Dow AgroSciences Garlon® Family of Herbicides

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General Information

The family of Garlon® herbicides is an important part of the Dow AgroSciences portfolio of products. The active ingredient in the family of Garlon herbicides is triclopyr, the common name for 3,5,6-trichloro-2-pyridinyloxyacetic acid. This ingredient is a member of the pyridine carboxylic acid chemical family — a growth regulator family of herbicides. Garlon herbicides are postemergence products that can be applied to the foliage, bark or cut surface of target plants, and triclopyr has little or no impact on grasses.[1] The family of Garlon herbicides has a long history of successful use worldwide; and is registered for use by landowners, foresters, farmers and industrial vegetation managers.

UTILITY ROADSIDE INVASIVE RAILROAD FORESTRY AQUATIC

Products and Characteristics

The family of Garlon herbicides includes these products: Garlon® 4 Ultra specialty herbicide, Garlon 3A specialty herbicide, Forestry Garlon XRT specialty herbicide and Pathfinder® II specialty herbicide.

Garlon 4 Ultra and Garlon 3A are registered for the long-term control of a wide variety of woody plants, broadleaf weeds and vines on forestry sites, noncrop areas, rights-of-way and wildlife openings across the United States.

The active ingredient in Garlon® 4 Ultra specialty herbicide is an ester formulation and has a methylated seed oil solvent, which reduces environmental impact when compared with formulations using petroleum distillates, such as kerosene. This ester formulation is readily soluble in oil for basal applications and contains an emulsifying agent, which allows it to be easily mixed with water for foliar applications. The active ingredient in Garlon 3A is formulated as an essentially nonvolatile amine salt, which is only readily soluble in water for foliar and cut-surface applications.

Forestry Garlon XRT is labeled for use in forested areas and in the establishment and maintenance of wildlife openings. This formulation uses no petroleum distillates, which helps reduce the environmental impact. It contains 6.3 pounds of active ingredient per gallon, leading to less product handling than the previous formulation. Forestry Garlon XRT provides control of woody plants and annual and perennial weeds for forest site preparation or conifer release.

Pathfinder II is a formulation of Garlon 4 Ultra, premixed with a nonpetroleum carrier that is derived from naturally occurring oils. It is a premier ready-to-use product that can be applied to the bark or the cut surface of vines and undesirable trees.

These products offer different label options, pounds of active ingredient in the concentrate and formulation attributes. In addition, Garlon® 4 Ultra specialty herbicide, Forestry Garlon XRT and Pathfinder II are ester formulations while Garlon 3A is an amine formulation.

Many people use amine formulations where there is a concern of volatilization — which can increase in hot weather — around sensitive plants. Ester formulations often display more activity on susceptible vegetation, so a slightly higher rate is often necessary to obtain the same woody plant control with an amine versus and ester.

In the environment and in the plant, both the ester and amine salt formulations of triclopyr convert rapidly to the biologically active acid form. For this reason, active ingredient concentration is commonly expressed as the acid equivalent (ae) in pounds per gallon or grams per liter. The term acid equivalent refers to the part of the formulation that can be converted to the acid, which is what eventually can kill susceptible plants.

Mode of Entry

For a systemic herbicide to work, the active ingredient must be absorbed by the plant and moved to the site(s) of action. Triclopyr is absorbed by the foliage of growing plants and translocated to the meristematic (high growth rate) regions of the plant. Prior to use as foliar treatments, Garlon 3A, Garlon 4 Ultra and Forestry Garlon® XRT specialty herbicides are usually diluted with water to facilitate coverage. In most cases, the label rate of spray solution is approximately 98 percent water.

The rate of absorption of the active ingredient into the leaf (or other plant tissues) varies with the formulation. The ester form moves through the waxy leaf cuticle more efficiently than the amine form, allowing slightly larger concentrations to be absorbed. Two rain-free hours are needed for adequate uptake of the amine formulation; one hour is needed for the ester formulation. Foliar applications generally achieve maximum efficacy when applied after full leaf expansion, before foliage begins to color in the fall, and when growing conditions are good.

