INTERNATIONAL JOURNAL OF PLANT PROTECTION | VOLUME 6 | ISSUE 2 | OCTOBER, 2013 | 467-472

IJPP

A REVIEW

Insect pest management in organic agriculture

■ D. PUJARI*, BADAL BHATTACHARYYA AND MRINMOY DAS

Department of Entomology, Assam Agricultural University, JORHAT (ASSAM) INDIA

ARITCLE INFO

Received : 17.08.2013
Accepted : 25.09.2013

Key Words :
Insect pest management, Organic agriculture, Preventive strategies

***Corresponding author:**
Email: dwiban.pujari2004@gmail.com

ABSTRACT

Organic farming is gaining popularity worldwide among the farmers, entrepreneurs, policy makers, scientists and other stackholders as it minimizes dependence on chemical inputs, thus safeguarding quality of natural resources and environment. In organic farming, insect pest pose a major challenge since genetically modified crops and synthetic pesticides are not permitted for use in organic production systems. The underlying principle of integrated pest management (IPM) in organic system of cultivation involves application of ecologically sound practices. Major emphasis is given on use of multiple and various tactics incorporated into the cropping system design to prevent the damage caused by the insect pests. The key strategies of IPM of organic farming are selection of resistance/tolerance varieties, planting trap crops, following crop rotation, conservation of biological agents and soil quality management. However, enhancement of soil quality and cultural practices are sometime found to be insufficient to manage the pest below economic injury level (EIL). In such situations, augmentative release of biological control agent helps in rapid suppression of insect pests. For organic cultivation, biopesticides are used as a last option when the levels of pest population or damage are not acceptable. Since no single practice is effective for all possible insect pests that threaten the crop, a combination of such practices (IPM) is necessary to maintain the pest population below the EIL. These practices when used in a compatible manner could make organic ecosystem unattractive to pest species.

How to view point the article : Pujari, D., Bhattacharyya, Badal and Das, Mrinmoy (2013). Insect pest management in organic agriculture. *Internat. J. Plant Protec.*, **6**(2) : 467-472.

INTRODUCTION

Global concerns about pesticide use, their residues in soil and plant systems as well as their hazardous effect on ecology and environment have diverted the attention of scientists to find out an ecofriendly approach of insect pest management. The world is still in search of the process of developing alternative farming techniques, which are sustainable for environment, crop production as well as from the socio-economic point of view. Organic agriculture is one among the broad-spectrum of production methods which is supportive of the environment. It is a holistic production management system which promotes and enhances agro-ecosystem health, biodiversity, biological cycles and soil biological activities. Organic farming is gaining gradual impetus across the world and it is now practiced in more than 120 countries of the world with a total area of 33 million hectares (Willer *et al.*, 2008). The trade in world organic market has now touched 26 billion US$ which further expected to increase to 102 billion US$ by 2020 (APEDA, 2011). However, insect pests are the major limiting factors in the production of good and high quantity agricultural products. Insect pests pose a major challenge in organic crop production systems since genetically modified crops and synthetic pesticides are not permitted for use in organic production systems. Therefore, it has been realized to formulate ecofriendly strategies for the integrated management of insect pests in organic agriculture. Integrated pest management (IPM) in organic production systems rely on ecologically-based practices such as cultural and biological pest management, and virtually exclude the use of synthetic chemicals and genetically modified crops in crop production. Under organic farming systems, the fundamental components and natural processes of ecosystems, such as activities of soil organisms, nutrient cycling, and species distribution and competition are used directly and indirectly as farm management tools and to prevent pest populations from reaching economically-damaging levels. In this article, we will highlight different insect pest management strategies for organic crop production with special emphasis on preventive strategies, biological control and ecofriendly chemical control. This review also describes some newly developed methods of pest management commonly used in the fields for insect pest management in organic agriculture.

