Original scientific paper
10.7251/AGRENG1802005A
UDC 632.951:595.799

IMPACT OF INSECTICIDES ON POLLINATOR POPULATIONS: ROLE OF PHYTOSANITARY PERFORMANCE INDICATORS IN TOMATO CROPS

Leïla ALLAL BENFEKIH[1*], Manel BELLACHE[2], Bilal AOUDIA[1], Abdelhaq MAHMOUDI[3]

[1] Laboratory for research on medicinal and aromatic plants, Department of Biotechnologies, Faculty of nature sciences and life, University of Blida 1, Algeria
[2] Mediterranean Institute of Agroforestry, Politecnical University of Valencia, Cami De Vera, Valencia, Spain
[3]Department of Agronomy sciences, University of Chlef, Algeria and Laboratory for research on medicinal and aromatic plants, Department of Biotechnologies, Faculty of nature sciences and life, University of Blida 1, Algeria
*Corresponding author: leilaallalbenfekih@yahoo.fr

ABSTRACT

Agrochemicals are considered to be among the major environmental threats to pollinators, including honey bees. At the time of foraging, bees are at risk of exposure to phytosanitary treatment as a result of widespread treatment and their location, often near orchards. In Algeria, the majority of farmers systematically over-treat their orchards in order to have good quality fruits for as long as possible towards the use of an effective product. We evaluated the comparative effects of lambda-cyhalothrin and spinosad insecticide treatments on bees in tomato plots. Fluctuations of bee populations abundance were established during a 16 days period of exposure using yellow-colored plates with water placed every two days inside the experimental units. Bee populations showed very high sensitivity (0 individuals registered) to both insecticides at the homologated dose and even half dose during 10 days following application of the treatments. Depending on the estimated temporal toxicity of the respective products, differences in recovery of bee activity are presented. Consideration of indicators of the intensity of use of plant protection products is discussed.

Keywords: *Pollinators, pollutants, toxic, pesticides, agrosystems, Algeria.*

INTRODUCTION

Pesticides are a major factor affecting agrobiodiversity. They may have short-term toxic effects on organisms that are directly exposed to them, or long-term effects, causing changes in habitat and the food chain (Geiger et *al*., 2010). Broad-spectrum insecticides such as carbamates, organophosphates and pyrethroids can cause population declines of beneficial insects such as bees, spiders, or beetles. Many of these species play an important role in the food web or as natural enemies of pest insects. Managed honey bee, *Apis mellifera* L., colonies placed in field crops are potentially exposed to carbamates pyrethroid insecticides used for broad-spectrum pest control (Pilling and Jepson, 2006). In Algeria, pesticide manufacturing was provided by autonomous pesticide management entities such as Asmidal and Moubydal. However, several companies have specialized in the importation of insecticides and various related products. Approximately 400 plant protection products are registered in Algeria, of which forty varieties are widely used by farmers (Belhadi et *al*., 2016)). Law No. 87-17 of 1st August 1987 on phytosanitary protection (J.O.R.A., 1995) introduced the mechanisms that allow the efficient use of pesticides. This law regulates aspects relating to the registration, importation, manufacture, marketing, labeling, packaging and use of pesticides (Bouziani, 2007). Numerous convergent observations show that chemical control has important effects on pollinating insects, which suffer immediate or delayed losses that affect adults or larvae (Carvalheiro et *al*., 2013)). Pyrethroids have been reported to pose repellency which alters foraging behavior with the benefit of preventing bees from encountering a lethal dose in the field (Ingram et *al*., 2015). However, sub-lethal exposure to pyrethroids may adversely impact bee behavior potentially resulting in social dysfunction or disruption of foraging (Ingram et *al.,* 2015).

This paper considers the effects and ecotoxic aspect of a pyrethroid and a bioinsecticide spinosad (Tracer) used in Algeria in vegetable field crops and orchards, on non-target fauna, particularly on functional groups of beneficial organisms.

