Foray Technical Manual

Protecting Our Forests Protecting Our Future

VALENT BIOSCIENCES

WELCOME TO THE FORAY TECHNICAL MANUAL

Thank you for your interest in Foray® Biorational Insecticide, the world's leading biological larvicide for the control of lepidopteran forest pests.

Foray technology has been used to safeguard forest health since the mid 1970s. Since that time, Foray products and application technologies have continued to evolve advantageously. To assist our current and future customers in their understanding and use of Foray, we have compiled this technical manual as a comprehensive reference to guide those efforts.

This manual includes detailed information on the physical properties of Foray, all manner of operational data pertaining to its use, and peripheral issues surrounding Foray applications in both forested and residential areas. Arranged in an easy-to-follow format, information contained in this manual combines fundamental research and product development data with more than 40 years of field experience achieved alongside forest health professionals like you.

We hope you find this publication valuable and encourage you to copy and distribute any relevant information as you see fit. As always, we welcome feedback from our customers as we work together to protect our forests and our future.

—The Valent BioSciences Forest Health Team

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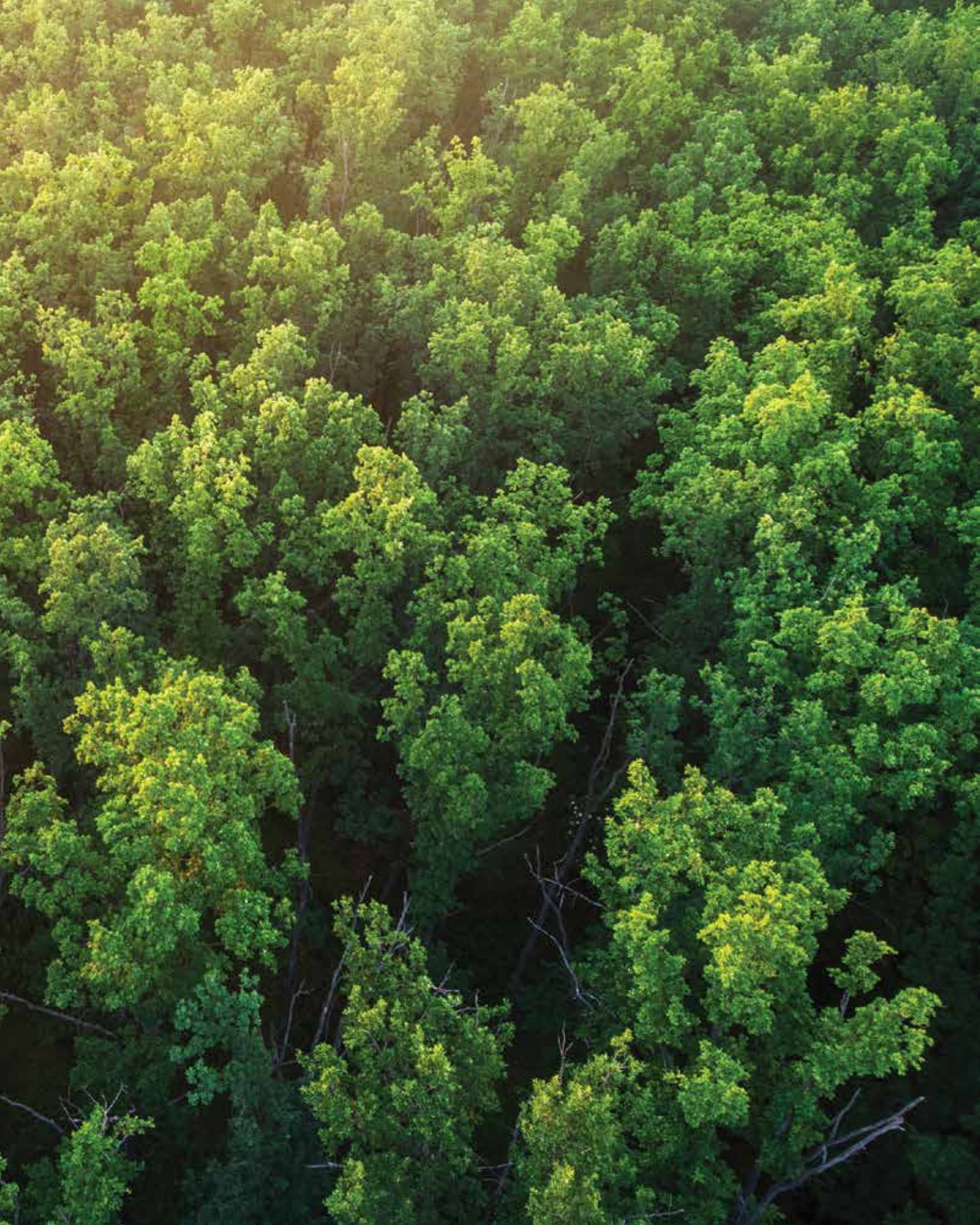
Always read and follow the label instructions.

Valent BioSciences LLC is an ISO 9001 Certified Company.

Introduction

section 1



1.1 WHAT IS FORAY AND WHY IS IT IMPORTANT?

Foray biorational insecticide technology is based on the gram-positive, rod-shaped bacterium *Bacillus thuringiensis* spp. *kurstaki* Strain ABTS-351, commonly known as Bt or Btk. The vegetative cells of Bt contain spores which enable it to survive in an adverse environment and reproduce in a favorable environment. During spore formation, the bacterium also produces unique crystalline proteins called delta-endotoxins. Together, the endotoxins and spores are toxic to many tree defoliating lepidopteran larvae.

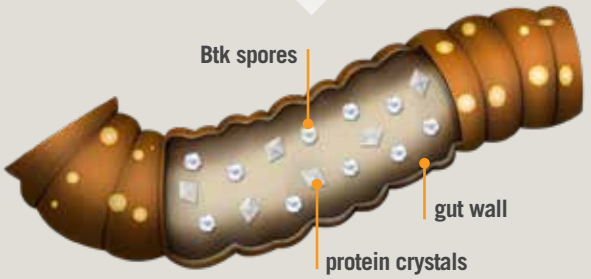
Foray was developed in response to the growing concern among the scientific community, policy makers, and the public in the 1960s and 70s regarding the use of synthetic chemicals in pest control. As it is derived from a ubiquitous, soil-borne bacterium, Btk is "friendly" to human beings, birds, fish, and other animal species because its activity is limited entirely to susceptible caterpillars.

The inert ingredients in Foray, which include various carriers, suspension agents, and stabilizers, are classified by the US Environmental Protection Agency (EPA) as inert ingredients of minimal toxicological concern to non-target organisms and

Figure 1.2

How Foray Works

Target pests ingest Btk protein crystals (protoxins) when feeding on treated leaves. Feeding stops within minutes as crystals are solublized in the gut and immediately begin damaging gut walls.



Btk spores germinate and pass through the compromised gut wall, causing blood poisoning.

Larvae perish in 1 to 3 days from a combination of sepsis and starvation.

the environment (List 4), and are Generally Recognized as Safe (GRAS).

This combination of efficacy and target specificity is what makes Foray biorational insecticide so important for forest health professionals around the world. In today's climate of sustainability and stakeholder awareness, forest program managers need highly effective tools that are safe and proven. Just as Btk exhibits a powerful insecticidal activity specific to caterpillar pests, Foray does not exhibit any of the hazards often associated with broad-spectrum chemical insecticides.

Several Foray formulations are available for control of forest defoliators. They are:

- **Foray 48B** 48 CLU*/gal (12.7 CLU/L)
- **Foray XG** 48 CLU/gal (12.7 CLU/L)
- **Foray 76B** 76 CLU/gal (20 CLU/L)

*Cabbage Looper Units: the standard measure of potency for Btk

Each of these products offers unique characteristics to address the diversified requirements of local pest control programs and aerial or ground applications.

1.2 HOW DOES FORAY WORK?

Btk is active only on the larval (caterpillar) stages of Lepidoptera, and must be ingested by the caterpillar to be effective. Activation of Btk toxic proteins takes place in the insect's mid-gut where the caterpillar's unique, alkaline pH and enzymes break the crystal down into smaller active toxins. (See **Figure 1.2**)

These activated toxins then bind to the cell membrane lining the gut, generating pores that lead to cellular swelling and lysis (disintegration of the cell wall). The effect of this process on the insect host is a complete cessation of feeding

(usually within an hour), lysis of gut lining cells through the action of active toxins, perforation of the intestinal wall, septicemia (blood poisoning), and ultimately death of the larvae.

Different subspecies of Btk have different protein crystals composed of specific toxin combinations. For example, Foray Btk contains four crystal-shaped toxin subtypes - CryIA(a), CryIA(b), CryIA(c), and CryIIA.

Sustainability

Foray is based on the ubiquitous, naturally-occurring soil-borne bacterium, *Bacillus thuringiensis* spp. *kurstaki* Strain ABTS-351 (Btk). While highly effective against various species of Lepidoptera, Btk has little to no impact on non-target species and the surrounding environment.

Each toxin aligns with a specific receptor site on the insect gut for binding (and subsequent gut wall disruption) to occur.

An insect must have the receptor sites for the specific Bt toxins to bind to in order to be susceptible to the insecticide. This unique 'lock and key' feature is what differentiates Bt from other types of bacteria and modes of action.

Foray® Aqueous Formulations: Technical Information

section 2

2.1 GENERAL DESCRIPTION

Foray products are water-based aqueous suspensions of Btk insecticide designed specifically for forestry and arboricultural applications. These formulations can be sprayed undiluted or (if required) diluted with water. Foray disperses readily into water to form a free-flowing spray suitable for conventional or low volume aerial applications. Foray formulations do not contain formaldehyde, benzene, xylene or other solvents of toxicological concern. Government regulatory agencies worldwide have expressed no concerns of a toxicological nature about Foray. These products are not classified as hazardous materials and are not regulated under DOT (US Department of Transportation or equivalent) hazardous materials regulations (49 CFR 100-199).

When applied undiluted or when tank-mixed with water, Foray suspensions are slightly acidic yet are not corrosive to metal fittings normally encountered on pesticide mixing and application equipment.

Foray is mildly acidic to help ensure product storage stability and microbial purity, and to optimize its efficacy. The different formulations of Foray exhibit the following characteristics:

Physical Properties of Foray 48B, Foray XG

***Appearance**: Light brown-colored liquid*
***Potency**: 10,600 IU/mg or 48 CLU[1] /gal (12.7 CLU/L)*
***Specific Gravity**: 1.14 +/- 0.05 g/mL*
***Weight**: 9.51 +/- 0.42 lb/gal (1.14 +/- 0.05 kg/L)*
***pH:** 4.7 +/- 1.5*
***Dispersibility**: Disperses readily into water*
***Viscosity**: @ 25°C –250-550 cP[2]*

Physical Properties of Foray 76B

***Appearance**: Light brown-colored liquid*
***Potency**: 16,700 IU/mg or 76 CLU[1]/gal (20 CLU[1]/L)*
***Specific Gravity**: 1.14 +/- 0.05*
***Weight**: 9.51 +/- 0.42 lb/gal (1.14 +/- 0.05 kg/L)*
***pH**: 4.7 +/- 1.5*
***Dispersibility**: Disperses readily into water*
***Viscosity**: @ 25°C 400-550 cP[2]*

[1] CLU = Cabbage Looper Units

[2] cP = centipoise

2.2 COMPATIBILITY STATEMENTS

Foray is a fully formulated product with ample, built-in surfactants that ensure wetting and adhesion to forest foliage.

APPLICATION TIP: Never Add Spray Sticker to Undiluted Foray.

As a general rule, Valent BioSciences does not recommend the use of a sticker except when applying extremely diluted applications for arboricultural purposes. If adding an anti-evaporant or a sticker, please check with the manufacturer on the compatibility of those products with Foray.

Never mix undiluted Foray with molasses or any thickening agents and/or evaporation retardants as an excessively viscous spray mix may result.

Do not tank mix Foray with other insecticides, miticides, fungicides, spray oils, foliar nutrients, or herbicides unless the physical compatibility and safety of the tank mixture to plants has been thoroughly evaluated by standard methods.

2.3 HANDLING UNDILUTED AND DILUTED AQUEOUS FORAY

Undiluted Applications

Foray is formulated to be applied as an undiluted ULV spray, but it can be mixed with water for higher volume applications. Undiluted applications increase payload efficiency, reduce application costs, and help ensure that every droplet contains a toxic dose of Btk. The only precaution recommended for handling undiluted Foray is to thoroughly flush all tanks, pumps, hoses, meters and aircraft systems with clean water, followed by complete draining, before the addition of undiluted Foray. Always clean inline strainers and inspect for holes or gaps. Use strainers between 20 and 30 size mesh. A 30 mesh or slotted strainer is a good general recommendation. For nozzle strainers, follow the equipment manufacturer's recommendations. See section 4 for a detailed description of spray system screens and nozzles.

Performance

Undiluted Foray applications are generally superior due to increased payload efficiency, reduced application costs, and optimal dose rate.

Foray is specifically formulated with the optimal amount of suspending agents that provides minimal settling of solids during storage and transport. However, it is recommended that the product be thoroughly recirculated immediately prior to use.

Photo Courtesy of ENVIROFOTO / SOPFIM

APPLICATION TIP: During spray operations and ferrying, do not maintain continuous agitation of Foray with bypass flow as this may incorporate air into the formulation thereby 'whipping' and thickening the formulation, which affects handling and flowrates.

Diluted Applications

Foray is completely miscible with water and can be mixed in any ratio with water to obtain desired spray volumes. The preferred mixing sequence is to add Foray to water; however, the reverse can also be done. All mixing and transfer equipment should be clean prior to the mixing of Foray. Always clean inline strainers and inspect for holes or gaps. Drums should be stirred, agitated, or rolled prior to dispensing. Water to be used in mixing should be clean and filtered to remove any coarse suspended matter. Water hardness levels should not exceed 340 ppm, and the pH of final mixture should be below 7.0.

Use strainers between 20 and 50 size mesh. A 30 mesh or slotted strainer is a good general recommendation. For nozzle strainers, follow the manufacturer's recommendations.

Mixing Procedure

1. Fill the mix tank or aircraft hopper with the necessary volume of water. Start hydraulic or mechanical agitation.
2. If a sticker is being used, add to the water.
3. Add Foray gradually to agitating water.
4. Rinse empty containers and bulk tanks previously holding Foray and use this rinse water for any subsequent mixing.

It is recommended that Foray tank mixes be used immediately. However, in the event of application delays, Foray tank mixtures are stable for 72 hours, depending upon storage temperatures and water quality. **Always recirculate tank mixes prior to loading aircraft**.

Performance

Always recirculate tank mixes prior to loading aircraft.

In cold weather, especially with the first load of each spray day, all product in the pumps and hoses, (including the loading hoses) should be recirculated back through the storage tank.

Aircraft Loading

In cold weather, especially with the first load of each spray day, all product in the pumps and hoses, (including the loading hoses) should be recirculated back through the storage tank. This will ensure that all pumps, meters, valves and filters are operating properly. In addition, the product in the first load will be of a temperature and viscosity consistent with normal operations.

2.4 CLEANING TRANSFER, MIXING AND SPRAY EQUIPMENT

Periodically, during the spray operation, it is recommended to rinse off any Foray residues which may be on the atomizers or the aircraft.

At the conclusion of the spray program, equipment should be cleaned according to the following recommendations:

- Remove inline screens, nozzle screens and nozzles, and clean these in a detergent/water

solution. If so equipped, Micronair® variable restrictor units (VRU) should be set at #13 or pulled out to the "full open" position.

- Filling the holding mix tank or the aircraft hopper with clean water, followed by agitation and spraying out, is usually sufficient to clean Foray residues from the system. Optionally, a detergent solution can be used, followed by a clean water rinse.

2.5 PUMP SEALS

Many centrifugal pumps used in aerial application programs are fitted with inexpensive carbon-ceramic mechanical seals. Some aircraft spray pumps and pesticide transfer/loading pumps equipped with these seals may have a tendency to leak when using Foray. As Foray is composed of suspended particles in a liquid medium, as with any such material, some buildup on the rotating faces of the seals may occur. **Inexpensive carbon seals should be replaced with harder faced seals** to help minimize the buildup mentioned above. This does not occur with all centrifugal pumps, but if it does, the problem may be alleviated with the substitution of tungsten carbide-silicon seals.

When buildup does occur, it has been our experience that the suspended particles can agglomerate and 'ball up' between the rotating and stationary seal faces, which will cause weeping of the seal. Over time, this weeping may increase to become a noticeable leak. Please note that the Foray will not harm or abrade the seal faces; simply disassemble and remove the seal assembly, rinse, wipe with a dry cloth, inspect and reinstall.

Some pumps will weep from first use while other pumps will not leak at all. Just be aware that loading pumps purchased as lower-priced water pumps available at discount centers and big box stores may not be as well machined, and the seals may be of a lower quality than pumps purchased from a specialty supplier.

Many aircraft spray systems are manufactured and/or distributed by a variety of specialized manufacturers. Please check with your airframe manufacturer or any of the manufacturers shown here for replacement components:

Agrinautics® (www.agrinautics.com), Isolair (www.isolairinc.com), Simplex Aerospace (https://www.dartaerospace.com/en/) and/or Transland® (www.translandllc.com).

There are also several manufacturers and numerous distributors for original equipment and/or replacement seals (manufacturers of mechanical pump seals are included in the references section), and technical advice. These manufacturers usually have international distribution.

Ordering new or replacement seals should be done well in advance of the operational program

Operations

Many centrifugal pumps used in aerial application programs come fitted with inexpensive carbon-ceramic mechanical seals. These should be replaced with higher performance, harder faced seals to help minimize buildup of Foray on the rotating seal face.

Photo Courtesy of U.S. Forest Service

because harder-faced carbide silicone tungsten seals are not generally an inventory item.

WHEN REPLACING PUMP SEALS:

1. **ALWAYS** refer to the manufacturer's directions for mechanical shaft seal replacement.
2. **DO NOT** run pump dry.
3. **ALWAYS** prime pump before starting.
4. In the case of self-priming models, **ALWAYS** fill the pump casing prior to use.

2.6 STORAGE AND DISPOSAL

Do not store Foray in the direct sun where product temperature will exceed 90°F (32°C) for prolonged periods of time. Higher temperatures are more detrimental to the product than freezing temperatures. If exposed to freezing temperatures, the Foray formulation will partially freeze but this will not reduce efficacy or handling characteristics if used by the "best before date." Always ensure that the product is well mixed before application.

Consult your local Valent BioSciences representative for further information regarding your specific product storage situation.

Performance

Within normal storage temperature ranges of 32° to 90°F (0° to 32°C), there will be no adverse effects on Foray formulations.

Within normal storage temperature ranges of 32° to 90°F (0° to 32°C), there will be no adverse effects on the formulation if used by the "best before date". Ensure that the product is agitated prior to use after exposure to low temperatures.