Preventive strategies :

The preventive strategies are attempted through cultural practices, increasing overall crop biodiversity and conservation of potential habitats for beneficial organisms (Zehnder *et al.*, 2007 and Lotter, 2003). The main logic behind this strategy is to stop pest outbreak/suppress pest infestation by encouraging Good Agricultural Practices (GAPs) and other measures. The different preventive measures which have relevance in organic farming are discussed below:

Cultural practices **:**

Cultural practices such as crop rotation/isolation, soil quality management and non-transgenic host plant resistance are used to modify the crop environment enough to increase environmental resistance to insect pests.

Crop rotation or sequence is designed to present a non-host crop to insect pests. Crop isolation/rotation strategies are most effective against pests that do not disperse over great distance and/or that overwinter in or near host crop field. Some of the serious insect pests *viz*., brinjal shoot and fruit borer, *Leucinodes orbonalis*, carrot rust fly, *Pistia rosae*, Colorado potato beetle, *Leptinotarsa decemlineata* and onion maggot, *Delia antique* were managed by following crop rotation techniques (Weisz *et al*., 1994; Walters and Eckenrode, 1996; Collier and Finch, 2000; Rath and Dash, 2006). However, this agro-technique was found much less effective in managing cabbage maggot, *Delia radicum* because of their abilities to move to a great distance (Collier *et al*., 2001). Similarly, the isolation of susceptible crops from surrounding host crops can be an effective management strategy for aphid-borne viral plant diseases, although distances of up to 25 km may be necessary to prevent the spread of virus (Schellhorn and Sork, 1997). Rotation with glucosinolate-containing crops belonging to Brassicaceae family was found to be through biofumigation effects against some soil borne pests and diseases (Kirkegaard *et al*., 1998).

Timing to avoid pest outbreaks and using resistance varieties are considered to be successful cultural management strategies. Varying the planting time of crops creates asynchrony between susceptible stage of the crop and insect's most potentially damaging stage thus resulting a reduced rate of colonization. The female Hessian fly, *Mayetiola destructor* has a small window of time after emergence in which to lay eggs and is primarily associated with wheat. However, if this preferred host is not available, eggs may be deposited on other grasses such as oats that do not support larval development (Harris and Rose, 1989). In order to avoid damage by Hessian fly, growers can delay planting of wheat to avoid adult emergence. Breeding wheat varieties for resistance to Hessian fly has also been successful. Low rice gall midge infestation was recorded in rice crop planted in the first fortnight of July (Singh *et al*., 2007). In some cases, if resistance varieties are not available, ultimate choice lies on selection of varieties which have the capacity to recover fast after insect pest infestation by quick development of new tillers, roots and leaves (Rautaray, 2006).

In organic farming, enhancement of soil fertility is accomplished through crop rotations, growing of cover crops, and application of plant and animal materials. Recent studies have shown that plant resistance to insect pests and diseases is linked to optimal physical, chemical and, perhaps most importantly, biological properties of soil (Altieri and Nicholls, 2003). A lower level of oviposition by European corn borer, *Ostrinia nubilalis* on corn grown in organically managed soil has been reported by Phelan *et al*. (1995) and according to them, the organic matter and microbial activity associated with organically managed soils provides a buffering capability to maintain optimal nutrient and mineral balance in plants, which in turn affects the performance of phytophagous insects (Alyokhin *et al*., 2005). Likewise, potato grown in manure-amended soils was an inferior host for the Colorado potato beetle compared with potato grown in synthetically fertilized soil (Alyokhin and Atlihan, 2005).

While comparing the population of natural enemies in organic vs. conventional tea sections, Borthakur *et al.* (1993) from Assam observed more population of natural enemies in organically raised tea sections. The number of natural enemies in organic rice ecosystem was higher than that recorded in the conventionally grown rice crops (Lawanprasert *et al.*, 2010).

