SEEDLING INJURY BY SIMAZINE AND OTHER TRIAZINE HERBICIDES

by

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Abstract

Triazine herbicides have been used successfully for weed control in forest nurseries and plantations of many coniferous and deciduous species. Choice of triazine herbicide depends on several factors including climate, soil, species, and size of stock. Injuries occur when herbicides are misused, site conditions lead to toxic accumulations in soil, or excessive amounts are applied. Avoidance of injury and recognition of symptoms are discussed.

Résumé

Les herbicides à base de triazine ont donné de bons résultats dans les pépinières et plantations forestières de nombreux conifères et feuillus. Le choix de ces herbicides dépend de plusieurs facteurs, y compris du climat, du soil, de l'essence et du nombre d'arbres. Des dommages surviennent si les herbicides sont mal utilisés, lorsque les conditions stationnelles mènent à l'accumulation de matières toxiques dans le sol ou lorsque des quantités excessives sont utilisées. On discute des moyens d'éviter ces dommages et de reonnaître les symptômes.

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Simazine has been widely used in forest nurseries and plantations since its introduction in 1956. When used according to label directions, simazine and other triazine herbicides can be safely applied to control broadleaf weeds and grasses. But despite these benefits, triazine herbicides have often caused injury to conifer seedlings in Maritime forest nurseries and plantations.

Some problems relating to the use of these herbicides are discussed in this paper, visual symptoms of injury are illustrated by color prints, and recommendations are made to avoid injuries.

How triazine herbicides work

In the soil Solubility and adsorption to soil colloids are the keys to the useful selectivities of the triazine herbicides; those of higher solubility, such as atrazine, are useful in arid regions and in heavy soils, whereas those of lower solubility, such as simazine, are useful where rainfall is moderate to heavy and for light soils (Crafts and Robbins 1962).

Differences in soil texture and organic matter affect the movement of triazine herbicides. Because simazine is only slightly soluble and is tightly held (adsorbed) by soil colloids (clay and organic matter), it cannot move freely through the soil. In fact, most of the simazine applied remains in the surface 5 cm of soil (Anon 1983a) where it is effectively kept from the root zone of established seedlings. Heavier application rates are required with increasing content of clay and organic matter in the soil (Ahrens *et al.* 1969; Flanagan and McCormack 1981). Soil organic matter is the most active soil component in reducing the phytotoxicity of triazines (Hayes 1970).

The peristence of simazine and other triazines in soil depends principally on microbial activity, which depends on other factors like temperature, pH, moisture, nutritional status, and texture. For example, the North Carolina Agricultural Extension Service (1977) listed the longevity of phytotoxic effects as 6-12 months for atrazine and simazine, 6-10 months for propazine, and 2-6 months for prometryn. The s-triazine-soil interactions are reviewed in Gunther and Gunther (1970).

In the plant Triazines are usually taken up by roots and translocated upward in the xylem to accumulate in apical meristems and foliage where toxic levels accumulate in sensitive species causing chlorosis (yellowing) and death by inhibiting photosynthesis. Tolerant plants can detoxify these compounds by altering them metabolically, even using them in growth processes (Conner and White 1968; Crafts and Robbins 1962). It is not known if additional growth occurs other than that resulting from removal of weeds, which compete for moisture, light, and nutrients.

Simazine is taken up by roots, not by foliage, and it washes off easily. Consequently, it can be applied at the time of planting dormant seedlings and on established seedlings during summer. Atrazine is more soluble and can be absorbed by foliage, so directed sprays can provide postemergence control of small actively-growing weeds in tolerant crops. Consequently, unlike simazine, atrazine cannot be used freely on conifers, particularly on actively-growing seedlings (see Anon 1983b). The use of other triazine herbicides such as propazine and prometryn also depends on their solubility and adsorption to soil colloids and effects on seedlings.

Problems in the use of triazines

Local experience has shown that triazine tolerance differs by conifer species, stock type, age, and size as reported by Ahrens *et al.* (1969, 1976). For example, balsam fir (*Abies balsamea* L. (Mill.)) is very tolerant to simazine whereas hemlock (*Tsuga canadensis* (L.) Carr.) is quite sensitive to triazines. Large transplants are more tolerant than small seedbed seedlings because the roots of larger seedlings are well below the surface soil where most of the simazine is held.