Re-close all unused containers. Foray is an EPA Category III pesticide; refer to the caution statement on Foray label for handling and storage.

Follow local regulations regarding container recycling and/or disposal.

HANDLING, MIXING AND LOADING

section 3

3.1 BASIC PRINCIPLES

All aqueous Btk formulations are suspensions, not solutions. They consist of water plus Btk spores and crystals, fermentation solids, adjuvants, stabilizers and other minor inert ingredients. Therefore, some basic principles can be stated about how these liquids should be handled in order to avoid problems in calibration and application.

Variable Viscosity

In some unique situations, temperature may affect the viscosity of the material.

Typical temperature changes during the day will not be noticeable in spray system flow rates. However, wide temperature ranges that could be experienced between the start and finish of a project, usually experienced at higher elevations, may require the use of different calibration constants in flow meters. Be aware of this and if required, consult with Valent BioSciences personnel about this unique situation.

Operations

Always have back-up pumps available in case of pump failure.

Suspensions

The suspended solids are small particles; filters finer than 30 (i.e. 50 to 100) mesh may collect these particles and eventually become plugged.

ⓘ **APPLICATION TIP**:DO NOT USE ANY FILTERS FINER THAN 30 MESH, ESPECIALLY WITH UNDILUTED APPLICATIONS.

Detergent Action

Foray formulations act as mild detergents and may loosen up dried-on accumulations of foreign matter from previous spray operations on the walls of spray tanks, aircraft hoppers, lines, pumps, booms and nozzles. Carefully check all filters in your loading and spray systems after the first few loads; this is when and where such debris will be found.

Stickers

Aqueous formulations of Foray contain additives to enhance sticking. Therefore, regular rinsing, especially of system parts exposed to the air where drying can occur, should be performed before complete drying of the Foray on atomizers and aircraft surfaces occurs.

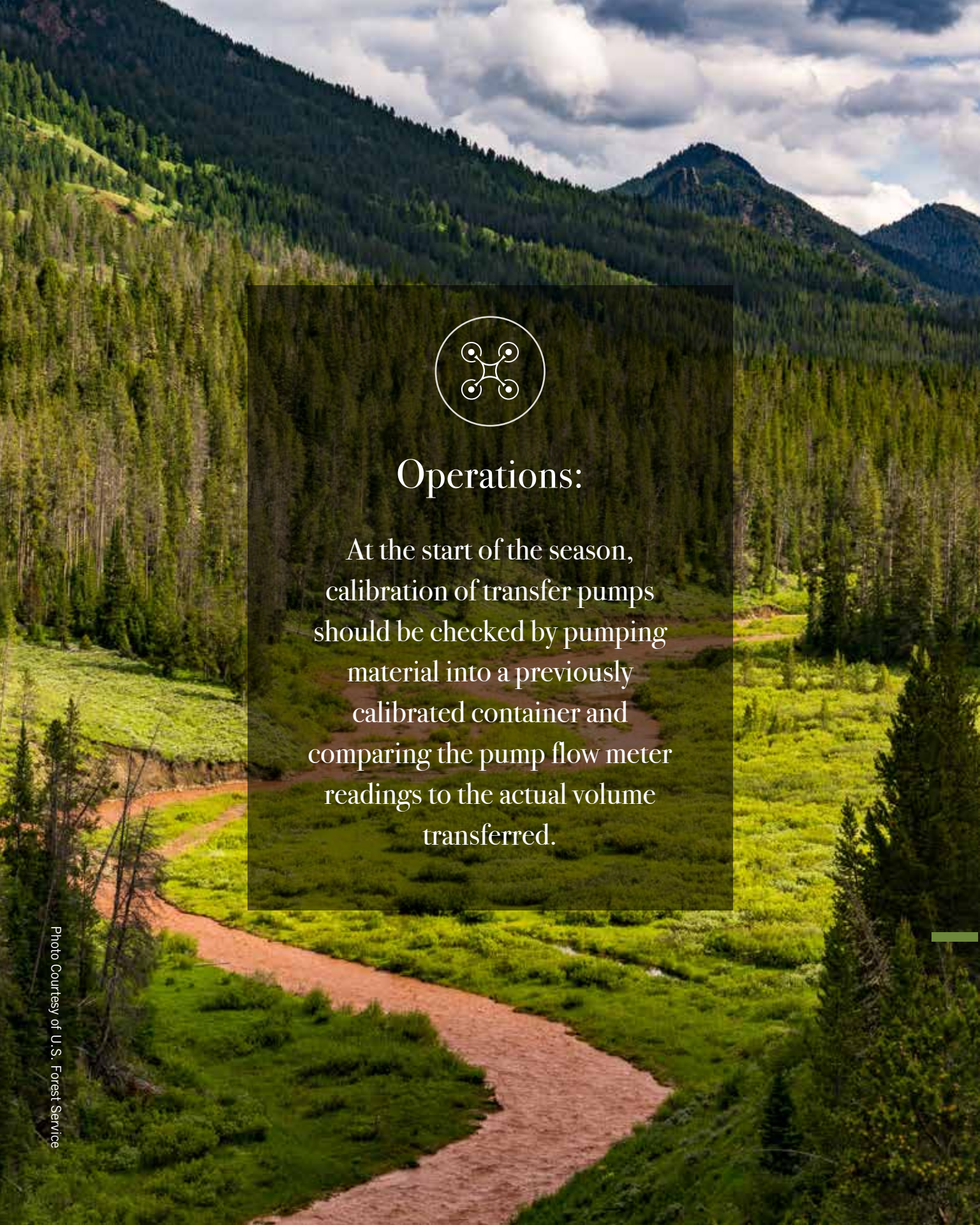
Aeration

Any heavy, viscous liquid can entrap air and hold it for some period of time. When recirculating or transferring these products, it is important to avoid the entrapment of air. Submerging both the inlet and the outlet of the hoses/tubes when recirculating these products will help prevent excessive aeration and producing a product with a milkshake-like consistency. If this situation arises, the pilot will first notice an increase in pressure and an altered flow rate, especially near the end of a load. This will alter the flow rate and ultimately the application rate.

3.2 EQUIPMENT

Pumps

Loading pumps with a 3-inch (7.5 cm) suction inlet is recommended. They should be powerful enough to transfer a minimum of 100 gpm (400 L/min). If 2-inch (5 cm) centrifugal pumps are used with bulk tankers, it is better to use a 3-inch suction hose from the tanker to the pump and then reduce from



Operations:

At the start of the season, calibration of transfer pumps should be checked by pumping material into a previously calibrated container and comparing the pump flow meter readings to the actual volume transferred.

Photo Courtesy of U.S. Forest Service

3-inch to 2-inch at the pump. Always have back-up pumps available in case of pump failure.

Hoses

Maximum hose diameters should be used wherever possible to improve the rate of flow of product from tank to tank or aircraft. Suction hoses of less than 2-inch (5 cm) in diameter and loading hoses of less than 1-inch (2.5 cm) diameter will be inefficient and should not be used. Hoses should be in good condition and suction hoses must be airtight and free of holes and leaks. All fittings on the suction side must be airtight. Use the shortest possible suction hoses.

With centrifugal pumps it is much more efficient to extend the hose length required on the pressure (outlet) side of the pump than on the suction (inlet) side of the pump.

Screens/Filters in Transfer/Loading Systems

Screens and filters in transfer and loading systems are designed to prevent damage to pumps and meters and to prevent larger particles from entering the aircraft spray system. Screens of 20-30 mesh size will accomplish this objective. A 20 mesh screen will allow improved flow rates and will not plug as easily. If no inline screens are being used in the aircraft system, then 30 mesh screens should be used in the loading system. See Section 4.2 for a detailed discussion on spray system screens.

Flow-Meters

Meters are used to measure the liquid volume of product being handled. Meter accuracies will vary with the slippage of the liquid past the meter vanes, and by the amount of entrapped air in the product.

Meters should be calibrated for (1) the product being pumped and (2) the system being used. If meters are calibrated with water only, aqueous Foray formulations produce meter readings which are typically 5-7% less than the actual amount of non-aerated product delivered.

For example, a meter calibrated with water reading 100 gallons (or liters) will have actually only delivered 93-95 gallons (or liters) of Foray. No single standard conversion factor can be provided because of variables such as viscosity of product as it passes through the meter and the extent of aeration. However, if you allow for a 5-7% flow differential, your aircraft will be very close to applying the desired rate.

At the start of the season, the calibration of transfer pumps should be checked by pumping material into a previously calibrated container, such as an aircraft hopper, and comparing the pump flow meter readings to the actual volume transferred. Some jurisdictions require a regular inspection and verification of the flow meter by an external agency certifying the accuracy of the flow meters.

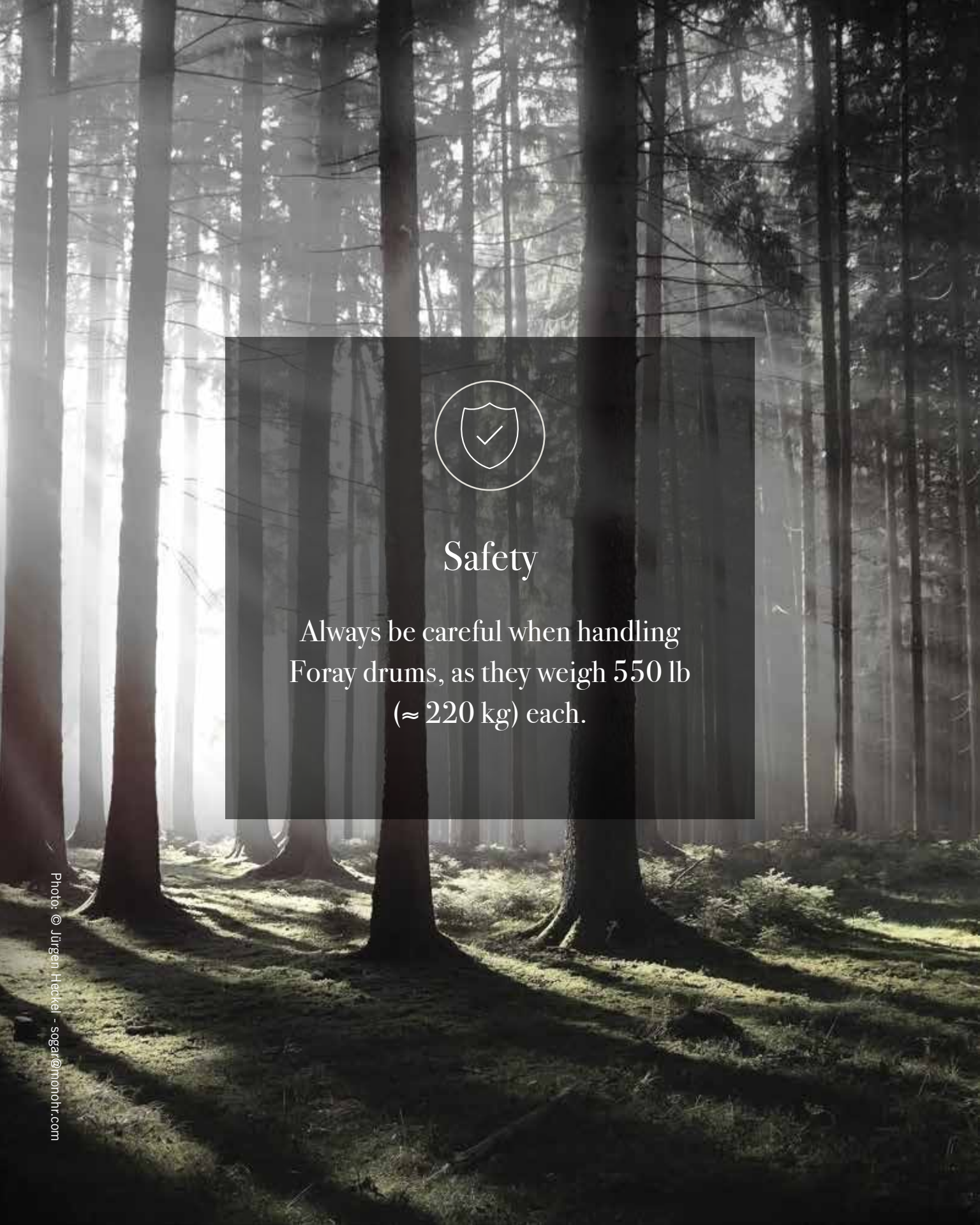
Current aircraft Differential Global Positioning System (DGPS) navigation systems integrate flow rates, flight speed, swath width and area treated to provide accurate flow and application rates across the treatment area. The pilot may ‘tweak’ the control inputs in the first one or two loads to improve the accuracy of the application.

Even with properly calibrated equipment, the pilot and ground crew should always check the volume pumped into the aircraft with the size of the areas treated to help ensure accuracy.

3.3 SPILL MANAGEMENT AND DISPOSAL

Spill Management of Aqueous Foray Formulations

Always assure adherence to federal, state/provincial and local regulations subsequent to disposal. Foray formulations are Category III pesticides



Safety

Always be careful when handling Foray drums, as they weigh 550 lb (≈ 220 kg) each.

Photo: © Jürgen Hackel - sogar@monohr.com

and are not classified as hazardous materials and are not regulated under DOT (US Department of Transportation) hazardous material regulations (49 CFR 100-199).

Foray degrades naturally in the environment and does not accumulate in the soil. There are no petroleum-based components in the formulation. Therefore, spills on soil surfaces may be handled as follows:

Hose the area down with ample water to disperse into the soil and/or grass. The dilution effect will facilitate the biodegradation of Btk. Cover the spill with a layer of soil to enhance degradation. (This would be the most likely option in remote forested areas).

If a spill occurs on an impervious surface such as concrete or asphalt, rinse the area with clean water if the runoff can be directed to a soil/grass surface.

OR Use an absorbent material such as cat litter, clean sand, or commercially available absorbents (e.g. SorbAll) to soak up spills. The contaminated material may be spread over the soil surface or taken to an approved landfill. While Btk has shown no adverse effects to aquatic organisms, do not rinse spills directly into streams, lakes or rivers.

ⓘ Foray is listed with the Chemtrec Spill Notification Network (800) 424-9300.

Most spills occur in and around the aircraft loading area and consequently the spill is accessible and clean-up is a simple procedure.

One or more emergency jettison sites should be identified on the treatment maps and discussed with the pilot in advance of the program. In the case of an in-flight emergency and if it is safe to do so, the pilot may proceed to the designated area(s) to dispose of the balance of the load. These sites should not be located near any water bodies.

3.4 DISPOSAL OF RINSATE

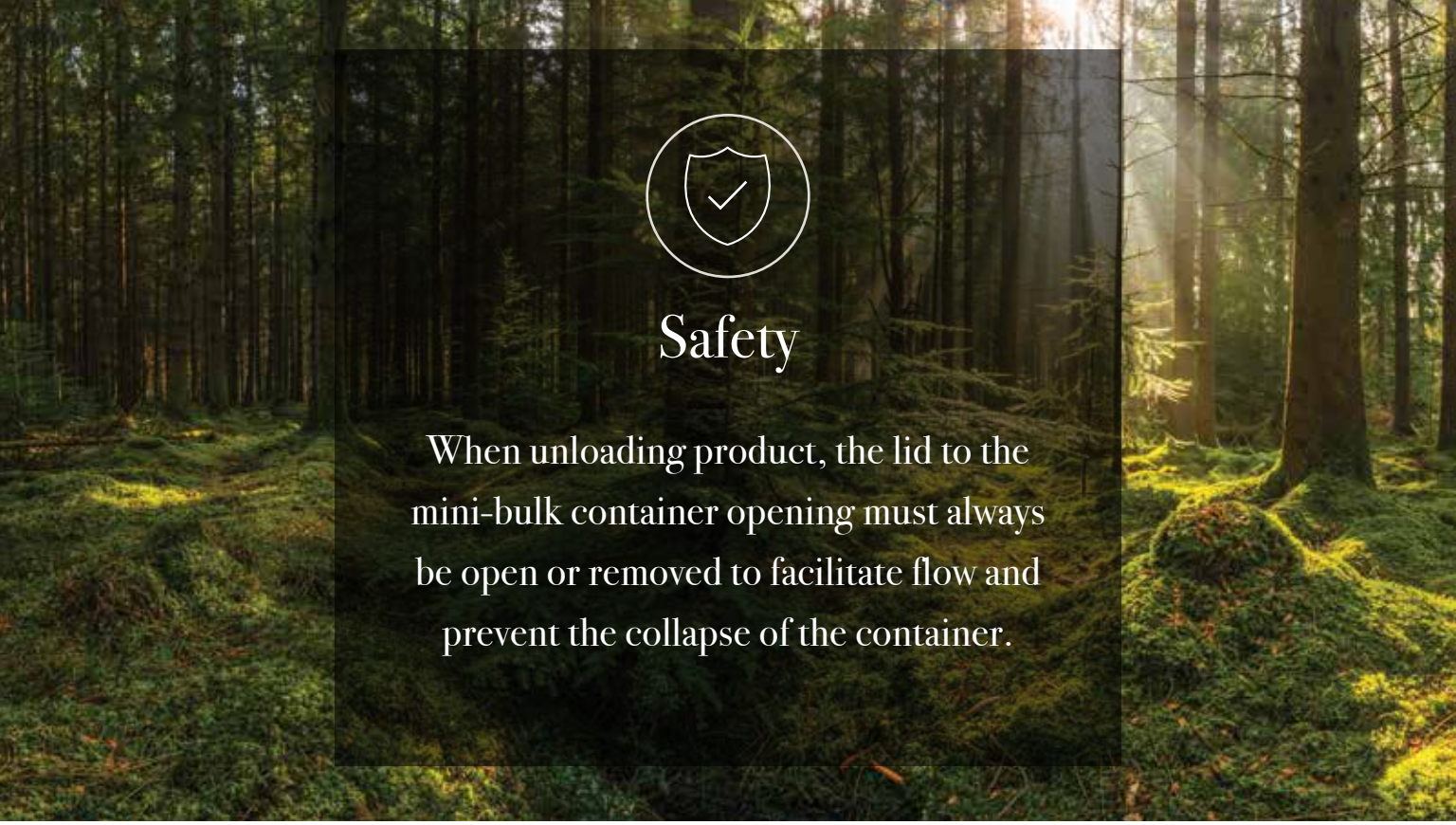
Foray must be disposed of in accordance with federal, state/provincial and local regulations. For product and container disposal procedures, see label directions.

Rinsates are best disposed of by adding them to the spray mixture during the operation and applying the material on the target area. Rinsate may be added to undiluted materials so long as it constitutes no more than 5% of the total volume at any time; this will not affect the calibration rate. Some program managers prefer to wait until program completion and then direct the pilot to apply the rinsate to the treatment area. Open up all nozzle restrictors and/or uncap the booms to apply the rinsate. Alternatively, the rinsate may be jettisoned over the pre-approved emergency jettison sites.

