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Effect of time of breaking water stress, planting density, organic manuring and certain new insecticides on incidence of Asian citrus psyllid, *Diaphorina citri* (Hemiptera: Psyllidae)

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ABSTRACT

Asian citrus psyllid (ACP), *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae) is one of the major insect pest of citrus cultivars grown across India. A series of experiments on the management of ACP, viz. effect of time of breaking water stress (T_1- 1st January, T_2- 10th January, T_3-20th January and T_4- 30th January), planting density (spacing 6 m × 6 m and 3 m × 3 m), organic manuring (Farmyard manure @ 20 kg/tree, vermicompost @ 10 kg/tree, poultry manure @ 10 kg/tree, green manuring with cowpea and sunnhemp) and evaluation of new insecticides [thiomethoxam @ 0.008%, acetamiprid @ 0.007%, imidacloprid @ 0.009% (soil and foliar application), abamectin @ 0.0006% and spinosad @ 0.015% (foliar application)] in Nagpur mandarin, *Citrus reticulata* Blanco were conducted at National Research Centre for Citrus, Nagpur during 2009-12. Results revealed that time of breaking water stress on 1st January, 6 m × 6 m spacing, application of vermicompost @ 10 kg/tree and soil application of thiamethoxam @ 0.008% recorded significantly reduced levels of ACP. The information generated helps in the development of pest management modules for the effective management of ACP in Nagpur mandarin orchards of central India.

Key words: Asian citrus psyllid, Efficacy, Incidence, Insecticides, Organic manure, Planting density, Time of breaking water stress

Asian citrus psyllid (ACP), *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae) is one of the major insect pest of citrus cultivars, viz. Nagpur mandarin, *Citrus reticulata* Blanco, Sweet orange, *Citrus sinensis* (L.) Osbeck and acid lime, *Citrus aurantifolia* Swingle either as a pest and/or vector (Shivankar and Rao 2010). Both nymphs and adults of ACP suck the vital plant sap from young shoots and cause heavy de-blossoming, thereby affects the fruit set seriously. ACP is also known to transmit the disease, huanglongbing (HLB), *Candidatus liberibactor asiaticus* (Bove 2006). It is active during spring and in dry spells during monsoon (Shivankar *et al.* 2001). ACP is important as a pest on Nagpur mandarin and as a vector of HLB on Sweet Orange as Sweet orange is more prone to HLB than Nagpur mandarin (Das *et al*. 2002). ACP epidemics on Nagpur mandarin were reported in central India during 1960-62, since then ACP has attained endemic pest status causing considerable loss (Shivankar and Rao 2010).

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At present, the most common practice for management of ACP is use of foliar application of insecticides particularly organo-phosphorous and carbamates (Patel *et al*. 1998, Dadmal *et al*. 2002, Arora *et al*. 2005). However, safer and effective alternative methods are the need of the hour to contain ACP on sustainable basis. In this context, cultural methods like time of breaking water stress, planting density, organic manuring and application of new insecticides play an important role in containing ACP in Nagpur mandarin orchards of central India. Therefore, the present study was conducted with an aim to study the effect of time of breaking water stress, planting density, organic manuring and evaluation of new insecticides on ACP population which may pave the way in the development of IPM module for effective management of ACP.

MATERIALS AND METHODS

Effect of time of breaking water stress at four different times (T_1- 1st January, T_2- 10th January, T_3-20th January and T_4- 30th January) in 20 year old Nagpur mandarin orchard on the incidence of ACP was studied at Pipla (Kinkheda), Kalmeshwar Taluka, Nagpur district during Spring 2010, 11 and 2012. Observations on ACP population/5 cm twig were recorded during II fortnight of February and I and II fortnight of March which coincides with the peak activity of ACP. The experiment was laid out in completely randomized block design and each treatment replicated five times. Each replication consisted of two trees. The data were transformed to square root values and were subjected to analysis of variance.

Effect of planting density on incidence of ACP in a 12 year old orchard of Nagpur mandarin with spacing of 6 m × 6 m and 3 m × 3 m was conducted during 2009-11 at Experimental Farm of National Research Centre for Citrus (NRCC), Nagpur. Forty plants in each spacing were selected and observations on ACP population/5 cm twig were recorded at fortnightly interval and data were pooled season wise in winter 2009, 10 and spring 2010, 11 seasons. The data were subjected to t-test.