From studies at the University of Wisconsin, (Kozlowski and Kuntz 1963; Kozlowski and Torrie 1965; Saski *et al.* 1968), preemergence and early postemergence sprays of atrazine, simazine, prometryn, and propazine did not affect germination, but caused severe injury to developing seedlings (Fig. 1). Delaying applications of simazine, prometryn, or propazine resulted in more and heavier seedlings. Incorporation into the soil was injurious. They (Ibid.) ranked toxicity of the triazines from highest to least: atrazine, simazine, prometryn, and propazine.

Prometryn and propazine Prometryn has foliage activity, propazine doesn't, but prometryn is adsorbed on soil colloids to a greater extent than most commercial triazines (Anon 1983a), particularly on organic matter (Harris 1966). For these reasons prometryn can injury conifer seedlings if applied too soon after emergence, yet prometryn is safer than propazine for application at the time of seeding (van den Driessche and Balderston 1974).

In British Columbia, van den Driessche and Balderston (1974) selected prometryn as a preemergence herbicide, and propazine for application over 6-to 8-week-old seedlings when roots were 5-8 cm. In New Brunswick, we found that propazine should not be used until white spruce (*Picea glauca* (Moench) Voss) and black spruce (*Picea marianna* (Mill.) B.S.P.) seedlings are well established, but it can be safely applied to red pine (*Pinus resinosa* Ait.) and jack pine (*Pinus banksiana* Lamb.) at the time of sowing. Ahrens and Cubanski (1981) reported that DCPA (dacthal) plus prometryn was applied a few weeks after crop emergence as standard treatment in a Connecticut nursery.

Simazine **Most weed specialists do not recommend use of simazine on seedbeds** (Kuhns 1982; Anon 1983c) because lethal or sublethal residues can result in growth reductions or loss of seedlings in subsequent rotations. Although simazine can be safely applied in the fall at the end of the first growing season and thereafter, it should not be used in 2 + 0 production schedules. In 3 + 0 schedules, it should not be used for at least one full year before seeding the next crop. It is preferable for control of annual grasses to use alternate herbicides such as pronamide (Kerb®) in the fall (Hallett and Burns 1979), and DCPA combined with low rates of prometryn or propazine.

Simazine has been used extensively in balsam fir Christmas tree plantations and is often applied at higher rates than for other species. Injury can occur (Fig. 2). Ahrens (pers. comm. 1983) pointed out that simazine injuries in plantations often are due to attempts to control perennial weeds which would be better controlled by another herbicide (or combined with simazine).

Atrazine **Atrazine is not suitable for seedbed use** (Kuhns 1982; Anon 1983c) and its use is cautioned in the plantation guide for the Northeastern United States (Anon. 1983b). Atrazine residues at one nursery resulted in injury to several conifer species even though that herbicide had been used several years earlier when the field was used for production of corn (*Zea mays* L.) (Fig. 3).

In plantations, atrazine cannot be applied over actively-growing stock because it is soluble and easily leached to root zones. Several instances of injuries to balsam fir were noted during 1982 where atrazine had been applied to actively-growing stock in nurseries and plantations. As soon as green starts to show at the tips of buds, application of atrazine will cause problems (M.L. McCormack pers. comm.; Fig. 4).

Ahrens (pers. comm. 1983) stated that atrazine tolerance during active growth in field plantings (2 + 2 or older stock) varies greatly with dosage. He said that 2.2 - 3.3 kg a.i./ha atrazine in combination with simazine rarely causes damage even during active growth, except on the lightest soils. However, since atrazine is more effective on perennial grasses than simazine, once these grasses are under control there is little advantage to using atrazine rather than simazine alone.

Other factors If seedlings are frost heaved, their roots are brought into the shallow zone of surface soil containing simazine and new root growth can take up toxic amounts of the herbicide (Fig. 5). Therefore, spring application of simazine is unsuitable for nursery or plantation stock which heaved over winter.

White grubs may be a serious problem and cause extensive mortality where sods or weeds are killed with triazines and the grubs have only the tree roots to consume (J.F. Ahrens pers. comm. 1983).