3.5 FORAY PRODUCT CONTAINER SIZES & HANDLING PROCEDURES

Foray formulations are available in North America in 55-gallon poly drums, 265-gallon (1000 L) mini bulk containers and in bulk quantities of 4000 to 5000 gallons (16,000 - 18,000 L) shipped in tanker trucks.

In the rest of the world (RoW), Foray is available in several package formats including 200 L poly drums, 1000 L mini bulk containers. Smaller package sizes may be available in some countries, depending upon local needs. Each type of packaging may require somewhat different handling procedures; please consult with Valent BioSciences staff regarding specific needs for your program.



Safety

When unloading product, the lid to the mini-bulk container opening must always be open or removed to facilitate flow and prevent the collapse of the container.

Drum Handling
(SEE APPENDIX 2 for drum photo and dimensions.)

Delivery: Drums are normally delivered by truck on pallets (4 drums/pallet). If a forklift is not available, drums may be rolled off the truck tailgate onto two or three old tires (without rims) stacked behind the tailgate where the drum impacts the ground. Be careful when handling drums in this manner and ensure that no one is located immediately behind the stacked tires; drums of Foray weigh 550 lb (≈ 220 kg) each.

Storage: Store drums upright in a dry location. Storage temperatures should be between 32° and 90°F (0° and 32°C). Keep out of direct sunlight at higher temperatures.

During shipping and storage, some normal settling of the formulation will occur. To re-suspend, roll or shake drums prior to dispensing.

Unloading: The drums may be configured with two, 2-inch NPT threaded openings (North America) or a combination of a 2-inch NPT and a (5 cm) metric threaded opening (RoW). Product can be dispensed either by pouring or by use of a transfer pump having a minimum flow capacity of 100 gal/min (400 L/min), e.g. 5 HP gasoline engine - centrifugal pump with a standpipe at least 42 inches (110 cm) in length, not more than 2 inches (5 cm) in diameter, and a non-collapsible hose. All pump and transfer lines should be flushed with plenty of clear water prior to use.

Performance

Container contents should be recirculated prior to use.

Diluted or undiluted Foray left in the lines and pumps will not cause damage or plugging.

ⓘ **APPLICATION TIP**: If a meter is unavailable and a partial drum quantity is required, a measuring stick may be used to determine the volume.

The liquid height in a standard drum containing 55 gal is approximately 33 inches. Therefore, 1 inch on the dipstick is equivalent to approximately 1.67 gallons and 1 cm is approximately equivalent to 2.5 L. You may check this by measuring the level of Foray in a full drum.

The 265 gallon/1000L mini bulk containers include a measuring gauge on the side of the outer frame. This can be used for estimating the volume of material remaining in the container if it is only partially emptied.

A properly calibrated flow meter is required for more precise measurements.

Mini Bulk Handling

(SEE APPENDIX 2 for photo and dimensions)

Delivery: When full, mini-bulk containers weigh about 2650 lb (≈1050 kg) and require a forklift to handle. When empty, the containers weigh 175 lb (80 kg) and can be handled manually.

Storage: Mini-bulk containers are mounted on a 4-way pallet and should not be stacked more than two high.

Store in a dry, preferably enclosed, location that is accessible to a forklift. Container contents should always be recirculated prior to use.

Unloading: A (5 cm) male metric threaded outlet is fitted with a valve and located at the base of the container. Each container also comes with a (5 cm) male metric to 2-inch female NPT adapter. The top of the container has a large 8-inch (20 cm) opening fitted with a screw-on lid, through which a 42-inch (110 cm) standpipe may be inserted.

Prior to use, the contents should be recirculated once by pumping the product from the outlet valve back through the top opening. The hose end should be submerged below the surface of the product.

Safety

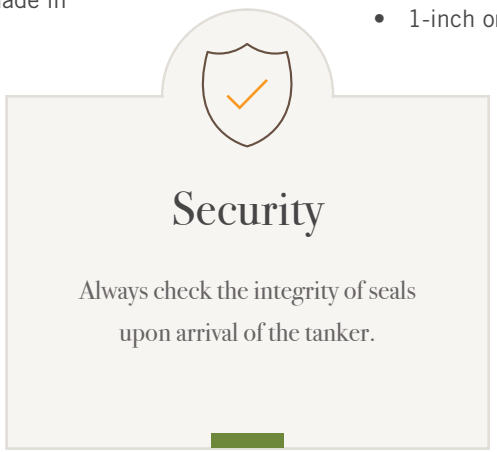
External valve controls should always be secured during non-use periods to prohibit unauthorized operation.

Replace the lid once the unloading operation is complete to prevent airborne contamination by dust, debris, rainfall or other moisture. If the entire mini-bulk is to be pumped into the aircraft or into a larger holding tank, recirculation is not required prior to pump out.

Bulk (Tanker) Handling

(SEE APPENDIX 2 for photo and dimensions)

Delivery: Bulk shipments are made in standard bulk tanker or ISO tanker trucks in North America. They may be off-loaded into the customer's bulk facility or "spotted"/"dropped" for direct use by the customer; the customer should have a large capacity pump to offload the tanker.



Note that all entries, outlets, and vents with removable caps on the tanker are sealed with a tamper evident numbered seal. There may be a dozen or more, depending upon the configuration of the tank. These seals are installed to verify the product has not been accidentally or purposefully tampered with. The numbers are recorded and included with the shipping documents as a Chain of Custody.

Storage: If the entire contents of the tanker are off-loaded into the customer's facility, no recirculation of the contents is required. Standard tank trucks are equipped with 3-inch (7.5 cm) male camlock outlet fittings; the customer may need to assemble a 3-inch/2-inch (7.5 cm/5 cm) adapter fitting to easily connect to the 3-inch male camlock fitting.

If it has been sitting for two days or more, the product should be recirculated at least once prior to use During recirculation, the return hose should always be submerged under the product surface to avoid entrapment of air and foaming of the product.

Unloading: Equipment recommended for off-loading and/or recirculating bulk tankers includes:

- a 3-inch (7.5 cm) non-collapsible suction hose
- a transfer pump capable of pumping 250 gpm (1,000 L/min)
- 1-inch or 2-inch (5 cm) loading hoses of sufficient length to reach the top manhole and/or one or more aircraft for direct loading.

Most bulk tankers are equipped with two control valves (internal and external) to avoid accidental discharge. Both valves must be open to allow discharge of contents. External valve controls should always be secured during non-use periods to prohibit unauthorized operation.

ⓘ **APPLICATION TIP**: If 2-inch suction pumps are used with bulk tankers, it is better to use a 3-inch suction hose from the tanker to the pump and reduce from 3-inch to 2-inch at the pump. A smaller loading hose provides a slower flow rate.

The contents of the tanker should be completely recirculated once before partial unloading or usage. This can be done by pumping the product from the outlet valve through the open manhole. The hose end at the manhole should be submerged below the surface of the product. Precautions should be taken to prevent the hose end from coming out of the manhole and causing a spill or injury; usually the hose is tied into place at the

manhole and a ground staff member stays beside the manhole for safety.

The lid of the tanker manhole must always be open when pumping to prevent the collapse of the tanker walls. The lid should be vented prior to opening the tanker to release any pressure that has built up. If the tanker has not been completely emptied, be sure to close the lid in order to prevent rain or debris from contaminating the contents.

If the delivery tanker is being dropped to use as on-site storage, it must be placed on solid ground with the front support dollies on solid planks or timbers between four and six inches thick. Upon arrival, ensure that the dollies can be easily raised and lowered so that the front of the tanker can be manipulated as it nears empty. The ground should be solid and level (or slightly inclined towards outlet) and the trailer wheels should be locked and chocked. If the tanker unloads from the tail, the rear of the tanker should be lower than the front. If it unloads from the center, it should be level. When unloading a tanker into another tanker or holding tank, the storage tanker or tank must be flushed and cleaned with clean water and completely drained prior to transferring the product into the empty vessel.

When the container is almost empty (less than 200 L), rinse down the sides of the container with small amounts of water. This will assure that all delivered product is removed as the water will reduce the viscosity of the remaining contents which will then flow readily from the tanker.

Please ensure that the tanker is completely empty, including any rinse water that was used to clean the tanker. Jack up the front dollies to their full extension to drain the tank. The tank haulers return all tankers to a washing facility for an acid wash decontamination before being put back into service. The customer will be charged a disposal fee by the hauler for any liquid left in the tank that has to be disposed of, including rinse water.

Performance

Small amounts (up to 5% by volume) of water in undiluted Foray will not adversely affect the handling or efficacy of the product.

3.6 RECIRCULATION PROTOCOL FOR FORAY FORMULATIONS

Undiluted formulations of Foray are stable suspensions. There is no need to periodically recirculate the contents during storage except prior to use.

AIRCRAFT OPERATIONS WITH FORAY PRODUCTS

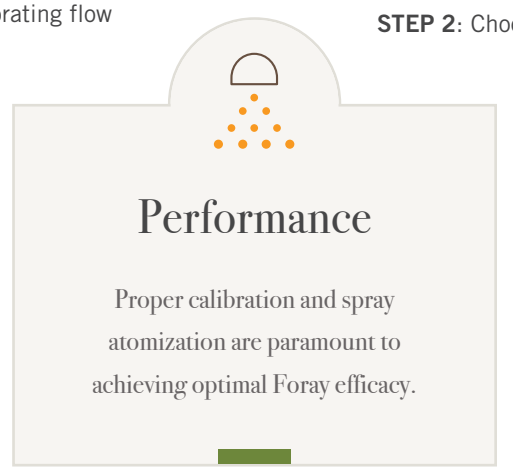
section 4

Photo Courtesy of ENVIROFOTO / SOPFIM

4.1 AIRCRAFT CALIBRATION

Proper calibration and spray atomization are paramount to achieving optimal Foray efficacy. Several methods exist for calibrating flow rates, each based on the type of equipment fitted to the aircraft. In all cases, some baseline calculations must be performed to establish the flow rate required by the spray system and the flow rate through each atomizer or nozzle.

STEP 1: Determine the spray system flow rate



Using example data, the formulas for determining system flow rates for US units and metric units can be found in **Figures 4.1(a) - 4.1(c)**.

STEP 2: Choose the atomizer type and number (**Figure 4.2(b)**).

The droplet spectrum required for effective Foray application is determined by the type of atomizer or hydraulic nozzle being used. Using nozzle or atomizer flow charts supplied by the manufacturer, determine an appropriate combination of units + pressure and flow settings (or nozzle orifice size) to deliver the desired flow per minute through each atomizer/nozzle.

ⓘ **APPLICATION TIP**: Hydraulic nozzles (e.g. TeeJet®, etc.) have a narrow pressure (and flow rate) range for any particular droplet size. Rotary atomizers can be adjusted for different droplet sizes independent of their flow rates.

To obtain the flow rate per atomizer for either US or metric units, divide the flow rate by the number of atomizers that will be fitted to the aircraft.

Example 4.1(c): (US units) If airspeed is 110 mph, and the expected swath width is 200 feet, what is the calibrated flow rate through each rotary atomizer if 6 Micronair AU5000 units will be

Figures 4.1: Flow Rate Calibration/Calculation Formulas

Figure 4.1(a)

US Units

$$\text{Flow rate (gal/min)} = \frac{\text{Airspeed (mph)} \times \text{Swath (ft)} \times \text{Application Rate (gal/acre)}}{495}$$

Metric Units

$$\text{Flow rate (L/min)} = \frac{\text{Airspeed (km/h)} \times \text{Swath (m)} \times \text{Application Rate (L/Ha)}}{600}$$

Figure 4.1(b)

$$\text{Flow/Atomizer/Minute} = \frac{\text{System Flow Rate}}{\text{No. of atomizers}}$$

Figure 4.1(c)

US Units

$$\text{Gal/min} = \frac{110 \text{ (mph)} \times (200) \text{ (ft)} \times \text{Application Rate } 0.5 \text{ (gal/acre)}}{495}$$

$$= \frac{22.2 \text{ gal/min}}{6 \text{ atomizers}}$$

$$= 3.7 \text{ gal/min/atomizer}$$

used and the applied volume is 64 fluid oz/acre? (Don't forget to convert ounces to gallons!)

The next step in the calibration process will depend upon the type of equipment fitted in the aircraft. If the spray system is powered by an engine driven pump (hydraulic or electric) and rotary atomizers are fitted, the aircraft can be statically calibrated on the ground by catching and measuring the output of the atomizers. If there are many nozzles, or if the system pump is wind-driven, then ground calibration becomes impractical and an airborne method is required.

Most aircraft are now equipped with flow meters which are used to accurately calibrate the system and monitor the pesticide flow rate during operations. Most GPS-based aircraft navigation systems (e.g. AG-NAV®, DynaNav, SatLoc®, TracMap®) offer flow monitor and flow control devices as part of their onboard systems. These flow control/flow monitoring devices link true ground speed to desired output and increase or decrease flow rates accordingly.

If applications are made over mountainous terrain, the systems automatically reduce output while the aircraft is flying uphill more slowly. Conversely, the output will be increased as the aircraft flies downhill to ensure that a consistent application rate is maintained.

At the start of a project, it may be a good idea to monitor the flow meter carefully to ensure that the "displayed" totals match the actual "spray total" volumes. Although it is not necessary to calibrate such-equipped aircraft on the ground, if there are any doubts as to meter accuracy, such a calibration can be performed as a simple cross-check.

Ground Calibration for Aircraft With Hydraulic or Electrical Pumps

STEP 1: Load sufficient product into the aircraft hopper (or saddle tanks installed on a helicopter) to prime the entire spray system, and allow enough product for the required number of tests.

STEP 2: Place collectors under each atomizer/nozzle and operate spray system for one or more minutes, so that a measurable volume is produced. Plastic jugs or plastic bags may be used to shroud the atomizers and to capture the spray being emitted.

STEP 3: Measure volume output per minute from each atomizer/nozzle and compare to calculated rate. Check total output.

STEP 4: Adjust the system pressure and/or atomizer setting, or change the nozzle orifice size, to increase or decrease output as needed. Retest system as per STEP 2.

Airborne Calibration for Aircraft With Wind-Driven Pumps

Note: It is often possible to obtain sufficient wind pump pressure by applying power while stationary. Consult the pilot for the standard operating procedure. In such cases, begin by following the calibration procedure in Section 4.1 and add these additional steps:

Operations

Always monitor calibration during operational spraying by comparing the volume of product applied with the area being treated.

Photo Courtesy of ENVIROFOTO / SOPFIM

STEP 1: Load product into the hopper as described previously, with the exception that the system must be primed in flight.

STEP 2: After the system is primed and the aircraft has landed, position the aircraft on a level surface and mark the spot. Add a measured volume of product to the spray tank and note the level either through the sight window or by measuring the distance from the top or bottom of the tank to the fluid surface of the product with a measuring stick.

Operations

If your are confident the application rate will be within +/-10 percent of the target rate when calibrating, you may want to use your assessment run as the first load of the operation.

STEP 3: Instruct the pilot to fly the aircraft as in a normal application and to operate the spray system for a set amount of time, e.g., 1 minute, using a stopwatch.

STEP 4: Return the aircraft to the exact spot on the ground as marked in STEP 3, and measure the volume of product needed to refill to the original level. This volume can then be used to calculate output per minute.

STEP 5: Make adjustments to the spray system, if necessary, to change output.

ⓘ **APPLICATION TIP**: If an aircraft has already had its spray system primed, a known quantity of spray mix can be pumped into the aircraft so that ground equipment, fitted with a previously calibrated and correct flowmeter, may be used for loading. The hopper site gauge may also be used if the aircraft is parked on level ground. The time taken to pump the measured volume is recorded with a stop watch, and the spray system settings adjusted accordingly and re-tested as necessary.

Aircraft with Electronic Flow Meters

Electronic flow monitors such as those manufactured by Onboard Systems® (Crophawk®) and Micronair or DGPS manufacturers (e.g. AG-NAV, DynaNav, Satloc, TracNav etc.) greatly facilitate aircraft calibration and enable in-flight adjustments when conditions demand. However, flow monitors and application computers should be calibrated with the product or spray mixture prior to operational use. Always refer to equipment manufacturers' directions for volumetrically calibrating flow meters with fluids other than water.

Also, flow monitors that have interchangeable cartridges of different flow range sensitivities should have the correct cartridge or flow turbine installed. Consult the appropriate manufacturers' directions.

DGPS manufacturers now offer flow monitoring systems interlinked with the DGPS system. Please consult with the technical representatives of the various DGPS manufacturers for more details. (See Appendix 1: Sources & Resources)

General Calibration Procedure

Foray formulations have been continually optimized to ensure that their viscosity is as low as possible.

When calibrating your system for Foray:

1) Assume that the Foray formulation will behave like water, and use the appropriate calibration factor in the flow meter.

Performance

In general, the flow rate differential between water and the aqueous suspensions of Foray 48B and 76B is about 5-7%.

Photo Courtesy of U.S. Forest Service

2) Add a known quantity of the spray material to the aircraft hopper. Ground equipment, fitted with a previously calibrated and correct flowmeter, may be used for loading. Alternatively, the hopper site gauge may be used if the aircraft is parked on level ground.
3) Make an adjustment to your flow meter calibration constant if the total volume sprayed (as indicated by your flow meter) is different from the amount that was pumped into the hopper. Typically this adjustment can be calculated as indicated below, but should also be cross-referenced with supplier operator's manual:

New Calibration Constant =

$$\text{Old Calibration Constant} \times \frac{\text{Volume Applied}}{\text{Volume Indicated}}$$

Both Foray 48B and 76B are aqueous suspensions with relatively consistent physical parameters. In general, the flow rate differential between water and Foray is about 5-7%. After the initial check with water, use this calibration factor (flow rate constant) to help calibrate the equipment more accurately and with fewer flow checks.

ⓘ **Pilot Tip**: Use the aircraft flow meter as your primary instrument for monitoring flow rate.

Performance

Strainer screens used with Foray should be no finer than 30 mesh. A 20 or 25 mesh slotted screen strainer is ideal. Aircraft manufacturers often install a 50 mesh screen as a standard on new planes. Although undiluted Foray will pass through a 50 mesh screen, product solids and foreign matter will likely build up on the screen and cause plugging.

With the new calibration constant, adjust the pressure of the spray system until the desired flow rate appears. This step may have to be repeated once or twice to determine the correct flow rate constant.

4.2 SPRAY SYSTEM FILTERS/SCREENS

Filters in aircraft spray systems are designed and installed to prohibit foreign particles from entering the system. Except for inline screens, the smallest orifices are found in the nozzles fitted to the aircraft.

Mesh size is defined by the number of openings there are per inch (e.g. a 30 mesh screen has 30 openings per linear inch of screen). But because of the thickness of the wire, the size of the orifice is not the inverse of the mesh size in inches.

