UNITED NATIONS

UNEP

SC

UNEP/POPS/POPRC.8/INF/14

Distr.: General
21 August 2012

English only

Stockholm Convention on Persistent Organic Pollutants

Persistent Organic Pollutants Review Committee
Eighth meeting
Geneva, 15–19 October 2012
Item 5 (e) of the provisional agenda*

Technical work: assessment of alternatives to endosulfan

Evaluation of non-chemical alternatives to endosulfan

Note by the Secretariat

As referred to in document UNEP/POPS/POPRC.8/8, the report on the evaluation of non-chemical alternatives to endosulfan is set out in the annex to the present note; it has not been formally edited.

* UNEP/POPS/POPRC.8/1.

K1282320 011012

Annex

Evaluation of non-chemical alternatives to endosulfan

Executive Summary

1. At its sixth meeting the Conference of the Parties to the Stockholm Convention agreed to list the insecticide endosulfan in Annex A of the Convention, thereby ending the production and use of endosulfan, apart from use for specific pests on a limited number of crops

2. This technical document was commissioned by the POPs Review committee (POPRC) to assist countries to find non-chemical alternatives to endosulfan for the listed exemptions, as provided for in POPRC's "General guidance on considerations related to alternatives and substitutes for listed persistent organic pollutants and candidate chemicals".

3. At POPRC 7, the representative of the Food and Agriculture Organisation (FAO) informed the meeting that the FAO's approach to pest management was an ecosystem approach and stressed the importance of this approach for sustainable crop production intensification. It was decided that this approach would be used as the basis for evaluating non-chemical alternatives to endosulfan. The ecosystem approach is also supported by other high level international bodies and studies, such as the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), the UN Special Rapporteur on the right to food, and the International Code of Conduct on the Distribution and Use of Pesticides.

4. Consequentially this document evaluates the non-chemical alternatives in two parts: the first-part is an evaluation of ecosystem approaches to management of pests in the listed crop/pest complexes, and the second part is an evaluation of non-chemical alternatives that are used within the existing chemical input-based agricultural approach as simple substitutes for endosulfan.

5. The first part considers FAO's approach to sustainable crop production intensification, including ecosystem-based IPM organic agriculture, and Community Managed Sustainable Agriculture. These systems rely on ecosystem management rather than external inputs, with the first line of defence against pests being a healthy agroecosystem. They are knowledge-intensive, location-specific farming systems based on conservation practices, appropriate seed varieties, plant nutrition based on healthy soils, efficient water management, and the integration of crops, pastures, trees and livestock. The focus is on managing the agro-ecosystem to avoid build up of pests, using wherever possible cultural, biological, and mechanical methods instead of synthetic materials. Practices include using resistant varieties better adapted to ecologically-based production than those bred for high-input agriculture, crop diversity, crop rotation, intercropping, optimised planting time and weed management, conserving natural enemies, and managing crop nutrient levels to reduce insect reproduction. Such approaches have shown increased or similar yields, greater returns to farmers, and improvement in social and environmental indicators. It is difficult to provide a simple prescription for a particular crop/pest complex in these systems as the entire interwoven management process is crucial to protecting crops from pests. Each crop/pest complex needs to be looked at within the specific agroecosystem, taking into account many aspects, including climatic and geographical variables, presence of natural enemies and availability of biological controls, the structure and function of the particular farm, and microclimatic variations within it.

6. The second part considers particular technical interventions that can be used in either an ecosytem approach or as substitutes within IPM or chemical-input based agriculture. These include natural plant extracts, attractant lures and traps, and biological controls such as pathogens, predators, and parasitoids.

7. Guidance is given on technical feasibility, a step-wise approach to shifting to ecology-based approaches, the need for farmer training, and websites for additional information are provided.

1. Background

8. By its decision SC-5/3, the Conference of the Parties to the Stockholm Convention on Persistent Organic Pollutants (COP) decided to amend part I of Annex A to the Convention to list therein technical endosulfan and its related isomers, with specific exemptions as set out in Table 1.

9. To support the development and deployment of alternatives to endosulfan, the COP decided to undertake a work programme as set out in the annex to decision SC-5/4. Accordingly, Parties were requested and observers were invited to submit information on chemical and non-chemical alternatives to endosulfan. The Persistent Organic Pollutants Review Committee (POPRC), beginning at its seventh meeting, was requested to assess the alternatives to endosulfan in accordance with the general guidance on considerations related to alternatives and substitutes to listed persistent organic pollutants and candidate chemicals.[1]

10. At its seventh meeting, the POPRC reviewed the information provided by the Parties and observers on alternatives to endosulfan[2] and adopted decision POPRC-7/4 which set out a work plan and terms of reference for the intersessional work related to the assessment of alternatives to endosulfan.

Table 1: Specific crop/pest exemptions for endosulfan in part I of Annex A

Crop	Pest	Requesting country
Cotton	cotton bollworms, pink bollworms, aphids, jassids, whiteflies, thrips, leafroller	Uganda, India, China
Jute	Bihar hairy caterpillar, yellow mites	India
Coffee	berry borer, stem borer	Uganda
Tea	aphids, caterpillars, tea mosquito bugs, mealybugs, scale insects, thrips, flushworm, smaller green leaf hopper, tea geometrid	India, China, Uganda
Tobacco	oriental tobacco bud worm, aphids	China
Cow peas, beans, tomato	whiteflies, aphids, leaf miner	Uganda
Okra, tomato, eggplant	fruit and shoot borer, diamondback moth, aphids, jassids	India (okra), Uganda (tomato, eggplant)
Onion, potato, chillies	aphids, jassids	India
Apple	yellow aphids	China
Mango	hopper, fruitflies	India
Gram, arhar	aphids, caterpillar, podborer, pea semilooper	India
Maize	aphids, stem borer, pink borer	Uganda, India
Paddy/rice	white jassids, stem borer, gall midge, rice hispa	India
Wheat	aphids, termites, pink borer	China
Groundnuts	aphids	India
Mustard	aphids, gall midge	India

2 Objectives

11. This document provides an evaluation of non-chemical alternatives[3] to endosulfan based on information made available to the POPRC, as well as additional information to address gaps in the information provided, in accordance with the POPRC document “General guidance on considerations related to alternatives and substitutes for listed persistent organic pollutants and candidate chemicals” (UNEP/POPS/POPRC.5/10/Add.1). The General guidance requires that both chemical and non-chemical products and processes be considered as alternatives to a POP or candidate POP.

1 UNEP/POPS/POPRC.5/10/Add.1.

2 UNEP/POPS/POPRC.7/INF/11/Rev.1 and UNEP/POPS/POPRC.7/INF/12.

3 In this document the term non-chemical is used to refer to substances and methods that are not synthetic pesticides, recognising that the borderline between some substances and synthetic pesticides is thin, and that some substances may be used as extracts from naturally occurring substances or as synthetic analogues – for example, neem, gibberllic acid, methyl eugenol, and pheromones. All of these substances were identified by countries and observers in the non-chemical category, and neem and pheromones at least are permitted in organic agriculture.

3 Methodology

12. At POPRC 7, the representative of FAO described how FAO is committed to reduce hunger and improve livelihoods among rural communities with sustainable crop production intensification that uses an ecosystem approach. Within this context, FAO promotes sustainable and environmentally sound plant protection and production strategies that reduce health and environmental risks associated with the use of pesticides. The emphasis of FAO's approach is to improve plant health through sound ecosystem management, and where necessary applying nonchemical pest management strategies that may be supplemented by using low hazard chemical pesticides.

13. It was decided that the ecosystem approach would be used as the basis for evaluating non-chemical alternatives to endosulfan.

14. Information provided by parties and observers to the Risk Management Evaluation of endosulfan, to POPRC 7, and the subsequent invitation by the Secretariat to provide further information, is collated (refer Annex 1). The drafter has provided additional information to fill the remaining gaps in nonchemical alternatives to some crop/pest complexes.

15. This document notes the high-level support for an ecosystem approach to agricultural production, describes what is meant by an ecosystem approach, and reviews examples relevant to the exempted crop/pest complexes under different agro-ecological conditions.

16. The non-chemical alternatives are evaluated in two parts:

a) The first-part is an evaluation of alternatives used in an ecosystem approach to sustainable agriculture.

b) The second part is an evaluation of non-chemical alternatives that are used within the existing chemical input-based agricultural approach as simple substitutes for endosulfan.

4 Ecosystem or agro-ecological approaches to crop production

4.1 High level support

17. Over the past decade there have been a number of statements from high level international bodies and studies that the current model of intensive agriculture, based on a high level of external inputs such as pesticides, synthetic fertilisers and irrigation, must change if the global community is to meet its commitments to feed itself and future generations, including meeting the Millennium Development Goal set in 2002 of reducing by half, between 1990 and 2015, the proportion of people who suffer from hunger. This high level support has been underpinned by the outcome document from the Rio + 20 United Nations Conference on Sustainable Development, *The Future We Want*, which in "affirming the necessity to promote, enhance and support more sustainable agriculture… recognize[s] the need to maintain natural ecological processes that support food production systems".[4]

4.1.1 International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD)

4.1.1.1 Description

18. In 2009, the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) concluded it is necessary to shift from current farming practices to sustainable agriculture systems capable of providing both significant productivity increases and enhanced ecosystem services.[5]

19. The IAASTD was a global assessment of the impacts of agricultural knowledge, science and technology on hunger, poverty, nutrition, human health, and environmental and social sustainability in relation to both the past and the future. The Assessment process was initiated in 2002 by the World Bank in partnership with a multi-stakeholder group of organizations, including FAO, GEF, UNDP, UNEP, WHO and UNESCO, and representatives of governments, civil society, private sector, and scientific institutions from around the world.[6]

20. The Assessment asked the question: How can we reduce hunger and poverty, improve rural livelihoods, and facilitate equitable, environmentally, socially and economically sustainable development through the generation, access to, and use of agricultural knowledge, science and

4 http://www.uncsd2012.org/futurewewant.html

5 FAO. 2011. Save and Grow. A policymaker's guide to the sustainable intensification of smallholder crop production. Chapter 6 Plant protection. http://www.fao.org/ag/save-and-grow/en/6/index.html.

6 History of the IAASTD. http://www.agassessment.org/index.cfm?Page=IAASTD_History&ItemID=159.

technology?[7] The findings include that "'Business as usual' is not an option if we want to achieve environmental sustainability" (p28), that the food security challenge is likely to worsen if …market-driven agricultural production systems continue to grow in 'a business as usual mode' (p24), and that sustainable development can be promoted through reduced agrochemical inputs and use of agroecological management approaches (p 29).[8]

4.1.1.2 Efficacy

21. The IAASTD concluded that productivity per unit of land and per unit of energy use is much higher in small-scale and diversified farms than in large intensive farming systems.[9]

4.1.2 UN Special Rapporteur on the right to food

4.1.2.1 Description

22. In 2011, the UN Special Rapporteur on the right to food, Oliver de Schutter, delivered a report to the 16th Session of the UN Human Rights Council, based on an extensive review of recent scientific literature.[10] The report demonstrated that, if sufficiently supported, agroecology could double food production in entire regions within 10 years, at the same time mitigating climate change and alleviating rural poverty. It can increase farm productivity and food security, improve incomes and rural livelihoods, and reverse the trend towards species loss and genetic erosion.

23. De Schutter describes agroecology as a set of agricultural practices that "enhance agricultural systems by mimicking natural resources, thus creating beneficial biological interactions and synergies among the components of the agroecosystem". One of the core principles is recycling nutrients and energy on the farm rather than introducing external inputs. The report states that agroecology is supported by the FAO, UNEP and Biodiversity International, as well as gaining ground in countries such as the United States, Brazil, Germany and France.

4.1.2.2 Efficacy

24. In ecology-based or agroecological systems of production, it is difficult to identify the efficiency of any one particular method of management of a particular pest/crop complex, as that management depends on the whole suit of measures taken to enhance the health and vigour of the agroecosystem. However an evaluation of efficiency can be arrived at by assessing the degree to which the practices are adopted by other farmers who are exposed to the practices, the effect on productivity, the effect on income, effects on the agroecosystem and wider environment, and effects on social indicators such as farmer health, food security, sustainability of livelihood, self-reliance, and poverty alleviation.[11]

25. De Schutter references a report by Pretty et al[12] which found an average crop increase of 79% in 286 sustainable agriculture projects based on agroecology, in 57 countries covering 37 million hectares, rising to 116% for all African projects and 128% for East Africa. He also refers to a study commissioned by Foresight Global Food and Farming Futures, of 30 projects in 20 African countries, which found 213% increase in yields with sustainable agroecological practices within 3-10 years.[13] He concluded that scaling up agroecological practices can simultaneously increase farm productivity and food security, improve incomes and rural livelihoods, reverse the trend towards species loss and genetic erosion, and assist adaption to climate change.

7 IAASTD. 2003. An Assessment of Agricultural Science and Technology for Development. The Final Report of the Steering Committee for the Consultative Process on Agricultural Science and Technology. 12 August 2003. http://www.agassessment.org/docs/SCReport,English.pdf.

8 IAASTD. 2009. Agriculture at the Crossroads. Synthesis Report. International Assessment of Agricultural Knowledge, Science and technology for Development (IAASTD). http://www.agassessment.org/.

9 IAASTD. 2009. Agriculture at the Crossroads. Synthesis Report. International Assessment of Agricultural Knowledge, Science and technology for Development (IAASTD). http://www.agassessment.org/. P.22.

10 De Schutter O. 2011. Agroecology and the Right to Food. United Nations Special Rapporteur on the Right to Food. A/HRC/16/49. http://www.srfood.org/index.php/en/component/content/article/1174-report-agroecology-and-the-right-to-food.

11 Ooi et al. 2004. Environmental Education for Poor Farmers. FAO-EU Programme for Cotton in Asia. UNEP/POPS/POPRC.7/INF/24.

12 Pretty J et al. 2006. Resource-conserving agriculture increases yields in developing countries. *Environ Sci Technol* 40(4):1114-9.

13 J. Pretty et al. 2011. Sustainable intensification in African agriculture. *Int J Agricul Sustain* 9(1):5-24.

4.1.3 International Code of Conduct on the Distribution and Use of Pesticides

26. The International Code of Conduct on the Distribution and Use of Pesticides (the Code) is a global guidance document on pesticide management for all public and private entities associated with the distribution and use of pesticides. It was adopted for the first time in 1985 by the Twenty-fifth Session of the FAO Conference and revised several times since then, most recently in 2002. The Code provides standards of conduct and serves as a point of reference for sound pesticide management practices, in particular for government authorities and the pesticide industry.[14] Various guidelines have been developed based on the framework of the Code, including the FAO Guidance on Pest and Pesticide Management Policy Development (2010).[15]

27. The Guidance promotes the adoption of an IPM approach to pest management, and states the following: "IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms. The main reason for the increased attention to IPM is the recognition that pesticide use, and associated risks, can often be reduced considerably without impacting negatively on production or profitability…. Modern pest management makes use of the "ecosystem approach", taking into account the life-cycle and ecology of pests and their natural enemies, and pest-host interactions. It then uses this knowledge to minimize pest damage to the crop through agronomic interventions or other non-chemical techniques that suppress the development of the pest or disease. Pesticides are only used in those cases where there are no effective or economically viable alternatives." It details the main principles of the IPM approach as growing a healthy crop through focus on cultural (cultivational) practices, managing the agro-ecosystem to avoid build up of pests, and deciding on the use of external inputs at a site-specific local level based on monitoring of pest levels. It states that pesticides should only be applied when threshold levels indicate that pesticide use is justified, their use be kept to a minimum, and be as specific as possible for the target with the least side effects on human health, non-target organisms and the environment. The document also describes the steps involved in an IPM approach, which are very similar to the FAO's ecosystem approach described below.

4.2 FAO's ecosystem approach

4.2.1 Description

28. FAO's website 'Save and Grow'[16] describes FAO's approach to sustainable agriculture. It states "the present paradigm of intensive crop production cannot meet the challenges of the new millennium. In order to grow [crop yields] agriculture must learn to save".[17] The challenges are stated to include failing to feed the world, declining rates of growth in yields, and the negative externalities of **c**urrent intensification approaches such as land degradation, salination of irrigated areas, over-extraction of groundwater, the build-up of pest resistance, the erosion of biodiversity, deforestation, greenhouse gas emissions, nitrate pollution of water bodies, and health risks for farmers and contamination of air soil and water from overuse of pesticides.

