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Short Communication

Herbicide Exposure to Crops - "*Making a Foe out of a Friend*"

Ramdas Kanissery*

University of Florida – IFAS, Southwest Florida Research and Education Center, USA

***Corresponding Author:** Ramdas Kanissery, University of Florida – IFAS, Southwest Florida Research and Education Center, USA.

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Introduction

Herbicides are a necessary tool in the weed management toolbox for crop production. Most weeds in crops can be controlled by adopting a weed management program that utilizes a combination of herbicides based on their selectivity and compatibility with the crop. This would be more cost-effective than the mechanical and cultural methods currently employed for weed management. Despite their beneficial weed control, herbicides may produce a wide range of adverse effects to both crops and the environment. The adage 'Anything can be toxic - in the wrong place, in the wrong amount, or at the wrong time' holds especially true regarding herbicide use in crops. For instance, although herbicidal products are designed to safely control undesired plants without harming desirable plants, the imprudent use of these products will result in crop injury. Likewise, given that only a small fraction of herbicides reaches the intended target, there is concern over the persistence of herbicides in the environment and the potential impacts of residual herbicides in soil and water.

Herbicide injury in plants: undesirable aftermath of weed control

Crop injury caused by phytotoxic effects of herbicides may occur as a result of drift, volatilization, runoff, tank contamination, or misapplication of a product, either on-site or from herbicides used on adjoining crop production or farmlands. Injury can occur in many forms. Visible symptoms of phytotoxicity include chlorosis, necrosis, and reduced growth or vigor. For example, the hallmark symptom of phytotoxicity due to glyphosate, a post-emergent herbicide commonly used in various crops, is bleaching or whitening at the base of leaflets and growing tips. Delayed symptoms such as reduced yield through flower abortion or reduction in fruit quality may be seen days or weeks after exposure. Also, it is not unusual for herbicide injury to be confused with damage caused by insects, disease, nutrition, or environmental or cultural factors. For instance, leaves of tomato plants exposed to higher doses of glyphosate are characterized by upward curling and browning of leaf edges. This is often confused with a physiological disorder, leaf roll, which is primarily caused by hot weather. Similarly, in many cases, 2,4-D injury closely resembles viral disease symptoms. Most plants are extremely susceptible to the auxin group of herbicides including 2,4-D, a widely-used selective broad-leaf killer. Symptoms of injury can occur with exposure to minuscule concentrations of the herbicide. The most identifiable symptoms of 2,4-D exposure are deformed petioles and downward cupped leaflets. Elongation and twisting of stems and yellowing of veins may be observed. Plants exposed to high doses will develop brown discoloration on the stem.

Herbicides can enter the soil from direct spraying during pre-emergent or post-harvest applications, irrigation runoff or leaching from the dead vegetation, resulting in concentrations varying from a few μg to mg per Kg of soil. There is an array of possible toxicological implications of residual herbicides on the ecosystem, and as a result, a wealth of research has been published on the occurrence, fate, and environmental effects from the use of herbicides in weed control. Persistence and carryover of herbicides applied during the previous season can be another cause of herbicide injury in most crop production systems, especially to sensitive plants such as vegetables. Such herbicide carryover can result in damage to the plants and suppressed growth due to elevated concentration of herbicides in the plant root zone. Moreover, storms and rain events can facilitate the movement of residual herbicides in farms.

Ways to reduce herbicide exposure: prevention is better than cure

As far as herbicide exposure to crops is concerned, prevention is always better than remediating adverse outcomes. The best way to avoid herbicide injury is to prevent the 'drift' or 'off-target' movement to an unintentional crop area from the application site.

Several weather factors like relative humidity, temperature, wind direction, and wind speed will influence the intensity of herbicide movement into non-targeted areas. For instance, herbicide application during hot weather with low relative humidity and high winds will increase the chance of herbicide volatilization and drifting. Additionally, the potential for spray drift is dependent on the spray droplet size. The common rule of thumb is that as spray particle size decreases, potential for drift increases. Figure 1 depicts the 'flight time' of various sized herbicide droplets in air. The more time the droplets spend in air, there is increasing opportunity for drifting onto non-target areas. Consequently, conditions that produce relatively larger spray droplets will reduce the drift hazard. One fact to keep in mind is that, although large sized droplets decrease the likelihood of spray drift, they can potentially hinder a uniform spray coverage. Hence, an ideal balance is required in the nozzle and spray particle size selections in order to achieve effective spray coverage while minimizing the risks of herbicide drifting.

Figure 1: 'Flight time' of herbicide droplets in air, shown as the time required by the herbicide spray droplets to fall from a height of 10 feet. (Adapted from Dexter 1993, North Dakota State University Agriculture and University Extension).

Soil analysis for residual herbicides and herbicide bioassays are useful to detect whether the affected soils contain herbicide residues well below injury threshold to crop plants. Herbicide bioassay is a technique that utilizes indicator plants to test whether an herbicide is present in soils at concentrations high enough to inhibit plant germination and alter plant growth.

Herbicide injury: Can crops be rescued?

Herbicide injury is difficult to predict and, in most cases, cannot be reversed. However, if the symptoms are not severe, the plant will most likely recover in due course of time. Plants' ability to recover from spray injury metabolically depends on the intensity of exposure and stage of growth. Furthermore, depending on the duration of the metabolic stress, this could adversely affect the yield of the crops. Herbicide injury to plants will not only result in a growth setback but also yield loss and fruit deformations. For example, drift from glyphosate and 2,4-D have been found to cause distorted fruit (often termed as 'cat-facing') to develop in tomatoes at sub-lethal rates of exposure. Fruit deformation in vegetables is a result of physiological stress that encumbers normal fruit development (Figure 2). Scarce information exists on the cause of such fruit deformation, but exposure to herbicides during early growth stages has been considered one of the primary factors. Other reasons for such fruit deformations include low temperatures during fruit set period, nutrient (e.g., calcium) imbalance in the soil, etc.

Figure 2: Tomato fruit deformation ('cat-facing') from exposure to sub-lethal doses of herbicides.

There is a growing awareness that herbicide injury can be minimized if crop nutrition is adequate. For instance, herbicide-induced injury and stress in many row crops have been found to be reversible by with foliar application of nutrients such as nitrogen, potassium, phosphorus, manganese, zinc, and boron. Similarly, recovery from herbicide injury through application of copper and zinc in vegetable crops has also been reported. Evaluating the utility of such nutrient applications for their potential rescue effects in crops exposed to herbicides are important future steps in crop production research.

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