Journal of Entomology

ISSN 1812-5670

Academic Journals Inc.

www.academicjournals.com

Journal of Entomology 11 (6): 306-318, 2014
ISSN 1812-5670 / DOI: 10.3923/je.2014.306.318

Effect of Lambdacyhalothrin 5% EC on *Cheilomenes lunata*, *Cheilomenes sulphurea* and *Cheilomenes propinqua* (Colleoptera: Coccinellidae) Predators of Cotton Aphids (*Aphis gossypii*) (Homoptera: Aphididae), in Eastern Tanzania

[1]F. Mrosso, [2]M. Mwatawala and [2]G. Rwegasira
[1]Ilonga Agricultural Research Institute, P.O. Box 33, Kilosa, Tanzania
[2]Department of Crop Science and Production, Faculty of Agriculture, Sokoine University of Agriculture, P.O. Box 3005, Morogoro, Tanzania

Corresponding Author: F. Mrosso, Ilonga Agricultural Research Institute, P.O. Box 33, Kilosa, Tanzania

ABSTRACT

This study investigated the effects of Lambdacyhalothrin 5% EC, insecticide, on three aphidophagous coccinellid species, *Cheilomenes lunata*, *C. sulphurea* and *C. propinqua* in cotton fields. The insecticide was tested on one 0.2 ha cotton field and an unsprayed control field of the same area. Lambdacyhalothrin 5% EC was sprayed at intervals of ten days with a total of six sprays in a season. Sampling followed a standard procedure in which twenty plants at the middle of the fields in each field were randomly selected and examined for coccinellids and aphids one day before and three days after each spray. Results show that Lambdacyhalothrin 5% EC has an impact on coccinellid populations. Larvae populations of coccinellids were reduced by 24, 28 and 49% for *C. lunata*, *C. sulphurea* and *C. propinqua* and 57, 50 and 39% in the first and second year, respectively. There were no significant differences in aphid populations between sprayed and unsprayed fields. These results suggest that coccinellids had a similar impact as Lambdacyhalothrin 5% EC in the reduction of aphid populations. The study concludes that Lamdacyhalothrin 5% EC could continue to be used as a strategic intervention to manage cotton aphids during the last sprays. If the insecticide is sprayed during the last sprays in the season, the coccinellids would have already finished their task of reducing the aphid populations in a particular field.

Key words: *Aphis gossypii*, coccinellids, lambdacyhalothrin 5% EC, biocontrol, Tanzania

INTRODUCTION

Insect pests are major setbacks of increased cotton production in eastern Tanzania (Kabissa, 1993). Average seed cotton yields obtained from sprayed and unsprayed cotton fields for four consecutive years from 2004-2007 in eastern part of the country were found to be 1650 and 442 kg ha^{-1}, respectively (Mrosso and Temu, 2008). This difference in yield is approximately 73% loss. The two most devastating insect pests of cotton in Tanzania are *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) and cotton aphids (*Aphis gossypii* Glover) (Homoptera: Aphididae) (Mrosso *et al.*, 2006). The *Helicoverpa armigera* is a bollworm which causes flared squares and dropping of fruiting bodies of the cotton plants. The *Aphis gossypii* is a sucking insect pest causing leaf curl and transmits diseases such as nematospora fungal disease resulting in weakening of the cotton plants. Cotton aphids are known to contaminate lint of the opened bolls by sugary excretions (honeydew) which ferment into sooty substance that may cause clogging problems during textile operations. The management of cotton aphids relies largely on the use of synthetic insecticides. The recommended insecticides for the control of cotton aphids are systemic insecticides such as organophosphates (Kabissa, 1993) and recently, Imidacloprid-based insecticides have shown a high efficacy on the insect pest. However, due to escalated prices of insecticides, farmers in the eastern zone of Tanzania prefer to use pyrethroid based insecticides mainly Lambdacyhalothrin 5% EC. Lambdacyhalothrin 5% EC is comparatively cheaper than systemic insecticides. Despite of pyrethroid based insecticides being less toxic to warm blooded animals and high knockdown effect on insects (Li and Harmsen, 1993; Wirtz *et al.*, 2009; Carca, 2011), it affect populations of natural enemies of several agricultural insect pests (Hoyt *et al.*, 1978; Zwick and Fields, 1978; Chapman and Penman, 1979; Fournier *et al.*, 1985). The negative effect of Lambdacyhalothrin 5% EC on some natural enemies of cotton of aphids and environmental concerns has increased the demand for alternative management options of cotton aphids which are friendly to the environment. This may include conserving predatory coccinellids and if Lambdacyhalothrin 5% EC should be used, it must be within an integrated aphid management system. In the above scenario, Lambdacyhalothrin 5% EC can be used during the last one or two sprays. The recommended number of sprays in the ECGA are six the first being at flowering, which occurs eight weeks after planting. The other sprays are carried out at intervals of 10 days (Kabissa, 1993; Mrosso *et al.*, 2006). This spray regime affects coccinellids and other predators which are suppressing the population of cotton aphids. Coccinellids have been known for a very long time as potential biocontrol agents for cotton aphids (Obrycki and Kring, 1998; Wells *et al.*, 2001; Rondon *et al.*, 2005; Conway and Kring, 2010). Their effectiveness is due to the feeding activity of the adults and the larvae; both consume cotton aphids. They have bright shining coloration, some with spots and contrasting background which is a characteristic of many coccinellid species (Joshi and Sharma, 2008). The body sizes (i.e., body lengths) of the adults of the study species are approximately 5.65, 5.51 and 4.22 mm (males) and 6.68, 6.75 and 5.01 mm (females) for *C. lunata*, *C. sulphurea* and *C. propinqua*, respectively (F.P.M, unpublished data). They consume aphids (prey) and other soft bodied insects (Veesar *et al.*, 2012). Aphids are tiny, usually green, soft-bodied, pear-shaped insects injurious to vegetation (Capinera, 2009). They are polyphagous (Kerns and Gaylor, 1993) and are found almost every place where cotton is cultivated. These predatory coccinellids could be one of the potential candidates for use as aphid biocontrol agents in the ECGA because they are native and freely available in most places where cotton is grown in the area. Three most predatory coccinellids which are found in the ECGA includes *Cheilomenes propinqua*, *C. sulphurea* and *C. lunata*. The survival of these coccinellids in the ECGA is threatened by the intensive use of synthetic pyrethroids. Coccinellids are affected by several insecticides including plant extract insecticide (Ofuya, 1997). However, if IPM techniques are followed, effect of insecticides to the coccinellids would be reduced. Most of the ECGA cotton farmers does not follow IPM techniques. The IPM strategy could be the most appropriate remedial measure that would ensure survival of the bio-control agents. Before developing an IPM programme it is necessary to evaluate the impact of Lambdacyhalothrin 5% EC on the three coccinellid species in the ECGA. The objective of the current study was therefore, to establish the effect of Lambdacyhalothrin 5% EC on populations of the three coccinellids, *C. propinqua*, *C. sulphurea* and *C. lunata* in cotton fields infested with *A. gossypii*.

