# Submission of information to Secretariat of the Rotterdam Convention regarding proposals for severely hazardous pesticide formulations (SHPF) containing lambda-cyhalothrin 50 g/l (EC) and 50 g/l (CS)

## PAN International
## July 2017

**Contact: Dr Meriel Watts, PAN Asia Pacific**
**meriel@merielwatts.net**

Pursuant to paragraph 3 of Article 6 (d), PAN offers the following relevant information.

## Contents:



## 1 Introductory comments

A considerable amount of information on poisonings has been located. Much of it does not identify the concentration of the formulation involved – where the information was available it has been provided. However, it is important to note that the poisonings in Chile were all reported to be caused by 2.5 EC formulations.

Concentrations in registered products in some countries are mainly 2.5g/L; in Canada mainly 100-120% with some formulations only 0.5-4%; and in others mainly 50 and 100g/L.

For the toxicological and ecotox studies, some use technical grade lambda-cyhalothrin and some formulations – this information is provided as available. Noting that the proposed SHPFs are in the mid-range of the spectrum of concentration of the commercially available formulations, and that Canada has concluded that all its registered formulations pose an unacceptable cancer risk for children, it is reasonable to accept that this risk applies to the formulations noted as SHPF. A similar argument can be made for genotoxic, oxidative, endocrine and reproductive effects.

## 2 Registrations and uses

Lambda-cyhalothrin is a non-systemic type II synthetic pyrethroid with contact and stomach action.

### *2.1 New Zealand*[1]

Nine products containing lambda-cyhalothrin are registered in New Zealand:

- Cobalt Advanced: 15.4 h/L lambda-cyhalothrin + 300g/l chlorpyrifos –
- Cyhella – 250 gm/L lambda-cyhalothrin
- Dovetail - 5g/L lambda-cyhalothrin + 100 g/L pirimicarb -
- Agpro Lambda Cyhalothrin – 250 g/L lambda-cyhalothrin –
- Karate Zeon - 250 g/L lambda-cyhalothrin
- Kaiso 50 WG - 50 g/kg lambda-cyhalothrin
- Halex - 250 g/L lambda-cyhalothrin
- Ampligo - 50 g/L lambda-cyhalothrin + 100 g/L chlorantraniprole –
- Lavron - 250 g/L lambda-cyhalothrin –

The labels uses for the formulations of > 50g/L lambda-cyhalothrin only are tomato fruitworm, cutworm, cereal and rose grain aphids, Fullers rose weevil, diamondback moth, white butterfly caterpillars, thrips, bronze beetle, grass grub, potato tuber moth, blue-green aphid, potato mirid, thrips, sod webworm, reflagged earth mite, potato/tomato pysllid.

The registrations are for use on beans, maize, onions, sweet corn, maize, tomatoes, cereals, citrus, brassicas, grapes, onions, potatoes, kumara (sweet potato), squash, pumpkin, white clover seed crops, amenity turf, ornamentals, public health situations (hospitals, food processing plants, outdoor surfaces – for ants, carpet beetles, cockroaches, fleas, flies, silverfish, spiders, woodlice).

Kaiso 50WG: foliar pests in amenity turf, beans, cereals, citrus, grapes, fodder beet, sweet potato, maize, onions, ornamentals, potatoes, pumpkins, sweetcorn, tomatoes, vegetable and forage brassicas, and winter squash.

### *2.2 India*

[1] Ministry of Primary Enterprises https://eatsafe.nzfsa.govt.nz/web/public/acvm-register

Formulations approved for use in India are: 2.43%CS, 5% EC, 10% WP, 2.5% EC, 0.5% Chalk, 22.8%CS(FI), 4.9%CS.[2]

**Approved uses of Lambda Cyhalothrin in India[3]**

| LAMBDA-CYHALOTHRIN 4.9% CS | | | | | |
|---|---|---|---|---|---|
| Cotton | Bollworms | 25.0 | 500 | 500 | 21 |
| Paddy | Stem borer, Leaf folder | 12.5 | 250 | 500 | 15 |
| Brinjal | Shoot & fruit borer | 15 | 300 | 500 | 5 |
| Okra | Fruit borer | 15 | 300 | 500 | 5 |
| Tomato | Fruit borer | 15 | 300 | 500 | 5 |
| Grapes | Thrips & Flea beetle | 12.5 | 250 | 500-1000 | 7 |
| Chilli | Thrips & pod borer | 25 | 500 | 500 | 5 |
| Soybean | Stemfly & Semilooper | 15.0 | 300 | 500 | 31 |

| LAMBDA-CYHALOTHRIN 2.5% EC | | | | | |
|---|---|---|---|---|---|
| Cotton | Bollworms, Jassids, Thrips | 15-25 | 600-1000 | 400-600 | 21 |
| Rice | Leaf folder, Stem borer GLH, Gall midge, Hispa, Thrips | 12.5 | 500 | 400-600 | 15 |

| LAMBDA-CYHALOTHRIN 5% EC | | | | | |
|---|---|---|---|---|---|
| Cotton | Bollworms, Jassids, Thrips | 15-25 | 300-500 | 400-600 | 21 |
| Rice | Leaf folder, stem Borer, GLH, Gall Midge, Hispa, Thrips | 12.5 | 250 | 400-600 | 15 |
| Brinjal | Shoot & fruit borer | 15 | 300 | 400-600 | 4 |
| Tomato | Fruit borer | 15 | 300 | 400-600 | 4 |
| Chilli | Thrips , mite, pod borer | 15 | 300 | 400-600 | 5 |
| Pigeon pea | Pod borer, pod fly | 20-25 | 400-500 | 400-600 | 15 |
| Onion | Thrips | 15 | 300 | 300-400 | 5 |

[2] Pesticides and Formulations Registered for Use in the Country Under the Insecticides Act, 1968. Government of India. Updated on 31.10.2016. http://cibrc.nic.in/

[3] Approved use of registered pesticides in India as on 30th June 2017. Central Insecticides Board and Registration Committee. http://cibrc.nic.in/mupi2012.doc

| | | | | | |
|---|---|---|---|---|---|
| Bhindi | Jassids , shoot borer | 15 | 300 | 300-400 | 4 |
| Chickpea | Pod borer | 25 | 500 | 300-400 | 6 |
| Groundnut | Thrips, leaf Hopper, leaf miner | 10-15 | 200-300 | 400-500 | 10 |
| Mango | Hoppers | 0.0025-0.005% | 0.5-1.0 ml/l of water | | 7 |

Lambda-cyhalothrin is also reported to be used illegally for fishing in Kerala, India (see attached report).[4] The two practices observed were:

i. lambda-cyhalothrin is mixed with sand or other granular materials wrapped in cloth as bundle. Many such bundles tied onto fishing net and then the net is laid in the water body;
ii. lambda-cyhalothrin is broadcasting mixed with sand or soil in low-lying paddy fields during the time of dewatering prior to rice cultivation.

### *2.3 Australia*

Lambda-cyhalothrin is registered in Australia for use on cereals (barley, wheat, sorghum), brassicas (cabbage, cauliflower, Brussels sprouts, broccoli, forage brassica), cotton, canola, legumes/pulses (faba beans, chick peas, vetch, field peas, lupins, navy beans, mung beans, soybeans), lucerne, pasture, citrus fruit (oranges, lemons), sunflower, potato and tomato. Lambda-cyhalothrin is also registered for use on sheep, as a backline pour-on formulation. MRLs and residue data are provided.[5] Further information on Australian registrations can be found at https://apvma.gov.au/search/google/lambda-cyhalothrin

### *2.4 Philippines*

According to the latest available information from the Philippines, there are 38 formulations of lambda-cyhalothrin registered. Of these 36 are 2.5 EC, i.e. 2.5 g/kg emulsifiable concentrates. The concentration of the other four - TYRANT 2.5 EC, 5 STAR GENERAL, BUGSEEK, and INFERNO have not been identified.[6]

### *2.5 European Union*

Lambda-cyhalothrin was approved on 01/04/2016, and expires on 31/03/23. It is registered

---

[4] Kumar D, Chelaton J. 2016. Illegal Use of Pesticides for Fishing in Central Kerala – A Case Study. Pesticide Action Network, India.

[5] Australian Pesticides and Veterinary Medicines Authority. http://archive.apvma.gov.au/residues/stockfeed/ARDS_cyhalothrin.php

[6] http://fpa.da.gov.ph/images/FPAfiles/DATA/Regulation/Pesticide/LISTOFREGISTEREDAGRICULTURALPESTICIDES.pdf

in AT, BE, BG, CY, CZ, DE, DK, EE, EL, ES, FI, FR, HR, HU, IE, IT, LT, LU, LV, MT, NL, PL, PT, RO, SE, SI, SK, UK.[7]

However, it is a candidate for substitution, because:[8]

i. the Acceptable Operator Exposure Level (AOEL) is significantly lower than those of the majority of the approved active substances within the group of insecticides;
ii. lambda-cyhalothrin meets the criteria to be considered a bioaccumulative and toxic substance, 2015/408).

