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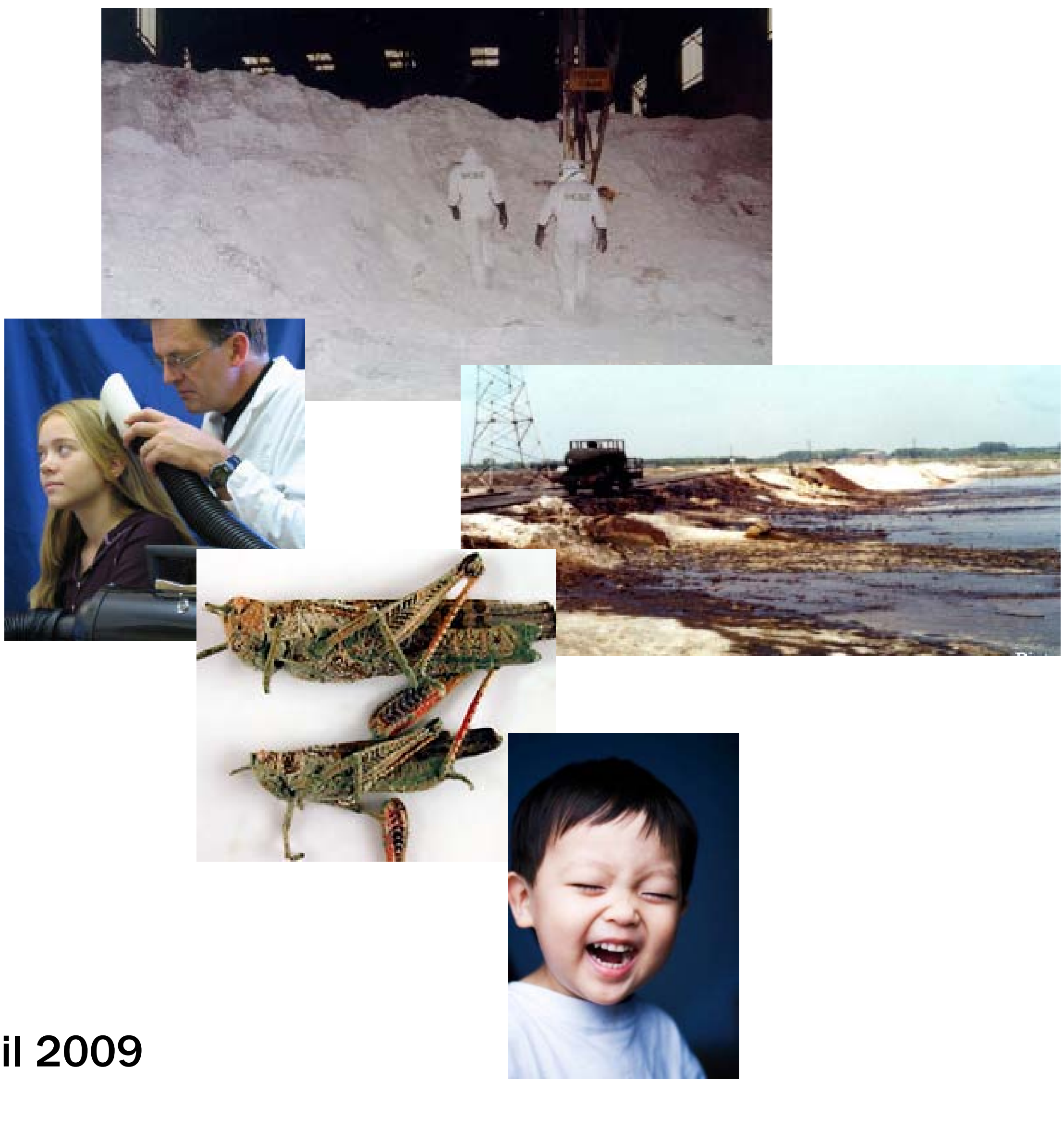
Lindane: Pharmaceutical and Agricultural Alternatives



April 2009

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(In descending order)

Images 1 and 3
Center for Environmental Cooperation of North America. Environmental Consequences of Lindane Production. 2009.
http://www.cec.org/programs_projects/pollutants_health/ smoc/presentations/Alaska/12Feb/John-Vijgen_en.pdf

Images 2 and 5
The U.S. Government Official Portal Image Library. 2009.
http://www.usa.gov/Topics/Graphics.shtml

Image 4
Commonwealth Scientific and Industrial Research Organisation. 2009.
www.ento.csiro.au/biocontrol/metarhizium.html

Introduction

Lindane is the gamma isomer of hexachlorocyclohexane (HCH). Lindane and its related isomers, alpha- and beta-HCH, have been recommended for listing under the Stockholm Convention by the POPs Review Committee (POPRC). Lindane, alpha-HCH, and beta-HCH should be included under provisions of Annex A of the Convention. Although lindane is the only HCH isomer that exhibits insecticidal properties, for every ton of lindane that is manufactured, approximately nine tons of toxic and persistent mixed-isomer HCH wastes are produced.[1] From 2 to 4.8 million tons of HCH wastes remain worldwide from lindane production.[2] These stockpiles have been poorly managed in many countries, creating hazardous waste sites that contaminate local water sources, habitats, and communities. In addition, these wastes become a source of long-range contamination to remote Arctic ecosystems where HCH isomers are among the most prevalent and persistent contaminants.

Lindane (gamma-HCH) is banned for use in at least 52 countries, restricted or severely restricted in 33 countries, not registered in 10 countries, and registered in 17 countries.[3] The properties of persistence, bioaccumulation, and long-range transport for lindane are well-recognized and the substance is known to have adverse human and ecological health effects. Nevertheless, lindane is currently is used in agricultural and pharmaceutical applications. These applications are superfluous inasmuch as economically viable and safer alternatives are available. This document provides a summary of health effects, as well as available information on alternatives to the pharmaceutical and agricultural uses of lindane.

I. Adverse Health Effects of Lindane

According to the U.S. Agency for Toxic Substances and Diseases Registry (ATSDR), inhalation of alpha, beta and gamma HCH can result in blood disorders, dizziness, headaches and changes in sex hormone levels in the blood.[4] The estrogenic effects of HCHs, including lindane, have been found in both animals and humans. In a nested case-control study conducted in Spain, maternal exposure to organochlorine pesticides including lindane is associated with cryptorchidism and hypospadias in their sons.[5] In women, HCH exposure has been linked to breast cancer and cancers of the reproductive tract. Beta-HCH accelerates the appearance and incidence of malignant breast tumors in mice.[6] It has also been shown to act as a breast cancer promoter in human breast cells.[7] A recent study in Jaipur, India found that blood lindane and organochlorine pesticide levels were significantly higher in women with cancers of the reproductive tract than in the control group.[8] The International Agency for Research in Cancer (IARC)

Workers in a lindane factory. For every ton of lindane that is produced, nine tons of toxic waste is discarded.[43] (John Vijgen, International HCH and Pesticides Association) has classified lindane as a possible human carcinogen and the World Health Organization (WHO) classifies lindane as moderately hazardous based on its acute toxicity.[9,10]

Health effects associated with the pharmaceutical use of lindane include seizures, dizziness, headaches, and paresthesia. "Seizures can happen in some people even if they use Lindane Shampoo exactly as directed."[11] When lindane products are utilized to treat head lice, the pesticide containing product is applied directly to the scalp. Children are particularly vulnerable to the adverse health effects of lindane. A letter from the American Academy of Pediatrics (Michigan, USA Chapter) urges a ban on the pharmaceutical use of lindane:

> ***Exposure to lindane is especially significant in young children because their brains are still evolving, even through adolescence. It is not recommended for use in persons less than 110 pounds in weight and yet it is still being used on small children, the major group afflicted by lice.***[12]

Animal studies confirm concerns over the use of the lindane on children, showing that younger animals are more sensitive to lindane's neurological effects.