The most common screen size found in aircraft inline screens is 50 mesh (holes in 50 mesh screens are 0.011" across).

Although undiluted Foray will pass through a 50 mesh screen, product solids will eventually build up the screen. When foreign matter is additionally collected on the screens, the buildup will occur more rapidly and will cause plugging of the screen.

Strainer screens should be no finer than 30 mesh when applying Foray formulations. A better alternative is the use of a 20 or 25 mesh slotted screen strainer as it is less prone to plugging.

Photo Courtesy of U.S. Forest Service

The same principle applies to 50 mesh nozzle screens. The pore sizes of various screen meshes, slotted strainer slots and nozzle openings are shown below in **Figures 4.2(a)** and **(b)**, in order of size increments.

It is clear from an evaluation of the sizes of various screen and nozzle openings shown in **Figures 4.2(a)** and **(b)** that the most commonly used nozzle openings (D-3, 8003 and VRU # 3 or 5) are significantly larger than a 30 mesh inline screen pore size.

Therefore the use of a 30 mesh inline screen or a 25 mesh slotted strainer installed in the nozzle body will enable the free flow of material to the atomizer orifices. No strainer or screen is necessary at the nozzle when using rotary atomizers.

Figure 4.2(a): Filter and screen mesh, sizes, ranked in order of size (inches)

INLINE SCREENS	NOZZLE SCREENS	NOZZLE* SLOTTED STRAINERS	HOLLOW CONE	NOZZLES FLAT FAN 80 SERIES	MICRONAIR VRU
50 mesh = 0.011	50 = 0.011	50 = 0.010			
30 mesh = 0.21		25 = 0.020			
	24 = 0.030	16 = 0.032		02 = 0.036	1 = 0.030
16 mesh = 0.045			D2 = 0.041	03 = 0.043	3 = 0.046
			D3 = 0.047		
				04 = 0.052	
				05 = 0.057	
			D4 = .0631	06 = 0.063	5 = 0.063
			D5 = .078		
					7 = 0.094

**Slotted strainers are recommended (required) for suspended solids where nozzle straining is required.*

Figure 4.2(b): Filter and screen mesh sizes, ranked in order of size (mm)

INLINE SCREENS	NOZZLE SCREENS	NOZZLE* SLOTTED STRAINERS	HOLLOW CONE	FLAT FAN 80 SERIES	NOZZLES MICRONAIR VRU
50 mesh = 0.28	50 = 0.28	50 = 0.25			
30 mesh = 0.53		25 = 0.51			
	24 = 0.76	16 = 0.81		8002 = 0.91	1 = 0.76
16 mesh = 1.14			D2 = 1.04	8003 = 1.09	3 = 1.17
			D3 = 1.19		
				8004 = 1.32	
				8005 = 1.45	
			D4 = 1.60	8006 = 1.60	5 = 1.60
			D5 = 1.98		
					7 = 2.39

**Slotted strainers are recommended (required) for suspended solids where nozzle straining is required.*

4.3 DROPLET SPECTRUM SIZE, ATOMIZER SELECTION & SPRAY ATOMIZATION

The manner in which Foray is atomized can markedly influence the effectiveness with which it controls the target insect. The impingement of droplets in a forest canopy, their distribution on foliage, and the likelihood of the target insect obtaining a lethal dose are all determined by the droplet size.

Because of differing foliage shapes and densities, broad-leaf forests have slightly different droplet size parameters than coniferous forests. Habitat differentiation means that the target species can affect droplet size selection; thus a free-roaming insect like the Gypsy Moth may require a different droplet spectrum than sequestered insects like the spruce budworm.

The choice of atomizer will be largely determined by the required droplet spectrum. At air speeds below 120 mph (190 km/h), rotary atomizers such as the Micronair can deliver smaller droplets than conventional hydraulic nozzles. Their great advantage is the ability to alter droplet size independently of aircraft boom pressure or airspeed, and to do this as spray conditions change.

At higher airspeeds (greater than 125mph/200 kph), small drop diameter ranges are possible with large capacity Micronair rotary atomizers or with standard hydraulic nozzles with the assistance of high pressure and wind shear. Such airspeeds are typically obtained with single engine turbine agricultural airplanes and multi-engine converted passenger/transport airplanes.

Hydraulic nozzles such as Spraying Systems® and TeeJet Flat Fan or Hollow Cone (Disc-Core) also produce the preferred droplet sizes, but rotary atomizers are more versatile as more options within which a narrow range of droplet sizes may be produced.

Another factor that should be considered when selecting an atomizer is the range of meteorological conditions that may be encountered during the spray project. For example, as conditions become hotter and drier during the day, rotary atomizers can be adjusted to produce bigger droplets, which evaporate less quickly than smaller droplets, and are more likely to reach their desired target.

Performance

The manner in which Foray is atomized can markedly influence the effectiveness with which it controls the target insect. The impingement of droplets in a forest canopy, their distribution on foliage, and the likelihood of the target insect obtaining a lethal dose are all determined by the droplet size.

4.4 DROPLET SIZE CONSIDERATIONS

Any particular droplet will produce eight smaller droplets, each equivalent to half the diameter of the original. One 200 µm droplet will produce eight 100 µm droplets, which in turn produces eight 50 µm droplets. Thus the original 200 µm droplet will produce sixty-four 50 µm droplets. It can be seen that given the same volume of spray material, when effectively distributed throughout the forest canopy, numerous small droplets would increase the likelihood of encounter by a larva than a single large droplet.

There are physical and biological limits to the useful size of the droplets:

- Does the droplet contain a lethal dose?
- Will the droplet survive the evaporation stresses during descent?
- Will the droplet drift off-target?

The next two subsections deal in general with droplet sizes in coniferous and deciduous forests. As a baseline, recommendations will be presented for the two most researched insects in the respective forest types, Eastern Spruce Budworm (*Choristoneura fumiferana*) and Gypsy Moth (*Lymantria dispar*). However, many defoliators show similar susceptibility ranges, and foliage deposition considerations remain the same for both forest types. Consequently, many of the broad recommendations are directly applicable to other species of defoliators found in North America (e.g., Tent Caterpillars, *malacsoma* sp., Tussock Moths, *orgyia* sp.) as well as major forest defoliators such as the Pine Processionary Moth (*Thaumetopoea pityocumpa*) or the Nun Moth (*Lymantria monacha*) in Europe. Please refer to the product label in your region for an inclusive list of pests controlled by Foray.

Droplet size is important in ensuring optimum efficacy of aerially applied insecticides. Droplets that are too small may not contain enough active ingredient and will only provide a sub-lethal dose. Droplets that are too large are wasteful in that they may contain more active ingredient than is required. Additionally, there may not be enough droplets available to ensure adequate deposition and thorough coverage throughout the forest canopy.

Droplet numbers are important too; an adequate number of droplets must be produced to ensure that thorough coverage in the forest canopy is obtained.

In Foray applications, the goals are to ensure that there are a maximum number of droplets produced, they are widely distributed where the larvae feed, and that each droplet contains a lethal dose of the active ingredient.

When referring to the number of spray droplets, scientists and application specialists will refer to the NMD and VMD.

NMD (Number Median Diameter) refers to the median or midpoint of the total number of spray droplets produced, where 50% are above the NMD and 50% are below the NMD.

VMD (Volume Median Diameter) refers to a

Performance

Eastern Spruce Budworm programs are advised to maximize the number of small droplets generated, penetrating the canopy.

40 micron droplet of Foray electron microscopy photo.

Photo courtesy of Chuck Davis, Natural Resources Canada, Canadian Forestry Service.

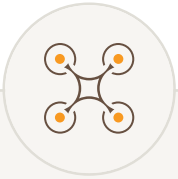
baseline, midpoint droplet size, where 50% of the total volume of the spray is contained in droplets smaller than the VMD and 50% of the total volume of the spray is contained in droplets larger than the VMD.

In general, scientists, program managers and application pilots will refer to a VMD or an average droplet size that is targeted for optimal control of the forest defoliator.

Optimum Droplet Sizes in Coniferous Forests

Managers of aerial spray programs targeting coniferous defoliators (budworms, tussock moths, pine processionary moth, etc.) are advised to maximize the number of small droplets produced by the atomizers to ensure effective distribution throughout the targeted forest canopy. At one time, program managers preferred the application of larger droplets due to concerns about sub-lethal doses associated with smaller droplets. However, research conducted in eastern Canada by the Canadian Forest Service and others during the last 20-25 years has shown that higher potency Btk formulations can deliver a lethal dose in a smaller droplet, thereby negating concerns about sublethal effects and smaller droplet sizes.

We recommend that the extremely low size regime be avoided, and that the atomizers (Micronair AU 4000 and AU5000 rotary atomizers are preferred) be set to produce droplets with VMD (sometimes referred to as DV0.5) of around 80-120 µm.



Operations

Aircraft with AU 5000 units flying at the upper end of the range may benefit from the addition of small deflector rings to minimize any sheering effect that would prevent the formation of controlled droplet sizes as the spray leaves the rotating sleeves.

Optimum Droplet Sizes in Deciduous Forests

As in coniferous forests, there are advantages and disadvantages to finely atomizing an application of Btk. Although small droplets can provide thorough distribution in the forest canopy, this must be balanced by the possibility of larvae obtaining sublethal doses from droplets that are too small. Such doses may inadvertently protect the larvae by inhibiting feeding, preventing them from ingesting further Btk deposits until they recover. Studies show the size of the droplet required for effective mortality of Gypsy Moth larvae increases with larval instar, so that although droplets in the 100 µm range (VMD) are optimally effective against second instars, their size should be increased to 125-150 µm range if the population is in the third and fourth instar stage.

Droplets larger than 200 µm should not be applied because the resulting low droplet densities reduce the chance of effective dose acquisition by larvae. (See **Figure 4.4**)

Field studies on Gypsy Moth performed by the Northeast Forest Aerial Application Technology (NEFAAT) Group in the early 90s with undiluted Foray 48B sprayed with different atomizers showed that a range of droplet sizes will provide a similar level of control on second and third instar larval populations. Small orifice hydraulic nozzles (Flat Fan 8004 and 8004 Twin-Jets), as well as Micronair rotary atomizers, all produced droplets in size classes shown to be effective.

Figure 4.4: Strategies to Decrease Droplet Size

HYDRAULIC NOZZLES	WIND-DRIVEN ROTARY ATOMIZERS	ELECTRICALLY OR HYDRAULICALLY POWERED ROTARY ATOMIZERS
Smaller orifice size, increase boom pressure, orientation to 45° forward	Increase unit rpm, decrease blade angle; in slower speed helicopters, use a longer blade	Increase rpm or change sleeve size

We recommend that for the control of Gypsy Moth and other broad leaf defoliators, atomizers should be selected and adjusted to deliver droplets in the 100-150 µm VMD range. If using hydraulic nozzles, use the smallest orifice flat fan nozzles which can deliver a sufficient volume with medium-speed agricultural aircraft (100-120 mph).

Higher speed single engine airplanes (e.g. Thrush® 660, Air Tractor® 802, etc.) should be equipped with the AU4000 atomizers as their working range may exceed the safety limits with the AU 5000 units. Please consult with Micronair regarding your aircraft and its flight speed when choosing the correct rotary atomizers to install.

Rotary atomizers are recommended, especially in slower aircraft. The shear atomization – which aids the production of small droplets by hydraulic nozzles – is not adequate at low airspeeds. If operating at the flow capacity limits of your nozzles/atomizers, it would be wise to modify the numbers and/or types of atomizers fitted to your aircraft.

If you are having to increase the VRU setting of the Micronairs to their highest setting, consider adding more atomizers.

If you are working considerably below 40 psi (275 kPa) for hydraulic nozzles and cannot reduce their number, consider changing the orifice size, so that the adequate atomization, which is obtained at higher boom pressure, is assured.

If you are having to increase the VRU setting of the Micronairs to their highest setting, consider adding more atomizers.

If you are working considerably below 40 psi (275 kPa) for hydraulic nozzles and cannot reduce their number, consider changing the orifice size, so that the adequate atomization, which is obtained at higher boom pressure, is assured.

4.5 UNDILUTED AND DILUTED APPLICATIONS

Foray may be applied as undiluted or diluted sprays to control Gypsy Moth larvae. Traditionally, Btk formulations were diluted with water to provide a spray volume in the range of 96-128 oz/acre (7.5-10.0 L/Ha).

Significant advances in application technology and formulation science have shown that undiluted applications are generally superior to diluted applications given that proper atomization and adequate deposition are achieved.

Dilution of the Foray spray with water can be advantageous in certain circumstances. For example, when controlling Forest Tent Caterpillar, as this larvae is very sensitive to Foray Btk toxins, very low rates of insecticide are required to control the larvae. Smaller wood lots or individual forested residential areas may also benefit. For these applications, dilution of Foray with water (1:1 – 1:2 ratio) may provide a higher volume of spray material, making a good and thorough canopy deposition easier to achieve.

Performance

Undiluted Foray applications are generally superior to diluted applications given that atomization and adequate deposition are optimized.

Photo Courtesy of ENVIROFOTO / SOPFIM

The effectiveness of undiluted ULV applications of Foray on other lepidopteran pests such as elm spanworm, cankerworms, and other native species has also been successfully demonstrated. Undiluted applications have been shown to provide significant improvements in aircraft payload efficiency, improve spray timing and help reduce application costs.

Micronair Rotary Atomizers and Droplet Sizes

Figure 4.5 shows wind tunnel data for droplet sizes (DV 0.5) for undiluted Foray 48B formulations applied using a Micronair AU5000 atomizer. The charts and figures provided in the Micronair AU5000 operator's handbook are based upon the atomization of water, and they encompass all possible applications in agriculture, vector and forestry spraying.

4.6 LANE SEPARATIONS

Lane separation (or the effective swath width) is the offset distance between parallel tracks flown by a spray aircraft. It represents the span under the aircraft and parallel to the flight path which receives an effective deposit of the pesticide.

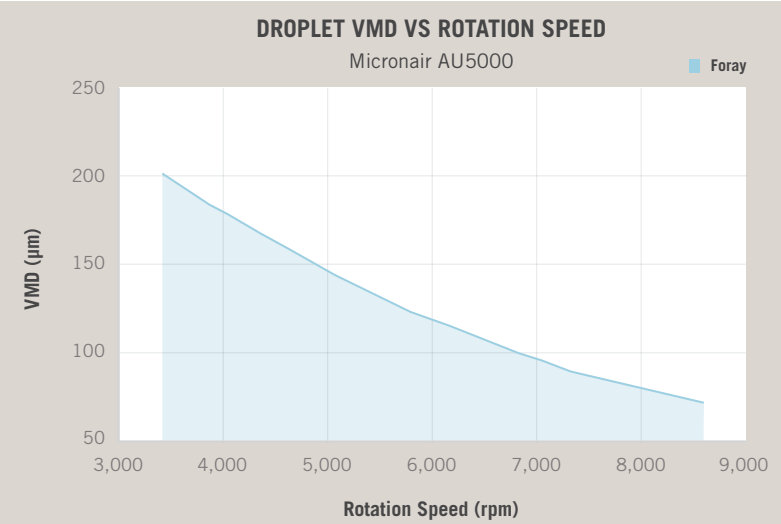
When accurately flown under most weather conditions, there will be no significant over- or under-application if this lane separation spacing is maintained. Note though that the effective swath is not the total swath, rather, it is that cross section portion of the spray deposited that is considered as adequate to provide a lethal dose to the larvae and to ensure uniform and homogenous coverage of the forest canopy.

The lane separation of aircraft varies depending upon the aircraft/spray system parameters (release height, atomizer setting, aircraft speed), the pesticide formulation, as well as factors such as meteorology and forest canopy architecture.

Pattern testing of aircraft over flat ground as well as in forests has shown that droplet size is one of the major factors which can affect the lane separation distance.

Smaller droplets are affected more by the aircraft wake and can travel greater distances. Wind direction has little effect on increasing the effective swath width. Although the finest droplets may drift long distances, they do not form part of the effective swath as there is very little biological activity in this portion of the droplet spectrum. For convenience, lane separation determinations are normally performed by flying the aircraft into wind so that the lateral drift of deposit is a function of the aircraft's wake rather than wind-borne distribution.

Figure 4.5



Please refer to the Micronair Operators Handbook and Parts Catalogue for more information.

The technique most used to measure the swath width is to assess deposit of dyed droplets on collectors, usually flat cards. White coated card stock (commercially known as Kromekote®) has been the most popular collector.

ⓘ **APPLICATION TIP**: A droplet density of between 5 - 20 droplets per square centimeter (range dependent on product potency) has been commonly held as a standard for an effective Btk deposit for field use. This numerical standard is now rarely used since the sole determinant of an adequate spray pattern. The number of fine droplets which are caught by flat cards is greatly influenced by the wind speed, and can give skewed readings under still conditions. With the increased use of image analysis pattern testing, it is more common to measure swath patterns in application rate units of gal/acre or L/Ha.

Although measuring spray deposit on the target foliage would provide a more meaningful representation of swath width, this requires more sophisticated measurement techniques and is generally not practical for most operational programs.

Consequently, despite their shortcomings in measuring fine droplets, the glossy-surfaced Kromekote-style cards are still a very cost-effective method of quickly assessing the spray pattern produced by an aircraft. Any reputable commercial printer can provide such cards. Request high-gloss coated card stock, coated on both sides and cut into convenient sizes of 5 inches x 3 inches (12cm x 8 cm), etc. Contact Valent BioSciences for additional information if required.

In general, for most forestry applications, the achievable swath width is approximately 3x the wing span/rotor diameter of the aircraft. For ultra-

Performance

Effective Swath Width: The span under the aircraft and parallel to the flight path which receives an effective deposit of pesticide.

low volume applications to large forested treatment areas, aircraft may fly at a higher altitude and achieve a wider swath width. This should be confirmed with calibration and characterization flight tests prior to the application.

Figure 4.7 presents various swath width ranges for a variety of aircraft and atomizers that have been used effectively in forestry programs with Btk formulations. Increasingly, many programs require the use of rotary atomizers for forestry work, but some allow hydraulic nozzles, although typically a shorter lane separation is then assigned. The US Forest Service and several states and provinces have performed extensive swath pattern testing using a variety of spray pattern analysis technologies. Multi-engine aircraft data were provided by the Forest Service and the US Air Force, based on similar studies.

Performance

COVERAGE TIPS: Btk must be ingested by larvae to be effective. To ensure larval mortality, an accurate application is required to ensure an adequate dose of Foray is deposited across the canopy.

The availability of high-capacity single-engine application aircraft has meant that older multi-engine aircraft are rarely used in modern forest protection programs. Where a range of lane separations is shown in **Figure 4.7**, the upper end of the range was obtained with aircraft equipped with Micronair rotary atomizers.

