

Management of Insect Pests using Chlorpyrifos Applications at Different Growth Stages of Tomato, *Solanum lycopersicum* L.

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Abstract
Field studies were conducted in Kumasi, Ghana in the major and minor planting seasons of 2013 to evaluate the effect of chlorpyrifos applications at different growth stages of tomato *(Solanum lycopersicum* L) for the management of insect pests. The treatments were: Chlorpyrifos at 1.5 ml / 0.5 litre of water applied (i) at the vegetative growth stage only (sprayed vegetative), (ii) at the reproductive growth stage only (starting at 50 % flowering (sprayed reproductive) and (iii) throughout the crop's growth period (sprayed throughout). A control plot that received only water was also maintained. In both seasons, significantly ($P < 0.05$) less number of *Bemisia tabaci* Gennadius and *Thrips tabaci* Linderman were collected from the insecticide-treated tomato plots than the untreated, control plots, but no significant differences were observed among the treatments in the aggregations of *Aphis gossypii* Glover and *Helicoverpa armigera* (Hubner). Chlorpyrifos application in the sprayed throughout plots significantly ($P < 0.05$) reduced damage to tomato fruits in the major season but not in the minor season. Tomato fruits from the sprayed vegetative and sprayed reproductive plots had comparable damage as the fruits from untreated control plots. Chlorpyrifos application also significantly ($P < 0.05$) increased yield of tomato from the sprayed throughout plots in both seasons. The best protection to the crop against the insect pests was obtained from weekly applications of chlorpyrifos throughout the growth period of the crop (sprayed throughout plots).
Key words: Tomato, Chlorpyrifos, insect pests, management, population dynamics

1.0 Introduction

Tomato (*Solanum lycopersicum* L) is an important source of nutrients in the diet of most families in Ghana and is therefore cultivated extensively in the country and produced mainly for domestic consumption (Norman 1992). Tomato is normally used in large quantities compared to other vegetables (Ellis *et al.,* 1998). Demand for tomato in Ghana is high and therefore production is all-year-round, under rain-fed conditions in the wet seasons and under irrigation in the dry seasons (Bonsu, 2002).

Yield values are however low. The average yield in Ghana stands at 10 tons per hectare, and the low yield is attributed to diseases, insect-pests and environmental factors such as temperature and humidity (Bonsu, 2002). Tomato is attacked by insect pests such as, whiteflies, *Bemisia tabaci* Gennadius, cotton aphids, *Aphis gossypii* Glover and American bollworm, *Helicoverpa armigera* Hubner. Aphids prefer to attack the tender shoots and the young leaves of the host plant, but they can also exist on older leaves. Apart from removing plant nutrients, whiteflies transmit a number of disease causing viruses including Tomato Yellow Leaf Curl Virus (TYLCV) which adversely affect tomato cultivation in Ghana (Horna *et al*., 2008). *Helicoverpa armigera* attacks the ripe and pre-ripe fruits, contaminating them with frass and exposing them to fungi and bacteria (Burgstaller and Hassan, 1984).

In view of the high incidence of insect pests on tomato, farmers tend to apply chemicals for their control (Ogemah, 2003). Tomato farmers in Ghana rely heavily on the use of pesticides (Dinham, 2003). Even though insecticides have proven to be highly effective in protecting vegetable crops under extreme pressure from insect pests (Cooper and Dobson, 2007), the indiscriminate and widespread use of synthetic insecticides in vegetable cultivation usually has resulted in insecticide resistance development (Wintuma, 2009; Owusu and Yeboah, 2007).

Many of these insecticides applications do not yield the desired control but their aggregate cost increases the production cost of farmers resulting in loss of revenue. One way to reduce this loss is to resort to judicious and timely application of insecticides to achieve desirable control with minimal pesticide application.

There is therefore the need to determine the appropriate time and stages of growth of tomato at which insecticides should be applied to ensure management of insect pests of the crop using optimal dosages of insecticides. It is in this light that this study with the objective to determine the effect of Chlorpyrifos application at different growth stages on insect pests of tomato was undertaken.

2.0 Materials and Methods

2.1: Experimental site

The experiment was conducted at the plantation crops section of the Department of Crop and Soil Sciences of the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana. The study was undertaken in the major planting season (May to mid-September) and repeated in the minor season (late September to late December) 2013. The soil texture is sandy loam.