MATERIALS AND METHODS

Experimental site: Studies were conducted for two consecutive years (2011 and 2012) during February to August at Ilonga Agricultural Research Institute (IARI), (S 06°46': E 037°02') in Kilosa District, Tanzania. Tests were carried out in two cotton fields measuring 0.2 ha each separated by 3 m apart to avoid drift of chemicals during spraying operations. The experiments conducted under rain fed conditions.

Test insects: The study insects were three species of predatory coccinellids, *C. propinqua*, *C. sulphurea* and *C. lunata* naturally found in cotton fields in ECGA. The target pest was cotton aphids which are preyed by coccinellids.

Field management and data collection: The cotton variety Mkombozi which is commercially cultivated in the whole of the ECGA of Tanzania was planted in the two experimental fields. The agronomic practices, which are recommended for farmers in the ECGA, were followed. Cotton was planted between 15-20 February at a spacing of 0.3 m within and 0.9 m between rows. The seed rate used was 25 kg ha^{-1} of fuzzy seed and thinning was done three weeks after planting. The insecticide was sprayed during flowering stage. Lambdacyhalothrin 5% EC was sprayed at a rate of 0.4 l ha^{-1} using a knapsack sprayer (Matabi Super Green 16). This rate is the one recommended for cotton in the ECGA. No fertilizer was applied. The method for determination of effect of insecticide on biocontrol agents described by Tillman and Mulrooney (2000) was followed. During sampling of coccinellids, twenty plants were selected randomly in each field, when they were approximately 8 weeks old and tagged with coloured tape. Three leaves in the lower part, middle and top of the plant were selected randomly for aphid sampling. Each leaf was tagged at the petiole.

Data was collected at one day before and three days after spraying. The field was sprayed six times in a season. A hand lens was used for easy identification and counting of the aphids. Aphids were counted on the underside of every leaf and recorded. Adult and larvae of coccinellids were counted on whole plants.

Statistical analysis: The counts of the larvae and beetles that were obtained from the sprayed and unsprayed fields were subjected to T-test (Graphpad.com/ quickcalcs/ttest2/) to know the effect of the insecticide on the coccinellid. In order to know which coccinellid was most affected by the insecticide in the sprayed field, the mean percentage difference between sprayed and unsprayed fields were calculated. The calculated percentage differences were compared between species using T-test (Graphpad.com/quickcalcs/ttest2/). Average counts of coccinellid larvae, beetles and that of aphid in ten days interval were subjected to bar graphs using Microspft Excel Programme 2007.

RESULTS

Abundances of predatory coccinellids, *Cheilomenes lunata*, *C. sulphurea* and *C. propinqua*: Colonization of the fields by the predatory coccinellids occurred from mid to late May in both years of the study and continued up to the end of June. The highest populations of coccinellid larvae were recorded between late May to early June in 2011 and 2012 (Fig. 1a, b).

Same trend was observed for the beetles in 2011 and 2012 (Fig. 2a, b). At any given spraying interval the populations of the predatory coccinellids in the sprayed field were lower than the populations in the unsprayed field (Fig. 1a, b for larvae and adults, respectively) during 2011 and 2012.