29. FAO promotes a new paradigm of sustainable crop production intensification (SCPI) that conserves and enhances natural resources. It uses an ecosystem approach in which inputs of land, water, seed and fertiliser compliment natural processes that support plant growth, pollination, natural predation for pest control, and soil biota to enhance plant access to nutrients. It draws first and foremost on nature's contribution to crop growth, and applies appropriate external inputs "at the right time, in the right amount". SCPI involves a major shift from the current homogenous model of crop production to one of knowledge-intensive, location-specific, farming systems, based on conservation practices, good seed of high-yielding adapted varieties, integrated pest management, plant nutrition based on healthy soils, efficient water management, and the integration of crops, pastures, trees and livestock. [18]

30. SCPI draws on natural sources of plant nutrition including manure, nitrogen-fixing crops, trees, and judicious use of mineral fertilisers. A healthy soil has a rich diversity of biota and a high content of organic matter, and is key to sustainable management of pests and diseases, such as stem borer. Farming practices aim to minimise soil disturbance, keep a protective cover on the soil surface

14 http://www.fao.org/agriculture/crops/core-themes/theme/pests/pm/code/en/.

15 http://www.fao.org/agriculture/crops/core-themes/theme/pests/pm/code/list-guide/en/.

16 Sustainable Intensification of Crop Production. Food and Agriculture Organisation of the United Nations. http://www.fao.org/ag/save-and-grow.

17 Save refers to soil, water, nutrients.

18 FAO. 2011. Save and Grow. A policymaker's guide to the sustainable intensification of smallholder crop production. Overview. http://www.fao.org/ag/save-and-grow/index.html.

through use of mulches, and cover crops, and to cultivate a wider range of plant species that enhance crop nutrition and system resiliency.[19]

31. It states that first line of defence against crop pests is a healthy agro-ecosystem. Crop losses can be kept to a minimum by using resistant varieties better adapted to ecologically based production than those bred for high-input agriculture, crop diversity, crop rotation, intercropping, optimised planting time and weed management, conserving predators, managing crop nutrient levels to reduce insect reproduction. Pests occur naturally in the agro-ecosystem and outbreaks usually follow breakdown of natural processes of pest regulation. The aim is not one of total eradication, which undermines the viability of populations of natural enemies, but one of balance and minimised crop losses. Over reliance on pesticides disrupts parasitoids and predators, resulting in outbreaks of secondary pests and pest resistance, followed by increased pesticide use, with serious health risks for farmers, negative effects on the environment, and sometimes reduced yields. To reduce losses, control strategies should take advantage of beneficial species of pest predators, parasites and competitors, along with biopesticides and selective, low risk synthetic pesticides, in an ecosystem-based IPM approach.[20]

32. The FAO publication “Save and Grow” states that “the ‘business as usual’ approach to pest management, still followed in many countries and by many farmers, limits their potential for implementing sustainable crop production intensification.”[21]

4.2.2 Efficacy

33. Smallholders use and manage more than 80% of farmland in Asia and Africa and FAO’s ecosystem approach is aimed particularly to assist them. FAO cited the report of Pretty et al referred to by De Schutter to demonstrate increase crop yields in sustainable agroecological systems.[22][23]

4.3 Organic agriculture

4.3.1 Overview

34. The IAASTD concluded that organic agriculture can contribute to socially, economically and ecologically sustainable development because it uses local resources and because the market for organic products offers farmers opportunities for increasing their income and improving their livelihoods (p 23). By 2006, more than 31 million ha of land in at least 120 countries was under certified organic management. Latin America has the greatest number of organic farms, but Australia has the largest area under certification. Thirty-three percent of West African agricultural production comes from non-certified organic systems; and in Cuba organic systems produce 65% of rice, 46% of fresh vegetables, 38% of non-citrus fruits and 5% of roots, tubers and plantains.[24]

35. The FAO has an organic agriculture programme, launched in 1999, the objective of which is “to enhance food security, rural development, sustainable livelihoods and environmental integrity by building capacities of member countries in organic production, processing, certification and marketing”.[25] The FAO hosts a web portal of organic research centres, searchable by country and region, a potential source of information on organic systems for growing the crops on which pests have been controlled using endosulfan.[26] For example, for Egypt it identifies 3 organisations, including the Central Laboratory of Organic Agriculture, which researches organic production of various crops and provides alternatives to agrochemicals.[27] For India, 27 organisations are identified

19 FAO. 2011. Save and Grow. A policymaker’s guide to the sustainable intensification of smallholder crop production. Chapter 3 Soil health. http://www.fao.org/ag/save-and-grow/en/3/index.html

20 FAO. 2011. Save and Grow. A policymaker’s guide to the sustainable intensification of smallholder crop production. Chapter 6 Plant protection. http://www.fao.org/ag/save-and-grow/en/6/index.html.

21 FAO. 2011. Save and Grow. A policymaker’s guide to the sustainable intensification of smallholder crop production. Chapter 6 Plant protection. http://www.fao.org/ag/save-and-grow/en/6/index.html.

22 Pretty J et al. 2006. Resource-conserving agriculture increases yields in developing countries. *Environ Sci Technol* 40(4):1114-9.

FAO. 2011. Save and Grow. A policymaker’s guide to the sustainable intensification of smallholder crop production. http://www.fao.org/ag/save-and-grow/.

24 IAASTD. 2009. Agriculture at the Crossroads. Global Report. International Assessment of Agricultural Knowledge, Science and technology for Development (IAASTD). http://www.agassessment.org/. Pp. 23, 182.

25 Organic Agriculture. Food and Agriculture Organization of the United Nations. http://www.fao.org/organicag/oa-home/en/.

26 Organic Research Centres Alliance. Food and Agriculture Organization of the United Nations. http://www.fao.org/organicag/oa-portal/en/?no_cache=1. Database search site is http://www.fao.org/organicag/oa-portal/orca-database/searchnew/en/.

27 http://www.fao.org/organicag/oa-portal/orca-database/list/en/.

as potentially providing information on organic pest management. The International Federation of Organic Movements can also provide links to sources of information of organic management of crops.[28]

36. Cambodia is undertaking the promotion of organic agricultural production, where the application of chemical pesticides would be reduced gradually.[29]

4.3.2 Description

37. Organic agriculture is described by IAASTD as a holistic production management system that promotes and enhances agroecosystem health including biodiversity, biological cycles, and soil biological activity.[30] It emphasises the use of management practices in preference to the use of off-farm inputs, using wherever possible cultural, biological, and mechanical methods instead of synthetic materials. FAO further adds that organic agriculture relies on ecosystem management rather than external inputs. It is a system that considers potential environmental and social impacts by eliminating the use of synthetic inputs, such as synthetic fertilizers and pesticides, veterinary drugs, genetically modified seeds and breeds, preservatives, additives and irradiation. These are replaced by site-specific management practices that maintain and increase long-term soil fertility and prevent pests and diseases.[31]

38. Organic production shares many of the features of FAO's sustainable crop production intensification (SCPI) approach, particularly the emphasis on soil health and fertility in producing plants that can better withstand pest and disease incursions, fostering natural controls, and adopting an integrated management system. One difference is that SCPI does include the use of synthetic chemical pesticides as a last resort, and these are not permitted under organic agriculture. Minimum tillage can be practiced within organic production systems by replacing the use of herbicides with, for example cover crops and a roller/mulcher developed by the Rodale Institute in the USA.[32]

39. Both systems depend on site-specific application of management techniques, so it is not possible to provide a 'recipe' for control of specific pests on specific crops that can be used globally. Each crop/pest complex needs to be looked at within the specific agroecosystem, taking into account many aspects, including climatic and geographical variables, presence of natural enemies and availability of biological controls, the structure and function of the particular farm, and microclimatic variations within it.

4.3.3 Example

40. Control of the coffee berry borer in Mexico's organic coffee production systems includes the use of the entomopathogenic fungus *Beauvaria bassiana*, the parasitic wasps *Prorops nasuta*, *Phymastichus coffea*, and *Cephalonomia stephanoderis*, attractant traps, removing dried berries from the plants (sanitary harvesting) to interrupt the pest's life cycle, and neem. The attractant traps contain methyl or ethyl alcohol, and farmers report that these are even more effective than using *Beauvaria bassiana.* Cultural controls which involve cleaning coffee fields, regulating shade, improved pruning methods, and sanitary harvesting have kept infestation to levels between 5 and 10%, without even the need for traps.[33]

4.3.4 Efficacy

41. Global organic cotton production is increasing. In Benin there was a 360% increase in the area under organic cotton cultivation between 2005 and 2008, the area having grown to 1,800 hectares.[34]

---

28 http://www.ifoam.org/.

29 UNEO-POPS-POPRC7FU-SUBM-Endosulfan-Cambodia-120210.En.doc.

30 IAASTD. 2009. Agriculture at the Crossroads. Global Report. International Assessment of Agricultural Knowledge, Science and technology for Development (IAASTD). http://www.agassessment.org/. P23. This is the FAO/WHO Codex Alimentarius (2001) description.

31 FAO. FAQ: What is organic agriculture? http://www.fao.org/organicag/oa-faq/oa-faq1/en/.

32 http://www.rodaleinstitute.org/introducing_a_cover_crop_roller.

33 Bejarano et al. 2009. Alternatives to Endosulfan in Latin America. International POPs Elimination Network (IPEN) and Pesticide Action Network in Latin America (Red de Acción sobre Plaguicidas y sus Alternativas en América Latina, RAP-AL). http://www.ipen.org/ipenweb/documents/ipen%20documents/summary%20endosulfan%20alternatives_english.pdf. UNEP-POPS-POPRC5FU-SUBM-ENDOSU-F-IPEN-100108-ref3-Latin America.En.pdf.

34 PAN/IPEN. 2009. Endosulfan in West Africa: Adverse Effects, its Banning, and Alternatives. POPs Pesticides Working Group, Pesticide Action Network (PAN) and International POPs Elimination Network (IPEN). In UNEP-POPS-POPRC5FU-SUBM-ENDOSU-F-IPEN-100108-01.En.pdf.

India is the world's largest organic cotton producer. Organic cotton output increased there by 292% during 2007-08 to 73,702 tonnes compared with the previous year. This resulted in a global organic cotton increase by 152%, to 146,000 tonnes. India contributes half of the world's organic cotton output.[35] In 2011, organic cotton production is reported to have declined 35% from 241,697 tonnes in 2010 to 151,079,[36] although that is still an increase over 2008. In 2011 organic cotton was grown by 218,966 farmers on 324,577 hectares.

Table.1 Global organic cotton production (tonnes)[37]

Country	2006-07	2007-08
India	18,790	73,702
Syria	2,5023	28,000
Turkey	1,520	24,440
China	4,079	7,354
Tanzania	1,662	2,852
USA	1,918	2,726

42. Organic coffee is grown in 40 countries including Bolivia, Burundi, Brazil, Cameroon, China, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Ethiopia, Ghana, Guatemala, Haiti, Honduras, India, Indonesia, Kenya, Lao PDR, Madagascar, Malawi, Mexico, Nepal, Nicaragua, Panama, Peru, Philippines, Rwanda, Sri Lanka, Thailand, Timor-Leste, Togo, Trinidad and Tobago, Uganda, United Republic of Tanzania, United States (Hawaii), Venezuela, Vietnam, and Zambia. The leading producer countries are Brazil, Ethiopia, Mexico, and Peru. Global sales of organic coffee reached 67,000 tonnes in 2006, a 56 % increase from 2003.[38] In 2005, Mexico had 123,000 producers of organic coffee, representing about 19% of the total land area grown in coffee, with this increasing to 25% in 2008. In 2006, there were 2,656,559 hectares of certified organic coffee in Argentina.[39]

4.4 Other ecology-based approaches: Community Managed Sustainable Agriculture

43. There are other ecology-based approaches, including some of the traditional agriculture practices of many countries, and those that have been augmented by the addition of modern biological controls and other techniques. One such approach is that of Community Managed Sustainable Agriculture (CMSA). [40]

4.4.1 Description

44. Community Managed Sustainable Agriculture (CMSA) was developed in the state of Andra Pradesh in India to address issues of low profitability in agriculture resulting from the high cost of external inputs of fertiliser and pesticides, with subsequent indebtness, land mortgages, suicides, and decline in the area being farmed. CMSA replaces pesticides with a combination of physical and biological measures and compliments it with biological and agronomic soil fertility measures leading to reduced use of chemical fertilisers. It is also referred to as 'Non-Pesticidal Management'. [41]

45. CMSA is based on understanding the crop ecosystem and adopting suitable cropping systems and practices; understanding insect biology and behaviour and adopting suitable preventative measures; and building farmers' knowledge and skills in making best use of local resources, natural

35 Subramani MR. 2008. India tops in world organic cotton output. The Hindu Business Line. Nov 1st. http://www.blonnet.com/2008/11/01/stories/2008110150302100.htm. In UNEP-POPS-POPRC5FU-SUBM-ENDOSU-F-IPEN-100108-01.En.pdf.

36 http://textileexchange.org/2011-farm-fiber-report.

37 Subramani MR. 2008. India tops in world organic cotton output. The Hindu Business Line. Nov 1st. http://www.blonnet.com/2008/11/01/stories/2008110150302100.htm. In: In UNEP-POPS-POPRC5FU-SUBM-ENDOSU-F-IPEN-100108-01.En.pdf.

38 Facts about organic coffee. The Organic Trade Association. http://www.ota.com/organic/organic_and_you/coffee_collaboration/facts.html.

39 Bejarano et al 2009 *op cit*.

40 Kumar TV, Raidu DV, Killi J, Pillai M, Shah P, Kalavadonda V, Lakhey S. 2009. Ecologically Sound, Economically Viable Community Managed Sustainable Agriculture in Andra Pradesh, India. The World Bank, Washington DC. In UNEP-POPS-POPRC5FU-SUBM-ENDOSU-F-IPEN-100108-ref4-India.En.pdf. UNEP-POPS-POPRC5FU-SUBM-ENDOSU-F-IPEN-100108-ref4-India.En,pdf

41 Ramamjaneyulu GV & Raghunath TAVS. 2011. Government of India Recommended Use of Endosulfan and Available Alternatives. Centre for Sustainable Agriculture, Secunderabad. UNEP-POPS-NPOPS-SUBM-SC5-4-ENDOSU-IPEN_5-110729.En.pdf.

processes and community activities. The aim is to manage pest populations, not try to eliminate them, and to focus on balancing predator and pest populations. It involves using good quality seed, building healthy soils, reducing abiotic stress, using mixed cropping systems, intercropping, crop rotation, planting trap and border crops, deploying pheromone and sticky traps, and spraying botanical extracts and natural preparations if preventative steps have not worked sufficiently. Soil health is enhanced by use of microbial formulations such as inoculations of nitrogen-fixing bacteria *Azospirillum* and *Azotobacter*, compost, green manure crops, mulches, vermiculture and bio-fertilisers. Diversity and intensity of crops is increased. CMSA practices are generally compatible with organic certification systems, and use an IPM approach to aid farmers in converting over three years to the CMSA system. They are similar to FAO ecosystem approaches except they use deep ploughing as a pest control method whilst FAO promotes minimum tillage.[42]

46. In Andra Pradesh the CMSA system has been managed by a network of community self-help groups that have provided financial services, extension through farmer field schools, on-farm research trials, development of technology, and other assistance.[43]

4.4.2 Efficacy

47. CMSA has significantly reduced cost of cultivation without significantly reducing productivity, resulting in net increase in farmers' income and significant health and ecological benefits. By 2009, over 300,000 farmers on 550,000 hectares of farmland in Andra Pradesh had adopted CMSA in four years.[44] In 2011, those figures were reported to have grown to over 10 million farmers on over 10 million hectares.[45]

4.4.2.1 Productivity [46]

48. Monitoring of 400 farmers in 5 districts found that yields were the same for chilli and groundnut, increased for red gram, and slightly decreased for cotton and rice. It was expected that over time as soil fertility improved, the yield reductions would diminish.