MATERIAL AND METHODS

Experimental device and sampling

The studied tomatoe plots (variety Escudero F1 HMX 3823), spread over 5 ha area is located at 7 km north of Boufarik (Blida, sublittoral central, Mitidja region-Algeria) and belongs to a private farmer. It is bounded to the north by fallow plots, to the south and west by a road (Ben Chabane - Ben Hamdani), to the east by an apple orchard. It is surrounded to the north, to the south and to the east by cypresses windbreak hedges. No orchard maintenance was done during the study period.

The insecticide treatment solutions (L: lambda-cyhalothrin, T: spinosad,) were sprayed at the registered dose (D) and half dose (HD) with a manual sprayer at the level of 5 micro-plots or units including 30 tomato plants in each treated and control units (tm).

Lambda-cyhalothrin is a polyvalent insecticide, belonging to the synthetic pyrethroid family and acting by contact and ingestion. It is formulated as a liquid at 50 gL^{-1}, at an application rate of 60 mL HL^{-1}. Spinosad is composed of two toxins A and B, with chemical formula C41H65NO10 and C42H67NO10 respectively, formulated in concentrated suspension (SC) at 480 g L^{-1}, at a use rate of 0.2 Lha^{-1}. It acts by contact and ingestion.

The toxicity and ecotoxicity were assessed through the availability of individuals from functional communities in the treated and untreated units. We placed four yellow water traps and renewed them after each sampling every two days after application and over a period of 15 days. The captured arthropods were identified under the binocular microscope and sorted according to their taxonomic affiliation and trophic groups (phytophagous, flower dwelling, parasitoid, predatory, others with diet without interest).

Data analysis

The toxic effect of the tested insecticide was estimated by calculating the percentage of residual populations (PR) expressed by the ratio of the number of alive individuals in the treated units to the number of alive ones in the controls. The degree of toxicity of the active substance was expressed by less than 30% of PR, greater than 60% or between 30 and 60% of PR for high, neutral or average toxicity respectively. We adopted the Generalized Linear Model (GLM) using the software (SYSTAT vers 12, SPSS 2009) to evaluate the influence of exposure duration, dose and insecticide treatment on the abundance of residual populations of the captured auxiliary arthropods.

RESULTS AND DISCUSSION

As a general rule, insecticides have a negative impact, according to the families and types of molecules and adjuvants, on the majority of arthropods but also according to the life cycle of organisms (Dennis et *al.,* 1993, Hokkanen et *al.,* 1988). The impact of long-term phytosanitary treatments is likely to vary depending on the size of the plots and the presence of vegetation at the edge of fields implies the possibility of recolonization (Hole *et al*., 2005).
Obviously, when pesticides are mentioned in the causes of decline in pollinator populations, herbicides are more often referred to than insecticides (Kevan, 1999; Wilcock and Neiland, 2002).

Evaluation of studied insecticides effect on tomato trophic groups
We recorded 5 flower dwelling species, 7 species of entomophagous parasites, 22 predator species, and 26 species with varied diets (others).
Taxa respond differently when exposed to dose and half dose of lambda-cyhalothrin and spinosad respectively. This difference seems to be due to the sensitivity variation of the target species to the active substances as well as to the applied dose, the exposure duration, the insecticide activity spectrum and its persistence in the field.
The parasitic and flower dwelling species group was the most sensitive to the lambda-cyhalothrin at the homologated dose (Figure 1). These species were absent during the 10 days of the experiment (F = 11.51, df = 4.199, p = 0.01 and showed very low percentages of abundance (29.41% for flower dwellings and 17.39% for parasitics on the 16th day, F = 16.54, df = 4.684, p = 0.005). The most sensitive species include *Andrena sp* pollinators, Formicidae *Lasioglossum* sp, Halictidae, Bethylidae, *Aphidius* sp parasitoid microhymenoptera, Tachinidae and *Oxytelus*

species (Figure 3). Spinosad at homologated dose has a high toxicity on flower dwelling trophic group (Figure 1). The most sensitive species were *Andrena* sp and *Lasioglossum* sp (Figure 3). There was a period of decline during the first 10 days (F = 11.51, df = 4.199, p = 0.01) where relative abundances increased from 29.16% to 4% compared to control, followed by a period of increase reaching 26.08% relative to the control on the 16th day, (F = 16.54, df = 4.684, p = 0.005).
Population abundances were higher after application of spinosad (T) and half-dose (HD) compared with those of lambdacyhalothrin (L) at the homologated dose (Figure 1and 2). The differences in abundances for each trophic category are very highly significant from the 1st to the 2nd week after treatment (F = 40.73, df = 5.183, p = 0.0003).
The richness of the trophic communities of pollinators and beneficial enemies is significantly different under the effect of the two doses of lambdacyhalothrin compared to the untreated control (p = 0.006, p = 0, p = 0.06 respectively) throughout exposure period, while diversity is considerably low (p = 0).