2.2 Field lay-out

The experimental field was laid out in a randomly complete block design (RCBD) with four treatments. Each treatment was replicated four times in four blocks. The experimental field measured 25 m x 25 m (625 m^2). Each treatment plot measured 5 m x 5 m with 1 m alley.

2. 3 Source of tomato seeds

The tomato variety used was CRI-POO and was obtained from the Crops Research Institute of the Council for Scientific and Industrial Research (CSIR-CRI), Kwadaso, Kumasi. CRI-POO is a locally improved open pollinated variety and is susceptible to insect pests of tomato.

2.4 Insecticide treatments and their application

Dursban (a. i. Chlorpyrifos) at 1.5 ml /0.5 litre water per plot was applied on tomato at the following times:

(i) vegetative growth period of the crop (from three weeks after transplanting to 50 % flowering) – sprayed vegetative stage only

(ii) reproductive growth period of the crop (starting at 50 % flowering until first harvest of the fruits) – sprayed reproductive stage only, (iii) throughout the entire growth period of the crop – sprayed throughout, and (iv) control (water - with no insecticide application)

Manual weeding was done at three weeks intervals throughout the period of the experiment. Irrigation was done as and when necessary. Inorganic fertilizer was applied in two splits. The first dose of NPK (15-15-15) was applied three weeks after transplanting at a rate of 10 g per plant while Urea (46 % N) was applied at the rate of 2.2 g per plant as the second dose three weeks after the first application.

2.5. Sampling of insect pests

Beginning two weeks after transplanting, weekly sampling for insects began. Sampling for whiteflies involved visual examination of five randomly selected plants from the two middle rows with the help of a magnifying lens. Number of insects present on five randomly selected plants per plot was counted. In addition, for the first two weeks of sampling, two leaves were cut from each sampling plant and put in a high density polyethylene bottle containing 70 % ethyl alcohol, but for the subsequent weeks, three leaves from the upper and lower canopies of tomato were collected in the bottles. They were later transported to the insectary for processing, identification and counting using a stereo-microscope. Sampling was done between 0800 and 1000 h for ten weeks on the tomato plants.

Tomato fruits were harvested after every two days and weighed. Damaged and healthy fruits were weighed separately and recorded. Any fruit with any blemish or injury apparently caused by insects, was considered damaged and the number was expressed over the total number of fruits to obtain the per cent damaged.

2.6 Data Analysis:

Insect data were transformed using square root transformation and data in percentages arcsine transformed. The data were then subjected to Analysis of Variance (ANOVA) using SAS (9) 2010. Treatment means were separated using Tukey at 5 % probability.

3.0 Results

3.1 Insect pests collected in the major and minor seasons in 2013

Insect pests collected were whiteflies, *B. tabaci,* aphids, *A. gossypii*, thrips, *T. tabaci* and tomato fruit borer, *H. armigera*. There were significant ($P < 0.05$) differences among treatment means with respect to the densities of *B. tabaci,* and *T. tabaci* (Table 1). Significantly ($P < 0.05$) more of these insects were collected on the untreated, control plots than the insecticide-treated plots. *A. gossypii* densities showed no significant difference ($P > 0.05$) among the treatments (Table 1).

Significantly fewer *B. tabaci* were collected from the plots that received insecticide application during the reproduction stage than that which received insecticide application during the vegetative growth period only. Plots that received insecticide application throughout the growth period had significantly ($P < 0.05$) less number of *B. tabaci* than the other insecticide-treated plots.

Significantly ($P < 0.05$) more *T. tabaci* were recorded in the control plots than the insecticide-treated plots. However, there were no significantly differences in the densities of the insect between the insecticide-treated plots (Table 1). No significant differences were observed among the treatments in the mean number of *H. armigera*.

There were significant (P < 0.05) differences among treatment means with respect to the densities of *B. tabaci* and *T. tabaci* (Table 2) in the minor season. The control plots had significantly (P < 0.05) more aggregations of *B. tabaci* and *T. tabaci* than the insecticide-treated plots.