Excessive erosion downhill or into depressions can result in toxic accumulations of simazine (Fig. 6). If applied too soon after transplanting in nursery beds, soil containing simazine may be washed into planting furrows or slits. Lower rates should be applied on sandy soils (Fig. 7).

Excessive dosages frequently result from purposeful application, improper calibration of equipment, failure to use check valves in nozzles, or miscalculation of quantity and rates applied (Fig. 8,9). Application causes problems where equipment has been slowed by ditches, headlands, or poor traction (Fig. 10).

One herbicide will not control all weed species at safe rates for conifers. For example, vetch (*Vicia eracca* L.) and field horsetail (*Equisetum arvense* L.) are not controlled by simazine (Figs. 8,11). **Combining herbicides provides broader control and safer rates of the individual herbicides can be used.** To test the effectiveness of a herbicide treatment, both for weed control and effects on trees, check plots can be used (Figs. 12, 13).

Further problems result when triazines are mixed inappropriately with other herbicides or fertilizers (Fig. 14). This has occurred in both nurseries and plantations in the Maritimes. Much damage occurs when treatments are made on actively growing stock, particularly when seedlings are under stress of heat, drought, or forced by excessive fertilizer. Directed sprays must be used if any material in the mix can be absorbed by foliage. There is evidence that highly limed soils can increase the activity and potential phytotoxicity of the triazines (DeVries 1963).

When spray mix combinations contain surfactants intentionally or otherwise, simazine can be absorbed by foliage, resulting in injury. In fact, surfactants can be used with simazine applications in late spring to speed kill (M.L. McCormack pers. comm. 1983). Ahrens (pers. comm. 1983) knew of only two instances of direct foliage effects on actively-growing conifers from use of simazine: both involved the use of emulsifiable oils.

Recognition of injuries

Visual symptoms Many useful publications deal with the principles of herbicide use (Swan 1978) and the diagnosis of herbicide injuries (Lockerman *et al.* 1978; North Carolina Agricultural Extension Service 1977). Unfortunately, no practical mention of reforestation species is given.

Injury may develop slowly or rapidly when too much triazine herbicide has been applied. Usually chlorosis of needles occurs before needle browning or seedling mortality. If a triazine herbicide is applied at a toxic rate at the time of seeding or if a crop is sown in soil with residues from a previous application, seed may germinate and begin to grow but will die slowly during the summer. Applications over actively-growing or small seedlings may kill. Injury to conifer seedlings in Maritime nurseries and plantations is outlined in Tables 1, 2, and 3. The tables are supplemented, in part, by color illustrations. **Not everything is simazine injury.** In Table 2 there are several look alike symptoms such as below ground injury by soil conditions (Fig. 15) or root injury, or above-ground injury such as foliage feeding by mites (Fig. 16).

Residues Aldhous (1966) reported investigations of simazine residues from use in British forest nurseries and concluded that residues should not be a problem when herbicides are applied at recommended rates. **A bioassay is an effective way to determine the presence of toxic residues** (the growing of a susceptible species in the field or in soil samples). Oats (*Avena* sp.) are very susceptible to triazine herbicides - that is often evident when oats or other grains are used for cover crops following a rotation in the nursery (Fig. 17). Oat seedlings quickly show chlorosis, browning, and mortality if toxic residues are present.

In an investigation of simazine residues in an old-field plantation, Flanagan and McCormack (1981) found that most of the simazine was gone after three seasons although weed suppression and beneficial tree responses lasted four seasons. In a nursery study, Anderson (1970) found that 85% of the simazine and 90% of the propazine was gone six months after application.

Where toxic residues exist, activated charcoal can be added to the soil before seeding or transplanting, or used as a seedling root dip before planting (Kuhns 1982). Organic amendments will also reduce the toxicity of herbicide residues.

Recommendations for use of triazines

To avoid injuries to conifers the following precautions are suggested

- **Follow label directions.**

- **Consider obvious factors** such as frost heaving, erosion, or state of growth.

- **Do not use simazine on seedbeds.** Instead, use alternate herbicides such as pronamide (Kerb®) in the fall, and other soil active herbicides during the growing season.

- **Use conservative application rates,** which can be followed by a booster application, rather than maximum doses.

- **Use conservative rates of two herbicides** rather than maximum single dose of one chemical to provide broad spectrum weed control.