Crop diversification/ Polyculture **:**

Crop diversification can help to realize the potential of resource-limited natural enemies by satisfying their requirements for food and shelter. Increased plant diversity can benefit natural enemies by providing them with favourable microclimate to act (Rao *et al*., 2002), a source of alternative hosts or prey or a supply of plant-based foods (*i.e*., nectar and pollen) (Wackers *et al*., 2007). Polyculture is an agricultural practice in which multiple plants are grown in the same space. In contrast to monoculture, polyculture imitates the diversity of natural ecosystems, which has a significant impact on the insect populations (Shrivastava *et al*., 2010). The population density of arthropod herbivores in polyculture was found to be lower than in monoculture (Andow, 1991). Growing plants of different species in close physical proximity may suppress insect pests problems by releasing different plant volatiles into the surroundings (Perrin and Phillips, 1978 and Uvah and Coaker, 1984) as compared to growing host plants in concentrated manners allowing easy and rapid colonization of insect pests depicting the hypothesis of resource concentration as suggested by Root (1973). The growing different distantly related plant species can visually or chemically interfere with specialist herbivores, making the habitat less favourable. Intercropping is one of the important forms of polyculture which is based on the principle of reducing insect pests by increasing the diversity of an ecosystem (Rao *et al.*, 2002). The presence of multiple crops in a same agro-ecosystem provides a habitat for a variety of insects and therefore increases the local biodiversity, especially the beneficial insects, such as parasitic wasps, leading to reduction of outbreaks of crop pests (Shrivastava *et al*., 2010). Colorado potato beetles were reported to attract to volatiles emitting from potato (*Solanum tuberosum*), but are repelled or not attracted by mixtures of potato and tomato (Thiery and Visser, 1986, 1987). The factors responsible for pest suppression in intercropping system were found to be many and among them, the role of natural enemies and the changes in microclimate play an significant role (Rao *et al.*, 2002).

Growing trap crops in organic farming can reduce pest pressure on the main crop by being more attractive to insect pests than main crops. In recent years, efforts in trap cropping has been increased considerably and become a vital component in IPM Package. Inherent characteristics of a trap crop may include not only differential attractiveness for feeding but also other attributes that enable the trap crops to serve as a sink for insects. Raising tomato with marigold in 3:1 combination gave maximum reduction in fruit damage caused by *Helicoverpa armigera* in tomato (Hussain and Bilal, 2007). Different species of plants may vary in their ability in serving as a trap crop. However, the effectiveness of trap cropping depends on the proper timing of planting, adequate spacing and size of the trap crop (Hokkanen, 1991).

Conservation of natural enemies **:**

Conservation biological control involves habitat manipulation to increase populations of predators and parasitoids, that can help keep pest populations below the economic injury levels. Cultivation of flowering insectary strips to provide pollen and nectar as a means of conservational biological control can enhance the survivability and performance of natural enemies by directly providing energy-rich sugars to beneficial insects (Altier *et al.,* 2005). Adult encyrtid wasps (*Copidosoma koehleri*) lived twice as long as control when provided nectar from buckwheat, faba beans, phacelia and nasturtium (Baggen *et al*., 1999). Other habitat management strategies to conserve beneficial insects are providing overwintering habitat as experienced by the adoption of 'beetle banks' in England. Beetle bank is a strip planted with grasses and/or perennial plants at the centres of cereal fields in order to provide temperature-moderating overwintering habitats for predaceous ground beetles. These grasses also provide refugia for predatory carabid and staphylinid beetles and spiders as well as for birds and small mammals. In the winter, beetle bank harbour more than 1000 predatory invertebrate individual per square meter (Zehnder *et al*., 2007). Likewise, the predatory spider fauna in rice ecosystem can be successfully augmented by placing straw bundles alone or in combination with other border crops (Tanwari *et al.*, 2011).