Crop	CMSA average yield (kg/acre)	Conventional average yield (kg/acre)
chilli	1750	1750
groundnut	1100	1100
red gram	550	500
cotton	900	1100
rice	2000	2300

49. In addition, intercropping and multi cropping has led to substantial increases in total productivity over the previous single crop system.

4.4.2.2 Cost of cultivation [47]

50. A survey of 141 farmers practising CMSA found the average cost of cultivation to be reduced by US $20-300 per acre, depending on the crop, compared with the costs under conventional agricultural production of the same crops.

Crop	Average saving on cost of cultivation (US$/acre)
Rice	20
Chilli	300
Cotton	100
Groundnut	16
red gram	24
other (fruits, vegetables, cereals, etc)	20

42 Ramamjaneyulu & Raghunath 2011 op cit.

43 Kumar et al 2009 *op cit.*

44 Kumar et al 2009 *op cit*.

45 Ramamjaneyulu GV & Raghunath TAVS. 2011. Government of India Recommended Use of Endosulfan andAvailable Alternatives. Centre for Sustainable Agriculture, Secunderabad.

46 Kumar et al 2009 *op cit*.

47 Kumar et al 2009 *op cit*.

4.4.2.3 Farmer income [48]

51. Lower costs of cultivation and relatively similar yields have led to higher net incomes for farmers practising CMSA. On the basis of the survey figures, a farmer raising cotton on 1 ha could save US $250 per year on cost of production. The average annual income for farmers in Andra Pradesh on 1-2 ha of land is US $441, so that reduction in cost of cultivation is 56% of the farmers' annual income. Where multi-cropping was introduced, significant gains in income were experienced, the most outstanding example being one farmer who increased her annual net income from US$100 to $875.

52. CMSA produce, although not organic is recognised in the market with a price premium and was fetching between 14 and 33 % higher prices for vegetables, red gram, chill, cotton and rice.

4.4.2.4 Food security [49]

53. Food security has improved with household expenditure on grains reduced by 44 percent.

4.4.2.5 Other social and environmental indicators[50]

54. Other benefits that farmers practising CMSA have experienced are stated to be relief from debt and mortgage, social empowerment, increases in area of cultivation, business innovation and new livelihood opportunities such as vermin-composting units, a drop in pesticide-related health impacts, improved soil ecology, and an increase in beneficial insects and birds.

4.4.3 CMSA pest management practices

55. Some of the pest management approaches practised under CMSA for the crop/pest complexes listed in Annex A are as follows: [51]

Crop	Pest	Practice
Arhar/gram	All	* deep summer ploughing to expose larvae and pupa to sun and predators * erect bird perches * spray with 5% neem seed kernel extract
Chilli	All	* deep summer ploughing to expose larvae and pupa to sun and predators * erect bird perches * spray with 5% neem seed kernel extract
Cotton	bollworm and other pests not listed	* deep summer ploughing to expose larvae and pupa to sun and predators * application of 200 kg neem cake during ploughing * soil inoculation with nitrogen fixing bacteria like *Azospirillum* and *Azotobacter* * apply cow dung-urine solution as pest repellent * spray with 5% neem seed kernel extract or 3% neem oil * apply cow dung-urine solution as pest repellent * spray 5% Vitex Solution (decoction of leaves of *Vitex negundo*)
Groundnut	All pests	* deep summer ploughing to expose larvae and pupa to sun and predators * erect bird perches
Jute	Bihar hairy caterpillar, and other non-listed pests	* deep summer ploughing to expose larvae and pupa to sun and predators * erect bird perches * spray with 5% neem seed kernel extract * spray with chilli-garlic solution

48 Kumar et al 2009 *op cit*.
49 Kumar et al 2009 *op cit*.
50 Kumar et al 2009 *op cit*.
51 Ramamjaneyulu & Raghunath TAVS 2011 *op cit*.

Crop	Pest	Practice
Maize	Stem borer	* deep summer ploughing to expose larvae and pupa to sun and predators * application of 200 kg neem cake during ploughing * spray with 5% neem seed kernel extract * spray with chilli-garlic solution
Mango	Mango hopper	* spray with 5% neem seed kernel extract or 3% neem oil
Rice/paddy	Rice hispa	* spray with 5% neem seed kernel extract * remove leaf folds using thorny twigs * spray with Vitex solution (decoction of the leaves of *Vitex negundo*)
Tomato	Fruit borer	* deep summer ploughing to expose larvae and pupa to sun and predators * erect bird perches * spray with 5% neem seed kernel extract * spray with chilli-garlic solution * deploy pheromone traps

4.4.4 A stepwise approach to change

56. The CSMA farmers take a step-wise approach in shifting from chemical input based production to non-pesticidal management and eventually organic farming:[52]

57. The first stage of adoption is based on IPM approaches. The farmers undertake training in management and pest prevention, learning skills for diagnosing, documenting and understanding the behaviour and lifecycles of pests and the roles of natural enemies such as predators. They introduce crop rotation, and begin to use compost and manure. In the second stage they begin replacing chemical pesticides with a combination of physical methods such as pheromone traps, sticky traps, bird perches and summer ploughing; and biological methods such as biopesticides like neem.

58. In the third stage physical and biological pest management is complimented by replacing conventional fertilisers with microbial formulations, scaled-up composting, vermiculture and bio-fertilisers. Trap crops are planted on the perimeters. Intercropping and multi- cropping may be practised.

5. Substitutes within chemical input-based agricultural systems

59. Any of the techniques or inputs listed in Annex A can be incorporated into ecosystem, IPM or chemical input-based agricultural systems to a greater or lesser degree. Those most commonly used in IPM and chemical input-based agricultural systems are plant extract sprays like neem (azadirachtin), pheromone traps, and biological controls such as parasitoids, predators, and pathogens like the bacteria *Bacillus thuringiensis* or the fungus *Beauvaria bassiana*. However, as most biological controls involve the use of living organisms, they may be adversely affected, and their efficiency reduced, by the use of pesticides; care must be taken to protect them.

5.1 Biological preparations

5.1.1 Neem/azadirachtin

60. The neem tree, *Azadiracta indica*, is native to South Asia, and now also grows in other tropical and subtropical regions. Both leaves and seeds have insecticidal properties. They have been used for thousands of years for cosmetic, personal hygiene, medicinal and insecticidal purposes.[53] As an insecticide, neem is used as a leaf extract, seed extract, neem oil, neem oil soap, and neem cake. Neem oil is pressed from the fruit and seeds; neem cake is the by-product of oil extraction. Neem contains more than 70 compounds, but azadirachtin is regarded as the main component active against insects, with insect growth regulator, anti-feedant and oviposition deterrent properties. Other compounds in neem appear to also be active against insects, but less is known about them.[54]

52 Ecologically Sound, Economically Viable Community Managed Sustainable Agriculture in Andra Pradesh, India. The World Bank, Washington DC. In UNEP-POPS-POPRC5FU-SUBM-ENDOSU-F-IPEN-100108-ref4-India.En.pdf. UNEP-POPS-POPRC5FU-SUBM-ENDOSU-F-IPEN-100108-ref4-India.En,pdf.

53 Azadirachtin (121701) Clarified Hydrophobic Extract of Neem Oil (025007) Fact Sheet. US EPA. http://www.epa.gov/opp00001/biopesticides/ingredients/factsheets/factsheet_025007.htm.

54 Material Factsheet – Neem. Resource Guide for Organic Insect and Disease Management. Cornell University. http://web.pppmb.cals.cornell.edu/resourceguide/mfs/08neem.php.

61. The US EPA classifies neem as Toxicity Category IV for acute oral and III for inhalation,[55] and regulates its use as a non-synthetic botanical pesticide. The US EPA states that risks to humans are not expected. Some people have reported skin and mucous membrane irritation from neem seed dust. There may be a toxicity difference between commercial formulations of azadirachtin, and neem leaf decoction, neem oil, and neem seed extract.[56]

62. Neem is said to be 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.[57]

63. Neem is permitted to be used in organic agriculture in the US but preventative, cultural, mechanical and physical methods are required to be first choice for pest control. It is regarded as suitable for IPM programmes.[58]

64. Neem is reported to have little or no adverse effect on adult beneficial insects, but negative effects have been noticed on immature stages of some. Product labels advise not to apply when bees are foraging, although it is reported to be relatively harmless to bees.[59] It is relatively safe for the ladybugs *Menochilus sexmaculatus* and *Verania vincta* compared with the insecticides monocrotophos and endosulfan;[60] but at higher doses caused mortality of *Chrysoperla carnea* larval instars and *Encarsia sophia*.[61]

65. Neem/azadirachtin has been recommended by countries and observers for the following uses:

Crop	**Pest**
Apple	aphids
arhar/gram	aphids,
Beans	aphids, leaf miner, whiteflies
Chillies	Aphids, jassids
Coffee	berry borer, stem borer
cotton	bollworm, jassids, whiteflies, pink bollworm, thrips
cow pea	leaf miner
eggplant	aphids
jute	Bihar hairy caterpillar
maize	stem borer, aphids,
mango	hoppers, fruitflies
okra	aphids
onions	aphids, jassids
potato	aphids, jassids
tomato	fruit and shoot borer, diamondback moth, leaf miner, aphids, jassids, whiteflies
rice/paddy	rice hispa, gall midge, white jassids
tea	tea mosquito bug, scale insects, thrips, smaller green leaf hopper

5.1.2 Gibberellic acid

66. Gibberellic acid is recommended by Argentina for control of fruit fly in mangoes.

55 Azadirachtin Summary Document Registration Review: Initial Docket September 2008. EPA-HQ-OPP-0632-0632-0002.pdf.

56 Material Factsheet – Neem *op cit*.

57 Material Factsheet – Neem *op cit*.

58 Material Factsheet – Neem *op cit*.

59 Material Factsheet – Neem *op cit*.

60 Gowri S, Ramachandrarao G, Nagalingam B. 2002. Impact of neem formulations on Coccinellid predators of okra pest complex. *Pestic Res J* 14(2):242-3.

61 Aggarwal N, Brar DS, 2006. Effects of different neem preparations in comparison to synthetic insecticides on the whitefly parasitoid *Encarsia sophia* (Hymenoptera: Apelinidae) and the predator *Chrysoperla carnea* (Neuroptera: Chrysopidae). *J Pest Sci* 79:201-7.

67. Gibberellic acid is a naturally occurring plant growth regulator, and is usually used as a plant growth regulator, including to slow ripening of mangoes after harvest. It is used to delay peel ripening in citrus fruit and this reduces their susceptibility to fruit fly.[62]

5.2 Attractant lures and traps

5.2.1 Pheromones

68. The deployment of traps containing insect pheromones are used to control pest numbers by disrupting mating, and by capturing pests in baited or sticky board traps. Pheromones have been available for this purpose since the 1970s. The basis of mating disruption is male confusion, in which the male follows false scents of female sex hormones and its energy is expended before it finds a mate. Pheromone lures are placed within a crop at certain distances depending on the crop and pest. In some cases a contact insecticide is added to pheromone-baited traps to kill the insect (e.g. commercial pink bollworm traps). Commercial formulations of pheromones for both trap baits and mating disruption mimic the natural chemical blends of females as closely as possible. There are pheromone products available for most pests of agricultural importance.[63] Countries and observers have recommended their use for boll weevil, pink bollworm, coffee berry borer, diamond back moth, aphids, fruit and shoot borer, and rice stem borer.

5.2.2 Methyl eugenol

69. Methyl eugenol traps were recommended by countries and observers to control fruitlfy in mango.

70. Methyl eugenol occurs in both natural and synthetic forms, is used as flavouring in food, a fragrance in soaps and cosmetics, and an attractant in insecticides. It is a component of rose, pimento, basil, hyacinth, citronella, anise, nutmeg, mace, cinnamon leaves, pixuri seeds, and laurel fruits and leaves, and a component of many essential oils. It also has been found in blackberry essence, bananas, black pepper, and bilberries.[64]

71. US EPA classifies its acute toxicity as Category III for oral and dermal routes. It may be a skin sensitizer, and requires precautionary statements on label to warn users that, "Prolonged or frequently repeated skin contact may cause allergic reactions in some individuals exposed to this product," and "Workers and Applicators must were chemical resistant gloves while mixing and/or when handling this product". It is regarded as being “reasonably anticipated to be a human carcinogen”, based on limited evidence in humans and sufficient evidence in animals. It causes benign and malignant tumours of the liver, stomach, kidney, mammary gland and skin, in rats.[65] The European Commission found it to be a multisite, multi species carcinogen, with a carcinogenic effect observed at the lowest doses tested (37mg/kg/ bw/day).[66]

72. Methyl eugenol is widely used in traps and lures for oriental fruit fly, including the US eradication program, Mediterranean fruit fly, solenaceous fly,[67] and for a number of fruit crops including mango.

5.3 Biological controls

73. Biological controls are used in three general approaches: importation, augmentation or conservation, of natural enemies of the pests. These three approaches can be used in combination with each other, or alone.

74. Importation: this may be undertaken when an insect that is alien to a country becomes a pest within that country because of a lack of natural enemies to keep it in check. Natural enemies are imported from the country of origin of the pest (or a third country), after ascertaining that they will not

62 Messing R. 1999. Managing fruit flies on farms in Hawaii. Cooperative Extension Service, University of Hawaii at Manoa. http://www2.ctahr.hawaii.edu/oc/freepubs/pdf/IP-4.pdf.

63 Radcliffe’s IPM World Textbook. University of Minnesota. http://ipmworld.umn.edu/chapters/landis.htm.

64 Final Report on Carcinogens. Background Document for Methyleugenol. Prepared for the U.S. Department of Health and Human Services, national Toxicology Program, by Technology Planning and Management Corporation. http://ntp.niehs.nih.gov/ntp/newhomeroc/roc10/me.pdf.

65 Final Report on Carcinogens *op cit*.

66 European Commission. 2001. Opinion of the Scientific Committee on Food on Methyleugenol (4-Allyl-1,2-dimethoxybenzene. SCF/CS/FLAV/FLAVOUR/4 ADD1 FINAL. http://ec.europa.eu/food/fs/sc/scf/out102_en.pdf

67 Methyl Eugenol (ME) (203900) Factsheet. United States Environmental Protection Agency. http://www.epa.gov/opp00001/biopesticides/ingredients/factsheets/factsheet_203900.htm.

damage other non-pest insect species. Populations are mass reared, and then released in crops where the pest has established.

75. Augmentation: action is taken to increase the effectiveness of existing natural enemies or where they are not present, by mass rearing and release. This approach generally seeks to adapt natural enemies to existing production systems, rather than adapt the existing production system to suit the biological controls, which is the Conservation approach. There are hundreds of biological control preparations available commercially for release to control pests, weeds, and pathogens, their availability differing between countries. Their release is timed to the presence of the susceptible stage of the host pest, i.e. the egg, larvae, pupae and/or adult. In China mass rearing of the parasitic wasp *Trichogramma* takes place in localised facilities ranging from open air insectaries to mechanised facilities that are said to be leading the world in development of artificial host eggs.

76. Conservation: conserving natural enemies is a critical element of biological control, and usually involves reducing or removing elements that limit their effectiveness, and/or providing resources to encourage them. Pesticides may directly kill them, or have indirect effects by reducing the number of hosts for them to feed on and hence cause the population to become unsustainable. Providing resources to encourage natural enemies may include providing appropriate microclimates, overwintering habitat, and/or alternative food resources. Reduced tillage, intercropping, providing shelterbelts, and buffer zones, crop edge plantings to provide refuges all help to foster natural pest enemies. [68] Biological control is a well-established practice in agriculture. For example, *Trichogramma* wasps, minute endoparasitoids of insect eggs and the most widely augmented species of natural enemy, having been mass-produced and field released for almost 70 years. Worldwide, over 32 million ha of agricultural crops and forests are treated annually with *Trichogramma* spp. in 19 countries, especially in China and republics of the former Soviet Union.[69] In 2010, 230 species of natural enemies were being used in pest management in all regions of the world.[70]

77. Annex 1 lists the biological controls and biological sprays for each crop/pest complex, and the section below describes them in detail.