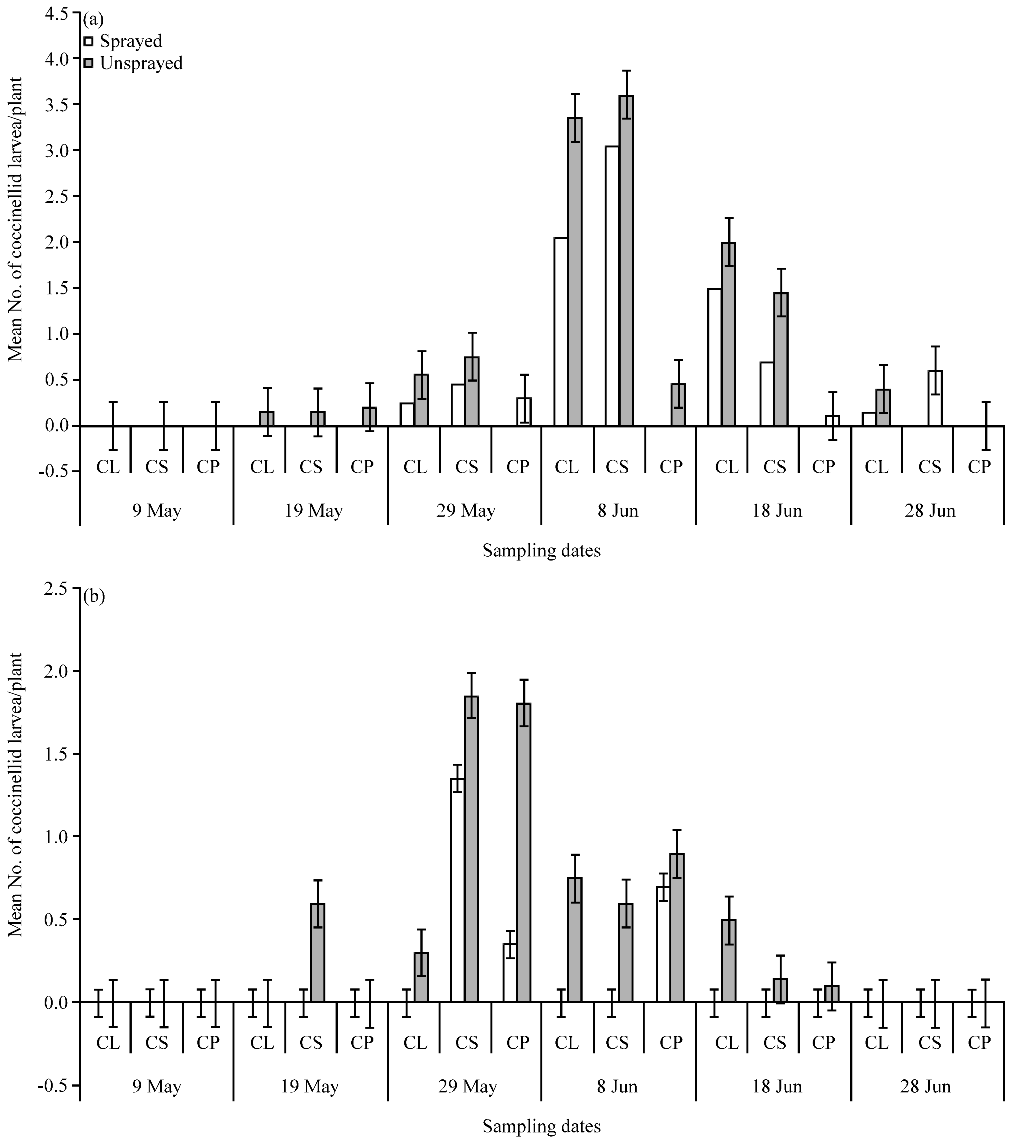

Fig. 1(a-b): Abundance of *Cheilomenes lunata* (CL), *C. sulphurea* (CS) and *C. propinqua* (CP) larvae at ten days interval during peak reproductive stage of cotton plants in cotton fields with or without Lambdacyhalothrin 5% EC insecticide treatment (N = 20) in, (a) 2011 and (b) 2012

Effect of Lambdacyhalothrin 5% EC on the predatory coccinellids: The mean number of larvae and adult populations of predatory coccinellids, *C. lunata*, *C. sulphurea* and *C. propinqua* in the sprayed field were significantly ($p<0.05$) lower than the mean numbers obtained in the unsprayed field in 2011 (Table 1). Similar trend was obtained in 2012 (Table 1). The results suggests that Lambdacyhalothrin 5% EC had negative effects on the tested coccinellids in both years of the study.

Comparisons of effect of insecticide on predatory coccinellid species and which coccinellid mostly affected by the insecticide: The effect of Lambdacyhalothrin 5% EC on the coccinellid larvae of different species in the 2011 spray season is shown in Fig. 3a. There were no

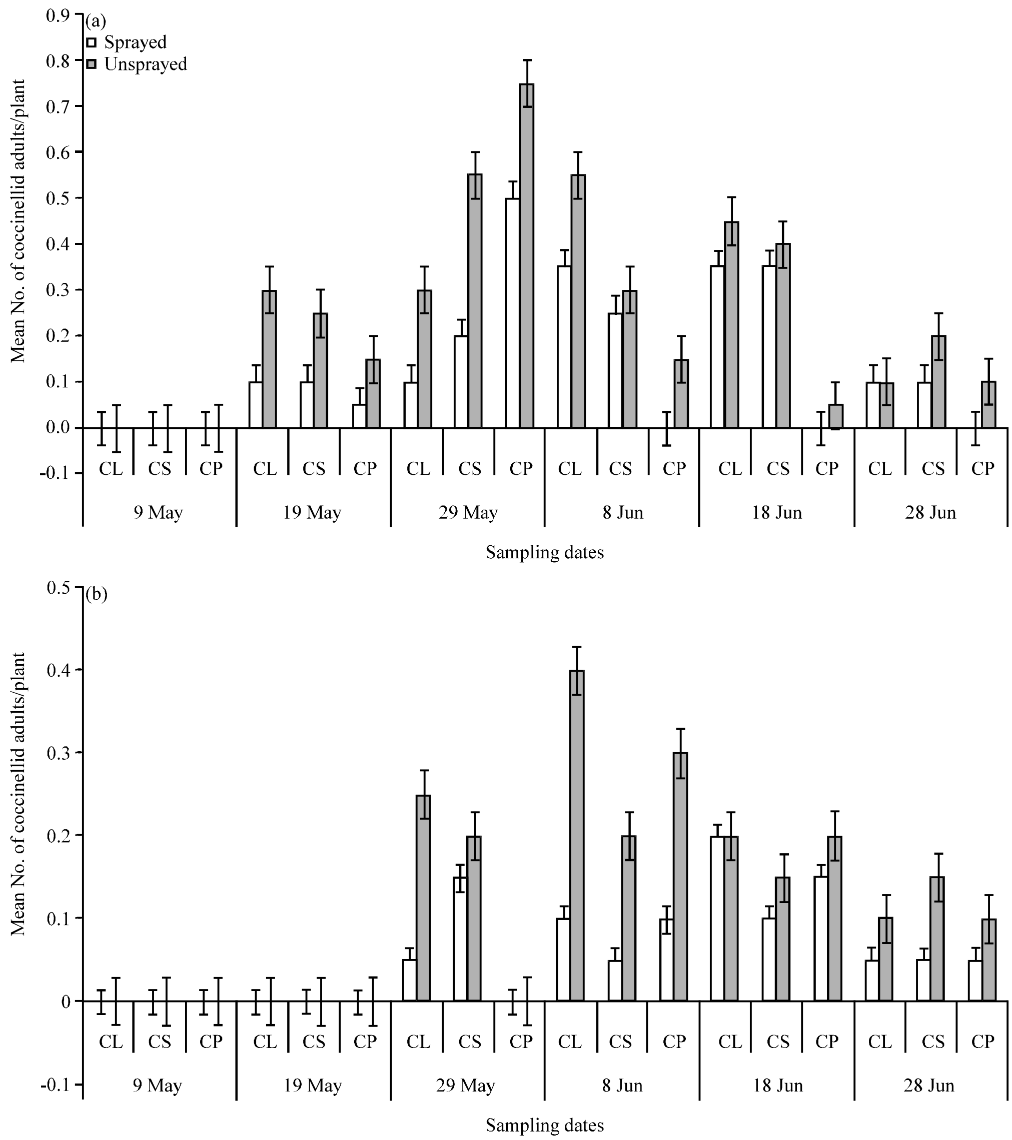

Fig. 2(a-b): Abundance of *Cheilomenes lunata* (CL), *C. sulphurea* (CS) and *C. propinqua* (CP) beetles at ten days interval during peak reproductive stage of cotton plants in cotton fields with or without Lambdacyhalothrin 5% EC insecticide treatment (N = 20) in, (a) 2011 and (b) 2012

significant differences ($p>0.05$) on their effects on larvae of different species of coccinellids during the 2011 season. Similar results were obtained during the 2012 season (Fig. 3b). These results suggest that larva populations are uniformly affected by Lambdacyhalothrin 5% EC irrespective of species.