There was no significant (P > 0.05) difference between the sprayed reproductive and sprayed throughout plots with respect to the densities of *B. tabaci* but the respective densities of the insect in these treatments were significantly (P < 0.05) less than that collected on the sprayed vegetative plots. There were no significant (P > 0.05) differences among the treatments with respect to the number of *A. gossypii*, and also, no significant differences were observed in the aggregations of *T. tabaci* among the insecticide-treated plots (Table 2).

3.2 **Insect pests population dynamics as influenced by chlorpyrifos applications in the major and minor seasons**

Whiteflies (*B. tabaci*)

The population of *B. tabaci* was < 1 per tomato plant when the insecticide application began but this increased above one per plant in all the treatments throughout the second and third weeks of insecticide application (Figure 1). There was a sharp drop in the aggregation of this insect by the fourth week before increasing steadily in all the treatments throughout August. However, *B. tabaci* population in the control remained consistently above two per plant throughout August and September. The lowest densities of *B. tabaci* densities was recorded in the sprayed throughout plots throughout August and September.

In the minor season, the population of *B. tabaci* was also < 1 per tomato plant in the insecticide-treated plots up to the 5^{th} week (19^{th} November) of insecticide application. Similarly, the lowest densities of *B. tabaci* was recorded in the sprayed throughout plots throughout the seven weeks of insecticide application (Figure 2). The densities of *B. tabaci* peaked at about three per plant in the control plots on 26^{th} November before declining the following week.

Thrips (*T. tabaci*)

The densities of *T. tabaci* were consistently low (< 0.5 per plant) in all the plots until the end of August (Figure 3). There was a drop in the aggregation of this insect in the second week in all the insecticide-treated plots and remained low throughout until 5^{th} September, when its density increased to about 1 per plant in the untreated, control.

The densities of *T. tabaci* in all the plots were low in the minor season when the insecticide application began. Its number continued to be low in the sprayed throughout and sprayed reproductive plots but gradually increased above one per tomato plant in the last two weeks in the sprayed vegetative and control plots (Figure 4).

Aphids (*A. gossypii*)

The density of *A. gossypii* was one per tomato plant when the insecticide application began, but increased in the second week and dropped in the third week in all the treatments. *A. gossypii* aggregations were similar in the sprayed vegetative and sprayed reproductive plots and peaked above 0.4 per tomato plant on 5^{th} September 2014 (Figure 5). After the third week of chlorpyrifos application, *A. gossypii* fluctuated week after week until after 22^{nd} August 2014.

Aggregation of *A. gossypii* started above 0.4 per tomato plant in the sprayed throughout plots, 0.2 in the cotrol plots and sprayed reproductive plots and < 0.1 in the sprayed vegetative plots when the insecticide application began in the minor season. Densities of *A. gossypii* dropped below 0.4 in all the treatments throughout the minor season (Figure 6).

3.3 Yield and percent damaged fruits of CRI-POO tomato as affected by chlorpyrifos applications in the major and minor seasons

In the major season, significant differences (P < 0.05) were observed among the treatments in the mean percent damaged fruits, but no significant differences were observed in this variable between the sprayed throughout and sprayed reproductive plots' fruits. No significant (P > 0.05) difference was also observed between the sprayed vegetative and control plots (Table 3). The mean percent damaged fruits ranged from 11.7 to 22.3 %. Significantly (P < 0.05) more fruit yield was recorded in the sprayed throughout plots than the other plots. The mean yield ranged from 2954.8 to 4066.8 kg / ha in the major season (Table 3).

In the minor season, no significant (P > 0.05) differences were obtained among the treatments in the mean percent damaged fruits (Table 3). There were also no significant (P > 0.05) differences among the sprayed throughout, sprayed vegetative and sprayed reproductive plots, but significantly more fruits were harvested from the insecticide-treated plots than the control plots. The mean yield ranged from 1230.5 to 1791.8 kg / ha (Table 3).

4.0 Discussion

Pesticides are used to manage insect pests, diseases and weeds in agriculture. Weekly applications of Chlorpyrifos at the rate of 1.5 ml in 0.5 litre of water suppressed *B. tabaci* and *T. tabaci* aggregations on tomato. The density of *B. tabaci* in the first week was low (< 1 per plant) but increased in all the treatment plots in the second and third weeks but dropped sharply thereafter (Figure 1). *B. tabaci* and *T. tabaci* aggregations increased steadily when chlorpyrifos applications were stopped in the sprayed vegetative plots, with general increases in the densities of all the insects during the latter part of the sampling (Figures 1, 2, 3, 4, 5, and 6).

