CHAPTER THIRTY

Pesticide Phytotoxicity

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Nursery managers have traditionally used a number of chemical pesticides to help manage pest populations in forest nurseries. Nursery pesticides can be separated into two classes: nonselective pesticides, which are toxic to all organisms, and selective pesticides, which are applied to control a specific pest organism but are not intended to injure nontarget organisms (the crop seedlings or beneficial organisms).

Most nonselective pesticides are used only in areas that do not currently contain seedlings. Many nurseries use soil fumigants to reduce fungal and weed seed populations before sowing. Nonselective herbicides are often used to control weeds that develop in noncrop areas such as irrigation lines and road ditches. Some nurseries apply nonselective pesticides between rows of seedlings, using specially designed sprayers that shield the crop trees.

Figure 30-1. Pesticide damage on a white pine progeny trial. Susceptibility was related to seed source.

> Pesticide phytotoxicity may be confused with:
> Frost damage
> Lygus bug damage
> Mineral nutrient problems
> Salt injury

Selective pesticides can be applied directly to the seedling crop. Fungicides and insecticides are selective pesticides that rarely injure the crop seedlings unless they are improperly applied. A relatively few selective herbicides are currently being used in forest nurseries. All nursery pesticides have been carefully screened for phytotoxicity before they are registered for use on tree seedlings, but pesticide injury still occurs. Most phytotoxicity incidents can be attributed to improper application of selective pesticides, drift of nonselective pesticides, or residual pesticides in soil.

Improper application of selective pesticides. Instructions for the proper use of a pesticide are listed on its label. Pesticide chemicals should be applied only by trained personnel; some registered pesticides can be purchased only by certified applicators. In spite of these familiar instructions, cases of phytotoxicity can usually be traced to some type of applicator error. Failure to completely read and follow label instructions and failure to correctly calculate pesticide dilutions or application rates are common mistakes. Pesticide equipment must be properly calibrated, regularly checked, and cleaned between applications. Applying pesticides during unfavorable weather conditions, such as hot or windy weather, can also lead to phytotoxicity problems.

Drift of nonselective pesticides. Fumigants and other nonselective chemicals may drift from treated areas and damage adjacent crop seedlings. The amount of drift depends on the characteristics of the pesticide, the application method, and local weather conditions. Because all fumigants convert to a gas in the soil, the treated area is usually covered with a plastic tarp or the soil surface is sealed with water. During temperature inversions, fumigants can drift and become concentrated in low areas of the nursery. Even liquid sprays can drift if a volatile ester formulation is used or if the pesticide is applied with a fine spray nozzle.

Residual pesticides in soil. Soil sterilants are designed to provide an extended period of weed control and therefore can persist in the soil for many years. Because of this residual action, sterilants can cause phytotoxicity when treated land is subsequently converted to a seedling crop. Some herbicides that are safe for one crop may persist in the soil and harm subsequent crops. Fumigants applied to cold, wet soil may also persist longer than usual and cause phytotoxicity after the normal waiting period.

Occurrence: species and season

All seedling species and stock types are susceptible to pesticide phytotoxicity, although some species are more tolerant than others. In an Oregon nursery, the herbicide DCPA produced stem swelling and stunting of Douglas-fir and true fir seedlings, but did not affect five different species of pines. Western larch has been shown to be highly susceptible to phytotoxicity from many of the pesticides used in forest nurseries.

There is evidently genetic variation in susceptibility to pesticide phytotoxicity. Pesticide damage was definitely related to seed source when a fumigant inadvertently drifted into a white pine progeny trial; the severity of injury was clearly related to the genetic origin of the seedlings (Figure 30-1). Phytotoxicity symptoms have been reported to vary considerably between different seedlots of Douglas-fir and true fir seedlings.

The occurrence and relative severity of phytotoxicity damage is also related to the developmental stage of the seedlings. Young germinants or actively elongating shoots are much more sensitive than hardened or dormant stock. Some selective herbicides, such as oxyfluorfen, have caused needle twisting when applied to actively growing shoots, whereas applications only a few weeks later in the growing season were safe.

Symptoms

Pesticide phytotoxicity and other types of chemical injury, including damage from air pollution and fertilizers, can often be distinguished from biological pest problems by the pattern and timing of symptom development. Pesticide damage symptoms occur all at once and often have a regular distribution in the seedbed, whereas symptoms caused by pathogens usually develop over an extended period of time and occur in random or grouped patterns.

Pesticide phytotoxicity can be expressed by a number of different foliar symptoms, including discoloration, needle tip burn, and needle twisting (Figure 30-2), as well as swelling of the stem (Figure 30-3), and stunting and mortality of seedlings (Figure 30-4).

B

C

Figure 30-2. Foliar symptoms due to pesticide phytotoxicity: (A) foliar discoloration and distortion, (B) needle tip burn, (C) needle twisting.

Phytotoxicity symptoms are similar for many different pesticides, although some chemicals produce unique symptoms that have particular diagnostic value. Herbicides with hormone-type actions produce easily identifiable symptoms, such as the leaf cupping and needle twisting that results from drift of the extremely volatile 2,4-D. Simazine and atrazine produce chlorosis between the veins and on the margins of hardwood leaves, and needle tipburn in conifers. Amitrole destroys chlorophyll, so that affected foliage is whitish or even pinkish in color.