However, for the adult beetles the mean percentage differences were significantly higher ($p<0.05$) for *C. propinqua* when compared to the mean percentages of the other two species (Fig. 4a). There were no significant mean percentage differences ($p>0.05$) between *C. lunata* and *C. sulphurea* beetles (Fig. 4a).

Table 1: Effect of lambdacyhalothrin 5% EC on larvae and adult predatory coccinellids in 2011 and 2012 (Mean±SE), N = 20 plants (sampled six times)

	Mean larvae/plant[a]				Mean beetles/plant[a]			
Coccinellid	Sprayed	Unsprayed	p	t	Sprayed	Unsprayed	p	t
Results obtained in 2011								
C. lunata	0.68±0.21	0.90±0.20	0.009	4.09	0.44±0.06	0.55±0.08	0.039	2.76
C. sulphurea	0.66±0.24	0.92±0.21	0.028	3.03	0.44±0.05	0.55±0.07	0.030	2.81
C. propinqua	0.22±0.00	0.43±0.19	0.043	2.68	0.32±0.08	0.45±0.09	0.009	4.12
Results obtained in 2012								
C. lunata	0.22±0.00	0.51±0.11	0.046	2.63	0.33±0.04	0.50±0.07	0.020	3.30
C. sulphurea	0.38±0.15	0.69±0.66	0.025	3.16	0.32±0.03	0.43±0.04	0.011	3.88
C. propinqua	0.40±0.11	0.65±0.10	0.050	2.50	0.29±0.03	0.41±0.05	0.019	3.41

[a]Transformed data: SQRT (X + 0.05)

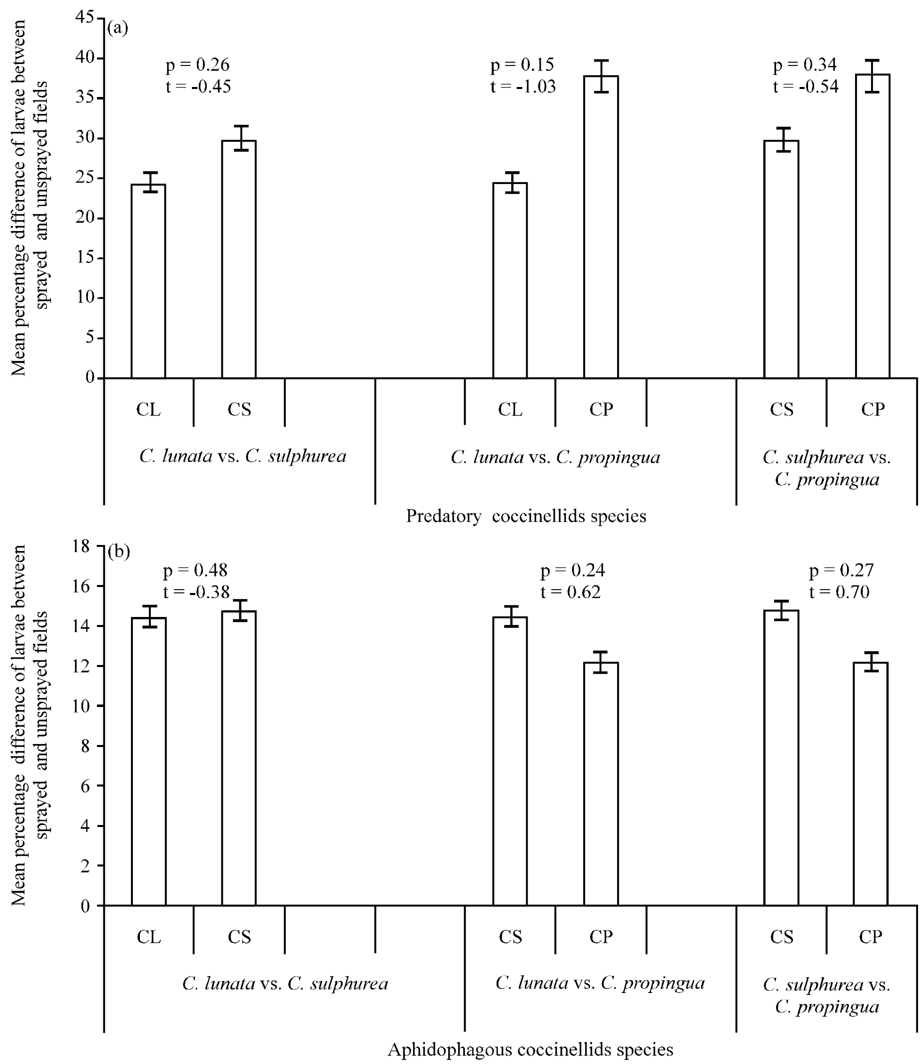

Fig. 3(a-b): Comparisons of the effect of Lambdacyhalothrin 5% EC on different species of coccinellid larvae in (a) 2011 and (b) 2012. (N = 20 plants/field)