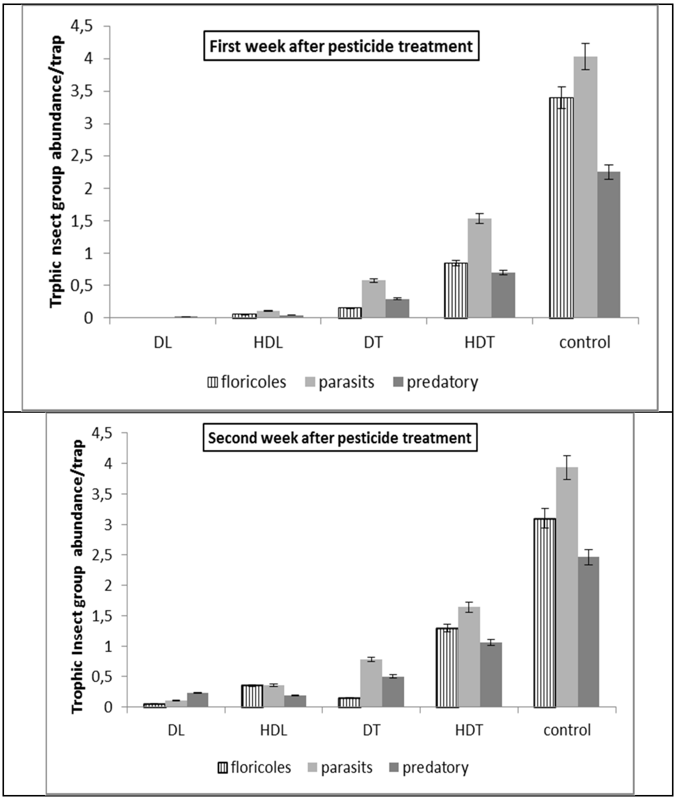

Figure 1. Variability of the abundances of main trophic groups encountered after treatment during two weeks of exposure.

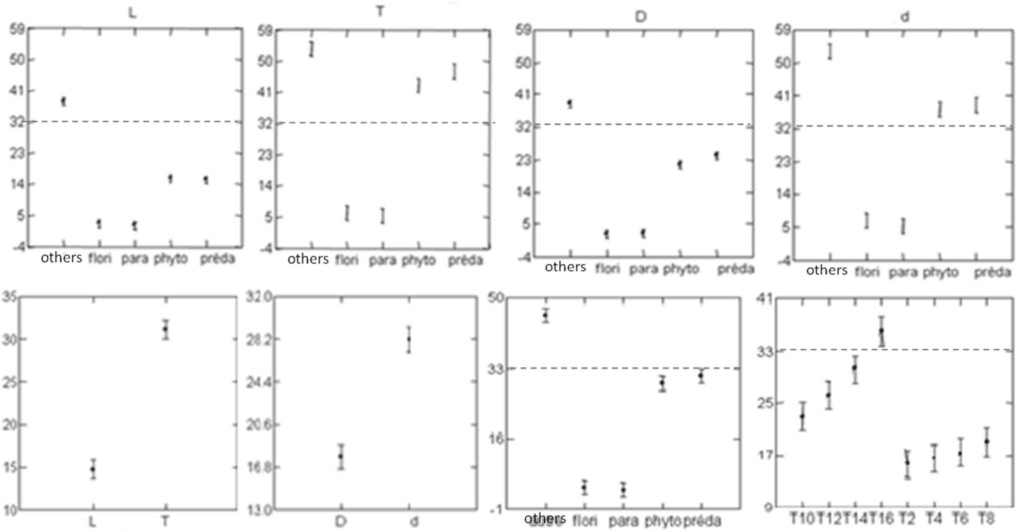

Figure 2. Influence of tested insecticides, dose, and exposure time on the abundance of trophic groups in the tomato field (L: lambdacyhalothrin, T: Spinosad, D: homologated dose, d: half dose, others, flori, phyto, pred: trophic groups, T2 to T10: time after application).

