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Evaluation of chemical control schedules against Asian citrus psyllid (*Diaphorina citri)* (Hemiptera: Liviidae)

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Citrus is one of the most important fruit crops of India with a production of 116.36 lakh tonnes from 11.03 lakh ha (NHB 2015). In India*,* Nagpur mandarin, *Citrus reticulata* Blanco is grown commercially on large scale in Vidarbha area of Maharashtra, Saunsar and Pandhurna area of Madhya Pradesh, Jhalawar area of Rajasthan. Citrus production and quality is severely affected by insect pests and more than 250 insect species have been reported to attack citrus right from nursery to maturity of fruits. Among the insect pests, Asian citrus psyllid (ACP), *Diaphorina citri* Kuwayama is the most destructive both as a pest and a vector. It is active during *ambia* (spring) and in dry spells during monsoon (Shivankar *et al.* 2001). New foliage/growth regulates the dynamics of several citrus pests requiring soft tissues for oviposition and development including ACP. Both nymphs and adults suck the vital sap from tender shoot and cause heavy de-blossoming, thereby affects the fruit set seriously.

ACP besides causing direct damage, it is an active vector of the deadly "Huanglongbing" (HLB) disease caused by *Candidatus liberibacter* asiaticus (Bindra and Chhabra 1967 and Capoor *et al.* 1967) which is the most serious problem in tropical and subtropical citrus orchards (Bove 2006). HLB is extremely difficult to manage because all commercial citrus species and cultivars appear susceptible, regardless of rootstock and no cure is currently available for infected trees. Control of its vector is one of the ways for management of spread of this disease. Chemical control has been followed mostly by growers for suppressing ACP population.

Several researchers reported effectiveness of organophosphates (Abbaszadeh *et al.* 2011, Farmanullah *et al*. 2005), carbamates (Qureshi and Stansly 2008, Childers and Rogers 2005), synthetic pyrethroids (Qasim and Hussain 2015) and neo-nicotinoids (Patel *et al*, 1998, Dadmal *et al*, 2002, Arora *et al* 2005, Qureshi *et al*. 2010, Rao *et al*. 2013) against ACP. Further, different methods of application may also influence the duration of effectiveness of an insecticide. Hence, selection of an insecticide coupled with timely and effective method of application is important in checking the incidence levels of ACP. In this present study, a field experiment was conducted to develop a chemical control schedule with combination of different group of insecticides viz. thiamethoxam, imidacloprid (neonicotinoids), dimethoate (organophosphate) and abamectin (avermectin) with soil and foliar applications to know their efficacy against ACP during spring 2013 and 2014.

The experiment was conducted in a 21 year old, Nagpur mandarin orchard at Pipla (Kinkhede), Tahsil- Kalmeshwar, District- Nagpur with 475 plants in 25 rows at 6×6 m spacing in a randomized block design (RBD) with four replicates and two trees/replication. The experiment was initiated during second fortnight of December and recommended cultivation practices were followed.

Different modules consisted of foliar/soil application of insecticides, viz. thiamethoxam 25WG @ 0.008%, imidacloprid 17.8 SL @ 0.009%, abamectin 1.9 EC @ 0.0006% and dimethoate 30% EC @ 0.06%. The pest management schedules followed were, viz. module – I: soil application of thiamethoxam @ 0.008% 20 days before flushing and during flushing at an interval of 20 days, module – II: soil application of thiamethoxam @ 0.008% 20 days before flushing followed by foliar application of thiamethoxam @ 0.008% and imidacloprid @ 0.009% during flushing at an interval of 20 days, module – III: soil application of thiamethoxam @ 0.008% 20 days before flushing followed by foliar application of abamectin @ 0.0006% and imidacloprid @ 0.009% during flushing at an interval of 20 days, module – IV: foliar application of thiamethoxam @ 0.008% 20 days before flushing followed by foliar application of abamectin @ 0.0006% and imidacloprid @ 0.009% during flushing at an interval of 20 days and module –V: foliar application of dimethoate 0.06% and imidacloprid @ 0.009% during flushing at an interval of 20 days. Components of respective modules were implemented before flushing and during flushing periods.