The EU report regarding substitution continues: "*Moreover, there are reasons for concern linked to the nature of its critical effects (developmental neurotoxic effects) and lambda-cyhalothrin may contain a significant proportion of non-active isomers.*"

List of uses for the EU:[9]

- Wheat – aphids, leafhopper, ground beetles, flies, gall midges, thrips.
- Potatoes – aphids, Colorado potato beetle

### *2.5.1 Germany*

There are 17 lambda-cyhalothrin products on the market in Germany, including two for household use.[10] Of these, 15 are $\geq$ 50 g/L:

- 50 g/L - CLAYTON SPARTA; CYCLONE; Hunter; Kaiso Sorbie; Lambda WG; Shock DOWN; TRAFO WG
- 100 g/L - JAGUAR; KARATE FORST flüssig; Karate Zeon; KARIS 10 CS; KORADO 100CS; KUSTI; Life Scientific Lambda-Cyhalothrin; Sparviero

## ***2.6 USA***

Lambda-cyhalothrin is a restricted use insecticide for the control of aphid, caterpillar and beetle pests on a wide variety of crops (including alfalfa, cotton, soybeans, wheat, rice) and for public health pests such as mosquitoes and cockroaches in non-agricultural settings (lawns, ships, etc).[11]

---

[7] http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=activesubstance.detail&language=EN&selectedID=1509

[8] Commission Staff Working Document: Lambda-cyhalothrin. SANCO/12282/2014 Rev 4. 11 December 2015. http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=activesubstance.detail&language=EN&selectedID=1509

[9] Commission Staff Working Document: Lambda-cyhalothrin. SANCO/12282/2014 Rev 4. 11 December 2015. http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=activesubstance.detail&language=EN&selectedID=1509

[10] https://apps2.bvl.bund.de/psm/jsp/ListeMain.jsp?page=1&ts=1499765966300

[11] US EPA. 2010. Lambda-cyhalothrin and gamma-cyhalothrin summary documents registration review: Initial Docket December 2010. EPA-HQ-OPP-2010-0480.

There are currently 330 registrations for lambda-cyhalothrin in the USA.[12] The major uses are on soybeans (210,000 lbs in 2015); corn (56,000 lbs in 2016); cotton (15,000 lbs in 2015); rice (7,000 lbs in 2016); peanuts (2,000 lbs in 2014); and oats (1,000 lbs in 2015).[13]

### *2.7 Canada*

Canada is proposing to cancel the following uses: all uses on food and feed, all indoor residential uses, residential turf use; and to continue to permit the following uses by commercial applicators: on shelterbelt, poplar and willow plantings, outdoor gardens, trees and ornamentals; structural use in non-residential areas, golf course turf, sod farms and industrial turf; and on tobacco. Canada also proposes buffer zones between point of application and non-target-aquatic habitats.[14]

## 3 Signs and Symptoms of Poisoning

Symptoms reported by the US EPA[15] from poisoning incidents are:

- dermal (32%) – itchiness, redness, hives, burning sensation, irritation, blisters
- neurological (19%) – headache, dizziness, disorientation, confusion, memory dysfunction, unable to concentrate, numbness, tingling sensations, unsteady movement, muscle weakness, muscle spasm, seizures
- respiratory (19%) – coughing, difficulty breathing, asthma-like symptoms, exacerbation of chronic obstructive pulmonary disease, sore throat, burning sensation in throat nasal passage and chest, hoarseness of voice, inability to take deep breathe due to chest pain, blood in sputum
- ocular (16%) – corneal abrasion, sensation of foreign body, burning sensation, pain, photophobia, itchiness, swelling, redness
- gastrointestinal (9%) – vomiting, diarrhoea, abdominal pain, stomach cramps
- fever (4%)
- muscle ache (2%)
- anaphylactic shock (1 case)
- flu-like symptoms

Paresthesia has been reported frequently, particularly after the inappropriate handling of lambda-cyhalothrin. Paresthesia occurs most commonly on the face. The symptoms are exacerbated by sensory stimulation (heat, sun, scratching), sweating or application of water

[12] https://iaspub.epa.gov/apex/pesticides/f?p=PPLS:1
[13] US Department of Agriculture survey data, National Agricultural Statistics Service https://quickstats.nass.usda.gov/#6428D068-FE85-39D3-A526-8169126E232E
[14] Health Canada. 23rd June 2017. Lambda-Cyhalothrin. Proposed Re-evaluation Decision. PRVD2017-03.
[15] [15]Lambda-cyhalothrin: review of human incidents. Memorandum August 24, 2010. United States Environmental Protection Agency. EPA-HQ-OPP-2010-0480-0010.

and may prevent sleep. Paresthesia generally starts 30 minutes to two hours after exposure and peaks after about six hours. Recovery is usually complete within 24 hours.[16]

Other symptoms reported include lack of appetite and fatigue. In severe poisonings, seizures and coma may occur.[17]

Villagers handling mosquito nets pre-treated with lambda-cyhalothrin complained of mild burning of the eyes and lacrimation.[18]

Acute pancreatitis was observed following the ingestion of 300ml of lambda-cyhalothrin[19] (product = Meilan).[20]

## 4. Incidents

### *4.1 Africa*

In a study of farmers' knowledge, practices and injuries associated with pesticide exposure in rural farming villages in Tanzania, lambda-cyhalothrin was reported to be associated with 5% of poisoning cases. It was in the top ten most frequent active ingredients reported as used, stored and associated with poisoning among coffee and vegetable farmers in Arumeru district. Its use was reported by 20.7% of coffee and vegetable farmers. No details of formulations were given.[21]

A hospital-based surveillance for acute pesticide poisoning in Tanzania reviewed hospital admission data for acute pesticide poisoning retrospectively (2000–2005) in 30 facilities in four regions of Tanzania. A prospective follow-up over 12 months in 2006 focused on 10 facilities with the highest reporting of acute pesticide poisoning. Lambda-cyhalothrin was reported as responsible for 0% poisoning in the retrospective study, but 2% in the prospective study. No details of formulations were given.[22]

---

[16] IPCS. UK Poison Information Document (UKPID): Cyhalothrin (January 1998). http://www.inchem.org/pages/ukpids.html
[17] http://npic.orst.edu/factsheets/l_cyhalogen.pdf
[18] IPCS. UK Poison Information Document (UKPID): Cyhalothrin (January 1998). http://www.inchem.org/pages/ukpids.html
[19] Initially referred to as permethrin, but otherwise referred to as lambda-cyhalothrin throughout the document. No product details provided.
[20] Wenjie W, Houqing L, Xuchan X, Genyun S. 2014. Acute pancreatitis during lambda cyhalothrin poisoning. *Tox Rev* 33(3):136-7. doi: 10.3109/15569543.2014.922582
[21] Lekei EE, Ngowi AV, London L. 2014. Farmers' knowledge, practices and injuries associated with pesticide exposure in rural farming villages in Tanzania. *BMC Public Health* 14:389. doi: 10.1186/1471-2458-14-389.
[22] Lekei E, Ngowi AV, London L. 2014. Hospital-based surveillance for acute pesticide poisoning caused by neurotoxic and other pesticides in Tanzania. *NeuroToxicology* 45:318–326.

In March 1990, a study was carried out in the village of Kicheba in Tanzania, in which lambda-cyhalothrin was sprayed on all the internal surfaces of houses and other shelters at a coverage of about 25 mg a.i./$m^2$. Every day for 6 days, 12 spraymen and 3 squad leaders were interviewed about symptoms of exposure to the insecticide. Each sprayman used up to 62 g of lambda-cyhalothrin over 2.7 – 5.1 hr every day. All the spraymen complained at least once of symptoms that were related to exposure to lambda-cyhalothrin, the commonest being itching and burning of the face, and nose or throat irritation frequently accompanied by sneezing or coughing. Facial symptoms occurred on non-protected areas only. The symptoms were experienced at various times after the beginning of exposure and disappeared before the following morning. The number of subjects affected and the duration of their facial symptoms were proportional to the amount of compound sprayed. A sample of individuals was interviewed 1 day and 5-6 days after their houses had been sprayed. One woman, who entered her house 30 min after the end of spraying, complained of periorbicular itching, but this lasted only a few minutes. No other significant, insecticide related adverse effect was reported by the inhabitants of the sprayed houses.[23]

In a recent (15th June 2017) University of Cape Town Pesticide forum, cyhalothrin was mentioned as one of the pesticides found during post mortems in Zambia, in association with suicides. No further information was given, but it may be possible to follow this up with the Zambian government.

### *4.2 USA*

According to the US EPA (2010)[24] "the number of reported incidents involving lambda-cyhalothrin is relatively large. The majority of health effects involved dermal, neurological, gastrointestinal, and respiratory symptoms. These symptoms were of low to moderate severity; however, two of the incidents resulted in death. Most of the cases occurred at home in a residential setting, although there were cases that occurred in occupational settings as well."

From 2002 to 2010, the US EPA identified 403 case reports allegedly attributed to lambda-cyhalothrin. It reviewed 159 of them including 2 fatalities, one in 2003 and one in 2008. It reported a trend of increasing incidents.[25]

- 10 cases were children under 6 years
- 42 cases resulted from drift – 34 of which was from cotton field applications entering an elementary school ventilation system resulting in the school being evacuated
- 4 cases of intentional ingestion, 2 of unintentional ingestion

[23] Moretto A. 1991. Indoor spraying with the pyrethroid insecticide lambda-cyhalothrin: effects on spraymen and inhabitants of sprayed houses. *Bull World Health Organ* 69(5):591-4.

[24] US EPA. 2010. Lambda-cyhalothrin and gamma-cyhalothrin summary documents registration review: Initial Docket December 2010. EPA-HQ-OPP-2010-0480.

[25] Lambda-cyhalothrin: review of human incidents. Memorandum August 24, 2010. United States Environmental Protection Agency. EPA-HQ-OPP-2010-0480-0010.