Triclopyr also can be absorbed through cut stems, stumps and tree trunks. Garlon 4 Ultra and Garlon 3A are labeled for cut-stump, and hack-and-squirt applications. Garlon 3A is still diluted with water for these applications. Only the ester formulations are absorbed through bark in basal bark or dormant-stem applications. Garlon 4 Ultra can be mixed with an oil-based carrier for basal bark or dormant-stem treatments. Forestry Garlon® XRT specialty herbicide is labeled for cut-stump, basal bark or dormant-stem applications. Pathfinder II is a ready-to-use formulation that is labeled for basal bark and cut-stump treatments and is not designed for use as a foliar treatment.

Mode of Action

Triclopyr is a systemic herbicide that deregulates plant growth metabolic pathways. To ensure proper growth, plants naturally produce very controlled, minute amounts of auxins, which bind to specific receptor proteins to turn on and off vital plant processes. The active ingredient in the family of Garlon specialty herbicides appears to act similarly to one of these plant auxins — indoleacetic acid.

When absorbed by the plant, this active ingredient moves through the phloem (and to a lesser extent the xylem) to all portions of the plant. It eventually concentrates in the parts of the plant that are rapidly growing (meristems), causing uneven cell division and growth. Within days of application, this disruption causes symptoms such as thickened, curved and twisted shoots, stems and leaves; cupping and crinkling of leaves; stem cracking; hardened growth on stems and leaves; and proliferated growth. Depending on application timing and the target species, complete control can take from three weeks up to a complete growing season for some woody plants.

Registration and Testing

Before pesticides can be sold or distributed in the United States, they must be registered by the U.S. Environmental Protection Agency (EPA). Initial pesticide registrations require a minimum of 120 tests that can take companies more than a decade to complete at a cost well in excess of $50 million or more. The EPA requires these studies be conducted for each pesticide to show if the pesticide can be used without posing unreasonable adverse effects to humans or the environment.

The extensive database on the active ingredient in Garlon 4 Ultra, Garlon 3A, Forestry Garlon XRT and Pathfinder II specialty herbicides contains more than 25 years of laboratory and field data on the health and environmental effects of these products. The EPA, state agencies and other regulatory bodies throughout the world have reviewed more than 500 separate studies.

General Information on Toxicity

All substances can be toxic. However, it is the dose level (or amount) and conditions of exposure that make their effect toxic or harmful.

Toxicological tests with laboratory animals serve as models for evaluating the potential of a substance to cause adverse effects in humans. Toxicology studies measure the effects of direct and indirect exposure to the substance. Toxicologists divide the toxicity of a substance into four categories: acute, subacute, subchronic and chronic.

Acute toxicity results from a single dose of the substance through ingestion, inhalation, or skin or eye exposure. Results from single-exposure oral or dermal tests are expressed as LD_{50}; single-exposure tests through inhalation are expressed as LC_{50} values. These values refer to the “lethal dose” or “lethal concentration” necessary to kill 50 percent of a test population. These tests are done with a product’s active ingredient as well as the end-use, diluted formulation.

Subacute, subchronic and chronic toxicity can potentially result from repeated exposure to a chemical for a period of

time. Subacute toxicity is based on repeated exposure for one month or less, subchronic for one to three months, and chronic for more than three months. It is not uncommon for the toxic effects of repeated exposure to differ from those produced by a single exposure.

In addition to these standard toxicology tests, numerous studies also are conducted on other nontarget species such as birds, small and large mammals, and aquatic organisms. This diverse testing focuses on specifics. For example, does the product affect birds' ability to lay eggs or the ability of the hatchlings to survive? Other studies examine the impact of the chemical on habitat change and bacteria in the soil.

It is important to recognize that most of these tests require exposure rates significantly above those expected under normal use conditions at labeled use rates.

