Side Effects of Insecticides on Natural Enemies and Possibility of Their Integration in Plant Protection Strategies

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1. Introduction

Recently, plant protection strategy has recommended, minimizing the use of chemical pesticides. Therefore, studying the side effect of insecticides on the natural enemies is highly required to exclude the detrimental effects on the natural enemies. Every crop is infested by various pests; some but not all of them may be controlled by biological means using pathogens, predators, parasitoids and spiders. But to achieve a satisfactory control of complexes of pests, selective pesticides are also indispensable. In fact, they are a prerequisite of Integrated Pest Management.

The integration of chemical and biological control is often critical to the success of an integrated pest management (IPM) program for arthropod pests (Smilanick et al. 1996; El-Wakeil & Vidal 2005; El-Wakeil et al. 2006; Volkmar et al. 2008). In contrast with nonsystemic insecticides, many systemic insecticides and their metabolites are claimed to be fairly safe for beneficial insects because direct exposure to these chemicals occurs when insects feed on plant tissue. However, systemic insecticides can potentially contaminate floral and extrafloral nectar when systemically distributed throughout the plant (Lord et al. 1968) and cause high mortality to nectarfeeding parasitoids for as long as some weeks after insecticide application (Stapel et al. 2000).

Most biological control agents, including predators, parasitoids and spiders, at work in the agricultural and urban environments are naturally occurring ones, which provide excellent regulation of many pests with little or no assistance from humans. The existence of naturally occurring biological control agents is one reason that many plant-feeding insects do not ordinarily become economic pests. The importance of such agents often becomes quite apparent when pesticides applied to control one pest cause an outbreak of other pests because of the chemical destruction of important natural enemies. There is great potential for increasing the benefits derived from naturally occurring biological controls, through the elimination or reduction in the use of pesticides toxic to natural enemies.

The main objective of this book chapter studying the insecticide side effects on development, parasitism or predation efficacy and emergence capacity as well as to preserve effective biological control agents is a combination of tactics including an understanding of the biology and behaviour of arthropods (parasitoids, predators and spiders), detailed monitoring of life history and population dynamics of pests and natural enemies, employment of selective pesticides, application only when absolutely necessary, basing chemical control on established economic injury levels and application at the least injurious time.

2. Side effects on parasitoid wasps

Integrated Pest Management (IPM) programs are used worldwide for controlling different agricultural pests. The use of natural enemy agents in combination with selected insecticides, which have no effect on them, is effective in depressing the population density of the pest. Generally, egg parasitoids such as *Trichogramma* have been widely used as biological control agent as reported by Hassan (1982), Bigler (1984) and El-Wakeil & Hussein (2009); who confirmed that 65 – 93% reduction in larval infestations of *Ostrinia nubilalis* in corn fields was achieved following *Trichogramma* releases in Germany and Switzerland as well in Egypt.

2.1. Egg parasitoids

2.1.1. Trissolcus grandis

The scelionid egg parasitoid *Trissolcus grandis* Thompson (Hymenoptera: Scelionidae) had a very important role in reducing *Eurygaster integriceps* (Puton) population (Radjabi 1995; Critchley 1998). However, intensive use of insecticides has caused severe damage to parasitoid populations (Radjabi 1995). It is estimated that egg parasitoids reduce *E. integriceps* pest population by ca. 23% yearly in Iran (Amirmaaif 2000). Presently, chemical control is the main tool used to control the *E. integriceps* populations. The chemicals currently used for controlling this pest are organophosphorous insecticides such as fenitrothion, fenthion, trichlorfon, chlorpyrifos, and pirimiphos methyl (Orr et al. 1989; Kivan 1996; Saber 2002), and synthetic pyrethroids such as deltamethrin, cypermethrin, cyßuthrin, and cyhalothrin (Kivan 1996). Fenitrothion and deltamethrin are the most commonly used insecticides to control the *E. integriceps* in Iran (Amirmaaif 2000; Sheikhi Garjan 2000). There are many studies on the effects of conventional insecticides on *E. integriceps* egg parasitoids (i.e. Novozhilov et al. 1973; Smilanick et al. 1996; Sheikhi Garjan 2000).

Saber et al. (2005) assessed effects of fenitrothion and deltamethrin, on adults and preimaginal stages of egg parasitoid *Trissolcus grandis*. Fenitrothion and deltamethrin reduced the emergence rates by 18,0 and 34.4%, respectively, compared with the control. However, neither insecticide significantly affected the longevity or reproductive capacity of emerged females, or the sex ratio of their progeny. This study revealed that application of these insecticides should be cautiously through season to conserve natural or released populations of *T. grandis*. Adult females of *T. grandis* usually produce the majority of offspring in the first few days after emergence. Proportion of male offspring produced by *T. grandis* in the early life span of the parasitoid is higher in the treatments than control that will result in a higher proportion of males in the insecticides treatments (Fig. 1).

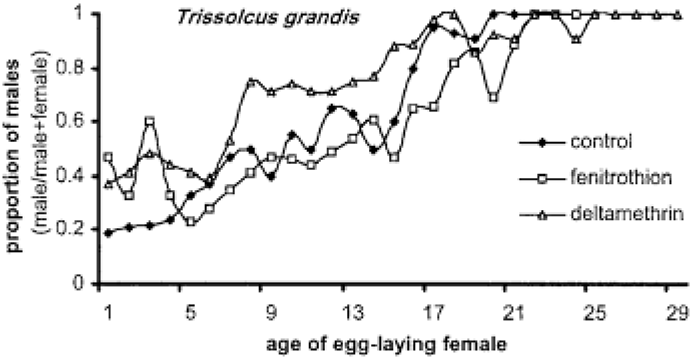

Figure 1. Proportion of male offspring produced by *Trissolcus grandis* adults emerged from treated parasitized eggs at pupal stage and control (after Saber et al. 2005)

2.1.2. *Telenomus remus*

It is very important studying the insecticide side effects on egg parasitoids. The first study on side-effects of neem products on egg- parasitoids was conducted by Joshi et al. (1982) in India. These authors applied a 2% aqueous NSKE on the egg masses of the noctuid *Spodopteru litura.* The egg parasitoid *Telenomus remus* was not repelled from egg laying. When the treatment was carried out before egg laying of the parasitoid, the emergence of adult parasitoids was normal but their duration of life was shorter than that of controls. On the other hand, spraying with NSKE after oviposition of *T. remus* increased the fecundity of the wasps developed in treated eggs and prolonged their life as compared with that of untreated controls; similar results were also reported by Golec (2007).

2.1.3. *Trichogramma species*

Trichogramma genus is a tiny parasitoid and some species are susceptible for chemicals. In both cases using insecticides alone or compatible with *Trichogramma*, there is a side effect on the later as studied by by Shoeb (2010), who mentioned that effect of five insecticides, Profect (w.p.), CAPL- 2, Lambda-cyhalothrin, Spinosad, and Fenitrothion (Sumithon) were studied on the immature stages of *Trichogramma evanescens* (West.). Longevity of the emerged parasitoid was affected by the tested insecticides. Treating eggs with chemical insecticides caused death of the emerged adults within few hours post emergence. The number of parasitized eggs was varied according to timing of treatment. Adult emergence rate varied according to the used insecticide and the parasitoid stage. There was no emergence for the parasitoid treated with Lambda-cyhalothrin, spinosad, and fenitrothion (Sumithon) one, two or four days after parasitism. On the other hand, El-Wakeil et al (2006) reported that there was no serious side effect on parasitism and emergence rates of *T. pretiosum* (Riley) and *T. minutum* (Riley) when treated with neem products. Similarly, neem products achieved a good control of *H. armigera* in greenhouse. Therefore, neem products are recommended for controlling *Helicoverpa* and are compatible with mass release of *Trichogramma*.

Assessment of the potential effects that pesticides have on the natural enemies is therefore an important part of IPM programs (Hirai 1993; Hassan 1994; Consoli et al. 1998; Takada et al. 2000). Detailed knowledge of the effects of different pesticides on the immature stages of natural enemies will help to determine the timing of sprays, thus avoiding the most susceptible stages (Campbell et al. 1991; Guifen and Hirai 1997). Mass breeding and release of parasitoids for control of various lepidopterous pests is now a commercial practice in many countries. However, the efficacy of the parasitoid is influenced a great deal by the insecticide spray schedule before and after parasitoid release. Candidate parasitoids for IPM programs should therefore be tested for susceptibility to the insecticides being used for controlling crop pests (Hassan et al. 1987). Egg parasitoids are known to be vqery effective against a number of crop pests. *Trichogramma dendrolimi* (Matsumura) has been described as a control agent for the pine moth, citrus swallowtail (Hirose 1986), *Spodoptera litura* (Hamada 1992), and other cruciferous insect pests (Dai et al. 1991). The cabbage moth, *Mamestra brassicae* (L.), is an important pest of ca. 20-51 species of plants (Hirata 1960). The use of broad-spectrum insecticides, however, has resulted in a decline in the natural enemies of *M. brassicae.* There are many research dealing with determining the susceptibility of *T. dendrolimi* to several insecticides, and evaluate its potential use for controlling the cabbage moth and other lepidopteran insects (Takada et al. 2000, 2001). Who tested toxicity of six insecticides, acephate, methomyl, ethofenprox, cartap, chlorfluazuron, and *Bacillus thuringiensis* (Bt) on different developmental stages of *Trichogramma dendrolimi* (Matsumura). Ethofenprox showed the highest toxicity and cartap showed relatively higher toxicity compared with the other insecticides. The development of the parasitoids treated with these two insecticides was normal, similar to that of the control group; the same trend of results was also obtained by Vianna et al. (2009) and Shoeb (2010).

Suh et al (2000) investigated effect of insecticides on emergence, adult survival, and fitness parameters of *Trichogramma exiguum*. Insecticides tested were lambda cyhalothrin, cypermethrin, thiodicarb, profenophos, spinosad, methoxyfenozide, and tebufenozide. All insecticides, with the exception of methoxyfenozide and tebufenozide, adversely affected *Trichogramma* emergence from *Helicoverpa zea* (Boddie) host eggs when exposed at different preimaginal stages of development (larval, prepupal, or pupal). However, the mean life span of emerged *T. exiguum* females significantly varied among insecticides, and was significantly affected by the developmental stage when treated.

During the past three decades, *Trichogramma* spp. wasps have been evaluated as biological control agents for heliothine pest suppression in cotton (Knutson 1998; Suh et al. 1998, 2000; El-Wakeil 2003). Results of augmentative releases have been variable and at least some of the variability has been attributed to the use of broad spectrum insecticides in or near release plots during the time releases were made (Varma & Singh 1987; Kawamura et al. 2001; Brunner 2001; Geraldo et al. 2003). These insecticides were generally used to manage boll weevil, *Anthonomus grandis* (Boheman) and sometimes used to salvage *Trichogramma* release plots under extreme heliothine infestations. Numerous laboratory and field studies have shown that *Trichogramma* spp. wasps are highly susceptible to most broad-spectrum insecticides (Bull & Coleman 1985). Consequently, use of insecticides and *Trichogramma* has historically been considered incompatible (Hassan 1983).