- 1 case of an emergency response fire fighter to a broken drum at the scene of an accident of a truck carrying the insecticide
- 42 non-occupational cases at residences, both indoors and outdoors – 37 of these during handling because of spilling, splashing, wind, blowback, accidentally spraying self, contact with treated surfaces; 5 were post application exposures
- 43 occupational cases – of these 4 at jobs that did not involve application, 21 were applicators not wearing PPE, 5 were mixers and loaders experiencing accidental spills, splashes and contact; 2 were post-application exposure; 4 were spills or splashes during transportation.

The US EPA (2010) also reported 12 ecological incidents reported to the Agency for lambda-cyhalothrin. Of these, 1 was reported as highly probable, 4 as probable, 7 as possible. Nine involved fish and aquatic invertebrates, 3 terrestrial plant species.

Since 2010, the US's National Poisons Information Center (NPIC) has reported further incidents:

- In 2013, lambda-cyhalothrin was one of the top 25 pesticide active ingredients for human and animal incidents, with 23 reported human incidents, 7 animal incidents and 12 "other" incidents. Of these, 4 human incidents were classed as definite or probable. There was no information on formulations involved. 'Other' includes environmental and property incidents.[26]

- In 2014, lambda-cyhalothrin was again in the top 25 actives for incidents; NPIC reported 28 human incidents, 8 for animals and 19 other incidents.[27]

- In 2016, with lambda cyhalothrin again in the top 25 actives for incidents, NPIC reported 16 human incidents, 10 for animals and 13 other incidents.[28]

### *4.3 Canada[29]*

As of February 28, 2017, Canada had received 95 human and 65 domestic animal incidents involving lambda-cyhalothrin, mostly during use or on re-entry into sprayed areas. The product reported most frequently in these incidents was Demand CS Insecticide.

---

[26] NPIC National Pesticide Information Centre -2013. Oregon State University. http://npic.orst.edu/reports.htm
[27] NPIC National Pesticide Information Centre -2014. Oregon State University. http://npic.orst.edu/reports.htm
[28] NPIC National Pesticide Information Centre -2016. Oregon State University. http://npic.orst.edu/reports.htm
[29] Health Canada. 23rd June 2017. Lambda-Cyhalothrin. Proposed Re-evaluation Decision. PRVD2017-03.

One major incident involved a toddler who had been in a hotel room shortly after it had been treated with a lambda-cyhalothrin product. The child experienced seizures and was hospitalised.

Canada also reports on incidents in the USA: as of August 26, 2016, there were 25 lambda-cyhalothrin and three cyhalothrin incident reports listed in the EIIS database. The reported organisms affected were bees (8 incidents), fish (9 incidents), aquatic invertebrates (2 incidents) and crop plants (6 incidents).

There were 6 incidents of honeybee death following application of Matador 120EC or Endigo in neighbouring fields during bloom.

### *4.4 Europe*

Twelve poisoning incidents involving lambda-cyhalothrin were reported in Germany between 2005 and 2010.[30]

Lambda cyhalothrin was detected in one fatal poisoning in Turkey in 2008 (the last date reported).[31]

There is a report in Chinese of an incident resulting in coma following exposure to cyhalothrin – it is not clear from the title if it is lambda-cyhalothrin.[32]

### *4.5 Latin America*

In Chile, there were 5 cases of acute poisoning by lambda-cyhalothrin 2.5EC between January and September 2015, representing 5.3 % of total pesticide poisoning.[33]

### *4.6 Unspecified*

Out of 38 field trials staff who returned questionnaires, only 4 reported experiencing any adverse effects as a result of exposure to lambda-cyhalothrin. Three of these individuals experienced a burning sensation or irritation around the face, cheeks, or eyes, which started between 45 and 60 min after initial exposure and lasted, respectively, for 5, 18, and 72 hr. In one case the symptoms were severe enough to prevent the individual from working. The other field trials worker experienced a rash on the hands that started 24 hr after exposure

---

[30] PAN Germany. 02.06.2016. Pestizid-Brief Nr.012016. http://www.pan-germany.org/download/pestizid brief/PB1_2016_Vergiftungen_%20§16e_Meldungen_F.pdf
[31] Daglioglu N, Akcan R, Gulmen M, Yener F, Efeoglu P. 2011. Pesticide intoxications in Cukurova, Turkey: three years analysis. *Hum Exp Toxicol* 30(12):1892-5. doi: 10.1177/0960327111402241.
[32] Wang W, Lu H. 2016. [Coma is caused by cyhalothrin: a report of two cases]. [Article in Chinese]. Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi 34(1):31. doi: 10.3760/cma.j.issn.1001-9391.2016.01.007.
[33] Boletín Epidemiológico Trimestral Enero a Septiembre de 2015. Volumen 111, nº 4, año 2015. Gobierno de Chile. [attached]

and lasted several days. All four field trials staff were involved in handling concentrated solutions of lambda-cyhalothrin (2.5% w/v ai) and three of the four sprayed diluted solutions. None of the three workers experiencing the facial sensation had experienced similar symptoms before, but the worker who developed the rash had suffered a similar rash after exposure to permethrin, cypermethrin, and deltamethrin following their application to top fruit. Eight of the other 34 field trials staff returning questionnaires stated that they had previously suffered symptoms of facial tingling or burning.[34] This report did not state if PPE was being worn.

Four reports involving 3 individuals were received from laboratories involved with lambda-cyhalothrin. The symptoms consisted of a facial tingling and burning sensation and in one case tingling on the tongue. Symptoms began within 30 min of exposure and lasted from 6 hr to 2 days. All three workers were involved in handling either technical material or concentrated lambda-cyhalothrin solutions (10% w/v ai). [35]

Two workers were reported to have suffered from subjective facial sensation. Both were exposed to technical cyhalothrin and symptoms began 1-6 h after exposure. The symptoms described were typical of subjective facial sensation, consisting of tingling and burning around the eyes and facial area, and lasted 6-24 hr.[36]

At least 12 workers involved in the manufacture of cyhalothrin have experienced symptoms of subjective facial sensation. The symptoms were described as burning, tingling, or sunburn, but clinical examination revealed no abnormal neurological signs. The areas of the face affected were the eyelids, cheeks, nostrils, forehead, and lips. In one case the penis was affected, probably from contact with contaminated hands. The symptoms started between 5 min and 3 hr from the onset of exposure and lasted from 5 to 30 hr. Wind, washing, and temperature increase led to a worsening of the symptoms, and relief could be obtained by using a local anaesthetic.[37]

## 5. Classification of lambda-cyhalothrin

***5.1 WHO*:** Class II moderately hazardous

***5.2 European Union*:**[38]

Acute Tox. 3 – H301
Acute Tox. 2 – H330
Acute Tox. 4 – H312

---

[34] WHO. 1990. Environmental Health Criteria 99: Cyhalothrin.
[35] WHO. 1990. Environmental Health Criteria 99: Cyhalothrin.
[36] WHO. 1990. Environmental Health Criteria 99: Cyhalothrin.
[37] WHO. 1990. Environmental Health Criteria 99: Cyhalothrin.
[38] http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=activesubstance.detail&language=EN&selectedID=1509

Aquatic Acute 1 – H400
Aquatic Chronic 1 – H410

“Member States shall pay particular attention to the protection of aquatic organisms.”

Classification according to IUPAC: [39]

| | |
|---|---|
| EC Risk Classification | T+ - Very toxic: R26<br>T - Toxic: R25; R43<br>Xn - Harmful: R21<br>N - Dangerous for the environment: R50, R53 |

### *5.3 US GHS Classification:*[40]

**Signal**: Danger
***GHS Hazard Statements*:**
H301: Toxic if swallowed [Danger Acute toxicity, oral - Category 3]
H311: Toxic in contact with skin [Danger Acute toxicity, dermal - Category 3]
H320: Causes eye irritation [Warning Serious eye damage/eye irritation - Category 2B]
H335: May cause respiratory irritation [Warning Specific target organ toxicity, single exposure; Respiratory tract irritation - Category 3]
H370: Causes damage to organs [Danger Specific target organ toxicity, single exposure - Category 1]
H372: Causes damage to organs through prolonged or repeated exposure [Danger Specific target organ toxicity, repeated exposure - Category 1]
H400: Very toxic to aquatic life [Warning Hazardous to the aquatic environment, acute hazard - Category 1]
H410: Very toxic to aquatic life with long lasting effects [Warning Hazardous to the aquatic environment, long-term hazard - Category 1]

## 6. Reference values

### *6.1 European Union*:[41]
ADI: 0.0025
ARfD: 0.005
AOEL: 0.00063

### *6.2 Canada (217):*[42]

[39] IUPAC. http://sitem.herts.ac.uk/aeru/iupac/Reports/415.htm
[40] https://pubchem.ncbi.nlm.nih.gov/compound/6435500#section=Safety-and-Hazards
[41] http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=activesubstance.detail&language=EN&selectedID=1509
[42] Health Canada. 23rd June 2017. Lambda-Cyhalothrin. Proposed Re-evaluation Decision. PRVD2017-03

ADI = 0.0003 mg/kg/ bw/day
ARfD = 0.0006 mg/kg bw
Cancer potency factor o = $2.66 \times 10^{-2}$ (mg/kg bw/day)$^{-1}$

## 7. Toxicology

Lambda-cyhalothrin has high acute mammalian toxicity, with an $LD_{50}$ of 56mg/kg (IUPAC). It is a respiratory and eye irritant, and a skin sensitiser.[43]

It acts by disrupting nervous system function. Oral administration of 100 ml cyfluthrin may be fatal.[44]

Canada's re-evaluation[45] of lambda-cyhalothrin found "potential risks of concern from dietary and certain residential exposures", and proposes to cancel all food and feed uses and some uses in residential areas. The dietary risks are acute,[46] chronic,[47] and for cancer.