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ACP population on 5 cm twig at 7, 14, 21, 40, 60 days after foliar application (DAT) and bioagent population on 10 cm twig/ 1 min. visual observation from four sides of the treated and control plants at 21, 40 and 60 DAT were recorded. Collected data was transformed to square root values and subjected to analysis of variance (ANOVA) to evaluate the effects on ACP and bioagent population, respectively.

All the five modules were recorded significantly low ACP population than control irrespective of days after treatments (DAT). Among the modules, module-IV recorded significantly low ACP population (7.8 and 5.0, 9.7 and 6.5, 7.5 and 6.3, 15.4 and 16.35 and 20.5 and 20.87 population/5cm twig at 7, 14, 21, 40 and 60 DAT, respectively) during 2013 and 2014 but was at par with module-III at 7 DAT (6.2 population /5cm twig), at 14 DAT (7.5 population /5cm twig) during 2014 and (13.1 population /5cm twig) during 2013, 40 DAT (16.6 population /5cm twig) and 60 DAT (21.4 population /5cm twig) during 2013. Similarly, mean (pooled mean) ACP population/5cm twig was significantly low in module-IV irrespective of DAT than other modules but was at par with module-III at 40 DAT and module-III, II and I at 60 DAT. Bioagent population /10 cm twig was significantly more in control irrespective of DAT and year but was at par with module-I at 21 (10.4 bioagent population /5cm twig), 40 (10.1 bioagent population /5cm twig), 60 DAT (9.2 bioagent population/5cm twig) during 2013 (Table 1). Similarly, mean (pooled mean) bioagent population was significantly more in control irrespective of DAT and year was at par with module-I at 21 (8.63 bioagent population/5cm twig), 40 DAT (9.35 bioagent population/5cm twig) and with module-III (7.25 bioagent population/5cm twig), II (7.53 bioagent population/5cm twig), I (8.66 bioagent population/5cm twig) at 60 DAT (Table 2).

The efficacy of module with foliar application of thiamethoxam @ 0.008% 20 days before flushing followed by foliar application of abamectin @ 0.0006% and imidacloprid @ 0.009% during flushing at an interval of 20 days might be due to suppression of ACP adult populations during pre-flush period and nymph and adult population during flushing period.

The results are in congruent with Dalvaniya *et al*. (2015) who reported that foliar applications of imidacloprid and thiamethoxam significantly reduced ACP population in lime plants. Farmanullah *et al.* (2005) also reported that the foliar application of thiamethoxam was effective and suppressed psyllid population up to 28 DAT, whereas the second foliar application of thiamethoxam proved to be the best treatment by suppressing psyllid population up to 40 DAT. Childers and Rogers (2005) reported foliar application of imidacloprid @ 0.25 oz/tree resulted in greatest reduction in ACP population up to 14 DAT. Foliar applications with thiamethoxam and imidacloprid was found to reduce ACP population of 86.9-96.4 % and 91.5-98.0 % over control up to 12 DAT (Sharma 2008). Foliar application with abamectin @ 0.3ml/l resulted in 90.2-92.5% reduction in ACP population (Rao and Shivankar 2011). Sarada *et al*.