Serious adverse effects are possible even when lindane is used according to directions. Of reported cases with a serious outcome (hospitalization, disability, or death) in the U.S. Food and Drug Administration's Adverse Event Reporting System, twenty percent of those reporting apparently used lindane according to the label instructions.[13] One study reported a statistically significant increase in the incidence of brain cancer in children who had been treated with lindane shampoo.[14] The Canadian Medical Association Journal published a Health and Drug Alert stating:

> ***Patients susceptible to scabies and head lice infestations include children and elderly people, homeless people, and people in institutions, and they may be the most vulnerable to the adverse effects of agents such as lindane***.[15]

An article in the journal *Lancet* states that lindane cannot be recommended because it is neurotoxic,[16] leading to symptoms such as numbness of skin, restlessness, anxiety, tremor, and convulsions. Nervous system damage and death can result from accidental oral ingestion of lindane.[17]

Occupational exposure to lindane in agriculture is also associated with increased morbidity and negative health outcomes. In a study of American farmers in Kansas, use of lindane on crops increased the risk for non-Hodgkin's lymphoma by 50%.[18] Farmers who applied lindane more than four times a year had an even higher risk for non-Hodgkin's lymphoma.[19] Application of lindane also significantly increases a farmer's risk for hypersensitivity pneumonitis or "farmer's lung" which can lead to permanent lung damage if left untreated.[20,21] A case control study of farm workers in California found that the use of lindane was associated with an increased risk for prostate cancer.[22] Researchers also found that the types of pesticides used were more important in determining prostate cancer risk than the overall amount of pesticides used.[23]

II. Alternatives to the Use of Lindane for the Treatment of Head Lice


Kanoria Chemicals and Industries Ltd's effluent discharge pipeline into Donki Nala River in India. (CAPE/IPEN Pesticide Working Group)

A study in the journal *Pediatrics* indicates that "the number of cases of head lice is increasing, because lice are evolving resistance to pediculicides." The article describes an effective non-chemical method for the treatment of head lice that resulted in nearly 100% mortality of eggs and 80% mortality of hatched lice. The authors conclude:

> ***Our findings demonstrate that one 30-minute application of hot air has the potential to eradicate head lice infestations. In summary, hot air is an effective, safe treatment and one to which lice are unlikely to evolve resistance. There were no adverse effects of treatment***.[24]

This article demonstrates that treatment without the use of pediculicides exceeds the efficacy of pediculicidal treatments. Documentation provided by the National Pediculosis Association supports mechanical removal using a wet combing method and specialized LiceMeister™ comb.[25] Dr. Martin Dawes, publishing a commentary in the journal *Evidence-Based Medicine* noted that the cure rate was greater in patients who used the "Bug Buster" kit (prescribed mechanical measure) than in those who used pediculicides. He states, "recent interest in the non-pharmaceutical approach is because of increasing parental concern about the use of pediculicides in children."[26]

A clinical report of the American Academy of Pediatrics states that "head lice are not a health hazard or a sign of uncleanliness and are not responsible for the spread of any disease." In the United States, approximately 6-12 million infestations occur each year mostly among children from ages 6-12 of all socioeconomic groups. Although infestation with head lice poses no direct threat to health, it may lead to secondary infections. The clinical report of the American Academy of Pediatrics recommends permethrin 1% as the preferred treatment for head lice. Lindane is not recommended, citing toxicity to the central nervous system in humans and several cases of severe seizures in children, as well as low efficacy.[27]

A study in the U.K. suggests that a treatment protocol of wet combing was more effective than pesticidal treatment.[28] In a blind, randomized, comparative study, researchers found that a prescribed mechanical method of treatment was four times more effective than current over-the-counter pediculicides for eliminating head lice. The authors cite treatment failure due to increased resistance to pediculicides as an important factor in the increased incidence of head lice infestations and raise concern about the additional toxicity this may pose to children.[29] Researchers also report a viable alternative to the use of pediculicidal treatments—the use of 4%

dimethicone lotion, a substance with a long-chain linear silicone base that acts through physical means that will not be affected by resistance to neurotoxic insecticides.[30] Dimethicone lotion has been shown to be more effective than malathion and permethrin treatments in recent observer blinded studies.[31,32] Another article in the journal *Pediatrics* reported that the use of Cetaphil cleanser was 96% effective and had a 94% long-term cure rate with no toxicity. Cetaphil cleanser was found to have cure rates exceeding those of permethrin, malathion, "Bug Busting" (particular type of mechanical removal used in the UK), and dimethicone.[33]

Stockpiles of toxic HCH waste isomers left over from lindane production. (John Vijgen, International HCH and Pesticides Association)

In an article advising clinicians published in *The Lancet*, the authors state:

Even without fully effective treatments, the management of head lice can be much improved by attention to diagnosis, contact management, and outcome of treatment. Diagnosis should be based on the presence of living, moving lice; best demonstrated using a fine-toothed detection comb. Household and close contacts should always be screened for lice in the same way, and any that are found to have lice should be treated. Because of the prevalence of resistance and the relative insensitivity of eggs to treatment, a second application of permethrin or pyrethrins should be applied after one week. The head should be re-examined a day or two after completion of treatment, when the presence of live lice of all sizes would indicate clinical resistance and the need to use a different class of product. Wet combing is also an option. Exclusion from school is disproportionate, harmful, and unnecessary.[34]

Pesticide Action Network North America published a series of non-insecticidal remedies for the treatment of head lice at http://www.panna.org/lindane/stories.