There was evidence that young animals were more sensitive than adult animals to cyhalothrin toxicity.[48] It also found cancer and non-cancer for children on residential turf, and from post residential application structural application in indoor areas, and application for bedbugs through hand-to-mouth exposure.

In rats there was significant distribution of the unchanged lambda-cyhalothrin to the mammary gland and to the neonate via maternal milk.[49]

### *7.1 Pathology*

Lambda-cyhalothrin has significant adverse effects on blood parameters and on liver, lungs, kidneys and heart.

In a study to investigate effects of lambda-cyhalothrin on clinical, haematological, biochemical and pathological alterations in rabbits, treated with lambda-cyhalothrin 1.0, 4.0 and 8.0 mg/kg bw, seven consecutive doses at an interval of 48 hours, the following was found:

- significant decrease in red blood cell and white blood cell counts, haemoglobin concentration and lymphocytes, while mean corpuscular haemoglobin

---

[43] http://sitem.herts.ac.uk/aeru/iupac/Reports/415.htm
[44] Wenjie W, Houqing L, Xuchan X, Genyun S. 2014. Acute pancreatitis during lambda cyhalothrin poisoning. *Tox Rev* 33(3):136-7. doi: 10.3109/15569543.2014.922582.
[45] Health Canada. 23rd June 2017. Lambda-Cyhalothrin. Proposed Re-evaluation Decision. PRVD2017-03.
[46] 364% of the ARfD (children 6-12 years old) to 913% of the ARfD (adults 20-49 years old).
[47] 40% of the ADI (youth 13-19 years old) to 115% of the ADI (children 1-2 years old).
[48] Health Canada. 23rd June 2017. Lambda-Cyhalothrin. Proposed Re-evaluation Decision. PRVD2017-03.
[49] Health Canada. 23rd June 2017. Lambda-Cyhalothrin. Proposed Re-evaluation Decision. PRVD2017-03.

concentration, mean corpuscular volume, neutrophils, monocytes and eosinophils were increased
- dose-dependent increase in the incidence of micronucleated polychromatic erythrocytes
- liver – extensive perihepatitis, hyperplasia of bile duct, necrosis, haemorrhages and congestion
- lungs – haemorrhages, thickened alveolar walls, congestion, emphysema, collapsed alveoli and accumulation of extensive inflammatory cells
- kidneys – congested and haemorrhagic
- heart – congestion of blood vessels and nuclear pyknosis, myodegeneration.[50]

### *7.2 Endocrine disruption*

The European Union concluded, in March 2016, that "*an endocrine-mediated mode of action could not be ruled out regarding the brain morphological changes observed in the developmental neurotoxicity study (and possible sperm effects, which have to be clarified in the first place) and the potential for endocrine disrupting effects could not be finalized".*[51]

However, Canada's re-evaluation stated that there was "evidence of endocrine toxicity in vitro and in vivo". It noted decreased plasma testosterone, increased serum corticosterone, decreased serum T3 and T4 levels, increased serum TSH levels, thyroid receptor binding antagonistic activity, oestrogenic activity, mammary and uterine tumours, and ovarian and testes effects.

We also provide information on a number of recent studies demonstrate its endocrine effects, particularly oestrogenic effects, but also antiandrogenic and thyroid effects.

For example, lambda-cyhalothrin, at 98% purity, was found to cause weak oestrogenic, antiandrogenic activity, and thyroid hormone antagonistic activity in receptor-mediated luciferase reporter gene assays.[52]

In a study evaluating enantio-selectivity in endocrine disruption activity in human breast carcinoma cell line MCF-7, lambda-cyhalothrin (LCT) (98% purity) showed significant enantiomer specific estrogenic activities in MCF-7 cell proliferation assay: (-)-LCT

---

[50] Basir A, Khan A, Mustafa R, Khan MZ, Rizvi F, Mahmood F, Yousaf A. 2011. Toxicopathological effects of lambda-cyhalothrin in female rabbits (*Oryctolagus cuniculus*). *Hum Exp Toxicol* 30(7):591-602. doi: 10.1177/0960327110376550.

[51] FINAL Review report for the active substance lambda-cyhalothrin finalised in the Standing Committee on Plants, Animals, Food and Feed at its meeting on 11 December 2015 in view of the renewal of the approval of lambda-cyhalothrin as active substance in accordance with Regulation (EC) No 1107/2009. SANCO/12282/2014 Rev 4. European Commission.

[52] Du G, Shen O, Sun H, Fei J, Lu C, Song L, Xia Y, Wang S, Wang X. 2010. Assessing hormone receptor activities of pyrethroid insecticides and their metabolites in reporter gene assays. *Toxicol Sci* 116(1):58-66. doi: 10.1093/toxsci/kfq120.

displayed about 1.8-fold stronger effect in inducing the proliferation of MCF-7 cells than (+)-LCT).[53]

In a study to investigate the "well-established oestrogenic effect" of lambda-cyhalothrin, Wang et al (2016) demonstrated that it disrupts the up-regulation effect of 17β-estradiol on post-synaptic density 95 protein expression via the oestrogen receptor α-dependent Akt pathway.[54]

Zhao et al (2008) tested on MCF-7 human breast carcinoma cell lines the oestrogenic potencies of lambda-cyhalothrin and its effect on regulation of the expression of oestrogen receptors (ER) and of ER-mediated genes. The results clearly suggest that pesticide has oestrogenic properties and may function as a xenoestrogen as it could significantly promote MCF-7 cell proliferation, with a relative proliferative effect ratio of 45%.[55]

Cyhalothrin (plus deltamethrin) was found in adipose tissue adjacent to an oestrogen-receptor positive mammary tumour in a female dog. A greatly increased incidence of mammary tumours in dogs led to an investigation, which found synthetic pyrethroids associated with 3 of 5 oestrogen receptor positive tumours.[56]

Lambda cyhalothrin was identified as antiandrogenic in an *in vitro* androgen receptor antagonism analysis using MDA-kb2 human breast cancer cells stably transfected with a firefly luciferase reporter gene that is driven by an androgen-response element–containing promoter.[57]

A study on thyroid secretary function in rats of the effects of pyrethroids found that lambda-cyhalothrin (2.5% EC formulation Karate, 0.2mg/rat) could suppress thyroid secretion and inhibit growth rate in young adult rats during 21-day treatment. It induced significant suppression of serum T3 and T4 levels, and concomitant stimulation of thyroid stimulating hormone concentrations. The $T_4$ / T3 ratio was decreased in rats treated with Karate.[58]

---

[53] Zhao M, Chen F, Wang C, Zhang Q, Gan J, Liu W. 2010. Integrative assessment of enantioselectivity in endocrine disruption and immunotoxicity of synthetic pyrethroids. *Environ Pollut* 158(5):1968-73. doi: 10.1016/j.envpol.2009.10.027.
[54] Wang Q, Xia X, Deng X, Li N, Wu D, Zhang L, Yang C, Tao F, Zhou J. 2016. Lambda-cyhalothrin disrupts the up-regulation effect of 17β-estradiol on post-synaptic density 95 protein expression via estrogen receptor α-dependent Akt pathway. *J Environ Sci (China)* 41:252-60. doi: 10.1016/j.jes.2015.04.037.
[55] Zhao M, Zhang Y, Liu W, Xu C, Wang L, Gan J. 2008. Estrogenic activity of lambda-cyhalothrin in the MCF-7 human breast carcinoma cell line. *Environ Toxicol Chem* 27(5):1194-200. doi: 10.1897/07-482.1.
[56] Andrade FH, Figueiroa FC, Bersano PR, Bissacot DZ, Rocha NS. 2010. Malignant mammary tumor in female dogs: environmental contaminants. *Diagn Pathol* 5:45.
[57] Orton F, Rosivatz E, Scholze M, Kortenkamp A. 2011. Widely used pesticides with previously unknown endocrine activity revealed as in vitro antiandrogens. *Environ Health Perspect* 119(6):794-800.
[58] Akhtar N, Kayani M, Ahmad M, Shahab M. 1996. Insecticide induced changes in secretory activity of the thyroid gland in rats. *J Appl Toxicol* 16:397–400.