Active Ingredient Studies

Acute Toxicity

The EPA classifies acute toxicity of pesticides by placing results of different laboratory tests into categories with Toxicity Category I being the most toxic and Category IV the least toxic. Categories are based on the dosage at which the toxic effect was observed. The active ingredient in Garlon® 4 Ultra specialty herbicide, Garlon 3A, Forestry Garlon XRT and Pathfinder® II specialty herbicide is rated a Category III compound for acute oral and dermal toxicity. (*See Table 1*)

The acceptable acute toxicity studies conducted with triclopyr indicate low toxicity with the exception of eye irritation with triclopyr TEA.[2] (*See Table 1*)

Carcinogenicity

The active ingredient in the Garlon specialty herbicides and Pathfinder II has been classified as Group D — "not classifiable as to human carcinogenicity" by the EPA, meaning there is no evidence it causes cancer in humans.

Mutagenicity

Tests were done to evaluate the potential for cell damage from exposure to triclopyr, including gene mutations, chromosome aberrations, and DNA repair and damage. The mutagenic potential of triclopyr has been adequately evaluated in a range of assays *in vivo* and *in vitro*. These assays demonstrate that triclopyr is nonmutagenic *in vivo* (in living organisms) and *in vitro* (in laboratory environments).[2]

Reproductive Tests

Studies show triclopyr does not cause birth defects or reproductive problems in laboratory animals that have been exposed to high levels of the active ingredient in the family of Garlon specialty herbicides. These effects include fertility, delivery and number of offspring of consecutive generations exposed to the active ingredient.[2]

Neurotoxicity

There is no indication from toxicity studies to suggest the active ingredient in Garlon® specialty herbicides or Pathfinder II causes neurotoxic effects.[2]

Environmental Fate Studies

Additional tests were conducted with the active ingredient in the family of Garlon specialty herbicides to determine how it breaks down in the environment.

Table 1 **Acute (single) exposure studies with triclopyr formulations.**

Exposure Route	Toxicity		
	Triclopyr acid	Triclopyr BEE	Triclopyr TEA
Oral LD_{50} (Rat)*	729 mg/kg (male), 630 mg/kg (female)	803 mg/kg*	1,847 mg/kg
Dermal (Rabbit)	>2,000 mg/kg	>2,000 mg/kg	>2,000 mg/kg
Inhalation LC_{50} (Rat)**	—***	>4.8 mg/L	>2.6 mg/kg
Eye Irritation (Rabbit)	Moderate	Minimal	Corrosive
Skin Irritation (Rabbit)	Nonirritant	Nonirritant	Nonirritant
Skin Sensitization (Rabbit)	Nonsensitizer	Positive skin sensitizer	Positive skin sensitizer

*Milligram test substance per kilogram of body weight.
**Milligram test substance per liter of air.
***Will not vaporize enough to inhale.

Degradation and Dissipation
In soil, triclopyr is degraded primarily by microorganisms into intermediates 3,5,6-trichloro-2-pyridinol (TCP) and 3,5,6-trichloro-2-methoxypyridine (TMP). These intermediate compounds ultimately degrade to carbon dioxide, water and other organic molecules. Under common conditions, microbes are able to degrade half of the applied triclopyr within 30 to 45 days in most situations; and six to 12 months after application, no detectable levels of triclopyr or its metabolites would be expected. The breakdown rate varies depending upon rainfall, soil temperature and how these conditions impact soil microbial populations and activity.[3]