Since the successful eradication of *A. grandis* in North Carolina, heliothines [predominantly *Helicoverpa zea* (Boddie)] have emerged as the primary mid to late season insect pest in North Carolina cotton (Bacheler 1998). Thus, most of the foliar insecticide applications (generally pyrethroids) made to cotton in North Carolina are aimed for control of the heliothine complex, *H. zea* and *Heliothis virescens* (F.). Unfortunately, these commonly used insecticides also are toxic to many non target organisms, including predators and parasitoids. Additionally, some heliothine pests (particularly *H. virescens*) have developed resistance to pyrethroids in some cotton growing areas. In an attempt to combat insecticide resistance, conserve arthropod natural enemies, and reduce health risks, several new insecticides (e.g., tebufenozide, methoxyfenozide, spinosad) have been developed and tested against lepidopteran pests in cotton (Bull & House 1983; Stapel et al. 2000; Vianna et al. 2009). Also, there is very important studies regarding the compatibility of these relatively new compounds with *Trichogramma* wasps, such as the detailed study involving *T. pretiosum* and tebufenozide (Cônsoli et al. 1998) with Neem (El-Wakeil et al. 2006) and with other biocontrol agent *Chrysoperla carnea* (El-Wakeil & Vidal 2005).

Example: Side effect on parasitism rates of *T. pretiosum* and *T. minutum* on *Helicoverpa* eggs

El-Wakeil et al. (2006) reported that their results indicated that NeemAzal-T/S reduced the parasitism rates to 50, 48.9, 71.1 and 73.3 % at 2, 1, 0.5, 0.25% cons, respectively (Fig. 2A), compared to 96.6% on control plants. NeemAzal PC 05 reduced the parasitism rates to 70, 67.8, 70 and 80% on succeeding concentrations; 2, 1, 0.5 and 0.25%. Neem blanks achieved a less side effect on *T. pretiosum*. NeemAzal Blank reduced the parasitism rates to 81.1%. NeemAzal PC05 Blank reduced the parasitism rates to 91.3% compared to 98.7% on control plants (Fig. 2A). El-Wakeil et al. (2006) mentioned further that NeemAzal-T/S had reduced the parasitism rates, to 40, 55.4, 77.8 and 81.3 % (at 2, 1, 0.5, 0.25% cons.), respectively, compared to 93.3% on control plants. NeemAzal PC 05 reduced the parasitism rates to 82.2, 82.2, 74.4 and 83.3% on succeeding concentrations; 2, 1, 0.5 and 0.25% (Fig. 2B). Neem blanks achieved a less side effect on *T. minutum*. Parasitism rates reached to 74.4% in neem blanks. Parasitism rates were reduced by NeemAzal PC05 Blank to 86.7% compared to 93.3% on control plants (Fig. 2B).

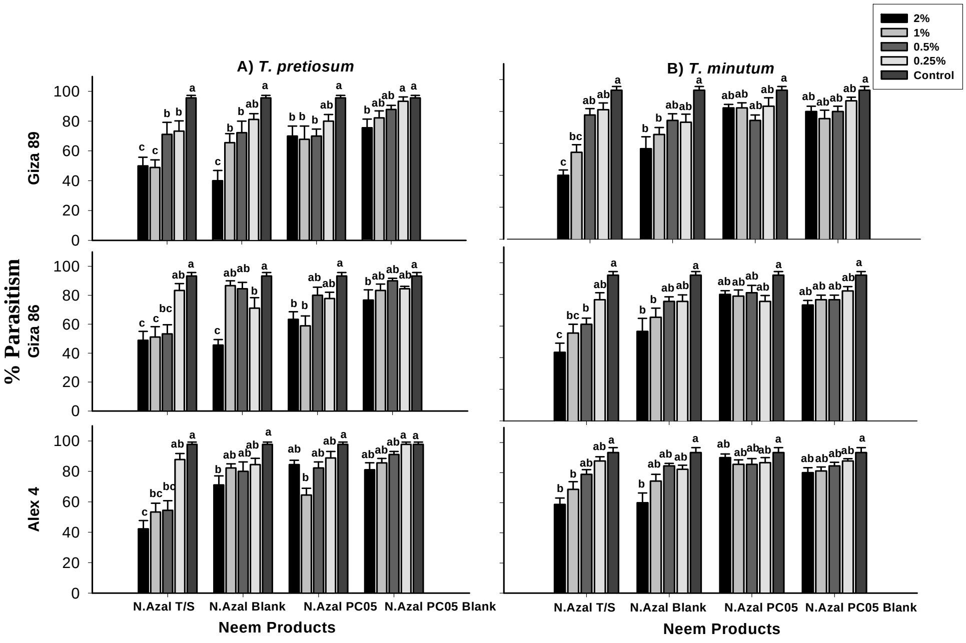

Figure 2. Effect of neem products on parasitism rates of *Trichogramma pretiosum* (A) and *T. minutum* (B) on *Helicoverpa armigera* eggs in the greenhouse. Different letters indicate significant differences.

Li et al. (1986) tested 29 insecticides including Bt & Non Bt in order to study their side-effects on *Trichogramma japonicum* in the laboratory. The authors concluded from the results that Bt & Non Bt were the safest pesticides for the parasitoid. Klemm & Schmutterer (1993) applied NSKE (2.5% and 3%) against *Trichogramma* spp., egg-parasitoids of the diamond-back moth, *Plutella xylostella. T. principium* accepted neem- treated eggs in the laboratory and *T. pretiosum* in the field but two treatments prevented the eclosion of adult parasitoids from treated *P. xylostella* eggs completely. Spraying of eggs with 0.2% NO reduced the number of eggs parasitized per female wasp by 13.3. As a further side-effect, Non Bt reduced the emergence of *T. principium* from treated eggs by 45.1%. Lyons et al. (1996, 2003) offered neem-treated eggs of *Ephestia kuehniellu* in shell vials to single females of *Trichogramma minutum* for parasitation. The eggs were fixed with adhesive to strips and held until all parasitoids had emerged from them. Azatin, Neem EC (experim. formul. 4.6% aza) and pure aza were tested at concns. of 50 g and 500 g/ha. At 50 g/ha no significant effect was observed, at 500 g/ha Azatin and Neem EC reduced the female survival by 64% and 40% respectively whereas pure aza showed no effect. Likewise, at 500 g/ha the number of parasitized eggs was reduced by 89% by Azatin, 29% by Neem EC but not reduced by aza. The parasitoid's development success was reduced by all treatments.

Cano & Gladstone (1994) studied the influence of the NSK-based extract NIM-20 on parasitization of eggs of *Helicoverpa zea* in a melon field in Nicaragua. Mass-reared *T. pretiosum* were released at six weekly intervals 1, 2, 6 and 24h after application of NIM-20 at 2.5g/l. No negative effect was observed as up to 84% of the eggs of the pest were parasitized.

Srinivasa Babu et al. (1996) studied the effects of neem-based commercial insecticides such as Repelin and Neemguard on *T. australicum* in laboratory and field conditions. They reported that both the insecticides were relatively safe at lower concentrations but higher concentrations adversely affected the parasitoids both in laboratory and in field. Effects of insecticides on the emergence of *T. japonicum* from eggs of *Corcyra cephalonica* on the third or sixth day after parasitization using chlorpyrifos, quinalphos, monocrotophos, cypermethrin, dimethoate, phosphamidon, fenvalerate, Biolep and Bioasp (both Btk products) and NeemAzal-F and Fortune Aza (both neem-based products) clearly indicate that Bt and neem products had the least effect on the emergence of parasitoids, similar results were stated by Koul & Wahab (2004). Of the other insecticides, fenvalerate and monocrotophos had the least effect while quinalphos had the most. Adult emergence was relatively less when eggs were sprayed on the sixth day after parasitization compared to third day after parasitization (Borah & Basit 1996). Similar results were obtained against *T. japonicum* using Econeem and NeemAzal-T/S (0.1-1.0 %) (Lakshmi et al. 1998). On the whole it has been assessed that neem products were fairly safe to *Trichogramma* spp. (Sreenivasa & Patil 1998; Sarode & Sonalkar 1999a; Koul & Wahab 2004).

However, some neem formulations such as Nimbecidine (0.25-4.0%), Neemgold (2.0-4.0%) and Rakshak (1.0%) are reported to possess adverse effects on parasitism (Lakshmi et al. 1998; Koul & Wahab 2004). Raguraman and Singh (1999) tested in detail the neem seed oil at concentrations of 5.0, 2.5, 1.2, 0.6 and 0.3% for oviposition deterrence, feeding deterrence, toxicity, sterility and insect growth regulator effects against *Trichogramma chilonis*. Neem seed oil at 0.3% deterred oviposition (parasitization) by the parasitoid but the sensitivity varied considerably both under choice and no-choice conditions. Neem seed oil also deterred feeding at or above 1.2% concentration both in choice and no-choice tests. In feeding toxicity tests, neem seed oil at 5% concentration caused < 50% mortality to both males and females but in contact toxicity tests, females were affected sparing males. No sterility effect was observed when the parasitoid was fed with neem seed oil treated honey. Both pre-and post-treatment of host eggs revealed no adverse effects on the development of the parasitoid, the same trend of results was obtained by Saikia & Parameswaran (2001). Thakur & Pawar (2000) tested two neem-based insecticides (3g Achook/litre and 2 ml Neemactin/litre), two biopesticides [1 g Halt (cypermethrin)/litre] and 1 ml Dipel (Btk)/litre], and endosulfan (1.5 ml/litre) in the laboratory for their relative toxicity to newly emerged adults of *T. chilonis*. Results revealed that neem-based pesticides and biopesticides were harmless while endosulfan was slightly toxic to egg parasitoid. These observations also get support from the studies on different groups of chemicals viz., insecticides, moult inhibitors and biopesticides against rice leaf folder, *C. medinalis* and its parasitoid *T. chilonis* (Koul & Wahab 2004).

2.2. Larval and larval/ pupal parasitoids

Schneider & Madel (1991) reported that there was no adverse effect on adults of the braconid *Diadegma semiclausum* after exposure for 3 days or during their lifetime in cages to residues of an aqueous NSKE (0.1- 5%). The longevity of the wasps exposed to neem residues was even prolonged but the difference between treated and untreated individuals was statistically not significant. Females of the braconid, derived from larvae developed in neem-treated larvae of *P. xylostella,* showed no reduced fecundity or activity as compared with controls. Fresh extracts showed no repellent effect. The influence of aza on *Diadegma terebrans,* parasitoid of *Ostrinia nubilalis,* was investigated in the laboratory by Mccloskey et al. (1993). These authors added sublethal doses (0.1 ppm and 0.3 ppm) of aza or ethanol (carrier solvent) to diets of 2^{nd} instar larvae of the pyralid. Both aza concns caused no significant difference of the parasitation percentage; host acceptance by the parasitoids was also not influenced. However, significantly higher mortality of parasitoids was observed in aza-treated groups compared with untreated groups, especially after emergence from the hosts. The duration of the larval instars in the hosts was prolonged and pupae weight and adults from treated groups was reduced.