According to Cluzeau and Paternelle (2000), lambda-cyhalotrine inhibits the multiplication of Aphididae populations. Krespi (1995) also showed that lambda cyhalothrin reduces the attack of cereal aphids and infestation by their parasitoid Hymenoptera. Predators such as coccinellidae, *Empis* sp, the ant *Cataglyphis bicolor*, *Macrolophus* sp, showed a high sensitivity to lambda-cyhalotrin at registered dose, compared to spinosad. According to our observations, lambda-cyhalothrin has a toxic effect on predator populations whereas spinosad maintains this group except Chrysopidae. Half-dose lambda-cyhalothrin has destructive effect of this auxiliary group. The trophic group of parasites and flower dwelling species such as Tachinidae, Bethylidae, *Aphidius* sp, *Oxytelus* sp, *Apis mellifera*, Halictidae, *Vespula vulgaris*, Trichogrammatidae, Chalcidae, Braconidae, Ichneumonidae showed high sensitivity to lambda cyhalotrin and spinosad at registered and half dose. They are more vulnerable groups with several parasites against chemical product show sensitivity to spinosad (Rafalimanana 2003; Williams et *al.,* 2003). These two groups are more sensitive to conventional products (methidathion 400gL^{-1}l and White Oil 76 (pc) sprayed in citrus orchards in central Mitidja region ((Belhadi et *al*., 2016)).
Schneider *et al.,* (2004) reported a decrease of adult emergence and longevity endoparasitoids, *Hyposoter didymator* (Thunberg), treated with spinosad. Similarly, Tillman and Mulroney (2000) and Miles and Dutton (2000) observed spinosad toxicity on *Bracon molitor*, *Cardiochiles nigriceps* and *Cotesia marginiventris*, parasitoids on cotton.

Temporal evolution of lambda-cyhalothrin and spinosad toxicity on bees

Lambda-cyhalothrin is characterized by high toxicity on residual populations of bees during the first 15 days at registered dose, and during the first 10 days at half dose. Spinosad at registered dose has a very toxic effect only on the first 9 days. Half dose in half dose Spinosad shows a variable effect, moderately toxic from the 2nd to the 5th day, and a neutral effect from 8th day (Figure 4).

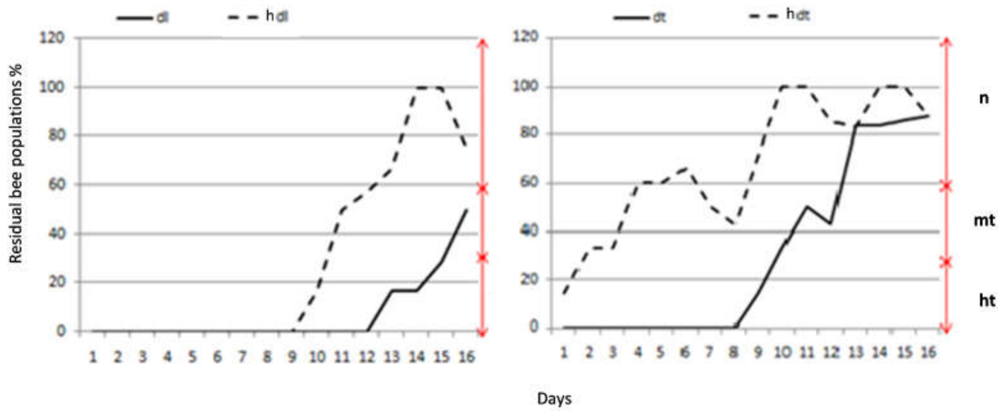

Figure 4. Evaluation of tested insecticides toxicity on bees residual populations in tomato field. (L: lambda-cyhalothrin, t: spinosad (Tracer), d: dose, hd: half-dose, n: no effect, mt: moderately toxic, ht: highly toxic).

