3.12.08

Bacillus thuringiensis – Safety Review

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Bacillus thuringiensis is a microorganism which produces species specific chemicals toxic to insects (*NPTN 2000*). Different subspecies of Bt are toxic to different insect species and the *kurstaki* subspecies (Btk) is the variety used on the light brown apple moth. Bt works by producing proteins (delta-endotoxins), which paralyze the cells in the gut of susceptible insects, interfering with normal digestion and triggering the insect to stop feeding on host plants (*Cranshaw 2003, EXTOXNET 1996*).

The Certis products *Crymax* and *Lepinox*, and the Valent products *DiPel DF* and *DiPel PRO DF*, are the specific formulations recommended by the CDFA on its *Light Brown Apple Moth Approved Treatments for Nurseries and Host Crops* list. These formulations contain different strains of *Bacillus thuringiensis* var. *kurstaki*, along with unidentified inert ingredients.

Btk is known to be toxic to a wide variety of lepidopteran species and post-spraying studies have also confirmed its toxicity to non-lepidopteran insect species.

Butterflies (including the monarch species) are particularly at risk in regard to *Bacillus thuringiensis* var. *kurstaki* (Btk) exposure. An Environmental Impact Report prepared by the New Zealand government prior to aerial and ground based spraying of Btk against the Painted Apple Moth warned that:

> "Any business involved in rearing moths and butterflies commercially, for example butterfly farms, would carry a heavy risk of damage if located within or near a spray area. Scientific institutions with insect rearing facilities for biological control work or study of Lepidoptera species would similarly be at risk. School biology classes or private individuals rearing caterpillars, such as monarch butterflies on swan plants, could expect caterpillar mortality if they were exposed to the spray." (*MAF 2003*)

Bt is closely related to *Bacillus cereus*, a bacterium that causes food poisoning (*Swadener 1994*). Studies have shown that registered *Bacillus thuringiensis* products may be able to produce the diarrheal enterotoxin usually associated with *Bacillus cereus* (*EPA 1998*), in fact tests have identified this toxin in several commercial Btk pesticides (*Damgaard 1995 and Tayabali and Seligy 2000, as cited by Ginsburg 2006*).

In 1991 French scientists called for a ban on Bt pesticides after finding that inhaled spores caused lung inflammation, internal bleeding and death in lab studies (*Birchard 1999 as cited by SES 2003*).

Foray 48B is a Btk pesticide composed of *Bacillus thuringiensis* var. *kurstaki* as the active ingredient, along with a large percentage of unidentified inert ingredients. Since pesticide manufacturers are required to disclose only the "active" ingredients in their products, the names of the "inert" ingredients in the formula have not been released to the public; however, in an independent study, scientists at the University of British Columbia were able to identify a large number of inert ingredients in the *Foray 48B* formula via laboratory testing (*Teschke et al. 2000*). Though much has been written regarding the active ingredient *Bacillus thuringiensis kurstaki*, little is known regarding the short-term, long-term, or synergistic effects of these potentially hazardous compounds in humans or in the environment.

Foray 48B has been aerially applied over population centers in New Zealand and Canada, as well as sites in the US including Washington and Oregon. Residents of the sprayed areas have reported numerous adverse effects in relation to the sprayings.

In a 1996-1997 pesticide campaign by the New Zealand government known as "Operation Ever Green", *Foray 48B* was aerially applied over parts of East Auckland, New Zealand. Following the spraying 375 people reported a wide variety of adverse effects. A second aerial spraying campaign of *Foray 48B* took place over urban areas in Auckland, New Zealand from 2002-2004 in an effort to eradicate the Painted Apple Moth. By the end of the first year of the campaign (2002) 1397 documented health symptoms had been reported by 315 people. Reported effects included respiratory, neurological, digestive, eye, skin, musculoskeletal, endocrine, and psychological symptoms (*Watts 2003*).