Schmutterer (1992, 1995, 2002) studied the side-effects of 10 ppm and 20 ppm of an aza-containing and an aza-free fraction of an aqueous NSKE, of AZT-VR-K and MTB/H,O-K-NR on *Cotesia glomerata,* a gregarious endoparasitoid of the larvae of the large cabbage white, *Pieris brassicae,* in Europe. When heavily parasitized 5th-instar larvae of the white were fed neem-treated cabbage leaves, numerous parasitoids could leave their moribund hosts, pupate and emerge as apparently normal wasps. On the other hand, high mortality was also recorded as many larvae could not spin a cocoon and adults were not able to emerge from normally looking cocoons. Intraspecific competition for food among larvae of *C. glomerata* in treated and untreated hosts could have been the main reason for high mortality, which was also observed in controls. In contrast, Osman & Bradley (1993) explained high mortality of C. *glomeraca* larvae and morphogenetic defects of adults derived troni larvae developed in neem-treated hosts mainly as effects of aza on the metamorphosis of the parasitoids. Spraying of high concns of AZT-VR-K on adult braconids and their contact with sprayed cabbage leaves for 2 days had no obvious effect on the wasps (Schmutterer 1992). Beckage et al. (1988) recorded that the development of *Cotesia congregata* was interrupted by aza in larvae of the tobacco hornworm.

According to Jakob & Dickler (1996) adults of the ectoparasitic, gregarious eulophid *Colporljpcus floriis,* an important parasitoid of the tortricid *Adoxophyes orana,* were not adversely affected by application of NeemAzal-S (25 ppm and 100 ppm) in the laboratory and in the field, but 100% of the larvae died, apparently due to lack of appropriate food on the neem-treated decaying larvae of the host.

Hoelmer et al. (1990) evaluated the side effects of Margosan-O on parasitoids of the whitefly *Bemisia tabaci* and the aphid *Aphis gossypii* in the laboratory. The survival of the aphelinid *Eretmocerus calijornicus* was identical on treated and untreated hibiscus leaves, whereas the aphid parasitoids *Lysiphlebus testaceipes* (Aphidiidae) and *Aphelinus asychis* (Aphelinidae) showed more sensitivity to neem-treated leaf surfaces. *E. californicus* pairs in sealed Petri dishes with treated and untreated leaves survived for 5 days. Dipping of aphid mummies parasitized by *L. testaceipes* in Margosan-0 solution did not prevent the eclosion of the wasps. The same applied to the emergence of *Encarsia formosa* and *E. transversa* after dipping of parasitized puparia of *B. tabaci*. Only in the case of *E. calfornicus* was the emergence from treated whitefly puparia reduced by 50% as compared with untreated. Other researches had studied the toxicity of abamectin and spinosad on the parasitic wasp *Encarsia formosa* (van de Veire & Tirry 2003; van de Veire et al. 2004).

Schauer (1985) reported that the aphid parasitoids *Diaeretiella rapae* and *Ephedrus cerasicola* developed normally after spraying of parasitized nymphs or mummies of *Myzus persicae,* using the neem products MeOH-NR (0.1%), AZT (0.05%) and MTB (0.01%) plus sesame oil. NO at concns of 0.5%, 1% and 2% did not reduce the rate of parasitism of *M. persicae* by *D. rapae,* but the emergence of adult wasps from aphid mummies collected from treated plants in the laboratory was reduced to 35, 24 and 0%, respectively, of the controls; similar results were obtained by Jenkins & Isaacs (2007) during their study about reducing the risk of insecticides for control of grape berry moth (Tortricidae) and conservation of its natural enemies, the same vision was recorded by Desneux et al. (2007).

In laboratory trials of Feldhege & Schmutterer (1993), using Margosan-0 as pesticide and *E. formosa,* parasitoid of *Trialeurodes vaporariorum,* as target insect, parasitized puparia of the whitefly were dipped in Margosan-0 solution containing 10 or 20 ppm aza. The lower concn showed little effect on the parasitoid emergence from the puparia and on longevity, but the higher concn caused a slight reduction of the walking activity of the wasps. Stark et al. (1992) studied under laboratory conditions the influence of aza on survival, longevity and reproduction of parasitoids of tephritid flies. The braconids *Psytallia incisi* and *Biosteres longicaudatus* developed in and eclosed from the tephritid *Bactrorera dorsalis* exposed in a diet to aza concns that inhibited adult eclosion. *Diachismomorpha tryoni* also eclosed from *Ceratitis capitata,* exposed to concns of aza that prevented eclosion of adult fruitflies. The longevity of parasitoids emerged from treated flies did not differ significantly from that of controls but reproduction of *P. incisi,* developed in flies exposed to 20 ppm aza, was reduced by 63-88%. The reproduction of other braconid species was not adversely affected.

Stansly & Liu (1997) found that neem extract, insecticidal soap and sugar esters had little or no effect on *Encarsia pergandiella* the most abundant parasitoid of *Bemisia argentifolii* in south Florida vegetable fields and can contribute significantly to natural biological control of this and other whitefly species. Of the 10 species of leaf-mining Lepidoptera collected in apple orchards in south-western Germany in 1996, the most abundant were *Phyllonorycter blancardella, Lyonetia clerkella* and *Stigmella malella* and a mining curculionid, *Rhamphus oxyacanthae*, the same trend of results was confirmed during studying effects of insecticides on two parasitoids attacking *Bemisia argentifolii* by Jones et al. (1998).

Total parasitism by Chalcidoidea and Ichneumonoidea ranged from 10 to 29%. Use of a neem preparation for pest control had no effect on the rate of parasitism (Olivella & Vogt 1997). Sharma et al. (1999) also reported that the extracts from neem and custard apple kernels were effective against the spotted stem borer, *Chilo partellus*, Oriental armyworm, *Mythimna separata*, head bugs, *Calocoris angustatus*, and the yellow sugarcane aphid, *Melanaphis sacchari* in sorghum, but neem extract was non-toxic to the parasitoids and predators of the sorghum midge; as well other parasitoids as stated by Raguraman & Singh (1998, 1999). Sharma et al. (1984) reported that an active neem fraction of NSK had adverse effect on larval parasitoid, *Apanteles ruficrus* of Oriental armyworm, *M. separata*. Injection of 2.5 to 10μg of azadirachtin to newly ecdysed fourth and fifth instar larvae of host either partially inhibited or totally suppressed the first larval ecdysis of braconid, *Cotesia congregata* an internal larval parasitoid of tobacco hornworm, *Manduca sexta* (Feng & Wang 1984; Mani & Krishnamoorthy 1984; Peter & David 1988; Beckage et al. 1988). They also reported that the parasitoid growth was arrested, while the host larvae survived for two weeks or longer, following injection of azadirachtin but their parasitoids never recovered and died encased within exuvial cuticle.

Stark et al. (1992) studied the survival, longevity and reproduction of the three braconid parasitoids namely *Psystallia incisi* and *Diachasmimorpha longicaudata* from *Bactrocera dorsalis* and *Diachasmimorpha tryoni* from *Ceratitis capitata*. They also studied the effect of azadirachtin concentration on these three parasitoids. Results of the first test were in conformity with Stark et al. (1990). All larvae that were exposed to sand treated with azadirachtin, pupated. Adult eclosion was concentration-dependent in both fly species, with little or no fly eclosion at 10 ppm. However, *P. incisi* and *D. longicaudata* successfully eclosed from pupae treated with < 10ppm azadirachtin. In all the cases after the exposure of azadirachtin, the adult eclosion was inhibited.

Facknath (1999) and Reddy & Guerrero (2000) evaluated biorational and regular insecticide applications for management of the diamondback moth *P. xylostella* in cabbage and side effects on aphid parasitoids and other beneficial insects; they reported that the these biocontrol agents were not affected by neem treatments, whereas Pirimor R treatments reduced beneficial insect numbers. Although Pirimor R would be the preferred choice for immediate aphid control through contact action in commercial crop production, neem still has a place in the control of aphids in situations such as organic crop production, or in crops where resistance to other chemicals by aphids or their natural enemies has resulted (Stark & Wennergren 1995; Holmes et al. 1999; Hoelmer et al 1999).

Perera et al. (2000) studied the effect of three feeding deterrents: denatonium benzoate, azadirachtin and Pestistat on 4th instar larvae of *Chrysodeixis eriosoma* and *P. xylostella* and on the parasitoid, *Cotesia plutellae*. Their results suggested that the three antifeedants were effective in managing cabbage pests, *C. eriosoma* and *P. xylostella* and could be used in integrated pest management programmes. Denatonium benzoate was comparatively safer to the parasitoids *C. plutellae*.

Bruhnke et al. (2003) evaluated effects of pesticides on the wasp *Aphidius rhopalosiphi*. They emphasize that whole-plant test designs seemed to be more attractive to the wasps than single leaves and there were no harmful side effects. Similar results were mentioned by Mead-Briggs (2008) and Dantinne & Jansen (2008).

3. Side effects of insecticides on coccinellids

Many research studies show that integration of chemical, cultural and biological control measures are getting popular as integrated pest management (IPM), components, throughout the world. In this regard, biological control occupies a central position in Integrated Pest Management (IPM) Programmes. Because biological control agents for pests and weeds have enormous and unique advantages, it is safe, permanent, and economical (Kilgore & Doutt, 1967). Augmentative releases of several coccinellid species are well documented and effective; however, ineffective species continue to be used because of ease of collect ion (Obrycki & Kring 1998). About 90% of approximately 4,200 coccinellid species are considered beneficial because of their predatory activity, mainly against homopterous insects and mites.

Pesticides are highly effective, rapid in action, convenient to apply, usually economical and most powerful tools in pest management. However, indiscriminate, inadequate and improper use of pesticides has led to severe problems such as development of pest resistance, resurgence of target species, outbreak of secondary pests, destruction of beneficial insects, as well as health hazards and environmental pollution. It is therefore, a high time to evaluate the suitable products to be used in plant protection strategy. In an integrated control programme, it was necessary to utilize some insecticides with minimal toxicity to natural enemies of pests. Such practice might help to alleviate the problems of pest resurgence, which is frequently associated with insecticide up use in plant protection (Yadav, 1989; Meena et al. 2002).

Coccinella undecimpunctata L. (Coleoptera: Coccinellidae) is a euryphagous predator that feeds especially on aphids (Hodek & Honěk 1996). Given its voracity toward these pests, *C. undecimpunctata* offers interesting potential as a control agent in the context of Integrated Pest Management (IPM) (ElHag 1992; Zaki et al. 1999a; Moura et al. 2006; Cabral et al. 2006, 2008, 2009). The success of IPM programs depends, in part, on the optimal use of selective insecticides that are less harmful to natural enemies (Tillman & Mulrooney 2000; Stark et al. 2007), which requires knowledge of their side-effects on the biological and behavioural traits of these organisms (Tillman & Mulrooney 2000; Sechser et al. 2003; Youn et al. 2003; Bozski 2006; Stark et al. 2007). Some studies have been done to assess the susceptibility of *C. undecimpunctata* to different insecticides but all, in some way, adversely affected this species (Salman & Abd-el-Raof 1979; Lowery & Isman 1995; Omar et al. 2002). Recent studies showed that, in general, pirimicarb and pymetrozine had no adverse effects on the biological traits (i.e. developmental time, fecundity, fertility, percentage of egg hatch) of immature or adult stages of *C. undecimpunctata* when sprayed on the insects, which makes these chemicals potentially suitable to use in combination with *C. undecimpunctata* for integrated control of sucking pests (Cabral et al. 2008, 2011).

The coccinellids predatory activity usually starts at medium high level of pest density, so the natural control is not quick, but is often effective. Untreated areas (such as edge rows) close to the orchards serve as refugia and play a strategic role in increasing biological control by coccinellids. The side effects (short term/ microscale) of several organophosphate and carbamate derived insecticides (commonly used to control tortricids, leafminers or scale pests in differnt orchards) against aphid-feeding coccinellid species were evaluated in fields tests in apple, pear and peach orchards according to the method described by Stäubli et al. (1985). The main species of aphid feeding coccinellids found were *Adalia bipunctata*, *C. septempunctata* & *Oenopia conglobata*, in order of population density observed (Pasqualini 1980; Brown 1989).