4.7 AIRCRAFT GUIDANCE

Over the last two decades, traditional aircraft navigation techniques (balloons, spotter aircraft etc.) have given way to the advent of satellite-based technology. Commonly referred to as GPS (Global Positioning System), the location of any feature, natural or man-made, can be confirmed through the use of intersecting signals from a network of geo-stationary satellites.

Not only can locations be identified on the earth's surface by latitude and longitude, aircraft may use these satellite transmissions to plan and follow a specific flight path above the earth's surface. Although accurate enough for waypoint navigation, the GPS system doesn't offer the level of accuracy required for proper spray aircraft guidance.

An extra signal, called differential correction, is necessary to achieve the precision required. When the satellite signals are differentially corrected (DGPS), an aerial application aircraft can follow a swath width (lane interval) to accuracies within two meters. DGPS systems calculate the aircraft's position (latitude, longitude and elevation) several times per second and use these calculations to provide the aerial applicator with highly accurate and sophisticated guidance. DGPS navigation has proven itself in the forest protection industry. Ground-based survey and assessment crews now use inexpensive and portable hand-held GPS systems to establish treatment boundaries or to locate assessment plots in the forest. No Spray Zones are also easily marked.

Aerial applicators, using the same basic technology as the portable hand-held GPS units, rely upon sophisticated instrumentation and cockpit displays to guide their aircraft across the spray block. Guidance

lights and small computer style screens provide continuous navigational assistance to the pilots by marking every swath and displaying the position of the aircraft in or near the treatment area. The most recent development in this technology is conjugation of the aircraft's spray system (flow control) with the DGPS, ensuring that an accurate application rate is maintained across the spray block regardless of the aircraft's groundspeed. Many DGPS units also provide a spray ON-OFF function that shuts flow off as the aircraft exits the spray block or while flying over No Spray or Exclusion Zones.

There are several manufacturers of high quality DGPS technologies available and approved for use in forest spraying programs. The most commonly used systems (AG-NAV, MapTrac and SatLoc) offer precise aircraft navigation along with flow control to compensate for air speed/ground speed fluctuations as well as auto ON-OFF features to enhance deposition accuracy.

The most advanced systems also offer real time remote flight tracking whereby the program managers may view progress and flight patterns of individual aircraft in the treatment area from a ground-based, Wi-Fi connected computer.

A list of DGPS manufacturers is included in Appendix 1: Sources & Resources

Spray Pattern Modeling

In the 80s and 90s, the US Forest Service invested a considerable amount of resources to create a computer program that could accurately predict aircraft spray patterns and deposition within a forest canopy when given inputs on the aircraft, atomizers, spray mixture properties, weather details, and spray canopy structure.

The program that emerged from those efforts exists either as AGDISP™—which models the 'near wake' deposit (the spray pattern closest to the aircraft) but not drift or canopy deposition, or FSCBG—which adds a Gaussian plume model to AGDISP to simulate the latter effects. A third derivative of AGDISP is Ag-Drift®, which was created by the Spray Drift Task Force to model drift away from the site of application.

All three programs require some instruction before they can be used to model aerial spraying situations. Although they can be made to run with minimum effort, the maxim that a little knowledge is a dangerous thing should be taken to heart when running these powerful programs for the first time.

These models are all available at no charge. See www.continuum-dynamics.com/pr-agdisp.html cfs.nrcan.gc.ca/projects/133

The most recent model is the 'Spray Advisor', which is a comprehensive product developed by the US Forest Service incorporating many of the features in AgDisp and earlier models. However, the software that drives this model is becoming outdated; please consult the US Forest Service for further information on the availability of this software.

Sustainability

DGPS systems calculate the aircraft's position (latitude, longitude and elevation) several times per second and use these calculations to modify flow rate to not waste etc. Accuracy within less than 1 m.

4.8 SWATH PATTERN ANALYSIS

In many forestry projects, it is common practice to examine the spray pattern of contracted spray aircraft before application to ensure that the aircraft has been optimally configured. Although established methods using microscopes to analyze cards exist, the last 20 years have seen the development of rapid and more powerful methods of measuring the deposition obtained on a line of cards laid out on the ground perpendicular to aircraft flight. Many of the earlier technologies have been superseded by advances in image analytics. Please contact Valent BioSciences if you need help searching for older or newer technologies.

Currently the REMSpC Stainalysis program is the most commonly used droplet size assessment technique. Valent BioSciences has made arrangements with the developers of this tool (REMSpec) to make it available online, free of charge. Visit http://www.remspc.com/Stainalysis/

Figure 4.7 Examples of Lane Separation for Btk Applications (Single Aircraft, Gypsy Moth Control*)

AIRCRAFT	LANE SEPARATION RANGE	
Single-Engine Fixed Wing Aircraft	**ft**	**m**
Piper Pawnee	65 - 100	20-30
Piper Brave	75	23
Cessna Ag Truck, Ag Wagon, Ag Husky	75 - 100	23-30
Ag Cat Model B	100 - 130	30-40
Antonov An-2	130 - 165	40-50
Thrush SR2 - Turbine	150	45
Thrush SR2 - Piston	150	45
PZL M-18 Dromader	150 - 175	45-53
Air Tractor 400 Piston	150	45
Air Tractor 402 Turbine	150	45
Air Tractor 502 Turbine	175	53
Air Tractor 602 Turbine	175	53
Air Tractor 802 Turbine	200	60

*Swath widths in programs for other pests may be larger. Please contact your Valent BioSciences Forest Health representative for more information.

AIRCRAFT	LANE SEPARATION RANGE	
Multi-Engine Fixed Wing Aircraft	**ft**	**m**
Beech 18	150	45
DC-3	225	75
DC-4, DC-6, DC7	400	120
C-130	400	120
Rotary Wing Aircraft	**ft**	**m**
Bell 47G	75	23
Hiller 12E	75	23
Hughes/MD 500	75 - 90	23 - 27
Kamov Ka-26	80 - 90	24-27
Bell 47G Soloy	100	30
Hiller 12E Soloy	100	30
Bell 206 Jetranger, Long Ranger	100 - 120	30 - 36
Mil Mi-2	100 - 130	30 - 40
Bell 204/205/212/412/ UH-1	150	45

With the advent of superior image analysis technology, there are numerous technologies that can be adapted for spray pattern analysis. You may also consult Valent BioSciences for any updates on these technologies and tools.

Droplet Spread Factors

Image analysis of spray deposits uses a spread factor to convert droplet stain sizes obtained on target cards to the diameters of the droplets that created the stains.

The spread factor is a ratio of droplet diameter to stain diameter. Thus a 100 µm droplet giving a stain diameter of 200 µm is said to have a spread factor of 0.5. Multiply the stain by the spread factor to determine the droplet size.

Some references use the inverse of 0.5 (2.0) to refer to the spread factor. If the spread factor is greater than 1.0, inverse notation is used. In making quick and simple assessments in the field, a spread factor of 0.5 (2.0) may be used for diluted and undiluted Btk sprays.

Tracer Dyes

To perform droplet deposit analysis using the glossy white spray cards, a dye must be added to make the formulation visible. A range of soluble food dyes can be used with aqueous Foray formulations and several manufacturers now produce special dyes to make applied sprays less visible on certain surfaces (i.e. green dye for turf grass spraying) and even dyes specifically for pattern analysis. Refer to Appendix 1: Sources and Resources for further information on the sources of dyes. Dye usually has to be incorporated at 1.5 to 2.0% (volume/volume) to allow for good visual acuity of smaller droplets.

Check with your nearest dyestuff supplier for a recommendation of a dye color and concentration that is suitable for spray pattern analysis; contact information is also included in Appendix 1: Sources and Resources. Please note that some of these tracer dyes are often available at a lawn and garden center, a big box store, or an agchem supply outlet.

Water-Sensitive Papers

One major alternative to using white target cards with added tracer dyes is the use of water-sensitive paper strips.

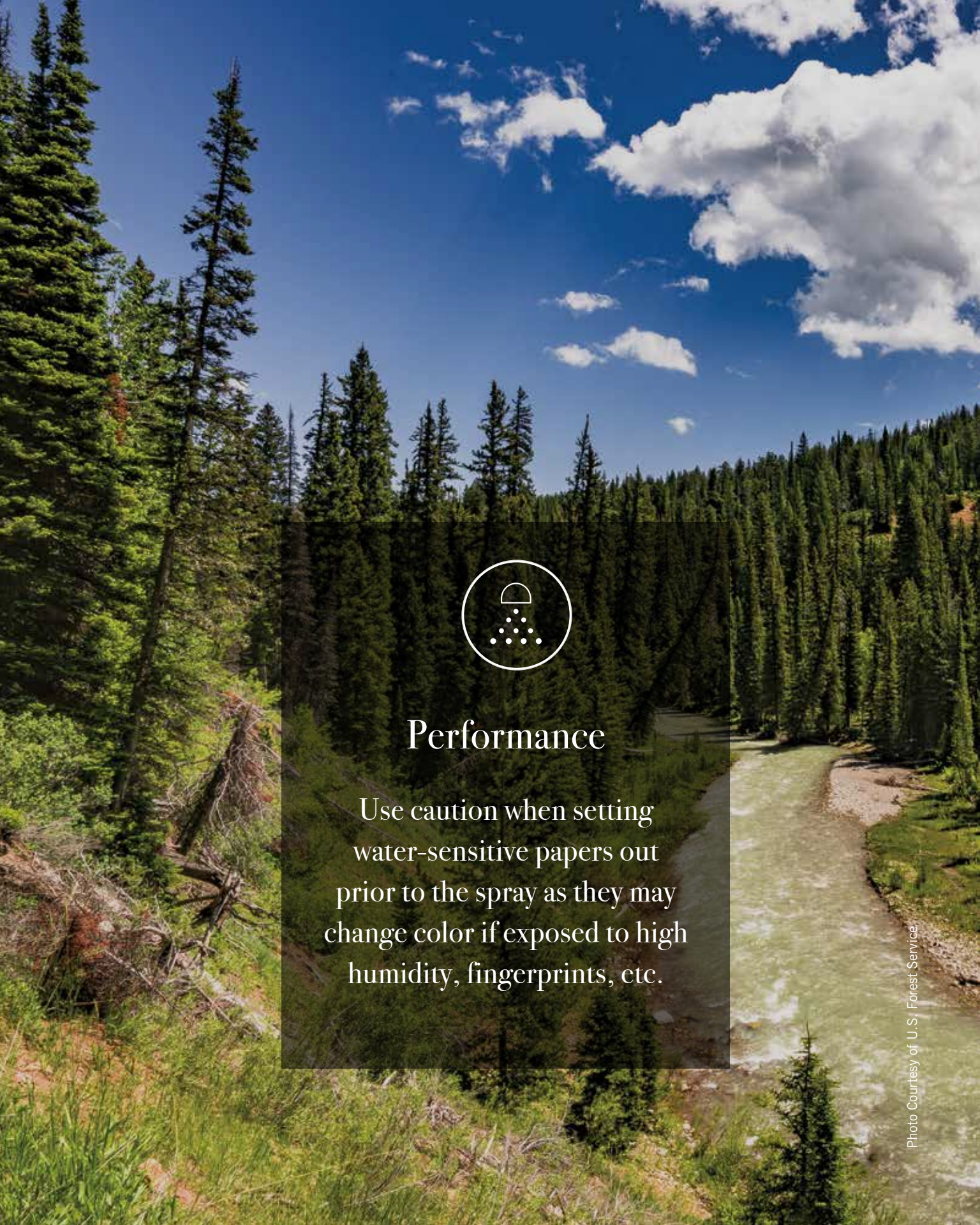
These cards have been developed specifically to react to aqueous formulations. Water sensitive cards work well with undiluted aqueous formulations, and with all diluted formulations. Following exposure to the spray droplets, the yellow papers will be stained blue.

What is a Spread Factor?

Droplets spread out upon impact so analysis requires a spread factor to correct for the difference between stain size and droplet size. The spread factor relates diameter of deposited drop to stain diameter (ratio).

Spread factor can vary with product used, tank mix, dye concentration, drop size, Time, Relative Humidity and type of collector surface (Glass, Petri dish, Kromekote card, sensitive cards).

Example: A 100 µm droplet giving a stain diameter of 200 µm has spread factor of 0.5 (2.0). Multiply the stain by the spread factor to come up with the droplet size (or vice versa).

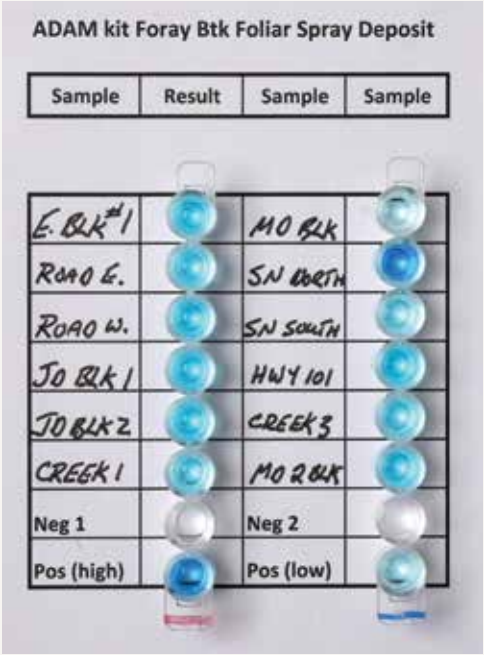


Performance

Use caution when setting water-sensitive papers out prior to the spray as they may change color if exposed to high humidity, fingerprints, etc.

Photo Courtesy of U.S. Forest Service

ADAM KIT TEST RESULTS



This shows the results of an ADAM kit application. The two bottom cells show a high level of Foray foliar deposit – labeled "Pos (high)" and a low level of deposit – labeled "Pos (low)". "Neg 1" and "Neg 2" cells should remain clear to ensure accuracy of sample processing. No color in any of the upper six cells would indicate that there was an inadequate deposit of Foray. The intensity of the blue reflects the amount of Foray deposited. The intensity of color in upper test cells should be greater than or equal to the Pos (low) cell.

Water-sensitive cards are produced in two sizes by Syngenta® in Switzerland and are available from a variety of sources including Spraying Systems Company. (see Appendix 1: Sources & Resources).

Accurate Deposit Assessment Methodology (ADAM)

Adequate spray deposition, penetration and coverage of the forest canopy are essential prerequisites for treatment success. Spray deposition has been traditionally assessed by visually analyzing spray deposit cards that have been placed in the treatment area. Colored dyes have also been routinely incorporated into the Foray formulation immediately prior to the application to assist in this visual assessment.

Spray cards, while a great tool for use in aircraft calibration and characterization, have shown to be an unreliable measure of spray deposit actually found on the foliage. More importantly, none of the traditional spray card technologies can accurately measure spray deposit remaining on the foliage after an unforeseen postspray rain event.

To this end, Valent BioSciences developed the ADAM (Accurate Deposit Assessment Methodology) kit to help program managers confirm the reliability of spray card analysis.

Dyes cannot be used on an operational basis due to several considerations including high cost, the significant effort required to place and retrieve spray deposit cards in the treatment area, and the potential for staining buildings or other objects located in forested, residential treatment areas.

The ADAM kit is based upon Enzyme Linked Immuno-Sorbent Assay (ELISA) technology to more accurately determine the presence of Foray spray deposit on conifer or deciduous foliage.

There is a kit for each type of foliage. This patented technology is produced by a reputable crop diagnostic firm using key components supplied by VBC to link the foliar spray deposit to the Btk forestry formulations produced by VBC. No laboratory equipment is needed. All essential components, including simple lab tools (forceps, etc.) are included in the kit. Twelve dozen foliage samples can be processed in 2 to 2.5 hours and the results are immediately visible and expressed in deepening shades of blue reflecting the relative level of Foray Btk deposited on the foliage.

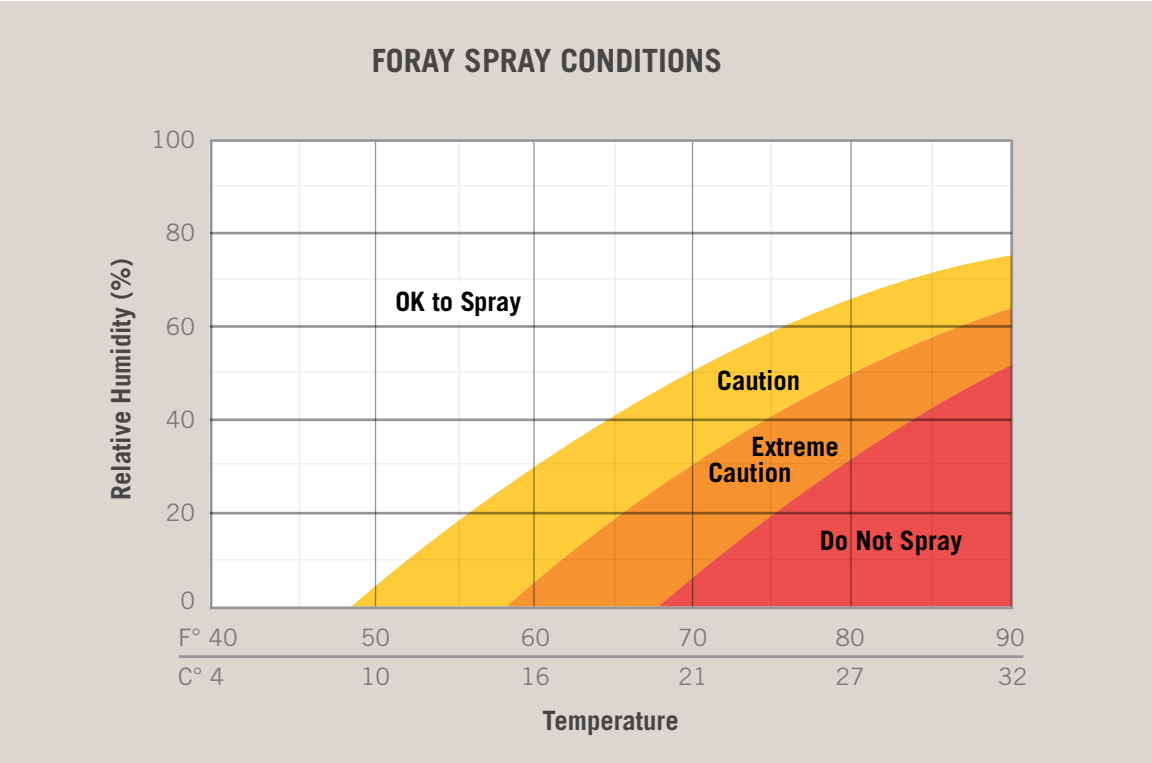
The ADAM kit has proven to be a valuable tool for forest protection program managers, especially in determining the need for a re-spray in the case of unexpected post-spray rainfall in the treatment area.

For further information on the ADAM kit, please contact your Valent Biosciences representative.

