

**SELECTIVITY OF ABAMECTIN TO *CHRYSOPERLA CARNEA* (STEPHENS)  
(CHRYSOPIDAE, NEUROPTERA)**

**ABSTRACT**

Relative toxicities of abamectin along with spinosad, cypermethrin and chlorpyrifos currently used in cotton fields to control bollworms on the general predator, *Chrysoperla carnea* (Stephens) at egg, larvae and adult stages were evaluated under laboratory conditions in Tamil Nadu, India. The insecticide concentrations studied were equivalent to those prescribed for field application inclusive of various doses for abamectin. The results revealed that there was no significant adverse effect on hatchability of *C. carnea* caused by abamectin 1.9 EC. However, the fecundity and longevity of adults were significantly reduced at higher concentrations (2 and 2.4 ml l<sup>-1</sup>) of abamectin. The larva upon direct exposure to insecticides recorded a maximum 40.0 per cent mortality at the highest dose of abamectin (2.4 ml l<sup>-1</sup>). When the larva were fed with the insecticides treated eggs at 2.4 ml l<sup>-1</sup>, the larval mortality was 36.7 per cent and the pupation and adult emergence were 68.4 and 61.5 per cent, respectively. Abamectin at lower doses had caused very little impact upon *C. carnea*. All the doses of abamectin were comparatively safer than chlorpyrifos and cypermethrin. Thus, abamectin is found harmless to *C. carnea* and can provide selectivity in an integrated control programme for cotton bollworms.

**INTRODUCTION**

The family Chrysopidae includes many species that could be considered important biological control agents. Chrysopid larvae and the adults of certain species are polyphagous predators and feed on several pests of economic importance. *Chrysoperla carnea* (Stephens) (Neuroptera, Chrysopidae) is an important predator of cotton bollworms. In the context of biological control, most attempts have evaluated the efficacy of *C. carnea* in augmentation

releases in the field or in the greenhouses (Ridgway and McMuphy, 1984; Hagen et al., 1999; Nordlund et al., 2001). In Integrated Pest Management (IPM) programs, biological pest control with chrysopids could be efficiently combined with the use of selective pesticides. There are many studies focusing on the effects of pesticides commonly used in agriculture on certain life-history traits of chrysopid species (Silva et al., 2005, 2006; Nadel et al., 2007; Rezaei et al., 2007; Giolo et al., 2009; Mandour, 2009; Schneider et al., 2009) some compounds are toxic; mostly suggesting the relatively broad tolerance of chrysopids to many pesticides. Selective insecticides could play a role in conserving natural enemies associated with cotton. So safety evaluation of a chemical to important natural enemies is as important as that of toxicity evaluation. Abamectin, one of the broad spectrum microbial insecticides derived from the soil actinomycetes, *Streptomyces avermitilis* Burg., has been reported to possess excellent performance against the pests of cotton (Birah, 2008). Keeping in view, the present study was taken up to assess the relative toxicity of the abamectin to *C.carnea*.

## **MATERIALS AND METHODS**

### **Mass production of *C. carnea***

Mass rearing of *C. carnea* was done with *Corcyra cephalonica* Stainton eggs as feed following the method described by Swamiappan (1996).

### **Larval rearing**

Larva of *C. carnea* were reared in galvanized iron (GI) basins (28 cm dia) at 250 larvae basin<sup>-1</sup> covered with kada cloth. The eggs of *C. cephalonica* were provided as feed for the larva. About 25cc of *C. cephalonica* eggs basin<sup>-1</sup> were provided on alternate days. After five feedings, the larvae pupated into white coloured round silken cocoon. The cocoons were collected and transferred into one litre plastic container with wire mesh window for emergence of adults.

## **Adult rearing**

The adults were collected and transferred to GI troughs (30 cm dia x 12 cm ht), wrapped inside with brown sheets for collecting the eggs. The trough was covered with nylon cloth and kept firm with the help of a rubber band. Over the cloth covering, two bits of foam sponge (2.5 cm<sup>2</sup>) dipped in water were kept; besides an artificial protein rich diet in the form of semi solid paste was smeared. This diet consisted one part of yeast powder, one part of fructose, one part of honey and one part of Protinex<sup>®</sup>. Water was mixed to make it a paste. The adults laid eggs on the brown sheet wrapped inside the trough. The adults were collected daily and allowed into fresh rearing troughs with fresh feed. From the old troughs the brown paper sheets along with chrysopa eggs were removed.