In the minor season, *B. tabaci* density was below one per tomato plant in all the treatment plots throughout the study period. More *T. tabaci* and *A. gossypii* were collected on tomato in the major season than in the minor season. However, comparable numbers of *B. tabaci* were collected on the crop in both seasons (Tables 1 and 2). Environmental factors may have played a role in the occurrence of low numbers of *T. tabaci*, *A. gossypii* and *H. armigera* in the minor season when relatively less amount of rainfall was recorded in addition to low relative humidity. This is being suggested as similar results and reasons had been reported by other researchers. Mailhot *et al.* (2000) reported that the effectiveness of the insecticides they used in their study on cotton varied across seasons and years they conducted their studies.

Overall, low aggregations of the insects were recorded during the later weeks of the studies irrespective of insecticide applications. Typically, as plants grow in space and time, insects find more hiding places to escape from predators and insecticide spray droplets. Consequently, predators are more challenged to sharpen their searching abilities to locate these insects. Martin (1999) reported that dense canopies provide a favourable environment for both nymphal and adult whiteflies to cluster in large numbers on the underside of leaves.

Chlorpyrifos applications significantly reduced aggregations of *B. tabaci* and *T. tabaci* irrespective of the period of application in both seasons. The sprayed throughout and sprayed reproductive plots had significantly less number of *B. tabaci* than the sprayed vegetative plots and the untreated control plots, and it appears that for *T. tabaci* chlorpyrifos application during any of the crop's growth stages is effective in reducing the densities of the insect on tomato, and the usual early occurrence of *T. tabaci* in a plant's growth may account for this observation. On the other hand, application of the insecticide can be restricted to the reproductive growth stage only and still achieve significant reduction in the aggregation of *B. tabaci*. According to Serra (1992) and Serra and Schmutterer (1993), sumicidin effectively reduced the number of whiteflies in their studies on tomato.

Sam *et al*. (2014) conducted a similar experiment using lambda–cyhalothrin at the same dosage as that used in the present study (1.5 ml / 0.5 litre of water per plot) and reported that lambda–cyhalothrin significantly reduced *B. tabaci*, *A. gossypii* and *H. armigera* numbers but had no adverse effect on *T. tabaci*, and their results, apart from the aspect on *B. tabaci*, are contrary to what were obtained in the present study, in which chlorpyrifos applications did reduce aggregations of *T. tabaci* but had no effective control of *A. gossypii* and *H. armigera*. Interestingly, Sam *et al*. (2014) caused significant reduction in the densities of *A. gossypii* and *H. armigera* while making lambda cyhalothrin applications at two weeks intervals while weekly applications of chlorpyrifos in the present study did not reduce the aggregations of the same insects.

Osekre *et al*. (2009) reported that lambda–cyhalothrin application had no adverse effect on the population of *Frankliniella* thrips and explained that these thrips species had developed resistance to insecticide applications. Schmutterer (1995) concluded that some thrips species can be controlled by early insecticide application on tomato and other vegetable crops. Based on the results obtained in the present study, *T. tabaci* appears highly susceptible to chlorpyrifos.

It can be explained that differences in the mode of action or the classes of the insecticides in the two studies may account for these differences in the effect of the insecticides on the insects - lambda cyhalothrin is a synthetic pyrethroid whilst chlorpyrifos is an organophosphate, with a different mode of action on insects. Ghanaian vegetable farmers use lambda–cyhalothrin far more than chlorpyrifos (Sam *et al*., 2014) and this could explain the seeming resistance of the insects to the former, irrespective of application regime used. Other researchers also have reported reduced adverse effects of lambda-cyhalothrin on other species of thrips (Hassen *et al*., 2003; Funderburk *et al*., 2002).

It is not clear why chloropyrifos application had no adverse effect on *A. gossypii.* Biotic and environmental regulatory factors may have impacted more on the insect than chlorpyrifos applications.