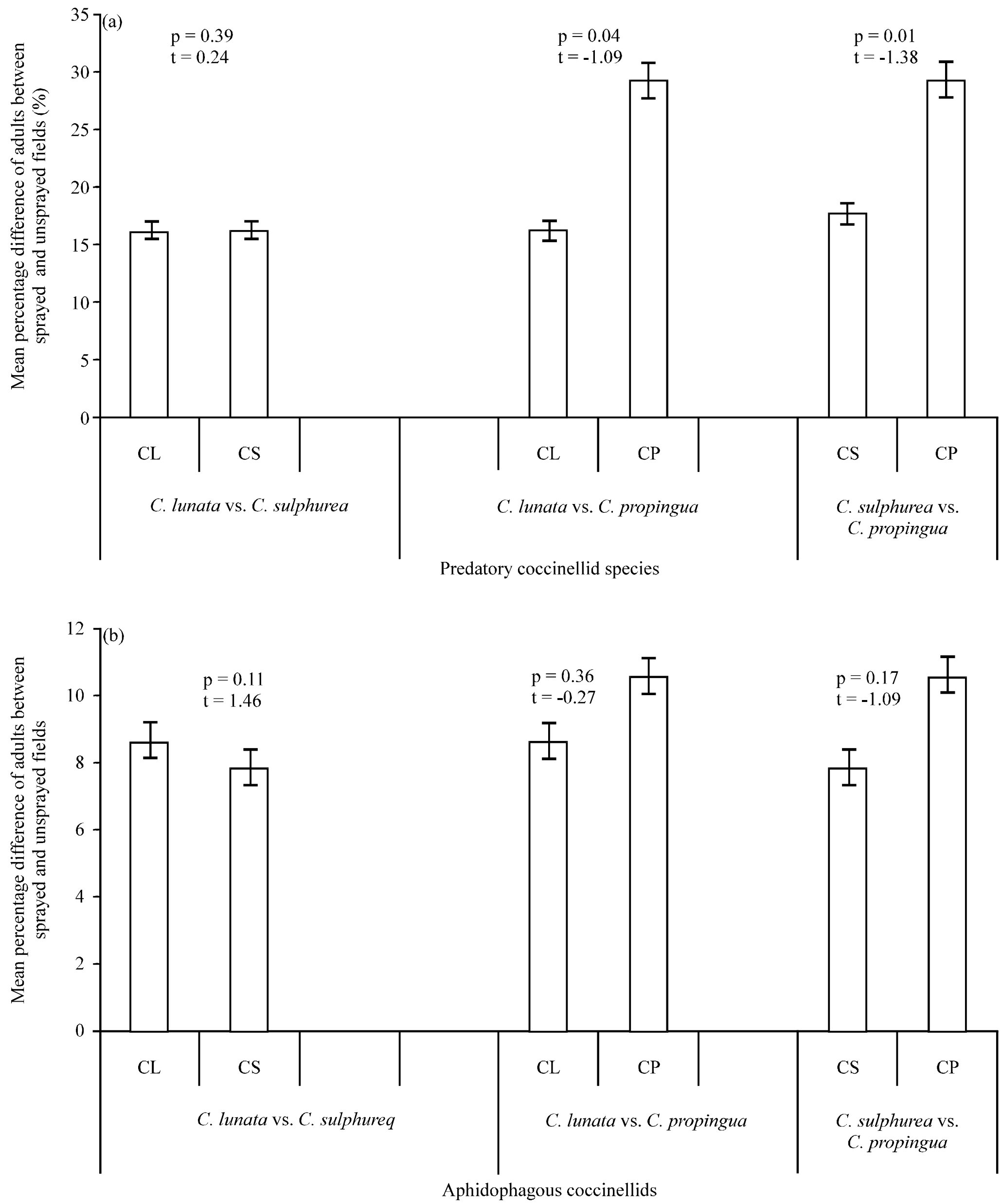

Fig. 4(a-b): Comparisons of the effect of Lambdacyhalothrin 5% EC on different species coccinellid adult beetle in, (a) 2011 and (b) 2012. (N = 20 plants/field)

These results show that *C. propinqua* adults are most affected by the insecticide compared to *C. sulphurea* and *C. lunata* adults. During the 2012 season, the mean percentage differences in population size did not differ significantly between the predatory species which indicates that the beetles were equally affected by the Lambdacyhalthrin 5% EC (Fig. 4b).

Effect of Lambdacyhalothrin 5% EC on *A. gossypii* population: The *Aphis gossypii* colonized cotton plants in early May and continued to infest the crop throughout the season. The highest

