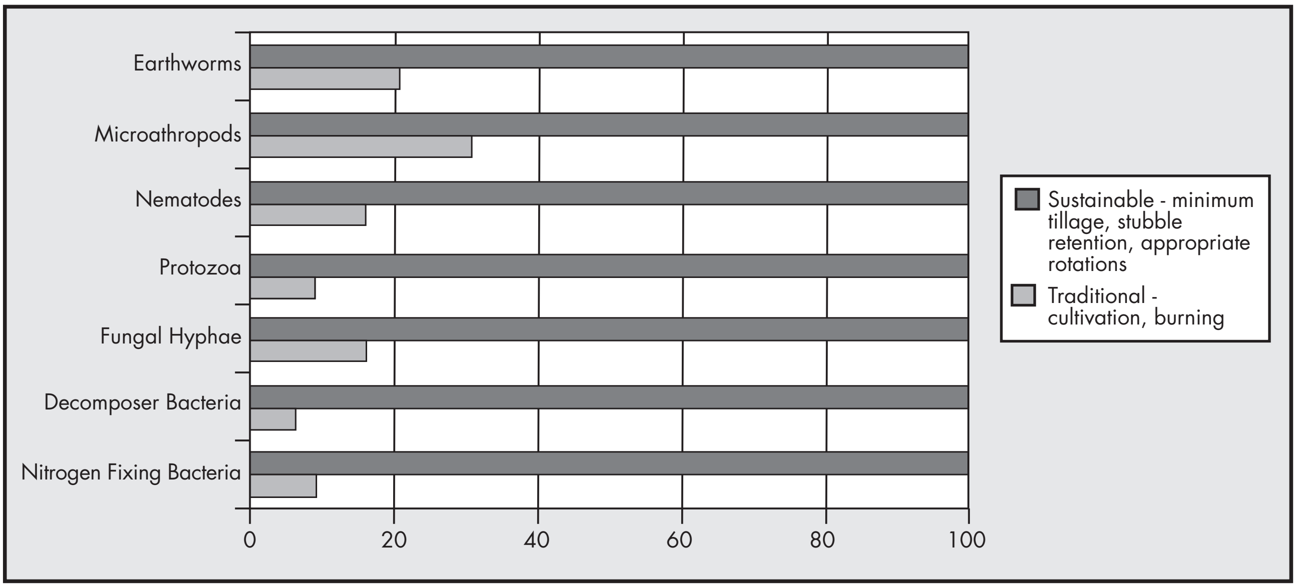
Appropriate use of herbicides could be less destructive to soil biota

The appropriate use of herbicides maybe less destructive to the soil environment and soil organisms than traditional weed control techniques of cultivation and stubble burning, (see graph 1)

For this to hold true the following management practices need to be in place:

- the retention of stubble/organic residues, a major carbon source for soil organisms
- low rates of chemical application
- a ‘recovery period’ for soil biota is allowed between herbicide applications
- repeated application of the same herbicide within a short period is avoided.

Graph 1: Impact of different farming methods on soil biota populations



Are all chemicals OK?

Appropriate chemical use with stubble retention may be better for soil biota than cultivation and burning but it does not mean that it is 'good' for soil biota. In general soil biota may be effected by herbicide applications either directly or indirectly. A direct effect is when the chemical kills the organism or inhibits its activity. Indirect effects include changes in soil temperature and moisture due to removal of weeds, the addition of weed residues with low C:N ratios and changes in the populations of predators and prey.

Details of the impact of some widely used agricultural herbicides are contained in table 3.

In many cases there are no definitive answers and only limited work has been carried out in Australia. Each herbicide needs to be considered separately.

Application of herbicides (such as SUs) should be avoided in situations where the crop is not robust and disease levels in soil are medium, especially in alkaline soils.

Table 3: A summary of findings for a range of chemicals tested in Australia or overseas.

Chemical and Group	General Findings from Australian and International Research
Sulfonylureas (SUs) Group B - Inhibitors of the enzyme acetolactate synthase - ALS inhibitors.	Reduced ability of microorganisms to grow up to six to eight weeks after application (microbial stress). May result in reduced nitrogen mineralisation. May cause increased incidence of plant diseases such as Rhizoctonia and Take-all. Some herbicides also reduce colonisation by mycorrhizal fungi. No information on long term effects.
Triazines Group C - Inhibitors of photosynthesis at photosystem II	Under long term field applications generally no effect on soil biota providing organic matter was continually returned to the soil. Short term effect on soil bacteria especially nitrogen fixers and those involved with nitrogen cycling. May increase the chances of some fungal, viral and nematode induced diseases.