III. Alternatives to the Use of Lindane for Scabies Treatment

Scabies is a parasitic disease that "is a major public health problem in many resource-poor regions. It causes substantial morbidity from secondary infections and post-infective complications such as acute post-streptococcal glomerulonephritis."[35] Scabies is strongly associated with poverty and overcrowding. Due to adverse events during use and the toxic effects of lindane and other scabicides, viable less toxic alternatives for the treatment of scabies have been developed. Essential oils have shown an impressive effect against mites in vitro as well as in field studies.[36] Tea tree oil (*Melaleuca alternifolia*) is highly successful against mites in vitro, and a paste made from neem extracts (*Azadirachta indica*) and tumeric (*Curcuma longa*) cured 97% of patients with scabies with no adverse reactions.[37,38] In a clinical trial in Nigeria, bush tea (*Lippia multiflora*) essential oil resulted in similar high cure rates. A randomized control study in Brazil demonstrated that a commercially available repellent containing coconut oil and jojoba was highly effective.[39]

In the journal *Archives of Dermatology*, researchers report that resistance is increasing against antiectoparasitic compounds and reported treatment failures with lindane, crotamiton, and benzyl benzoate. They also reported that a 5% solution of tea tree oil (*Melaleuca alternafolia*) with the active component terpinen-4-ol was highly effective in treating scabies.[40] Australian researchers compared the survival time of scabies mites exposed to 5% tea tree oil with those exposed to ivermectin and permethrin and found that tea tree oil was more effective than the other treatments.[41] However, caution should be exercised with the topical use of tea tree oil because it may cause contact dermatitis in some individuals.[42]

IV. Case Study: California, USA

In the United States, the State of California took regulatory action to ban the pharmaceutical use of lindane in 2002. A recent article published in the journal *Environmental Health Perspectives* concluded: "The California experience suggests that elimination of pharmaceutical lindane produced environmental benefits, was associated with a reduction in reported unintentional exposures, and did not adversely affect head lice and scabies treatment. The ban serves as a model for governing bodies considering limits on the use of lindane or other pharmaceuticals…Given the recognition of lindane and other HCH isomers as toxic and persistent chemicals with health consequences, coupled with the ethical issues of manufacturing in developing countries for use elsewhere, the harms of use and production may outweigh any residual benefit from maintaining it as a second-line therapy."[43]

The following case study provides the imperative and strong evidence that pharmaceutical uses of lindane can be replaced with safer alternatives. The case study is excerpted from the North American Regional Action Plan for Lindane and Other HCH Isomers:

"In May 2000, the California Toxics Rule (CTR)[44] established a new water quality criterion of 19 ppt (parts per trillion) lindane in existing or potential drinking water supplies for protection of public health based on potential cancer risk to humans. Studies conducted of water exiting the Los Angeles County Sanitation Districts' treatment facilities found both peak and mean levels in many cases to be higher than the new (state) effluent standards. These standards were equal to the US national water quality criterion for water bodies that are existing or potential drinking water sources.[45] As available treatment technology was unable to adequately remove lindane from the water, a preventive strategy to allow compliance was required."

"The Los Angeles County Sanitation Districts calculated that a single treatment for head lice, when rinsed down the drain, contributed enough lindane to the water entering treatment facilities to bring 6 million gallons of water over the CTR standard. Based on a review of California pesticide applicator records and physician surveys conducted by these same districts, there were no significant agricultural

sources identified in the region, indicating that nearly the entire load was the result of pharmaceutical use. Initially, an education campaign with pharmaceutical lindane providers was started to discourage use. While this appeared to decrease the inflow levels of contamination, it was inadequate to comply with the new standards. A bill was then sponsored in the California assembly, which passed without opposition, to ban the sale of all pharmaceutical lindane in the state of California beginning in Jan 2002."

"A review of medical and public health authorities conducted by the Los Angeles County Sanitation Districts noted no difficulties or concerns that have been raised by the ban after over two years in a population of over 30 million.[46] Lindane concentrations in wastewater exiting these Districts' treatment plants have declined from non-attainment of the 19 ppt goal to almost non-detectable following the 2002 institution of the ban on pharmaceutical sales. From 2000 - 2004, four scabies outbreaks were reported by four counties to the California Department of Health Services (CDHS) Surveillance and Statistics Section. Statewide the number of scabies outbreaks decreased the first year following the ban with a slight increase the second and third year. A 2005 random survey of California pediatricians (135 responded) indicated that 98.5% of them had not seen any increase in scabies since the ban.[47] Since 1999, CDHS has recommended against the use of lindane for scabies[48] and against its use for head lice since 1987.[49] Prior to the ban, CDHS issued guidelines to all physicians to use malathion instead of lindane."[50]

"Outbreaks of scabies in healthcare facilities, particularly acute care hospitals, are not uncommon in California, and can last for months if not promptly recognized and managed aggressively. To address this problem, the CDHS developed and distributed to healthcare facilities a guideline for the management of scabies outbreaks (www.dhs.ca.gov/ps/dcdc/disb/disbindex.htm). In it, CDHS recommends the use of ivermectin to treat patients with severe (e.g. keratotic) scabies that are likely to be refractory to cutaneous medication, and that are the source for outbreaks in healthcare facilities. Although not recommended by CDHS for typical scabies or prophylaxis, ivermectin has also been used in outbreaks for treatment of symptomatic cases and for mass prophylaxis because of its ease in application and probable greater compliance and efficacy compared to permethrin. It should be noted that ivermectin has not been approved by the FDA for use for scabies. Institution of mass prophylaxis has always been successful in terminating the outbreak. CDHS has received no reports of adverse effects from any of these uses. However, it is not known how adverse effects were monitored for and controlled studies have not been conducted."[51]

Two case studies involving large institutional settings indicate that treatments for head lice and scabies are effective without the use of lindane products. The California Department of Corrections, with a population of over 150,000 inmates per year has treated head lice and scabies without lindane, instituting alternative treatments two years prior to the ban on the use of pharmaceutical lindane enacted by the California legislature in 2002. The corrections system has effectively treated both lice and scabies through the use of Elimite cream (5% permethrin) for scabies and several non-lindane products for head lice. The Department of Corrections recommends the use of combs to treat head lice. Dr. Evalyn Horowitz, Chief of Public Health at the California Department of Corrections, advised against the use of lindane because its use was ineffective and unnecessarily increased pesticide exposure and resistance.[52] A second case study of the Sutter Delta Medical Center in Antioch California demonstrates effective treatment of lice and scabies without the use of lindane. A 1% permethrin compound is used for head lice treatment and scabies is treated with a 5% permethrin cream. Both alternative treatments have been successful with no problems reported.[53] The U.S. Centers for Disease Control and the American Social Health Association consider a 5% permethrin cream or lotion to be the most effective treatment for scabies.[54]

V. Summary of Alternatives to Pharmaceutical Uses of Lindane

The use of lindane as a treatment for lice and scabies is outmoded due to increasing resistance, lack of efficacy, and toxicity. We have presented a variety of viable alternatives to replace the use of lindane for pharmaceutical purposes in the treatment of lice and scabies. Exemptions within the Stockholm Convention for the continuing use of pharmaceutical lindane are unnecessary and would perpetuate the threat to global health associated with lindane production and use.