Table 1 Effect of chemical control schedules on Asian citrus psyllid (ACP) population during *Ambia* 2013 and 2014

Module	Asian citrus psyllid population/5cm twig													
	7 DAT			14 DAT			21 DAT			40 DAT			60 DAT		
	2013	2014	Pooled mean	2013	2014	Pooled mean	2013	2014	Pooled mean	2013	2014	Pooled mean	2013	2014	Pooled mean
Module-I	17.8	16.46	17.26	22.8	18.4	20.61	32	29.5	30.75	21.5	24.57	23.03	18.2	25.85	22.02
	(4.22)bc	(4.05)bc	(4.15)c	(4.68)bc	(4.27)bc	(17.65)c	(5.65)c	(5.42)b	(5.54)c	(4.63)c	(4.95)c	(4.79)c	(4.25)c	(5.08)c	(4.68)b
Module-II	16.0	15.1	15.63	18	17.3	7.65	23	22.4	22.70	19.2	20.6	19.90	20.8	23.05	21.92
	(3.96)cd	(3.88)c	(3.95)d	(4.20)cd	(4.15)c	(4.20)d	(4.79)d	(4.73)c	(4.76)d	(4.37)c	(4.53)d	(4.46)cd	(4.54)c	(4.80)d	(4.68)b
Module-III	12.8	6.2	9.5	13.1	7.5	10.3	11.3	9.4	10.35	16.6	17.23	16.91	21.4	22.75	22.07
	(3.58)d	(2.47)d	(3.08)e	(3.59)de	(2.73)d	(3.21)e	(3.36)e	(3.06)d	(3.21)e	(4.06)c	(4.23)e	(4.11)de	(4.62)c	(4.77)d	(4.69)b
Module-IV	7.8	5.0	6.43	9.7	6.5	8.03	7.5	6.3	6.90	15.4	16.35	15.88	20.5	20.87	20.68
	(2.79)e	(2.22)d	(2.53)f	(3.10)e	(2.54)d	(2.83)f	(2.72)f	(2.50)e	(2.62)f	(3.91)c	(4.04)f	(3.98)e	(4.52)c	(4.56)e	(4.54)b
Module-V	21.2	19.7	20.73	27.0	21.7	24.35	44	32.0	38.00	36.3	35.10	35.70	41.9	43.40	42.65
	(4.60)b	(4.42)b	(4.55)b	(5.13)b	(4.65)b	(4.93)b	(6.62)b	(5.65)b	(6.16)b	(5.98)b	(5.9)b	(5.96)b	(6.44)b	(6.58)b	(6.52)a
Control	48.3	40.8	44.48	60.0	48.4	54.21	66.0	51.4	58.73	48.6	53.4	51.0	52.7	40.57	46.63
	(6.95)a	(3.68)a	(6.67)a	(7.69)a	(6.95)a	(7.36)a	(8.12)a	(7.16)a	(7.66)a	(6.98)a	(7.30)a	(7.14)a	(7.25)a	(7.04)a	(6.82)a
CD (P=0.05)	0.55	0.46	1.56	0.63	0.49	2.10	0.51	0.36	1.68	0.79	0.92	4.05	0.76	0.96	3.98
CV%	7.03	6.65	4.52	7.37	6.42	5.13	5.44	4.32	3.16	8.92	2.20	8.22	8.18	2.06	7.47

DAT= Days after treatment; Figures in parentheses are square root transformed values; Values followed by same letter in a column are not significantly different (P=0.05)

Table 2 Effect of chemical control schedules on bioagent population during *Ambia* 2013 and 2014