An examination of hospital discharge data undertaken following the 2002-2004 Auckland Btk spraying campaign, revealed that:

- asthma discharge rates doubled over the period 2002-mid 2004 for boys aged 0 to 4 years old in the [spray] exposed population
- discharge rates also increased for girls aged 0 to 4 and 5 to 14 (50% and 80% increases, respectively)
- comparing the year 2001 with 2004, there was an increase in asthma admissions in residents inside the spray zone, but a decrease in asthma admissions in residents just outside the spray zone. These trends were statistically significant.
- monthly hospitalization rates among the exposed group gradually increased over the period under study while national rates remained relatively constant, resulting in statistically significant increases for the spray population compared to national rates in years 2003 and 2004
  (*Gallagher et al. 2005*)

A variety of serious health concerns related to Btk pesticide exposure were identified during two hearings in Canada on whether to permit aerial spraying of *Foray 48B* Btk pesticide. Both permits were canceled by the provincial Environmental Appeal Board (EAB) Panel on the grounds that the pesticide posed a risk to human health, and that the spraying was unlikely to be effective (*SES 2003*).

In its decision, the EAB Panel stated:

> "The Panel finds that aerial spraying will create an unacceptable risk of health problems among the residents of these densely populated areas. In particular, the Panel agrees with the Appellants that there is a risk to the health of children, people of all ages who have allergies, asthma, and other respiratory ailments, people with immuno-deficiencies, chemical hypersensitivities, and the elderly. It also poses an unreasonable adverse effect to the environment (non-target species.)" (*SES 2003*)

As cited by the Saskatchewan Environmental Society, the EAB Panel based its decisions on evidence indicating that:

- Btk had caused health reactions in previously sprayed areas, including: "..skin rash and other immune, allergic and sensitization responses such as dry, itchy skin; red, burning eyes; dry sore throat; cough and tightness in the chest.." (*SES 2003*)
- children particularly at risk from the effects of Btk. "With smaller weight, and developing systems, children are likely to be more susceptible for all potential health effects." (*SES 2003*)
- Btk is respirable in mammals, so there is the possibility of lung injury on exposure (*SES 2003*)

- repeated exposure via inhalation can result in sensitization and allergic response (stated on product label). (*SES 2003*)
- ground spray workers have suffered health reactions and remained culture positive for prolonged periods of time. (*SES 2003*)
- no long-term studies have been conducted on the effects of Btk on human health. (*SES 2003*)

In a 2000 campaign to combat the Asian Gypsy Moth, *Foray 48B* was aerially applied 3 times over parts of Seattle, Washington. Adverse effects reported by 59 individuals following the sprayings included: cough, wheezing, headache, trouble breathing, sore throat, nasal congestion, irritated eyes, skin rashes, upper respiratory and nasal symptoms, flu-like or viral symptoms, worsening asthma and/or asthma attacks, and allergic bronchitis (*Washington State Dept. of Health 2001*).

Bacillus thuringiensis

- *Bacillus thuringiensis* var. *kurstak*i, genetically engineered strain EG7826 lepidopteran active toxin (Lepinox)
- *Bacillus thuringiensis* var. *kurstaki*, genetically engineered strain EG7841 lepidopteran active toxin (Crymax)
- *Bacillus thuringiensis* var. *kurstaki*, strain ABTS-351, fermentation solids and solubles (DiPel DF, DiPel Pro DF)

Synonyms

- *Bacillus thuringiensis*: Bt, B.t.
- *Bacillus thuringiensis kurstaki*: Btk., B.t.k., BtK

CAS Number

- 68038-71-1 (EG7841, EG7826 strains) (*PAN Database*)
- no CAS # listed for ABTS-351 strain in the PAN Database

Class

- ***use type*** – insecticide (*PAN Database*)
- ***chem class*** – microbial (*PAN Database*)

European Classification

- ***hazard symbols***
  - none listed
- ***risk phrases***
  - none listed
- ***safety phrases***
  - S2 (keep out of reach of children)
  - S13 (keep away from food, drink and animal feeding stuffs)
  - S20/21(when using do not eat, drink or smoke)
  - S25 (avoid contact with eyes) (*EC Annex IV*; *Fargro Safety Data Sheet*) (this refers to the DiPel DF formulation, which includes unspecified inerts)

WHO (World Health Organization) Classification

- not listed (*PAN Database*)

Toxicity (selected LD_{50}s and LC_{50}s)