Decreased testosterone levels were measured in a study on male rabbits orally administered doses of lambda-cyhalothrin every other day for 16 weeks.[59]

### *7.3 Oxidative stress*

A significant number of studies have demonstrated that lambda-cyhalothrin causes oxidative stress, including the following:

In a study on blood and brain of male Wistar rats, in which 1 group received orally 668 ppm lambda-cyhalothrin (as formulation Karate 5EC, Syngenta), the pesticide caused significant reduction in red blood cell count (16%), haemoglobin content (32% and haematocrit (33%) in lambda cyhalothrin group compared to those of controls. A significant increase of malondialdehyde levels in erythrocytes and brain were observed compared to controls; and a significant decrease in brain (52%) and in erythrocytes (27%,) of glutathione levels. Antioxidant enzyme – superoxide dismutase, glutathione reductase, glutathione peroxidase and glutathione transferase – activity was decreased, while catalase activity was increased by 35% compared to those of control group.[60]

Exposure of rats to lambda-cyhalothrin for 3 weeks caused a significant increase in kidney malondialdehyde and protein carbonyl levels compared to controls. Kidneys exhibited severe vacuolations, cell infiltration and widened tubular lumen. The activities of catalase, superoxide dismutase, glutathione peroxidase, glutathione reductase and glutathione-S-transferase were significantly decreased due to lambda-cyhalothrin exposure.[61]

In mice exposed orally to lambda-cyhalothrin for 28 days, activities of superoxide dismutase, catalase and glutathione-S-transferase were depleted significantly in both kidney and brain causing oxidative damage to the kidney and brain of mice, which in turn could be responsible for nephrotoxicity and neurotoxicity.[62]

El-Demerdash (2007)[63] demonstrated cytotoxic effects of lambda-cyhalothrin on rabbit erythrocytes *in vitro*. Erythrocytes are particularly sensitive to oxidative damage but at the same time they are well equipped with several biological mechanisms to defend against intracellular oxidative stress. Despite their well-developed antioxidant defence system, it

---

[59] Yousef MJ. 2010. Vitamin E modulates reproductive toxicity of pyrethroid lambdacyhalothrin in male rabbits. *Food Chem Toxicol* 48(5):1152-9.
[60] Fetoui H, Garoui el M, Makni-Ayadi F, Zeghal N. 2008. Oxidative stress induced by lambda-cyhalothrin (LTC) in rat erythrocytes and brain: Attenuation by vitamin C. *Environ Toxicol Pharmacol* 26(2):225-31. doi: 10.1016/j.etap.2008.04.002.
[61] Fetoui H, Makni M, Garoui el M, Zeghal N. 2010. Toxic effects of lambda-cyhalothrin, a synthetic pyrethroid pesticide, on the rat kidney: Involvement of oxidative stress and protective role of ascorbic acid. *Exp Toxicol Pathol* 62(6):593-9. doi: 10.1016/j.etp.2009.08.004.
[62] Pawar NN, Badgujar PC, Sharma LP, Telang AG, Singh KP. 2017. Oxidative impairment and histopathological alterations in kidney and brain of mice following subacute lambda-cyhalothrin exposure. *Toxicol Ind Health* 33(3):277-286. doi: 10.1177/0748233715627736.
[63] El-Demerdash F.M. 2007. Lambda-cyhalothrin-induced changes in oxidative stress biomarkers in rabbit erythrocytes and alleviation effect of some antioxidants. *Toxicology In Vitro* 21(3):392-7.

has been shown that erythrocytes exposed to lambda-cyhalothrin can be oxidatively damaged. The pesticide has the capability to induce oxidative damage as evidenced in terms of increased lipid peroxidation and perturbations in various antioxidant enzymes like superoxide dismutase (SOD), catalase (CAT) and glutathione S-transferase (GST). Fetoui et al. (2010)[64] observed similar effects *in vivo*. The analysis of renal tissue of rats exposed to lambda cyhalothrin has shown the decreased activities of antioxidant enzymes (SOD, CAT, GPx, GR and GST). This indicates the failure of antioxidant defence system to overcome the influx of reactive oxygen species (ROS) induced by lambda-cyhalothrin exposure. In following research, El-Demerdash (2012) observed that fenitrothion and lambda-cyhalothrin mixture increased thiobarbituric acid reactive substances levels in rat kidney homogenate and decreased its glutathione content.

### *7.4 Cytotoxic and Genotoxic effects*

Health Canada noted that "the results of genotoxicity studies conducted with cyhalothrin and lambda-cyhalothrin were mixed, with some positive results observed in vitro and in vivo."[65]

Toxic effects of lambda cyhalothrin at sub lethal concentration have been observed on human lymphocytes by Naravaveni et al (2005).[66] Their experiments indicated a clear dose-dependent cytotoxic effect. The percentage viability of the cells decreased with increase in the concentration of the pesticide. Chromosomal aberrations were found after exposure to lambda-cyhalothrin, and DNA strand breaks measured by the comet assay. The dose–response relationship of lambda-cyhalothrin showed genotoxic effects at the highest concentrations and contributed to DNA damage. Lowest doses also caused single strand breaks in DNA.

Human lymphocytes exposed to lambda cyhalothrin for 2 hours exhibited dose-response DNA strand breaks measured by comet assay. [67]

In a recent study, Muranli (2013)[68] investigated the genotoxic, cytotoxic and aneugenic effects of lambda cyhalothrin on human peripheral blood lymphocyte culture. The results show that the pesticide has cytotoxic effect and can induce cell death (apoptosis). In

[64] Fetoui H, Zeghal N. 2010. Toxic effects of lambda-cyhalothrin, a synthetic pyrethroid pesticide, on the rat kidney: involvement of oxidative stress and protective role of ascorbic acid. *Exp Toxicol Pathol* 62(6):593-9.

[65] Health Canada. 23rd June 2017. Lambda-Cyhalothrin. Proposed Re-evaluation Decision. PRVD2017-03.

[66] Naravaneni R, Jamil K. 2005. Evaluation of cytogenetic effects of lambda-cyhalothrin on human lymphocytes. *J Biochem Mol Toxicol* 19:304-10. doi:10.1002/jbt.20095.

[67] Naravaneni R, Jamil K. 2005. Evaluation of cytogenetic effects of lambda-cyhalothrin on human lymphocytes. *J Biochem Mol Toxicol* 19(5):304-10.

[68] Muranli F. 2013. Genotoxic and cytotoxic evaluation of pyrethroid insecticides λ-cyhalothrin and α-cypermethrin on human blood lymphocyte culture. *Bull Environ Contam Toxicol* 90:357–363. doi 10.1007/s00128-012-0909-z.

addition lambda cyhalothrin can affect the cell cycle even at low concentrations, while at higher concentrations it induces a weak genotoxic effect.

Male rats were exposed to lambda cyhalothrin through drinking water (at 1/10th of the median lethal dose - 612 mg/kg) for a period of 7, 14 and 21 days. It induced a noticeable genotoxic effect in rat peripheral blood ethryrocytes, evidenced by a significant increase in the frequency of micronuclei at day 21 of treatment. Significant differences between the treatment and control were observed in erythrocyte osmotic fragility. Further, a significant increase in reactive oxygen species, nitrite formation, protein carbonyl levels and lipid peroxidation in erythrocytes were observed at different times of treatments, suggesting the implication of oxidative stress in toxicity.[69]

Lambda-cyhalothrin induced a statistically significant dose-related increase in micronucleus formation in the bone marrow and the colonic crypt cells of rats treated *in vivo* by gavage at doses of 0.8, 3.06 and 6.12 mg/kg body weight.[70]

Lambda-cyhalothrin (formulation Karate) induced micronucleus formation in erythrocytes of the fish *Cheirodon interruptus interruptus*.[71]

Cavuşoğlu et al (2011) demonstrated genotoxicity in Swiss albino mice with increases in micronuclei induction, chromatid breaks, acentric fragments, chromatid gaps and rings in mouse bone marrow cells.[72]

Significantly increased frequency of micronucleated erythrocytes in the fish *Garra rufa* exposed to the commercial formulation of lambda-cyhalothrin, Karate (Zeneca; concentration not provided) demonstrated genotoxicity.[73]

### *7.5 Cancer*

As already noted, lambda-cyhalothrin increases the growth of human breast cancer cells, and has been found in association with dog mammary tumour. In addition, Canada's re-evaluation[74] states that "female mice, treatment in the diet for 104-weeks with cyhalothrin

---

[69] Fetoui H, Feki A, Salah GB, Kamoun H, Fakhfakh F, Gdoura R. 2015. Exposure to lambda-cyhalothrin, a synthetic pyrethroid, increases reactive oxygen species production and induces genotoxicity in rat peripheral blood. *Toxicol Ind Health* 31(5):433-41. doi: 10.1177/0748233713475516.
[70] Celik A, Mazmanci B, Camlica Y, Askin A, Cömelekoglu U. 2005. Induction of micronuclei by lambda-cyhalothrin in Wistar rat bone marrow and gut epithelial cells. *Mutagenesis* 20(2):125-9.
[71] Campana MA, Panzeri AM, Moreno VJ, Dulout FN. 1999. Genotoxic evaluation of the pyrethroid lambda cyhalothrin using the micronucleus test in erythrocytes of fish Cheirodon interruptus. *Mutation* Research 438:155–161.
[72] Cavuşoğlu K, Yapar K, Oruç E, Yalçın E. 2011. The protective effect of royal jelly on chronic lambda-cyhalothrin toxicity: serum biochemical parameters, lipid peroxidation, and genotoxic and histopathological alterations in Swiss albino mice. *J Med Food* 14(10):1229-37.
[73] Cavaş T, Ergene-Gözükara S. 2003. Evaluation of the genotoxic potential of lambda-cyhalothrin using nuclear and nucleolar biomarkers on fish cells. *Mutat Res* 534(1-2):93-9.
[74] Health Canada. 23rd June 2017. Lambda-Cyhalothrin. Proposed Re-evaluation Decision. PRVD2017-03.

produced an increase in the incidence of mammary adenocarcinomas, and an increase in the combined incidence of uterine leiomyomas and leiomyosarcomas. These tumors had a positive test for trend, incidences which exceeded concurrent controls, and incidences which exceeded or were at the top of the range for historical controls. In view of this evidence, the mammary and uterine tumors in mice were considered to be treatment-related. In female rats treated in the diet with cyhalothrin for 104-weeks, there was an increase in the incidence of mammary fibroadenomas. These tumors were considered to be equivocal, however, due to poor dose-response and lack of statistical significance in pair-wise tests."

### *7.6 Immune effects*

A small number of studies demonstrate the potential adverse effects of lambda-cyhalothrin on the immune system.