No significant differences were observed among the treatment plots in the minor season for *H. armigera* (Table 2). Mathirajan *et al*. (2000) had reported that lambda–cyhalothrin applied at the rate of 30 g a i ha $^{-1}$ significantly reduced the number of the shoot and fruit borer on brinjal than endosulfan and fenvalerate. However, Romeis *et al*. (1999) had reported that the management of *H. armigera* is very difficult in many crops, and Ahmed *et al*. (2009) also reported that the same insect showed some resistance to lambda-cyhalothrin in their work.

It was only the sprayed throughout plots that consistently had increased yield of tomato in both seasons (Table 3). Fruits' damage was significantly reduced in the sprayed throughout and sprayed reproductive plots in the major season but not in the minor season, but judging from the overall performance of the insecticide application periods vis-à-vis the yield obtained, it can be deduced that the sprayed throughout regime gave the best protection to tomato.

5.0 Conclusions

From the results of the study, it can be concluded that chlorpyrifos application was able to significantly reduce the densities of *B. tabaci* and *T. tabaci* but had no adverse effect on *A. gossypii* and *H. armigera*. Overall, the sprayed throughout regime gave the best protection to tomato and also consistently increased the yield, and therefore, where it is the insecticide of choice on tomato, it should be applied weekly throughout the growth stages of the crop for best results.

6.0 References

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Appendix 1 - Tables

Table 1: Mean number of insect pests collected on tomato, *Solanum lycopersicum* L. as affected by chlorpyrifos applications in the major season in Kumasi, Ghana in 2013.

	Mean number (± SEM) of insect per plant			
Treatment	*B. tabaci*	*T. tabaci*	*A. gossypii*	*H. armigera*
Sprayed throughout	1.22 ± 0.06 [d]	0.05 ± 0.01 [b]	0.14 ± 0.02 [a]	0.01 ± 0.01[a]
Sprayed vegetative	1.84 ± 0.08 [b]	0.06 ± 0.01 [b]	0.14 ± 0.02 [a]	0.01 ± 0.01 [a]
Sprayed reproductive	1.54 ± 0.06 [c]	0.05 ± 0.01 [b]	0.11 ± 0.02 [a]	0.02 ± 0'01 [a]
Control	2.55 ± 0.10 [a]	0.27 ± 0.03 [a]	0.13 ± 0.03 [a]	0.06 ± 0.10 [a]

Means with the same letter(s) in a column are not significantly different from each other (P < 0.05, according to Tukey).

Table 2: Mean number of insect pests collected on tomato, *Solanum lycopersicum* L. as affected by chlorpyrifos applications in the minor season in Kumasi, Ghana in 2013.

	Mean number (± SEM) of insect per plant		
Treatment	*B. tabaci*	*T. tabaci*	*A. gossypii*
Sprayed throughout	0.49 ± 0.04 [c]	0.21 ± 0.03 [b]	0.09 ± 0.02 [a]
Sprayed vegetative	0.95 ± 0.06 [b]	0.35 ± 0.04 [b]	0.07 ± 0.02 [a]
Sprayed reproductive	0.64 ± 0.05 [c]	0.24 ± 0.03 [b]	0.09 ± 0.02 [a]
Control	1.33 ± 0.07 [a]	0.67 ± 0.06 [a]	0.11 ± 0.03 [a]

Means with the same letter(s) in a column are not significantly different from each other (P < 0.05, according to Tukey).

Table 3. Yield and percent damaged fruits as affected by chlorpyrifos applications in the major and minor seasons in Kumasi, Ghana.

	Major season		**Minor season**	
Treatment	Mean % damaged fruit	Yield (kg/ha)	Mean % damaged fruit	Yield (kg/ha)
Sprayed throughout	11.7 ± 0.8 [b]	4066.8 ± 162.8 [a]	15.55 ± 2.4 [a]	1791.8 ± 127.9 [a]
Sprayed vegetative	18.1 ± 0.3 [ab]	3229.0 ± 169.4 [b]	19.2 ± 2.3 [a]	1709.1 ± 81.7 [a]
Sprayed reproductive	12.9 ± 1.3 [b]	2768.3 ± 148.7 [b]	12.0 ± 2.2 [a]	1746.1 ± 38.6 [a]
Control	22.3 ± 2.5 [a]	2954.8 ± 162.1[b]	15.7 ± 2.0 [a]	1230.5 ± 65.9 [b]

Means with the same letter(s) in the column are not significantly different from each other (P < 0.05, according to Tukey).

