Detection of plant-damaging herbicide residue in soil

By Prof Charlie Reinhardt

Crop damage due to the plant-damaging (phytotoxic) effects of herbicides is often confused with crop injury or growth limitation caused by various other factors, such as extreme climate conditions, pest infestations, soil properties, and/or poor farming practices. Such confusion is to be expected in semi-natural settings, such as field crop production, and often results in herbicides being wrongly implicated in crop damage. By the same token, damage caused by herbicides can go undetected or be ascribed to various other factors.

Damage to crop plants can occur as a result of freshly applied herbicide. Most cases of herbicide damage can be linked to direct injurious effects on the crop when unregistered products or mixtures of products are involved or, less likely, when registered products do not show sufficient selectivity in herbicidal effect, i.e. killing both weeds and the crop. However, herbicides could also have an indirect impact on crop plants long after application.

Damage due to herbicide residue

A somewhat surreptitious form of indirect crop damage caused by herbicides can occur when bioactive or phytotoxic herbicide residues are 'carried over' in the soil from the season in which it was applied to the next season/s, where it can cause injury to or even kill susceptible crops. Herbicide carryover is particularly difficult to diagnose, mainly due to the lapse in time since product application and the consequent relatively low concentration of residue which, in turn, can result in indistinct manifestation of symptoms of damage on affected plants.

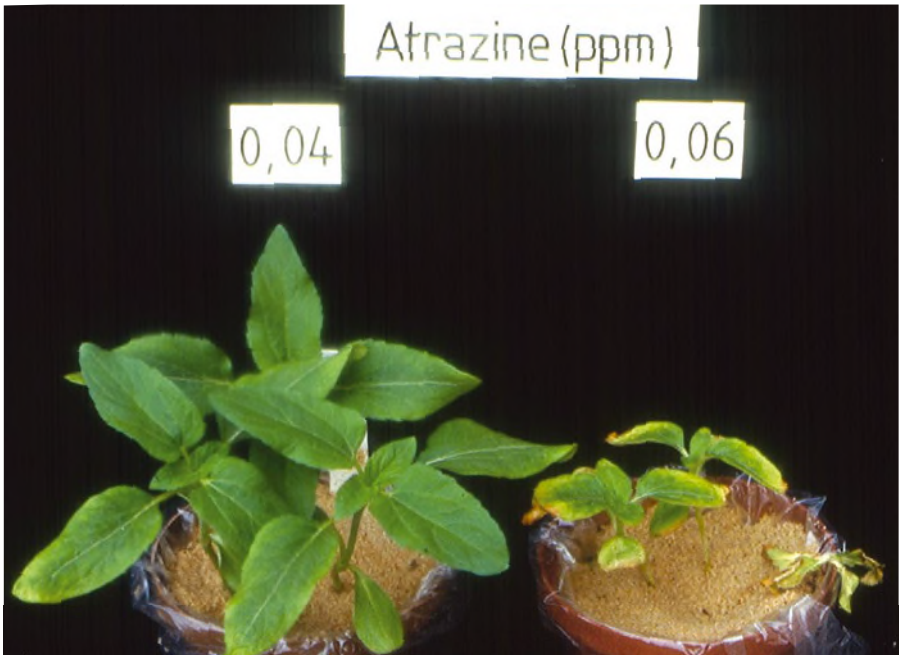
Herbicide carryover damage to crops used to be less of a problem when monocropping was in vogue because replanting the same crop and using the same herbicide in successive seasons, presented zero risks for crop damage.

Since the advent of crop rotation, cases of damage caused by herbicide residue to susceptible follow-up crops have been reported from time to time. Before dosage rates of triazine-type herbicides such as atrazine were capped at a maximum of 1kg active ingredient per hectare for use in maize in South Africa, high dosage rates (2kg active ingredient per hectare) and high use frequency of atrazine resulted in a high carryover risk of this herbicide to the following growing season and, consequently, a high risk for occasional damage to atrazine-susceptible crops such as soya beans, sunflowers and groundnuts.

Due to the low concentrations involved, the effects of herbicide residue in soil are not always obvious. Symptoms of plant damage that are described in literature as being typical of specific herbicides usually portray the effects of relatively high herbicide concentrations or dosages, and those symptoms often differ from symptoms caused by low (residual) concentrations of the same herbicide.