VI. Alternatives to the Use of Lindane for Agricultural Use

Banning lindane has accelerated the identification, development, and adoption of non-insecticidal alternatives and control strategies. A variety of alternative methods that build on innovative practices, including organic agriculture and integrated pest management are currently known to manage pests of concern, such as wheat midge and locust infestations.[55]

India Pesticides Limited's "Muck Yard" seen behind the plant. Worker's shed and cycle stand is located right next to the yard. (CAPE/IPEN Pesticide Working Group)

With the banning of lindane, many countries have established alternative methods to effectively prevent harm to seeds and crops *in lieu of* the use of lindane. The non-insecticidal strategies currently known include: crop rotation where a non-host species is planted to reduce the damage of infestation and maintain low levels of pests; site selection and monitoring to determine if a crop-damaging pest is present; fallowing the area for a few years before planting to starve the pests; careful seed selection and re-seeding with resistant crops; timing of seeding and planting; zero or reduced tillage regimes; increasing seeding rates; shallow seeding; good seed to soil contact; balanced fertility levels to ensure that plants are not predisposed to disease; avoidance of excessively wet seed beds; and use of more competitive crop varieties to limit losses from these pests.[56,57] Other non-chemical alternatives to lindane include biological control methods that utilize predators of the target pest to reduce populations. Methods employing the use of microbials are technically feasible, efficacious and commercially available. In Costa Rica, for instance, *Metarhizium* and other biological controls such as *Trichodama* spp, *Piper aduncum*, *Trichogram* wasps, and *Bacillus thuringiensis*. are registered alternatives in commercial formulae available for use.[58] Chemical alternatives used to replace lindane include those in the neonicotinoid class (imidicloprid, thiamethoxam). Although these chemical alternatives are considered less environmentally harmful than lindane, integrated pest management and organic methods replace the need for any chemical insecticidal treatments.

Control of Wheat Midge

The wheat midge, *Sitodiphlosis mosellana Gehin*, is a pest of both spring and winter wheat in Canada, parts of the United States, Europe, Russia, and China.[59,60] The damage to crops occurs during the larval stage.[61,62,63] Eggs of this wheat midge are laid on spikes as they emerge and larvae feed on the developing kernel.[64,65]

Integrative Pest Management (IPM) strategies have been incorporated in countries such as Canada and the United States to control populations of the wheat midge. Crop rotation deters the buildup of midge populations in the soil when wheat fields are replaced with crops not susceptible to midge, such as oilseeds, soybeans, flax, beans, lentils, chickpeas, and pulse crops as well as cereal crops including barley, oats and annual canary grass.[66,67,68,69,70] Proper timing of seeding also contributes to the effective management of midge populations. The early seeding of early maturing varieties minimizes wheat midge infestation inasmuch as these varieties tend to head and flower before the peak emergence of wheat midge from the soil. For varieties that head out over a longer period of time, the susceptible stage of the crop and the presence of midge coincide. Thus late seeding of these varieties results in the least amount of damage incurred by the wheat midge.[71,72,73,74,75] Farming practices that support higher crop uniformity (such as uniform seeding depth and higher seeding rates to reduce tillage) also reduce midge kernel damage.[63,69] Growers can monitor wheat midge populations to determine if methods are effectively controlling populations, and whether or not to rotate crops. Monitoring methods include sex pheromone traps, sticky traps, and emergence traps.[76,77,78,79,80,81,82]

Macroglenes penetrans, egg-larval parasite of the wheat midge.
(Saskatchewan Agriculture and Food)

Biological controls are also integral to controlling wheat midge populations through Integrative Pest Management. Biological control methods for wheat midge have been researched in Canada, the United Kingdom, and the United States. Polyphagous predators, such as Carabidae, Staphylinidae, and spiders contribute to the control of the wheat midge, feeding on it throughout its life stages—larval stages in the soil, larvae when they pupate in the soil, larvae in the crop and crop floor when they return to the soil after feeding on the ear, eggs, and adults. Though these predators have little impact prior to oviposition, they reduce the number of midge returning to the soil to diapauses, thus preventing populations building up in the soil affecting future damage.[83] One study indicated that polyphagous predators were found to reduce midge larvae populations when other integrative farming system methods, namely timing of seeding, were utilized concurrently.[84] Important biological control agents for wheat midge are parasitoid wasps, such as *Macroglenes penetrans*, *Euxestonotus error*, and *Platygaster tuberosula*. Eggs from the wasp are laid in the egg of the wheat midge; the parasite larva then develops in the midge larva, killing the larva in the late spring of the next year.[85,86] It has been reported that the *Macroglenes penetrans* can control about 40 percent of the overwintering midge larvae.[87]

Although we cannot verify or advocate the safety of genetically modified crops, the following study was reported in the peer-reviewed literature. A highly effective resistance gene (*Sm1*) to wheat midge was recently identified, characterized, and incorporated into breeding lines of spring wheat classes grown in Canada. In fields of resistant wheat, two percent or fewer midge larvae completed development, compared with about eighty percent in susceptible wheat. In response to concerns that the use of this gene by itself would lead to the evolution of a virulent population, a study was conducted interspersing five percent vulnerable wheat refuges with ninety-five percent resistant wheat. The study found that an interspersed refuge of susceptible wheat in resistant wheat provides effective control of wheat midge damage, produces mostly avirulent wheat midge, and protects the biological control agent parasitoids.[88]

<u>Control of Locust</u>

Locusts are major economic pests that cause crop losses and damage throughout the world's dry zones. There have been serious outbreaks of this insect in recent decades. The Food and Agriculture Organization of the United Nations (FAO) has worked in collaboration with other agencies to develop alternative control methods to chemical pesticides to manage locust populations. Their research included the development of a natural and cost-effective bio-pesticide based on the acridid-specific fungal pathogen, *Metarhizium anisoplia var. acridum,* which presents a viable alternative to chemical pesticides to control locusts.[89] IMI 330189, the strain of *Metarhizium anisoplia var. acridum* most studied for its ecological risks and efficacy was developed by the international research project LUBILOSA (*Lutte Biologique contre les Locustes et Sauteriaux)* and is currently commercially available under the trade name Green Muscle®. The CSIRO (*Commonwealth Scientific and Industrial Research Organisation*) developed another strain, also commercially available known as Green Guard®.[90,91,92,93] *Metarhizium anisoplia var. acridum* has successfully been shown to be effective in controlling the Desert Locust (*Schistocerca gregaria*),[94] the Red Locust (*Nomadacris septemfasciata*), Migratory Locust (*Locusta migratoria*)[95] and the Australian plague locust (*Chortoicetes terminifera*).[96,97,98] Infection of the fungus occurs through conidia landing on the locust at the time of spraying as well as contact with the

Plague locust (*Chortoicetes terminifera*) covered with *Metarhizium anisoplia* fungal spores. (CSIRO) vegetation for some days after.[99] The spores adhere to the locust and, after germination, penetrate the host and begin to grow inside of the body, eventually killing the insect. Mortality occurs 6-14 days after application and results in >90 percent mortality,[100,101] with premortality effects observed such as reduced appetite and movement and increased susceptibility to predation.[102,103,104] Field and laboratory tests showed that *Metarhizium anisoplia var. acridum* does not have an adverse impact on non-target beneficial insects and other terrestrial and aquatic insects, reptiles, fish, crustaceans, and mammals.[105,106]