The influence of 7 pesticides (6 insecticides & 1 acaricide) on different stages (adults, larvae, eggs) of *C. septempunctata* and adults of *A. bipunctata* was evaluated under laboratory conditions by Olszak et al. (2004). It was found that food (aphids) contaminated with such chemicals as pirimicarb, novaluron, pyriproxyfen and fenpyroximate did not decrease neither the longevity nor the fecundity of females of both tested species.

Olszak et al. (1994) investigated influencing of some insect growth regulators (IRGs) on different developmental stages of *Adalia bipunctata* and *C. septempunctata* (on eggs, larvae and adults); who stated generally that the tested IGRs affected all developmental stages of both coccinellid species but the results varied according to stage. Some of the insecticides elicited a drastical reduction of the fecundity, especially in ladybirds (e.g. with teflubenzuron, fenoxycarb and flufenoxuron). Moreover, chlorfluazuron was the most dangerous one for almost all larval stages. From the other hand IGRs exerted a relatively low influence on adult coccinellids, the same trend of results obtained by Olszak (1999) and Olszak & Sekrecka (2008).

Pasqualini & Civolani (2003) examined six insecticides on adults of the aphidophagous coccinellids *Adalia bipunctata* (L.), *C. septempunctata* (L.) and *Oenopia conglobata* (L.) in apple, pear and peach orchards. The insecticides evaluated were the organophosphates (OP) chlorpyrifos, chlorpyrifos-methyl, azinphos-methyl and malathion, the carbamate derived Methomyl and the Nereistoxin analogues Cartap. Azinphos-methyl was consistently toxic to coccinellids with between 76% and 90.5% mortality occurring in four studies. Chlorpyrifos EC resulted in mortality ranging from 40.2% (apples, 1999) to 63% (peach, 2001) over five studies. Chlorpyrifos WDG mortality ranged from 50.8% to 70% over three studies. Chlorpyrifos-methyl resulted in 31% mortality in apples in 1999 and 86.1% mortality in pears in 1998. Methomyl and cartap were evaluated in a single study in apples and resulted in 66.7 and 10% mortality respectively. Malathion was evaluated in a separate study and caused 43.5% mortality.

To further develop IPM against aphids, it is important to evaluate the effects that these insecticides might have on *C. undecimpunctata* predatory capacity, since it is considered relevant to evaluate the predator's potential as a biological control agent (ElHag & Zaitonn 1996; Omkar 2004; Tsaganou et al. 2004). Previous studies indicated that sublethal effects of insecticides may result in an immediate disruption of predatory behaviour and a potential reduction in the efficiency of coccinellids to locate and capture their prey, since chemicals may interfere with the feeding behaviour by repellent, antifeedant or reduced olfactory capacity effects (Singh et al. 2001, 2004; Stark et al. 2004, 2007). The behavioural responses may also alter the predator's search pattern (Thornham et al. 2007, 2008) by avoidance of treated surfaces or ingestion of treated prey, to minimize their contact with insecticides (Wiles & Jepson 1994; Singh et al. 2001, 2004). On the other hand, insecticides can indirectly induce modifications on the dynamic predator/prey, through changes in the state and behaviour of the aphid colony that will influence relative prey value and consequently the predator's active choice. In addition, reductions (or absence) in the mobility and of defensive responses by the aphids can influence the predator's choice, as shown by several authors (Eubanks & Denno 2000; Provost et al. 2005, 2006; Cabral et al. 2011).

In the field, beneficial arthropods can be exposed to insecticides in several ways: by direct contact with spray droplets; by uptake of residues when contacting with contaminated plant surfaces; by ingestion of insecticide contaminated prey, nectar or honeydew (i.e. uptake of insecticide-contaminated food sources) (Longley & Stark 1996; Obrycki & Kring 1998; Lewis et al. 1998; Youn et al. 2003). Since it is known that the susceptibility of natural enemies to insecticides varies with the route of pesticide exposure (Longley & Stark 1996; Banken & Stark 1998; Naranjo 2001; Grafton-Cardwell & Gu 2003), it is important to perform both topical and residual tests as they can provide valuable information about the expected and observed impacts of insecticides on natural enemies in the field (Tillman & Mulrooney 2000). On the other hand, in the field predator/ prey interactions generally occur in structurally complex patches (i.e. plant architecture and surface features), which thereby influences the predator's foraging efficacy (Dixon 2000). Thus, studies regarding insecticide effects on predator's voracity should also reflect such scenarios (i.e. the tri-trophic system predator/prey/plant), particularly when testing systemic insecticides where the presence of the plant allows prey contamination not only by contact, but also through the food source.

Some studies have addressed the susceptibility of immature and adult coccinellids to pirimicarb and pymetrozine, when directly sprayed on prey and/or predators (e.g. James 2003) but nothing is known about the side effects of these chemicals on prey/predator interactions within tri-trophic systems. Thus, Cabral et al. (2011) evaluated effects of pirimicarb and pymetrozine on the voracity of 4th instar larvae and adults of *C. undecimpunctata*, under distinct scenarios of exposure to chemicals within a prey/plant system. Voracity of *C. undecimpunctata* was not significantly affected by pirimicarb or pymetrozine when treatments were directly sprayed on the predator; however, when insecticides were sprayed on the prey/plant system, the predator's voracity was significantly increased. Results suggest that *C. undecimpunctata* does not detect the insecticide on the aphids and indicate that the increase in voracity may be due to a decrease in the mobility of insecticide-treated aphids, since their capture should be easier than highly mobile non-treated prey as reported by Cabral et al. (2011). The consequences of such increase in the voracity for IPM programs are vital and required in aphid control programs.

Other studies suggested that the predatory efficiency of both adult and fourth instar larvae of *C. septempunctata* was significantly reduced, due to the sub-lethal effects of dimethoate residues and treated prey. Prey-choice experiments revealed that adult coccinellids consumed significantly fewer treated than untreated aphids over the 5-h experimental period. Fourth instar larvae preferentially consumed untreated aphids when given the choice of full rate dimethoate treated aphids or untreated aphids. The implications for post-treatment coccinellid survival and integrated pest management are considerable (Swaran 1999; Singh et al. 2004; Solangi et al. 2007)

The cultural practice that has the greatest effect on local populations of coccinellids is the application of insecticides. Accordingly, the greatest gains may be attained through reduction of toxic pesticides in coccinellid habitats. Insecticides and fungicides can reduce coccinellid populations. They may have direct or indirect toxic effect s (DeBach & Rosen 1991). Surviving coccinellids may also be directly affected, *e. g*. reductions in fecundity or longevity, or indirectly affected by decimation of their food source(s). Adults may disperse from treated areas in response to severe prey reductions or because of insecticide repellence (Newsom 1974). Pesticides vary widely in their effect on coccinellids, and similarly, coccinellids vary greatly in their susceptibility to pesticides (Polonsky et al., 1989; Lewis et al. 1998; Decourtye & Pham-Delegue 2002). Botanic insecticides are safer on natural enemies as well insect pathogens as confirmed by many studies (i.e. Ofuya 1997; Schmutterer 1997; Simmonds et al. 2000; Smitha et al 2006). Swaminathan et al. (2010) Evaluated side effects of botanicals *viz*., neem (*Azadirachta indica* A. Juss) leaves (NL), neem seed kernel extract (NSKE), eucalyptus oil (EO) and neem oil (NO) against aphidophagous coccinellids, *Adonia variegata* (Goeze). The side effects of neem seed kernal botanicals on the coccinellid recorded the highest mortality (73.33%) due to NSKE (10%) followed by (65.0% mortality) for neem oil (5.0%); and the post treatment effect (one day after) evinced maximum reduction in feeding (72.0 %) for NSKE (10%) followed by that recorded as 68% for *neem* oil (5%).

Vostrel (1998) stated that most of times tested acaricides, insecticides (carbamates & synthetic pyrethroids), exerted negative effects to varying degrees on all stages of *C. septempunctata*. Average mortality was lowest for acaricides, while fungicides were slightly more toxic. Insecticides nearly always caused comparatively higher mortality of all development stages, but adults were more resistant in many cases.

Based on many years of research, it is stated that bacterial and fungal biological preparations at rates recommended for use in agriculture show low toxicity to the predators *C. septempunctata* and *Chrysoperla carnea*, and to the parasitoids *Encarsia formosa* and *Trichogramma pintoi* (Mikul'skaya, 2000). There is a great importance of biological control in integrated pest management strategy.

4. Side effects on lacewings (*Chrysoperla* spp.)

The common green lacewing, *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) is one of the most common arthropod predators (Tauber et al. 2000; McEwen et al. 2001) with a wide prey range including aphids, eggs and neonates of lepidopteran insects, scales, whiteflies, mites, and other soft bodied insects (New 1975; McEwen et al. 2001). It has long been considered as a promising candidate for pest management programs worldwide (Tauber et al. 2000; McEwen et al. 2001) due to its wide prey range and geographical distribution, resistance/tolerance to pesticides, voracious larval feeding capacity as well as commercial availability (Medina et al. 2003a). Inundative releases of *C. carnea* were effective in controlling populations of pest complexes in various crops (Ridgway & Murphy 1984).

Insecticides, earlier considered as the backbone in crop protection, have become subordinate to other control methods, such as biocontrol which has gained more credibility in the last decades (Zaki et al. 1999b; Sarode & Sonalkar 1999b; Senior & McEwen 2001). But, the effectiveness of bioagents has been jeopardized by these insecticides. The sensitivity of *C. carnea* to insecticides differs from compound to compound. Medina et al. (2001) demonstrated that spinosad had little effect on *C. carnea* adult longevity and fecundity with no impact on eggs and pupae. Also, pyriproxyfen and tebufenozide were harmless at recommended field rates, whereas azadirachtin and diflubenzeuron were toxic to *C. carnea* third instar larvae (Medina et al. 2003 a, b; Güven & Göven 2003). In greenhouses, where organic farming system was applied, spinosad was used to control *Spodoptera littoralis* (Boisd.) on pepper and *Plutella xylostella* (L.) on cabbage, whereas *Chrysoperla carnea* and *Coccinella undecimpunctata* (L.) were released to control aphid populations on pepper and cabbage (Mandour 2009).