Trap technology **:**

Uses of sticky traps, physical barriers and pheromone lures to suppress insect pests have more relevance in organic farming with a view to monitor their population and management as well. When paired with traps, pheromone and scent lures utilize both chemical and visual attractants (Foster and Harris, 1997). Yellow sticky traps can be used as an efficient tool to monitor the population of leaf miners, aphids, thrips and whiteflies as these insect pests are attracted to the yellow colour. This control method when used at proper time, can suppress specific insect pests. Yellow sticky traps have been used as a practical control measures for *Liriomyza* flies as well as for whiteflies in vinyl houses producing vegetables (Wu *et al*., 1998). Physical traps or barriers can also be used to manage snails to determine if they continue to spread. Exploration of pheromone trap is another important approach to monitor and manage key destructive insect pest species which are really difficult to manage in organic system of cultivation. Mass trapping of males of squash vine borer (*Melittia cucurbitae*) by using pheromone deprived the females from successful mating and oviposition. In India, pheromone traps have already been successfully used against pests like rice stem borer and brinjal fruit and shoot borer (Rath and Dash, 2006 and Chakraborty, 2011).

Use of attractants **:**

Among the various alternate strategies available for the management of fruit flies, use of methyl eugenol traps stands as the most outstanding alternative. Methyl eugenol has both olfactory as well as phagostimulatory action and is known to attract fruit flies from a distance of 800 meter (Roomi *et al.*, 1993). Methyl eugenol, when used together with an insecticide impregnated into a suitable substrate, forms the basis of male annihilation technique. This technique has been successfully used for the eradication and control of several *Bactrocera* species in India (Ravikumar and Viraktamath, 2007 and Dhillon *et al.*, 2005)). In Taiwan the use of McPhail trap to attract female oriental fruit flies as well as melon fruit flies (*Bactrocera dorsalis*) was found to be effective. The trap is fruit-like in shape and consists of a yellow plastic reservoir containing protein hydrolysis solution as an odour attractant for female oriental fruit flies (Wu *et al.*, 1998). The melon fruit fly can successfully be managed over a local area by cue-lure traps. The application of molasses + malathion and water in the ratio of 1: 0.1: 100 provides good control of melon fly (Dhillon *et al.*, 2005).

Fruit bagging **:**

Fruit bagging has been used to protect the infestation of fruit by insects. Individual fruits are bagged when they were young and remain bagged until harvest. No additional pesticidal sprays are needed once the bags are placed on the fruits. Bagging has been considered as a traditional practice adopted by farmers for controlling insects, especially melon flies, fruit flies and banana leaf and fruit scarring beetles. (Wu *et al.*, 1998). Bagging of fruits on the tree (3 to 4 cm long) with 2 layers of paper bags at 2 to 3 day intervals minimizes fruit fly infestation and increases the net returns by 40 to 58 per cent (Fang, 1989; Jaiswal *et al.*, 1997). Akhtaruzzaman *et al.* (1999) suggested that cucumber fruits should be bagged at 3 days after anthesis, and the bags should be retained for 5 days to achieve effective control.

Augmentative biological control :

Augmentative biological control involves the deliberate release of predators and parasitoids to manage pests in a controlled environment. Most success with release of biological control agents for control of insect pests has occurred in greenhouse systems (Van Lenteren, 2000). In greenhouse system, whitefly has been controlled by releasing parasitoid wasps, *Eretmocerus mundus* (Weintraub *et al.*, 2002). In field-grown crops parasitoid releases have been effective in the management of lepidopteran pests of vegetables (Lorenz *et al.*, 2003), aphids in wheat (Mohamed *et al.*, 2000) and leaf hoppers in vineyards (Daane *et al.*, 2005). In India, the parasitoids *viz.*, Trichogrammatids (for Lepidopteran pests), *Cotesia plutellae* (for Diamond back moth), *Encarsia formosa* (for green house whiteflies), *Chrysoperla* spp. (for sucking pests), *Cryptolaemus montrouziery* (for mealy bugs on fruit crops), phytoseilus mites have been found successful for biosuppression of field and horticultural crop pests (Kadam *et al.*, 2007). However, timely availability of bioagents and their quality parameters are major constrains. For this, establishment of localized mass production units and hybridization through selective breeding of potent indigenous/exotic bioagents are the major needs.