In China, another strain of *Metarhizium anisoplia var. acridum*, CQMa102, was isolated from the local *Ceracris Kiangsu* and found to be more virulent than IMI 330198 against the main species of locusts in China including *Lucusta migratoria manilensis, Chondracris rosea, Ceracris nigricornis, Oxya chinensis* and *Acrida chinensis*.[107] This strain also resulted in a high mortality rate at >90 percent 9-11 days after treatment in a wide variety of habitats in China and did not negatively affect natural locust predators such as ants, walking beetles, and wolf spiders.[108] Another microbial control for locust utilized in China and other countries is the protozoan *Nosema locustaei*. Also commercially available, this microbial control agent suppresses the aggregation behavior and significantly reduces the number of nymphs.[109] It is currently applied annually in China, providing 40-60 percent population reductions.[110]

Recent studies have shown that the male pheromone of the Desert Locust, phenylacetonitrile (PAN), affects behavior and at high concentrations disrupts gregarization, reduces feeding and marching, and increases mortality due to predation.[111,112,113,114] Though the pheromone system is complex, research suggests that combining PAN with *Metarhizium anisoplia var. acridum* results in bands dispersing and moving more slowly before dying of fungal infection, possibly reducing the effective dose of *Metarhizium anisoplia var. acridum* as PAN may affect the immune system's ability to fight the fungus.[115,116,117]

VII. Summary of Alternatives to the Use of Lindane for Agricultural Use

The use of lindane as a pest control method to reduce damage to economic crops, specifically the wheat midge and locust, is unnecessary given a wide variety of non-insecticidal methods. Integrative pest management methods, including biological controls that can be synthesized and massed produced are an adequate alternative to lindane, an insecticide with known persistence, bioaccumulation, and long-range transport properties, as well as known adverse human and ecological health effects.

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April 2009

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References

[1] Center for Environmental Cooperation of North America. The North American Regional Action Plan (NARAP) on Lindane and Other Hexachlorocyclohexane (HCH) Isomers. November 30, 2006.
[2] Vijgen, J. 2006. The Legacy of Lindane HCH Isomer Production: A Global Overview of Residue Management, Formulation, and Disposal. A Report of the International and HCH Association.
[3] Center for Environmental Cooperation of North America. The North American Regional Action Plan (NARAP) on Lindane and Other Hexachlorocyclohexane (HCH) Isomers. November 30, 2006.
[4] ATSDR. 2005. Toxicological profile for alpha-, beta-, gamma-, and delta hexachlorocyclohexane (HCH). Available: www.atsdr.cdc.gov/toxprofiles/tp43-c1.pdf (accessed 2009 April 23).
[5] Fernandez MF et al. 2007. Human exposure to endocrine-disrupting chemicals and prenatal risk factors for cryptorchidism and hypospadias: A nested case-control study. *Environmental Health Perspectives*, *115*(S-1): 8-14.
[6] Wong PS, and Matsumura F. 2007. Promotion of breast cancer by beta-hexachlorocyclohexane in MCF10AT1 cells and MMTV-neu mice. *BMC Cancer*, *7*(130).
[7] Zou E, & Matsumura F. 2003. Long-term exposure to beta-hexachlorocyclohexane (beta-HCH) promotes transformation and invasiveness of MCF-7 human breast cancer cells. *Biochemical Pharmacology*, *66*(5): 831-840.
[8] Mathur V et al.. 2008. Blood levels of organochlorine pesticide residues and risk of reproductive tract cancer among women from Jaipur, India. *Advances in Experimental Medicine and Biology*, *617*, 387-394.
[9] IARC Monographs. 1998. Hexachlorocycolhexane: Summary of data reported and evaluation. Available: http://www.inchem.org/documents/iarc/Suppl7 /hexachlorocyclohexanes.html. (accessed 23 April 2009).
[10] World Health Organization. 2005. The WHO recommended classification of pesticides by hazard. Available: http://www.who.int/ipcs/publications/pesticides_hazard_rev_3.pdf (accessed 23 April 2009).
[11] Food and Drug Administration (U.S.) Center for Drug Evaluation and Research. Lindane Shampoo and Lindane Lotion Information Page. March 2003. http://fda.gov/cder/drug/infopage/lindane/lindaneshampooguide.htm
[12] Letter to the Michigan Department of Community Health from the American Academy of Pediatrics Michigan (USA) Chapter, 2006.

