Research Article

Management of Asian Citrus Psyllids, *Diaphorina citri* Kuwayama, The Direct and Vector Pest of Citrus Via Synthetic Insecticides in Khyber Pakhtunkhwa, Pakistan

Ashraf Khan[1]*, Suliman Shah[2], Maid Zaman[3] and Komal Habib[2]

[1]National Tea and High Value Crops Research Institute, PARC, Shinkiari Mansehra, Pakistan; [2]Department of Entomology, The University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan; [3]Department of Entomology, the University of Haripur, Pakistan.

Abstract | Asian citrus psylla, *Diaphorina citri* Kuwayama, is considered to be the most noxious pest of almost all species and varieties of citrus and its infestation found throughout the world. It is becoming serious threat to the brightening future of citrus growing areas of Pakistan. Thirteen different insecticides were usedfor effective control against citrus psylla under field conditions. Population density of pest was recorded as number of adults per branch. Efficacy of the insecticides was evaluated as percent mortality (%) of citrus psylla. Overall highest percent mortality was observed in plants treated with combination of Nitenpyram + Chlorfenapyr (99.20 and 99.89 %) followed by Flubendiamide (89.83 and 99.39 %) and Imidacloprid (89.31 and 98.77 %) after spray 1 and 2, respectively. Least effective insecticide was proved to be Melathion with 39.79 and 65.43 percent reduction in citrus psyllidspopulation except untreated plants with 9.27 and 15.94 percent decrease after first and second spray, respectively. Decline in overall population recorded from 91.73 to 13.20 and 17.40 to 4.43 percent after multiple sprays, respectively. All the insecticides endowed withstatistically significant control of citrus psylla comparable to untreated plants.

Received | March28, 2018; **Accepted** | September 1, 2018; **Published** | October 29, 2018
***Correspondence** | Ashraf Khan, National Tea and High Value Crops Research Institute, PARC, Shinkiari Mansehra, Pakistan; **Email:** ashraf_ento60@yahoo.com
Citation | Khan, A., S. Shah, M. Zaman and K.Habib. 2018. Management of Asian citrus psyllids, *Diaphorina citri* Kuwayama, The direct and vector pest of citrus via synthetic insecticides in Khyber Pakhtunkhwa, Pakistan. *Pakistan Journal of Agricultural Research,* 31(4): 300-305.
DOI | http://dx.doi.org/10.17582/journal.pjar/2018/31.4.300.305
Keywords | Insecticides, Percent mortality, Nitenpyram + Chlorfenpyr, Flubendiamide, Imidacloprid

Introduction

Among the major insect pests of citrus, Asian citrus psylla (ACP) *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae), is the most destructive and consequently the most annoying pest as it vectors the phloem-limited bacterium,*Candidatus Liberibacterasiaticus*, the causal organism of "huanglongbing" (HLB) or citrus greening disease (Halbert and Manjunath, 2004; Catling, 1969). HLB is one of the world's most devastating diseases of citrus, responsible for the decline and death of infected trees (Bové, 2006; Roistacher, 1996). After attack of both nymphs and adults of *D. citri* on buds and soft young shoots, curling, defoliation and distortion of the leaves starts, production of honey dews take place and ultimately infection of sooty mould fungus resulting in premature fruit drops (Shah and Saleem, 2000). Death of the plant may occur as a result of distortion by heavy infestation of the pest within 4-5 years (Bove, 2006). Saliva of the pest is thought to be toxic which probably induce such distortion (Dennis, 1983). Near-

ly worldwide extension of Asian citrus psyllid and HLB to citrus growing regions (Halbert and Manjunath, 2004; Halbert and Nunez, 2004; Pluke et al., 2008), have increased research efforts on ACP and HLB over the past 85 years and making expanded our comprehension of the insect, the disease and their interactions.

In the management of pest and disease, soil and foliar applied insecticides are essential tools (McCoy et al., 2009). Foliar sprays are considered most effective against adult psyllids because they are more exposed than the immature psyllids which are secluded in the young shoots and are more susceptible to systemic poisons. In addition to that adult psyllids are responsible for the spread of *C. Liberibacter*asiaticus from infected trees to the adjoining healthy trees (McCoy, 1985; Stansly and Qureshi, 2008).