5.3.1 Pathogens

78. Pathogens used to control pests include bacteria, viruses, and fungi. These may be referred to as microbial insecticides, biorational insecticides, or bio-insecticides. Diseases are an important natural control of some insects under some conditions, particularly those of high humidity and/or high pest abundance. The pathogens can multiple rapidly to cause outbreaks of disease that decimate the pest population. This natural process has been harnessed to provide improved control of a number of pests. Some pathogens are mass-produced and are available in commercial formulations for use in standard spray equipment. Some, such as the bacterium Bacillus thuringiensis, are widely used by gardeners and commercial growers. Most insect pathogens are relatively specific to certain groups of insects and life stages. They kill, reduce reproduction, slow growth or shorten the life cycle of the pests. They are stated to not directly affect beneficial insects and therefore are compatible with predators and parasites. They are said to be non-toxic to wildlife or humans, however applicators should minimise exposure. Pathogens may take longer than chemical insecticides to kill the pest, and effectiveness may depend on environmental conditions and pest abundance. An understanding of the pest life-cycle is necessary as the pathogens need to be applied at the appropriate life-cycle stage.[71]

5.3.1.1 Bacillus thuringiensis var kurstaki (Btk)

79. *Bacillus thuringiensis* (Bt) is a naturally occurring bacteria used as a biological pesticide. There are a number of different strains that are active against different insect species; for example *Bacillus thuringiensis* Israeli is active against mosquito larvae and is widely used as a larvicide in mosquito control programmes.

80. Although commonly referred to as a pathogen for biological control purposes, the action of Bt on insects is not truly pathogenic in that it does not generally cause the insect to develop disease. Its action is more akin to that of a stomach insecticide: it contains an endotoxin that when ingested by the larva is activated by the larval stomach and interferes with digestion causing it to die; septicaemia may contribute to death. Human stomach conditions do not activate the endotoxin, hence it is

68 Radcliffe's IPM World Textbook. University of Minnesota. http://ipmworld.umn.edu/chapters/landis.htm.

69 Radcliffe's IPM World Textbook. University of Minnesota. http://ipmworld.umn.edu/chapters/landis.htm.

70 Van Lenteren JC.2012. The state of commercial augmentative biological control: plenty of natural enemies, but a frustrating lack of uptake. *BioContol* 57:1-2.

71 Sheldon A. undated. Predators. Pathogens. Department of Entomology, College of Agriculture and Life Sciences, Cornell University. http://www.biocontrol.entomology.cornell.edu//pathogens.html.

generally regarded as being safe for humans.[72] However there are reports of human health effects following urban aerial spray campaigns with Btk, when people have been significantly more exposed via inhalation than they would be in the normal course of agricultural use.[73]

81. *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. Btk has been registered in the USA since 1996, and there it can be ground or aerially sprayed or used in chemigation systems.[74] It is widely used around the world as a foliar spray. It is also used in some countries as a component of genetically modified cotton to protect it against bollworm and pink bollworm. Sudan is planning to grow 150,000 acres of Bt cotton in 2012.

82. The use of Btk in genetically modified cotton crops has caused problems in India. An advisory from the agriculture Ministry is reported to have stated that cotton farmers are in deep crisis after shifting to Bt cotton, with falling yields, increasing pest attacks, rising costs resulting in farmer suicides.[75] A second report[76] states that, of 47 lakh acres planted with Bt cotton in the state of Andhra Pradesh, the crop failed in 33.73 lakh acres. More than two-thirds of the crop suffered a yield loss of more than 50%. The government of the state of Maharashtra paid compensation packages to Bt cotton farmers. The country's overall yield of cotton has decreased as the acreage of Bt cotton has increased. One reason given for this is the high fertiliser and water requirements of Bt cotton resulting in high fertiliser input, water problems in rain-fed areas, and nutrient deficiency physiological disorders. Other reasons are pest resistance (bollworm and pink bollworm) and the emergence of secondary pests including mealy bug and whiteflies. Expenditure on pesticides has increased. It is not expected to have adverse effects on non-pest species of insects other than those in the Lepidopteran family, although some effects, adverse and beneficial, on parasitoids have been observed. [77]

83. Countries and observers have recommended the use of Btk for the following crop/pest complexes:

Crop	Pests
Arhar/gram	caterpillars, semilooper, pod borers
cotton	bollworm, pink bollworm, leaf miner, diamondback moth
maize	pink borer
okra	diamondback moth
tomato	fruit and shoot borer, diamondback moth, leaf miner
tea	caterpillars
tobacco	Oriental budworm
wheat	pink borer, termites

84. Btk should also be effective against leafminer on cow peas, fruit and shoot borer on eggplant, and pink borer on wheat because they are all lepidopteran.

85. Resistance has been reported for cotton bollworm to Btk in China.[78]

5.3.1.2 *Beauveria bassiana*

86. *Beauveria bassiana* is a naturally occurring entomopathogenic fungus, causing white muscadine disease in foliar pests through contact action. When the fungal spores come in contact with the cuticle of susceptible insects, they germinate and grow through the cuticle to the inner body of their host. The fungus proliferates throughout the insect's body, producing toxins and draining the

72 *Bacillus thuringiensis* subspecies *kurstaki* strain M-200 (006452) Fact Sheet, United States Environmental protection Agency. http://www.epa.gov/oppbppd1/biopesticides/ingredients/factsheets/factsheet_006452.htm.

73 Govern J, Kerns T, Quijano R, Wihongi D. 2007. Report of the March 2006 People's Inquiry into the Impacts and Effects of Aerial Spraying Pesticides over Urban Areas of Auckland. http://www.peoplesinquiry.co.nz/component/option,com_frontpage/Itemid,1/.

74 *Bacillus thuringiensis* subspecies *kurstaki* strain M-200 (006452) Fact Sheet *op cit*.

75 Haq Z. 2012. Ministry blames Bt cotton for farmer suicides. Hindustan Times. May 17. http://www.hindustantimes.com/News-Feed/Business/Ministry-blames-Bt-cotton-for-farmer-suicides/Article1-830798.aspx.

76 Radhakishnan S, Kuruganti K. 2012. 10 Years of Bt Cotton: False Hype and Failed Promises. Cotton farmers' crisis continues with crop failure and suicides. Coalition for a GM-Free India. http://indiagminfo.org/?p=393.

77 *Bacillus thuringineis*. Environmental Health Criteria 217. WHO, 1999. http://whqlibdoc.who.int/ehc/who_ehc_217.pdf.

78 Arthropod Pesticide Resistance Database. http://www.pesticideresistance.org/.

insect of nutrients, eventually killing it. Once the fungus has killed it's host, it grows back out through the softer portions of the cuticle, covering the insect with a layer of white mould, which produces millions of new infective spores that are released to the environment. Many soil insects appear to have a natural tolerance to *Beauvaria*. [79]

87. Susceptible foliar pests include 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.[80 81 82]

88. Countries and observers recommend *Beauvaria bassiana* for the following uses, with the third column being additional potential uses, according to information in references (Groden, Mahr, Cornell University, India's Ministry of Science and Technology[83]):

Crop	Pests recommended by Countries & Observers	Additional potential uses
apple		yellow aphids
Arhar/gram		aphid, caterpillar, pod borer
beans		aphids, whiteflies, leaf miner
chilli		aphids
coffee	berry borer, stem borer	
cow pea	aphids, whiteflies	leaf miner
cotton	bollworm	pink bollworm, aphids, whiteflies, leafroller, thrips
eggplant	diamondback moth	
groundnut		aphids
jute		Bihar hairy caterpillar, yellow mites
maize		aphids
mustard		aphids
okra	diamondback moth	
onion		aphids
potato		aphids
tomato	diamondback moth	whiteflies, aphids, leaf miner,
tea		aphids, caterpillars, thrips, mealybugs, smaller green leaf hopper
tobacco		aphids
wheat		aphids,

89. *Beauvaria bassiana* is available in a number of commercial formulations in different countries and can be applied by standard spray equipment. These products are generally non-toxic to beneficial insects although some, such as ladybugs,[84] and at least five other biocontrol agents (*Orius insidiosus, Phytoseiulus* persimilis, *Encarsia formosa, Aphidius colemani* and *Ipheseius degenerans*)[85] can be affected. Bees exposed to *Beauvaria* showed very low mortality;[86] however, applications to areas where bees are actively foraging should be avoided. *Beauveria* products should not be applied to

79 Groden E. 1999. Using *Beauveria bassiana* for insect pest management. University of Connecticut Integrated Pest Management. http://www.hort.uconn.edu/ipm/general/htms/bassiana.htm.

80 Groden 1999 *op cit*.

81 Mahr S. Know Your Friends: the entomopathogenic Fungus *Beauveria bassiana*. University of Wisconsin-Madison. http://www.entomology.wisc.edu/mbcn/kyf410.html.

82 Material Factsheets – *Beauvaria bassiana*. Resource Guide for Organic Insect and Disease Management. Cornell University. http://web.pppmb.cals.cornell.edu/resourceguide/mfs/03beauveria_bassiana.php.

83 Expert Committee, Government of India, 2008-09 for use in the State of Orissa.http://india.gov.in/allimpfrms/alldocs/10051.pdf. UNEP-POPS-NPOPS-SUBM-SC%-$-ENDOSU-IPEN_1-110729.En.pdf.

84 Mahr S. Know Your Friends: the entomopathogenic Fungus *Beauveria bassiana*. University of Wisconsin-Madison. http://www.entomology.wisc.edu/mbcn/kyf410.html.

85 Ludwig SW, Oetting RD. 2001. Susceptibility of natural enemies to infection by *Beauvaria bassiana* and impact of insecticides on *Ipeseius degenerans* (Acari: Phtytoseiidae). http://scentsoc.org/Volumes/JAUE/v18/169.pdf.

86 Al mazraawi MS. 2007. Impact of the entomopathogenic fungus *Beauvaria bassiana* on the honey bee, *Apis mellifera* (Hymenoptera: Apidae). *World J Agric Sci* 3(1):7-11.

water, as they are potentially toxic to fish.[87] When and how often to apply depends on the pest being targeted, and the temperature. As it is a fungus, *Beauvaria bassiana* is susceptible to the effects of fungicides and should not be applied with them.

5.3.1.3 Metarhizium anisopliae

90. *Metarhizium anisopliae* is a widely distributed natural soil fungus that attacks a variety of insects, causing green muscadine disease. It was first used for biocontrol in 1879,[88] and is now massed produced, available commercially in a number of countries, and applied by spraying.

91. It is said to be not toxic or infectious to mammals but inhalation of the spores can cause allergic reactions,[89] and not harmful to earthworms or to lady beetles, green lacewings, parasitic wasps, honey bee larvae, and honey bee adults.[90]

92. Susceptible pests include aphids, thrips, leaf hopper, whiteflies, scarabs, weevils, mites, gnats, ticks, locusts, termites, cockroaches, flies, and mosquito larvae.[91]

93. Countries and observers recommend *Metarhizium anisopliae* for control of eggplant fruit and shoot borer. It also can be used for gram pod borer,[92] and according to the list in the paragraph above, it can potentially be used for a great many of the other exempted pest/crop complexes.

5.3.1.4 Other entomopathogenic fungi

94. *Neumorea riley* attacks the larvae of stem borers, leaf folders, army worms and case worms. It is effective against gram pod borer.[93] It is recommended by countries and observers for cotton bollworm. India's Ministry of Science and Technology states it is pathogenic to a number of economically important lepidopterous pests.[94]

95. *Streptomyces avermetilis* is recommended by countries and observers for control of eggplant fruit and shoot borer. No information could be found about how this acts or is used.

96. *Cephalosporium* spp, *Entomophthora* spp and *Verticillium lecanii* are recommended for control of aphids in mustard.[95]

5.3.1.5 Helicoverpa armigera nuclear polyhedrosis virus

97. Viruses of insects (bacculoviruses) are naturally occurring insect-specific pathogens that play an important role in natural control of insect populations. Nuclear polyhedrosis viruses affect mainly moths and butterflies.

98. Preparations of the live *Helicoverpa armigera* nuclear polyhedrosis virus are applied by foliar spraying. The virus is ingested by the larvae of *H. armigera,* and they begin to die within 2-5 days. Because the virus is degraded by ultra violet light it is best applied in the late afternoon.

99. Countries and observers have recommended it for use against podborer on arhar/gram, cotton bollworm, pink bollworm on cotton, fruit and shoot borer on tomato.

---

87 Groden 1999 *op cit*.

88 Mahr S *op cit*.

89 Mahr S *op cit*.

90 *Metarhizium anisopliae* strain F52(029056) Biopesticide Fact Sheet. United States Environmental Protection Agency. http://www.epa.gov/oppbppd1/biopesticides/ingredients/factsheets/factsheet_029056.htm.

91 Sources include: (i) Conclusion On Pesticide Peer Review. Conclusion on the peer review of the pesticide risk assessment of the active substance *Metarhizium anisopliae* var. *anisopliae* BIPESCO 5/F521. European Food Safety Authority. http://www.efsa.europa.eu/en/efsajournal/doc/2498.pdf. (ii) *Metarhizium anisopliae* strain F52(029056) Biopesticide Fact Sheet. United States Environmental Protection Agency. http://www.epa.gov/oppbppd1/biopesticides/ingredients/factsheets/factsheet_029056.htm.(iii) Biocontrol Strategies for Eco-friendly Pest Management. Department of Biotechnology, Ministry of Science & Technology, Government of India. http://www.dbtbiopesticides.nic.in/index.php.

92 IPM Programme, Jawaharlal Nehru Krishi Vishwavidyalaya Agricultural University, Jabalpu, Madya Pradesh, India. http://jnkvv.nic.in/IPM%20Project/natural_enemy.htm.

93 IPM Programme *op cit*.

94 Biocontrol Strategies for Eco-friendly Pest Management. Department of Biotechnology, Ministry of Science & Technology, Government of India. http://www.dbtbiopesticides.nic.in/index.php.

95 IPM Programme *op cit.*

5.3.2 Predators

100. The arthropod predators of insects and mites include beetles, true bugs, lacewings, flies, midges, spiders, wasps, and predatory mites. They can be found throughout crop plants, including the parts below ground, as well as in nearby shrubs and trees, and in most agricultural and natural habitats.[96]

101. Each group has different life cycles and habits. Some predators are specialized in their choice of prey, others are generalists. Both sexes, and both adult and immature stages, may be predatory. They can attack both immature and adult prey, consuming many pests during their development. Some are extremely useful natural enemies of insect pests; some prey on other beneficial insects as well as pests. Some species may play an important role in the suppression of some pests. Others may provide good late season control, but appear too late to suppress the early season pest population. Many beneficial species may have only a minor impact by themselves but contribute to overall pest mortality when combined with other complementary pest control measures.[97]

102. The number and diversity of predators in a crop can be very high. Over 600 species of predators in 45 families of insects and 23 families of spiders and mites have been recorded in Arkansas (USA) cotton. There may be thousands of predators per hectare, in addition to many parasitoids. Although the impact of any one species of natural enemy may be minor, the combined impact of predators, parasitoids, and insect pathogens can be considerable.[98]

103. The following predators have been recommended by countries and observers.

5.3.2.1 Lacewings

104. *Chrysoperla carnea (=Chrysopa carnea), Chrysoperla rufilabris*: common green lacewing. This is one of the most important biological controls for the exempted crop/pest complexes and it can be conserved, or mass reared and released into fields. The larvae 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. They can be augmented and conserved by plantings of flowering plants and artificial foods for the adult lacewings.[99]

105. They are considered important aphid predators in cotton in Russia and Egypt. In USA one study found that a mass release of *C. carnea* resulted in 96% reduction in cotton bollworm infestation. It is desirable to match the appropriate strain to specific pest management situations. They have some natural tolerance to some insecticides.[100] Lacewings are commercially available in a number of countries and are one of the most commonly released predators.[101]

106. *Chrysoperla carnea* is common throughout parts of Asia, America and Europe. It is recommended by countries and observers for a considerable proportion of the exempted crop/pest complexes:

Crop	Pests
Arhar/gram	aphids
Beans	aphids, whiteflies
Chilli	aphids, jassids
Cotton	aphids, jassids, whiteflies, thrips
Eggplant	aphids
Groundnut	aphids
Maize	aphids
Mustard	aphids
Okra	aphids, jassids
Potato	aphids, jassids
Tomato	aphids, jassids, whiteflies

96 Sheldon A. Predators. Biological Control. Department of Entomology, College of Agriculture and Life Sciences, Cornell University. http://www.biocontrol.entomology.cornell.edu/predators.html.