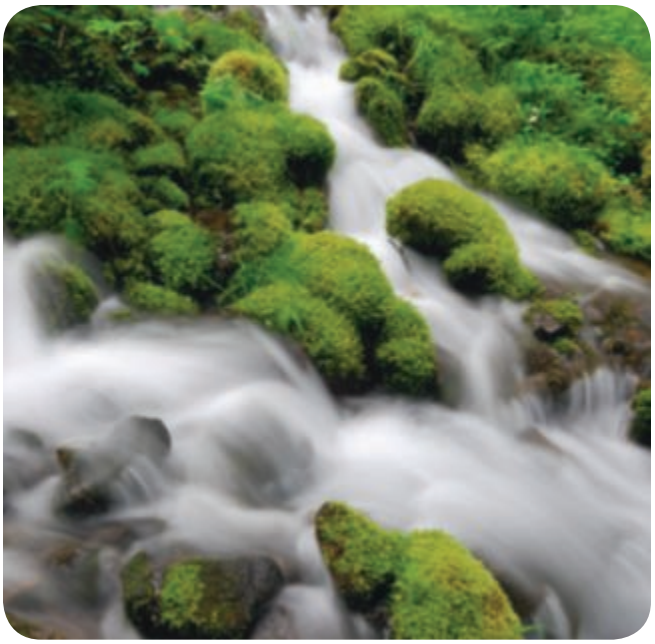
In water systems, this active ingredient is degraded by sunlight. In natural water, the photodegradation half-life is about one half of a day. Photodegradation is not a major pathway of degradation in the soil.[3]

In aquatic and soil environments, the ester form of this active ingredient is rapidly hydrolyzed to the acid form. The amine salt rapidly dissociates to the acid form of triclopyr.[3]

Water Quality
The movement of triclopyr in the soil profile is controlled not only by the adsorption (binding) of the chemical to soil particles, but also by its rate of degradation. Depending on soil and climatic conditions, fairly rapid degradation by microbial activity occurs to triclopyr,[4] and the soil half-life is around 30 days.

Laboratory and field studies, carried out both in Canada and in the United States, indicate movement of triclopyr in soil is determined by several factors, such as soil organic matter content, surface cover and soil pH. These studies found triclopyr has a very limited potential to leach below the immediate soil surface.[5]

Volatility
The amine salt and acid forms of the active ingredient in the Garlon family of specialty herbicides are essentially nonvolatile.[2] Under high temperature conditions, some vaporization of the ester formulation can occur. However, since it is rapidly converted to the acid form and quickly taken up by the leaf or stem of the plant, the opportunity for significant vaporization to occur is reduced.



Effects on Animals/Wildlife
To ensure there are no unintended effects to pets, livestock or wildlife, the EPA requires extensive testing. Researchers determine the highest dose of an active ingredient an animal can be exposed to and show no negative effect. This is called the No-Observable-Adverse-Effect-Level (NOAEL). Researchers also estimate the highest concentration of the active ingredient that could be expected through label use. Using these two measurements, they can calculate a “safety factor” to ensure no negative effects on animals.

Based on review of these and other studies, the EPA has determined the effects of the acid and amine salt forms of triclopyr are slightly toxic to birds (bobwhite and mallard) and practically nontoxic (the least toxic category) to fish (bluegill and trout). These results are only observed in laboratory tests where triclopyr is evaluated at very high exposure levels. The ester form of this herbicide is moderately toxic to birds and fish. However, the ester form hydrolyzes rapidly to the acid form. For this reason, researchers have concluded there is little chance the ester form would impact these organisms.

In Idaho in 1996, Whisenat conducted a study to determine the persistence of triclopyr in animal forage. The researchers found that although triclopyr was still detectable in forage,

it did not result in bioaccumulation in the food chain. By comparing this study with toxicological data, the authors indicated there is little or no risk to herbivores foraging in areas treated with triclopyr when applied at the label rates.[6] Other tests on livestock-grazing-treated forage have shown triclopyr does not bioaccumulate, moves through the animals' system essentially unchanged and is excreted in their urine.

Tests With End-use Formulations

Acute Toxicity

Several acute (single-exposure) toxicology tests have been conducted with the members of the Garlon family of specialty herbicides at labeled rates. The results of these oral, dermal, inhalation and eye irritation tests are summarized in Table 2.