In a study evaluating enantio-selectivity of lambda-cyhalothrin (98% purity) in immunotoxicity to macrophage cells (RAW264.7) in a cell viability assay, a clear dose-dependent enantio-selectivity in cytotoxic effects on macrophages was observed for lambda-cyhalothrin, with a 50% mortality concentration of (-)-lambda-cyhalothrin than (+)-lambda-cyhalothrin.[75]

Another study using the RAW 264.7 macrophage cell line identified the increase in generation of reactive oxygen species as co-mediators of lambda cyhalothrin-induced cytotoxicity in macrophages.[76]

### *7.7 Neurotoxicity*

According to the European Union assessment: "*observed brain morphological changes … were the critical effects in a developmental neurotoxicity study*".[77]
In a study carried out to investigate the effect of lambda-cyhalothrin on brain dopaminergic and serotonergic systems and functional alterations associated with them, post-lactational exposure to lambda-cyhalothrin (Syngenta, India, 5% EC, suspended in corn oil) (1.0 mg/kg or 3.0 mg/kg body weight) from post-natal day (PD)22 to PD49 caused a significant decrease in the motor activity and rota-rod performance in rats on PD50 as compared to controls. Decrease in motor activity in lambda-cyhalothrin treated rats was found to persist

[75] Zhao M, Chen F, Wang C, Zhang Q, Gan J, Liu W. 2010. Integrative assessment of enantioselectivity in endocrine disruption and immunotoxicity of synthetic pyrethroids. *Environ Pollut* 158(5):1968-73. doi: 10.1016/j.envpol.2009.10.027.

[76] Zhang Q, Wang C, Sun L, Li L, Zhao M. 2010. Cytotoxicity of lambda-cyhalothrin on the macrophage cell line RAW264.7. *J Environ Sci (China)* 22(3):428-32.

[77] Commission Staff Working Document: Final Review report for the active substance lambda-cyhalothrin finalised in the Standing Committee on Plants, Animals, Food and Feed at its meeting on 11 December 2015 in view of the renewal of the approval of lambda-cyhalothrin as active substance in accordance with Regulation (EC) No 1107/2009. SANCO/12282/2014 Rev 4. European Commission. http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=activesubstance.detail&language=EN&selectedID=1509

15 days after withdrawal of exposure on PD65 while a trend of recovery in rota-rod performance was observed. A decrease in the binding of 3H-Spiperone, known to label dopamine-D2 receptors in corpus striatum associated with decreased expression of tyrosine hydroxylase (TH)-immunoreactivity and TH protein was observed in lambda-cyhalothrin treated rats on PD50 and PD65 compared to controls. Increase in the binding of 3H-Ketanserin, known to label serotonin-2A receptors in frontal cortex was observed in lambda-cyhalothrin exposed rats on PD50 and PD65 as compared to respective controls. The changes were more marked in rats exposed to lambda-cyhalothrin at a higher dose (3.0 mg/kg) and persisted even 15 days after withdrawal of exposure. The results exhibit vulnerability of developing rats to lambda-cyhalothrin and suggest that striatal dopaminergic system is a target of lambda-cyhalothrin. Involvement of serotonin-2A receptors in the neurotoxicity of lambda-cyhalothrin is also suggested. The results further indicate that neurobehavioral changes may be more intense in case exposure to lambda-cyhalothrin continues.[78] It may also suggest a possible association with Parkinson's disease.

Acute exposure of rats to lambda-cyhalothrin resulted in decreased locomotor activity directly correlated to peak brain and plasma concentrations.[79]

Post-lactational exposure to lambda-cyhalothrin (1.0 or 3.0 mg/kg body weight) affected grip strength and learning activity in rats on post-lactational day 50 and the persistent impairment of grip strength and learning was observed at 15 days after withdrawal of exposure on post-lactational day 65. A decrease in the binding of muscarinic-cholinergic receptors in frontocortical, hippocampal, and cerebellar membranes associated with decreased expression of choline acetyltransferase (ChAT) and acetylcholinesterase (AChE) in hippocampus was observed following exposure to lambda-cyhalothrin on post-lactational day 50 and post-lactational day 65. Exposure to lambda-cyhalothrin was also found to increase the expression of growth-associated protein-43 in hippocampus of rats on post-lactational day 50 and post-lactational day 65 as compared to controls. A significant increase in lipid peroxidation and protein carbonyl levels and decreased levels of reduced glutathione and activity of superoxide dismutase, catalase, and glutathione peroxidase in brain regions of lambda-cyhalothrin exposed rats were distinctly observed indicating increased oxidative stress. Inhibition of ChAT and AChE activity may cause down-regulation of muscarinic-cholinergic receptors consequently impairing learning activity in developing rats exposed to lambda-cyhalothrin. The data further indicate that long-term exposure to lambda-cyhalothrin at low doses may be detrimental and changes in

---

[78] Ansari RW, Shukla RK, Yadav RS, Seth K, Pant AB, Singh D, Agrawal AK, Islam F, Khanna VK. 2012. Involvement of dopaminergic and serotonergic systems in the neurobehavioral toxicity of lambda-cyhalothrin in developing rats. *Toxicol Lett* 211(1):1-9. doi: 10.1016/j.toxlet.2012.02.012.

[79] Moser VC, Liu Z, Schlosser C, Spanogle TL, Chandrasekaran A, McDaniel KL. 2016. Locomotor activity and tissue levels following acute administration of lambda- and gamma-cyhalothrin in rats. *Toxicol Appl Pharmacol* 313:97-103. doi: 10.1016/j.taap.2016.10.020.

selected behavioural and neurochemical end points may persist if exposure to lambda-cyhalothrin continues.[80]

### *7.8 Reproductive*

As already noted under the endocrine section, Canada assessed that lambda-cyhalothrin has a considerable number of endocrine mediated reproductive effects. It also noted that there is "high deposition and retention of the cyhalothrins in female (and male) reproductive tissues" and the mammary gland appears to be a target for distribution of lambda-cyhalothrin. It reports decreased testes weights, degenerative histopathology in the testes, abnormal sperm morphology, decreased sperm count, motility and viability, increased semen lipid peroxidation, increased dead sperm, decreased testicular antioxidant enzyme activities, decreased semen volume, decreased plasma testosterone levels and decreased libido.

We further report the results of some peer-reviewed independent studies below.

Oral lambda-cyhalothrin (Icon 2.5% EC, Syngenta) administration to adult male mice at 3 doses (0.2, 0.4, and 0.8 mg/kg/day) for 6 weeks caused a significant reduction in the weight of the seminal vesicles. The epididymal sperm count was lower in mice that received at the highest dose than in control mice. However, the proportions of live and motile spermatozoa were reduced at both the medium and the high doses compared with control mice. All doses induced an increase in the number of morphologically abnormal spermatozoa. Histopathological observations of the testes, liver, kidneys, and spleen showed dose-related degenerative damage in LCT-treated mice. The results indicate that lambda-cyhalothrin has reproductive toxicity, hepatotoxicity, nephrotoxicity, and splenotoxicity in male mice at the tested doses.[81]

In a study to assess the adverse effect of lambda cyhalothrin on reproductive organs and fertility in male rats, in which the rats received 668 ppm of LC through drinking water for 10 consecutive weeks, lambda-cyhalothrin caused a significant increase in testicular malondialdehyde, catalase, superoxide dismutase, glutathione-S-transferase activities, and sperm abnormalities and a significant reduction in testicular glutathione concentration, sperm count, sperm motility, and a live sperm percentage.[82]

---

[80] Ansari RW, Shukla RK, Yadav RS, Seth K, Pant AB, Singh D, Agrawal AK, Islam F, Khanna VK. 2012. Cholinergic dysfunctions and enhanced oxidative stress in the neurobehavioral toxicity of lambda-cyhalothrin in developing rats. *Neurotox Res* 22(4):292-309.

[81] Al-Sarar AS, Abobakr Y, Bayoumi AE, Hussein HI, Al-Ghothemi M. 2012. Reproductive toxicity and histopathological changes induced by lambda-cyhalothrin in male mice. *Environ Toxicol* 29(7):750-62. doi: 10.1002/tox.21802.

[82] Abdallah FB, Fetoui H, Zribi N, Fakhfakh F, Keskes L. 2012. Protective role of caffeic acid on lambda cyhalothrin-induced changes in sperm characteristics and testicular oxidative damage in rats. *Toxicol Ind Health* 28(7):639-47. doi: 10.1177/0748233711420470.