Several herbicides have been reported to arrest seedling root development, often resulting in abrupt cessation of root growth at a uniform depth in the soil (Figure 30-5). The herbicide napropamide snubbed off the roots of western larch about 1 inch below the ground line, and most symptomatic seedlings eventually died.

Predisposing factors

Weather events often predispose seedlings to pesticide phytotoxicity. With nonselective pesticides, temperature inversion may trap fumigant gases near the ground, causing them to accumulate in low areas. Soil fumigants should be applied only when temperatures are warm enough that the vapor can completely disperse within the recommended period after application. Heavy rainfall can cause surface runoff of water-soluble nonselective pesticides into crop areas.

Pesticide phytotoxicity appears:
All ages
Any time after application

Even normally safe selective herbicides can cause injury under predisposing weather conditions. Sprays and soil drenches should not be applied when the soil is extremely dry and the seedlings are under moisture stress. The fungicide captan has caused stem damage and even mortality to young, succulent seedlings when applied under hot, dry conditions. On the other hand, cool weather after application is reported to increase the incidence of DCPA phytotoxicity.

Loss potential

Losses caused by pesticide phytotoxicity can range from imperceptible reductions in growth to mortality of seedlings. The exact amount of loss varies considerably; it depends on weather conditions, the susceptibility of the crop, and the size of the affected area. As an example, DCPA phytotoxicity affected 50 to 80 percent of the Douglas-fir and true fir seedlings in an Oregon nursery. At an Idaho nursery, mortality from napropamide phytotoxicity caused a 50-percent reduction in seedbed density of western larch, and the associated stunting reduced the number of shippable seedlings by almost 90 percent. Minor growth losses are difficult to assess, but damaged foliage can cause seedlings to be culled on the grading table.

Management

Prevention is the only management option for controlling phytotoxicity losses. Nursery managers should consider the following measures:

1. **Train pesticide applicators.** Pesticide applicators are required by state law to attend regular training sessions. Nursery managers should ensure that all employees who handle pesticides become certified. In-house pesticide training should also be regularly scheduled so that applicators can be informed of local weather conditions and trained in proper calibration and use of the nursery's specific application equipment.

2. **Keep accurate pesticide application records.** Pesticide applicators should be required to fill out predesigned application forms that ensure that the same relevant information is always recorded. This information should include date, pesticide used, area treated, prescribed application rate, actual application rate, and weather and soil conditions. In case suspicious symptoms show up, these application records can be checked to see if phytotoxicity could be the cause. The exercise of calculating the actual pesticide application rate each time also serves as a cross-check of whether the application equipment is operating properly.

Figure 30-3. Abnormal swelling of the stem due to pesticide phytotoxicity.

Figure 30-4. Mortality and stunting caused by a residual soil herbicide.

3. **Monitor weather conditions before and during pesti-**

cide applications. Nursery managers should check nursery weather stations and consult local forecasts before applying pesticides. Critical operations, such as seedbed fumigation, should never be attempted if marginal weather conditions exist or are forecast. The early morning is usually the best time to apply liquid sprays because winds are minimal and temperatures near the soil surface are low.

4. **Leave control plots.** Phytotoxicity can be very difficult to diagnose because similar symptoms can be caused by other factors. Growth losses due to phytotoxicity are almost impossible to identify. Nurseries, therefore, should establish a policy requiring that untreated control plots be established each time a pesticide is applied. These plots should be clearly marked and regularly checked during the growing season so that slow-to-develop symptoms can be identified. Control plots can also be used to illustrate the effectiveness of a specific pesticide treatment, documenting differences in seedling growth or yield. These data are essential for calculating cost-benefit ratios when determining the economics of pesticide use.

5. **Conduct nursery-specific phytotoxicity trials.** Because soil type, local climate, and seedling genotypes differ among nurseries, each nursery should test new pesticides before beginning large-scale operational use. Many phytotoxicity incidents could have been prevented if the nursery had first tested the pesticide under its own unique conditions.

6. **Isolate pesticide-sensitive species.** Species that are especially susceptible to chemical injury—western larch, for example—should be planted in sections of the nursery that are isolated from production areas where pesticides will routinely be used.

7. **Test the soil for persistent pesticides in newly developed seedbeds.** If pesticide contamination or residues are suspected, a sample of the soil can be enclosed in a glass jar and sown with seeds of a fast-growing plant, such as radish or lettuce. If the seeds fail to germinate or if the germinants exhibit abnormal growth, additional tests or corrective treatments are warranted. If the soil was recently fumigated, allow more time for the fumigant to escape. In the case of persistent nonselective pesticides, treating the soil with activated charcoal may be effective.

Selected references

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Figure 30-5. Bean and Douglas-fir showing abnormal root development. The healthy bean plant on the far left shows normal root elongation. Beans, highly sensitive to the herbicide, were sown as an assay to detect residual chemical.