## **Insecticide bioassays**

Laboratory experiments were conducted to assess the selectivity of abamectin 1.9 EC, spinosad 45 SC, cypermethrin 10 EC and chlorpyrifos 20 EC to *C. carnea* in Tamil Nadu Agricultural University. The experiments were conducted in a completely randomized design with ten treatments replicated thrice. The treatments were abamectin 1.9 EC at 9, 11, 13, 15, 18.5 and 22.5 g a.i ha<sup>-1</sup>, spinosad 45 SC at 75 g a.i ha<sup>-1</sup>, cypermethrin 10 EC at 70 g a.i ha<sup>-1</sup>, chlorpyrifos 20 EC at 220 g a.i ha<sup>-1</sup>, and untreated check. The different treatment doses were obtained by dissolving 1.0, 1.2, 1.4, 1.6, 2.0 and 2.4 ml of abamectin 1.9 EC and 0.3 ml of spinosad 45 SC, 1.5 ml of cypermethrin 10 EC and 2.4 ml of chlorpyrifos 20 EC in one litre of distilled water and used. The percentage values were converted to arcsine percentage. The mean values of treatments were then separated by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez 1976, 1984).

## **Eggs of *C. carnea***

Studies were conducted to assess the effect of abamectin 1.9 EC and other insecticides on the eggs of *C. carnea* as per the method described by Krishnamoorthy (1985). The eggs along

with stalks on brown paper strips were sprayed with different concentration of insecticides using an atomizer with 100 eggs per treatment. Untreated check was maintained by spraying distilled water. The number of larva hatched from each treatment was recorded and per cent hatchability worked out by the formula,

$$\text{Per cent hatchability} = \frac{\text{No. of larva hatched}}{\text{Total number of eggs}} \times 100$$

## **Larva of *C. carnea***

### **a. Larval feeding method**

Eggs of *C. cephalonica* were exposed to UV radiation of 15 W for 15 min to kill the embryo. The UV killed *Corcyra* eggs were sprayed with different concentrations of the insecticides dose with an atomizer. The treated eggs were shade dried for 15 min. and then transferred to test tubes @ 1 cc per test tube. The untreated check was maintained by spraying distilled water. Second instar *C. carnea* larva were transferred to these test tubes @ 10 per test tube. After the larva completely fed the insecticide treated eggs, the larva were provided with untreated *Corcyra* eggs till pupation. Observations were made on the grub mortality (12, 24 and 48 h after treatment), pupation and adult emergence.

$$\text{Per cent mortality} = \frac{\text{No. of larva dead}}{\text{Total Number of larva}} \times 100$$

### **b. Dry film method**

The bioassay method described by McCutchen and Plapp (1988) was adopted with modifications (Chelladurai, 1999). The insecticidal concentrations were prepared using acetone and water in a ratio of 80: 20. Glass scintillation vials of 20 ml capacity were evenly coated with 1 ml of insecticide formulations dissolved in acetone - water and dried by rotating the tube horizontally on a table with palm. Second instar larva were released into the vials @ 10 per vial and covered with muslin cloth secured with a rubber band. After 24 h exposure of the larva, 1 cc *Corcyra* eggs were given as feed and observations on the mortality of the larva made. Per cent

mortality of the larva was worked out. Likewise, pupation (%) and adult emergence (%) were also worked out.

### **Adults of *C. carnea***

Five pairs of freshly emerged *C. carnea* adults were allowed in separate plastic containers. The adults were fed with 10 per cent sucrose solution containing different concentrations of insecticide formulation. In the untreated check, the adults were fed with 10 per cent sucrose solution alone. The eggs laid in each treatment were collected daily by keeping a brown paper sheet of 21 x 6 cm size along the inner side of the plastic container. Observations were made on the adult longevity and fecundity by recording the number of days the adults were alive and the number of eggs laid per five females.