- **Do not use atrazine in nurseries.** Use only in plantations under closely controlled conditions.

- **Equipment must be properly calibrated and applications monitored.** Avoid nasty suprises because of improper calibration of equipment, worn-out nozzles, speed changes on hills or under conditions where traction is poor.

- **Use check valves** to prevent the boom from draining when the sprayer stops; thus prevent overdosing in spots.

- **Use check plots** in any situation. Monitoring will indicate whether the herbicide is doing the job and if growth is better or poorer because of treatment.

- **Use bioassays to test for harmful residues** in the soil if you are unsure. Oats are very sensitive to triazines so are an effective bioassay when sown in plots on the field in question, or in pots filled with soil from the field.

- **Where toxic residues exist, apply activated charcoal** to the soil before seeding or transplanting; organic amendments also help.

- **Be forewarned of potential damage by enhanced uptake** when triazines are

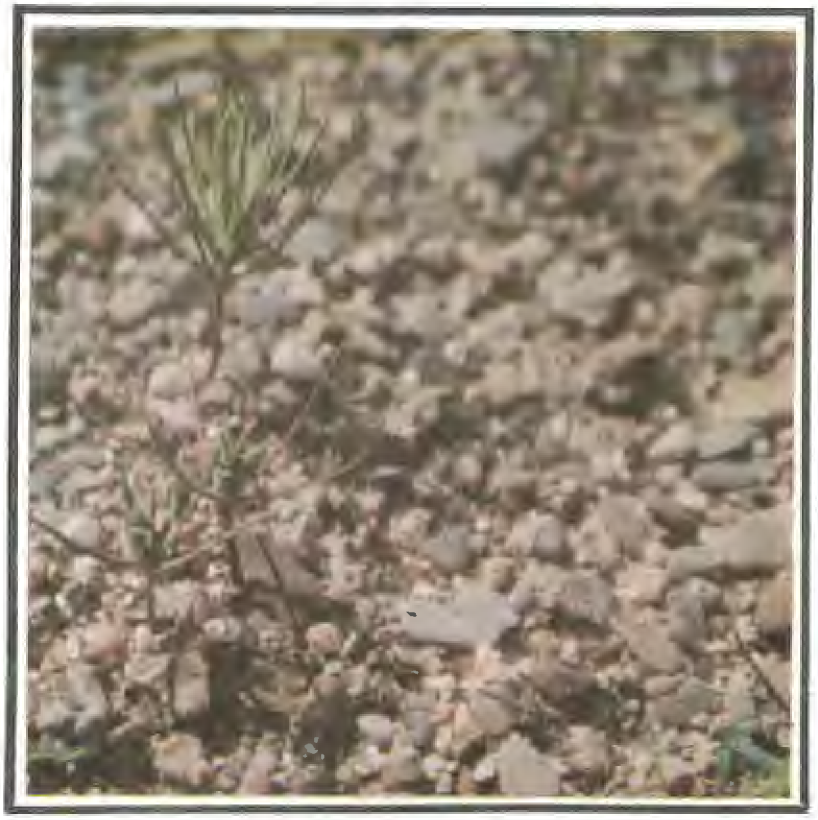

Fig. 1. Jack pine 1 + 0 seedlings injured by propazine applied at the time of sowing.

Fig. 2. Balsam fir plantation seedling injured by uptake of simazine.

Fig. 3. Red pine 2 + 0 seedlings injured by atrazine residues from previous application to corn.

Fig. 4. Balsam fir plantation seedlings injured by spring application of atrazine after bud activity had started.

Fig. 5. Black spruce 2 + 0 injured following spring application of simazine over frost-heaved stock.

Fig. 6. Black spruce 2 + 2 transplants injured by excessive simazine eroded into depressions.

Fig. 7. Spruce plantation seedling injured by application of simazine on sandy soil.

Fig. 8. Balsam fir 2 + 1 injured by normal rate of simazine applied by an uncalibrated sprayer during a very hot season.

Fig. 9. White spruce G + 1 seedlings injured by excessive application of simazine and DCPA to actively-growing greenhouse stock.

Fig. 10. Typical end-of-field or start-up spot damaged by excessive application of a herbicide when the tractor was slowed.