Lebaili et al (2008) found that 7-day oral exposure to lambda-cyhalothrin damaged rat testicles, including increased diameter of seminiferous tubules, blocking of spermatogenesis, presence of the apoptotic cells and absence of the spermatozoids in certain lumens.[83]

In a study to analyze the reproductive toxicity caused by lambda-cyhalothrin, and to evaluate the possible protective effect of vitamin E as an antioxidant, male rabbits were orally administered their respective doses of lambda-cyhalothrin every other day and given drinking water supplemented with vitamin E for 16 weeks. Results showed that semen quality deteriorated following treatment with lambda-cyhalothrin; and testosterone levels, body weight, feed intake, and relative testes and epididymis weights were significantly decreased. Concentrations of thiobarbituric acid-reactive substances were significantly increased in seminal plasma of rabbits treated with lambda cyhalothrin compared with control. Activity of glutathione S-transferase, transaminases and acid phosphatase were significantly decreased.[84]

### *7.9 Human residues*

Lambda-cyhalothrin has found in almost 100% of samples of human breast milk from 50 women in areas where it was being used of malaria control in Brazil, Colombia and Spain.[85]

## 8. Ecotoxicology

Canada's environmental assessment found that  there are potential risks to pollinators (including bees), beneficial arthropods, mammals, amphibians, aquatic invertebrates and freshwater and marine fish.[86]

### *8.1 Aquatic*

According to the EU assessment, *"A high acute and chronic risk to aquatic organisms was indicated for all representative uses."*[87]

---

[83] Lebaili N, Saadi L, Mosbah R, Mechri N. 2008. Exploration of the cytotoxic effects of an insecticide, lambda cyhalothrine on sexual exocrine function in the white rat. *Commun Agric Appl Biol Sci* 73(4):883-9.
[84] Yousef M. 2010. Vitamin E modulates reproductive toxicity of pyrethroid lambda-cyhalothrin in male rabbits. *Food Chem Toxicol* 48(5):1152-9. doi: 10.1016/j.fct.2010.02.002.
[85] Corcellas C, Feo ML, Torres JP, Malm O, Ocampo-Duque W, Eljarrat E, Barceló D. 2012. Pyrethroids in human breast milk: occurrence and nursing daily intake estimation. *Environ Int* 47:17-22. doi: 10.1016/j.envint.2012.05.007.
[86] Health Canada. 23rd June 2017. Lambda-Cyhalothrin. Proposed Re-evaluation Decision. PRVD2017-03.
[87] Commission Staff Working Document: Lambda-cyhalothrin. SANCO/12282/2014 Rev 4. 11 December 2015. http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=activesubstance.detail&language=EN&selectedID=1509

IUPAC gives the following values:

| | | | |
|---|---|---|---|
| Fish - Acute 96 hour $LC_{50}$ (mg $l^{-1}$) | 0.00021 | A5 *Lepomis macrochirus* | High |
| Fish - Chronic 21 day NOEC (mg $l^{-1}$) | 0.00025 | A5 *Oncorhynchus mykiss* | High |
| Aquatic invertebrates - Acute 48 hour $EC_{50}$ (mg $l^{-1}$) | 0.00036 | A5 *Daphnia magna* | High |
| Aquatic invertebrates - Chronic 21 day NOEC (mg $l^{-1}$) | 0.3 | A5 *Daphnia magna* | Moderate |
| Aquatic crustaceans - Acute 96 hour $LC_{50}$ (mg $l^{-1}$) | 0.000003 | F3 *Americamysis bahia* | High |
| Sediment dwelling organisms - Acute 96 hour $LC_{50}$ (mg $l^{-1}$) | - | - | - |
| Sediment dwelling organisms - Chronic 28 day NOEC, static, water (mg $l^{-1}$) | 0.00016 | A5 *Chironomus riparius* | High |
| Sediment dwelling organisms - Chronic 28 day NOEC, sediment (mg $kg^{-1}$) | 0.105 | A5 *Chironomus riparius* | Moderate |

In the state of California (USA), lambda-cyhalothrin residues have been detected in runoff from agricultural, public health, and residential uses. As the pesticide has potential for aquatic toxicity, concerns over its impact on aquatic ecosystems have arisen.

The US EPA classifies lambda-cyhalothrin as very highly toxic to fish and aquatic invertebrates.[88]

The $LC_{50}$ (48 hours) was 390 ng/L for *Daphnia magna*. The $LC_{50}$ for fish and shellfish (96 hours) have been reported as: 190 or 240 ng/L for rainbow trout, 4.9 ng/L for mysid shrimp; 0.8 ng/L for sheepshead minnow. The $EC_{50}$ for the eastern oyster is 0.59 ng/L.[89] [90]
In California, the common use of lambda-cyhalothrin in rice fields can lead to water and sediment contamination, which can be toxic to aquatic organisms such as fish and shrimps. Mosquitofish added pre-application to enclosures that were sprayed with a formulation containing lambda-cyhalothrin product (applied at a rate of 5.8 g active ingredient/hectare)

---

[88] US EPA. 2010. Lambda-cyhalothrin and gamma-cyhalothrin summary documents registration review: Initial Docket December 2010. EPA-HQ-OPP-2010-0480.
[89] US EPA. 2017. ECOTOX. Environmental Chemistry, Ecotoxicity, and Fate of Lambda-Cyhalothrin.https://cfpub.epa.gov/ecotox/quick_query.htm Accessed July 13, 2017.
[90] Hw L-M, Troiano J, Wang A, Goh K. 2008. Environmental chemistry, ecotoxicity, and fate of lambda-cyhalothrin. *Rev Environ Contam Toxicol* 195:71-91.

had 100% mortality; most of the fish added 7 days later survived.[91] The 96-hour $LC_{50}$ was 20-70 ng/L for shrimp and 0.98-7.55 μg/L for zebrafish.[92]

### *8.2 Terrestrial*

Lambda-cyhalothrin is highly toxic to honeybees and moderately toxic to earthworms, according to IUPAC:

| | | | | |
|---|---|---|---|---|
| Honeybees | Contact acute 48 hour $LD_{50}$(μg $bee^{-1}$) | 0.038 | A5 | High |
| | Oral acute 48 hour $LD_{50}$ (μg $bee^{-1}$) | 0.91 | A5 | High |
| | Unknown mode acute 48 hour $LD_{50}$ (μg $bee^{-1}$) | - | - | - |
| Earthworms - Acute 14 day $LC_{50}$ (mg $kg^{-1}$) | | > 500 | A5 *Eisenia foetida* corr | Moderate |

US EPA reported a high risk to pollinators and other beneficial insects.[93]

Canada reported a potential hazard to mammals.[94]

## 9. Environmental Fate

When the Stockholm Convention POPs Review Committee analysed alternatives to endosulfan, it concluded that lambda-cyhalothrin “could be a POPs substance”.[95]

### *9.1 Volatility*

– moderate (IUPAC)

| | |
|---|---|
| Henry's law constant at 20°C (dimensionless) | 7.38 X $10^{-06}$ |

---

[91] Lawler SP, Dritz DA, Godfrey LD. 2003. Effects of the agricultural insecticide lambda-cyhalothrin (Warrior (TM)) on mosquitofish (*Gambusia affinis*). *J Am Mosq Control Assoc* 19:430–432.

[92] Gu BG, Wang HM, Chen WL, Cai DJ, Shan ZJ. 2007. Risk assessment of lambda-cyhalothrin on aquatic organisms in paddy field in China. *Regul Toxicol Pharmacol* 48:69–74.

[93] US EPA. 2010. Lambda-cyhalothrin and gamma-cyhalothrin summary documents registration review: Initial Docket December 2010. EPA-HQ-OPP-2010-0480.

[94] Health Canada. 23rd June 2017. Lambda-Cyhalothrin. Proposed Re-evaluation Decision. PRVD2017-03

[95] UNEP. 2012. Report on the assessment of chemical alternatives to endosulfan. UNEP/POPS/POPRC.8/CRP.18

Lambda-cyhalothrin has been measured in the air at Baraki in Algeria at a concentration of 0.29 ng/m$^3$.[96]

### *9.2 Persistence*

According to the IUPAC database,[97] lambda-cyhalothrin is persistent, with the following half-life values for aerobic soil degradation:

| | | | |
|---|---|---|---|
| DT50 (typical) | 175 | | Persistent |
| DT50 (lab at 20ºC) | 175 | | Persistent |
| DT50 (field) | 26.9 | | Non-persistent |
| DT90 (lab at 20ºC) | 1193 | | - |
| DT90 (field) | 33.4 | | - |
| Note | EU dossier Lab studies DT50 range 43-1000 days, DT90 range 82 - >5000 days; Field study DT50 range 10.1-47.5 days (Germany), DT90 range 33.6-158 days | | |

POPRC notes that lambda-cyhalothrin is stable under anaerobic conditions, such as exist in the Arctic region.

### *9.3 Bioaccumulation*

Lambda-cyhalothrin is highly lipophilic. The IUPAC database gives a bioconcentration factor of 4,982, only marginally below the Stockholm Convention threshold of 5,000, but above that of some listed POPs. POPRC gives its log Kow as 5-6.9, above the Stockholm threshold for bioaccumulation

US EPA: based on a bioaccumulation factor of 4,600X in whole fish, lambda-cyhalothrin is bioaccumulative

## 10. Resistance

As of July 2017, 41 pest species are showing resistance to lambda-cyhalothrin, including 8 mosquito species, aphids, cabbage whitefly, fruit fly, weevils, cockroaches, bollworms, codling moth, armyworm, cutworm and thrips.[98]

---

[96] Moussaoui Y, Tuduri L, Kerchich Y, Meklati BY, Eppe G. 2012. Atmospheric concentrations of PCDD/Fs, dl-PCBs and some pesticides in northern Algeria using passive air sampling. *Chemosphere* 88(3):270-7.
[97] http://sitem.herts.ac.uk/aeru/iupac/Reports/415.htm
[98] MSU. 2017. Arthropod Pesticide Resistance Database. Michigan State University. Accessed July 14th, 2017. http://www.pesticideresistance.org

## 11. Alternatives to lambda-cyhalothrin

There is a wide range of nonchemical, agroecological techniques available for control of the pests for which lambda-cyhalothrin is currently used. These include biological controls, pheromone-based mating disruption, biopesticides such as *Bacillus thuringiensis*, biopesticides such as neem, and traps; as well as cultivational techniques such as providing a healthy soil environment, selecting appropriate and resistant varieties and cultivars, efficient water management, providing habitat for naturally occurring biological controls, crop diversity, crop rotation, intercropping, and optimised planting time and weed management.[99] All of these approaches can be used in agroecology, organics and IPM.