## **RESULTS AND DISCUSSION**

### **a. Eggs**

The hatchability of the eggs varied from 96.7 per cent for untreated check and 86.7 - 93.3 per cent for different doses of abamectin. Abamectin at all doses were less toxic to *Chrysoperla* eggs. Maximum hatching was recorded in untreated check (96.7 %), whereas the lowest was observed in cypermethrin 10 EC at 1.5 ml l<sup>-1</sup> (80.0 %) (Table 1)

### **b. Larva**

The results on the influence of abamectin to *C. carnea* larva determined by larval feeding method revealed that abamectin at higher concentrations tested caused significant mortality. The maximum mortalities of the larva were noticed in cypermethrin (46.7 %). In abamectin doses, the mortality ranged between 6.7 and 36.7 per cent, which implies that abamectin is safe to the larva. Spinosad and chlorpyrifos at 0.3 and 2.4 ml l<sup>-1</sup> recorded 20.0 and 30.0 per cent mortality respectively (Table 2)

In the dry film method, the mortality was somewhat higher than in larval feeding method. Among the abamectin doses, abamectin at high dose (2.4 ml l<sup>-1</sup>) recorded higher per cent mortality of 40.0 followed by abamectin at 2.0 ml l<sup>-1</sup> (33.3 %). Among the treatments, cypermethrin recorded the highest mortality of 50.0 per cent. The untreated check registered higher percentage of pupation (100%) in both the tests followed by abamectin at 1.0 ml l<sup>-1</sup> (96.4 and 92.9 %). Spinosad, chlorpyrifos and cypermethrin recorded 87.5 and 82.6, 76.2 and 70.0 and 56.3 and 53.3 in both the tests, respectively. Cent per cent adult emergence was observed in untreated check and abamectin @ 1ml l<sup>-1</sup>. Cypermethrin (1.5 ml l<sup>-1</sup>) registered the lowest adult emergence of 44.4 and 37.5 per cent followed by abamectin at higher doses with 61.5 and 58.3 per cent in both the tests, respectively.(Table 2)

### **c. Adults**

The results revealed that the adult longevity was maximum days in untreated check (14.7 days), while it was 7.5, 8.3, 8.8, 9.3, 9.7 and 10.3 days when abamectin was applied at 2.4, 2.0, 1.6, 1.4, 1.2 and 1.0 ml l<sup>-1</sup> respectively. The adult longevity was reduced significantly in cypermethrin (3.5 days) and chlorpyrifos (5.9 days). Likewise, significantly more number of eggs was laid in untreated check (253 eggs per 5 females). However, the fecundity was reduced to 185.0, 173.7, 161.7, 149.7, 138.0 and 116.0 eggs per 5 females, when the adults were exposed to abamectin 1.0, 1.2, 1.4, 1.6, 2.0 and 2.4 ml l<sup>-1</sup>, concentrations, respectively. (Table 1)

The insecticidal effect on non-target organisms are categorized according to the recommendations of the International Organisation for Biological Control, West Palaearctic Regional Section (IOBC/WPRS) working group (Hasan 1989; Nasreen *et al.* 2000) as harmless (< 50% mortality), slightly harmful (50 to 79% mortality), moderately harmful (80 to 89 % mortality) and harmful (> 90% mortality) when tested at the field recommended dose. The natural egg mortality recorded in the untreated check was 3.3 per cent and mortality due to the application of abamectin varied from 6.7 to 13.3 per cent and hence, it can be categorized as a

harmless insecticide. The longevity and the fecundity of adults decreased as the concentration of abamectin increased. Spinosad was also found to come under harmless category.

Badawy and Arnaouty (1999) reported that abamectin was safer than all tested conventional insecticides to *Chrysoperla* eggs at the recommended dose. It caused only seven per cent mortality of third instar larvae of *C. carnea*. Spinosad was safe to predators (predatory bugs, spider and green lace wing) and parasitoids (*Trichogramma chilonis* Ishii) whereas conventional insecticides caused higher mortality (Dhawan, 2000).

The present finding was in agreement with the report of Bueno and Freitas (2004) that *Chrysoperla externa* Hagen egg viability was not affected by abamectin. Neonate larvae from abamectin sprayed eggs as well as first, second and third instar larvae that were directly treated, developed normally and yielded normal adults. Likewise, the present finding was in tune with Giolo *et al.* (2009) who reported that abamectin was slightly harmful to *C. carnea* larvae when exposure to fresh pesticide residue on glass plates and found harmless after direct spraying on eggs and pupae. Alexandre *et al.* (2010) concluded that abamectin, sulfur, and trichlorfon were harmless when applied to adults, while carbaryl, fenitrothion, and methidathion were harmful, according to the IOBC classification.