Chemical control :

Insecticides of biological and mineral origin, pheromones for mating disruption, and repellent agents as physical barriers are used as a last option for the control of pests when all preventive methods used in the preceding phases have failed (Zehnder *et al.*, 2007). There are some organic insecticides approved by the Organic Materials Review Institute for use in organic cropping systems. The permitted list of insecticides includes plant based extracts, such as neem oil, pyrethrums, ryania, rotenone and sabdilla and microbe-derived chemicals such as spinosad. Soaps and mineral oils may also be used to manage small, soft bodied insects. Mineral products such as kaolin clay and diatomaceous earth are also allowed to prevent pest infestation.

Insecticides of biological and mineral origin approved for organic systems have been developed and tested on a variety of crops including vegetables, fruits, and vine crops (Wyss *et al.*, 2005). However, the use of pyrethrin (extract of chrysanthemum) is restricted owing to the side effects on many species of beneficial organisms. Azadirachtin preparations (extract of neem kernels) are now replacing pyrethrin to a large extent because of more specific ingestion toxicity effects and low impact on beneficial organisms. In apple and potato production, azadirachtin has been used effectively to control the rosy apple aphid (Wyss, 1997). Spinosad (an environmentally safe insecticidal agent obtained from the soil bacterium, *Saccharopolyspora spinosa* through fermentation) is one of the few relatively new insecticidal agents used in organic farming. It has been successfully tested worldwide against a large number of insects on various crops (Premachandra *et al.*, 2005). The toxic effects of neem against a number of arthropods have already been reported (Pandey and Vibha, 2010). Botanicals derived from garlic, papaya leaves and wood ash could be effectively considered as pest management options under organic farming to reduce insect pest populations and increase eggplant and okra productivity (Mochiah *et al.*, 2011). The application of mycopathogenic formulations *viz.*, *Beauveria bassiana, Verticillium lecani* and *Metarhizium anisopliae* were also found effective against leaf hopper (*Amrasca biguttula biguttula*) and aphids (*Aphis gossypii*) infesting okra (Naik *et al.*, 2012).

Conclusion :

In order to achieve successful pest management in organic agriculture, the development of ecologically sound, appropriate insect pests management systems for each crop is necessary. The strategies should include:

– Understanding the local pest type and the ecologies of the crops to be cultivated.
– Encouraging the soil-ecosystem's diversity via application of beneficial microbes and reasonable organic fertilizers to create a healthy soil environment to support stronger plant growth.
– Deciding on an appropriate integrated pest

management programme suitable for organic practices including various insect pest control measures under the advisory and suggestion of the certifying agencies or research institutes.

– Practicing pest management following strict control procedure under the guidance of pest management experts.

Moreover, some Indigenous Technical Knowledge (ITKs) developed by the farmers of their respective localities can also be included in the IPM programme because these ITKs are ecofriendly and compatible to other pest management practices. The development of more advanced techniques for use in organic agriculture is necessary, and the extension and promotion of organic farming practices to meet the goal of sustainable agricultural development are of vital importance.

REFERENCES

Akhtaruzzaman, M., Alam, M. Z. and Ali-Sardar, M.M. (1999). Suppressing fruit fly infestation by bagging cucumber at different days after anthesis. *Bang. J. Ent*., **9**: 103-112.

Altier, M.A. and Nicholls, C. (2003). Soil fertility and insect pests: harmonizing soil and plant health in agroecosystems. *Soil Tillage Res.*, **72** (2) : 203–211.

Altier, M.A., Nicholis Clara, I. and Fritz Martin, A. (2005). Designing habitat management strategies. In: *Manage insects on your farm: A guide to ecological strategies*. Published by the Sustainable Agriculture Network, Beltsville, MD, pp. 87-89.