Appendix 2- Figures

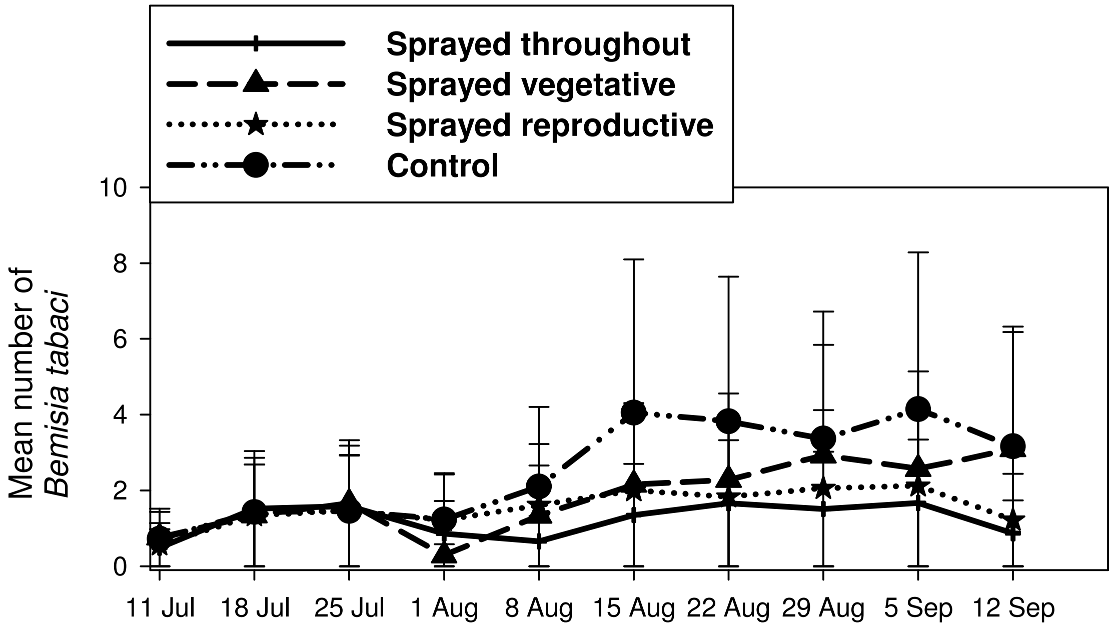

Figure 1: Mean number of *Bemisia tabaci* on tomato, *Solanum lycopersicum* plant as influenced by chlorpyrifos application in the major season in Kumasi, Ghana in 2013.

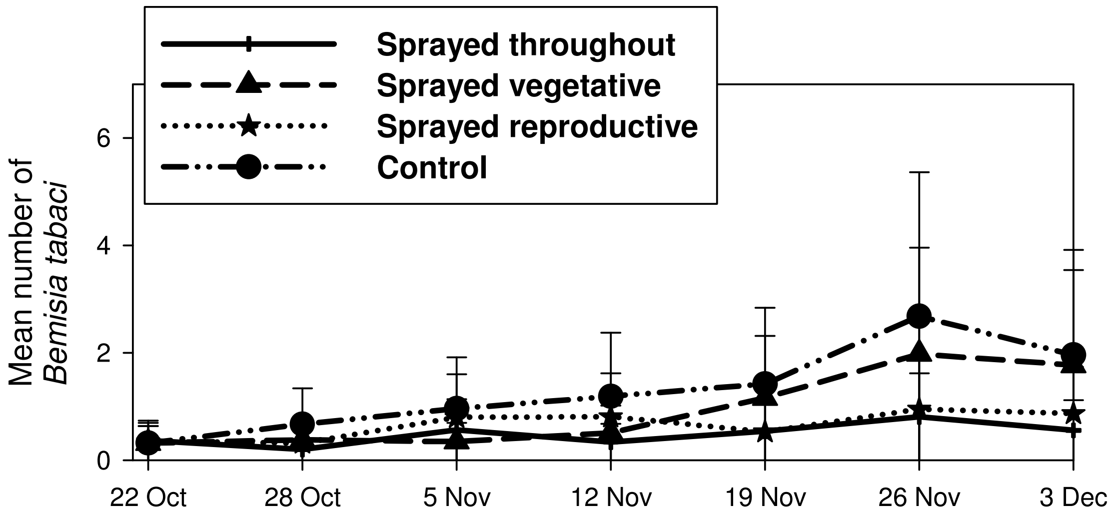

Figure 2: Mean number of *Bemisia tabaci* per tomato, *Solanum lycopersicum* plant as influenced by insecticide application in the minor season in Kumasi, Ghana in 2013.