Abamectin has translaminar activity which provides residual activity against foliage feeding insects, but the surface residues degrade rapidly, making it less hazardous to beneficial organisms (Aston *et al.*, 2001). This is in line with the finding of Giolo *et al.* (2009) who reported that abamectin was classified as short lived in the persistence tests, and therefore it could be considered for use in Integrated Pest Management (IPM) programs under special conditions (i.e. reduced direct contact).

In the present study, chlorpyrifos and cypermethrin recorded 13.3 and 20.0 per cent unhatched eggs, respectively, besides reduced adult longevity and fecundity. This finding is in conformity with the results of Krishnamoorthy (1985) who reported that the newly hatched

larvae of *C. carnea* were more susceptible to organophosphates, carbamates and pyrethroids when compared to the egg stage. Shour and Crowdar (1980) stated that fenvalerate affected the larval survival, adult emergence, fecundity and female life span of *C. carnea*. Our findings deviated from the findings of Singh and Varma (1986) who stated that that chlorpyrifos caused 74 per cent larval mortality over a 72-h period when freshly emerged larvae of *C. carnea* were released on insecticide-treated food (eggs of *C. cephalonica*) for 24 h, whereas cypermethrin recorded 38.1 per cent.

A selective insecticide is one that is more toxic to the pests than to non targets (Croft, 1990). The low level of adverse impact of abamectin to natural enemy observed in the laboratory will not be the same in the field. Care should be taken while spraying abamectin in the field when *C. carnea* is there and the parasitoid releases should not coincide with the insecticide spray. Abamectin, however, was found harmless to *C. carnea*.

## References

- Alexandre P. M., Carvalho, G. A. Moscardini, V. F. Lasmar, O. Rezende D. T. and Marques, M. C. 2010. Selectivity of Pesticides used in Integrated Apple Production to the Lacewing, *Chrysoperla externa*. *Journal of Insect Science* **10**(121): 1-20.
- Aston, S., Streit, L. McKee K. and Clarke. C. 2001. Field selectivity makes emamectin suitable for IPM. In: Proc. 10th Australian Agronomy Conf., Hobart. pp.41-47.
- Badawy, H.M.A and Arnaouty. S.A.E. 1999. Direct and indirect effects of some insecticides on *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). *Journal of Neuropterology*, **2**: 67-74.
- Birah, A. 2008. Effect of abamectin against bollworm complex and yield response in cotton. *International Journal of Operational Research* **70**(1):75-79
- Bueno, A.F and Freitas. S. 2004. Effect of the insecticides abamectin and lufenuron on eggs and larvae of *Chrysoperla externa* under laboratory conditions. *BioControl*, **49**(3): 277-283.
- Chelladurai, M. 1999. *Studies on bioefficacy of betacyfluthrin against Helicoverpa armigera (Hub.) and Spodopteralitura (Fab.) (Noctuidae: Lepidoptera) on groundnut (Arachis hypogaea L.) and determination of residues.* Unpub. M.Sc. (Ag.) Thesis, Tamil Nadu Agric. Univ., Coimbatore, India, 126p.