Fig. 11. Balsam fir seedlings 2 + 1 injured by application of simazine while field horsetail or vetch escaped control.

Fig. 12. Check plot in black spruce 2 + 0 seedbeds illustrating reduced growth from use of a herbicide.

Fig. 13. A check plot in white spruce 2 + 1 transplants illustrating the weed species present in the field and their control by herbicides.

Fig. 14. Red pine 2 + 0 seedlings injured by application of simazine in combination with aminotriazole.

Fig. 15. White spruce 2 + 2 seedlings showing potassium deficiency which may be confused with herbicide injury.

Fig. 16. Foliage from balsam fir plantation seedlings injured by mites.

Fig. 17. Cover crop of oats injured by simazine residues left after rotation.

applied in spray mix combinations containing surfactants or fertilizers.

● **Soil can hide the root of the problem, dig up a few trees**

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Table 1. Injuries to conifer nursery-stock from use of simazine and atrazine where residues in soil or concentrations in foliage were measured[1]

Herbicide and application rate[2] kg/ha	Species and age class	Injury symptoms	Residue ppm		Remarks
			Foliage samples	Soil samples	
Simazine 3.5	Black spruce 2+2	No injury - green seedlings		0.21	Simazine collected in depressions
		Chlorotic older needles		2.84	
Simazine 1.7	White spruce 3+0	No injury - green seedlings		0.12	Tractor slowed at ditch during application
		Chlorotic older needles		1.01	
Simazine 2.3	Red pine 2+1	Curly needles	0.10		Erosion down slope resulted in increasing toxicity and severe injury
		Dead buds	0.12		
		Dead tops	0.51		
Atrazine unknown	Red pine 1+0	Chlorotic needles		0.056	Residues remained from atrazine applied several years earlier to corn crop
		Bronze needles		0.112	
		Mortality		0.136	

[1]Soil analysis conducted at Kentville Agricultural Research Station, N.S. B4N 1J5
Foliage analysis conducted at Provincial Pesticide Residue Testing Lab, Guelph, Ont. N1G 2W1
[2]Application rate in active ingredient per hectare.

Table 2. Injuries to conifer nursery stock from use of various triazine herbicides

Herbicide and application rate[1] kg/ha	Species and age class	Injury symptoms
Simazine 1.7	White spruce 2 + 0	Frost heaved seedlings had chlorotic or dead needles, some mortality
Simazine 3.5	White spruce G + ½	Excessive simazine applied to greenhouse transplants resulted in chlorosis and some mortality
Simazine 3.3	Winter rye cover crop	Erosion of simazine into depression resulted in chlorosis and kill of rye grass
Propazine 1.1	Black and white spruce germinants	Preemergence use of propazine results in loss of germinants and gradual decline of established seedlings. Straw-colored, dry seedlings
Aminotriazole plus simazine[2]	Red pine 2 + 0	Aminotriazole has foliage activity and cannot be used over red pine; in combination with simazine resulted in severe chlorosis and seedling injury

[1]Application rates in active ingredient per hectare.
[2]Rates unknown.

Table 3. Symptoms of injury to conifer seedlings which can occur with normal applications of various triazine herbicides or through inappropriate use

State of growth	Symptom	Similar injury
Germination	Germinants are not usually affected (germination can be increased)	
Establishing seedlings	Cotyledons twisted or curled or die back from the tip	2,4-D injury; fertilizer injury
	Begin to die slowly from top; results in dry, straw-colored condition; roots remain turgid at first	*Fusarium* or *Sirococcus* shoot blights - but these are watery and rot Damping-off causes seedlings to fall over Heat injury
Small seedlings	Needle tips or whole needles yellow, may die and turn brown, portion of shoot dead, shoot may die	Magnesium deficiency, root rots, or heat injury
Larger seedlings, transplants, plantation	Pine needles twist and curl	
	Needle tips or whole needles yellow, may brown	Magnesium or potassium deficiency, mites, root deterioration by root rots, or damage by white grubs feeding on roots.
	New foliage withers and browns	Root rots or fertilizer burn
	Older needles on inner portion of seedling chlorotic	Soil low nutrient content, or drought stress
	Buds fail to develop	*Scleroderris* canker
	Needle banding	Air pollution injury