Alyokhin, A. and Atlihan, R. (2005). Reduced fitness of the Colorado potato beetle (Coleoptera: Chrysomelidae) on potato plants grown in manure-amended soil. *Environ. Entomol*., **34** (4) : 963–968.

Alyokhin, A., Porter, G., Groden, E. and Drummond, F. (2005). Colorado potato beetle response to soil amendments: a case in support of the mineral balance hypothesis. *Agric. Ecosyst. Environ*., **109** (3-4) : 234–244.

Andow, D. A. (1991). Vegetational diversity and arthropod population response. *Annu. Rev. Entomol*., **36**: 561–586.

APEDA (2011). Agricultural and processed food products export development (APEDA): available from *http://www.apeda.gov.in/apedawebsite/ organic/Organic_Products.htm.*

Baggen, L. R., Gurr, G. M. and Meats, A. (1999). Flowers in tri-trophic systems: mechanisms allowing selective exploitation by insect natural enemies for conservation biological control. *Entomol. Exp. Appl*., **91** (1) : 155–161.

Borthakur, M., Sarmah, M., Rahman, A. and Kakoty, N. N. (1993). Population dynamics of tea pests and their natural enemy complex in relation to various agro-management practices in tea. Proc. Tock. Conf. on tea tech., Calcutta : 158-165.

Chakraborty, Kaushik (2012). Evaluation of integrated pest management module against paddy yellow stem borer, *Scirpophaga incertulas* Walk. *Karnataka J. Agric. Sci*., **25** (2): 273-275.

Collier, R.H. and Finch, S. (2000). Strategies for reducing carrot fly (*Psila rosae* F.) damage in organic crops. *Med. Fac. Landbouww. Univ. Gent.*, **65** (2) : 227–233.

Collier, R.H., Finch, S. and Davies, G. (2001). Pest insect control in organically produced crops of field vegetables. *Med. Fac. Landbouww. Univ. Gent.*, **66** (2a) : 259–267.

Daane, K.M., Smith, R.J., Klonsky, K.M. and Bentley, W.J. (2005). Organic vineyard management in California. *Organic Res.* Com., (May), 37N–55N.

Dhillon, M.K., Singh, Ram, Naresh, J.S. and Sharma, H.C. (2005). The melon fruit fly, *Bactrocera cucurbitae*: A review of its biology and management. *J Insect Sci*., **5** (40):

Fang, M.M. (1989). Studies on using different begging materials for controlling melon fly on bittergourd and spongegourd. *Bulletin of Taichung District Agriculture Improvement Station*, **25**: 3-12.

Foster, S.P. and Harris, M.O. (1997). Behavioral manipulation methods for insect pest-management. *Annu. Rev. Entomol.*, **42**: 123–146.

Harris, M.O. and Rose, S. (1989). Temporal changes in the egglaying behaviour of the Hessian fly. *Entomol. Exp. Appl.*, **53** (1) : 17–29.

Hokkanen, H.M.T. (1991). Trap cropping in pest management. *Annu. Rev. Entomol.*, **36**: 119–138.

Hussain, B. and BilaL, S. (2007). Marigold as a trap crop against tomato fruit borer (Lepidoptera: Noctuidae). *Internat. J. Agric. Res.*, **2**(2): 185-188.

Jaiswal, J.P., Gurung, T.B. and Pandey R.R. (1997). Finding of melon fruit fly control survey and its integrated management 1996/97, Kashi, Nepal, Lumle Agriculture Research Centre working paper 97/55, pp.1-2.

Kadam, J.R., Chandele, A.G. and Pokharkar, D.S. (2007). Bioagents and biopesticides for organic plant protection. National symposium on recent trends in organic farming held on September, 11-12, 2007, PUNE (INDIA).

Kirkegaard, J.A., Sarwar, M. and Matthiessen, J.N. (1998). Assessing the biofumigation potential of crucifers. *Acta Hort*., **459**: 105–111.