- Croft, B.A. 1990. Arthropodbiological control agents and pesticides. Wiley International SciencePublication, New York. 130 p.
- Dhawan, A.K. 2000. Impactofsome new insecticideson natural enemycomplexofcottonecosystem. *Pestology*, **24**(5): 8-14.
- Giolo, F.P., Medina, P. GrutzmacherA.D. and Vinuela, E. 2009. Effectsofpesticidescommonlyused in peachorchards in Brazilonpredatorylacewing*Chrysoperla carnea*underlaboratoryconditions. *Bio Control*, **54**: 625-635.
- Gomez, K.A andGomez A.A. 1976. StatisticalProceduresforAgriculturalResearchwithSpecialEmphasison Rice. Int. Rice Res. Institute, Los Banos, Philippines, 368 pp.
- Gomez, K.A andGomez A.A. 1984. StatisticalProceduresforAgriculturalResearch. Wiley, New York, 680 pp.
- Hagen, K.S., Mills, N.J. GordhG and McMurtry, J.A. 1999. TerrestrialArthropodPredatorsofInsect and Mite Pests, Chrysopidae. In: HandbookofBiological Control: Principles and ApplicationsofBiological Control, Bellows T.S. and T.W. Fisher (Eds.). AcademicPress, San Diego, California, pp: 415-423.
- Hassan, S.A. 1989. Testingmethodology and theconceptsofthe IOBC/WPRS Workinggroup. p. 1–18. In: “Pesticides and Non Target Invertebrates” (P.C. Jepson, ed.). Intercept, Wimborn, Dorset, 240 pp.
- Krishnamoorthy, A. 1985. Effectofseveralpesticidesoneggs, larvae and adultsofthegreenlacewing*Chrysopascelestes* (Banks). *Entomon*, **10**(1): 21-28.
- Mandour, N.S., 2009. Influenceofspinosadonimmature and adultstagesof*Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). *Bio Control*, **54**: 93-102.
- Mccutchen B.F andPlapp. F.W. 1988. Monitoringprocedureforresistancetosyntheticpyrethroids in tobaccobollwormlarvae. p. 356–358. In: Proc. Beltwide Cotton Prod. Res. Conf., New Orelans. Natl. Cotton Council ofAmerica. Memphis Teen, 3–8 January 1988.
- Nadel, H., Johnson, M.W. GerikM.andDaane, K.M. 2007. Ingestionofspinosadbait GF-120 and resultingimpactonadult*Chrysoperla carnea* (Neuroptera: Chrysopidae). *BiocontrolScience and Technology*,**17**:995-1008.
- Nasreen, A., Ashfaq, M.andMustafa,G.2000. Intrinsicotoxicityofsomeinsecticidestoeggparasitoid, *Trichogrammachilonis* (Hymenoptera:Trichogrammatidae). Bull. Inst. Trop. Agri. Kyushu Univ. **23**: 41–44.
- Nordlund, D.A., Cohen A.C. and Smith,R.A.2001. Mass-Rearing, ReleaseTechniques, and Augmentation. In: Lacewings in theCropEnvironment, McEwen P.K., T.R. New and A.E. Whittington (Eds.). Cambridge UniversityPress, Cambridge, pp: 303-319.
- Rezaei, M., Talebi, K. NavehV.H. and Kavousi, A. 2007. Impactsofthepesticides imidaclopid, propargite, and pymetrozineon*Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae): IOBC and life table assays. *Bio Control*, **52**: 385-398.

- Ridgway, R.L. and McMuphy, W.L. 1984. Biological Control in the Field. In: Biology of Chrysopidae, Canard, M., Y. Semeria and T.R. New (Eds.). W. Junk Publisher, Boston, The Hague, pp: 220-228.
- Schneider, M.I., Sanchez, N. Pineda, S. Chi H. and Ronco, A. 2009. Impact of glyphosate on the development, fertility and demography of *Chrysoperla externa* (Neuroptera: Chrysopidae): Ecological approach. *Chemosphere* **76**: 1451-1455.
- Shour, M.H and Crowder, L.A. 1980. Effects of pyrethroid insecticides on the common green lacewing. *Journal of Economic Entomology* **73**(2): 306-309.
- Silva, R.A., Carvalho, G.A. Carvalho, C.F. Reis, P.R. Pereira A.M.A.R. and Cosme, L.V. 2005. Toxicity of pesticides used in coffee crop to larvae of *Chrysoperla externa* (Hagen) (Neuroptera: Chrysopidae) and their effects on subsequent stages of the predator. *Neotropical Entomology*, **34**: 951-959.
- Silva, R.A., Carvalho G.A. Carvalho, C.F. Reis, P.R. Souza B and Pereira, A.M.A.R. 2006. Action of pesticides used in coffee crop on the pupae and adults of *Chrysoperla externa* (Hagen, 1861) (Neuroptera: Chrysopidae). *Cienc. Rural*, **36**: 8-14.
- Singh P. P. and Varma G. C. 1986. Comparative toxicities of some insecticides to *Chrysoperla carnea* (Chrysopidae: Neuroptera) and *Trichogramma brasiliensis* (Trichogrammatidae: Hymenoptera), two arthropod natural enemies of cotton pests. *Agriculture, Ecosystems & Environment*. **15**(1): 23-30.
- Swamiappan, M. 1996. Mass production of Chrysopa. In: National training on mass multiplication of biocontrol agents, Training division, DDE, Tamil Nadu Agric. Univ., Coimbatore, India. 95p.