Saleem & Matter (1991) observed that the neem oil acted as temporary repellent against the predatory staphylinid beetle, *Paederus alfierii*, the coccinellid, *C. undecimpunctata* and the lacewing, *Chrysoperla carnea* in cotton but otherwise neem oil had no adverse effect on these predators of *Spodoptera littoralis*. That neem oil had no adverse effect on predators is also obvious from the studies of Kaethner (1991), as it was found harmless to the eggs, larvae or adults of *C. carnea* and also *C. septempunctata* (Lowery & Isman 1996)

Joshi et al. (1982) noted that 2 percent neem seed kernel suspension, when sprayed on tobacco plants, conserved the *Chrysopa scelestes*, an egg and larval predator of *S. litura*. The adults of the lacewing, *C. scelestes* were repelled from egg laying on cotton plants after they were sprayed with various commercial neem products of Indian origin and aqueous NSKE (Yadav & Patel 1992). First instar larvae of the predator emerged normally from treated eggs. Polyphagous predator, *C. carnea* treated in laboratory and semi-field trials with AZT-VR-K (1000 ppm) and with a mixture of this product with NO (25030000 ppm) induced no toxicity on eggs or adults; the fecundity of the latter was also not significantly affected (Kaethner 1991). The number of eggs (fecundity) laid by adult females developed from treated larvae was normal. The mortality of larvae fed with neem-treated aphids did not differ from that of controls. In laboratory experiments of Hermann et al. (1998) high mortality of larvae and pupae of *C. carnea* occurred if larvae were kept on NeemAzal-T/S (0.3% and 0.6%) contaminated glass plates, but practically no mortality was found in semi-field trials. Vogt et al. (1997) also studied the effectiveness of NeemAzal-T/S at 0.3 percent against *Dysaphis plantaginea* on apple and on its side-effects on *C. carnea*. A single application of NeemAzal-T/S in April gave very good control of *D. plantaginea* for about 5-6 weeks. After this period *D. plantaginea* builtup new colonies and *Aphis pomi*, too, increased in abundance. The side-effect test revealed that in the field NeemAzal-T/S was harmless to larvae of *C. carnea*. Neem seed extract was also found safe to *C. carnea* in comparison to nine insecticidal products (Sarode & Sonalka 1999a) where chlorpyrifos, deltamethrin and cypermethrin were found highly toxic to *Chrysoperla*. There was no mortality of *C. carnea* due to neem-based pesticides like NSE 5 per cent, Neemark, Achook, and Nimbecidine each at 0.003 per cent and neem oil at 1 per cent (Deole et al. 2000; Viñuela et al. 2000).

Spinosad is registered in many countries including Egypt for controlling lepidopteran and dipteran pests in fruit trees, ornamental plants, field- and vegetable crops. Medina et al. (2001, 2003b) studied the effect of spinosad on *C. carnea* eggs, pupae and adults using direct contact and ingestion treatments. As most of *C. carnea* immature stages do not die when exposed to sublethal doses, sublethal effects may exist that reduce the effectiveness of *C. carnea* progeny in controlling aphid control (Desneux et al. 2007). Mandour (2009) studied toxicity of spinosad to immature stages of *C. carnea* and its effect on the reproduction and survival of adult stages after direct spray and ingestion treatments. Spinosad was harmless to *C. carnea* eggs and pupae irrespective of concentrations or method of treatments. Mandour (2009) stated that oral ingestion of spinosad in artificial diet resulted in rapid death in *C. carnea* adults. After 7 days of ingestion, all tested adults in the three highest concentrations were dead compared to 100% of adult survival in control (Fig. 3). He mentioned also that spinosad ingestion had a profound effect on fecundity of *C. carnea*. In the three highest concentrations, almost all eggs were laid on the first two days after spinosad ingestion, and then surviving adults stopped laying eggs until death (Fig. 4).

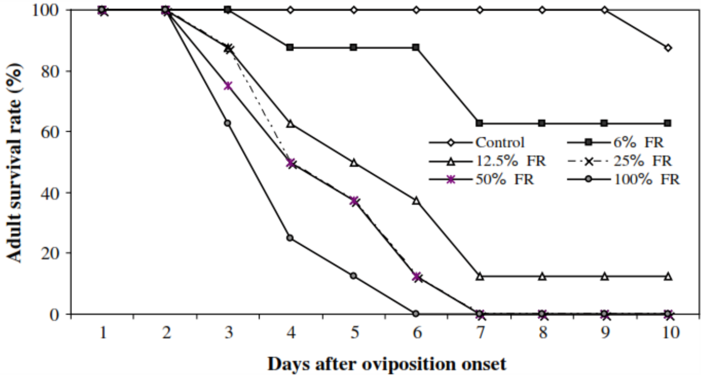

Figure 3. Rate of *C. carnea* adult survival after feeding on spinosad treated artificial diet from the onset of oviposition, FR = field rate (*n*=8) (after Mandour 2009).

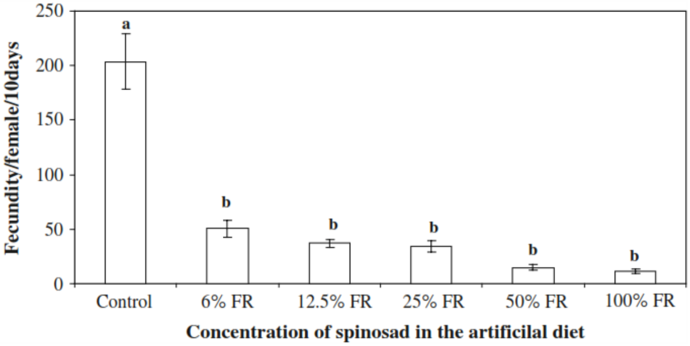

Figure 4. Influence of spinosad concentration on fecundity of *C. carnea* adults when fed with treated artificial diet from the onset of oviposition FR = field rate (*n*=8) (after Mandour 2009).

5. Side effects on predatory spiders and mites

There is an increasing interest in the ecology of polyphagous predators (e.g. Araneae) in agriculture. Spiders are important natural enemies of many insect pests, as they are generalist predators and comprise a large part of the beneficial arthropod community in agricultural fields (Nyffeler 1982; Riechert & Lockley 1984; Sunderland et al. 1986; Young & Lockley 1985; Everts 1990), and a number of case studies in different crops (e.g. Mansour et al. 1981; Nyffeler & Benz 1987, 1988) show that spiders can indeed be effective pest control agents in many situations. However spiders are also easily affected by pesticides (Boller et al. 1989; Everts et al. 1989; Aukema et al. 1990; Volkmar 1995, 1996; Volkmar & Wetzel 1993; Volkmar & Schier 2005; Volkmar et al. 1992, 1996 a, b, 2003, 2004).

Agricultural entomologists recorded the importance of spiders as a major factor in regulating pest and they have been considered as important predators of insect pests and serve as a buffer to limits the initial exponential growth of prey population (Volkmar 1996; Snyder & Wise 1999; Nyffeler 2000; Sigsgaard 2000; Maloney et al. 2003; Venturino et al. 2008; Chatterjee et al. 2009; Jayakumar & Sankari 2010). However researchers have exposed those spiders in rice field can play an important role as predators in reducing plant hoppers and leafhoppers (Visarto et al. 2001; Lu Zhong- Xian 2006, 2007). Several workers reported the predatory potency of spiders in rice ecosystem (Samiyyan 1996; Sahu et al. 1996; Pathak & Saha 1999; Sigsgaard 2000; Vanitha 2000; Mathirajan 2001; Sunil Jose et al. 2002; Satpathi 2004; Sudhikumar et al. 2005; Sebastian et al. 2005; Motobayashi et al. 2006). According to Peter (1988), the crop having more insects or insect visitors always had more spiders.

Many studies have demonstrated that spiders can significantly reduce prey densities. Lang et al. (1999) found that spiders in a maize crop depressed populations of leafhoppers (Cicadellidae), thrips (Thysanoptera), and aphids (Aphididae). The three most abundant spiders in winter wheat, *Pardosa agrestis* (Westring) and two species of Linyphiidae, reduced aphid populations by 34% to 58% in laboratory studies (Volkmar et al. 1992, 1996 a, b; Feber et al. 1998; Yardim & Edwards 1998; Marc et al. 1999; Nyffeler 1999; Holland et al. 2000). Both web-weaving and hunting spiders limited populations of phytophagous Homoptera, Coleoptera, and Diptera in an old field in Tennessee (Riechert & Lawrence 1997). Spiders have also proven to be effective predators of herbivorous insects in apple orchards, including the beetle Anthonomus pomorum Linnaeus, and Lepidoptera larvae in the family Tortricidae (Marc & Canard 1997; Buchholz & Kreuels 2009). In no-till corn, wolf spiders (Lycosidae) reduce larval densities of armyworm (Laub & Luna 1992). Wolf spiders also reduced densities of sucking herbivores (Delphacidae & Cicadellidae) in tropical rice paddies (Fagan et al. 1998). Spiders are capable of reducing populations of herbivores that may not be limited by competition and food availability in some agroecosystems (Buchsbaum 1996; Sunderland 1999; Lemke 1999).

Among the identified species, *Lycosa pseudoannulata* (Boes & Stand) was the most prevalent followed by *Atypena formosana* (Oi), *Argiope catenulate* (Doleschalland) *Clubiona japonicola* (Boesenberg and Strand) (Sahu et al. 1996). The population of these four species also varied at different growth stages of rice (Heong et al. 1992). In the first 35 DAT of rice, *Pardosa pseudoannulata* and *Atypena formosana* are considered as the important predators of Green leafhopper (Sahu et al. 1996; Mathirajan, 2001). Moreover *P. pseudoannulata* is the vital predator against brown plant hopper and can also effectively regulate the pest population of Leafhoppers Plant hoppers, Whorl maggot flies, leaf folders, Case worms and Stem borers (Kenmore et al. 1984; Barrion & Litsinger, 1984; Rubia et al. 1990; Ooi & Shepard 1994; Visarto et al. 2001; Drechsler & Settele 2001; Lu Zhong-xian et al. 2006).

Samiyyan & Chandrasekaran (1998) reported spiders were effective against leaf folders, Cut worms and Stem borers. *Atypena formosana* has been observed to hunt the nymphs of plant hoppers and Leafhoppers small dipterans, such as whorl maggot flies (Barrion & Litsiger 1984; Sigsgaard et al. 1999). According to Mathirajan (2001) *Tetragnatha javanas,* is one of the common spider found in rice ecosystem and they effectively reduce the population of Green leafhopper s and brown plant hoppers. The feeding efficiency of four spiders, namely *Lycosa pseudoannulata, Clubiona japonicola, Argiope catenulate* and *Callitrichia formosana* were also studied.

Integrated Pest Management (IPM) aims to avoid harming natural crop spiders. For this, IPM, attempts to synchronize the timing of spraying of pesticides with the life cycle of the pests, their natural enemies (predatory spiders and mites) (Bostanian et al. 1984; Volkmar 1989; Volkmar & Wetzel 1992). IPM also endeavours to use chemicals that act selectively against pests but not against their enemies. Few studies actually investigate effects of insecticides other than their direct toxicity (usually LD_{50}) on non-target animals. However, living organisms are finely tuned systems; a chemical does not have to be lethal in order to threaten the fitness (physical as well as reproductive) of the animal, with un-predictable results on the structure of the biological community (Culin & Yeargan 1983; Volkmar & Schützel 1997; Volkmar & Schier 2005). Pesticides may affect the predatory and reproductive behaviour of beneficial arthropods short of having direct effects on their survival. Thus to show that a pesticide is relatively harmless, or indeed has no measurable effect at all, behavioural studies on the effects of sublethal dosages are necessary. Such studies are not often done, presumably because of their costs in methodological difficulties (Vollrath et al. 1990; Volkmar et al. 1998, 2002, 2004).

5.1. Side effects on predatory spiders

Agricultural fields that are frequently sprayed with pesticides often also have lower spider populations in winter wheat (Feber et al. 1998; Yardim & Edwards 1998; Holland et al. 2000; Amalin et al. 2001). In general, spiders are more sensitive than many pests to some pesticides, such as the synthetic pyrethroids, cypermethrin and deltamethrin; the organophosphates, dimethoate and malathion and the carbamate, carbaryl. A decrease in spider populations as a result of pesticide use can result in an outbreak of pest populations (Marc et al. 1999; Holland et al. 2000; Maloney et al. 2003).