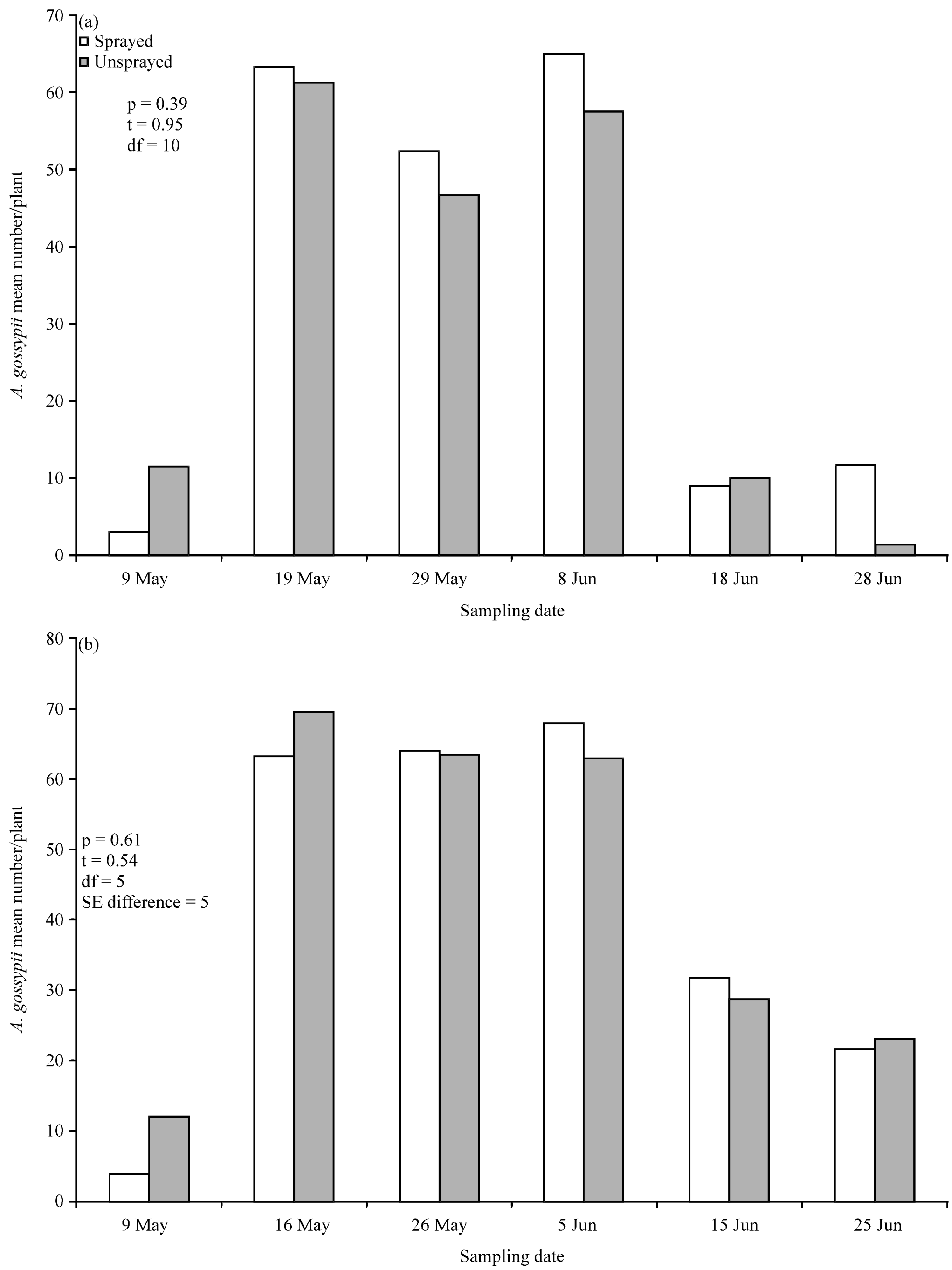

Fig. 5(a-b): Populations of *A. gossypii* at ten days interval during peak reproductive stage in fields with or without Lambdacyhalothrin 5% EC treatment in (a) 2011 and (b) 2012

aphid populations were recorded between mid May and early June 2011 (Fig. 5a). At any one spraying interval, the populations of aphids were similar in both spraying conditions with slight increase of aphids in the sprayed field during 19 May, 29 May, 8 June and 28 June (Fig. 5a), did not differ significantly ($p>0.05$). However, the mean number of aphids in the sprayed field in early May 2011 was slightly lower than the mean obtained from the unsprayed field (Fig. 5a) although not significant. In the 2012 season (Fig. 5b) the general population trend of mean number of aphid records was similar to that obtained in the 2011 season. The mean aphid population records of 9 May and 16 May from the sprayed field were slightly lower than the mean obtained from the unsprayed field. But after mid-May, three records of aphid population towards the end of the season in sprayed field were higher than the populations recorded from the unsprayed field but were not significantly different (Fig. 5b).

DISCUSSION

The results from this study show clearly that predatory coccinellids are vulnerable to synthetic Lambdacyhalothrin 5% EC insecticide. The chemical is commonly used for the control of insect and mites pests of cotton in eastern Tanzania. Generally, it had reduced the populations of all tested predatory coccinellids to a significant extent. These results suggest that there is no relative advantage of using any of the three species over the other i.e., *C. lunata*, *C. sulphurea* and *C. propinqua* in aphid management programs (IPM). However, the insecticide did not entirely exclude the coccinellids which supports the results obtained by House *et al.* (1985). The slight susceptibility of *C. propinqua* beetles to a sprayed insecticide over the other two species suggest that it would not be the most suitable for aphid control when compared to the rest in programs that would need to use pyrethroids in IPM. Its susceptibility could probably be caused by its small size compared to *C. lunata* and *C. sulphurea*. The observed non-significant impact of lambdacyhalothrin 5% EC to *A. gossypii* populations suggests two kinds of effects. One was that the insecticide used could have some impact in reducing aphid populations but in the unsprayed field the coccinellids together with other natural enemies had a greater impact on *A. gossypii* than the insecticide in the sprayed field. The other is that Lambdacyhalothrin 5% EC has a low impact in reducing populations of *A. gossypii* due to development of resistance in this insect pest. Several authors including Sun *et al.* (1994) and Amad *et al.* (2003) attributed lower control of aphids than expected due to development of resistance. The unsprayed field had higher mean number of aphids than the sprayed field early in the season although it was not significantly different. When the coccinellids and probably the other natural enemies started to colonize the field and increased in numbers, during mid-May, the unsprayed field had lower mean number of aphids compared to the sprayed field. This observation suggests that the coccinellids suppressed the aphids in the unsprayed field at higher extent than the Lambdacyhalothrin 5% EC.

It is important to note that a single predatory coccinellid may consume more than 300 aphids in a day (Chimoga, 2002). The predatory coccinellid populations were reduced in numbers in the sprayed field and most likely, the threshold population of predators required to suppress the aphid population was low and therefore resulting into greater numbers of the pest than in the unsprayed field. Tillman and Mulrooney (2000) reported similar results.

The larval abundance of the predatory coccinellids species were changing at each sampling occasions both in the sprayed and unsprayed condition, most certainly through a natural increase by reproduction. After the colonization of cotton by the coccinellids, the population increased steadily and achieved a peak during May to mid-June after which it dropped in both fields. It is important to note that the coccinellids lay an average of 250-750 eggs per female in the ECGA depending on prey populations in the field and favourable conditions, especially temperature (F.P.M., unpublished data). In the ECGA temperature starts dropping in early June which is associated with lower populations of coccinellids.

The lower mean populations of coccinellids in the sprayed field at any of the sampling occasions suggest that Lambdacyhalothrin 5% EC has adverse effects on the coccinellids whenever it was applied in the cotton growing cycle. This was also implied in the second season of the study. The observed reduction of the adult predatory coccinellid populations in the sprayed field at each sampling occasion during the 2011 and 2012 seasons suggest that the insecticide had the same effect on both the adult and larval coccinellids. The significant effect of Lambdacyhalothrin 5% EC on individual species during 2011 and 2012 indicates that the insecticide might lead to very low populations of predatory coccinellid that would colonize the field in subsequent seasons. This might lead to disruption of the predator-prey ecosystem. It is obvious that the mean number of *C. propinqua* and *C. sulphurea* larvae were reduced to approximately 50%.