**Table 1 Safety of abamectin 1.9 EC to eggs and adults of green lacewing *Chrysoperla carnea* Stephens**

(Mean of three observations)

| Treatments                                  | Per cent egg hatchability*    | Per cent unhatched eggs*     | Adult longevity (days)#     | No. of eggs laid by five pairs of adults # |
|---|-------------------------------|------------------------------|-----------------------------|--|
| Abamectin 1.9 EC @ 1.0 ml l <sup>-1</sup>   | 93.3<br>(75.17) <sup>b</sup>  | 6.7<br>(14.95) <sup>b</sup>  | 10.3<br>(3.28) <sup>b</sup> | 185.0<br>(13.62) <sup>b</sup>              |
| Abamectin 1.9 EC @ 1.2 ml l <sup>-1</sup>   | 93.3<br>(75.17) <sup>b</sup>  | 6.7<br>(14.95) <sup>b</sup>  | 9.7<br>(3.20) <sup>b</sup>  | 173.7<br>(13.20) <sup>bc</sup>             |
| Abamectin 1.9 EC @ 1.4 ml l <sup>-1</sup>   | 93.3<br>(75.17) <sup>b</sup>  | 6.7<br>(14.95) <sup>b</sup>  | 9.3<br>(3.12) <sup>bc</sup> | 161.7<br>(12.73) <sup>cd</sup>             |
| Abamectin 1.9 EC @ 1.6 ml l <sup>-1</sup>   | 90.0<br>(71.64) <sup>bc</sup> | 10.0<br>(18.42) <sup>c</sup> | 8.8<br>(3.05) <sup>bc</sup> | 149.7<br>(12.25) <sup>de</sup>             |
| Abamectin 1.9 EC @ 2.0 ml l <sup>-1</sup>   | 90.0<br>(71.64) <sup>bc</sup> | 10.0<br>(18.42) <sup>c</sup> | 8.3<br>(2.97) <sup>bc</sup> | 138.0<br>(11.76) <sup>e</sup>              |
| Abamectin 1.9 EC @ 2.4 ml l <sup>-1</sup>   | 86.7<br>(68.62) <sup>c</sup>  | 13.3<br>(21.40) <sup>d</sup> | 7.5<br>(2.82) <sup>cd</sup> | 116.0<br>(10.79) <sup>f</sup>              |
| Spinosad 45 SC @ 0.3 ml l <sup>-1</sup>     | 93.3<br>(75.17) <sup>b</sup>  | 6.7<br>(14.95) <sup>b</sup>  | 9.1<br>(3.10) <sup>bc</sup> | 153.3<br>(12.40) <sup>de</sup>             |
| Cypermethrin 10 EC @ 1.5 ml l <sup>-1</sup> | 80.0<br>(75.17) <sup>d</sup>  | 20.0<br>(26.55) <sup>e</sup> | 3.5<br>(2.00) <sup>e</sup>  | 47.0<br>(6.87) <sup>h</sup>                |
| Chlorpyrifos 20 EC @ 2.4 ml l <sup>-1</sup> | 86.7<br>(68.62) <sup>c</sup>  | 13.3<br>(21.40) <sup>d</sup> | 5.9<br>(2.53) <sup>d</sup>  | 100.3<br>(10.03) <sup>g</sup>              |
| Untreated check                             | 96.7<br>(79.93) <sup>a</sup>  | 3.3<br>(10.51) <sup>a</sup>  | 14.7<br>(3.90) <sup>a</sup> | 253.0<br>(15.93) <sup>a</sup>              |

In a column means followed by a common letter are not significantly different at P = 0.05 by DMRT

\*Figures in parentheses are arcsine  $\sqrt{P}$  transformed values

#Figures in parentheses are  $\sqrt{x+0.5}$  transformed values

**Table 2. Safety of abamectin 1.9 EC to grubs of green lacewing *C. carnea***

(Mean of three observations)