Chemical and Group	General Findings from Australian and International Research
Trifluralin Group D - Inhibitors of Tubulin formation	No indication of long term effects. It has been found to interfere with legume/rhizobia symbiosis. May increase the chances of some fungal, viral and nematode induced diseases.
Hormonal Sprays Group I - Disrupters of plant cell growth	Negative effects have been recorded for nitrogen fixation by rhizobia and reduction in colonisation by mycorrhiza. Long term effects are variable and dependant on soil type and environment.
Paraquat Group L - Inhibitors of photosynthesis at photosystem I	Reduced rate of stubble decomposition when sprayed on to stubble rather than on to the soil containing stubble. Non-symbiotic nitrogen fixing bacteria are inhibited even at very low concentrations.
Glyphosate Group M - Inhibitors of EPSP	No indication of any long term effects. Nitrogen fixation by legumes has been shown to be reduced in some crops. Any negative effects are dependent on soil type.

In recent laboratory and field studies carried out in Australia a range of herbicides where applied as single applications at a range of rates. The following information details the key results.

Short term versus long term impact

Soils with a healthy biota may recover or compensate better from the short-term negative effects due to herbicide application.

The impact of a herbicide on soil biota may be reversible or irreversible. A reversible impact is one where levels of microbial growth are returned to 'normal' over a period of time after a singe application.

The duration of reversible impacts has been found to vary with:

- rate of application
- place of application - soil, stubble or plant
- type of herbicide
- frequency of application.

Results from both field and laboratory research have shown symptoms of microbial stress (reduced new microbial growth) even at recommended rates up to six to eight weeks following the application some herbicides eg. Glean®, Logran® (See table 4). These effects where found to be soil type dependent. For example, in sandy soils with low organic matter and low microbial activity the negative effects of these herbicides were found to be greater.

Table 4: The impact of different chemicals on microbial biomass (MB) and carbon dioxide production (MA)

Positive or no impact	No impact on MB & positive impact on	Negative impact on MA both MA & MB
Fusilade® Roundup®	Ally® Glean® Hoegrass® Logran®	Paraquat® Brodal® Logran® Eclipse®

In similar experiments the herbicides Ally®, Hoegrass® and Paraquat® were applied directly on to soil without any stubble cover at two and five times the recommended rate. Micro organisms were found to be under stress and not functioning properly six weeks after the application. In most situations this low level of functioning continued up to nine weeks.

However when the chemical was applied directly to the soil or to growing plants the stress time for soil organisms was reduced.

Multiple application of the same or different herbicides within the six to eight week window is a common practice in broadacre agriculture. The research has shown that it takes six weeks for the microbial activity to return to normal. Consequently multiple applications before the end of the six to eight week recovery period would be expected to reduce soil biota function, especially if organic carbon food sources were also limited.

Stubble is home to 60% of the biota population therefore, applications to stubble will impact on a large proportion of the soil population.

The duration of this reduced biota function may be less significant than the timing. The majority of herbicides in broadacre cropping are applied around seeding. At germination the plant is at its most vulnerable as the root system is still developing. Reduction in biota functions such as nutrient release and disease suppression may reduce the early vigour of a crop or leave it more susceptible to root diseases. Application of another herbicide prior to the biota recovering from the first herbicide may accentuate the undesirable effects. More research work is needed in this area.

A recovery period of six to eight weeks should be allowed between applications of herbicides.

Impact on functions

Disease Transmission

Some herbicides were found to alter the balance between bacteria and fungi populations near the plant litter. For example, some SU herbicides and Hoegrass® increased the proportion of fungi near litter. This could result in the growth of opportunistic pathogenic organisms near the stubble increasing the chance of root diseases development.

Organic Matter Breakdown

Application of Ally® and Hoegrass® at twice the recommended rate reduced the ability of bacterial populations to use some of carbon substrates available from decomposing residues and near the growing root. This could result in a slower rate of stubble breakdown and associated nutrient mineralisation. Table 5 illustrates the significant reduction in cellulytic bacteria and fungi after herbicides have been applied.

Table 5: The number and percentage of microorganisms which can breakdown cellulose (a major part of straw) found near wheat straw after the application of herbicides.

	Bacteria		Fungi	
	population/g stubble	% remaining of control	population/g stubble	% remaining of control
Control	389000	100%	335000	100%
Ally®	3640	0.9%	6510	2%
Hoegrass®	38900	10%	313	0.09%

This work suggests Ally® is harder on bacteria and Hoegrass® is more detrimental to fungi.