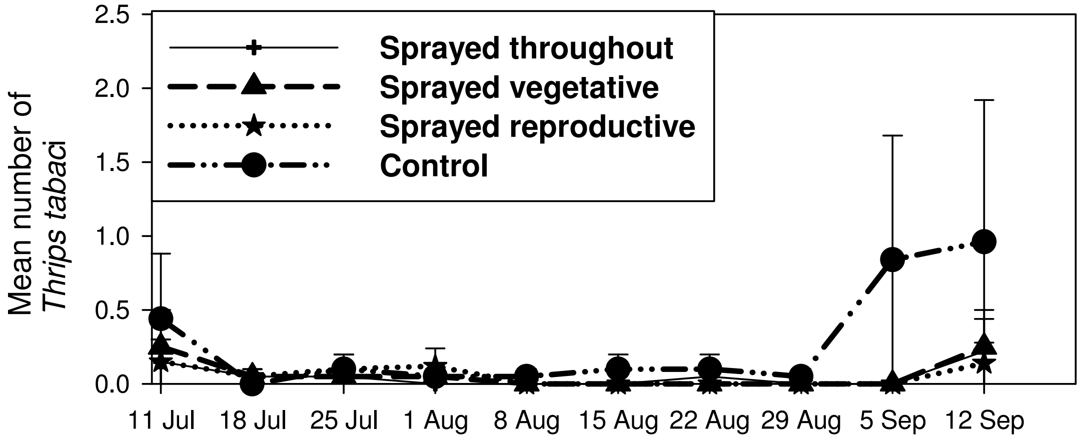

Figure 3: Mean number of *Thrips tabaci* per tomato, *Solanum lycopersicum* plant as influenced by chlorpyrifos application in the major season in Kumasi, Ghana in 2013.

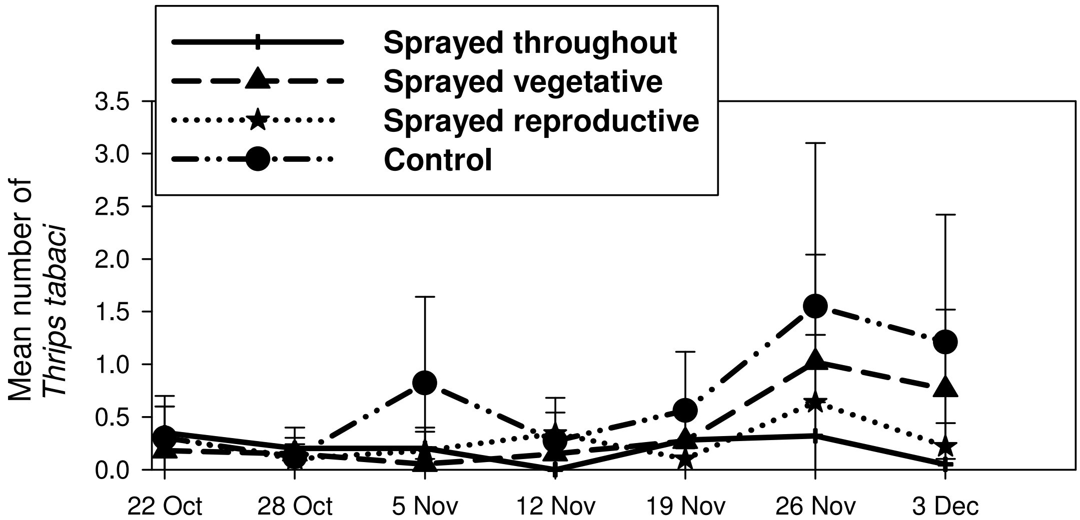

Figure 4: Mean number of *Thrips tabaci* per tomato, *Solanum lycopersicum* plant as influenced by chlorpyrifos application in the minor season in Kumasi, Ghana in 2013.