The toxicity gradient ranges from the dose of lambda-cyhalothrin, followed by the spinosad dose, then the half-dose of lambda-cyhalothrin and finally the half-dose of spinosad which has the lowest effect. Tested insecticides toxicity on bees is due to the mode of penetration. Both act by contact and ingestion. The contact of the bee with the insecticide occurs when the foragers visit a field during or after a chemical treatment. It is when spreading in the presence of foragers that the damage is the most severe (Atkins *et al.,* 1981). Young bees will then be able to get intoxicated by consuming the contaminated pollen stores. It has been demonstrated by a tunnel assay that synthetic pyrethroids may disrupt the flight behavior of forager's bees, which took longer to return to the hive after treatment (Taylor et *al.,* 1987).

Pyrethrins are practically highly toxic to honey bees (author). However, some of the risk to pollinators is limited by their slight repellent activity and rapid breakdown. Sublethal exposure to pyrethroids impacted bee behavior over a 24-h period. Pyrethroid-treated bees traveled 30–71% less than control bees (Ingram et *al*., 2015). Esfenvalerate and permethrin decreased social interaction time by 43% and 67% (Ingram et *al*., 2015). Permethrin increased time spent in close proximity to a food source. The longevity of honey bee workers is reduced after carbaryl, diazinon and malathion treatments. Parathion also caused low losses of forager orientation due to the disruption of the information transmission system regarding the location of food resources, (Thompson, 2003). Based on laboratory dose response data, pyrethroids are considered to be either highly toxic (LD 50 of 0.1-1.0µg a.i/bee) or extremely toxic (LD 50 <0.1µg a.i/bee) to honeybees, according to classification proposed by the International Commission for Bee Botany. An analysis of the pyrethroid data within the IOBC database shows that the synthetic pyrethroids are all classified as harmfull to non targeted arthropods, according to laboratory toxicity data. When the same pyrethroids were classified according to available IOBC semifield or field data, then classifications of moderately harmfull pyrethroids harmless were often reported for some species. This significates that the effects of the pyrethrinoids on NTAs at recommended application rates under field conditions is significantly less (Matsuo and Mori, 2012).