Pakistan prostrate among the leading citrus growing countries of the world where citrus is cultivated on a land of 194.5 million hectares with 1982.2 million tons production (MINFA, 2010-11) in different districts of Punjab, and many districts of Khyber Pakhtunkhwa such as Malakand, Haripur, Swat, Mardan, Dir Upper and Lower and Peshawer (Jillani et al., 1989). Citrus have been observed under severe infestation of citrus psylla since the last few years resulting in high reduction of production. Keeping in view the great commercial importance of citrus fruit all over the world and especially in Khyber Pakhtunkhwa whose climatic conditions are most congenial for the production of different citrus species cultivated since ancient times in the sub content (MINFA, 2010-11), the current study was conducted for the management of its noxious pest via insecticides application.

Materials and Methods

Selection of experimental plants

The experiment was carried out at New Developmental Farm of the University of Agriculture, Peshawar, during 2016. For this purpose, 42 sour orange plants bearing equal size were randomly selected. The number of treatments were kept 14 including control (untreated plants). A single plant was left untreated between all the two treatments supposed to be buffer zone. The experiment was designed as randomized complete blocks. No artificial interventions were involved to trigger the infestation of Asian Citrus Psylla (ACP).

Population density/ Infestation

Seven reference points (top, middle, bottom, east, west, north and south) bearing adults of ACP were randomly selected and tagged prior to application of the treatments for evaluation of their efficacy on each plant. High infestation of citrus psylla was observed in the month of August. The population of pest was counted on 05 leaves of each tagged branch (total 35 leaves/ tree). Infestation of Asian citrus psylla was observed on both the upper and lower surface of each leaf. Percent decrease over control was calculated using the following formula: (Khattak et al., 1987);

$$C = A/B * 100$$

Where;
A = population infestation in treated plants
B = population infestation in control
C = decrease over control
Percent decrease = 100 – C

Chemical control

To study the efficacy of insecticides against citrus psylla population, the following 13 insecticides were tested along with control. Water spray was used as control. Trees were sprayed twice at four weeks interval early in the morning leaving the control untreated. Application of insecticides was made when infestation of the pest was confirmed on both sides of the leaves.

S. No	Treatments
1	Thaiachloprid
2	Emamectin benzoate
3	Nitenpyram + Bimetrozen
4	Deltamethrin
5	Flubendiamide
6	Lambda cyhalothrin
7	Melathion
8	Pyriproxifen
9	Nitenpyram (20%) + Chlorfenapyr (30%)
10	Fenpyroxymate
11	Chlorpyrifos
12	Acetamaprid
13	Imidacloprid
14	Control

Statistical analysis

The recorded data were subjected to ANOVA by repeated measurement analysis using Statistix 8.1 taking spray as repeated measure factor, whereas time and treatments were arranged in randomized complete

block design. Means were separated using DMRT contingent on a significant treatment effect (P<0.05) (SAS Institute, 2004).

Results and Discussion

A total of 13 insecticides efficacy was investigated against Asian citrus psylla for evaluation of most suitable active ingredient(s) (Table 1). After application, data recorded after one week indicated significantly high reduction (97.72 %) in plants treated with Nitenpyram + Chlorfenpyr followed by Pyriproxifen and Flubendiamide with 81.02 and 78.06 %, respectively. Lowest and statistically non-significant decrease in the percent pest density was observed in Thaiacloprid, Melathion and Control (Untreated) which was 2.6, 3.36 and 6.02 percent, respectively. Similarly, highest butnon significant decrease in week 2 (post treatment) was indicated between Nitenpyram + Chlorfenpyr and Flubendiamide treated plants with 99.90 and 98.81 percent, respectively, but was statistically significant from rest of the treatments. These highly effective insecticides were followed by Imidacloprid (95.79%) and Nitenpyram + Bimetrozen (95.03 %). After the same duration, lowest decrease (0.66%) in percent pest infestation was noted in untreated plants (control). After week 3, complete elimination of the pest from the plants was occurred which were treated with Nitenpyram + Chlorfenpyr (100 %) followed by Flubendiamide with 99.98 percent reduction. Both the treatments were significantly different from untreated plants (control), Melathion, Thaiacloprida nd Deltamethrin and were non-significant with rest of the treatments.