Spiders can lower insect densities, as well as stabilize populations, by virtue of their top-down effects, microhabitat use, prey selection, polyphagy, functional responses, numerical responses, and obligate predatory feeding strategies and we aim to review the literature on these topics in the following discussion. Nevertheless, as biological control agents, spiders must be present in crop fields and prey upon specific agricultural pests. Indeed, they are present and do eat pest insects. Spiders of several families are commonly found in agroecosystems in winter wheat and many have been documented as predators of major crop pest species and families (Roach 1987; Nyffeler & Benz 1988; Riechert & Bishop 1990; Young & Edwards 1990; Fagan & Hurd 1991; Nyffeler et al. 1992; Marc & Canard 1997; Wisniewska & Prokopy 1997; Fagan et al. 1998; Lang et al. 1999; Marc et al. 1999). Spiders may be important mortality agents of crop pests such as aphids, leafhoppers, planthoppers, fleahoppers, and Lepidoptera larvae (Rypstra et al. 1999; Maloney et al. 2003).

Many farmers use chemical pesticides to help control pests. An ideal biological control agent, therefore, would be one that is tolerant to synthetic insecticides. Although spiders may be more sensitive to insecticides than insects due in part to their relatively long life spans, some spiders show tolerance, perhaps even resistance, to some pesticides. Spiders are less affected by fungicides and herbicides than by insecticides (Yardim & Edwards 1998; Maloney et al. 2003). Spiders such as the wolf spider *Pardosa pseudoannulata* are highly tolerant of botanical insecticides such as Neem-based chemicals (Theiling & Croft 1988; Markandeya & Divakar 1999).

Saxena et al. (1984) reported that the wolf spider, *Lycosa* (=*Pardosa*) *pseudoannulata*, an important predator of leafhoppers in rice fields in Asia, was not harmed by neem oil (NO) and alcoholic or aqueous NSKE. In fact, NO (3%) and aqueous NSKE (5%) were quite safe for the spiders, though endosulfan induced 100 per cent mortality of the predators (Fernandez et al. 1992). NSKE, NO or NCE (10%) treated rice plots had better recolonization of spider *L. pseudoannulata* than in monocrotophos (0.07%) treated plots after seven days of treatment (Raguraman 1987; Raguraman & Rajasekaran 1996). The same neem products also spared the predatory mirid bug, *C. lividipennis* (Mohan 1989). The population of *L. pseudoannulata* and *C. lividipennis* were reported to be unaffected by different neem seed kernel extracts in paddy crop (Saxena 1987, 1989; Jayaraj et al. 1993). Similar observation on rice crop was made by Nirmala & Balasubramanian (1999) who studied the effects of insecticides and neem based formulations on the predatory spiders of riceecosystem.

Samu & Vollrath (1992) assessed a bioassay to test (ultimately in the field) such hidden effects of agrochemicals in their application concentrations. As a paradigm we chose the web- building behaviour of the cross spider *Araneus diadematus* Clerck (Araneidea, Argiopidae) and we selected four commonly used pesticides: Oleo Rustica 11E (mild insecticide), Fastac (pyrethroid insecticide), Bayfidan and Sportak (fungicides). Neither fungicides nor the mild insecticide seem to affect web-building behaviour significantly, whereas the pyrethroid insecticide suppressed web-building frequency and severely affected web size and building accuracy.

There are also some studies that prove the neem's lack of toxicity against spiders and mites. Like *Cheiracanthium mildei* (predator of citrus fruit) with its prey *Tetranychus cinnabarinus* that is highly susceptible to neem (Mansour et al. 1986). *Phytoseiulus persimilis* is also not harmed by NSE, specially its fecundity while *T. cinnabarinnus* is up to 58 times more toxic than it (Mansour et al. 1987); the same trend of results was stated by Schmutterer (1997, 1999). Mansour et al. (1993, 1997) reported that the commercial products namely Margosan-O, Azatin and RD9 Repelin showed no toxicity to the spider. Serra

(1992) observed that the neem products were not at all toxic to spider predators. Nandakumar & Saradamma (1996) observed the activity of natural enemies in cucurbit fields, where neem-based pesticides were applied for the control of *Henosepilachna vigintioctopunctata*. Natural enemies observed in considerable numbers were *Tetrastichus* sp., *Chrysocoris johnsoni*, *Tetragnatha* sp., *Oxyopes* sp. and orb-web spiders, and neem product did not inflict any harm to them. Lynx spider, *Oxyopes javanus* was less sensitive to NO (50% EC) than *L. pseudoannulata* (LC_{50} values = 9.73 and 1.18%, respectively) (Kareem et al. 1988; Karim et al. 1992), thereby confirming that NO was the safest pesticide for spiders. In cornfields (Breithaupt et al. 1999) and cabbage fields (Saucke 1995) in Papua New Guinea no significant effect was observed against *Oxyopes papuanus* from aqueous NSKEs (2%) or NeemAzal-S treatments. Serra (1992) did not observe adverse effects from NSKE 4 per cent applied on unidentified spiders in tomato fields in the Caribbean.

Babu et al. (1998) reported that a combination of seedling root dip in 1 percent neem oil emulsion for 12h + soil application of neem cake at 500 kg/ha + 1 per cent neem oil spray emulsion at weekly intervals gave an effective level of control of green leafhopper (*Nephotettix virescens*) infesting rice (var. Swarna). A combination of neem oil+urea at a ratio of 1:10 when applied three times at the basal, tillering and panicle initiation stages gave a superior level of control of brown planthopper (*Nilaparvata lugens*). The treatments, urea+nimin [neem seed extract] and a seedling root dip with 1 per cent neem oil emulsion+neem cake at 500 kg/ha+1 per cent neem oil spray emulsion at weekly intervals was equally effective against *N. lugens*. All neem products had little effect on predators, *C. lividipennis* and *L. pseudoannulata* (Sontakke 1993; Babu et al. 1998). NSKE sprays at 5, 10 and 20 per cent were also substantially safe for spiders and ants in cowpea ecosystems (Sithanantham et al. 1997).

Nanda et al. (1996) tested the bioefficacy of neem derivatives against the predatory spiders, wolf spiders (*L. pseudoannulata*), jumping spider (*Phidippus* sp), lynx spider (*Oxyopes* sp.), dwarf spider (*Callitrichia formosana*), orb spider (*Argiope* sp.), damselflies (*Agriocnemis* sp.) and mirid bug (*C. lividipennis*). It was observed that the neem kernel extract and oil were relatively safer than the insecticides to *L. pseudoannulata*, *Phidippus* sp. and *C. lividipennis* in field conditions. Markandeya & Divakar (1999) evaluated the effect of a commercial neem formulation (Margosan 1500 ppm) in the laboratory against two parasitoids and two predators. The formulation was tested at the field recommended dose of 10 ml/l. The neem formulation Margosan 1500 ppm was safe to all the four bioagents studied viz., *T. chilonis, B. brevicornis, L. pseudoannulata* and *C. sexmaculata*. Spider population in rice ecosystem was the lowest in carbofuran treatment and highest in neem cake treatments. The mean predator population of *Ophionea indica, Paederus fuscipes, Lycosa* sp. and coccinellid beetles was significantly higher in plots with *Azolla* at 5 t/ha, with or without neem cake at 1.5 t/ha, in field trials conducted in southern Tamil Nadu, India under lowland rice irrigated conditions (Baitha et al. 2000).

5.2. Side effects on predatory mites

Members of the family Phytoseiidae show a remarkable ability to reduce red spider mite infestations. There are many behavioural aspects that need to be considered in the phytophagous and predacious mites. Recognizing these behaviours and the side effects of pesticides on predatory mites can increase the success of biological control. Therefore, successful utilization of biological control could depend on the compatibility of the natural predators with pesticides. Studies on the side effects of pesticides on phytoseiid mites in Portugal have begun in 1995 (Rodrigues et al. 2002; Cavaco et al. 2003). Further research to evaluate these side effects of pesticides on all sensitive stages of the phytoseiid mites were conducted (Blümel et al. 2000; Broufas et al. 2008; Olszak & Sekrecka 2008).

The predatory mite *Phytoseiulus persimilis* (Athias-Henriot) is an economically important species in integrated mite pest management and biological control of spider mites in many countries throughout the world. Mass rearing and releasing natural enemies mainly phytoseiid mites are one of the goals of biological control of these pests in indoor and outdoor conditions (McMurtry & Croft 1997); additional food should be found for predatory mites (Pozzebon et al. 2005; Pozzebon & Duso (2008) in case of rareness of preys. For optimal biological mite management, it is important to know if acaricides have adverse undesirable effects on the predatory mites (Arbabi 2007). Nadimi et al. (2008) evaluated the toxic effects of hexythiazox (Nisorun®, EC 10%), fenpyroximate (Ortus®, SC 5%) and abamectin (Vertimec®, EC 1.8%) on *P. persimilis*. The results showed that the total effect values of all concentrations of hexythiazox were below the lower threshold thus it could be considered a harmless acaricide to this predatory mite. In contrast, the total effect of all concentrations of fenpyroximate, and field, as well as, one half the field concentration of abamectin were found toxic to predatory mite and above upper threshold. The overall results confirmed that *P. persimilis* is promise and crucial to develop IPM programs in agricultural crops; similar results were obtained by (Cloyd et al. 2006, Pozzebon & Duso 2010).

There are many spider mites such as *Tetranycus urticae* (Koch), which is considered one of the most important mite pest species with a wide range of host plants (Herron & Rophail 1993; Bolland et al. 1998). Many efforts have been undertaken to manage *T. urticae* problems in agricultural crops such as the application of new acaricides with the lower concentrations and release of predacious mites such as *Phytoseiulus persimlis* in glasshouses on cucumbers (Arbabi 2007) and in fields of beans, cotton as well as soybeans (Daneshvar & Abaii 1994). It has gained increasing attention by research scientists in many parts of the world. Selective pesticides that can be used to control pests without adversely affecting important natural enemies are urgently needed. Testing programme represented by IOBC (International Organization for Biological Control), is not only meant to provide valuable information on the side effects of pesticides on beneficial organisms but it also gives the testing members an opportunity to improve testing techniques, compare results and exchange experience with colleagues in the Working Group (Hassan et al. 1991).

Biological control of these pests is increasing because of the pressure on growers to find alternatives to chemical pesticides (van Lenteren 2000). In the presence of chemical applications, biological control of spider mites may be achieved by the selective use of pesticides that are less toxic to natural enemies than to pest species (Zhang & Sanderson 1990). Ruberson et al. (1998) suggested that selective pesticide were the most useful tool of integration of biological control agents into pest control programs. A strain of *P. persimilis* was introduced into Iran from the Netherlands (Department of Entomology, Wageningen Agricultural University) in 1988 (Daneshvar 1989) and it was effective in controlling spider mites under greenhouses and outdoor conditions (Daneshvar & Abaii 1994). However, Biological control of spider mites using this predaceous mite is effective only against low population densities of the pest (Pralavorio et al. 1985). When the population densities are high an acaricide treatment is needed to reduce the pest population before release of beneficial mites (Malezieux et al. 1992; Bakker et al. 1992; Hassan et al. 1994). Although various aspect of pesticide effects on *P. persimilis* have been studied by many workers in the past (Samsøe-Petersen 1983; Zhang & Sanderson 1990; Oomen et al. 1991; Blümel et al. 1993, 2000; Blümel & Gross 2001; Blümel & Hausdorf 2002; Cloyd et al. 2006). Only Kavousi & Talebi (2003) investigated side-effects of heptenophos, malathion and pirimiphosmethyl on *P. persimilis*. Moreover, there is no adequate information on the susceptibility of many strains and species to other pesticides, especially acaricides (Zhang 2003).