97 Sheldon *op cit*. A.

98 Sheldon *op cit*.

99 (i) Sheldon *op cit*. (ii) IPM Programme *op cit*.

100 Sheldon *op cit*.

101 Natural Enemies Gallery. UCI PM Online. University of California. http://www.ipm.ucdavis.edu/PMG/NE/index.html.

Crop	Pests
Rice	jassids
Tea	mealy bug, scale insects, thrips, leafhopper

107. It can also be used for aphids in apples[102], tobacco, and wheat.[103]

5.3.2.2 Ladybird beetles or ladybugs

108. *Cocciniella septempunctata* – seven-spotted ladybird beetle. These prey on aphids, whiteflies, and bollworms, attacking eggs, nymphs and adults. They can be released at random on the crop canopy.[104] They may be tolerant to some pesticides at recommended application rates, and overwintering adults may be less susceptible than active adults and larvae.[105]

109. *Hippodamia convergens* – orange convergent ladybug. This is one of the most common American ladybirds and is found from southern Canada to South America. Adults and larvae prey mainly on aphids, including cotton, pea, melon, cabbage, potato, green peach, and corn leaf aphids. If aphids are scarce, beetles and larvae may feed on small insect larvae, insect eggs, mites and, occasionally, nectar and honeydew secreted by aphids and other sucking insects.[106] They can be collected from overwintering sites and released, but have a tendency to disperse after release.[107]

110. *Hippodamia variegata* – a ladybug that feeds on aphids on a variety of plant species, including cotton.[108]

111. *Harmonia conformis* – common spotted ladybug. Both adults and larvae feed on aphids, mites, and scale insects. A ladybird will consume at least 2,400 aphids during its life-span of about one to two months.[109]

112. *Harmonia axyridis* – multicoloured Asian lady beetle. It preys on many soft-bodied pest species such as aphids, scales, and psyllids. In Japan, *Harmonia axyridis* is considered primarily an arboreal species and is common on various aphid-infested trees and bushes such as maple, walnut, willow, and rose; it is also an important predator of various destructive scales in Japan and mainland China. An adult is capable of consuming 90 to 270 aphids per day, and each larva can consume 600 to 1,200 aphids during its development.[110]

113. *Cheilomenes vicina* – a ladybug that feeds on aphids on a variety of plant species, including cowpea.[111]

114. *Cheilomenes sexmaculata / Menochilus sexmaculata* – six-spotted zigzag ladybird, or black-spotted ladybird, found throughout Asia, Iran, and Australasia. It feeds on aphids, psyllids, whiteflies, mealybugs, tingids, leaf and planthoppers, mites, and early instar caterpillars.[112]

115. *Cryptolaemus montrouzieri* – mealybug ladybird, or mealybug destroyer. Both adults and larvae feed on mealybug species and other homopterans (sucking insects) such as green shield scale. These are commercially available in some countries.[113]

---

102 http://www.ipm.ucdavis.edu/PMG/NE/convergent_lady_beetle.html.Hagley EAC. 1989. Release of *Chrysoperlac carnea* Stephens (Neuroptera: Chrysopidae) for control of the green apple aphid, *Aphis pomi* Degeer (Homoptera: Aphididae). Canadian Entomol 121(4): 309-314.

103 Iqbal J, Muhammad Ashfaq M, Ali A. 2008. Management of aphids by augmentation of coccinellids and *Chrysoperla carnea* under field conditions on wheat. *Pak J Agri Sci* 45(1).

104 IPM Programme *op cit.*

105 Sheldon *op cit*. A.

106 Sheldon *op cit*. A.

107 Natural Enemies Gallery. UCI PM Online. University of California. http://www.ipm.ucdavis.edu/PMG/NE/index.html.

108 Franzmann BA. 2002. Hippodamia variegata (Goeze) (Coleoptera: Coccinellidae), a predacious ladybird new in Australia. *Aust J Entomol* 42(4):375-7.

109 Brisbane Insects and Spiders. http://www.brisbaneinsects.com/brisbane_ladybirds/CommonSpotted.htm.

110 S heldon *op cit*. A.

111 Ofuya TI, Akingbohungbe AE. 1988. Functional and numerical responses of *Cheilomenes lunata* (Fabricius) (Coleoptera: Coccinellidae) feeding on the cowpea aphid, *Aphis craccivora* Koch (Homoptera: Aphididae). *Int J Trop Insect Sci* 9:543-6.

112 http://www.aphidweb.com/aphidbioagents/Cheilomenes.htm.

113 Natural Enemies Gallery. UCI PM Online. University of California. http://www.ipm.ucdavis.edu/PMG/NE/index.html.

116. *Leis dimidiata* and *Verania vincta* are recommended for control of aphids on tea by The Tea Research Association in India.[114]

117. Other recommended ladybug species include *Scymnus* spp. which are generalist predators recommended for bollworm, pink bollworm, aphids, jassids, whiteflies on cotton, and *Brumnus* spp. recommended for whiteflies on cotton by the IPM programme at Jawaharlal Nehru Krishi Vishwavidyalaya Agricultural University in Madhya Pradesh, India.[115]

118. Ladybirds are recommended by countries and observers for the following crop/pest complexes:

Crop	Pests	Additional uses
Beans	aphids, whiteflies	
Chillies	aphids, jassids	
Cotton	aphids, bollworm jassids, pink bollworm, whiteflies	
Cowpea		aphids
eggplant	aphids	
groundnut	aphids	
Maize	aphids	
Mustard	aphids	
Okra	aphids, jassids	
onion	aphids, jassids	
Potato	aphids, jassids	
Tomato	aphids, jassids	
Rice	white jassids	
Tea	mealybug, scale, smaller green leaf hopper, aphids	
Tobacco		aphids
Wheat		aphids

5.3.2.3 Bugs

119. *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, whiteflies, and small caterpillars. They are reported to be important predators of the eggs and new larvae of the bollworm and of spotted tobacco aphid, but it is believed that thrips and mites are the more basic part of their diet. They can also be important predators of corn earworm eggs laid on the silks of the corn cob. Other reported prey include the eggs and small stages of European corn borers and potato leafhopper nymphs. Both immature and adult bugs can consume 30 or more spider mites per day.116

120. Diversified cropping systems, use of microbial insecticides such as *Bacillus thuringiensis*, and use of economic thresholds to minimize insecticide applications, are all recommendations to maximize the natural biological control from *Orius*. Plantings of spring and summer flowering plants will help them survive periods of scarce prey. Foliar insecticides, and soil-applied systemic insecticides can greatly reduce *Orius* numbers. [117]

121. *Orius* spp are recommended by countries and observers for the control of leaf miner on beans; jassids on chillies, okra, onion, potato, tomato, rice; and scale insects, thrips and green leaf hopper on tea.

122. *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. They can also prey on other predators such as *Orius* sp and *Geocoris tricolor.*[118]

123. Damsel bugs are recommended by countries and observers for the control of aphids on arhar/gram, beans, chillies, eggplant, groundnut, maize, okra, onion, potato, and tomato.

114 Pest Management in Tea. Tea Research Association, India. http://www.tocklai.net/cultivation/pests.aspx.

115 IPM Programme *op cit*.

116 (i)Sheldon *op cit*. (ii) Natural Enemies Gallery. UCI PM Online. University of California. http://www.ipm.ucdavis.edu/PMG/NE/index.html.

117 Sheldon *op cit*.

118 AgriLife Extension, Texas A&M University. http://insects.tamu.edu/fieldguide/aimg49.html.

124. *Geocoris tricolor* F. – big eyed bug. Adults and nymphs predate whiteflies, thrips and jassids. They are very susceptible to broad-spectrum insecticides.[119] This has been not recommended by countries and observers but is recommended by the IPM programme at Jawaharlal Nehru Krishi Vishwavidyalaya Agricultural University in Madhya Pradesh, India.[120]

5.3.2.4 Syrphid flies / Hoverflies / Flower Flies

125. Syrphid flies, also called hoverflies or flower flies, are a large family of about 6,000 species, some of which are natural biological control agents, their larvae feeding on aphids, thrips, and other plant-sucking insects.

126. Syrphid flies that feed on aphids include *Sphaerophoria sulphuripes*, *Sphaerophoria contigua*, *Sphaerophoria pyrrhina*, *Toxomerus marginatus*, *Platycheirus stegnus*, *Platycheirus obscurus*, *Allograpta oblique*, *Allograpta exotica*, *Syrphus opinator*, *Eupeodes volucris*, *Toxomerus occidentalis*, and *Paragus tibialis*. There are many more. The activity of syrphid flies can be enhanced by improving the agroecosystem by, for example, providing windbreaks, hedgerows, and/or cover crops which provide shelter for the flies.[121] Several species of syrphid fly i.e., *Sphaerophoria* spp., *Eristallis* spp., *Metasyrphis* spp., *Xanthogramma* spp. and *Syrphus* spp. predate on aphids in mustard crops in India.[122]

127. *Volucella* is a genus of hoverflies recommended for control of scale insects on tea by OISAT, the Online Information Service for Non-Chemical Pest Management in the Tropics.[123]

128. Syrphid flies are recommended by countries and observers for the control of aphids on arhar/gram, beans, chillies, cotton, eggplant, groundnut, maize, mustard, okra, onion, potato, and tomato.

5.3.2.5 Other predators

129. *Triphles tantilus* is a predator that can suppress the population of bollworm larvae,[124] and is recommended by countries and observers for the control of pink bollworm.

130. *Pyremotes ventricosus* is a predatory mite that has been recommended for control of pink bollworm.[125] However, as this mite is also associated with causing dermatitis in humans,[126] other biological controls, such as egg parasitoids *Trichogramma chilonis*, *Bracon elechidae* or *Elasmus johnstoni*, pupal parasitoid *Microbracon lefroyi* and predators *Chrysoperla carnea* or *Scymnus* spp. might be preferable.

131. *Camponotus* spp. are carpenter ants that prey on the nymphs of jassids, and the eggs and larva of spotted pod borer,[127] and is recommend for the control of aphids and jassids on cotton.

132. *Aphidoletes aphidimyza* - aphid midge. The larvae prey on adult aphids, mites and other soft-bodied insects. It is commercially available in some countries.[128] One Canadian study reported that complete aphid control was achieved in a few days at ratios of 5 apple aphids per midge egg. Partial control was provided at 8-12 aphids per egg, and no control was provided by 12-14 aphids per egg. Research in Massachusetts, USA, has shown that predator-prey ratios of at least 1 midge larva to 15 aphids are suitable for control.[129]

133. The aphid midge is recommended by countries and observers for the control of aphids on arhar/gram, beans, chillies, eggplant, groundnut, maize, okra, onion, potato, and tomato.

---

119 IPM Programme *op cit*.

120 IPM Programme *op cit*.

121 Bugg RL, Colfer RG, Chaney WE, Smith HA, Cannon J. 2008. Flower flies (Syrphidae) and other biological control agents for Aphids in vegetable crops. University of California, Division of Agriculture and Natural Resources. http://anrcatalog.ucdavis.edu/pdf/8285.pdf.

122 IPM Programme *op cit*.

123 Online Information Service for Non-Chemical Pest Management in the Tropics. PAN Germany. http://www.oisat.org/pestsmap.htm.

124 IPM Programme *op cit*.

125 IPM Programme *op cit*.

126 Nath R, Saikia L, Choudhury M, J Mahanta J. 2007. Dermatitis due to straw itch mite in Assam. *Indian J Dermatol* 52(4):199-200.

127 IPM Programme *op cit*.

128 UC IPM Online. University of California. http://www.ipm.ucdavis.edu/PMG/NE/aphidoletes_aphidimyza.html.

129 The Mid-Atlantic Regional Fruit Loop. Virginia Tech. http://www.virginiafruit.ento.vt.edu/midge.html.

5.3.3 Parasitoids

134. Insect parasitoids have an immature life stage that develops on or within a single or several related insect hosts, ultimately killing the host, whilst the adult parasitoids are free-living and may be predaceous. Most beneficial insect parasitoids are wasps or flies. Different parasitoid species can attack different life stages of hosts. The immature parasitoid developing on or within the pest feeds on body fluids and organs, eventually leaving the host to pupate, or emerging as an adult, and in the process killing the host. In some species only one parasitoid will develop in or on each pest while, in others, hundreds of young larvae may develop within the pest host. Female parasitoids may also kill many pests by direct feeding on the pest eggs and immature stages.

135. Pests attacked by parasitoids die more slowly than those killed or disabled by predators. Some hosts are paralyzed while others can continue to feed or even lay eggs before succumbing to the attack. Parasitoids, however, often complete their life cycle much more quickly and increase their numbers much faster than many predators. Parasitoids can be the dominant and most effective natural enemies of some pest insects, but their presence may not be obvious.[130]

136. Adult parasitoids are usually more susceptible than their hosts to chemical pesticides. Immature parasitoids, especially if protected within the egg of their host or in their own cocoon, may tolerate pesticides better than adults, but immature parasitoids will usually die if their host is killed.[131]

137. The following parasitoids have been recommended by countries and observers.

5.3.3.1 Egg parasitoids

138. The most important genus of egg parasitoids is *Trichogramma* - all members parasitize eggs. They have hundreds of hosts. They are extremely tiny wasps with a short life span and many more generations than their hosts, so populations increase rapidly. A number of species are available commercially for release.[132] *Trichogramma* are active *above* 15°C, with an optimum temperature range of 23-25°C with 75% humidity. Many insecticides are toxic to *Trichogramma* especially organophosphates and carbamates, but *Bacillus thuringiensis* is tolerated.[133] Species and strains vary considerably in their ability to control different insects and in their adaptation to different environmental conditions and crops. *T. chilonis* is used for gram pod borer, *T. evanescens* for Bihar hairy caterpillar. *T. chilonis, T. brasielenis,* and *T. Achaea* are all used for cotton bollworm, and *T. japonicum* for rice stem borer.[134] *Trichogramma chilonis* is also recommended by countries and observers for pink bollworm and thrips on cotton, fruit and shooter borer on okra, and rice hispa.

139. *Gonatocerus* spp. are tiny parasitic wasps that lay their eggs in the eggs of jassids. They are very vulnerable to insecticides.[135]

140. *Telonmus heliothidae* parasitizes bollworm eggs. There is also a species of *Telonmus* that parasitizes the gram caterpillar.[136]

141. *Telonmus heliothidae* parasitizes bollworm eggs. There is also a species of *Telonmus* that parasitizes the gram caterpillar.[137]

142. *Eulophids* spp. are wasps that parasitize both eggs and larvae of pests such as leaf miner.[138]

---

130 Sheldon A. undated. Parasitoids. Biological Control. Department of Entomology, College of Agriculture and Life Sciences, Cornell University. http://www.biocontrol.entomology.cornell.edu/parasitoids.html.

131 Sheldon A. undated. Parasitoids. Biological Control. Department of Entomology, College of Agriculture and Life Sciences, Cornell University. http://www.biocontrol.entomology.cornell.edu/parasitoids.html.

132 Natural Enemies Gallery. UC IPM Online. University of California. http://www.ipm.ucdavis.edu/PMG/NE/index.html.

133 (i)Wang Y, Xu R, Zhao X, Chen L, Wu C, Cang T, Wang Q. 2012. Susceptibility of adult *Trichogramma nubilae* (Hymenoptera: Trichogrammatidae) to selected insecticides with different modes of action. *Crop Protect* 34:76-82. (ii) Suh CP-C, Orr DB, van Duyn JW. 2000. Effect of insecticides on *Trichogramma exigum* (Trichogrammatidae: Hymenoptera) preimaginal development and adult survival. *J Econ Entomol* 93(3):577-83. (iii) Vianna UR, Pratissoli D, Zanuncio JC, Lima ER, Brunner J, Pereira FF, Serrao JE. 2009. Insecticide toxicity to *Trichogramma pretiosum* (Hymenoptera: Trichogrammatidae) females and effect on descendant generation. *Ecotoxicology* 18(2):180-6.