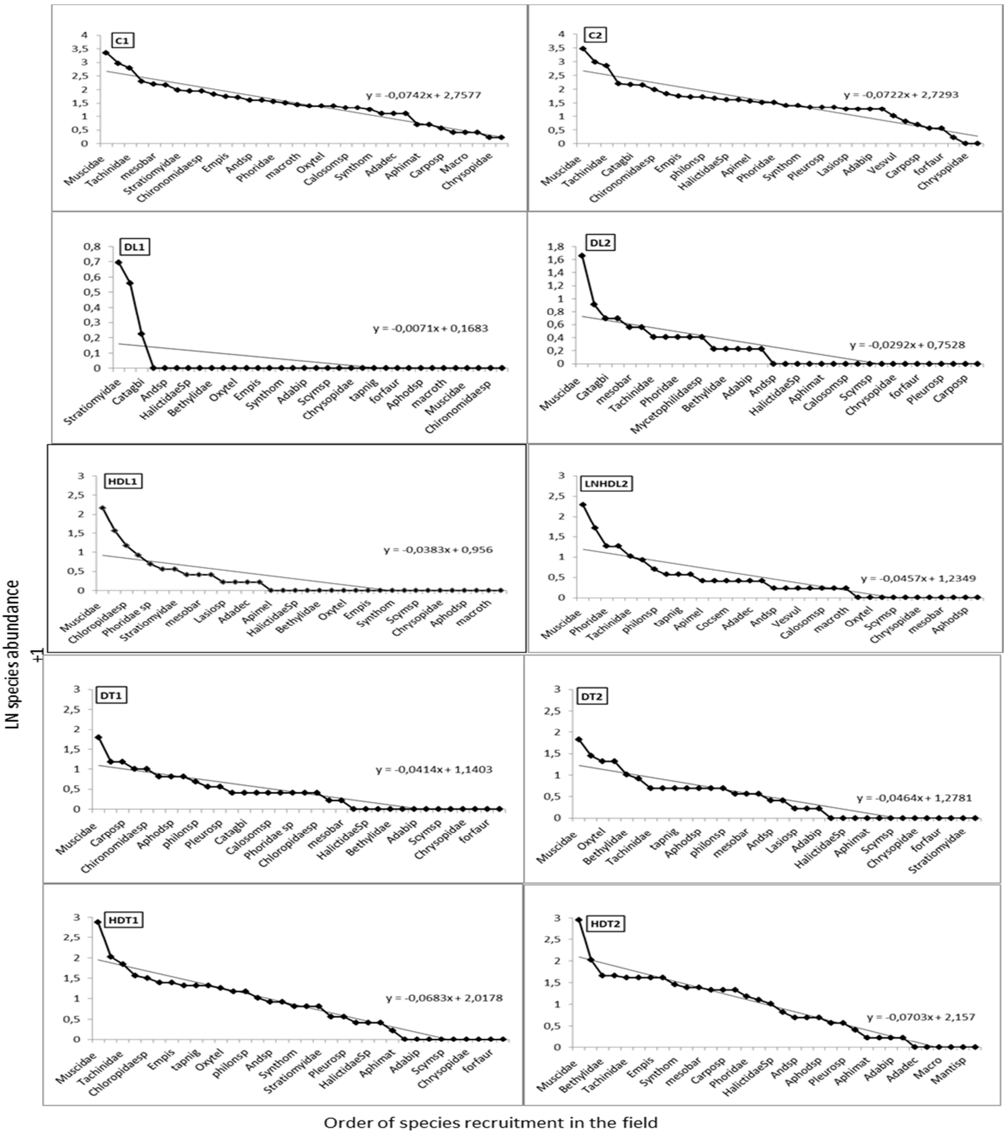

Figure 3. Recruitment order of trophic communities after treatments effect during two weeks of exposure

CONCLUSION

Like all chemical insecticides, lambda-cyhalothrin has a negative effect on non-target entomofauna, but with varying degrees depending on species and application rate. The most sensitive were parasites and flower dwelling species, followed by predators. The half-dose of this active substance showed a destructive effect on the beneficial fauna, but with low degrees compared to the homologated dose. These results lead us to predict the phytosanitary status of our crop if we use this product in an anarchic way. Thus, it is necessary to think of replacing this active substance in spite of its effectiveness on the pests and its broad spectrum of activity which minimizes the cost of protection, by other insecticides more specific on the targeted pests. For effective integrated control, spinosad has demonstrated its compatibility with most predators and its ability to regulate certain pest populations that are primarily flying insect species. The formulation with baits could be the best solution to minimize contact of parasitic and flower dwelling species with the treatment.

REFERENCES

Atkins, E.L., Kellum, D. Atkins, K.W. (1981). Reducing pesticide hazards to honey bees: mortality prediction techniques and integrated management strategies. *University of California, Leaflet*, 2883. 23p.

Belhadi, A., Mehenni, M. Reguieg, L.Yakhlef, H. (2016) Revue Agriculture. Special number 1: 09 – 16

Bouziani, M. (2007). The immoderate use of pesticides: Serious health consequences. *Journal le républicain*, 26 june 2007.

Carvalheiro, L.G., Kunin, W.E., Keil, P., Aguirre-Gutiérrez, J., Ellis, W.N., Fox, R., Groom, Q., Hennekens, S., Van Landuyt, W., Maes, D., Van de Meutter, F., Michez, D., Rasmont, P., Ode, B., Potts, S.G., Reemer, M., Roberts, S.P.M., Schaminée, J., WallisDeVries, M.F. Biesmeijer, J.C. (2013). Species richness declines and biotic homogenisation have slowed down for NW-European pollinators and plants. *Ecology Letters*;16 (7):870–878.

Cluzeau, S. Paternelle, M.C. (2000). Phytosanitary index. 36th edition. ACTA. 73; 78- 79, 117p.

Decourtye A, Lacassie E, Pham-Delègue MH. 2003 Learning performances of honeybees (*Apis mellifera* L) are differentially affected by imidacloprid according to the season, Pest Management Science 59(3): 269-278, 2003.