[13] Food and Drug Administration (U.S.) Center for Drug Evaluation and Research. Revised Lindane Lotion Label. March 2003. http://fda.gov/cder/drug/foi/label/2003/006309/lotionlbl.pdf.
[14] Davis, J.R. et al. Family pesticide use and childhood brain cancer. Arch. Environ. Contam. Toxicol. 24(1):87-92.
[15] Wooltorton, E. 2003. Concerns over lindane treatment for scabies and lice. *CMAJ* 168(11):1447-1448.
[16] Roberts, R.J. and I.F. Burgess. 2005. New head lice treatments: hope or hype? *The Lancet* 365:8-9.
[17] Heukelbach, J. and Feldmeier. 2006. Scabies. *The Lancet* 367:1767-1774.
[18] Blair A, Cantor KP, & Zahm SH. 1998. Non-Hodgkin's lymphoma & agricultural use of the insecticide lindane. *American Journal of Industrial Medicine, 33*(1): 82-87.
[19] Blair A, Cantor KP, & Zahm SH. 1998. Non-Hodgkin's lymphoma & agricultural use of the insecticide lindane. *American Journal of Industrial Medicine*, *33*(1): 82-87.
[20] Hoppin JA, Umbach DM, Kullman GJ, Henneberger PK, London SJ, Alavanja MC, et al. 2007. Pesticides and other agricultural factors associated with self-reported farmer's lung among farm residents in the Agricultural Health Study. *Occupational Environmental Medicine, 64*(5): 334-341.
[21] National Agriculture Safety Database. 1990. Farmer's lung: It takes your breath away. Available: www.cdc.gov/nasd/docs/d001501-d001600/d001538/d001538.html (accessed 23 April 2009).
[22] Mills PK, and Yang R. 2003. Prostate cancer risk in California farm workers. *Journal of Occupational Environmental Medicine, 45*(3): 249-258.
[23] Mills PK, and Yang R. 2003. Prostate cancer risk in California farm workers. *Journal of Occupational Environmental Medicine, 45*(3): 249-258.
[24] Goates, B.M. 2006. An effective non-chemical treatment for head lice. *Pediatrics* 118(5):1962-1970.
[25] The National Pediculosis Association. The NPA's Ten Tips for Head Lice and Nit Removal. Accessed April 22, 2009. www.headlice.org/downloads/tipsremoval.htm.
[26] Dawes, M. 2006. The bug buster kit was better than single dose pediculicides for head lice. *EBM* 11:17.
[27] Frankowski, B.L. et al. 2002. American Academy of Pediatrics Clinical Report on Head Lice. *Pediatrics* 110 (3):638-643.
[28] Workshop on Alternatives to Lindane Use, sponsored by the North American Commission for Environmental Cooperation Lindane Task Force in Mexico City (October 4-6, 2005).
[29] Hill, N. et.al. 2005. Single blind, randomized, comparative study of the Bug Buster kit and over the counter pediculicides treatments against head lice in the United Kingdom. *BMJ* 331:384-387.
[30] Burgess, I.F., C.M. Brown, and P.N. Lee. 2005. Primary Care: Treatment of head louse infestation with 4% dimethicone lotion: randomized controlled equivalence trial. *BMJ* doi:10.1136/bmj.38497.506481.8F
[31] Burgess, I.F., Lee, P.N., and Matlock, G. 2007. Randomized, controlled assessor blinded trial comparing 4% dimethicone lotion with 5% malathion liquid for head louse infestation. PLoS ONE, 2(11): e1127.
[32] Heukelbach, J., Pilger, D., Oliveira, F.A., Khakban, A., Ariza, L., Feldmeier, H. 2008. A highly efficacious pediculicide based on dimethicone: randomized observer blinded comparative trial. *BMC Infectious Diseases*, 8(115).
[33] Pearlman, D. 2005. Cetaphil cleanser cures head lice. *Pediatrics* 116(6):1612-1613.
[34] R.J. and I.F. Burgess. 2005. New head lice treatments: hope or hype? *The Lancet* 365:8-9.
[35] Heukelbach, J. and Feldmeier. 2006. Scabies. *The Lancet* 367:1767-1774.
[36] Heukelbach, J. and Feldmeier. 2006. Scabies. *The Lancet* 367:1767-1774.
[37] Heukelbach, J. and Feldmeier. 2006. Scabies. *The Lancet* 367:1767-1774.
[38] Charles, V. 1992. The use and efficacy of *Azadirachta indica* and *Curcuma longa* in scabies. Trop. Geogr. Med. 44(1-2):178-81.
[39] Heukelbach, J. and Feldmeier. 2006. Scabies. *The Lancet* 367:1767-1774.
[40] Walton, S.F. et al. 2004. Acaricidal activity of *Melaleuca alternifolia*: in vitro sensitivity of *Sarcoptes scabiei var hominis* to terpinin-4-ol. *Arch. Dermatol*. 140(5):563-6.
[41] Walton, S.F. et al. 2004. Acaricidal activity of *Melaleuca alternifolia*: in vitro sensitivity of *Sarcoptes scabiei var hominis* to terpinin-4-ol. *Arch. Dermatol*. 140(5):563-6.
[42] Hammer KA, Carson CF, Riley TV, & Nielsen JB. 2006. A review of the toxicity of *Melaleuca alternifolia* (tea tree) oil. *Food and Chemical Toxicology*, *44*(5): 616-625.
[43] Humphreys, E.H. et al. 2008. Outcomes of the California ban on pharmaceutical lindane: clinical and ecologic impacts. *Environmental Health Perspectives* 116(2):297-302.

[44] Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California; Rule. May 16, 2000, Federal Register; 31682. http://www.swrcb.ca.gov/rwqcb2/Agenda/07-21-04/07-21-04-5afinalto.doc and www.waterboards.ca.gov/water_issues/programs/tmdl/records/state_board/2003/ref476.pdf.
[45] Nationally Recommended Water Quality Criteria; Notice. December 7, 1988. Federal Register; 67548.
[46] Personal communication Ann Heil, Los Angeles County Sanitation Districts, 2004.
[47] Survey conducted by Mark Miller, American Academy of Pediatrics, University of California, San Francisco, Pediatric Environmental Health Unit.
[48] Prevention and Control of Scabies in California Long-Term Care Facilities, California Department of Health Services 1999.
[49] "Head Lice Infestation-Treatment Failures with 1% Lindane." California Morbidity Report, California Department of Health Services, April 17, 1987
[50] Husted, S. "California Program to Prevent and Control Head Lice," Medical Board of California ACTION REPORT, Jan 2000
[51] Center for Environmental Cooperation of North America. The North American Regional Action Plan on Lindane Background Document. Accessed April 22, 2009. Available: http://www.cec.org/files/PDF/POLLUTANTS/Backgrounder-Key_en.pdf
[52] INFORM. September 2003. Fact Sheet. Successful Lindane-Free Control of Head Lice and Scabies. www.informinc.org
[53] INFORM. September 2003. Fact Sheet. Successful Lindane-Free Control of Head Lice and Scabies. www.informinc.org
[54] Centers for Disease Control, "Sexually Transmitted Diseases Treatment Guidelines 2002. http://www.cdc.gov/STD/treatment and American Social Health Association http://www.ashastd.org/inst/crd/em41.htm
[55] Center for Environmental Cooperation of North America. The North American Regional Action Plan on Lindane Background Document. Accessed April 22, 2009. Available: http://www.cec.org/files/PDF/POLLUTANTS/Backgrounder-Key_en.pdf
[56] Center for Environmental Cooperation of North America. The North American Regional Action Plan on Lindane Background Document. Accessed April 22, 2009. Available: http://www.cec.org/files/PDF/POLLUTANTS/Backgrounder-Key_en.pdf
[57] Stockholm Convention on Persistent Organic Pollutants Report of the Persistent Organic Pollutants Review Committee: Lindane Risk Management Evaluation. Adopted by the Persistent Organic Pollutants Review Committee at its third meeting. November 2007. Available: http://www.pops.int/documents/meetings/poprc/chem_review/Lindane/Lindane_RME_e.pdf
[58] Miller, Pam K. and Medha Chandra. Annex F Submission for Lindane; Chemical name: Gamma-hexachlorocyclohexane(gamma -HCH). February 9, 2007. Available: http://www.pops.int/documents/meetings/poprc/prepdocs/annexFsubmissions/Lindane%20IPEN.pdf
[59] Smith, MAH, et al. 2004. An interspersed refuge for *Sitodiplosis mosellana* (Diptera: Cecidomyiidae) and a biocontrol agent *Macroglenes penetrans* (Hymenoptera: Pteromalidae) to manage crop resistance in wheat. *Bulletin of Entomological Research,* 94: 179-188.
[60] Oakley, J.N. et al. 1998. Prediction of orange wheat blossom midge activity and risk of damage. *Crop Protection*, 17(2): 145-149.
[61] Government of Alberta, Agriculture and Rural Development. 2001. Wheat Midge. *Agri-Facts: Practical Information for Alberta's Agricultural Industry.* Agdex 622-22 Available: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex2507/$file/622-22.pdf?OpenElement.
[62] Government of Saskatchewan, Saskatchewan Agriculture and Food. 2007. Wheat Midge. Available: http://www.agriculture.gov.sk.ca/Default.aspx?DN=71c404d9-9420-4f72-8f6f-1a337259aa29
[63] Government of Manitoba, Manitoba Agriculture and Food. Wheat Midge. Accessed: April 22, 2009. Available: http://www.gov.mb.ca/agriculture/crops/insects/fad47s00.html.
[64] Government of Alberta, Agriculture and Rural Development. 2001. Wheat Midge. *Agri-Facts: Practical Information for Alberta's Agricultural Industry.* Agdex 622-22 Available: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex2507/$file/622-22.pdf?OpenElement.