Bostanian et al. (2004) studied the toxicity of Indoxacarb to two predacious mites: *Amblyseius fallacis* (Garman) (Phytoseiidae) and *Agistemus fleschneri* (Summers) (Stigmaeidae). They reported that Indoxacarb had no adverse effects on *A. fallacis* and *A. fleschneri* adults, number of eggs laid by treated adults of both species and percent hatch of treated eggs of these two species, as stated also by Kim et al. (2000, 2005).

Rodrigues et al (2004) evaluated the toxicity of five insecticides (*Bacillus thuringiensis,* tebufenozide, flufenoxuron, phosalon and deltamethrin) on predatory mites (Acari: Phytoseiidae). The results were similar in both trials: phosalon and deltamethrin had a poor selectivity (harmful) on the phytoseiid mites, *Bacillus thuringiensis,* tebufenozide and flufenoxuron showed a good selectivity to these predators. The most abundant Phytoseiid species identified were *Phytoseius plumifer* (Canest & Fanzag) (91.8%) in Minho region and *Typhlodromus phialatus* Athias-Henriot (96.7%) in Castelo Branco region.

Cavaco et al (2003) studied evaluating the field toxicity of five insecticides on predatory mites (Acari: Phytoseiidae). The dominant species of phytoseiid in the region of Guarda was *Typhlodromus pyri* Scheuten (99.9%) and the dominant species in the region of Castelo Branco was *Typhlodromus phialatus* Athias-Henriot (96.4%). The results of imidacloprid showed good selectivity for phytoseiids while dimethoate was harmful. It was found that *T. pyri* was more tolerant to the other insecticides tested than *T. phialatus*. These results are of interest for the enhancement of integrated pest management programs. They suggest differences in susceptibility of *T. pyri* and *T. phialatus* to the tested insecticides, mainly to vamidothion.

Spinosad controls many caterpillar pests in vines, pome fruit and vegetables (including tomatoes and peppers), thrips in tomatoes, peppers and ornamental cultivation and dipterous leafminers in vegetables and ornamentals (Bylemans & Schoonejans 2000). Spinosad can be used to control pests in crops where the conservation of predatory mites is an important component of Integrated Pest Management (IPM) (Thompson et al. 1997). Additionally, there are governmental and environmental pressures to develop and use products safely with minimum impact on non-target arthropods. Predatory mite species are recognised as both important antagonists of pest species and sensitive indicators of ecologically significant effects (Overmeer 1988; Sterk & Vanwetswinkel 1988).

Miles & Dutton (2003) conducted extended laboratory experiments, semi-field and field tests to examine effects of spinosad on predatory mites. Under extended laboratory conditions (exposure on natural substrates) no effects were seen on *Amblyseius cucumeris*, *Hypoaspis aculeifer* or *Hypoaspis miles* at rates up to 540 g a.i./ha. When *Phytoseiulus persimilis* was tested under semi-field conditions, spinosad was harmless at rates of 9.6, 19.2 and 36 g a.i./hL. No effects were noted to *Amblyseius californicus* at 19.2 g a.i./hL under semi-field conditions. In the field, single applications of spinosad at 48 or 96 g a.i./ha in vines caused no unacceptable effects to populations of *T. pyri* or *Kampimodromus aberrans*. It was concluded that spinosad was highly selective to most predatory mite species and that effects noted in tier I laboratory studies did not translate to higher tiers of testing or use in the field. The reason for this is not clear but could be due to agronomic practice, difference in species sensitivity, sublethal or behavioural effects or even effects on prey. However use patterns safe to predatory mites and compatible with IPM have been developed for a wide range of crops.

Papaioannou et al. (2000) studied the effects of a NSKE (Neemark) and Bioryl(R) vegetable oils against phytophagous and predatory mites using bean leaves treated with different concentrations. Neemark (3 and 5%) was moderately toxic to *T. urticae*, and highly toxic to *P. persimilis*. Other studies investigated the toxicological tests (acute and sublethal effects) of fungicides on predatory mites (Blümel et al. 2000; Auger et al. 2004; Bernard et al. 2004).

6. Conservation and enhancement of natural enemy assemblages

Conservation of predators in the field can be accomplished by reducing both chemical and physical disturbance of the habitat. Natural enemy densities and diversities are significantly higher in orchards and fields where no pesticides have been sprayed (Yardim and Edwards 1998; Marc et al. 1999; Holland et al. 2000; Amalin et al. 2001). Restricting insecticide treatment to crucial periods in the pest life cycle or limiting spraying to midday when many wandering natural enemies are inactive and in sheltered locations can help conserve spider numbers (Riechert & Lockley 1984). Natural enemies can recolonize if the interval between chemical applications is long enough, but several applications per season can destroy natural enemy communities. Some pesticides are also retained in the natural enemies and can be detrimental to those spiders that ingest their webs daily (Marc et al. 1999).

Besides pesticides, other human practices that can disrupt natural enemy populations are mowing, plowing, harvesting, and crop rotation (Nyffeler et al 1994; Marc et al. 1999). Soil disturbance by plowing destroys overwintering sites and can kill any agent already present in the soil (Marshall & Rypstra 1999; Maloney et al. 2003). The movement of farm equipment through a crop field damages spider webs and may destroy web attachment sites (Young & Edwards 1990). Consequently, density and diversity of natural enemies are higher in organic fields than in conventional ones. For example, in cereal fields, Lycosidae made up only 2% of the community in conventional fields, but 11% in organic fields. Most lycosids were found in field edges (Marc et al. 1999). Clearly, human input is harmful to natural enemies, and the best spider conservation strategy may be non-intervention (Young & Edwards 1990; Maloney et al. 2003).

Traditional biological control efforts have focused on using specialist predators to control pest outbreaks, which Riechert & Lockley (1984) liken to “putting out fires rather than preventing their conception”. Encouraging natural enemy populations may have the effect of keeping pest levels low and not letting them get out of control. Spiders may be potential the helpful biocontrol agents because they are relatively long lived and are resistant to starvation and desiccation. Additionally, spiders become active as soon as conditions are favourable and are among the first predators able to limit pests. The risks associated with using natural enemies to control pests are minimal. Since diverse species of natural enemies are naturally present in an agricultural system (thus avoiding the problems associated with introductions) and predaceous at all stages of their development, they fill many niches, attacking many pest species at one time (Agnew & Smith 1989; Marc et al. 1999). Because they are sensitive to disturbance, natural enemies may best be used in perennial agroecosystems, such as orchards, that suffer the least disruption and human intervention (Riechert & Lockley 1984; Marc et al. 1999). Natural enemies do have the potential to be highly effective pest management agents, but the overall level of control is specific to each combination of crop and management style (Maloney et al. 2003).

7. Conclusions

Neem products are now widely acclaimed as broad-spectrum pesticides. Schmutterer & Singh (1995) listed 417 insect species as sensitive to neem. In the present era of biocontrol, safety concerns predominate the agro-ecosystem besides pest control. Since neem products are now on large-scale use, their safety to natural enemies has also become a debatable issue. In the case of microbial agents, NPV and Bt are the most successful commercial products. Neem products either pure, crude or commercial so far did not show any adverse effects when combined with NPV or Bt. Though combining neem products with antifeedant property and microbials with stomach poison activity is disputed, the vast volume of research work carried out reveals that the antifeedant principles of neem do not influence in any way the activity of the microbials inside the insect gut. The growth disrupting principles of neem were found to add to the activity inside the insect system along with microbial principles leading to quicker mortality to give a cumulative effect.

In the case of parasitoids, certain guiding principles are suggested in accordance with multi-array activities of neem products in insects. Parasitoids are also susceptible, when they come in direct contact with neem products. In such circumstances blanket application of neem products without understanding the behaviour of the parasitoid may adversely affect the beneficial capacity of the parasitoid. For example, the inundative release of the egg parasitoid *T. chilonis*, should be resorted 3-4 days before/ after neem products application. The external larval parasitoids are no exception to the ill effects if they are in direct contact with neem products. To avoid this, for inundative releases, application of neem products may be followed by the release of the parasitoids and spraying may be avoided if the parasitoids are in larval stages in the field. Hence presampling is suggested to know the stage of the parasitoid, be it internal or external, for timing the application of neem products.

In the case of predatory insects, mites and spiders, certain degree of selectivity is nevertheless appararent, as adult insects show, no or relatively low sensitivity as in the case of earwigs, crickets, true bugs, beetles, lacewings and wasps. This can be explained by the fact that growth-disrupting compounds affect the first line juvenile instars of insects. The fecundity of neem-treated adult, predaceous parasitic insects and the fertility of their eggs are also not or only slightly affected by neem, in contrast to some phytophagous species. In some cases the predation efficiency may be reduced Nymphal/larval instars of beneficial insects are sensitive to neem products. When topically treated, reduction in food ingestion, delayed growth, difficulties in moulting, teretological and morphogenetic defects, reduced activity and increased mortality are normally observed in the laboratory. But, far less drastic or even no effects are observed under semi-field or field conditions. This is partly due to the fast breakdown of the active principles underfield conditions.

A desirable biological control agent is a predator that not only reduces pest densities, but also stabilizes them at low levels, while maintaining stable populations itself (Pedigo 2001). Stability in predator-prey systems is achieved by density-dependent responses of the predator to the prey. As prey populations increase, predation pressure should increase, and predation pressure should lessen as prey population decrease. Usually, the greater the importance of a given prey in the diet of a predator, the lower the population size the predator effectively controls. Density-dependent control is thereby affected by the functional response and the numerical response of the predator (Riechert & Lockley 1984; Morin 1999).

The reproductive response of spiders is less studied. Some spiders, especially web-weavers, do show an increase in fecundity with increasing amounts of prey ingested. Such spiders include *Neriene radiate* (Linyphiidae), *Mecynogea lemniscata*, *Metepiera labyrinthea* (Araneidae) and *Agelenopsis aperta* (Agelenidae) (Riechert & Lockley 1984). The extent to which this increase in fecundity can permit tracking of prey populations is limited by long generation times compared to those of pest insect species. Spiders are usually univoltine while generation times for many insect pests are a few weeks (Maloney et al. 2003).

Competition, intraguild predation, and cannibalism can limit the aggregation response of spiders. Spiders are usually territorial and will compete for space and prey at high spider densities, limiting the number of spiders that can coexist in the same area. The result may be migration from a patch of high prey densities and, therefore, less pest control (Marc et al 1999; Marshall & Rypstra 1999). Intraguild predation predation upon members of the same trophic level is a major factor limiting aggregation and spiders' pest control abilities (Fagan et al. 1998; Wise & Chen 1999).

The evidence to date suggests that insecticides derived from the neem tree are unlikely to cause substantial environmental damage and these products appear to be safer than synthetic neurotoxins. However, pesticides derived from neem are poisons and thus should be treated as such. Certain organisms are particularly sensitive to neem and this should be taken into consideration when contemplating their use (Maloney et al. 2003). Currently the development of new means for plant protection has different motivations. Three major groups are apparent: synthetic chemicals, genetically modified products and biological products. The present scenario of regulatory situation in different countries is not very clear and comprehensively laid down; therefore, NeemAzal has been taken as a specific example. An extract "NeemAzal" obtained from seed kernels of the Neem tree *Azadirachta indica* A. Juss and its formulation contains about 54 per cent azadirachtins. NeemAzal-T/S is a formulation of NeemAzal containing 1 percent w/w of azadirachtin A.