The toxic effect of Lambdacyhalothrin on coccinellids has been reported by several authors (USDA, 1989; Tillman and Mulrooney, 2000). Studies by Tillman and Mulrooney (2000) indicated that Lmbdacyhalothrin had highest toxicity on two coccinellids, *Hippodamia convergens* and *Coleomegilla maculata*. These studies show that cotton fields which would be sprayed with Lambdacyhalothrin 5% EC without following Integrated Pest Management approach (IPM) might significantly lose the coccinellid populations. However, Lambdacyhalothrin 5% EC will probably continue to be sprayed on cotton for a long time because of its high knockdown efficacy (Wirtz *et al*., 2009; Carca, 2011), especially on the lepidopteran insect pests, low human toxicity (Carca, 2011) compared to other cotton insecticides and low cost. However, if it is used wisely following an IPM approach, it could be applied without much harm on predators in cotton ecosystems. This might be achieved by developing spray windows. In this case, three spraying windows are formed whereby for the case of ECGA, the first window would begin one week just before flowering, a second window at the third week after flowering and the third window during last sprays. In this scenario, the pyrethroid-based insecticide would be used during the last sprays when the predatory coccinellids are no longer needed during that particular season. The reduced predatory coccinellid population during the last sprays would re-establish during the off season in weed and wild plants waiting for the next cotton cropping season. This observation was also pointed out by Elliott *et al*. (1978) that the pyrethroids are used to control late season pests. Insecticides that are not too harmful to the coccinellids shall be used in the first and second spray windows. Some insecticides which are less toxic to coccinellids including Emamectin 5% SG (Jasmine and Kuttalam, 2011) and Fenvalerate have been indicated to be suitable for the conservation of coccinellids (Poehling, 1988) but others like Kaakeh *et al*. (1996) found them to be toxic. Some other insecticides (e.g., Acephate) have been indicated to have the lowest toxicity to predacious coccinellids (Obrycki and Kring, 1998). Fortunately, several newer insecticides are more judicious and selective than the earlier generations (Wood, 1988), enabling IPM programs to be conducted more smoothly.

This study suggests that there is no relative advantage of using one species of coccinellids over the other among three larvae species (*C. lunata*, *C. sulphurea* and *C. propinqua*) with regard to the magnitude of effect caused by the Lambdacyhalothrin 5% EC on them in the 2011 and 2012 seasons. The highest magnitude of the effect of Lambdacyhalothrin on adult *C. propinqua* was in the 2011 season which therefore suggests this species may not be the best choice as biocontrol agents in IPM programmes intending to use pyrethroid insecticides. The 2012 season results were similar to the 2011 season. Although these effects appeared higher for *C. propinqua*, but they were not significant. These results indicated almost similar effects of Lambdacyhalothrin on the three coccinellids. Some coccinellids respond differently when exposed to a certain insecticide. For example, Tillman and Mulrooney (2000) found that Lambdacyhalothrin residuals on cotton leaves had some effects on *Coleomegilla maculata* but not on *Hippodamia convergens*.

The *Aphis gossypii* started colonizing cotton fields in early May 2011 season and increased to a maximum between mid-May and early June. However, the population decreased sharply later in June. This period is also the period when the cotton in the Eastern Tanzania is at peak reproductive stage. Although populations numbers of *A. gossypii* were not statistically different between the sprayed and unsprayed fields, the recorded numbers during 9 May in the sprayed field indicated slightly lower mean number than in the unsprayed field. Thereafter during mid May, the population of aphids in the sprayed fields were slightly higher than the population from the unsprayed field although did not differ significantly. These results suggest that Lambdacyhalothrin 5% EC had little effect on the aphids compared to the coccinellids effect. The effect of lambdacyhalothrin on aphids was masked by the activity of the predatory coccinellids. It is important to note that coccinellids colonized the fields in mid-May, which is the period when the number of aphids started to decrease in the unsprayed field. The reason for the slightly higher number of aphids observed in the sprayed field was probably due to the fact that predatory coccinellids were killed by the synthetic insecticide applied and the effect of the insecticide was not enough to suppress the aphids as the coccinellids could do in the unsprayed field. This implied that activity of the insecticide used could not mask the activity of the coccinellids and probably other predatory fauna in that field. Studies by Hoyt *et al*. (1978), Zwick and Fields (1978), Hall (1979) and Li and Harmsen (1993) have indicated resurgence of mites because of predator exclusion caused by the application of pyrethroids. Probably Lambdacyhalothrin had the same effect in the current study on the populations of the coccinellids, consequently causing increase of aphid populations. During early May, the predatory coccinellids and probably other aphidophaghous bio-control agents were yet to colonize the fields. At that time, the activity of the Lambdacyhalothrin 5% EC was clearly noted.

It can be concluded that Lambdacyahlothrin 5% EC has a negative impact on the populations of both larvae and adult coccinellids. However, it is likely that it will continue to be used for an extended period because it is cheap; it has a high knockdown effect and low toxicity to mammals. It is further concluded that Lambdacyhalothrin 5% EC has lower activity on cotton aphids than the activity of coccinellids and other bio-control agents during the peak reproductive stage of cotton in eastern Tanzania. It is however important to note that due to difficulties involved in synchronizing various natural enemies in order to reduce several insect pests which might be present within the season, it is unlikely that bio-control agents will replace synthetic insecticides in the near future. Instead, integration of the two is vital.

CONCLUSION AND RECOMMENDATION

Since the effect of the insecticide was determined in open fields in this study, the reduction of the aphid populations was not necessary due to coccinellids alone. Some other natural enemies might have contributed in the reduction of aphid population in the unsprayed field. Therefore, further studies are needed to determine the individual roles of coccinellids and other bio-control agents in suppressing aphid populations in the field.

ACKNOWLEDGEMENTS

I would like to acknowledge Zonal Director, Research and Development for allowing us to undertake the study at Ilonga Agricultural Research Institute. Crop science and Production Department staff at the Sokoine University of Agriculture gave moral support during the whole period of the study. Cotton Research Staff at ARI did a great job of data recording. Gratitude is extended to the Manager, Cotton Development Trust Funds and the Principal Secretary Ministry of Agriculture, Food Security and Cooperatives for donating funds for the study.

REFERENCES

Amad, M., M.I. Arif and I. Denholm, 2003. High resistance of field populations of the cotton aphid *Aphis gossypii* Glover (Homoptera: Aphididae) to pyrethroid insecticides in Pakistan. J. Econ. Entomol., 96: 875-878.

Capinera, J.L., 2009. Melon aphid or cotton aphid, *Aphis gossypii* Glover (Insecta: Hemiptera: Aphididae). Publication No. EENY-173, Institute of Food and Agricultural Sciences (IFAS), University of Florida, USA., Revised June 2009, pp: 1-5.

Carca, P., 2011. Sublethal Effects of Pyrethroids on Insect Parasitoids: What We Need to Further Know. In: Pesticides: Formulations, Effects and Fate, Stoycheva, M. (Ed.). Chapter 24, InTech Publishing Co., Reijeka, Croatia, ISBN: 978-953-307-532-7, pp: 477-494.