Ecosystem Studies

Triclopyr is found in many products used throughout the world. For this reason, ecotoxicological studies have been conducted to assess what effect, if any, these products have on ecosystems.

Research on the use of selective herbicides and their impact on wildlife habitat have been going on for more than 50 years. A recent compendium of references on the impact of these products on nontarget species cites numerous studies. These studies evaluate potential impact on environmental parameters, such as birds, fish, amphibians, water quality, soils and biodiversity. Some of these studies were conducted with only the active ingredient, others with the end-use formulations.

Through the promotion and maintenance of desirable and diverse plant species following treatment, vegetation management programs, including the Garlon family of specialty herbicides, have been shown to result in the development of large and diverse avian and mammalian populations compared with nontreated surroundings. Aside from the intended removal of target vegetation, triclopyr-based products have little, if any, impact on terrestrial and aquatic animals or on ecosystems in which the animals live.[7,8]

Grazing Restrictions

There are no grazing restrictions on triclopyr products other than for lactating dairy animals. See the specific product label for lactating dairy animal restrictions.

Endocrine Disruption

There is no evidence typical human or wildlife exposures to triclopyr-containing products would result in unreasonable adverse effects on the function of the endocrine system. These studies include: reproduction studies, subchronic studies, and developmental toxicity and chronic toxicity tests. Although none of these tests are specifically designed to assess endocrine mediated effects, data from these studies provides an assessment of the most important aspects of endocrine toxicity.[2]

Thermodegration

After sites have been sprayed with herbicides, sometimes foresters burn the sites to reduce the amount of debris and to make access easier for planting crews. On rare occasions, a wildfire may impact a just-sprayed site. For this reason, a number of studies were done to evaluate the impact of burning sites recently sprayed with triclopyr-based herbicides. These studies found no significant parent herbicide residues in the smoke and concluded the risk of airborne herbicide residues to firefighters or others is insignificant.[9]

Table 2 **Acute (single) exposure studies with Garlon® 3A, Garlon 4 Ultra and Pathfinder® II specialty herbicides.**

Product	Oral LD_{50} (Rat)	Dermal LD_{50} (Rabbit)	Inhalation	Eye Irritation
Garlon 3A	2,140 mg/kg (male) 2,830 mg/kg (female)	>5,000 mg/kg*	Brief exposure unlikely to cause adverse effects	May cause severe irritation; corneal injury
Garlon 4 Ultra	1,581 mg/kg (male) 1,338 mg/kg (female)	>2,000 mg/kg	Excessive exposure may cause irritation to upper respiratory tract	Slight, temporary eye irritation
Pathfinder II	2,598 mg/kg (male) 1,000 mg/kg (female)	>2,000 mg/kg	4 hr. LC_{50} (rats), -5.0 mg/L**	Slight, temporary eye irritation

*Milligram test substance per kilogram of body weight.
**Milligram test substance per liter of air.

Registration

The EPA requires all pesticides registered before 1984, including products containing triclopyr, must be reregistered to ensure they meet current and more stringent agency standards. As part of the reregistration process, in 1998 the EPA concluded all currently registered products containing triclopyr are eligible for reregistration — "the use of currently registered products containing triclopyr in accordance with labeling required will not pose unreasonable risks of adverse effects to humans or the environment."[10] Triclopyr products have been reregistered and the labels have been revised according to requests from the EPA.[2]

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Dow AgroSciences, the manufacturer of Garlon® 4 Ultra specialty herbicide, Garlon 3A, Forestry Garlon XRT and Pathfinder II, encourages the public to become more knowledgeable about its products.

For additional information, consult the appropriate federal and state labels, supplemental labels and Material Safety Data Sheets for Garlon 4 Ultra, Garlon 3A, Forestry Garlon® XRT specialty herbicide and Pathfinder II.

More information can be obtained by calling 1-800-263-1196, e-mailing info@dow.com or logging on to www.vegetationmgmt.com.

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