[65] Smith, MAH, et al. 2004. An interspersed refuge for *Sitodiplosis mosellana* (Diptera: Cecidomyiidae) and a biocontrol agent *Macroglenes penetrans* (Hymenoptera: Pteromalidae) to manage crop resistance in wheat. *Bulletin of Entomological Research,* 94: 179-188.
[66] Government of Alberta, Agriculture and Rural Development. 2001. Wheat Midge. *Agri-Facts: Practical Information for Alberta's Agricultural Industry.* Agdex 622-22 Available: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex2507/$file/622-22.pdf?OpenElement.
[67] Government of Manitoba, Manitoba Agriculture and Food. Wheat Midge. Accessed: April 22, 2009. Available: http://www.gov.mb.ca/agriculture/crops/insects/fad47s00.html.
[68] Government of Saskatchewan, Saskatchewan Agriculture and Food. 2007. Wheat Midge. Available: http://www.agriculture.gov.sk.ca/Default.aspx?DN=71c404d9-9420-4f72-8f6f-1a337259aa29
[69] Knodel, Janet and O Olfert. 2008. Seasonal development of wheat midge, *Sitodiplosis mosellana* (Gehin) (Diptera: Ceciodmyiidae), in Saskatchewan, Canada. *Crop Protection*, 27: 951-958.
[70] HGCA. 2009. Orange wheat blossom midge – guidelines for assessment and control. Available: http://www.hgca.com/document.aspx?fn=load&media_id=1769.
[71] Government of Alberta, Agriculture and Rural Development. 2001. Wheat Midge. *Agri-Facts: Practical Information for Alberta's Agricultural Industry.* Agdex 622-22 Available: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex2507/$file/622-22.pdf?OpenElement.
[72] Government of Manitoba, Manitoba Agriculture and Food. Wheat Midge. Accessed: April 22, 2009. Available: http://www.gov.mb.ca/agriculture/crops/insects/fad47s00.html.
[73] Government of Saskatchewan, Saskatchewan Agriculture and Food. 2007. Wheat Midge. Available: http://www.agriculture.gov.sk.ca/Default.aspx?DN=71c404d9-9420-4f72-8f6f-1a337259aa29
[74] Knodel, Janet and O Olfert. 2008. Seasonal development of wheat midge, *Sitodiplosis mosellana* (Gehin) (Diptera: Ceciodmyiidae), in Saskatchewan, Canada. *Crop Protection*, 27: 951-958.
[75] Doane, J.F. and O. Olfert. 2008. Seasonal development of wheat midge, *Sitodiplosis mosellana* (Gehin) (Diptera: Ceciodmyiidae), in Saskatchewan, Canada. *Crop Protection,* 27: 951-958.
[76] Oakley, J.N. et al. 1998. Prediction of orange wheat blossom midge activity and risk of damage. *Crop Protection,* 17(2): 145-149.
[77] Government of Saskatchewan, Saskatchewan Agriculture and Food. 2007. Wheat Midge. Available: http://www.agriculture.gov.sk.ca/Default.aspx?DN=71c404d9-9420-4f72-8f6f-1a337259aa29
[78] Government of Alberta, Agriculture and Rural Development. 2001. Wheat Midge. *Agri-Facts: Practical Information for Alberta's Agricultural Industry.* Agdex 622-22 Available: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex2507/$file/622-22.pdf?OpenElement.
[79] Government of Manitoba, Manitoba Agriculture and Food. Wheat Midge. Accessed: April 22, 2009. Available: http://www.gov.mb.ca/agriculture/crops/insects/fad47s00.html.
[80] Knodel, Janet and O Olfert. 2008. Seasonal development of wheat midge, *Sitodiplosis mosellana* (Gehin) (Diptera: Ceciodmyiidae), in Saskatchewan, Canada. *Crop Protection*, 27: 951-958.
[81] HGCA. 2009. Orange wheat blossom midge – guidelines for assessment and control. Available: http://www.hgca.com/document.aspx?fn=load&media_id=1769.
[82] Hooper, Antony M. et al. 2007. Synthesis of (2*S*,7*S*)-dibutyroxynonane, the sex pheromone of the orange wheat blossom midge, *Sitodiplosis mosellana* (Gehin) (Diptera: Cecidomyiidae), by diastereoselective silicon-tethered ring-closing metathesis. *Tetrahedron Letters*, 48: 5991-5994.
[83] Holland, J.M. and S.R. Thomas. 2000. Do polyphagous predators help control orange wheat blossom midge, *Sitodiplosis mosellana Gehin* (Dipt., Cecidomyiidae) in winter wheat? *Journal of Applied Entomology*, 124: 325-329.
[84] Holland, J.M. et al. 1996. Some effects of polyphagous predators on an outbreak of cereal aphid (*Sitobion avenae F.*) and orange wheat blossom midge (*Sitodoplosis mosellana Gehin). Agriculture, Ecosystems and Environment, 59: 181-190.*
[85] Charlet, Laurence D. et al. 2002. Biological Control of Insect and Weed Pests in North Dakota Agriculture. NDSU Extension Service. Available: http://www.ag.ndsu.edu/pubs/plantsci/pests/e1225.pdf.
[86] Shanower, Thomas G. 2005. Occurrence of *Sitodiplosis mosellana* (Diptera: Cecidomyiisae) and its parasitoid, *Macroglenes penetrans* (Hymenoptera: Platygasteridae), in northeastern Montana. *Canadian Entomology, 137: 753-755.*