Avoid application of herbicides to legumes that may have negative effects on symbiotic nitrogen fixation

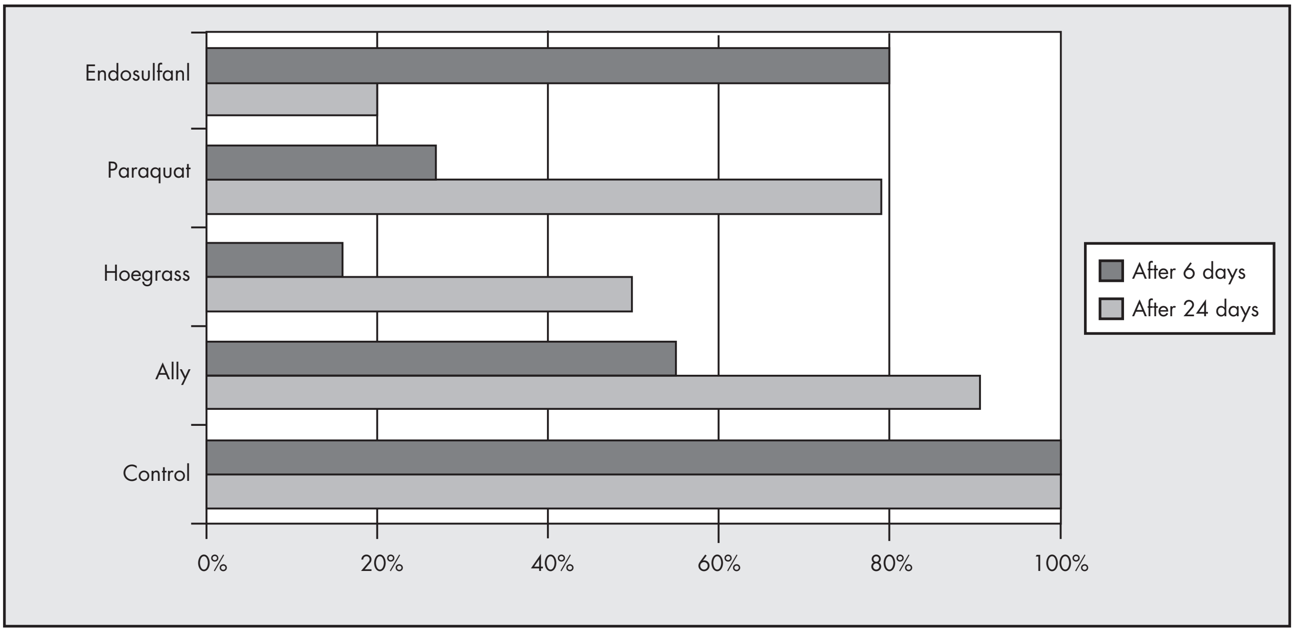
Nutrient Cycling

Other work has shown that the nitrifying bacteria, responsible for the transformation of ammonia nitrogen to plant available nitrate, are the most susceptible to herbicide applications.

Modified applications of fertilizer N may be appropriate to compensate for reduced N mineralisation during the first six to eight weeks following herbicide application.

Herbicide effect on mycorrhizal colonisation is two folded. Firstly herbicide effect the mycorrhizal fungi it self and secondly herbicides reduce root growth affecting the available root length for mycorrhizal colonisation.

Graph 2: Changes in levels of mineral nitrogen after application of a chemical to the soil.



Results are shown as a percentage of the mineral nitrogen available under the control. The larger percentage suggests high levels of mineralisation by soil organisms.

Pesticides as food

Microorganisms feed on simple carbon compounds and agrochemicals, therefore all pesticides, to a lesser or greater extent, can be used as a food source by the soil biota. Different chemicals will be used by different microbes, therefore populations of appropriate microbes must be present if the pesticide is to be degraded by microbes

It may take time for the populations of appropriate microbes to build-up. During this period these pesticides may harm other soil organisms and temporarily or permanently alter the balance of biota populations present in the soil.

Sulfonylureas have been found to persistent longer in alkaline soils. However, it is coming to light that in some alkaline soils sulfonylurea residues are becoming less of a problem. This is thought to be due to an increase in the number of organisms which breakdown these chemicals in an alkaline environment. Management practices that could lead to the build-up of these microbes are as yet unknown.

Microbial degradation of herbicides is an important method of breakdown. As the majority of microbes in southern Australian soils are located in the top 10 cm soil, movement of herbicides beyond this zone may result in long-term persistence of herbicides.