Results regarding percent decrease of Citrus psylla after second application of the treatments are given in Table 2, which indicated that various treatments, Nitenpyram + Chlorfenpyr, Flubendiamaide, Imidacloprid, Fenpyroximate, Nitenpyram + Bimetrozen and Emamectin benzoate proved to be most effective with more than 90%reduction of the pest after 1 week of application, which were non-significant among themselves but significantly different from rest of the treatments. Maximum numbers of adults were found in the untreated plot (control) with 14.28 percent reduction in their number after the same duration. Highest significant reduction in population was again recorded in the plants treated with Nitenpyram + Chlorfenpyr, Imidacloprid, Flubendiamide, Emamectin benzoate, Deltmethrin, lamdacyhalothrin, Nitenpyram + Bimetrozen, and Fenpyroximate, respectively, fluctuating the pest from 99.09 to 96.11 percent 2 weeks post application of the treatments. A 16.36 percent reduction was recorded in untreated plants after the same duration. After week 3, similar insecticides were observed to be effective with the exception of Emamectin benzoate bearing the lowest number of adults with 99.93 percent decrease and untreated plants (control) with the highest number of adults showing 17.18 percent reduction in their population.

Table 1: *Percent reduction in number of Asian citrus psylla per branch (5 leaves) at various time intervals on citrus after first application of different insecticides.*

S. No	Treatment	Dose/100 LOW	Post spray timings		
			Week 1	Week 2	Week 3
1	Thaiachloprid	125 ml	2.65h	64.35g	80.79d
2	Emamectin benzoate	80 ml	49.47ef	88.21c	97.92ab
3	Nitenpyram + Bimetrozen	100 gm	56.95de	95.03b	97.46ab
4	Deltamethrin	200 ml	27.55g	68.36f	87.34cd
5	Flubendiamide	30 gm	78.06bc	98.81a	99.98a
6	Lambda cyhalothrin	250 ml	46.75f	76.33e	92.90abc
7	Melathion	500 ml	3.36h	55.96h	65.56e
8	Pyriproxifen	350 ml	81.02b	86.59c	94.59ab
9	Nitenpyram (20%) + Chlorfenapyr (30%)	150 gm	97.72a	99.90a	100.00a
10	Fenpyroxymate	180 ml	45.05f	76.00e	93.36abc
11	Chlorpyrifos	500 ml	41.00f	82.01d	91.67bc
12	Acetamaprid	85 g	59.38d	86.04c	94.76ab
13	Imidacloprid	150 ml	74.45bc	95.70b	97.79ab
14	Control		6.02h	0.66i	21.14f
	LSD Value		9.44	2.61	7.14

Values in columns followed by different letter(s) are significantly different at 5 % level of probability using DMR test.

Comparison of overall percent reduction among various insecticides reveals that maximum percent decrease of 99.20 was recorded in Nitenpyram + Chlorfenpyr followed by Flubendiamide (89.83), Imidacloprid (89.31) and Pyriproxifen reducing the pest by 89.83, 89.31 and 87.40 percent, respectively, which were significantly effective than the rest of the treatments while minimum percent decrease of 9.27 percent was recorded in control (untreated plants) after first spray (Table 3). Nitenpyram + Chlorfenpyr (99.89%), Flubendiamide, Imidacloprid, Emamectin benzoa-

teand Fenpyroximate recorded highest population reduction ranged upto 99.39 percent after second spay while minimum decrease was recorded in untreated plants with overall 15.94 percent mortality. The least effective insecticide was observed to be Melathion with 38.79 and 65.43 percent reduction in citrus psyllids population after both the sprays, respectively.