[87] Charlet, Laurence D. et al. 2002. Biological Control of Insect and Weed Pests in North Dakota Agriculture. NDSU Extension Service. Available: http://www.ag.ndsu.edu/pubs/plantsci/pests/e1225.pdf.
[88] Smith, MAH, et al. 2004. An interspersed refuge for *Sitodiplosis mosellana* (Diptera: Cecidomyiidae) and a biocontrol agent *Macroglenes penetrans* (Hymenoptera: Pteromalidae) to manage crop resistance in wheat. *Bulletin of Entomological Research,* 94: 179-188.
[89] Desert Locust Control Committee; Thirty-ninth Session. 2009. Introduction and use of bio-pesticides in locust control and challenges – when is Green Muscle® an operational option? (Agenda Item 17). Food and Agriculture Organization of the United Nations (FAO). AGP:DLCC – 09/14.
[90] Desert Locust Control Committee; Thirty-ninth Session. 2009. Introduction and use of bio-pesticides in locust control and challenges – when is Green Muscle® an operational option? (Agenda Item 17). Food and Agriculture Organization of the United Nations (FAO). AGP:DLCC – 09/14.
[91] Shi, W.P. and P.G.N. Njagi. 2004. Disruption of aggregation behaviour of oriental migratory locusts (*Locusta migratoria manilensis*) infected with *Nosema locustae. Journal of Applied Entomology*, 128(3): 414-418.
[92] Lomer, C.J. et al. 1999. Development of strategies for the incorporation of biological pesticides into the integrated management of locusts and grasshoppers. *Agricultural and Forest Entomology,* 1: 71-88.
[93] Food and Agriculture Organization of the United Nations (FAO). 2007. The Future of Biopesticides in Desert Locust Management; Report of the International Workshop held in Saly, Senegal on 12-15 February 2007.
[94] Gillespie, Jeremy P. et al. 2000. The immune response of the desert locust *Schitocerca gregaria* during mycosis of the entomopathogenic fungus, *Metarhizium anisopliae* var *acridum. Journal of Insect Physiology,* 46: 429-437.
[95] Hunter, D.M. et al. 1999. Aerial treatment of the migratory locust, *locusta migratoria* (L.) (Orthoptera: Acrididae) with *Metarhizium anisopliae* (Deuteromycotina: Hyphomcetes) in Australia. *Crop Protection,* 18: 699-704.
[96] Desert Locust Control Committee; Thirty-ninth Session. 2009. Introduction and use of bio-pesticides in locust control and challenges – when is Green Muscle® an operational option? (Agenda Item 17). Food and Agriculture Organization of the United Nations (FAO). AGP:DLCC – 09/14.
[97] Shi, W.P. and P.G.N. Njagi. 2004. Disruption of aggregation behaviour of oriental migratory locusts (*Locusta migratoria manilensis*) infected with *Nosema locustae. Journal of Applied Entomology*, 128(3): 414-418.
[98] Food and Agriculture Organization of the United Nations (FAO). 2007. The Future of Biopesticides in Desert Locust Management; Report of the International Workshop held in Saly, Senegal on 12-15 February 2007.
[99] Hunter, D.M. et al. 1999. Aerial treatment of the migratory locust, *locusta migratoria* (L.) (Orthoptera: Acrididae) with *Metarhizium anisopliae* (Deuteromycotina: Hyphomcetes) in Australia. *Crop Protection*, 18: 699-704.
[100] Food and Agriculture Organization of the United Nations (FAO). 2007. The Future of Biopesticides in Desert Locust Management; Report of the International Workshop held in Saly, Senegal on 12-15 February 2007.
[101] Hunter, D.M. et al. 1999. Aerial treatment of the migratory locust, *locusta migratoria* (L.) (Orthoptera: Acrididae) with *Metarhizium anisopliae* (Deuteromycotina: Hyphomcetes) in Australia. *Crop Protection,* 18: 699-704.
[102] Desert Locust Control Committee; Thirty-ninth Session. 2009. Introduction and use of bio-pesticides in locust control and challenges – when is Green Muscle® an operational option? (Agenda Item 17). Food and Agriculture Organization of the United Nations (FAO). AGP:DLCC – 09/14.
[103] Gillespie, Jeremy P. et al. 2000. The immune response of the desert locust *Schitocerca gregaria* during mycosis of the entomopathogenic fungus, *Metarhizium anisopliae* var *acridum. Journal of Insect Physiology,* 46: 429-437.
[104] Hunter, D.M. et al. 1999. Aerial treatment of the migratory locust, *locusta migratoria* (L.) (Orthoptera: Acrididae) with *Metarhizium anisopliae* (Deuteromycotina: Hyphomcetes) in Australia. *Crop Protection,* 18: 699-704.
[105] Lomer, C.J. et al. 1999. Development of strategies for the incorporation of biological pesticides into the integrated management of locusts and grasshoppers. *Agricultural and Forest Entomology,* 1: 71-88.
[106] Desert Locust Control Committee; Thirty-ninth Session. 2009. Introduction and use of bio-pesticides in locust control and challenges – when is Green Muscle® an operational option? (Agenda Item 17). Food and Agriculture Organization of the United Nations (FAO). AGP:DLCC – 09/14.
[107] Peng, Guoxiong et al. 2008. Field Trials of *Metarhizium anisopliae* var. *acridum* (Ascomycota: Hypocreales) against oriental migratory locusts, *Locusta migratoria manilensis* (Meyen) in Northern China. *Crop Protection,* 27: 1244-1250.

[108] Peng, Guoxiong et al. 2008. Field Trials of *Metarhizium anisopliae* var. *acridum* (Ascomycota: Hypocreales) against oriental migratory locusts, *Locusta migratoria manilensis* (Meyen) in Northern China. *Crop Protection,* 27: 1244-1250.

[109] Shi, W.P. and P.G.N. Njagi. 2004. Disruption of aggregation behaviour of oriental migratory locusts (*Locusta migratoria manilensis*) infected with *Nosema locustae. Journal of Applied Entomology*, 128(3): 414-418.

[110] Lomer, C.J. et al. 1999. Development of strategies for the incorporation of biological pesticides into the integrated management of locusts and grasshoppers. *Agricultural and Forest Entomology,* 1: 71-88.

[111] Desert Locust Control Committee; Thirty-ninth Session. 2009. Introduction and use of bio-pesticides in locust control and challenges – when is Green Muscle® an operational option? (Agenda Item 17). Food and Agriculture Organization of the United Nations (FAO). AGP:DLCC – 09/14.

[112] Food and Agriculture Organization of the United Nations (FAO). 2007. The Future of Biopesticides in Desert Locust Management; Report of the International Workshop held in Saly, Senegal on 12-15 February 2007.

[113] Lomer, C.J. et al. 1999. Development of strategies for the incorporation of biological pesticides into the integrated management of locusts and grasshoppers. *Agricultural and Forest Entomology*, 1: 71-88.

[114] Rono, Edwin et al. 2008. Concentration-dependent parsimonious releaser roles of gregarious male pheromone of the desert locust, *Schistocerca gregaria. Journal of Insect Physiology*, 54: 162-168.

[115] Desert Locust Control Committee; Thirty-ninth Session. 2009. Introduction and use of bio-pesticides in locust control and challenges – when is Green Muscle® an operational option? (Agenda Item 17). Food and Agriculture Organization of the United Nations (FAO). AGP:DLCC – 09/14.

[116] Lomer, C.J. et al. 1999. Development of strategies for the incorporation of biological pesticides into the integrated management of locusts and grasshoppers. *Agricultural and Forest Entomology*, 1: 71-88.

[117] Food and Agriculture Organization of the United Nations (FAO). 2007. The Future of Biopesticides in Desert Locust Management; Report of the International Workshop held in Saly, Senegal on 12-15 February 2007.