Chapman, R.B. and D.R. Penman, 1979. Toxicity of synthetic pyrethroid insecticides to phytophagous orchard mites. Proceedings of the 32nd New Zealand Weed and Pest Control Society Conference, August 7-9, 1979, Dunedin, New Zealand, pp: 240-244.

Chimoga, A.R., 2002. Cotton aphid control strategy in Zimbabwe. The International Cotton Advisory Committee Report, Technical Information Section, The ICAC Recorder, Vol. 20, No. 2, June 2002.

Conway, H.E. and T.J. Kring, 2010. Coccinellids associated with the cotton aphid (Homoptera: Aphididae) in Northeast Arkansas cotton. J. Entomol. Sci., 45: 129-139.

Elliott, M., N.F. Janes and C. Potter, 1978. The future of pyrethroids in insect control. Annu. Rev. Entomol., 23: 443-469.

Fournier, D., M. Pmlavolio, J.B. Berge and A. Cuany, 1985. Pesticide Resistance in Phytoseiidae. In: Spider Mites: Their Biology, Natural Enemies and Control, Helle, W. and M.W. Sabelis (Eds.). Elsevier, Amsterdam, The Netherlands, ISBN-13: 9780444423740, pp: 423-430.

Hall, F.R., 1979. Effects of synthetic pyrethroids on major insect and mite pests of apple. J. Econ. Entomol., 72: 441-446.

House, G.J., J.N. All, K.T. Short and S.E. Law, 1985. Impact of synthetic pyrethroids on beneficial insects from cotton grown in the Southern Piedmont. J. Agric. Entomol., 2: 161-166.

Hoyt, S.C., P.H. Westigard and E.C. Burtz, 1978. Effects of two synthetic pyrethroids on the codling moth, pear psylla and various mite species in Northwest apple and pear orchards. J. Econ. Entomol., 71: 431-434.

Jasmine, R.S. and S. Kuttalam, 2011. Emamectin benzoate 5 SG and 1.9 EC: A safer insecticide to coccinellids of bhendi ecosystem. Madras Agric. J., 98: 92-94.

Joshi, P.C. and P.K. Sharma, 2008. First records of coccinellid beetles (Coccinellidae) from the Haridwar, (Uttarakhand), India. Nat. History J. Chulalongkorn Univ., 8: 157-167.

Kaakeh, N., W. Kaakeh and G.W. Bennett, 1996. Toxicity of imidacloprid fipronil and seven convectional insecticides to the adult Convergen lady beetle (Coleoptera: Coccinellidae). J. Entomol. Sci., 31: 315-322.

Kabissa, J.C.B., 1993. Studies on the biology and ecology of Chrysopid (Neuroptera: Chrysopidae) predators of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) and *Aphis gossypii*, (Glover) (Homoptera: Aphididae) on cotton, *Gossypium hirsutum* (L.) in Eastern Tanzania. Ph.D. Thesis, University of Dar es Salaam, Tanzania.

Kerns, D.L. and M.J. Gaylor, 1993. Biotic control of cotton aphids (Homoptera: Aphididae) in cotton influenced by two insecticides. J. Econ. Entomol., 86: 1824-1834.

Li, S.Y. and R. Harmsen, 1993. Pyrethroid lambdacyhalothrin-induced population increase of *Tetranychus urticae* koch Acari: Tetranychidae in an apple orchard. J. Agric. Entomol., 10: 197-203.

Mrosso, F.P. and E.E. Temu, 2008. Tanzania Cotton Pest Control Manual. 2nd Edn., Interpress, Dar es Salaam, Tanzania, Pages: 250.

Mrosso, F.P., E.E. Temu and J.C.B. Kabissa, 2006. Management of Cotton Pests (Insect and Mites) in Tanzania. In: Management of Selected Crop Pests in Tanzania, Makundi Rhodes, H. (Ed.). Tanzania Publishing House Ltd., Dares Salaam, Tanzania, pp: 80-119.

Obrycki, J.J. and T.J. Kring, 1998. Predaceous coccinellidae in biological control. Annu. Rev. Entomol., 43: 295-321.

Ofuya, T.I., 1997. Effect of some plant extracts on two coccinellid predators of the cowpea aphid, *Aphis craccivora* (Hom.: Aphididae). Entomophaga, 42: 277-282.

Poehling, H.M., 1988. Influence of cereal aphid control on aphid specific predators in winter wheat (Homoptera: Aphididae). Entomologia Generalis, 13: 163-174.

Rondon, S.L., D.J. Cantliffe and J.F. Price, 2005. Population dynamics of the cotton aphid, *Aphis gossypii* (Homoptera: Aphididae), on strawberries grown under protected structure. Florida Entomol., 88: 152-158.

Sun, Y., G. Feng, J. Yuan and K. Gong, 1994. Insecticide resistance of cotton aphid in North China. Insect Sci., 1: 242-250.

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

USDA, 1989. Insects and diseases of trees in the South: Cotton wood leaf beetle, *Chrysomela scripta* F. Protrotection Report R8-PR16, U.S. Department of Agriculture Forest Service, USA., pp: 1-98.

Veesar, G.M., S.N. Khuhro, M.K. Lohar, T.A. Khuhro and F.N. Khoso, 2012. Life table of coccinellid predator, *Hippodamia variegate* Goeze (Coleoptera:Coccinellidae) under field conditions. Pak. J. Agric. Eng. Vet. Sci., 28: 65-70.

Wells, M.L., R.M. McPherson, J.R. Ruberson and G.A. Herzog, 2001. Coccinellids in cotton: Population response to pesticide application and feeding response to cotton aphids (Homoptera: Aphididae). Environ. Entomol., 30: 785-793.

Wirtz, K., S. Bala, A. Amann and A. Elbert, 2009. A promise extended-future role of pyrethroids in agriculture. Bayer Crop Sci. J., 62: 145-158.

Wood, B.J., 1988. Overview of IPM Infrastructure and Implementation on Estate Crops in Malaysia. In: Pesticide Management and Integrated Pest Management in Southeast Asia, Teng, P.S. and K.L. Heong (Eds.). Consortium for International Crop Protection, College Park, MD., USA., pp: 31-41.

Zwick, R.W. and G.J. Fields, 1978. Field and laboratory evaluations of fenvalerate against several insect and mite pests of apple and pear in oregon. J. Econ. Entomol., 71: 793-796.