134 IPM Programme *op cit*.

135 IPM Programme *op cit*.

136 IPM Programme *op cit*.

137 IPM Programme *op cit*.

138 http://www.apples.msu.edu/eulophids.htm.

143. *Elasmus johnstoni* is an egg parasitoid, recommended for control of pink bollworm as part of an IPM programme by *Jawaharlal* Nehru Krishi Vishwavidyalaya Agricultural University in India. It can be found throughout Southeast Asia and parts of Africa.[139]

5.3.3.2 Larval parasitoids

144. Braconids are small wasps that parasitize the larvae of a number of pest species, mostly killing their host, although in some cases making them sterile. There are over 1000 known parasitizing species. They are popular biological controls because they are good at searching out their prey even at low pest densities.[140] Prey include the larvae of aphids, beetles, caterpillars, flies and sawflies. Braconid wasps that *parasitize* cotton bollworm larvae include *Bracon brevicornis*, *Chilonus blackburni, Telenomus heliothidae*, *Carcelia illota* all parasitize cotton bollworm. *Apanteles*/*Cotesia* spp. are braconids that parasitize cotton bollworm and pink bollworm (*Apanteles angaleti*), and caterpillars on gram/arhar (*Apanteles prodeniae)*. Eggs are laid in the host larvae, and these die within 24hr of parasite emergence (3 days after eggs laid). *Phanerotoma hendicusisella* is a small braconid wasp that parasites leaf roller.[141]

145. Ichneumonids are a large family of wasps, many of which parasitize other insects. *Diadegma insulare* is the most important parasitoid of the diamondback moth (*D. semiclausum*, *D. mollipla, D. fenestral* are also recommended for this pest). *Diadegma* pupates inside the cocoon made by the diamondback moth larva, replacing the host pupa. Measures for conserving and augmenting this parasitoid include limiting insecticide use and replacing with *Bacillus thuringiensis* where possible, and providing nectar sources by allowing wildflower, and especially wild brassicas, around the edges of field crops. A nectar source can increase the longevity of this insect from 2-5 days to 20 days. *Campoletis chloridae* is a small black ichneumonid wasp that parasitizes gram/arhar caterpillar, and cotton bollworm. *Enicospilus sp* are small black wasps that attack immature gram pod borer.[142]

146. *Aphytis melinus* is a tiny yellow wasp that parasitizes armoured scale and *Metaphycus helvolus* is a tiny black and yellow wasp that parasitizes soft scale, both laying their eggs inside the bodies of larval scale insects. They are recommended for use against scale insect as part of an IPM programme by OISAT, the Online Information Service for Non-Chemical Pest Management in the Tropics.[143] They were recommended by countries and observers for scale in tea. Both are considered important in the control of scale in California citrus orchards. They are commercially available in the USA, at least. Avoid use of insecticides around these biological controls.[144] Distribution of both species includes Asia, Africa, Europe, North and South America, Australia and Middle East.[145] *Aphytis diaspidis* is one of several species of wasps attaching tea scale in the USA.[146] Distribution is global.

147. The larval parasitoids *Diglyphus isaea, Dacnusa sibirica,* and *Neochrysocharis formosa* are recommended by countries and observers for control of leaf miner in tomato. Distribution is global and they are commercially available in some countries.

148. *Encarsia shafeei* (also referred to as *E. Sophia, E bemisiae, E. transvena*) – belongs to a large genus of parasitic wasps (generally of larval stages) of worldwide distribution, many of which are used in biological control particular of whiteflies. *E. shafeei* is used for control of whiteflies on cotton. It is recommend for cotton whitefly control as part of an IPM programme by Jawaharlal Nehru Krishi Vishwavidyalaya Agricultural University in India.[147]

149. Other recommended larval/pupal parasitoids include *Eretmocerous mundus* which attacks the nymph and pupa stages of whiteflies. *Eucelatoria bryani* are small dull-coloured parasites of the larval stage of bollworm. *Geocoris tricolour* F parasitizes immature stages of whiteflies. These are very

139 Natural History Museum, London. http://www.nhm.ac.uk/index.html.

140 http://www.entomology.umn.edu/cues/Web/270Insecta.Hymenoptera.Braconidae.pdf.

141 IPM Programme *op cit.*

142 IPM Programme *op cit.*

143 Online Information Service for Non-Chemical Pest Management in the Tropics. PAN Germany. http://www.oisat.org/pestsmap.htm

144 (i) Natural Enemies Gallery. UCI PM Online. University of California. http://www.ipm.ucdavis.edu/PMG/NE/index.html. (ii) Midwest Biological Control News. http://www.entomology.wisc.edu/mbcn/kyf604.html.

145 Natural history Museum, London. http://www.nhm.ac.uk/index.html.

146 Tea Scale, *Fiorinia theae* Green (Insecta: Hemiptera: Diaspididae). University of Florida IFAS Extension. http://edis.ifas.ufl.edu/in522

147 IPM Programme, Jawaharlal Nehru Krishi Vishwavidyalaya Agricultural University, Jabalpu, Madya Pradesh, India. http://www.jnkvv.nic.in/IPM%20project/insect-cotton.html

susceptible to broad-spectrum insecticides. *Goniozus* sp are ectoparasites of the larvae of bollworm and pink bollworm. *Carcelia illota* is a tachinid fly that parasitizes cotton bollworm.[148]

150. *Distina albida, Camonotus* spp. are species of spiders that can be conserved to assist in control of aphids and jassids on cotton; they feed on nymphs and adults.[149]

151. There are three parasitic wasps that attack the coffee berry borer: *Prorops nasuta* attacks the larval stage borer: *Phymastichus coffea* attacks the adult beetle, and *Cephalonomia* stephanoderis attacks all stages but prefers eggs and adults.

152. The parasitoids *Thripoctenus briu*, *Triphleps tantilus*, and the mite *Campsid* sp. are recommended for control of thrips on cotton as part of an IPM programme, by Jawaharlal Nehru Krishi Vishwavidyalaya Agricultural University.[150] Very little information could be found about these; it is possible they have been renamed.

5.3.3.3 Pupal parasitoids

153. Pupal parasitoids recommended by countries and observers include the braconid wasps *Brachymeria* sp for cotton bollworm, and *Microbracon lefroyi* for pink bollworm.

5.3.4 Biological controls for certain crops

5.3.4.1 Cotton

154. Natural enemies in the cotton ecosystem in India are as follows:

Natural enemy	Host	Stage
Predators		
Chrysopa carnea	aphid, whiteflies, thrips, mites	all stages
Menochilus sexmaculata	aphids	nymphs, adults
Coccinella septumpunctata	aphids	nymphs, adults
Scymnus sp.	aphids	nymphs, adults
Syrphus spp.	aphids	nymphs, adults
Parasitoids		
Trichogramma chilonis, T. brasiliensis, T.acheae, T. pretiosum	bollworms	eggs
Chelonus blackburni	bollworms	eggs, larvae
Telenomus remus	*Spodoptera* sp. (e.g cotton leafworm)	eggs
Rhogas aligarhensis	*Earias* sp. (a bollworm)	larvae
Eucelatoria bryani	cotton bollworm	larvae
Carcella illota	cotton bollworm	larvae
Campoletis chloridae	cotton bollworm	larvae
Bracon greeni, B. kirkpatricki, B. brevicornis	bollworms	larvae
Palexorista laxa	bollworms	larvae
Agathis sp.	bollworms	larvae
Encarsia shafeei	whiteflies	nymphs
Pyemotes ventricosus (mite)	pink bollworm	larvae
Goniozus sp	pink bollworm	larvae
Apanteles pectinophorae	pink bollworm	larvae
Microbracon gelechidiphagus	pink bollworm	larvae

148 IPM Programme *op cit.*

149 IPM Programme *op cit.*

150 IPM Programme, Jawaharlal Nehru Krishi Vishwavidyalaya Agricultural University, Jabalpu, Madya Pradesh, India. http://www.jnkvv.nic.in/IPM%20project/insect-cotton.html.

Natural enemy	Host	Stage
Pathogens		
Bacillus thuringiensis var. kurstakii	cotton bollworm *Spodoptera*, *Earias vitella* (spotted bollworm)	larvae
nuclear polyhedrosis virus	cotton leafworm, cotton bollworm	larvae
Beauveria bassiana	cotton bollworm	larvae
Nomuraea rileyi	*Spodoptera* sp.	larvae
Entomophthora aphidis	aphids	all stages
Vairrimorpha sp	cotton bollworm	larvae
Nosema sp	*Spodoptera* sp.	larvae

Source: Central Institute for Cotton Research, Nagpur, India. 2010. http://www.cicr.org.in/Database/pest_nat_enemies.html.

5.3.4.2 Coffee

155. There are three parasitoids, native to Africa, and specific to coffee berry borer that have been introduced to many countries: *Phymastichus coffea, Prorops nasuta, Cephalonomia stephanotheris.* All three wasps have been used in Mexico. The most widely used is *Cephalonomia stephanoderis* because of its excellent ability to establish it self once released. *P. coffea* attacks the coffee berry borer in its adult stage, outside the coffee berry, and is seen as an important complement to managing the pest.[151] One study in Mexico shows a 3 to 5.6-fold decrease in damage from coffee berry borer with release of *P. coffea* at a density of 1 parasitoid per 10 hosts.[152]

6. Technical feasibility

156. Many of the methods described have proven to be successful in India, or Latin America, or other countries or regions. They may or may not be equally successful in other areas. Farmers and extension agents should check with local growers, especially those growing organically, or using agroecological methods, to see what works best in their particular circumstances. Academic and research institutions are likely to have additional information to that provided here, specific to their countries or regions. In some countries, some or all of the biological controls may not be available. On the other hand there may be more successful techniques and biological controls available locally that are not described here.

157. Most of the techniques need to be applied in coordinated programmes; some of the biological controls are very sensitive to synthetic chemical pesticides. If biological control insects are released, care should be taken with applying any sprays, even natural sprays, in order to maximise the benefits of these parasites and predators of pests.

158. It may take several seasons of implementing these techniques before control is established at the level the farmer desires, as the agroecological system seeks balance after endosulfan and other harmful sprays are withdrawn. It may be desirable to make gradual transitions to these techniques.

159. Whilst this document gives an overview of what nonchemical methods exist as alternatives to the use of endosulfan, and other pesticides, on crop/pest complexes listed in Annex A of the Convention, practitioners should seek more detailed information on how to use these methods in their particular context. Additionally, there will be a need for farmer training and institutional support in order to help farmers successfully change to ecology-based approaches to pest management. The farmer field schools conducted within FAO's ecosystem approach to sustainable crop production intensification have contributed significantly to sustainable crop production intensification and reduced pesticide use.

7. Conclusion

160. An ecosystem approach to pest management is now the internationally preferred option. FAO refer to this as sustainable crop production intensification, in which emphasis is placed on improving soil health, conserving natural enemies of pests, a preventative approach, and cultural and management techniques, with pesticides used as a last resort. Ecosystem approaches, or agroecology, have received high-level support including from the IAASTD, the UN Special Rapporteur on the right to food and the International Code of Conduct on the Use and Distribution of Pesticides. They include

151 Bejarano et al 2009 *op cit*.

152 Espinoza JC, Infante F, Castillo A, Pérez J, Nieto G, Pinson EP, Fernando E. Vega FE. 2009. The biology of *Phymastichus coffea* LaSalle (Hymenoptera: Eulophidae) under field conditions. *Biol Control* 49(3):227-33.

organic agriculture and some traditional, and improved traditional, approaches such as Community Managed Sustainable Agriculture. Such approaches have shown increased or similar yields, greater returns to farmers, and improvement in social and environmental indicators.

161. Ecosystem approaches rely on ecosystem management rather than external inputs, with the first line of defence against pests being a healthy agroecosystem. They are knowledge-intensive, location-specific farming systems, based on conservation practices, good seed of high-yielding adapted varieties, plant nutrition based on healthy soils, efficient water management, and the integration of crops, pastures, trees and livestock. The focus is on managing the agro-ecosystem to avoid build up of pests, using wherever possible cultural, biological, and mechanical methods instead of synthetic materials. Practices include using resistant varieties better adapted to ecologically based production than those bred for high-input agriculture, crop diversity, crop rotation, intercropping, optimised planting time and weed management, conserving natural enemies, and managing crop nutrient levels to reduce insect reproduction. It is difficult to provide a prescription for a particular crop/pest complex in these systems as the entire interwoven management process is crucial to protecting crops from pests. Each crop/pest complex needs to be looked at within the specific agroecosystem, taking into account many aspects, including climatic and geographical variables, presence of natural enemies and availability of biological controls, the structure and function of the particular farm, and microclimatic variations within it.

162. In addition there is a large range of discrete non-chemical options that can be used in ecosystem, IPM, or in chemical-input based agriculture as simple substitutes. These include natural plant extracts, attractant lures and traps, and biological controls such as pathogens, predators, and parasitoids. The availability and technical feasibility of these may differ between countries.

8. Further technical information

163. Further technical information on nonchemical management options for the listed pests can be found at a number of websites, including the following:

http://www.ipm.ucdavis.edu/PMG/NE/index.html
http://ipmworld.umn.edu/ipmchap.htm
http://www.oisat.org/
http://www.fao.org/organicag/oa-home/en/
http://www.ifoam.org/
http://nysipm.cornell.edu/
http://www.vegetableipmasia.org
http://www.ipm-neareast.com
http://www.fao.org/organicag/oa-portal/orca-database/searchnew/en/
http://www.ifoam.org/
http://jnkvv.nic.in/IPM%20Project/ipm-home.html
ftp://ftp.fao.org/docrep/fao/meeting/017/ak569e.pdf

Some specific crops:
Cotton, India
http://ipmworld.umn.edu/chapters/Arora.htm; http://ipmworld.umn.edu/chapters/sharma.htm;
http://jnkvv.nic.in/IPM%20Project/insect-cotton.html
http://www.cicr.org.in/Database/pest_nat_enemies.html
Eggplant, Asia
http://www.avrdc.org/publications/technical_bulletin/TB28.pdf
http://www.avrdc.org/LC/eggplant/efsborer.pdf

Annex I

Crop-pest complexes in Part VI of Annex A to the Stockholm Convention with non-chemical alternatives to endosulfan reported by Parties and observers

Crop	Pest[153]	Control option	Source
Apple	Aphids	* Spray with azadirachtin.	Netherlands-Endosulfan inquiry
		* Release and encourage predators *Chrysoperla carnea.*	Consultant
Arhar / Gram	Aphids	*Control ants (ants cultivate aphids to gain access to plant sugars); where appropriate cultivate and flood the field to destroy ant colonies and expose eggs and larvae to predators and sunlight. * Avoid using heavy doses of highly soluble nitrogen fertilizers. * Use sticky board traps: 1-4 per 300 sq m field area; replace at least once a week. * Use yellow basin traps with soapy water. * Spray with ginger rhizome extract, custard apple leaf extract, neem leaf extract, neem seed extract, soap spray. * Release braconid wasps. * Encourage or release predators: aphid midge, damsel bug, hoverfly, lacewing, ladybird beetle.	PAN & IPEN
	Caterpillars	* Apply *Bacillus thuringiensis*.	Japan, Mexico
	Pea semilooper	* Apply *Bacillus thuringiensis*. * Natural enemies like birds, reptiles.	Mexico
	Pod borers	* Apply *Helicoverpa armigera* Nuclear polyhedrosis virus (NPV): 250 LER/ha, 2-3 times at 10-day intervals in evening. * Apply *Bacillus thuringiensis* - 2kg/ha, 2-3 times at 10-day intervals in evening.	PAN & IPEN
		* Release parasitoid *Trichogramma chilonis.*	drafter
	All pests	* Deep summer ploughing to expose pests to birds and sunlight. * Erect bird perches. * Spray 5% neem seed kernel extract.	PAN & IPEN
Beans	Aphids	* Control ants (ants cultivate aphids to gain access to plant sugars); where appropriate cultivate and flood the field to destroy ant colonies and expose eggs and larvae to predators and sunlight. * Avoid using heavy doses of highly soluble nitrogen fertilizers. * Use sticky board traps: 1-4 per 300 sq m field area; replace at least once a week. * Use yellow basin traps with soapy water. * Spray with ginger rhizome extract, custard apple leaf extract, neem leaf extract, neem seed extract, soap spray. * Release braconid wasps. * Encourage or release predators: aphid midge, damsel bug, hoverfly, lacewing, ladybird beetle.	PAN & IPEN
	Leaf miner	* Use greased yellow traps. * Spray with neem seed extract. * Spray with ginger, garlic and chilli extract.	PAN & IPEN
		* Microbiological preparations.	Honduras