Lawanprasert, A., Kunket, K., Arayarangsarit, L. and Prasertsak, A. (2010). Comparison between conventional and organic paddy fields in irrigated rice ecosystem. 4th INWEPF Steering Meeting and Symposium, Bangkok. p. 1-9.

Lorenz, N., Zimmermann, O. and Hassan, S.A. (2003). Use of *Trichogramma* parasitoids against the leek moth (*Acrolepiopsis assectella*, Lep., Plutellidae) for the solution of plant protection problems in organic farming. *DGAAE Nachr*., **17** (1) : 19-24.

Lotter, D.W. (2003). Organic agriculture. *J. Sustain. Agric.*, **21**: 59–128.

Mochiah, M. B., Banful, B., Fening, K. N., Amoabeng, B. W., Offei Bonsu, K., Ekyem, S., Braimah, H. and Owusu-Akyaw, M. (2011). Botanicals for the management of insect pests in organic vegetable production. *J. Entomol. & Nematol.*, **3**(6): 85-97.

Mohamed, A.H., Lester, P.J. and Holtzer, T.O. (2000). Abundance and effects of predators and parasitoids on the Russian wheat aphid (Homoptera: Aphididae) under organic farming conditions in Colorado. *Environ. Entomol.,* **29** (2) : 360–368.

Naik, R.H., Devakumar, N., Rao, G.E., Vijaya, N., Khan, H.S.I. and Subha, S. (2012). Performance of botanical and fungal formulation for pest management in organic okra production system. *J. Biopest,* **5** (supplementary): 12-16.

Pandey, R. and Vibha, P. (2010). Potentials of neem. *Indian Farming,* April, 2010, pp. 19-20.

Perrin, R.M. and Phillips, M.L. (1978). Some effects of mixed cropping on the population dynamics of insect pests. *Entomol. Exp. Appl.,* **24** (3) : 585-593

Phelan, P.L., Mason, J.F. and Stinner, B.R. (1995). Soil-fertility management and host preference by European corn borer on *Zea mays*: a comparison of organic and conventional chemical farming. *Agric. Ecosyst. Environ*., **56** (1) : 1–8.

Premachandra, D.W.T. ., Borgemeister, C. and Poehling, H.M. (2005). Effects of neem and spinosad on *Ceratothripoides claratris* (Thysanoptera: Thripidae), an important vegetable pest in Thailand, under laboratory and greenhouse conditions. *J. Econ. Entomol.,* **98** (2) : 438–448.

Rao, M.S., Reddy, K.D., Singh, T.V.K. and Reddy G.S. (2002). Crop-crop diversity as akey component of IPM-a review. *Agric. Rev*., **23** (4): 272-280.

Rath, L.K. and Dash, Baijayeeny (2006). Non-chemical management of shoot and fruit borer infesting brinjal. *Indian Farming,* May, 2006. pp. 33-34.

Rautaray, S.K. (2006). Rice hispa in Assam and its management. *Indian Farming*, July, 2006.

Ravikumar, P. and Viraktamath, S. (2007). Attraction of fruit flies to different colours of methyl eugenol traps in guava and mango orchards. *Karnataka J. Agric. Sci*., **20** (4): 749-751.

Roomi, M.W., Abbas, T., Shah, A.H., Robina, S., Qureshi, A.A., Sain, S.S. and Nasir, K.A. (1993). Control of fruitflies (*Dacus* sp.) by attractants of plant origin. *Anzeiger fiir Schadlingskunde, Pflanzeschutz, Umwelschutz*, **66**: 155-157.

Root, R.B. (1973). Organization of a plant-arthropod association in simple and diverse habitats: the fauna of collards (*Brassicae oleracea*). *Ecol. Monogr.,* **43**: 95–124.385–393.

Schellhorn, N.A. and Sork, V.L. (1997). The impact of weed diversity on insect population dynamics and crop yield in collards *Brassica oleraceae* (Brassicaceae). *Oecologia,* **111** (2) : 233–240.