4.9 WEATHER CONDITIONS FOR SPRAYING

The weather has a tremendous impact on the aerial application process. Wind, temperature, and relative humidity (RH) affect how the spray is deposited on the forest canopy; temperature affects the feeding activity of the caterpillars, and sun and rain both serve to reduce the longevity of the Btk deposit.

Figure 4.9 Temperature/Relative Humidity relationship showing safe and unsafe meteorological conditions for spraying Foray.



Wind

Two considerations drive forest Btk application decisions: maximizing spray deposit in the forest canopy and minimizing spray drift outside the target area.

Wind is an factor affecting both variables.

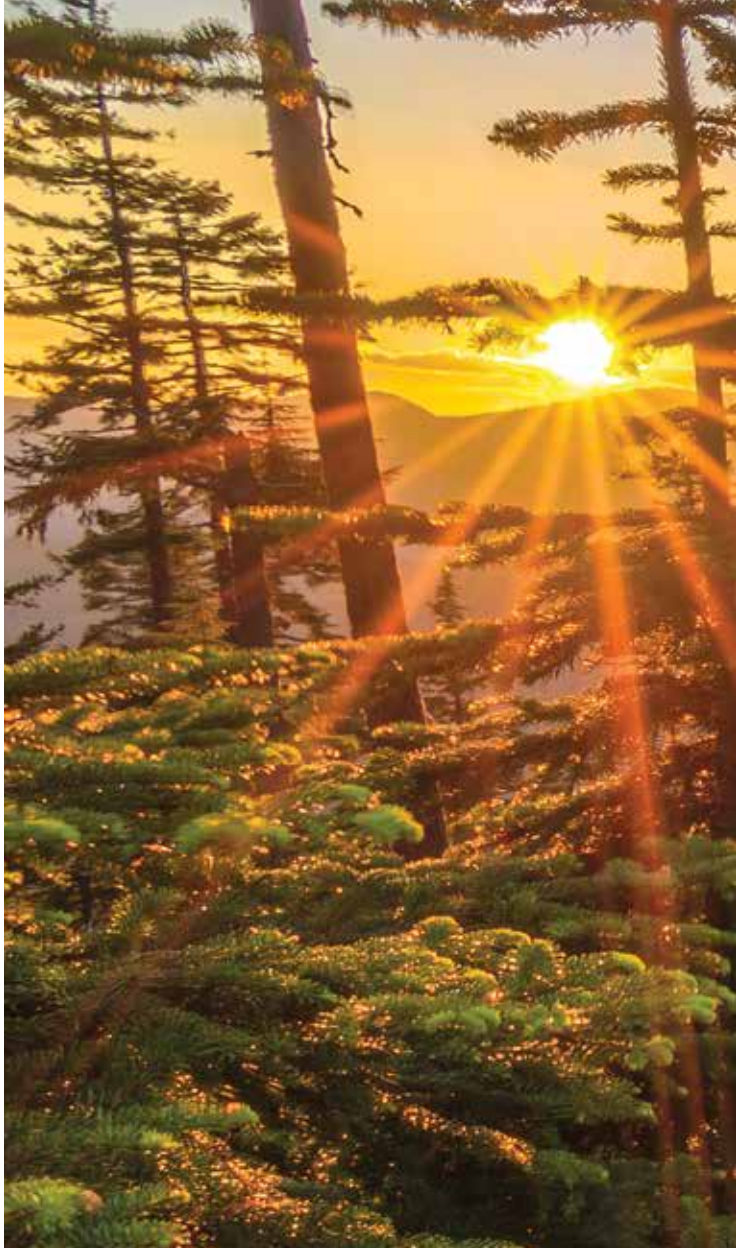
The best spraying conditions are under light to moderate wind with neutral stability, such as during cloudy or overcast days. Stable atmospheric conditions result in good foliage coverage in partly expanded broad leaf canopies, but carry the risk of drift of fine droplets, with little dispersal as the spray cloud drifts downwind.

The atmosphere shows a stable condition when air movements are dampened by the temperature gradient in the air. A temperature inversion, where a layer of cold air lies below a layer of warmer air after a cold clear night is a typical case of stable air. An unstable atmospheric condition occurs when any air movement is strengthened by the temperature gradient. A wind gust may start an upward movement which will then continue as a thermal. Neutral conditions imply that any air movement will not be dampened or magnified by the state of the atmosphere.

Temperature & Humidity

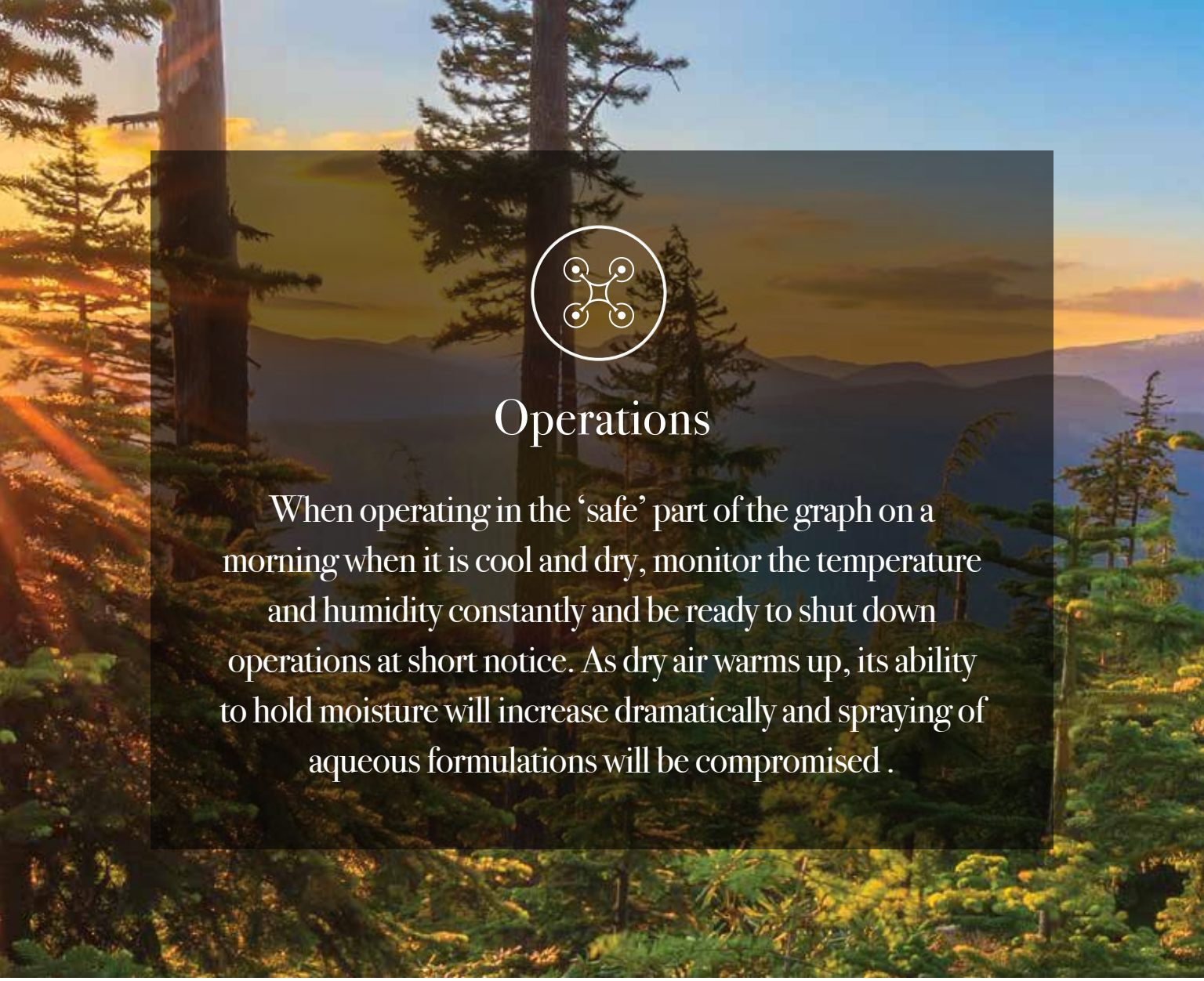
Foray aqueous formulations are designed to be highly resistant to evaporation under dry conditions but should never be sprayed under extreme conditions. Such extreme conditions are defined by a combination of temperature and humidity.

Relative humidity alone is not a valid parameter for determining whether or not you can spray. Cool air can be very dry, but because of its low temperature, it is not able to hold much moisture and does not substantially affect the evaporation of the water content of droplets.



In response to numerous subjective opinions on what is appropriate 'spray weather' and the use of seemingly arbitrary temperature and humidity conditions (e.g. 75° F, 50% RH), meteorological researchers at Penn State University were requested to develop a temperature/relative humidity reference chart that could be used in support of aerial spraying of Foray Btk formulations.

Figure 4.9 shows the risks of spraying Foray aqueous formulations under different temperature/



Operations

When operating in the ‘safe’ part of the graph on a morning when it is cool and dry, monitor the temperature and humidity constantly and be ready to shut down operations at short notice. As dry air warms up, its ability to hold moisture will increase dramatically and spraying of aqueous formulations will be compromised .

relative humidity conditions. The figure is advisory in nature and assumes that the correct droplet size is selected for the spray operation.

Because all Foray formulations are manufactured to be resistant to evaporation, the most common reason for shutting down spray operations during the day is vertical movement of air in thermal convection cells, which form after the air close to the ground has been heated by the sun. Applications made under such conditions can result in a highly variable coverage in the forest canopy and significant (but highly dispersed) spray drift.

This chart is also available in an electronic format that allows temperature and humidity readings to be plotted over time, allowing program managers the ability to detect a trend in weather during a spray operation and make appropriate decisions to continue or stop the operations due to current temperature and relative humidity conditions.

Rain & Dew

Formulation components of Foray provide good weatherability of spray deposits, particularly with undiluted applications. However, rainfall (1/10" [2.5 mm] or more) within several hours after spray application can reduce the biological activity of the spray deposit. It is recommended that a 6-hour period free of precipitation be allowed for the spray deposit to dry and adhere to the foliage.

Performance

A 6-hour period free of precipitation should be allowed for Foray spray deposits to adhere to the foliage and dry.

Foray should not be applied when rain is forecast within six hours. However, once the Foray deposit is dry, it is difficult to dislodge the droplets from the foliage surface.

If early morning dew (or previous night's rainfall) is sufficient to wet the foliage to the point of run-off, it is advisable to wait for a mild breeze or for warmer temperatures to dry the surface of the foliage before starting to spray. A small amount of foliage wetness (which does not produce run-off) will not affect the quality of the spray. However, if rainfall is forecast, ensure that the spray deposit has adequate time to dry before any precipitation. In general, six hours drying/feeding time is considered as adequate in these circumstances.

This cautionary 6-hour time interval can be reduced in certain circumstances. For example, if the spraying is completed in the morning and the spray deposit has had ample time to dry on the foliage, especially in sunny conditions, an afternoon rain shower should not have a negative impact upon the spray.

However, if the application was made during cool and cloudy weather which deteriorates into showers later that day, there will have been insufficient sunlight to dry the spray deposit adequately.

There is a great deal of subjectivity in the interpretation of the degree of foliage wetness that may prevent an aerial application. This lack of standardization led to the development of the Domino Foliage Wetness Scale for use by ground-based observers during Gypsy Moth control operations in Wisconsin. Five levels of leaf moisture were identified and are now used by ground observers to assess foliage wetness in the treatment areas.

DOMINO FOLIAGE WETNESS SCALE

1. **Dry**: No moisture visible or felt when limb is shaken or foliage is rubbed with fingers.
2. **Damp**: Moisture can be felt when rubbing foliage.
3. **Moist**: There are only several droplets of water coming off a limb when it is shaken.
4. **Wet**: It has rained at some point during the night. When you shake a limb, a fair amount of water falls, comparable to a sprinkle.
5. **Drenched**: It has recently rained; when a limb is shaken it simulates a steady rain.

(John Domino, Wisconsin Department of Agriculture, Trade and Consumer Protection.)

Cold Weather Operations

Aerial applications over forests are usually conducted in a forest canopy in which the new foliage has at least partially expanded and ambient temperatures encourage larvae feeding. At higher latitudes, such conditions may still provide considerable diurnal temperature variations, with the possibility of near freezing temperatures occurring over night.

A few common sense procedures minimize possible flow problems when applying Btk in cool weather conditions:

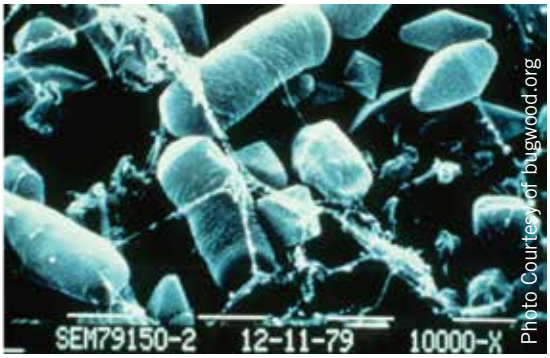
- If possible, store product in bulk, as it is less likely to experience changes in temperature and viscosity.
- Before loading aircraft, recirculate any product that may be in loading hoses back into the bulk storage containers. This will ensure that all product is of a similar viscosity, and allows for a quick check of equipment before the aircraft is loaded with product.

FREQUENTLY ASKED QUESTIONS

section 5

5.1 WHAT IS FORAY?

Foray is the brand name of a microbial biorational insecticide produced by Valent BioSciences. It contains the spores and unique crystalline proteins produced by a naturally occurring bacterium, *Bacillus thuringiensis* spp. *kurstaki* (Btk). These biological components are combined with approved ingredients and water to make the final product. Foray is commonly used to protect many forests, woodlots, and forested residential areas from defoliating caterpillar pests.



5.2 WHAT IS BACILLUS THURINGIENSIS OR Bt?

Bacillus thuringiensis or Bt is a naturally occurring spore forming bacterium that is found throughout most areas of the world. It can be found in soils and on leaves/needles and in other common environmental situations. When growing and reproducing spores, the bacteria also produces unique crystalline proteins. When eaten, these natural proteins are toxic to certain insects, but not to human beings, birds, or other animals.

Bacillus thuringiensis was first isolated in silkworm colonies in Japan the early 1900s, but it is named after the town of Thuringia in Germany where it was discovered killing flour moths a few years later. In 1938, the first commercial product was released in France, but commercial interest did not really develop until the late 1950s and early 1960s.

Today, various strains of Bt are produced commercially in several countries and are used to control pests in forestry, agriculture, and public health.

5.3 HOW MANY VARIETIES OF Bt ARE THERE?

There are several dozen varieties or subspecies of Bt, and they do not all share the same properties. *Bacillus thuringiensis* spp. *kurstaki* (Btk) is the most widely used, protecting agricultural crops, fruit trees, and rural and urban forests from defoliating lepidopteran larvae.

Other subspecies of Bt developed commercially by Valent BioSciences are subspecies *aizawai*, active against lepidopteran pests, *israelensis*, active against mosquito, gnat and blackfly larvae, *sphaericus*, active against mosquito larvae, and *tenebrionis*, which is active against some leaf eating beetle larvae.

5.4 HOW DOES Btk WORK?

Btk must be ingested by the target larvae in order to cause mortality. The ingested bacterium does not kill the larvae immediately, but instead sets a chain of events in motion that causes death of the larvae by multiple modes of action (sepsis and starvation).

Upon ingestion, the protein crystal metabolites (protoxins) produced by the Btk bacterium immediately begin interacting with the highly specific alkaline environment found in the gut of lepidopteran larvae. The gut of the insect is paralyzed and the larva ceases feeding within minutes. Soon after, the midgut wall of its gut becomes compromised: holes are formed in the midgut lining and the Btk spores contained in Foray begin germinating. The ongoing destruction of the midgut wall allows the bacteria to enter the circulatory system of the target insect, causing full-scale infection and death.

This process usually happens within a single day, but may take as long as 3-5 days. It is important to note, however, that the insect stops feeding within minutes of consuming Foray.

5.5 DOES Btk OCCUR NATURALLY?

Yes. Soil is the natural environment for Btk. Its ecological niche is infection of lepidopteran larvae, where it completes its life cycle. Various species and strains of Bt were isolated from urban, forest, and agricultural soils long before the material was used in insect control programs. Bt has been detected in soils and other substrates around the world including Canada, the United States, Japan, Germany, France, and Israel. Bt can also be found on the leaves of deciduous and coniferous trees and some varieties of Bt have also been found in grain elevators and grain dust.

5.6 HOW IS FORAY MADE?

Foray is produced from Btk using a proprietary, industrial-scale fermentation process developed by Valent BioSciences and conducted at its state-of-the-art manufacturing facility in Osage, IA. This process is similar to the technology used for the production of antibiotics.

The process begins with a small flask of pure Btk inoculum that is introduced into enclosed, sterilized fermentation tanks along with an optimized combination of growth media, water, heat, and aeration (among others). As the bacteria reproduce, all aspects of the fermentation broth are monitored and precisely controlled. Foray is unique in that its best-in-class manufacture includes a step-wise bioassay process to validate its efficacy on live insects all the way through production and final formulation. The fermentation broth containing spores and crystalline proteins is formulated with approved ingredients and water to make the final formulation of Foray.

5.7 HOW IS FORAY DIFFERENT FROM CHEMICAL INSECTICIDES?

Btk is not a chemical insecticide, rather it is a naturally occurring organism. Chemical pesticides have a single mode of action (making them susceptible to insecticide resistance) and typically kill a wider range of insects, including many beneficial ones. The active ingredient of Foray is a natural bacterium, *Bacillus thuringiensis*, spp. *kurstaki* Strain ABTS-351. This strain of Btk produces a finely balanced profile of four different protoxins specific to the larvae of certain caterpillars.

This means that non-targets (birds, bees, fish, people) are unaffected by Foray. Foray is quickly biodegraded in nature, unlike a number of chemical pesticides that form by-products and residues of environmental concern. Most formulations of Foray are approved in Certified Organic programs.

5.8 WHY IS FORAY THE Btk YOU SHOULD USE?

Foray was developed in response to growing concern among the scientific community, policy makers, and the public in the 1960s and 70s over the use of chemical pesticides. At that time, forest managers realized that an alternative to broad spectrum chemical insecticides would be needed if protection against defoliators was to remain a component of future forest management efforts. In order to be successful, the new insecticide would have to be:

- Highly effective when applied in small amounts
- More target-specific than synthetic chemicals
- Formulated such that it can penetrate dense foliage to hit target leaves
- More quickly broken down in the environment than synthetic chemical compounds
- Harmless to non-target organism populations such as bees, birds, fish and mammals
- Comparable to the cost of chemical insecticides

The Caterpillar Bioassay Laboratory

Expert entomologists in Osage diligently maintain insect colonies to provide a continuous supply of insects for bioassay testing. Insects are maintained at various stages of their life cycles in order to ensure healthy and consistent populations.