| Treatments                                  | Larval feeding method         |                               |                               | Dry film method               |                               |                               |
|---|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
|   | Per cent mortality            | Per cent pupation             | Per cent adult emergence      | Per cent mortality            | Per cent pupation             | Per cent adult emergence      |
| Abamectin 1.9 EC @ 1.0 ml l <sup>-1</sup>   | 6.7<br>(15.00) <sup>b</sup>   | 96.4<br>(79.61) <sup>b</sup>  | 100.0<br>(89.43) <sup>a</sup> | 6.7<br>(15.00) <sup>b</sup>   | 92.9<br>(74.65) <sup>b</sup>  | 100.0<br>(89.43) <sup>a</sup> |
| Abamectin 1.9 EC @ 1.2 ml l <sup>-1</sup>   | 13.3<br>(21.37) <sup>c</sup>  | 92.3<br>(74.05) <sup>c</sup>  | 95.8<br>(78.63) <sup>b</sup>  | 16.7<br>(24.11) <sup>c</sup>  | 88.0<br>(69.80) <sup>c</sup>  | 95.5<br>(78.04) <sup>b</sup>  |
| Abamectin 1.9 EC @ 1.4 ml l <sup>-1</sup>   | 16.7<br>(24.05) <sup>d</sup>  | 92.0<br>(73.71) <sup>c</sup>  | 91.3<br>(72.96) <sup>c</sup>  | 20.0<br>(26.51) <sup>cd</sup> | 87.5<br>(69.46) <sup>cd</sup> | 90.5<br>(72.12) <sup>c</sup>  |
| Abamectin 1.9 EC @ 1.6 ml l <sup>-1</sup>   | 23.3<br>(28.85) <sup>e</sup>  | 87.0<br>(68.98) <sup>cd</sup> | 85.0<br>(67.33) <sup>d</sup>  | 26.7<br>(31.11) <sup>e</sup>  | 81.8<br>(64.83) <sup>d</sup>  | 83.3<br>(65.98) <sup>d</sup>  |
| Abamectin 1.9 EC @ 2.0 ml l <sup>-1</sup>   | 30.0<br>(33.21) <sup>f</sup>  | 81.0<br>(64.20) <sup>de</sup> | 70.6<br>(57.20) <sup>e</sup>  | 33.3<br>(35.24) <sup>f</sup>  | 75.0<br>(60.05) <sup>e</sup>  | 66.7<br>(54.78) <sup>e</sup>  |
| Abamectin 1.9 EC @ 2.4 ml l <sup>-1</sup>   | 36.7<br>(37.28) <sup>g</sup>  | 68.4<br>(55.84) <sup>f</sup>  | 61.5<br>(51.66) <sup>f</sup>  | 40.0<br>(39.23) <sup>g</sup>  | 66.7<br>(54.78) <sup>f</sup>  | 58.3<br>(49.79) <sup>f</sup>  |
| Spinosad 45 SC @ 0.3 ml l <sup>-1</sup>     | 20.0<br>(26.56) <sup>de</sup> | 87.5<br>(69.46) <sup>c</sup>  | 85.7<br>(67.91) <sup>d</sup>  | 23.3<br>(28.85) <sup>de</sup> | 82.6<br>(65.44) <sup>cd</sup> | 84.2<br>(66.69) <sup>d</sup>  |
| Cypermethrin 10 EC @ 1.5 ml l <sup>-1</sup> | 46.7<br>(43.10) <sup>h</sup>  | 56.3<br>(48.60) <sup>g</sup>  | 44.4<br>(41.78) <sup>g</sup>  | 50.0<br>(45.00) <sup>h</sup>  | 53.3<br>(46.90) <sup>g</sup>  | 37.5<br>(37.74) <sup>g</sup>  |
| Chlorpyrifos 20 EC @ 2.4 ml l <sup>-1</sup> | 30.0<br>(33.18) <sup>f</sup>  | 76.2<br>(60.85) <sup>e</sup>  | 68.8<br>(56.04) <sup>ef</sup> | 33.3<br>(35.22) <sup>f</sup>  | 70.0<br>(56.82) <sup>ef</sup> | 71.4<br>(57.72) <sup>e</sup>  |
| Untreated check                             | 3.3<br>(10.51) <sup>a</sup>   | 100.0<br>(89.43) <sup>a</sup> | 100.0<br>(89.43) <sup>a</sup> | 3.3<br>(10.47) <sup>a</sup>   | 100.0<br>(89.43) <sup>a</sup> | 100.0<br>(89.43) <sup>a</sup> |

In a column means followed by a common letter are not significantly different at P = 0.05 by DMRT

Figures in parentheses are arcsine  $\sqrt{P}$  transformed values