153 Additional information reported on the names of pests appears in parentheses.

Crop	Pest[153]	Control option	Source
		* Proper cultural practices such as soil preparation, planting dates, crop rotation. * Use of resistant varieties. * Extracts of plants such as tobacco. * Biological control with parasitoids such as *Opius* sp.	Mexico
	Whiteflies	* Plant *Nicotiana* as a trap crop. * Spray with garlic oil spray, Madre de Caco and neem leave spray, neem oil, soap spray. * Use yellow sticky board traps. * Release parasitoid *Encarsia* spp. * Release predators *Chrysoperla carnea, Chrysopa rufilabris, Harmonia conformis, Harmonia axyridis, Hippodamia convergens*.	PAN & IPEN
Chillies	Aphids	* Control ants (ants cultivate aphids to gain access to plant sugars); cultivate and flood the field to destroy ant colonies and expose eggs and larvae to predators and sunlight; ants use the aphids to gain access to nutrients from the plants. * Plant trap crops such as lupine, dill, nasturtiums, and timothy grass near the crop to be protected. * Avoid using heavy doses of highly soluble nitrogen fertilizers. * Use sticky board traps: 1-4 per 300 sq m field area; replace at least once a week. * Deploy yellow basin traps with soapy water. * Release braconid wasps. * Release or encourage predators: aphid midge, damsel bug, hoverfly, lacewing, ladybird beetle. * Spray with ginger rhizome extract, custard apple leaf extract, neem leaf extract, neem seed	PAN & IPEN
	Jassids	* Release *Chrysoperla carnea*: 50,000 1st instar larvae/ha, 2 times at 15 day intervals. * Release and encourage other predators: *Chrysopa rufilabris, Harmonia conformis, Harmonia axyridis, Hippodamia convergens*, *Orius tristicolor*, *Orius insidiosus*, generaliset preadatory spiders and birds. * Spray with neem, or garlic.	PAN & IPEN
Coffee	Berry borer (*Hypothenemus hampei*)	* Collect infested coffee beans before and after harvest. * Use attractant traps. * Spray neem.	PAN & IPEN
		* There are a wide range of biological control organisms including the parasitic wasps *Prorops nasuta, Phymastichus coffea,* and *Cephalonomia stephanoderis.*	PAN & IPEN
		* Use biopesticide formulations containing the entomopathogenic fungus *Beauveria bassiana*. * Release biological control parasitoid *Cephalonomia stephanoderis*.	Diagnóstico de la situación del Endosulfán en México
		* *Beauveria bassiana*.	Honduras
	Stem borer	* Spray neem (Azadirachtin). * Apply entomopathogenic fungus *Beauveria bassiana*.	Honduras

Crop	**Pest**[153]	**Control option**	**Source**
Cotton	Cotton bollworm	* Plough deeply to expose the resting pupae; clean cultivation, crop rotation, and avoidance of ratooning reduces pest populations. * Use bollworm-tolerant varieties. * Plant trap crops like tomato, destroying them when the pest population is high. * Sow maize and cowpea on borders, and wild brinjal and *Setaria* (millet) as intercrops, helps significantly reduce the pest population.	PAN & IPEN
		* Release egg parasitoids like *Trichogramma chilonis*, *T. brasielenis*, or *T. Achaea* @ 1,500,000 /ha from 45th day onwards at 10-15 days interval (6 releases). * Release larval parasitoids such as *Chilonus blackburni*, *Bracon brevicornis*, *Telenomus heliothidae*, *Carcelia illota*, *Coteria kazat* or *Campoletis chloridae* @ 2000 adults/ha at 15 day-intervals. * Release pupa parasitoids *Brachymeria* sp. * Release the predators *Chrysoperla carnea*, *Scymnus* sp. or *Eulophids* sp. to suppress the population of larvae. * Apply *Helicoverpa armigera* NPV @ 250-750 LE/ha from 35th to 60th day of crop stage, 2-3 times at 10 day intervals in evening. * Spray *Bacillus thuringiensis* var *kurstaki* @ 1-2 kg/ha, 2-3 times at 10 day intervals in evening. * Apply fungal pathogens *Beauveria bassiana* or *Neumorea riley* under humid conditions. * Spray 5% neem seed kernel extract. * Deploy pheromone traps: 20-25/ha, lure to be changed at 15-30 day intervals.	PAN & IPEN
	Aphids (*Aphis gossypii*)	* Avoid late sowing and excessive use of nitrogen fertilizers. * Destroy infested shoots during early stages.	PAN & IPEN
		* Handpick and destroy various insect stages and the affected plant parts.	PAN & IPEN
		* Release predator *Chrysoperla carnea* -50,000 1st instar larvae/ha, 2-3 times at 15 day intervals. * Release predators *Coccinella septumpunctata*, *Syrphus* / *Scymnus* spp. * Conserve spiders *Distina albida* and ants like *Camponotus* sp.	PAN & IPEN
	Jassids (*Amrasca biguttula biguttula*)	* Sow the crop early. * Use resistant varieties (such as Khandwa-2 in India) or varieties with high tannin content in leaves. * Avoid high doses of nitrogen fertilizers. * Grow cowpea/onion/soybean as an intercrop in cotton to reduce early stage of pest. * Use okra as trap crop. * Adopt proper crop rotation. * Practice deep ploughing in summer to expose soil inhabiting insects. * Remove and destroy crop residues/alternate host plants.	PAN & IPEN
		* Use yellow sticky traps. * Hand pick and destroy various insect stages. * Destroy affected plant parts. * Destroy stressed floral bodies. * Destroy resettled flowers.	PAN & IPEN

Crop	Pest[153]	Control option	Source
		* Install bird perches: "T" shape wooden/bamboo sticks @ 50/ha to encourage predatory birds like king crow, mynah and blue jay.	
		* Release predators *Chrysoperla carnea* 50,000 1st instar larvae/ha, 2-3 times at 15 day intervals. * Release predators *Coccinella septumpunctata* or *Syrphus / Scymnus sp.* * Conserve spiders *Distina albida* and ants like *Camponotus* sp. * Spray with neem or garlic.	PAN & IPEN
	Whiteflies (*Bemisia tabaci*)	* Avoid late sowing and adopt crop rotation with crop that is not the host of whiteflies. * Use resistant varieties, such as K-2 in India. * Cultivate alternate host crops such as tomato and castor on the boundaries to trap and destroy pest. Plant nicotiana as a trap crop.	PAN & IPEN
		* Set up yellow sticky board traps at various places at canopy height in field. * Remove and destroy crop residues after last picking. * Remove alternate host plants like kangni and ambadi (India).	PAN & IPEN
		* Release or encourage activities of parasitoids like *Encarsia shafeei* or *Eretmocerous mundus*; * Release predators such as *Brumus* spp., *Chrysopa rufilabris, Coccinella septampunctata, Harmonia conformis, Harmonia axyridis, Hippodamia convergens*; *Melachilus sexaculatus*, or *Scymnus* spp. * Release predator *Chrysoperla carnea* @ 2 larvae/plant in early stage of the plant and 4 larvae/plant in later stage; or 50,000 1st instar larvae/ha, 2-3 times at 15 day intervals. * Release *Cheilomenes sexmaculata* @ 150,000 adults/ha at random on crop canopy. * Spray neem products @ 1500 ppm.	PAN & IPEN
	Pink bollworm	* Use pheromone 'Gossyplure'.	Mexico
		* Spray *Bacillus thuringiensis* Berliner var *kurstaki.*	Honduras
		* Apply *Heliothis armigera* NPV	China
		* Practice clean cultivation and destruction of crop residues (fallen leaves, twigs etc) before the onset of season. * Plough deeply in summer to expose hibernating larvae / pupae. * Apply neem cake 200 kg/ha during ploughing. * Inoculate soil with nitrogen-fixing bacteria like *Azospirillum* and *Azotobacter*. * Avoid late sowing of the crop; early sowing helps in early maturity facilitating escape. * Use tolerant varieties (Khandwa-2, JKH-1, Abadita, LH 900, Sujay and Desi cotton in India). * Withhold irrigation water to avoid prolonged late boll production / formation to reduce the build up of over-wintering population.	PAN & IPEN
		* Deploy pheromone traps: 20-25/ha, lure to be changed at 15-30 day intervals. * Release egg parasitoid *Trichogramma chilonis*: 1,500,000/ha; 6-8 times at 10 day intervals; * Release of egg parasitoids *Bracon elechidae, Elasmus johnstoni* and pupal parasitoid *Microbracon*	PAN & IPEN

Crop	Pest[153]	Control option	Source
		lefroyi. * Encourage or release predators *Chrysoperla carnea*, *Scymnus* sp., *Triphles tantilus* or *Pyremotes ventricosus* (mite). * Apply *Helicoverpa armigera* NPV: 500-750 LE/ha, 2-3 times at 10 day intervals in evening.	
		* Spray neem seed kernel extract 0.5%, or 3% neem oil. *Spray *Bacillus thuringiensis* var *kurstaki*: 1-2kg/ha, 2-3 times at 10 day intervals in evening. * Spray 5% Vitex solution (decoction of leaves of *Vitex negundo*). * Apply Cow dung-urine solution as pest repellent.	PAN & IPEN
	Thrips (*Thrips tabaci*)	* Deep plough in summer and maintain weed free field and surroundings. * Grow certified acid delinted seeds of tolerant varieties. * Avoid late sowing. * Grow cowpea/onion/soybean as an intercrop in cotton to reduce early stage pest. * Remove alternate host plants like kangni and ambadi (In India).	PAN & IPEN
		* Encourage the activity of parasitoids *Thripoctenus briu*, *Triphleps tantilus* and the mite *Campsid* sp. * Release *Trichogramma chilonis* 150,000/ha. * Release *Chrysoperla carnea* @ 2 larvae/plant in early stage of the plant and 4 larvae/plant in later stage. * Release *Cheilomenes sexmaculata* @ 150,000 adults/ha at random on crop canopy.	PAN & IPEN
	Leafroller	* Spray 5% neem seed kernel extract.	PAN & IPEN
	Anticarsia gemmatalis (a type of leaf miner)	* Spray *Bacillus thuringiensis*.	Argentina
	All pests	FAO-EU Integrated Pest Management (IPM) Programme for Cotton in Asia.	POPRC7/INF-24
Cow pea	Aphids	*Apply *Beauveria bassiana.*	Mexico
	Leaf miner	* Spray with neem seed extract. * Use greased yellow traps. * Spray with ginger, garlic, and chilli extract.	PAN & IPEN
		* Proper cultural practices such as soil preparation, planting dates, crop rotation. * Use of resistant varieties. * Extracts of plants such as tobacco. * Biological control with species that parasitize larvae such as *Opius* sp.	Mexico
	Whiteflies	* Apply *Beauveria bassiana.*	Mexico
Eggplant	Aphids	* Control ants (ants cultivate aphids to gain access to plant sugars); where appropriate cultivate and flood the field to destroy ant colonies and expose eggs and larvae to predators and sunlight. * Avoid using heavy doses of highly soluble nitrogen fertilizers. * Use sticky board traps: 1-4 per 300 sq m field area; replace at least once a week. * Use yellow basin traps with soapy water. * Spray with ginger rhizome extract, custard apple leaf extract, neem leaf extract, neem seed extract, soap spray. * Release braconid wasps.	PAN & IPEN

Crop	Pest[153]	Control option	Source
		* Encourage or release predators: aphid midge, damsel bug, hoverfly, lacewing, ladybird beetle.	
	Fruit and shoot borer	* Plough field to expose larvae to predators and weather. * Plant resistant varieties, e.g. in India Pusa Purple Long, H-128, H-129, Aushey, Thorn Pendy, Black Pendy, H-165, H-407, Dorley, PPC-17-4, PVR-195, Shyamla Dhepa, and Banaras Long Purple. * Raise seedlings under row covers and/or nets to prevent the moths from laying eggs on them. * Practice crop rotation to reduce pest populations. * Practice proper field sanitation - destroy or burn all plant residues as they may harbour the pupating pest. *Prune immediately any larvae-infested shoots; burn or cut them into small pieces; continue pruning the shoots at least once a week before the final harvest. * Uproot all old plants after harvest and burn them. * Deploy pheromone traps.	PAN & IPEN
		* Metazan (*Metarhizium anisopliae*). * Newmectin (*Streptomyces avermetilis*).	Honduras
		The following are recommended for fruit and shoot borer in tomato, a close relative of eggplant; they should also control the same pest in eggplant: * *Helicoverpa armigera* NPV: 250 LE/ha, 2-3 times at 10 day intervals in evening. * *Trichogramma chilonis*: 1,00,000/ha, 6 times at 10 day intervals. * *Bacillus thuringiensis*: 2kg/ha, 2-3 times at 10 day intervals in evening.	drafter
	Diamond back moth	* Deploy pheromone traps. * Apply *Bacillus thuringiensis*. * Release parasitoids *Diadegma semiclausum, D. insulare, D. mollipla, D. fenestral, Cotesia* sp. * Spray with decoction of *Eupatorium odoratum* leaves.	PAN & IPEN
		* Apply *Bacillus thuringiensis*.	Argentina
		* Apply *Bacillus thuringiensis.* * Apply *Beauveria bassiana.*	Japan
	Jassids	* Release and encourage predator *Chrysoperla carnea*.	PAN & IPEN
Groundnut	Aphids; all pests	* Practice deep summer ploughing to expose pests to predators and sunlight. * Erect bird perches. * Deploy pheromone traps. * Spray 5% solution of neem seed kernel extract.	PAN & IPEN
		The following are recommend for aphids on other crops and should be appropriate for aphids on groundnut: * Deploy sticky board traps: 1-4 per 300 sq m field area; replace at least once a week. * Deploy yellow basin trap with soapy water release braconid wasps. * Encourage or release predators: aphid midge, damsel bug, hoverfly, lacewing, ladybird beetle.	drafter

Crop	Pest[153]	Control option	Source
Jute	Bihar hairy caterpillar	* Practice deep summer ploughing to expose pests to predators and sunlight. * Erect bird perches. * Spray with 5% solution of neem seed kernel extract. * Spray with chilli-garlic solution.	PAN & IPEN
		* Spray with azadirachtin.	India
		* Release *Trichogramma evanescens*.	drafter
	Yellow mites	* Spray with 2% wettable sulphur.	PAN & IPEN
Maize	Stem borer	* Practice deep summer ploughing to expose pests to predators and sunlight. * Apply 200kg neem cake during ploughing. * Spray with 5% neem seed kernel extract. * Spray with chilli-garlic solution. * Release *Trichogramma chilonis*: 50,000/ha, 6 times at 10 day interval.	PAN & IPEN
	Pink borer	* Release *Trichogramma chilonis*: 50,000/ha, 6 times at 10 day interval.	PAN & IPEN
		* Spray *Bacillus thuringiensis*.	Mision Permanente de Mexico
	Aphids	* Plant trap crops such as lupine, dill, nasturtiums, and timothy grass near the crop to be protected. * Avoid using heavy doses of highly soluble nitrogen fertilizers. * Deploy sticky board traps: 1-4 per 300 sq m field area; replace at least once a week. * Deploy yellow basin trap with soapy water. * Spray with ginger rhizome extract, custard apple leaf extract, neem leaf extract, need seed extract, or soap spray. * Release Braconid wasps. * Encourage or release predators: aphid midge, damsel bug, hoverfly, lacewing, ladybird beetle.	PAN & IPEN
	Aphids (*Aphis* spp., *Ropalosiphum maidis*, *Schizaphis graminum*, *Macrosiphum* spp,)	* Natural control with several species of predators. A group of at least 15 species has been identified, among which the orange convergent ladybug *Hippodamia convergens* and *Chrysopa* spp stand out. * Use of yellow traps (sticky traps or trays with water).	Diagnóstico de la situación del Endosulfán en México
Mango	Hoppers (mango hopper)	* Spray with 5% neem seed kernel extract. * Spray with 3% neem oil.	PAN & IPEN
	Hoppers (leafhoppers)	* Garlic oil spray. * Neem spray.	PAN & IPEN
	Fruit fly	* Remove fruits with dimples and oozing clear sap. * Harvest crops early when mature green. * Remove overripe fruits. * Practice crop and field sanitation: collect and destroy fallen and damaged ripe fruits; do not put collected damaged fruits in compost heaps, instead feed to pigs or poultry, or bury to eliminate all sources of possible breeding sites. * Bag the fruit. * Use fruit fly baits: (ripe banana peel cut into small pieces and mixed with sugar, flour, and water; mixture of 1 cup vinegar, 2 cups water, and 1 tbsp of honey. * Yellow sticky traps.	PAN & IPEN