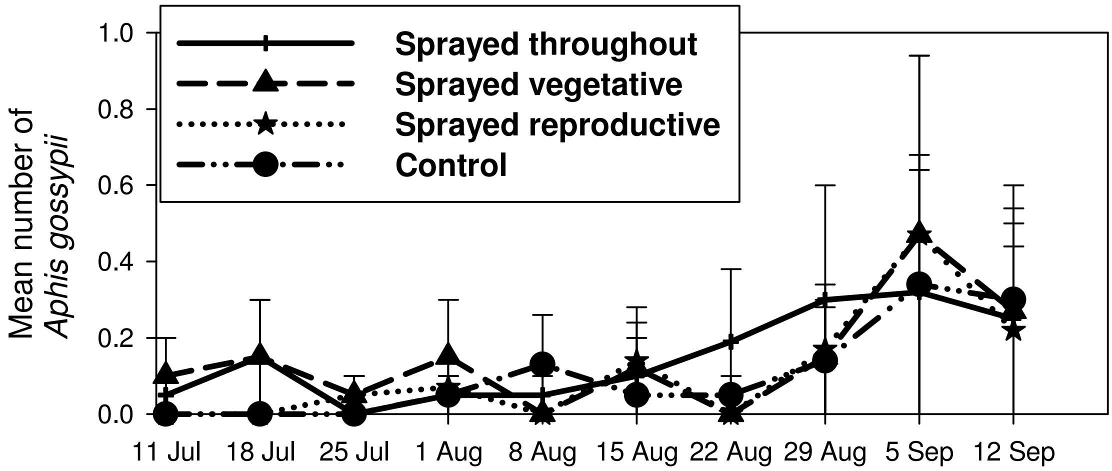

Figure 5: Mean number of *Aphis gossypii* per tomato, *Solanum lycopersicum* plant as influenced by chlorpyrifos application in the major season in Kumasi, Ghana in 2013.

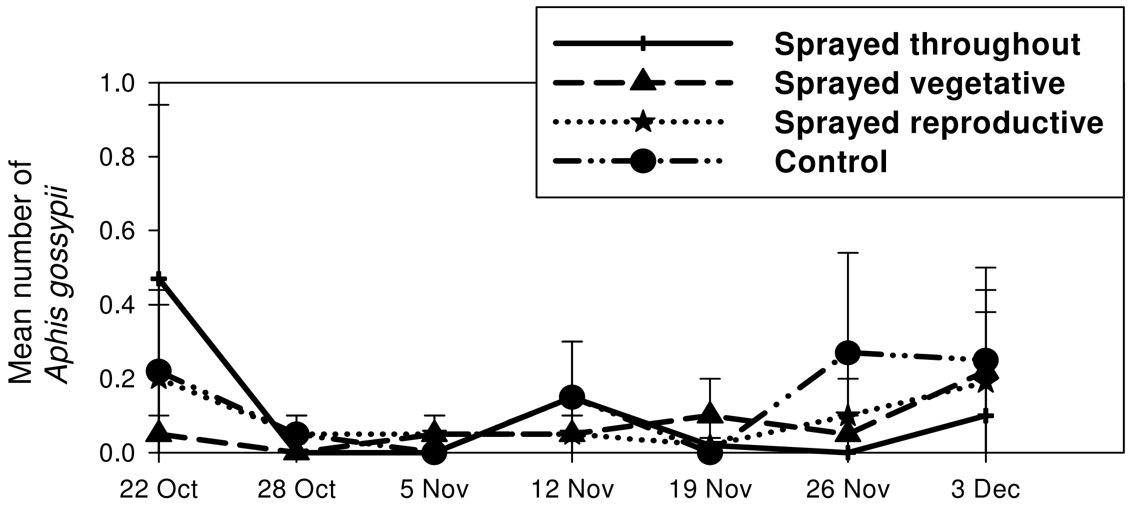

Figure 6: Mean number of *Aphis gossypii* per tomato, *Solanum lycopersicum* plant as influenced by chlorpyrifos application in the minor season in Kumasi, Ghana in 2013.

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