Sustaining the Insect Colony

Expert entomologists in Osage diligently maintain insect colonies to provide a continuous supply of insects for bioassay testing. Insects are maintained at various stages of their life cycles in order to ensure healthy and consistent populations.

Fermenter

Large-scale fermentation is used to grow microorganisms using a proprietary process that includes sophisticated controls and monitoring. The fermentation process takes multiple days, with production time varying by the product. A proprietary media mix is inoculated with VBC's proprietary organism strains, continually tested for purity. Valves and piping allow for multiple inputs including air and nutrients.

Fermenter Motor and Drive

Fermentation requires a significant amount of agitation powered by a motor and drive system mounted on top of the tank. The large hatch on the right is called the manway, which gives technicians access to the tank between production runs.

Btk was not an immediate success in terms of effectiveness and cost, but intensive research and development has resulted in a product that now meets all of these criteria. Foray (first registered in 1986) is now the product of choice in the majority of forest protection programs in North America and western Europe due to its formulation science, unique strain, and superior quality. This product has gained an unprecedented level of public acceptance and as a result, Foray is the most widely used biological larvicide in the world to protect trees from insect infestations in both rural and urban settings. The foundation of Foray's success is simple and two-fold: it is both highly effective and ecologically friendly. In fact, some formulations of Foray are approved for use in the production of certified organic products, such as maple syrup.

Performance

Because of its high efficacy and environmental friendliness, Foray is the product of choice in local pest eradication efforts in North America and many other locations around the world–particularly to control invasive species, such as Gypsy Moth.

5.9 HOW EFFECTIVE IS FORAY?

Foray efficacy has been proved to be comparable to chemical applications in controlling many lepidopteran pests when pest population densities are low to moderate. As it is not systemic and requires ingestion, Btk is less likely to be as effective as chemicals when pest populations are extremely high unless multiple applications are conducted.

However, a forest pest control strategy does not have to kill all the target insects in order to be successful. In fact, studies indicate that there are benefits to maintaining some pest insects in an area to support the population of natural enemies.

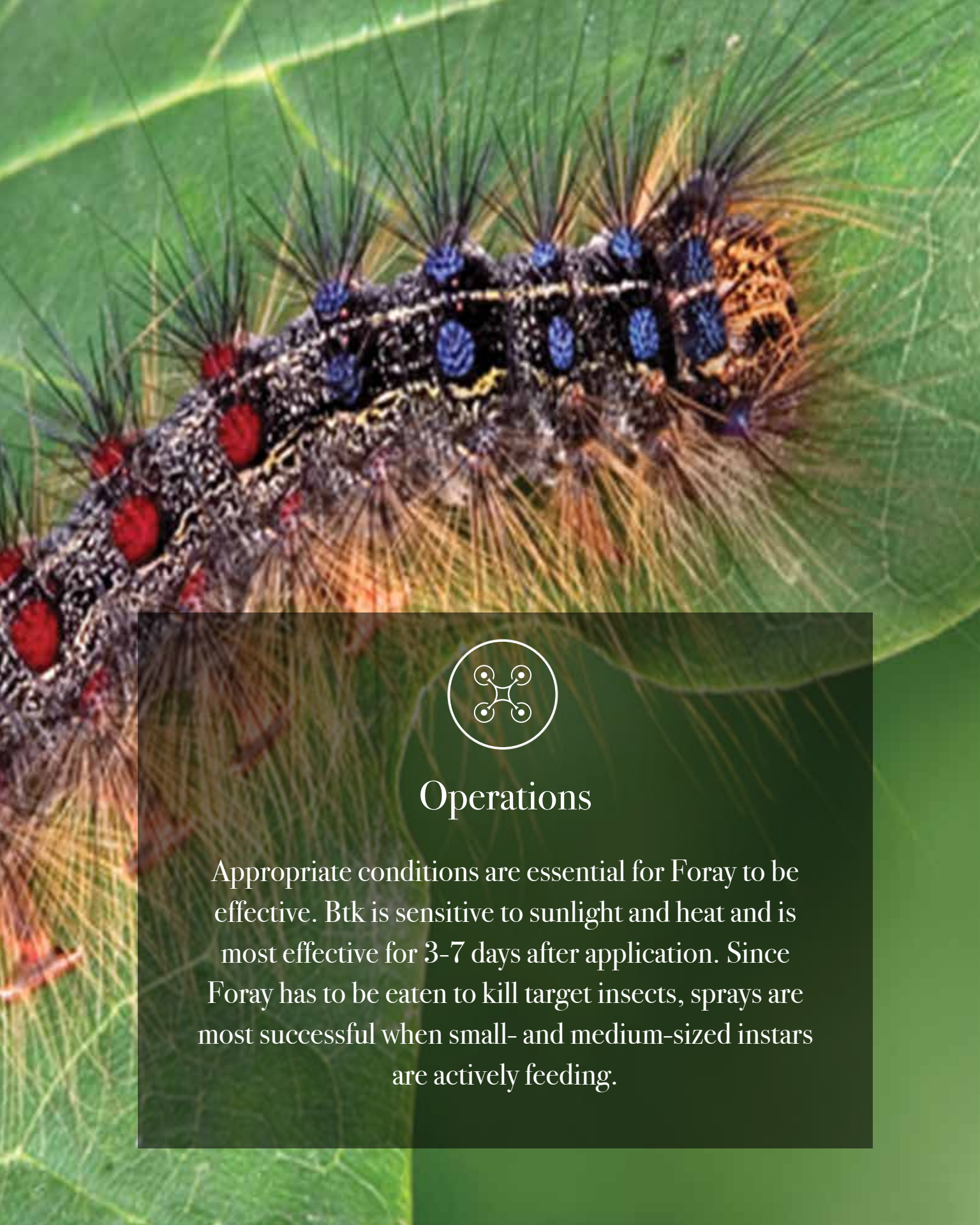
Because it can take up to a few days for larvae to die after a Foray application, there is not an immediate reduction in the pest population. When using Foray, it is important that forest health managers understand that Lepidoptera feeding cessation occurs within minutes of ingesting Foray, and that death to affected larvae is imminent.

Depending on the life cycle of the pest and climatic conditions, more than one application of Btk may be necessary to achieve the desired level of control.

When eradication is the goal of a control program, a single application of Btk may be somewhat less effective than some chemical insecticides in reducing the population to zero. However, because of its low impact on non-target organisms, Btk is the product of choice for most forest pest control programs (including eradications) conducted in North America and around the world.

5.10 IS FORAY HARMFUL TO HUMANS AND ANIMALS?

As required by the United States Environmental Protection Agency (EPA) and the Pest Management Regulatory Agency (PMRA) of Health Canada, extensive oral and intravenous animal studies have been conducted with



Operations

Appropriate conditions are essential for Foray to be effective. Btk is sensitive to sunlight and heat and is most effective for 3-7 days after application. Since Foray has to be eaten to kill target insects, sprays are most successful when small- and medium-sized instars are actively feeding.

Foray. No evidence of any poisonous, infectious or disease-causing effects were found. In inhalation tests with Btk, there were no mortalities and Btk was shown to have a low pathogenic potential.

Feeding, skin, breathing, and eye irritation animal studies were also carried out with Foray. No toxic effects were seen when significant quantities of Foray were fed or inhaled. Very mild, temporary skin irritation and moderate, temporary eye irritation was observed in the tests when Foray were applied directly to the skin and into the eyes. These effects were totally reversible.

In addition, EPA and PMRA have determined that Foray is exempt from residue tolerance. Due to this exemption, there is no required interval before re-entering a sprayed area during government-sponsored pest control programs.

Finally, Btk has been used extensively in commercial urban and rural forest pest management for over 40 years. A solid record of safety and health has been amassed over this time.

Sustainability

Foray is based on the ubiquitous, naturally-occurring soil dwelling bacterium, Bacillus thuringiensis spp. kurstaki (Btk). While highly effective against various species of Lepidoptera, Btk has little to no impact on non-target species and the surrounding environment. In fact, Btk and other common microbes are frequently found in blood, urine, and other samples from healthy people.

5.11 WHAT EFFECT WILL Btk HAVE ON PEOPLE, ESPECIALLY THOSE WITH IMMUNODEFICIENCY, ASTHMA OR ALLERGIES?

Bt is a common bacterium found in soils throughout the world. People are exposed to Bt and many other microbes every day. Many of the microbes we encounter, including Btk, do not produce any toxins which affect humans. Btk and other common microbes are frequently found in blood, urine, and other samples from healthy people. It has been shown that the presence of Btk in patient specimen samples is not indicative of pathological or toxic effects. As with many other microbes naturally present in the environment, it can be detected as an insignificant contaminating organism among infection-causing organisms isolated from patient samples.

Individuals with an immuno-deficient condition are somewhat more likely to be affected by microbes that are normally controlled by a healthy immune system. Such microbes are referred to as opportunistic pathogens, and Bt is not considered an opportunistic pathogen.

Exposure to a Btk spray program is not likely to result in the development of new allergies, asthma or other hypersensitive reactions. Individuals with pre-existing allergies, asthma or hypersensitive individuals, especially those sensitive to normal exposure to soil or smoke and pollutants, could feel some temporary effects. Note that in studies conducted by public health agencies in Canada and in New Zealand, there was no increased incidence of asthma in children living within a treatment area compared to children living outside of the treatment area.

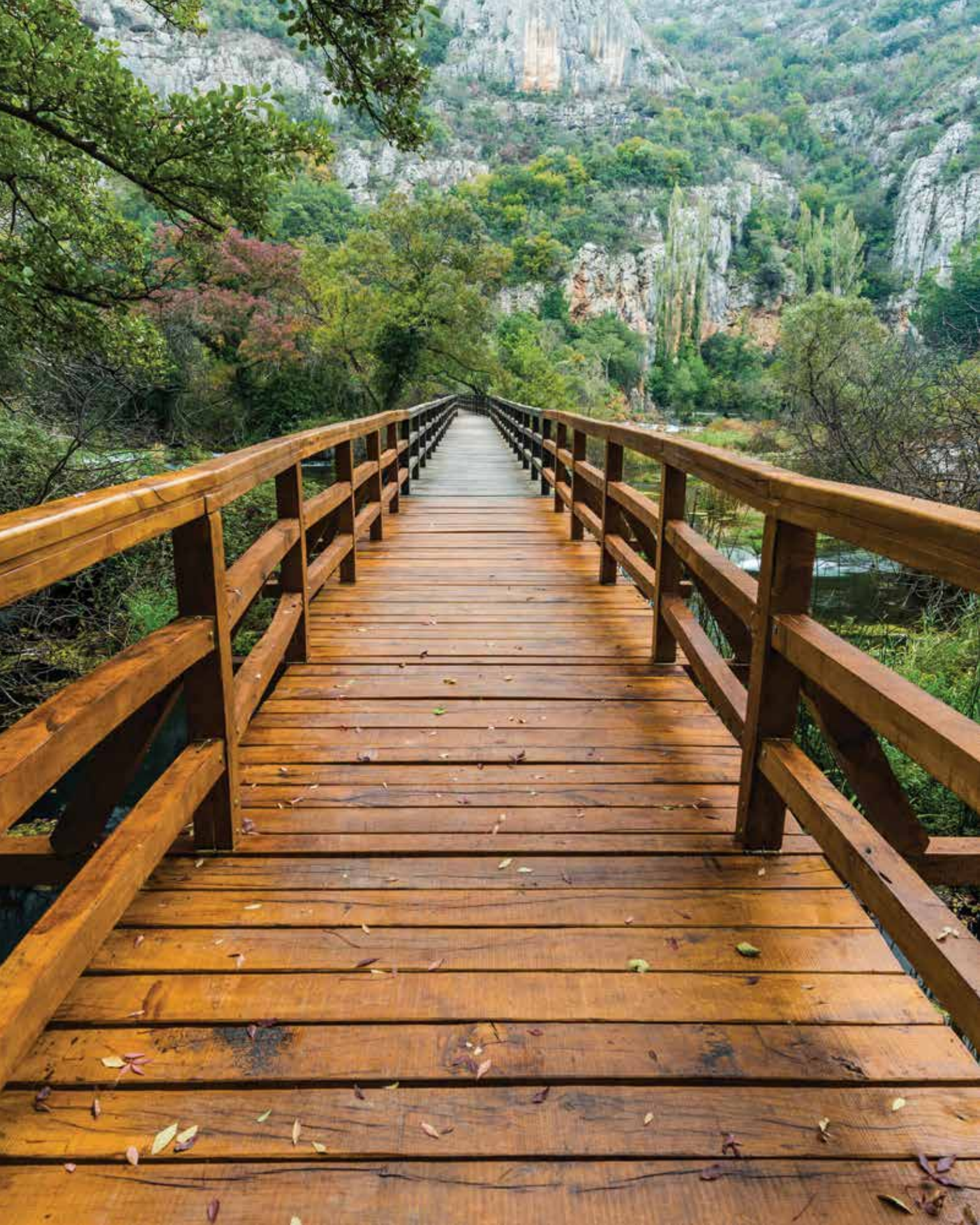


Photo Courtesy of U.S. Forest Service

It is wise for Forest Health managers and applicators to make proactive communication with the public part of their application strategy.

The exposure level to Btk from an aerial spray program is very low in comparison to the levels applied in safety and health related testing. Btk has been shown to be of low risk to residents of forested residential areas when aerially applied to control forest defoliators. That safety record has been confirmed in over 40 years of use in urban and rural applications.

While it may be true that applications of Foray do not pose risks to human health, it is wise for Forest Health managers and applicators to make proactive communication with the public part of their application strategy. Individuals with any of the particular medical conditions described above should consider seeking the advice of their physician prior to the start of the spraying program. Furthermore, residents of the treatment areas may wish to remain indoors during the actual time of treatment to allow the fine droplets to deposit on the foliage.

5.12 WILL FORAY INJURE PLANTS?

Foray has been sprayed on millions of acres of trees and other plants. There have been no reports of any plant damage. Foray and other Bt products produced by Valent BioSciences are commonly used in commercial agriculture, market gardens and in greenhouses.

5.13 IS FORAY HARMFUL TO NON-TARGET ANIMALS, BIRDS AND BENEFICIAL INSECT POPULATIONS?

No. Foray has been tested against mammals, birds and other insects. In all cases, when Foray was tested at doses far in excess of the levels to which these organisms would be exposed during a routine

forestry or urban tree spray program, no harmful effects were observed.

5.14 IS FORAY HARMFUL TO AQUATIC ORGANISMS?

Foray has shown no adverse effects in aquatic environments. Btk has been tested against freshwater fish and aquatic invertebrate. After extended exposure tests, there were no adverse effects observed.

5.15 CAN Btk GROW AND REPLICATE IN THE ENVIRONMENT?

Btk is a naturally occurring bacterium but it requires alkaline conditions to complete its life cycle. The vegetative form of Btk is generally not well adapted to soil, and it requires the specialized habitat of vulnerable insects to persist. However, Btk endospores can survive in some soils for at least four months. Foliage, water, and acidic soils are not suitable environments for Btk growth and replication. In these environments, Btk will degrade quite rapidly.

5.16 WON'T TARGET INSECTS BUILD UP A RESISTANCE TO Btk?

It is very unlikely that forest pests will build up a resistance to Btk. For an insect species to develop resistance to a pesticide, it must produce several generations per year and must be exposed to multiple applications of the pesticide over a relatively short period of time. Moreover, the 1:1 active ingredient-to-receptor-site dynamic between chemical insecticides and target pests is fundamental to the onset of resistance. With its multiple modes of action and a multiple protoxin profile, resistance to Foray has never been observed in the field. As a result of the combined effect of all these factors, resistance to Btk in forestry applications is highly unlikely to develop.

It should be noted that more intensive spray programs are used to control agricultural pests, and there are a few recorded incidents of Bt resistance after repetitive (10-20 applications/season) applications of Btk to control diamondback moth. In forestry, only a very small area of the total forest is sprayed, and that area will likely not receive more than two or three treatments over the entire lifespan of the trees. The pest population exposure to Btk remains, therefore, extremely low.

The techniques of implanting Btk genes into cotton and food crops have been shown to lead to the development of resistance in the species that feed on the plants. However, these genes do not express the full profile of protoxins present in Foray nor do those particular insect pests cause infestations on tree species. It is also highly unlikely that Btk genetic material will ever be implanted into forest tree species.

5.17 WHAT ELSE IS IN FORAY BESIDES BTK? WILL THESE OTHER INGREDIENTS HARM THE ENVIRONMENT?

Foray is a biological insecticide which contain spores and crystal-shaped proteins produced by the naturally occurring bacterium *Bacillus thuringiensis* spp. *kurstaki*, or Btk. Foray is a very selective insecticide and is not designed as a broad-spectrum control.

All of VBC's industry-leading Bt products, including Foray, are produced in a similar fashion. Btk is grown in large enclosed fermentation tanks. Foray is produced using ingredients and a technology that is similar to those which are used to make many pharmaceuticals, beer, or spirits. During fermentation, the bacteria (Btk) reproduce in a pre-sterilized growth medium containing basic food sources, such as corn, potatoes, grains, etc. After the fermentation is complete and the bacteria are grown, the fermentation material, including Btk, is collected. This material becomes the basic ingredient of Foray.

This basic ingredient is composed of Btk, which is the active ingredient, and the residual fermentation growth material and water. The water and residual fermentation growth material are referred to as "inerts" or inactive, because they are not "active" against insects. Several other inerts are added to this fermentation material, Btk, and water to make up the final formulations of Foray. These other ingredients comprise a small proportion of the total formulation.

For example, nearly 90% of Foray 48B is composed of water, the residual fermentation growth material, and Btk. The one other inert is a food-approved carbohydrate.

The other inert ingredients are added to maintain the quality of the Foray formulation: to make it easier to handle and apply, and to protect the activity of the Btk. Some of these ingredients help ensure the microbial quality and purity of the Foray formulation by acting to control the level of possible contaminating natural microorganisms. These ingredients, added in very minor amounts to control contaminating bacteria and molds, are also used in many foods in Canada and the US. for the same purpose. All components in Foray formulations are EPA- and PMRA-approved, and many are used in food or in the production of food. Most formulations of Foray are approved in Certified Organic programs.

Sustainability

All inert ingredients in Foray formulations are included in 40 CFR 180.1001. This list has been designated by the US EPA as "exempt from the requirements of a residue tolerance on raw agricultural commodities."

5.18 HOW CAN WE PROVE THAT BTK IS NOT A HARMFUL PRODUCT?

One can't prove a negative. In the case of Foray and other VBC Bt-based insecticides, we can only cite decades-worth of empirical data and demonstrate that when Btk is applied following the label instructions, that the risk to nontarget organism populations, whether they are birds or humans, is acceptably low.

As a society, we must set standards and we do not permit the sale of commercial products until they have met the safety standards set forth by the scientific community and policy makers. Foray meets or exceeds the safety standards set in the US, Canada, and in all other countries. It should be noted that Canada has some of the toughest regulatory standards in the world. Most formulations of Foray are approved in Certified Organic programs.