Shrivastava, Gitika, Rogers Mary, Wszlaki, Panthee, D.R. and Chen, Feng (2010). Plant volatiles-based insect pest management in organic farming. *Critical Reviews in Plant Sci*., **29** (2) : 123-133.

Singh, K.M., Singh, M.P. and Singh, T.K. (2007). Influence of planting time on the incidence of rice gall midge, *Orseolia oryzae* (Wood Mason) in Manipur. *Indian J. Ent.,* **69**(1): 26-29.

Tanwari, R.K., Garg, D.K., Singh, S.P., Dhandapani, A. and Bmbawale, O.M. (2011). Enhancement of spiders'population through habitat management in rice (*Oryza sativa*) fields. *Indian J. Agric. Sci*., **81** (5): 462-474.

Thiery, D. and Visser, J.H. (1986). Masking of host odour in the olfactory orientation of the Colorado potato beetle. *Entomol. Exp. Appl.,* **41** (2) : 165–172.

Thiery, D. and Visser, J.H. (1987). Misleading the Colorado potato beetle with an odor blend. *J. Chem. Ecol.,* **13** (5) : 1139–1146.

Uvah, I.I.I. and Coaker, T.H. (1984). Effect of mixed cropping on some insect pests of carrots and onions. *Entomol. Exp. Appl*., **36** (2) : 159–167.

Van Lenteren, J.C. (2000). Success in biological control of arthropods by augmentation of natural enemies". In: *Biological control: measures of success*, edited by Gurr, G. and Wratten, S. D. Norwell, MA: Kluwer Academic Publishers, pp. 77–103.

Wackers, F.L., Romeis J. and Van, R.P. (2007). Nectar and pollen-feeding by insect herbivores and implications for tri-trophic interactions. *Annu. Rev. Entomol.,* **52**: 301–323.

Walters, T.W. and Eckenrode, C.J. (1996). Integrated management of the onion maggot (Diptera: Anthomyiidae). *J. Econ. Entomol*., **89** (6) : 1582–1586.

Weintraub, P., Sapira, N., Chiel, N. and Steinberg, S. (2002). Effects of various release schedules of *Eretmocerus mundus* on the control of *Bemisia tabaci* in organic greenhouse peppers in Israel: preliminary results. *IOBC/WPRS Bull.,* **25** (1) : 301–304.

Weisz, R. Z., Smilowitz, Z. and Crist, B. (1994). Distance, rotation, and border crops affect Colorado potato beetle colonization and population density and early blight severity in rotated potato fields. *J. Econ. Entomol*., **87** (3) : 723–729.

Willer, H., Yussefi, M. and Sorensen, N.E. (2008). The world of organic agriculture: Statistics and emerging trends 2008.

Wu, Y.F., Young, L.C., Tseng, F.S. and Fan , G.Y. (1998). *Protection of horticultural crops.* (3rd ed.) Departmnt of Taiwan Agriculture and Frest, Taiwan Provineial Government Press, Nantou, Taichung, 266 pp. (in Chinese).

Wyss, E. (1997). Verschiedene Strategien zur Regulierung der Mehligen Apfelblattlaus Dysaphis plantaginea im biologischen Obstbau. *Mitt. Dtsch. Ges. Allg. Angew. Entomol.* **11** : 233–236 (Source: *Ann. Rev. of Entomol*., 2007, Vol. 52, pp. 57-80).

Wyss, E., Luka, H., Pfiffner, L., Schlatter, C., Uehlinger, G. and Daniel, C. (2005). Approaches to pest management in organic agriculture: a case study in European apple orchards. *Organic Research* (May) pp. 33–36.

Zehnder, G., Gurr, G.M., Kühne, S., Wade, M.R., Wratten, S.D. and Wyss, E. (2007). Arthropod pest management in organic crops. *Annu. Rev. Entomol*., **52**: 57-80.