Effect of different organic manures, viz. farmyard manure (FYM) @ 20 kg/tree, vermicompost @ 10 kg/tree, poultry manure @ 10 kg/tree, green manuring with cowpea and sunnhemp along with inorganic fertilizer (300g N, 100g P, 50g K/tree) in a 12 year old orchard of Nagpur mandarin on incidence of ACP was conducted during 2010, 11 and 12 at Experimental Farm of NRCC, Nagpur. Sunnhemp and cowpea plants were grown in the basin of the Nagpur mandarin tree during rainy season and on reaching flowering stage they were incorporated into the soil. The experiment was laid out in completely randomized block design and each treatment replicated five times. Each replication consisted of two trees. Observations on ACP population/5 cm twig were recorded at fortnightly intervals during spring 2010, 11 and 12. The data were transformed to square root values and were subjected to analysis of variance.

Field appraisal of efficacy of five new insecticides and method of application against ACP was conducted in a 20 year old Nagpur mandarin orchard at Pipla (Kinkheda), Kalmeswar Taluka, Nagpur district during spring 2010, 11 and 12. The treatments of soil application (thiomethoxam @ 0.008%; acetamiprid @ 0.007% and imidacloprid @ 0.009%) were given 25 days before the new flush emergence (coinciding with second irrigation at the time of breaking stress) in spring and treatments of foliar application (abamectin @ 0.0006%, spinosad @ 0.015%, thiomethoxam @ 0.008%, acetamiprid @ 0.007% and imidacloprid @ 0.009%) were given 25 days after soil application coinciding with new flush emergence. Observations on ACP population/ 5 cm twig were recorded at 7, 14, 21 days after the foliar application. The experiment was laid out in completely randomized block design and each treatment replicated three times. Each replication consisted of two trees. The data were transformed to square root values and were subjected to analysis of variance.

RESULTS AND DISCUSSION

Effect of time of breaking water stress

Effect of time of breaking water stress in Nagpur mandarin on incidence of ACP during spring 2010,11 and 12 showed that that time of breaking water stress on 1 January recorded significantly low ACP population (5.10-7.62 population/5 cm twig in II fortnight of February; 3.37-11.59 population/5 cm twig in I fortnight of March, 2.18-20.5 population/5 cm twig in II fortnight of March) than other treatments irrespective of the year and time of observation but at par with time of breaking water stress on 10th January in II fortnight of February (8.08 population/5 cm twig) and I fortnight of March (11.72 population/5 cm twig) during 2011. The treatment of time of breaking water stress on 30th January recorded significantly high ACP population (8.68-

Table 1 Effect of time of breaking of water stress on incidence of Asian citrus psyllid (*Diaphorina citri*) during spring 2010, 11 and 2012

Treatment	ACP population/5 cm twig											
	IInd Fortnight of February				Ist Fortnight of March				IInd Fortnight of March			
	2010	2011	2012	Pooled mean	2010	2011	2012	Pooled mean	2010	2011	2012	Pooled mean
T_1–1 January	5.1 (2.25)c	7.62 (2.75)c	7.26 (2.69)b	6.78 (2.56)	10.5 (3.19)c	11.59 (3.40)c	3.37 (1.82)c	8.48 (3.0)	20.5 (4.51)c	2.18 (1.56)c	3.31 (1.81)c	8.66 (2.62)
T_2–10 January	6.25 (2.50)b	8.08 (2.81)bc	11.43 (3.09)a	8.58 (2.8)	24.12 (4.89)b	11.72 (3.42)c	5.12 (2.24)b	13.65 (3.51)	35.25 (5.92)b	4.68 (2.22)b	5.12 (2.24)b	15.01 (3.46)
T_3–20 January	8 (2.82)ab	10.18 (3.18)ab	8.75 (2.95)a	8.97 (2.98)	34.12 (5.82)ab	12.98 (3.59)b	7.06 (2.65)a	18.05 (4.02)	35.47 (5.91)b	8.8 (3.04)a	5 (2.23)b	16.42 (3.72)
T4–30 January	9 (2.99)a	12.62 (3.53)a	8.68 (2.94)a	10.1 (3.15)	32.5 (6.31)a	14.41 (3.79)a	5.62 (2.36)ab	17.51 (4.15)	47.81 (6.88)a	7.45 (2.81)a	7.46 (2.64)a	20.9 (4.11)
SEd±	0.36	0.6	1.49		0.25	0.67	0.35		0.77	1.5	0.54	
CD (5%)	0.23	0.42	0.22		1.02	0.17	0.32		0.81	0.51	0.36	

Figures in parentheses are square root transformed values.