Crop	Pest[153]	Control option	Source
		* Spray with basil leaf extract. * Spray with neem.	
		* Gibberellic acid.	Argentina
		* Methyl eugenol trap to attract fruitflies.	Myanmar
Mustard	Aphids	* Use tolerant varieties e.g. in India JM-1 and RK-9501. * Sow early, e.g. crop sown before 20th October in India escapes the damage. * Destroy the affected parts along with aphid population in the initial stage.	PAN & IPEN
		* Release the predatory lacewing *Chrysoperla carnea*: 50,000 1st Instar larvae/ha, 2 times at 15 day intervals. * Release or encourage ladybird beetles *Cocciniella septempunctata*, *Menochilus sexmaculata*, *Hippodamia variegata* and *Cheilomenes vicina*; they are most efficient predators of the mustard aphid; adult beetle may feed an average of 10 to 15 adults/day. * Release or encourage several species of predatory syrphid fly i.e., *Sphaerophoria* spp., *Eristallis* spp., *Metasyrphis* spp., *Xanthogramma* spp and *Syrphus* spp. * The braconid parasitoid Diaretiella *rapae* is a very active bio control agent, causing the mummification of aphids. * Predatory bird *Motacilla cospica* actively feeds on aphids during February-March in India. * A number of entomogenous fungi, such as *Cephalosporium* spp., *Entomophthora* spp and *Verticillium lecanii* infect aphids.	PAN & IPEN
	Gall midge (assumed to be *Contarinia nasturtii*)	* Practcie 3-year crop rotation. *Practice field sanitation. * Plant early in season. * Release predator *Harmonia axyridis.* * Release the entomopathogenic nematode *Heterorhabditis bacteriophora.*	drafter[154]
Okra	Fruit and Shoot Borer	* Release *Trichogramma chilonis*: 50,000 /ha, 6 times at 10 day intervals. * Deploy pheromone traps: 20-25 ha, lures to be changed at 15-30 day intervals.	PAN & IPEN
	Aphids	* Release *Chrysoperla carnea*: 50,000 1st instar larvae/ha, 2 times at 15 day intervals.	PAN & IPEN
		* Control ants (ants cultivate aphids to gain access to plant sugars); cultivate and flood the field to destroy ant colonies and expose eggs and larvae to predators and sunlight; ants use the aphids to gain access to nutrients from the plants. * Plant trap crops such as lupine, dill, nasturtiums, and timothy grass near the crop to be protected. * Avoid using heavy doses of highly soluble nitrogen fertilizers. * Use sticky board traps: 1-4 per 300 sq m field area; replace at least once a week.	PAN & IPEN

154 (i) The Swede Midge – a pest of crucifer crops. Ontario Ministry of Agriculture, Food and Rural Affairs. http://www.omafra.gov.on.ca/english/crops/facts/08-007.htm. (ii) Corlay F, Boivin G, Beliar G. 2007. Efficiency of natural enemies against the swede midge *Contarinia nasturtii* (Dipteria: Cecidomyiidae), new invasive species in North America. Biol Control 43(2):195-201.

Crop	Pest[153]	Control option	Source
		* Deploy yellow basin traps with soapy water. * Release braconid wasps. * Release or encourage predators: aphid midge, damsel bug, hoverfly, lacewing, ladybird beetle. * Spray with ginger rhizome extract, custard apple leaf extract, neem leaf extract, neem seed.	
	Jassids	* Release *Chrysoperla carnea*: 50,000 1st instar larvae/ha, 2 times at 15 day intervals. * Release and encourage other predators: *Chrysopa rufilabris, Harmonia conformis, Harmonia axyridis, Hippodamia convergens, Orius tristicolor, Orius insidiosus,* generaliset preadatory spiders and birds. * Spray with neem, or garlic.	PAN & IPEN
	Diamond back moth	* Deploy pheromone traps. * Release parasitoids *Diadegma semiclausum, D. insulare, D. mollipla, D. fenestral, Cotesia* sp. * Spray with *Bacillus thuringiensis*. * Spray with decoction of *Eupatorium odoratum* leaves.	PAN & IPEN
		* *Bacillus thuringiensis* Berliner. * *Beauveria bassiana.*	Japan
		* Spray neem.	Myanmar
Onion	Aphids	* Spray neem.	Myanmar
		* Control ants (ants cultivate aphids to gain access to plant sugars); cultivate and flood the field to destroy ant colonies and expose eggs and larvae to predators and sunlight; ants use the aphids to gain access to nutrients from the plants. * Plant trap crops such as lupine, dill, nasturtiums, and timothy grass near the crop to be protected. * Avoid using heavy doses of highly soluble nitrogen fertilizers. * Use sticky board traps: 1-4 per 300 sq m field area; replace at least once a week. * Deploy yellow basin traps with soapy water. * Release braconid wasps. * Release or encourage predators: aphid midge, damsel bug, hoverfly, lacewing, ladybird beetle. * Spray with ginger rhizome extract, custard apple leaf extract, neem leaf extract, neem seed.	PAN & IPEN
		* Potassium salt of fatty acids.	Honduras
	Jassids	* Spray neem.	Myanmar
		* Release *Chrysoperla carnea*: 50,000 1st instar larvae/ha, 2 times at 15 day intervals. * Release and encourage other predators: *Chrysopa rufilabris, Harmonia conformis, Harmonia axyridis, Hippodamia convergens, Orius tristicolor, Orius insidiosus*, generaliset predatory spiders and birds. * Spray with neem, or garlic.	PAN & IPEN
Potato	Aphids	* Control ants (ants cultivate aphids to gain access to plant sugars); cultivate and flood the field to destroy ant colonies and expose eggs and larvae to predators and sunlight; ants use the aphids to gain access to nutrients from the plants. * Plant trap crops such as lupine, dill, nasturtiums, and timothy grass near the crop to be protected. * Avoid using heavy doses of highly soluble nitrogen fertilizers. * Use sticky board traps: 1-4 per 300 sq m field area;	PAN & IPEN

Crop	Pest[153]	Control option	Source
		replace at least once a week. * Deploy yellow basin traps with soapy water. * Release braconid wasps. * Release or encourage predators: aphid midge, damsel bug, hoverfly, lacewing, ladybird beetle. * Spray with ginger rhizome extract, custard apple leaf extract, neem leaf extract, neem seed.	
	Jassids	* Release *Chrysoperla carnea*: 50,000 1st instar larvae/ha, 2 times at 15 day intervals. * Release and encourage other predators: *Chrysopa rufilabris, Harmonia conformis, Harmonia axyridis, Hippodamia convergens, Orius tristicolor, Orius insidiosus,* generaliset preadatory spiders and birds. * Spray with neem, or garlic.	PAN & IPEN
Tomato	Fruit and shoot borer /fruit borer	* Practice deep summer ploughing to expose pests to predators and sun. * Erect bird perches. * Deploy pheromone traps: lures to be changed at 15-30 days. * Apply *Helicoverpa armigera* NPV: 250 LE/ha, 2-3 times at 10day intervals in evening. * Release *Trichogramma chilonis*: 1,00,000/ha, 6 times at 10 day intervals. * Spray *Bacillus thuringiensis:* 2kg/ha, 2-3 times at 10 day intervals in evening. * Spray 5% solution of neem seed kernel extract. * Spray chilli-garlic solution.	PAN & IPEN
	Diamondback moth	* Spray *Bacillus thuringiensis* Berliner. * Apply *Beauveria bassiana.*	Japan
		* Spray *Bacillus thuringiensis* var kurstaki.	Canada
		* Spray *Bacillus thuringiensis.*	Argentina, Honduras
		* Spray azadirachtin.	Ecuador
	Leaf miner	* Release parasitoids *Diglyphus isaea, Dacnusa sibirica*, and *Neochrysocharis Formosa.*	Japan
		* Spray azadirachtin.	Estonia
		* Spray *Bacillus thuringiensis.*	Honduras, Argentina
	Aphids	* Control ants (ants cultivate aphids to gain access to plant sugars); cultivate and flood the field to destroy ant colonies and expose eggs and larvae to predators and sunlight; ants use the aphids to gain access to nutrients from the plants. * Plant trap crops such as lupine, dill, nasturtiums, and timothy grass near the crop to be protected. * Avoid using heavy doses of highly soluble nitrogen fertilizers. * Use sticky board traps: 1-4 per 300 sq m field area; replace at least once a week. * Deploy yellow basin traps with soapy water. * Release braconid wasps. * Release or encourage predators: aphid midge, damsel bug, hoverfly, lacewing, ladybird beetle. * Spray with ginger rhizome extract, custard apple leaf extract, neem leaf extract, neem seed extract, or soap spray.	PAN & IPEN

Crop	Pest[153]	Control option	Source
	Jassids	* Release and encourage predators: *Chrysoperla carnea, Chrysopa rufilabris, Harmonia conformis, Harmonia axyridis, Hippodamia convergens, Orius tristicolor, Orius insidiosus*, generaliset preadatory spiders and birds. * Spray with neem, or garlic.	PAN & IPEN
	Whiteflies	* Plant *Nicotiana* as at trap crop. * Deploy yellow sticky board traps. * Release parasitoid *Encarsia* spp. * Release predators *Chrysoperla carnea, Chrysopa rufilabris, Harmonia conformis, Harmonia axyridis, Hippodamia convergens.* * Spray with garlic oil spray, Madre de caco and neem leave spray, neem oil, soap spray.	
Rice	Stem borers	* Release parasitoid *Trichogramma japonicum*: dose = 50,000/ha, 6 times at 10 day intervals. * Deploy pheromone traps: 20-25 /ha, lure to be changed at 15-30 day intervals.	PAN & IPEN
	Rice hispa (and all pests)	* Innoculate soil with nitrogen-fixing bacteria like *Azospirillum* and *Azotobacter*, inconjunction with various cultural techniques. * Release parasitoid *Trichogramma chilonis*: dose = 50,000/ha, 6 times at 10 day intervals. * Remove leaf folds using thorny twigs. * Spray with 5% neem seed kernel extract. * Spray with 5% Vitex Solution (Decoction of leaves of *Vitex negundo*).	PAN & IPEN
	Gall midge	* Remove grassy weeds surrounding rice fields, to remove the pests' alternate hosts. * Plant resistant varieties - there are several gall midge biotypes. * Delay wet season planting of photoperiod sensitive variety to reduce the length of the vegetative period before a gall midge transfers from its alternate hosts. * Split the nitrogen application 3 times; during the seedling, vegetative, and reproductive growth stages. * Plough-under the ratoons of the previous crop to expose the pests to sunlight and predators. * Encourage generalist predatory spiders. * Spray with neem.	PAN & IPEN
	White jassids	* Release and encourage predators: *Chrysoperla carnea, Chrysopa rufilabris, Harmonia conformis, Harmonia axyridis, Hippodamia convergens, Orius tristicolor, Orius insidiosus*, generaliset preadatory spiders and birds. * Spray with neem, or garlic.	PAN & IPEN
Tea	Caterpillars	* Spray with *Bacillus thuringiensis*.	PAN & IPEN
	Tea mosquito bug	* Encourage or release weaver ants. * Spray with neem seed extract.	PAN & IPEN
	Mealybugs	* Release *Cryptolaemus montrouzieri, Chrysoperla carnea, Chrysopa rufilabris, Harmonia conformis, Harmonia axyridis, Hippodamia convergens*. * Spray with chilli extract, soap spray, citrus peel spray.	PAN & IPEN
	Scale insects	* Release parasitic wasps *Aphytis melinus* or *Metaphycus helvolus*; or predators *Eristalis* spp., *Volucella* spp., *Chrysoperla carnea, Chrysopa rufilabris, Harmonia conformis, Harmonia axyridis, Hippodamia convergens, Orius tristicolor*, or *Orius insidiosus*.	PAN & IPEN

Crop	Pest[153]	Control option	Source
		* Spray with neem or horticultural spraying oil or vegetable.	
	Thrips	* Release predators *Chrysoperla carnea*, *Chrysopa rufilabris*, *Orius tristicolor*, or *Orius insidiosus*. * Spray with neem extract.	PAN & IPEN
	Smaller green leaf hopper /green leafhopper	* Release and encourage predators *Chrysoperla carnea*, *Chrysopa rufilabris*, *Harmonia conformis*, *Harmonia axyridis*, *Hippodamia convergens*, *Orius tristicolor*, *Orius insidiosus*, generalist predatory spiders and birds. * Spray with neem, or garlic.	PAN & IPEN
	Flushworm	* Release parasitoid *Apanteles* sp.	PAN & IPEN
	Aphids	* Release predators *Leis dimidiata*, *Menocillus sexmaculatusw*, *Verania vincta*, *Syrphid* sp.	PAN & IPEN
	Tea geometrid: *Ectropis obliqua*	* Nuclear polyhedrosis virus * Pheromones *biological controls include braconid and ichnuemonid wasps, and a nematode (Mermithidae)	Drafter[155]
Tobacco	aphids	* Release predator *Coccinella transversalis.*	Drafter[156]
	Oriental tobacco budworm	* Spray botanical extract of matrine (from *Sophora flavescens*). * Spray *Bacillus thuringiensis.*	China
		* Spray *Bacillus thuringiensis.* * Apply *Helicoverpa armigera* Nuclear Polyhedrosis Virus.	Mexico
		* Spray *Bacillus thuringiensis* kurstaki.	Argentina
Wheat	Aphids	* Release and encourage predator *Chrysoperla carnea*, and others.	Drafter
	Pink borer (assumed to be *Sesamia inferens*)	* Spray *Bacillus thuringiensis*. * Spray azardirachtin. * The following biological controls may be helpful: *Trichogramma chilonis*, *Cotesia flavipes*, *Myosoma chinensis*, *Xanthopimpla stemmator*, *Tetrastichus howardi*, *Sturmiopsis inferens* and *Orius tantillus*.	Drafter[157]
		* Spray *Bacillus thuringiensis* kurstaki.	Argentina
	Termites	* Apply the entomopathogenic fungus *Metarhizium anisopliae.*	Drafter
		* Spray *Bacillus thuringiensis* kurstaki.	Argentina

155 (i)Hazarika LK, Puzari KC, Wahab S. 2001. Biological Control of Tea Pests. In: Upadhyay RK, Mukerji KG, Chamola BP (Eds), 2001, *Biological Control and Its Exploitation in Sustainable Agriculture. Vol 2 Insect Pests*, Kluwer Academia/Plenum Publishers, New York. (ii) Zeng W, Zhou G, Deng Z, Kuan C, Huang Y, Tan J. 2008. Biological control progress of *Ecotropis obliqua* Prout. Tea Communication 2008-04. (iii) Hu ZQ-Q, Zheng R-L. 1979. The larval parasites of the tea geometrid *Ectorpis obliqua* hypulina Wehrli. Acta Entomologica Sinica.

156 K. S. Jagadish, M. Jayaramaiah, B. Shivayogeshwara. 2010. Bioefficacy of three promising predators on *Myzus nicotianae* Blackman (Homoptera : Aphididae). J *Biopestic* 3(1):062-7.

157 Insect Information Database. Nation Bureau of Agriculturally Important Pests, India. http://202.141.78.173/NABG/pestrecdis.php?keyword=Millets%20Ragi&pname=Sesamia%20inferens.