Dennis, P., Fry, G.L.A. Thomas, M.B. (1993**).** The effects of reduced doses of insecticide on aphids and their natural enemies in oats. *Norwegian Journal of Agricultural Sciences* **7** (3/4): 311-325.

Geiger, F. et *al*, (2010). Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. *Basic and Applied Ecology* 11(2): 97-105.

Hokkanen, H., Husberg, G.B. Soderblom, M. (1988). Natural enemy conservation for the integrated control of the rape blossom beetle *Meligethes aeneus* F. *Annales Agriculturae Fennicae* 27(4): 281-194.

Hole, D.G., Perkins, J. Wilson, A.J. Alexander, D. Grice, I.H. P.V. EVANS, A.D. (2005). Does organic farming benefit biodiversity? *Biological Conservation*, 122: 113-130.

Ingram, E.M. Augustin, J. Marion, D. Blair, E. Siegfrieda, D. (2015). Evaluating sub-lethal effects of orchard-applied pyrethroids using video-tracking software to quantify honey bee behaviors. *Chemosphere* 135, September 2015, Pages 272-277.

J.O.R.A., (1995). Official Gazette, Act No. 87-17 of 1 August 1987, on plant health protection.

Kevan, P.G. (1999). Pollinators as bioindicators of the state of the environment: species, activity and diversity. *Agriculture, Ecosystems and Environment*, 74, 373-393.

Krespi, L. (1990). Study of parasitic biocenosis of cereal aphids in the Rennes basin: special case of *Aphidius uzbekistanicus* Luz. PhD thesis, University of Rennes I, pp: 80-105.

Noritada Matsuo, Tatsuya Mori (2012). Pyrethroids: From *Chrysanthemum* to Modern Industrial Insecticide. Springer Science & Business Media, 224 pages.

Miles, M. Dutton, R. (2000). Spinosada naturally derived insect control agent with potential for use in integrated pest management systems in greenhouses. In: Proceedings of the BCPC Conference—Pests and Diseases, 13–16 November 2000, Brighton, UK. British Crop Protection Council, Farnham, Surrey, UK, pp: 339–344.

Pilling, E.D. Jepson, P.C. (2006). Synergism between EBI fungicides and a pyrethroid insecticide in the honeybee (*Apis mellifera*). *Pesticide Science* 39(4): 293-297.

Rafalimanana, H.J. (2003). Evaluation of the effects of insecticides on two types of crop auxiliary Hymenoptera, domestic honeybee (*Apis mellifera* L.) and aphid parasitoids: field studies in Madagascar and laboratory in France, Thesis Doc., National Institute of Agronomy, Paris-Grignon, 205p.

Schneider M.I., Smagghe, G. Pineda, S. Viuela, E. (2004). Action of insect growth regulator insecticides and spinosad on life history parameters and absorption in third-instar larvae of the endoparasitoid *Hyposoter didymator*. *Biological Control* 31, 189–198.

Taylor, K.S. Waller, G.D. Crowder, L.A. (1987). Impairment of a classical conditioned response of the honey bee (*Apis mellifera* L.) by sublethal doses of synthetic pyrethroid insecticides. *Apidologie*, 18, 3, 243-252.

Thompson, H.M. (2003). Behavioural effects of pesticides in bees. Their potential for use in risk assessment. *Ecotoxicology*, 2003, 12, 317-330.

Tillman, P.G Mulrooney, J.E. 2000. Effect of selected insecticides on the natural enemies *Coleomegilla maculata* and *Hippodamia convergens* (Coleoptera: Coccinellidae), *Geocoris punctipes* (Hemiptera: Lygaeidae), and *Bracon mellitor*, *Cardiochiles nigriceps*, and *Cotesia marginiventris* (Hymenoptera: Braconidae) in cotton. *Journal of Economic Entomology* **93**: 1638-1643.

Wilcock, C. Neiland, R. (2002). Pollination failure in plants: why it happens and when it matters. *Trends in Plant Science*, 4, 270-277.

Williams, T. Valle, J. Vinuela, E. (2003). Is the naturally derived insecticide Spinosad compatible with insect natural enemies? *Biocontrol Sci. Technol.* 13, 459–475.