- LD_{50} (Oral Rat) > 5,050 mg/kg (*Fargro Safety Data Sheet*) (this refers to the DiPel DF formulation, which includes unspecified inerts)
- LD_{50} (Dermal Rabbit) > 2,020 mg/kg (*Fargro Safety Data Sheet*) (this refers to the DiPel DF formulation, which includes unspecified inerts)
- LC_{50} (Inhalation Rat) not determined since the maximum attainable concentration of respirable particle in aerosol is extremely low (*Fargro Safety Data Sheet*) (this refers to the DiPel DF formulation, which includes unspecified inerts)

Health Effects (Warnings)

- ***ingestion***
  - if ingested, may cause bacterial gastroenteritis: abdominal cramps, vomiting and diarrhea [EG7826, EG7841 strains] (*PAN Database*)

    - ingestion could result in gastrointestinal irritation, purging, fluid loss, drop in blood pressure and hypernatremia, with long term exposure producing pneumonociosis and lung fibrosis (*Valent 2001a*) (this refers to the DiPel PRO DF formulation, which includes unspecified inerts)
- ***inhalation***
    - irritation of the respiratory tract [EG7826, EG7841 strains] (*PAN Database*)
    - in a 4-week inhalation study in guinea pigs, animals receiving 0.2mg/l exhibited evidence of inflammation and reduced adrenal weights; two of twenty animals died (NOEL = 0.02mg/l or 20mg/m3) (*Fargro Safety Data Sheet, Valent 2001a*) (this refers to the DiPel DF & DiPel PRO DF formulations, which include unspecified inerts)
    - one major component has been reported to produce lung fibrosis in experimental animals and exposed workers (*Fargro Safety Data Sheet, Valent 2001a*) (this refers to the DiPel DF & DiPel PRO DF formulations, which include unspecified inerts)
    - harmful if inhaled (*Valent 2005*, *Valent 2006*) (this refers to the DiPel DF & DiPel PRO DF formulations, which include unspecified inerts)
    - inhalation may result in respiratory tract irritation and chemical pneumonitis (*Valent 2001a*) (this refers to the DiPel PRO DF formulation, which includes unspecified inerts)
    - avoid breathing dust or spray mist (*Valent 2005*, *Valent 2006*) (this refers to the DiPel DF & DiPel PRO DF formulations, which include unspecified inerts)
- ***eye***
    - irritation of the eyes [EG7826, EG7841 strains] (*PAN Database*)
    - may cause infection or corneal ulcers in the eyes [EG7826, EG7841 strains] (*PAN Database*)
    - causes moderate eye irritation (*Certis 2001a*, *Valent 2006*) (this refers to the Crymax & DiPel DF formulations, which include unspecified inerts)
    - causes substantial but temporary eye injury (*Certis 2001b*) (this refers to the Lepinox formulation, which includes unspecified inerts)
- ***skin***
    - harmful if absorbed through skin (*Valent 2005*, *Valent 2006*) (this refers to the DiPel DF & DiPel PRO DF formulations, which include unspecified inerts)
- ***cholinesterase activity***
    - no (*PAN Database*)
- ***long term or repeated exposure***
    - available information suggests that long term exposure could cause lung fibrosis (*Valent 2001a*) (this refers to the DiPel PRO DF formulation, which includes unspecified inerts)
- ***carcinogenicity***
    - no available weight-of-the-evidence summary assessment (*PAN Database*)
- ***mutagenicity***
    - *B. thuringiensis* appears to have mutagenic potential in plant tissue, thus, extensive use of Bt on food plants might be hazardous to these crops (*Ray 1991 as cited by EXTOXNET 1996*)
- ***developmental or reproductive toxin*** –
    - no available weight-of-the-evidence summary assessment (*PAN Database*)
    - a minor component has been reported to produce fetotoxicity and musculoskeletal abnormalities in reproductive studies in animals (*Fargro Safety Data Sheet, Valent 2001a*) (this refers to the DiPel DF & DiPel PRO DF formulations, which include unspecified inerts)
- ***endocrine disruptor***
    - no available weight-of-the-evidence summary assessment (*PAN Database*)

Animal toxicity

- following the 1993 and 1994 aerial spraying of *Foray 48B* over urban areas in BC, Canada residents reported a variety of effects on birds including:
    - bird feces black - from 1st spray day
    - bird feces with pieces of gut - from 1st spray day
    - dead fledgling birds
    - generally lower bird populations
    - many bird species gone
    - no more house finches
    - reduced wild bird song
    - three dead chickens
    - chickens with diarrhea (whole flock)
    (*Young 1994*)