Table 2: *Percent reduction in number of Asian citrus psylla per branch (5 leaves) at various time intervals on citrus after second application of different insecticides.*

S. No	Treatment	Dose/100 LOW	Post spray timings		
			Week 1	Week 2	Week 3
1	Thaiachloprid	125 ml	78.12f	80.67f	76.96f
2	Emamectin benzoate	80 ml	96.92ab	97.41ab	99.93a
3	Nitenpyram +bimetrozen	100 gm	97.00ab	96.96b	98.45b
4	Deltamethrin	200 ml	93.88c	97.34ab	98.10ab
5	Flubendiamide	30 gm	98.91ab	98.10a	98.21a
6	Lambda cyhalothrin	250 ml	92.94cd	97.07ab	99.24ab
7	Melathion	500 ml	31.19g	75.89g	89.23d
8	Pyriproxifen	350 ml	90.12de	94.62c	76.06fg
9	Nitenpyram + Chlorfenpyr	150 gm	99.99a	99.09a	99.10a
10	Fenpyroxymate	180 ml	97.05ab	96.11abc	98.45ab
11	Chlorpyrifos	500 ml	80.91f	91.57e	79.89e
12	Acetamaprid	85 g	87.73e	94.94d	91.23d
13	Imidacloprid	150 ml	98.51ab	98.76a	98.85a
14	Control		14.28h	16.36h	17.18h
	LSD Value		3.03	1.75	1.41

Values in columns followed by different letter (s) are significantly different at 5 % level of probability using DMR test.

As indicated in Figure 1, decline in the population of the pest with time was recorded from 91.73 to 13.20 percent after first application. After first week of spray, change in overall population of citrus psyllids seemed to be magnificent and reduced to 52.38 percent. After week 2, the population fluctuated to 13.20 percent of pests/ branch. When the plants were treated for the 2nd time the initial population was recorded 17.11 percent/ branch where no reasonable changes were noted after week 1 of the spray and the population decreased slightly to 17.40 percent/branch. The population declined to 10.48 percent/branch after week 2 and minimum population of the pest was observed 3 weeks after the spray which was recorded to be 4.43 percent /branch.

Figure 1: *Effect of spray (Once and Twice) and time intervals on the percent population means of citrus psylla on citrus orchard.*

Figure 2 indicated the percent fluctuation in number of citrus psylla for each treatment applied to plants. Slight changes were observed in population density of the pest in untreated plants throughout the treated intervals. All the treatments illustrated significant decline in number of pest with maximum control observed in Nitenpyram + Chlophenpyr and Flubendiamide followed by Imidacloprid. The figure also demonstrated that sufficient number of pests were present after first spray which was brought under control with the second application of insecticides.

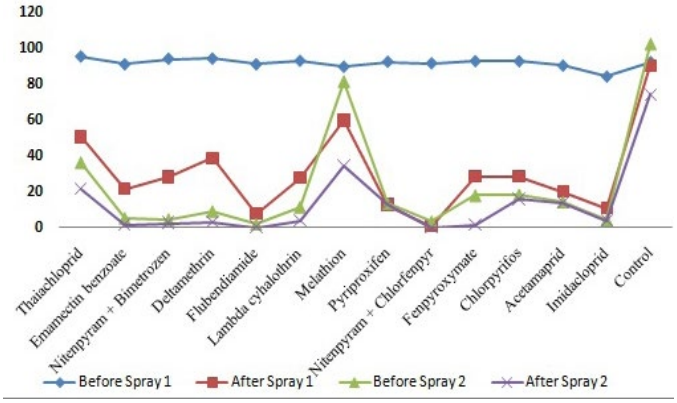

Figure 2: *Effect of spray (once and twice) and treatments on percent reduced population means of D. citrion citrus orchard.*

Asian citrus psylla is considered to be the serious pest of citrus in terms of direct attacking the leaves as well as serving as vector for Huang Long Bing (HLB), the citrus greening disease. Insecticidal application provides quick control of pest and is more effective in case of severe infestation which otherwise may not be control with conventional methods. Applying insecticides at critical flushing periods and during winter can greatly reduce populations of ACP. Surveys in Brazil indicated reduction in the rate of newly infested trees by intensive chemical programs and belligerent removal eradication of infested tress with ACP.