The factors that influence effects of either neem products or pesticides on natural enemies (insects, mites & spiders) are type of solvent, soil type, moisture, percent organic matter, temperature, and time of day of spraying. Further, the microhabitat, hunting style, prey preference, and behavior of biocontrol agent also influence their response to pesticide application (Schweer 1988; Volkmar & Wetzel 1993; Krause et al. 1993; Marc et al. 1999). Wisniewska & Prokopy (1997) reported that if pesticides were only used early in the growing season, natural enemy populations increased. Presumably, spiders have a chance to recolonize the field if pesticide use ceases after early June. Spatial limitation of pesticides (such as only applying the pesticides to certain plants or certain plots) also results in higher natural enemy numbers, since they can move out of the treated areas and return when the chemicals dissipate (Riechert & Lockley 1984; Dinter 1986, 1995; Maloney et al. 2003). Comparative studies have been carried out on various beneficial organisms such predatory spiders and mites, providing important data on the impact of pesticides on agro-ecosystems (Sterk et al. 1999; Holland et al. 2000; Amalin et al. 2001; Olszak & Sekrecka 2008).

After the treatment with NeemAzal-T/S larvae suffer feeding and moulting inhibition and mortality; adults show feeding inhibition, infertility and to a lesser degree, the mortality. This specific mode of action is called "insectistatic". These studies with NeemAzal definitely imply that this and several other developments in neem-bsed pesticides have convinced registration authorities not only in Europe and Asia but in USA and Canada as well and Neem has been included among reduced-risk pesticides. That is why main opportunities are seen as arising from the discovery of new leads from high-throughput screening of plant extracts. It is hoped that international harmonized approach will come into force with a uniform set of rules to encourage the development of plant-based products for rational and sustainable agriculture. Of course, the lead from neem-based products now already exists and should be followed globally in order to develop safe and standardized products. NP virus and Bt are highly compatible with neem products. Parasitoids/predators, pre-sampling and timing of application are necessary to avoid the ill effects of neem products, if any, on them. It is obvious that next years will look forward to IPM that will include natural enemies vis-à-vis other biopesticides synchronizing with ecological and behavioural aspects of pests (Landis et al. 2000).

El-Wakeil et al. (2012 unpublished data) studied effects of some insecticides on wheat insect pests (thrips, aphids,creal leaf beetle, click beetles, cicadas, bugs leafhopper and frit fly) and the associated natural enemies (dance flies, coccinellids, hover flies, lacewings, Staphylindis, predatory spider and wasp parasitoids) in winter wheat 2012 in central Germany. The sequential sampling plans (direct count, sweep net, sticky traps and water traps) were used and described in this research to provide an integrated method for less wheat insects. The results showed that both chemical insecticides (Karate and Biskaya) caused more mortality to wheat insects and their side effects were harmful to the natural enemies. On the other hand, neem treatments caused adequate mortality of insects and were safer to the natural enemies (Figs. 5 & 6).

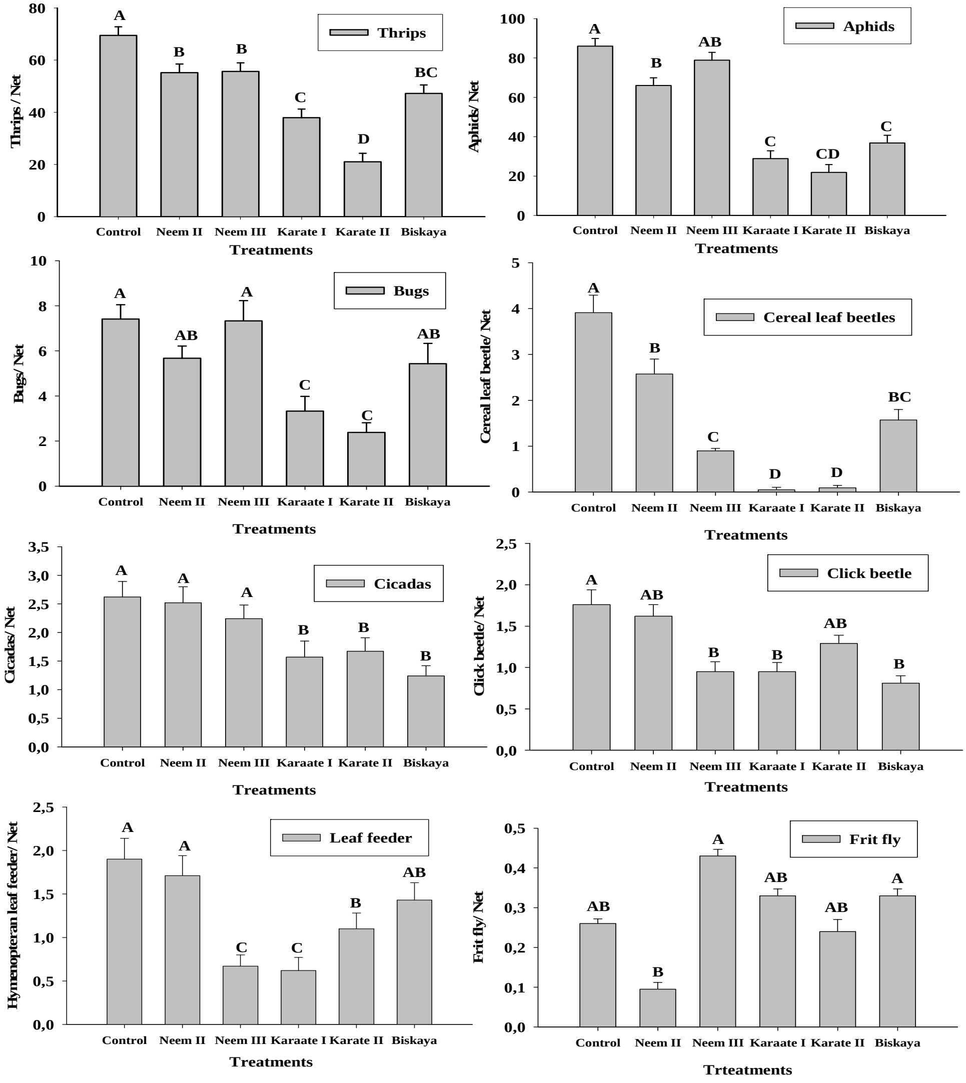

Figure 5. Mean of population ± SE of some wheat insects treated with different treatments and surveyed by sweep net in winter wheat 2012. Different letters indicate significant differences.

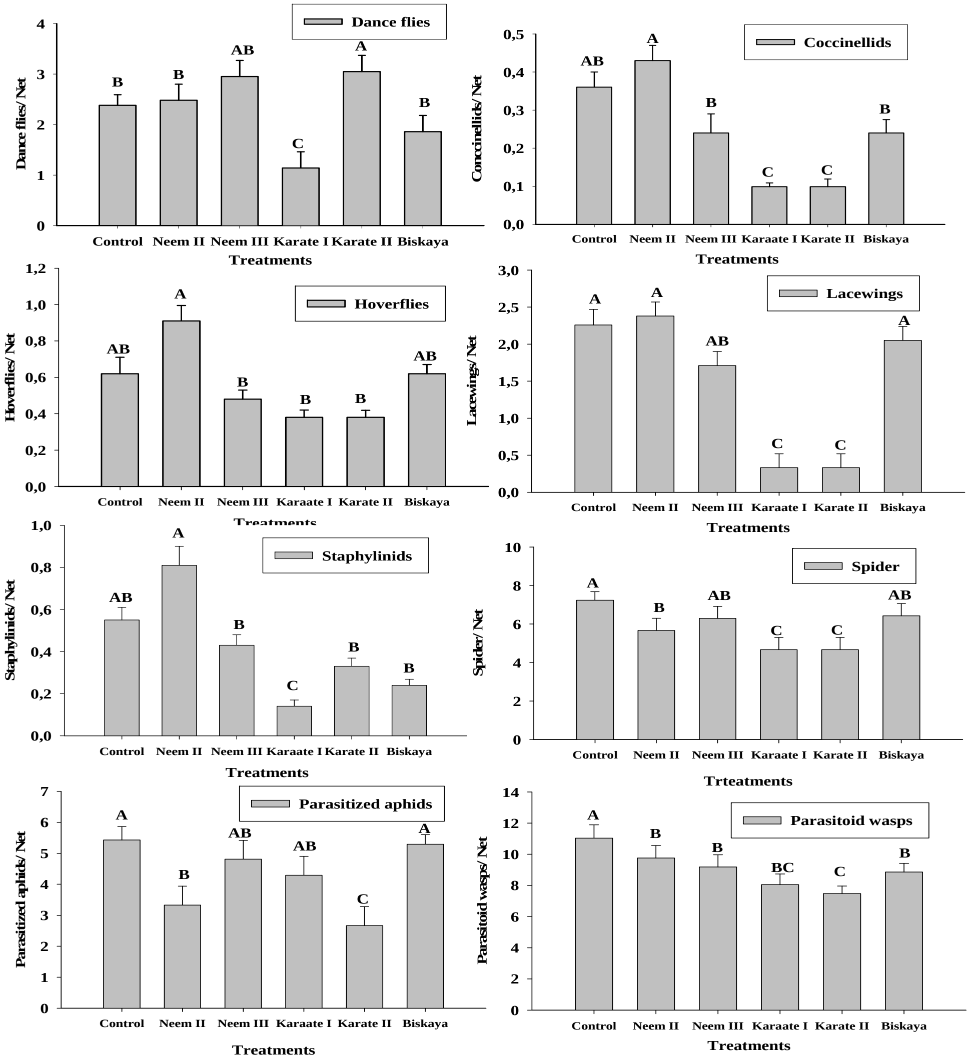

Figure 6. Mean of population ± SE of some natural enemies treated with different treatments and surveyed by sweep net in winter wheat 2012. Different letters indicate significant differences.

Agricultural sustainability requires a focus on the long run, on intergenerational equity. It must be capable of meeting the needs of the present while leaving equal or better opportunities for the future. It must be ecologically sound and socially responsible as well as economically viable. It must also include, as much as possible, the element of local or regional production, and aim for a reasonable level of regional food security. It encourages a shortening of the distance between producers and consumers, to the benefit of both. In a local economy consumers have influence over the kind and quality of their food; they contribute to the preservation and enhancement of the local landscape. It gives everybody in the local community a direct, long-term interest in the prosperity, health, and beauty of their homeland (Buchholz & Kreuels (2009); Shoeb 2010; Cabral et al. 2011).

Organic farming falls under this broader classification of "sustainable agriculture." It is commonly thought of as farming without chemicals, and that is usually the case, but it is much more than that. Organic farmers try to farm holistically - that is, they design production systems that capitalize on the positive synergies among crops, soils, seeds, and animals, in such away that each element of the system promotes the productivity and health of other elements. The rapid growth of organic and sustainable agriculture in Canada is occurring with almost no support from the federal government, whose policies are almost entirely devoted to encouragement of industrial agriculture (El-Wakeil 2003). Other countries are heading in the opposite direction. The cornerstone of Egypt as well Germany's new agricultural policies will be sustainability.

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