Herbicide persistence

Not all herbicides have the same capacity for extensive persistence in soil. Most soil-applied herbicides generally have some persistence. Some lose their bioactivity in a few days, whereas others only become inactive after several weeks or months have passed.



Sunflower seedlings showing typical symptoms caused by a triazine herbicide. In this bioassay experiment, atrazine concentrations represent those which could conceivably be encountered in soil to be planted to sunflower that follows on maize in which atrazine was used. Note that only the use of a control treatment makes such findings conclusive as various other stress factors can cause similar symptoms.

Soya bean plants showing severe damage ascribed to a particular herbicide. For such a diagnosis to be valid there must be compelling evidence to discount the role of other factors that cause lookalike symptoms, e.g. other herbicides or nutrient deficiency.

Factors such as the type of herbicide, environmental conditions, applied dosage and crop type, individually or in combination, determine how long a particular herbicide will persist and remain bioactive in soil. Thus, correct diagnosis of herbicide carryover damage on crop plants is complicated and best left to experts in the field.

Residue detection methods

In order to mitigate the risk for herbicide carryover in crop rotation systems, labels of herbicide products containing active ingredients, which have the propensity for carryover in soil, carry warnings in the form of specified waiting or crop-withholding periods in respect of susceptible crops. However, due to natural elements the rate of residue inactivation in soil is highly variable and hence, specified crop-withholding periods may fail to protect the next crop against damage from carried over herbicide residue.

Detection of herbicide residue present in soil, water or plants is generally done through laboratory or chemical analysis. Such analyses typically target the original molecule in its unaltered form for purposes of residue identification and, consequently, risk assessment.

By-products of original molecules that retain some level of bioactivity are generally ignored in standard laboratory analysis. Chemical analysis in the laboratory quantifies the total amount of residue present in a sample but does not reveal the response of susceptible plants to that residue concentration. Therefore, it is near impossible to directly link the residue concentration to plant response, unless research findings exist for growth responses of the same plant to that same residue type and concentration in the particular medium (e.g. plant, soil or water).

The most sensible approach in risk assessment is to integrate the results of laboratory or chemical analysis with that of the bioassay technique.

The bioassay technique

This technique is used specifically for experiments aimed at identifying pesticide concentrations that either affect or have little or no effect on growth and development of the organism under investigation.

Organism response to a pesticide is usually measured as a growth response (e.g. biomass accumulated over the trial period) to a range of pesticide concentrations established in a dose-response experiment. A control treatment (i.e. zero pesticide applied) is included in bioassay experiments for determining the effects (relative to the control) of different concentrations of a pesticide in the so-called dose-response bioassay approach. In this way growth-inhibiting effects, and even growth-stimulating effects, can be revealed for different concentrations of the herbicide under investigation.

The bioassay technique can be adapted to estimate the concentration of a given herbicide, or its bioactive residue, in soil by comparing the growth response of a test or bio-indicator plant on a sample of said soil with its growth response to a range of concentrations of this herbicide in a dose-response experiment that employs the same soil.

In a simplified way, producers can exploit the basic principles of the bioassay technique for assessing whether there is a risk for herbicide-susceptible crops grown in rotation with a crop in which herbicide/s had been applied at an earlier stage in the current season, or in previous planting seasons.

In situations where soil moisture and temperature allow test-planting of the crop well in advance of the actual planting date, a few rows can be planted diagonally across a field and crop development monitored for abnormal growth. Alternatively, because there is seldom time for this approach once the crop season commences, another approach can be to collect representative soil samples long before the planned crop planting period (e.g. sample soil during winter in the case of a summer crop). The sampled soil is placed in pots to conduct a bioassay experiment.

This technique will be most effective if soil sampling is done from different depths of the soil profile, and if the same crop and cultivar that is to be eventually cultivated on the field in question, are used as bio-indicator plant in the bioassay.

For example, when soya bean or sunflower is to be grown in rotation with maize, this technique can be valuable because these crops are highly sensitive to herbicides with potentially long persistence in soil, which are generally used in maize, such as mesotrione and the triazine herbicides, atrazine and terbuthylazine.

A significant drawback for the producer doing this bioassay work with reasonable accuracy is probable lack of suitable facilities for growing plants in pots under controlled conditions. As such, the task may be best left to herbicide experts who have access to controlled-condition facilities such as greenhouses.

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