Table 3: *Percent reduction of Citrus psylla per branch (5 leaves) overtime in citrus in comparison to control after both sprays.*

S. No	Treatment	Dose/100 LOW	Spray 1	Spray 2
1	Thaiachloprid	125 ml	49.26g	78.58g
2	Emamectin benzoate	80 ml	78.53d	98.75ab
3	Nitenpyram+bimetrozen	100 gm	83.15cd	97.47bcd
4	Deltamethrin	200 ml	61.09f	96.77cd
5	Flubendiamide	30 gm	89.83b	99.39a
6	Lambda cyhalothrin	250 ml	71.99e	96.42d
7	Melathion	500 ml	39.79h	65.43h
8	Pyriproxifen	350 ml	87.40bc	86.93e
9	Nitenpyram+Chlorfenpyr	150 gm	99.20a	99.89a
10	Fenpyroxymate	180 ml	71.47e	98.34abc
11	Chlorpyrifos	500 ml	71.56e	84.13f
12	Acetamaprid	85 g	80.06d	85.97e
13	Imidacloprid	150 ml	89.31b	98.77ab
14	Control		9.27i	15.94i

*Values in columns followed by different letter (s) are significantly different at 5 % level of probability using DMR test. *LSD value for Spray 1: 4.92; *LSD value for Spray 2: 1.80*

Scheduled insecticides have also been recommended in Florida against ACP (Rogers, 2008; Stanlsy et al., 2010b). Different insecticides showed different behavior at various intervals after spraying. Immediate reduction in population of the pest demonstrated quick knock down effect of Nitenpyram + Chlofenpyr just after application. The same was continued in later intervals as well which was followed by Flubendiamide and Imidacloprid. Complete removal was observed for Nitenpyram in combination with Chlorfenpyr after a week and nearly the same results were recorded after the second application. Neonicotinoids proved to be a better solution for ACP and hence HLB. Our results are in agreement with Dahiyaet al. (1994) and Chakrvarthy (1998). Similarly, Shivankaretal. (2000) also reported almost complete removal of psyllids by treating with Imidacloprid. Our findings are also in coincidence with that of Ahmed et al. (2004) and Sharma (2008) who investigated that neonicotinoids were significantly effective against citrus psylla. Similarly, Arora and Sharma (2011) also reported the latest group of insecticides to be more efficient against this pest. After first spray the fluctuation in overall population was reasonable in terms of time intervals after application of the treatments. Slight decrease during the first-time interval was observed in the population after second spray however it significantly increased in the later stages. Overall results revealed that negligible pests were present in the recorded duration after two times application of the insecticides.

Conclusions and Recommendations

All the insecticides were influential in regulating the population of *Diaphorina citri*, and revision of spray significantly reduced their occurrence. Although some insecticides affected the pest gradually. Nitenpyram + Chlorphenfyr proved to be highly effective and it should be sprayed twice with an interval of at least 4 weeks. Further studies should be conducted at various agro-climatic conditions for the effectiveness of these insecticides and identification of other species of citrus psylla.

Author's Contribution

Ashraf Khan: Coceived, supervised and conducted research, wrote manuscript and is the corresponding author.
Suliman Shah: Conducted Research and Wrote manuscript.
Maid Zaman: Proof checking and provided technical assistance.
Komal Habib: Analyzed and Incorporated reviewers comments.

References

Ahmed, S., N. Ahmed and R.R. Khan. 2004. Studies on population dynamics and chemical control of citrus psylla, *Diaphorinacitri* Kuw. Int. J. Agric. Biol. 6: 970-973.

Arora, P.K. and D.K. Sharma. 2011. Bio-efficacy of some neonicotinoids against citrus psylla (*Diaphorinacitri*Kuw.) on kinnow mandarin. J. Insect Sci. 24: 399-401.

Bove, J.M. 2006. Huanglongbing: a destructive, newly-emerging,century-old disease of citrus. J. Plant Pathol. 88: 7–37.

Catling, H.D. 1669. The bionomics of the South African citrus psylla, *Triozaerytreae* (DelGuercio) (Hymenoptera: Psyllidae)1. The influence of the flushing rhythum of citrus and factors which regulate flushing. J. Entomol. Soci. South Africa. 32(1): 191-208.

Chakravarthi, V.P., P. Savithri, P.R. Prasad and P.P.

Reddy, 1998. Efficacy of various insecticides against citrus psylla, *Diaphorina citri* kuwayama (Psyllidae: Hemiptera). Advances in IMP Hort. Crops, Banglore, India, l: 32–3.