Module	Bioagents population/10 cm twig								
	21 DAT			40 DAT			60 DAT		
	2013	2014	Pooled mean	2013	2014	Pooled mean	2013	2014	Pooled mean
Module-I	10.4 (3.22)ab	6.9 (2.62)b	8.63 (2.93)a	10.1 (3.17)ab	8.6 (2.93)b	9.35 (3.05)a	9.2 (3.03)a	8.19 (2.86)b	8.66 (2.94)a
Module-II	7.8 (2.79)bc	5.8 (2.41)bc	6.80 (2.60)c	7.5 (2.72)bc	7.6 (2.75)c	7.55 (2.74)b	7.1 (2.66)b	7.97 (2.82)bc	7.53 (2.74)ab
Module-III	7.6 (2.73)bc	5.6 (2.36)c	6.61 (2.57)cd	7.16 (2.67)c	6.2 (2.48)d	6.68 (2.58)c	6.9 (2.62)bc	7.60 (2.75)cd	7.25 (2.7)ab
Module-IV	7.1 (2.67)c	5.1 (2.25)c	6.10 (2.47)d	6.5 (2.53)c	5.4 (2.32)e	5.95 (2.43)d	6.2 (2.48)c	7.20 (2.68)d	6.70 (2.58)b
Module-V	4.2 (2.04)d	3.5 (1.85)d	3.85 (1.96)e	3.9 (1.97)d	4.3 (2.07)f	4.10 (2.02)e	3.2 (1.78)d	6.60 (2.56)e	4.90 (2.19)a
Control	11.5 (3.38)a	8.5 (2.91)a	10.03 (3.16)a	10.5 (3.23)a	9.6 (3.09)a	10.05 (3.16)a	9.4 (3.06)a	8.80 (2.96)a	9.10 (3.01)a
CD (P=0.05)	0.53	0.23	0.69	0.45	0.62	0.73	0.11	0.47	0.32
CV%	10.37	6.52	5.46	9.43	5.92	5.51	3.82	3.40	6.69

DAT= Days After Treatment; Figures in parentheses are square root transformed values; Values followed by same letter in a column are not significantly different (P=0.05).

(2014) also reported foliar application of abamectin @ 0.0007% reduced ACP population more than 80 % after 3 and 7 DAT.

Thiamethoxam and imidacloprid possesses high systemic activity and is rapidly taken up by the shoots, leaves and roots of the plant (Anonymous 2000, Farmanullah 2005) and with translaminar activity. Pre-flush application of neo-nicotinoid thus reduced the previous overwintering sustainable ACP population that ultimately reduced the next subsequent generation. Similarly, abamectin also plays an important role by attacking the nervous system of insects, causing paralysis within hours which is irreversible. The combined treatment showed better results for a long period by suppressing psyllid population even during high temperature in March-April. First foliar application of thiamethoxam target the overwintering survival ACP adult populations that were low and at the same time non availability of new flush for reproduction, such condition act as both side hammer attack. Another advantage of systemic insecticides over conventional insecticides is that the entire plant is protected from attack of such sap sucking insects like ACP. Hence, application of this identified effective module on wider scale could help in reducing ACP population in citrus groves.

SUMMARY

Five chemical control schedules (modules) consisting of imidacloprid, abamectin, dimethoate and thiamethoxam along with control were evaluated against Asian citrus psyllid (ACP) *Diaphorina citri* Kuwayama during spring 2013 and 2014. Results showed that module- with foliar application of thiamethoxam @ 0.008% 20 days before flushing followed by foliar application of abamectin @ 0.0006% and imidacloprid @ 0.009% during flushing at an interval of 20 days) was recorded significantly low psyllid population (6.43, 8.03, 6.90, 15.88 and 20.68 psylla/5cm twig at 7, 14, 21, 40 and 60 days after treatment, DAT, respectively) and was at par with module- soil application of thiamethoxam @ 0.008% 20 days before flushing followed by foliar application of abamectin @ 0.0006% and imidacloprid @ 0.009% during flushing at an interval of 20 days (9.5, 10.3, 10.35, 16.91 and 22.07 psylla/5cm twig at 7, 14, 21, 40, 60 DAT, respectively). Bioagent population was found higher on control trees (9.10-10.05 bioagents/10 cm twig) followed by module with soil application of thiamethoxam @ 0.008% 20 days before flushing and during flushing at an interval of 20 days (8.63-9.35 bioagents/10 cm twig at 21, 40 and 60 DAT) as compared to rest of the modules. For ACP control, module with foliar application of thiamethoxam, abamectin and imidacloprid at 20 days interval before, during and after flushing periods was found to be superior in protecting new flush from ACP compared to other insecticides modules.

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