5.19 WILL FORAY CAUSE DAMAGE TO CAR FINISHES?

No. There is nothing in Foray that will cause damage to automobile finishes. Foray products are formulated to stick to the surface of leaves when dry. Therefore, it is easiest to remove the spray deposit from any surface while it is still wet. To remove dried Foray deposits from any surface, simply soak the dried droplets with water and then sponge or wipe with a soft cloth. As with many other foreign substances such as frass, bird droppings, or pulverized insect residue, a cleaning product normally labeled for car washing may be needed if the dried spray has been on the surface for several days. The sooner the surface is cleaned, the easier it will be to remove the spray droplets.

Appendices

APPENDIX 1: SOURCES & RESOURCES

This section lists manufacturers of equipment and products and sources of information which can facilitate your operations. We have tried to make this manual as comprehensive as possible, but invariably we may have left out some key contacts. Please contact us with any omissions; for inclusion in future versions. References used in the production of this manual are listed in Appendix 4.

As always, if a name of a supplier appears in our list, is should not be considered as an endorsement by Valent BioSciences. Rather, it is an industry-recognized supplier of the product or service.

Businesses move or merge, mail and electronic addresses change, new area codes appear and websites may change. At time of writing, every effort has been made to have up-to-date information. If you find that some of the information is outdated, please contact Valent BioSciences so we can update the information for the next release of the Manual.

ATOMIZERS

Hydraulic:

TeeJet Nozzles

Spraying Systems Company
200 W. North Ave.
Glendale Heights, Illinois USA 60139
Tel: 1 630 665-5000
Fax: 1 630 260-0842
Website: www.spray.com

Rotary:

Micron Sprayers (Micronair)
Bromyard Industrial Estate,
Bromyard, Herefordshire,
HR7 4HS, U.K.
Tel: +44 (0) 1885 482397
Fax: +44 (0) 1885 483043
Micronair
Bembridge Fort
Sandown, Isle of Wight, PO36 8QY
England
Tel: +44 1983 406111
Fax: +44 1983 404461

Photo Courtesy of the Micron Group

For local distributors, and further information about rotary atomizers and additional application equipment, please consult their website.
Website: http://www.microngroup.com

FLOW METERS

Crophawk flow monitors and data recording systems

Onboard Systems
13915 NW 3rd Court
Vancouver, WA 98685 USA
Toll free: 800-275-0883
Tel: 360 546 3072

Fax: 360 546 3073
Website: https://www.onboardsystems.com

Micronair flow monitoring turbines and recording systems: See Micronair, page 67.

DIFFERENTIAL GPS EQUIPMENT

MANUFACTURERS

Most DGPS manufacturers now provide a complete suite of aerial application control equipment, including DGPS linked flow controls, auto ON-OFF, granular metering gates, and fleet management software. Some companies, such as AG-NAV even provide spray optimization software and onboard meteorological systems.

AG-NAV
30 Churchill Drive
Barrie, Ontario, Canada L4N 8Z5
Toll free: 1-800-99-AG-NAV (24-628)
Tel: 905-764-3744
Fax: 905-764-3792
Website: https://www.agnav.com

DynaNav Systems Inc
730-11731 Baynes Road
Pitt Meadows Airport
Pitt Meadows, British Columbia
Canada V3Y 2B3
Toll free: 1 877 333 9626
Tel: 1 604 4645 009
Fax: 1 604 465 0084
Website: http://www.dynanav.com

SATLOC
Transland LLC
1206 Hatton Rd., Suite A,
Wichita Falls, Texas 76302
Tel: 1 940 687 1100
Fax:1 940 687 1941
Website: http://www.satloc.com/

TracMap
15 East Gabilan St.,
Salinas CA 93901 USA
Toll Free: 1 888 656 3165
Tel: 1 831 800 6768
Website: www.tracmap.com

DROPLET ASSESSMENT TECHNOLOGIES

REMSpC's Stainalysis is available online free of charge.

To download the software, visit http://www.remspc.com/Stainalysis/

COLOR TRACERS & DYES

Several manufacturers now produce dyestuff in powder or liquid formats specifically for spray pattern testing. Remember, when using dye to color the spray to facilitate droplet scanning and assessment, use a high rate of dye to ensure adequate coloring of the small droplets. Otherwise these small but important droplets will not be dark enough to provide a visible contrast for image detection and analysis by the scanning devices.

Powder dyes are generally less expensive than liquid dyes but must be thoroughly mixed with water before adding to the spray tank.

Liquid dyes are easier to use but may have some shipping restrictions.

Dyestuffs traditionally used for these purposes are no longer in production or are now restricted to industrial uses only. It is recommended that you consult with the manufacturers about your specific needs.

BASF Chemical:
Turf Mark® 10059 Spray Indicator
Website: https://betterturf.basf.us
Available from numerous online suppliers

Milliken Chemical:
Blazon® Turf Dye
920 Milliken Rd.,
Spartanburg South Carolina,
USA 29303
Toll free:1 800 910 5592
Fax: 866 503 2430
Website: https://chemical.milliken.com

Sensient Colors:
SensiPro™ Application Colorant
Sensient Technologies Corporation
World Headquarters
777 East Wisconsin Avenue
Milwaukee, Wisconsin 53202-5304 USA
Tel: 1 414-271-6755
Website: www.sensientindustrial.com

Blazon Turf Dye
Milliken Chemical: North America, Europe

Sensi-Pro, powder & liquid
Sensient Colors, Global

Turf Mark, various powder & liquid
BASF Chemical: Global

SPRAY DEPOSIT CARDS & PAPERS

Kromekote Cards

Kromekote® paper has been used for many years by printers for brochures and calendars etc. It is recommended to use card stock that is glossy on both sides to prevent card warping in moist environments; this will be referred to as Kromekote C/2S.

Since spread factors will vary depending upon the quality of 'Kromekote' cardstock used, it is preferred to use only one supplier for spray cards, or at least determine the brand name and specifications of the cardstock that is used so that you will have consistency in your card stock.

Many print shops carry coated card stock, and will be able to cut it to size. For typical Btk spray deposit analysis, 2" x 3" to 3 X 5" (5 cm X 7.5 cm to 7.5 cm to 12 cm) Kromekote cards are an ideal size.

Request "coated card stock, coated two sides."

Water Sensitive Cards

Manufactured by Syngenta and currently available from numerous sources, including online discount suppliers. A universal supplier is TeeJet Technologies, a business division of Spraying Systems. Also numerous local pesticide equipment dealers and related retail outlets also carry a supply of water sensitive papers. (Gempler's, Sprayer Depot, etc.)

TeeJet Technologies,
200 W. North Ave
Glendale Heights, Illinois
USA 60139
Tel: 1 630 665 5000
Fax: 1 630 665 529
Website: www.Teejet.com (Search Tech Support> Nozzle Technical Information>Calibration/ Adjustment Accessories)

Numerous local pesticide equipment dealers and related retail outlets also carry a supply of water sensitive papers. (Gempler's, Sprayer Depot, etc.)

PUMP SEALS

The following companies are major manufacturers of mechanical pump seals; these suppliers can direct you to distributors for service in your area.

FlowServe®, Inc.
5215 N. O'Conner Blvd.,Ste 2300
Irving Texas USA 75049
Tel: 1 972 443 6500
Fax: 1 972 443 6800
Website: www.flowserve.com

John Crane® Inc.
227 West Munroe St.
Suite 1800
Chicago, Illinois USA 60606
Tel: 1 312 605 7882
Website: www.johncrane.com

US Seal Manufacturing™
400 Apgar Dr #A,
Somerset, New Jersey
USA 08873
Toll free: 1 800 243 5489
Tel: 1 732 667-1100
Fax 1 877 849 7325
Website: www.ussealmfg.com

SPILL NOTIFICATION

Chemtrec Spill Notification Network
(800) 424-9300

Chemtrec (Chemical Transportation Emergency Center) is a public service of the Manufacturing Chemist Association to deal with chemical transportation emergencies.
In the event of chemical transportation emergency, Chemtrec provides immediate advice for those at the scene of emergencies, then promptly contacts the shipper of the chemicals for more detailed assistance and appropriate follow-up.

APPENDIX 2: PRODUCT CONTAINERS AND DIMENSIONS

DRUM

Outside Diameter:	23 ¼"
Outside Height:	34 ¾"
Color:	Blue
Body:	High molecular weight polyethylene with ultraviolet light protection.

MINI BULK

Capacity: 1000 litres	275 gallons
Length:	47 ¼"
Width:	40"
Height:	45 ¾"
Color:	White
Body: polyethylene	Blow molded high density
Cage:	¼" solid rod steel
Filling port:	6"
Discharge Valve:	2" ball style valve. NPT threading
Stacking:	2 high

BULK TANKER

Capacity:	Up to 7,000 gallons
Tank Length:	43'
Tank Height:	12'
Unloading:	Center or rear

APPENDIX 3: INSECT PESTS CONTROLLED WITH FORAY BTK

Foray Biological Insecticide (Btk) is registered for use on a wide variety of major and minor forest Lepidoptera pests in many countries around the world. Table 1 shows a list of the most common forest Lepidoptera against which Foray has been successfully used.

Table 1. Most common pests Foray is used to control

COMMON NAME	LATIN NAME	MAIN HOST(S)
Eastern Spruce Budworm	*Choristenaura fumiferana*	Balsam Fir (*Abies balsamea*), White Spruce, Black Spruce, Red Spruce (*Picea* spp.)
Western Spruce Budworm	*Choristenaura occidentalis*	Primarily Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), true firs (*Pseudotsuga* spp.), Larch (*Larix* sp.), Spruce (*Picae* spp.)
Jack Pine Budworm	*Choristenaura pinus pinus*	Jack Pine (*Pinus anksiana*), Scots Pine (*Pinus ylvestre*)
Pine Moth (or Pine Lappet Moth)	*Dendrolimus pini*	Scots Pine (*Pinus sylvestris*), occasionally other conifers such as Fir (*Abies*), Spruce (*Picea*) and Larch (*Larix*)
Douglas-Fir Tussock Moth	*Orgyia pseudotsugat*	Douglas-Fir (*Pseudotsuga menziesii*), Grand Fir (*Abies grandis*), Subalpine Fir (*Abies lasiocarpa*), White Fir (*Abies concolor*), and less frequently on Ponderosa pine (*Pinus ponderosa*), Eastern Larch (*Larix occidentalis*)
Gypsy Moth	*Lymantria dispar*	Most species of Oak (*Quercus*), as well as Apple (*Malus*), Basswood (*Tilia*), Willow (*Salix)*, and many other species of trees and shrubs. It is estimated that Gypsy Moth will feed upon over 500 species of trees shrubs and vines.
Eastern Hemlock Looper	*Lambdina fiscellaria fiscellaria*	Balsam fir (*Abies balsamea*), Hemlock (*Tsuga canadensis*) and occasionally Spruce (*Picea*), and Larch (*Larix*)

COMMON NAME	LATIN NAME	MAIN HOST(S)
Western Hemlock Looper	*Lambdina fiscellaria lugubrosia*	Primarily Western Hemlock (*Tsuga heterophylla*), Sitka Spruce (*Picea sitchensis*), Pacific Silver fir (*Abies amabilis*), Western Red Cedar (*Thuja plicata*) and Douglas-fir (*Pseudotsuga menziesii* var. *glauca*)
Nun Moth	*Lymantria monacha*	Spruce (*Picea*), Pine (*Pinus*). Fir (*Abies*), Larch (*Larix*) Oak (*Quercus*), Maple (*Acer*), Birch (*Betula*), Ash (*Fraxinus*) and sometimes, fruit trees
Pine Processionary Moth	*Thaumetopoea pityocampa*	Pine (*Pinus* sp.), Cedar (*Cedrus* sp.) and occasionally European Larch (*Larix decidua*)
Forest Tent Caterpillar	*Malacosoma disstria*	Sugar Maple (*Acer saccharum*), Red Oak (*Quercus rubra*), Trembling Aspen (*Populus tremuloide*s), White Ash (*Fraxinus americanus*), White Birch (*Betula papyrifera*), fruit trees and others

Foray also controls other lepidopteran defoliators. For formulation, region-specific labels, and application recommendations for other forest Lepidoptera, contact your local Valent BioSciences Forest Health representative.

APPENDIX 4: REFERENCES

Otvos, I.S. and S. Vanderveen. 1993. Environmental report and current status of *Bacillus thuringiensis* var. *kurstaki* use for control of forest and agricultural insect pests. Forestry Canada and Provincof British Columbia, Ministry of Forests; Victoria, B.C. 81 pp.

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Bacillus thuringiensis: Biology, Ecology and Safety. Glare, T and O'Callaghan, M. John Wiley & Sons Chichester UK. 2000 ISBN 0-471-49630-8

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Kreutzweiser, D.P., S.S. Capell, and D.R. Thomas.

1994. Canadian Journal of Forest Research 24: 2041-2049 Aquatic insect responses to *Bacillus thuringiensis* var. *kurstaki* in a forest stream. Phero Tech Inc. and Deloitte & Touche. 1994. A risk assessment of European Gypsy Moth in British Columbia. Report prepared for the B.C. Ministry of Forests, Agriculture Canada, and the B.C. Ministry of Agriculture, Fish and Food. 73 pp. Reardon, R. and A.E. Hajek. 1995. Gypsy Moth News 39: 3-4 Entomophaga maimaiga in North America: A review.

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Health Risk Assessment of the Proposed 1997-1998 Control Programme for the White-Spotted Tussock Moth in the Eastern Suburbs of Auckland, NZ. A report to the Ministry of Forestry. Public Health Protection Service, Auckland Healthcare Services Limited. September, 1997, 79pp.

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D.R. Miller, R.C. Reardon and M.L. McManus (1995) An Atmospheric Primer for Aerial Spraying of Forests USDA Forest Service-Pub FHM-NC-07-95.

Van Frankenhuizen, K., N. Payne, L. Cadogan, B. Mickle and A. Robinson (1996) Effect of droplet size spectrum and application rate on field efficacy of *Bacillus thuringiensis*. Report submitted to the Spray Efficacy Research Group.

N.R. Dubois, K. Mierzejewski, R. C. Reardon, W.

McLane, and J.J. Witcosky (1994) J. Environ. Sci. Health, B29(4), 679-695 *Bacillus thuringiensis* Field Applications: Effect of Nozzle Type, Drop Size, and Application Timing on Efficacy Against Gypsy Moth. Dubois, Normand R., Richard C. Reardon and Karl Mierzejewksi (1993) Field Efficacy and Deposit Analysis of *Bacillus thuringiensis*, Foray 48B, against Gypsy Moth. Journal Econ. Entomol. 86 (1) 27-33.

Maczuga, Steven A. and Karl J. Mierzejewski (1195) Journal Econ. Entomol. 88 (5) 1376-1379 Droplet Size and Density Effects of Bacillus thuringiensis kurstaki on Gypsy Moth.

Other information sources include internal research reports performed by and for Valent BioSciences and manufacturer literature.

APPENDIX 5: FORAY TOXICOLOGY PROFILE

Foray is a selective, microbial insecticide that effectively protects forests throughout the world from defoliating lepidoptera larvae, including Gypsy Moths, spruce budworms, and other leaf-eating caterpillars.

The active ingredient in Foray, *Bacillus thuringiensis* spp. *kurstaki*, or Btk, is a naturally occurring bacterium commonly found on foliage and in soil. Unlike chemicals, Foray works by quickly paralyzing the digestive system of the pest after the active ingredient, Btk, is eaten, causing the insects to stop feeding immediately and die within a few days. Foray formulations are used to economically and effectively control a wide variety of damaging forest pests.

Toxicity Studies

Oral Toxicity Studies

No oral toxicity has been demonstrated in rats given Foray at 5000 milligrams per kilogram of animal body weight. In a separate study, a dose of 108 Btk Colony Forming Units (CFU: a measure of viable spore concentration) did not cause any toxic or pathogenic effects.

Inhalation Toxicity Studies

No toxic effects were observed in rats exposed to approximately 7 milligrams of Foray per liter of air for 4 hours.

The low pathogenic potential of Btk was demonstrated when rats were exposed to a concentration of approximately 108 CFU of Btk per liter of air for 4 hours. No overt symptoms of toxicity have been reported by individuals during the use of this or other Btk containing products.

Dermal Toxicity Studies

No toxic effects were observed when Foray at 2.5 gram per kilogram of body weight was applied as a single dose exposure to the skin of rats.

Dermal Irritation Studies

Very mild, temporary dermal irritation was seen when Foray was applied to the skin of rabbits for 4 hours. All signs of irritation cleared in all animals within 2 days after application.

Eye Irritation Studies

Foray was moderately irritating in a rabbit eye irritation test. No apparent redness or other ocular finding remained 7 days after the application of 109 CFU of Btk to the eye.

I.V. Injection Studies

A single I.V. dose of 108 CFU of Btk was not toxic to rats. Btk was not able to multiply in the tissue as examined periodically during the 167 days of the study.

Freshwater Fish Toxicity Studies

No toxicity or pathogenicity was shown in rainbow trout exposed to Btk for 31 days at a dose of 1010 CFU per liter of water and in the diet at 1010 CFU per gram of feed.

Freshwater Aquatic Invertebrate Toxicity Studies

Btk had no observed effect on Daphnia magna exposed to over 108 CFU of Btk per liter of water for 21 days.

Bird Toxicity Studies

No toxicity or pathogenicity was seen in bobwhite quail after they were orally dosed with Btk at 1011 CFU per kilogram body weight each day for 5 consecutive days.

No toxicity or pathogenicity was seen in mallard ducks orally dosed with Btk at 1011 CFU per kilogram body weight each day for 5 consecutive days.

Honey Bee Toxicity Studies

The LC50 for Btk on honey bees was determined to be 108 CFU per gram of feed and the no-observed-effect-concentration was determined to be 106 CFU per gram of feed.

Non-Target Insect Toxicity Studies

The LC50 of Btk on green lacewing larvae was greater than 108 CFU per gram of feed and the no-observed-effect-concentration was 108 CFU per gram of feed.

The LC50 of Btk on ladybird beetles was greater than 108 CFU per gram of feed and the no-observed- effect-concentration level for pathogenicity was 106 CFU per gram of feed.

The LC50 of Btk on a species of parasitic wasps was greater than 108 CFU per gram of feed and the no-observed-effect-concentration was 108 CFU per gram of feed.

Residues

As Foray has been shown to be non-toxic to non-target organisms, residues and spray drift are not considered hazardous.

APPENDIX 6: VALENT BIOSCIENCES FOREST HEALTH CONTACT INFORMATION

Valent BioSciences LLC
1910 Innovation Way, Suite 100
Libertyville, IL 60048
U.S.A.

www.valentbiosciences.com
1-800-323-9597
foresthealth@valentbioscienes.com

valentbiosciences.com

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