Dahiya, K.K., R.K Lakra, A.S. Dahiya and S.P. Singh. 1994. Bio efficacy of some insecticides against citrus psylla(*D.citri*Kuw.) (Psyllidae: Hemiptera). Crop Res., (Hisar). 8: 137-140.

Dennis, S.H. 1983. Agricultural insect pests of the tropics and their control. Cambridge Univ. Press. 2(1): 289.

Halbert, S.E. and K.L. Manjunath. 2004. Asian citrus psyllids (Sternorrhyncha: Psyllidae) and greening disease of citrus: a literature review and assessment of risk in Florida. Flor. Entomol. 87: 330–353. https://doi.org/10.1653/0015-4040(2004)087[0330:ACPSPA]2.0.CO;2

Halbert, S.E. and C.A. Nunez. 2004. Distribution of the Asian citrus psyllid, Diaphorinacitri Kuwayama (Rhynchota: Psyllidae) in the Caribbean basin. Flor. Entomol. 87: 401–402. https://doi.org/10.1653/0015-4040(2004)087[0401:DOTACP]2.0.CO;2

Jillani, M.S., M. Ishtiaq and A. Ghafoor. 1989. Physico-chemical characteristics of sweet oranges (*Citrus sinensis* L.) cultivars grown in D.I. Khan. Sarhad J. Agric. 5(2): 145-148.

Khattak, S.U.K., Amanullah, A. Sattar and A. Zeb. 1987. Monitoring and controlling of fruit flies by male annihilation technique in NWFP. NIFA Ann. Rep. pp.141-145.

McCoy, C.W. 1985. Citrus: Current status of biological control in Florida, p. 481–499. In: M.A. Hoy and D.C. Herzog (eds.). Biological control in agricultural IPM systems. Acad. Orlando, FL. https://doi.org/10.1016/B978-0-12-357030-7.50032-6

McCoy, C.W., H.N. Nigg, L.W. Timmer, S.H. Futch, and M.E. Rogers. 2009. Florida citrus pest management guide: Use of pesticides in citrus IPM. UF–IFAS, CPMG 03.

MINFA. 2010-11. Agricultural statistics of Pakistan, Ministry of food agriculture division. pp. 89. Islamabad.

Pluke, R.W.H., J.A. Qureshiand P.A. Stansly. 2008. Citrus flushing patterns, Diaphorinacitri (Homoptera: Psyllidae) populations and parasitism by Tamarixiaradiata (Hymenoptera: Eulophidae) in Puerto Rico. Flor. Entomol. 91: 36–41. https://doi.org/10.1653/0015-4040(2008)091[0036:CFPDCH]2.0.CO;2

Rogers, M.E. 2008. General pest management considerations – responses to greening and its vectors have modified pest management programs. Citrus Ind. 89: 12–17.

Roistacher, C.N. 1996. The economics of living with citrus diseases: Huanglongbing (greening) in Thailand. In: J.V. da Graça, P. Moreno, and R.K. Yokomi (eds.). Proc. 13th Conf. Intl. Org. of Citrus Virologists IOCV). Univ. Calif. Press, Riverside. pp. 279–285.

SAS Institute. 2004. SAS for Windows, Version 9.1. SAS Inst., Cary, NC.

Shah, H.A and M.A. Saleem. 2000. Applied Entomology. 2nd Ed. Izhar sons Printers, Lahore.

Sharma, D.R. 2008.Population dynamics in relation to abiotic factor and management of citrus psylla in Punjab. Indian J. Hort. 65:17-422.

Shivankar, V.J., C.N. Rao, S. Shyam and S. Singh. 2000. Studies on citrus psylla *Diaphorinacitri* Kuwayama. Agric. Rev. 21: 199-204.

Stanlsy, P., H.A. Arevalo and M. Zekri. 2010 b. Area-wide psyllid sprays in southwest Florida: an update on the cooperative program aimed at controlling the HLB vector. Citrus Ind. 91: 6–8.

Stanlsy, P., J.A. Qureshi and B.C. Kostyk. 2012. Effectiveness ranking for insecticides against Asian citrus psyllid. Citrus Ind. 93: 6–9.

Stansly, P.A. and J.A. Qureshi. 2008. Controlling Asian citrus psyllid: Sparing biological control. Citrus Ind. 89: 20–24.