Insect toxicity

- this product must not be applied aerially within ¼ mile of any habitats of endangered species or threatened lepidoptera; no manual application can be made within 300 feet of any threatened or endangered lepidoptera (*Valent 2006*) (this refers to the DiPel DF formulation, which includes unspecified inerts)
- in studies, *B. thuringiensis* subspecies *kurstaki* displayed a high level of activity against Lepidopteran species (*EPA 1998*)
- there have been numerous reports of a wide variety of lepidopteran species being affected by Btk spraying (*Ota & Restino 2001*).
    - the oak-caterpillar and other caterpillar numbers were reduced for 3 and 2 years after spraying to control gypsy moth (*Miller 1990 as cited by Ota & Restino 2001*)
    - following spraying for spruce budworm the population of caterpillars feeding on tobacco brush collapsed. The number of species in untreated areas was about 30% higher and number of caterpillars was about 5 times higher than in Btk treated areas (*Miller 1990 as cited by Ota & Restino 2001*)
    - the spring moth population was reduced by 90% following spraying for gypsy moth in Washington. One rare species seems to have been eradicated and an effect on Lepidopteran populations was observed outside the treatment area (*Crawford 1993 as cited by Ota & Restino 2001*)
    - the total weight of caterpillars decreased by 90-95%, abundance decreased by 80%, and number of species decreased by 60% following treatment, in another study (*Swadener 1994 as cited by Ota & Restino 2001*)
- there have also been numerous reports of Btk toxicity to non-lepidopteran insect species (*Ota & Restino 2001*).
    - a variety of insects including aphid eating flies, *Simulium vittatum* (an aquatic invertebrate), ground beetles, and predaceous phytoseiid mites (*Tetranychus urtichae* and *Typhlodromus sp*.) experienced mortality following Btk treatment (*Horm 1983, Eidt 1985, Addison 1993, and Chapman & Hay 1991, as cited by Ota & Restino 2001*)
- following the 1993 and 1994 aerial spraying of *Foray 48B* over urban areas in BC, Canada residents reported a variety of effects on insects including:
    - no honeybees from first spray to end of July
    - reduction in wasp populations
    - reduction in bumble bee populations
    - ladybird populations drastically depleted all season
    - wood bugs speckled with yellowish blotches
    - drastically reduced butterfly and skipper populations
    - population overgrowth of other caterpillar species outside the sprayed area, including the tent caterpillar
    - mutated, more aggressive, blue (new color) tent caterpillars were observed in year following the spraying
    - first year spraying did not eradicate small introduced gypsy moth population (*Young 1994*)

Aquatic toxicity

- ***daphnia*** - moderately toxic; 21-day LC_{50} is between 5 ppm and 50 ppm (*EPA 1998*)
- research has shown that *Foray 48B* at high concentrations (about 3 percent) is acutely toxic to rainbow trout, probably because the product is highly acidic (*Watts 1992 as cited by SES 2003*)
- some juvenile coho salmon died at the high dose rate when they were exposed for 7 days to doses [of Btk] ranging from 5.2 x 10 to 26.4 x 10 spores per ml (*Surgeoner 1989 as cited by SES 2003*)
- following the 1993 and 1994 aerial spraying of *Foray 48B* over urban areas in BC, Canada residents reported that sprayed pond fish had developed tumors (*Young 1994*)

Ecological Toxicity

- ***ground water contaminant*** –
    - no available weight-of-the-evidence summary assessment (*PAN Database*)
    - do not apply directly to water, or to areas where surface water is present, or to areas below the mean high water mark; do not contaminate water when cleaning equipment or disposing of equipment washwaters (*Certis 2001a*, *Certis 2001b Valent 2005*, *Valent 2006*) (this refers to the Crymax, Lepinox, DiPel DF, & DiPel PRO DF formulations, which include unspecified inerts)

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- Annex II – hazard symbols http://ec.europa.eu/environment/dansub/pdfs/annex2_en.pdf
- Annex III – risk phrases http://ec.europa.eu/environment/dansub/pdfs/annex3_en.pdf
- Annex IV - safety phrases http://ec.europa.eu/environment/dansub/pdfs/annex4_en.pdf

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