The information below is drawn from the POPs Review Committee Evaluation of non-chemical alternatives to endosulfan; lambda-cyhalothrin is used for many of the same pests for which endosulfan was used.[100]

Neem (azadirachtin) is effective on over 200 pests including some species of whiteflies, thrips, leaf miners, caterpillars, aphids, scales, beetles, true bugs and mealybugs, but efficacy varies. It is best used on immature stages of pests, before pest levels are high, and with repeated applications.

*Bacillus thuringiensis* var kurstaki, commonly referred to as Btk, is active against larvae of members of the Lepidopteran family, i.e. moth and butterfly caterpillar.

*Beauveria bassiana*, a naturally occurring entomopathogenic fungus may be used to control foliar pests including aphids, boll weevil, caterpillars, codling moth, coffee berry borer, Colorado potato beetle, diamondback moth, European corn borer, fire ants, flies, grasshoppers, Japanese beetle, leafhoppers, leaf-feeding insects, mealybug, Mexican bean beetle, mites, psyllids (lygus bugs and chinch bugs), thrips, whiteflies, and weevils.

*Metarhizium anisopliae*, a widely distributed natural soil fungus that attacks a variety of insects, causing green muscadine disease, can be used to control aphids, thrips, leaf hopper, whiteflies, scarabs, weevils, shoot and fruit borer, mites, gnats, ticks, locusts, termites, cockroaches, flies, and mosquito larvae.

*Nomuraea riley* attacks the larvae of stem borers, leaf folders, army worms and case worm.

---

99 UNEP. 2012. Evaluation of non-chemical alternatives to endosulfan. UNEP/POPS/POPRC.8/INF/14/Rev.1

100 UNEP. 2012. Evaluation of non-chemical alternatives to endosulfan. UNEP/POPS/POPRC.8/INF/14/Rev.1

*Helicoverpa armigera* nuclear polyhedrosis virus affects mainly moths and butterflies, can be used to control podborer, cotton bollworm, pink bollworm, fruit and shoot borer amongst others.

Biological controls include:

i. Lacewings such as *Chrysoperla sp* prey on the nymphs and adults of aphids, bollworms, spider mites, jassids, thrips, whiteflies, leafhopper eggs, leaf miners, small caterpillars, beetle larvae, tobacco budworm, and others.

ii. Ladybugs: a number of species that prey mainly on aphids, mites, scale insects, psyllids, whiteflies, mealybugs, tingids, leaf and planthoppers, bollworm, jassids, whitefly, early instar caterpillars.

iii. *Orius tristicolor* (minute pirate bug); Orius insidiosus (insidious flower bug) – both adults and nymphs feed by sucking juices from their prey through a sharp, needle-like beak. They feed on a variety of small prey including thrips, spider mites, insect eggs, aphids, mites, psyllids, leaf miner, whiteflies, and small caterpillars.

iv. *Nabis* sp – damsel bugs. There are over 400 species of damsel bugs. Adults and nymphs feed on many soft-bodied insects including aphids, spider mites, leafhoppers, caterpillar eggs and small caterpillars.

v. *Geocoris tricolor* F. – big eyed bug. Adults and nymphs predate whiteflies, thrips and jassids.

vi. Syrphid flies feed on aphids, thrips, scale insects, and other plant-sucking insects.

vii. Other predator insects help control bollworm, jassids, pod borer, aphids, etc.

viii. Egg parasitoids, such as *Trichogramma*, parasitize eggs - they have hundreds of hosts that they helps to control, such as bollworm, pod and stem borers, caterpillars, jassids, leaf miner, etc.

ix. Other parasitoids including braconid wasps (prey include the larvae of aphids, beetles, caterpillars, flies and sawflies) and ichneumonid wasps (the most important parasitoid of the diamondback moth), help control more than a 1000 species including larvae of aphids, beetles, caterpillars, bollworm, diamondback moth, pod borer, scale insects, leaf miner, whiteflies, coffee berry borer, jassids, thrips, flies and sawflies.

Below is an example of an IPM programme for whiteflies in tomatoes, common controlled with lambda-cyhalothrin, utilising agroecological practices:[101]

**A. Preventative measures**

(i) ***Careful site selection and timing of potato cultivation***: Most Colorado beetles emerging after winter or the non-potato season are only able to walk a short distance (around 500m) so siting potato fields greater than this distance away from fields which were infested in the previous season will reduce numbers colonising the new crop. Avoiding the local peak period of beetle attack is another sensible tactic, by either planting early-maturing potato varieties or planting considerably later than the average.

(ii) ***Rotating with other crops***: crop rotation alone will rarely be enough to avoid Colorado beetle infestation but it plays a major role in reducing the numbers colonising fields and surviving to the following season. *In Afghanistan*: IPM recommendations are to follow potato with one year of wheat, one of alfalfa and one of maize. *In California*: farmers can reduce beetle populations surviving from infested fields by planting a dense cereal crop the following year, which makes it difficult for the beetles to escape by flying, exposes them to predators and starves them of suitable food.

(iii) ***Trap crops***: These attract the first colonising beetles into a border strip, where they can be destroyed. Trap cropping works well for small or medium farms. *In the USA*: planting a trap crop of early sown potato two weeks before the main crop diverts beetles onto these plants in a confined strip, where they can be controlled mechanically before they move onto the main crop.

(iv) ***Good field hygiene***: All potato haulms and other crop waste should be removed from the field after harvest. Removing weeds, especially those in the Solanaceae family, helps to reduce sites where the beetles can survive during the winter or dormant period.

(v) ***Physical barriers and other protective methods:*** The Colorado beetle's limited flight ability and slow walking behaviour makes it relatively easy to trap at field edges using some form of pitfall trap. Another option is to use 'floating' row covers of fine fabric or mesh which exclude beetles from access to the growing foliage. *In Canada and USA*: plastic-lined trenches constructed along potato field edges, with walls sloping at an angle of 460 or steeper, can capture over 80% of adult beetles migrating. Portable field-edge traps are now available. Mulching with wheat or other cereal straw can reduce the beetle's ability to

[101] Williamson S. 2016. IPM Factsheet 2: Alternatives to carbosulfan for controlling Colorado beetle in potato. PAN UK. http://www.pan-uk.org/site/wp-content/uploads/IPM-Factsheet-2-Alternatives-to-carbosulfan-for-controlling-Colorado-beetle-in-potato.pdf

locate potato fields and the microenvironment under the mulch encourages the presence of predatory natural enemies of this pest.

(vi) ***Encouraging natural biological control***: Ground beetles are important predators of Colorado beetle in the first half of the season and will climb up plants to feed on the second and third larval stages of the first generation of beetles. Later in the season, ladybird beetles and green lacewings are major predators, feeding on eggs and very small larvae. Mulched plots support larger numbers of predators than non-mulched ones, resulting in less defoliation. Research in organic fields in the US shows that mulching to encourage natural enemies can increase tuber yields by 30%.

## B. Direct interventions when extra control is needed

(vii) ***Regular field monitoring*** to observe the health of the crop is a basic principle of IPM. This aspect is very important for Colorado potato beetle management and field observation enables growers to know when the first beetles arrive and identify 'hot spots' for control actions. This pest tends to invade from the field edge, often only from one direction, so that actions can be targeted to the vulnerable area. *In Afghanistan*: monitoring is recommended weekly, looking for adults and larvae on the upper leaf surface and egg masses underneath. Control action is needed when more than 10-15 larvae are found on a single plant.

(viii) ***Manual removal and other physical destruction methods***: The Colorado beetle lays clumps of relatively large eggs on leaf undersides and the larvae tend to remain in clumps after hatching. This makes eggs and larvae fairly easy to find and target by physical methods in smallholder potato production. *In Afghanistan*: egg masses, immature and adult beetles can be collected by hand and destroyed. Placing larvae and adults into a container of soapy water is sufficient to drown them. Flaming equipment, used for weed control, can also be used to destroy overwintering Colorado beetles. Flaming should be done after the potato shoots emerge but before the plants reach 20cm in height, when they become more sensitive to heat and the canopy will hide more beetles. It is best done on sunny days when beetles are feeding actively on the top of plants. This method is especially suitable for organic growers who have no chemical options permitted. Studies in the US show that it can kill over 90% of overwintering adults, compared with 25-50% mortality using insecticides, and flaming also reduces egg hatch. Deep tillage after harvest helps to uncover adults burrowing into the soil to survive the off-season or winter, and expose them to predators, damage and dessicate them.

(ix) ***Biopesticides***: Several products based on the bacterium *Bacillus thuringiensis* (Bt) are available, but growers should make sure to use only Bt products designed for beetles (usually with the tenebrionis strain of this bacterium). Note that Bt products need to be ingested by the beetle (i.e. they do not kill by contact) and only work against the larval stages, with the newly hatched larvae being most susceptible. Fungal-based biopesticides using selected strains of *Beauveria bassiana* can infect and kill all stages of the beetle larvae and adults but don't work well at high temperature. For the most effective use of biopesticides (just as for synthetic insecticides), growers need to monitor the pest development and time their applications to target newly hatching larvae.

(x) ***Botanical extracts and other non-chemical methods***: Neem extract products have some efficacy against Colorado beetle in the early crop stages, although high spray concentrations can provoke phytotoxic damage to the plants. Sprinkling dry wheat bran over plants as a food source is a method for smallholders recommended in some countries. The ingested bran swells inside the beetle's stomach, reduces its feeding and can even kill it. Several Colorado beetle attractant lures are available, using sex pheromones, male aggregation signals or lures based on the odours emitted by potato plants.