Values followed by same letter in a column are not significantly different (P=0.05)

12.6 population/5 cm twig in II fortnight of February; 5.62-32.5 population/5 cm twig in I fortnight of March; 7.45-47.8 population/5 cm twig in II fortnight of March) than other treatments (Table 1). Increase in ACP population with the advancement of breaking water stress is probably due to more availability of new flush coinciding with peak activity of ACP during February and March months. In central India with-holding irrigation (soil water deficit stress) for a period of 30-40 days followed by resuming irrigation at near field capacity moisture level during January month is usually practised for induction of spring flushing/flowering in Nagpur mandarin (Deshmukh *et al*. 1988, Srivastava *et al*. 2000). The results clearly showed that breaking water stress on 1 January resulted in reduced ACP population in spring flushes of Nagpur mandarin in central India which may well be taken into consideration as an important component of IPM for the management of ACP.

Effect of planting density

Effect of planting density on ACP population revealed that 3 m × 3 m spacing recorded significantly more (t–test at 0.05) ACP population (14.2/5 cm twig in winter, 42.62/5 cm twig in spring) than 6 m × 6 m spacing (8.23/5 cm twig in winter, 20.26/5 cm twig in spring). The results are in agreement with Arora *et al.* (1999) who reported that insect pest incidence (whiteflies, psylla, leaf miner and mealy bugs) was more in close plant spacing (20'×10'; 20'×15') as compared to the recommended (20'×20') and wider plant spacing (20'×22' and 25'×25') in Kinnow mandarin. Similarly, Sidhu *et al.* (1997) reported more incidence of citrus leaf miner and psylla in 3 m × 3 m and 4.5 m × 4.5 m spacing in Kinnow. Increase in ACP populations in 3 m × 3 m spacing in the present study on Nagpur mandarin is probably due to more availability of new flush coupled with favourable micro climate (less sunlight and more humidity) due to intermingling branches between trees which favoured the ACP development than 6 m × 6 m spacing. Therefore, under normal plant protection measures, avoid high density planting in Nagpur mandarin. However, in the recent past high density planting is being emphasized in fruit crops including citrus to achieve higher yield/ha. High density planting necessitates extra care with respect to intensive management measures to contain insect pests including ACP.

Effect of organic manuring

Effect of organic manuring on ACP population showed that among the organic manuring treatments, ACP population was significantly low in vermicompost (15.91-18.55 population/5 cm twig) than other treatments but was at par with FYM (16.38-19.46 population/5 cm twig) during 2010 and 11. In all the three years, ACP population was significantly high in in-organic fertilizer treatment (24.0-36.36 population/5 cm twig) than organic manure treatments (15.91-33.34 population/5 cm twig) (Table 2). The results are in congruent with Ravi *et al.* (2006) who reported reduced incidence of leafhopper, *Amrasca biguttula biguttula* (Ishida) and whitefly, *Bemisia tabaci* Genn. in vermicompost treated sunflower (*Helianthus annuus* L.). The low ACP populations in vermicompost treatment are probably due to the accumulation of more potassium in soil as well as leaves of the Nagpur mandarin trees treated with vermicompost over the years (Anonymous 2012). Further, increased levels of potassium fertilizer in Valencia orange (*Citrus sinensis*) plants grown under greenhouse conditions resulted in decreased fitness (psyllid weight, egg production, development time) of psyllid population (Rogers 2010). The organic vermicompost amendment probably increased the total phenol content (Ravi *et al.* 2006) and also the activity of enzymes, viz. polyphenol oxidase and peroxidase in Nagpur mandarin trees which might be responsible for the reduced ACP incidence.

Table 2 Effect of organic manuring on incidence of Asian citrus psyllid (*Diaphorina citri*) during spring 2010, 11 and 12

Treatment	Asian citrus psyllid nymphs/5 cm twig			
	2010	2011	2012	Pooled mean
T_1 – FYM @ 20 kg/tree	16.38 (4.08)[a]	19.46 (4.40)[a]	23.3 (4.80)[b]	19.71 (4.42)
T_2 –Vermicompost @ 10 kg/tree	15.91 (4.00)[a]	18.55 (4.27)[a]	18.1 (4.24)[a]	17.52 (4.17)
T_3-Poultry manure @ 10 g/tree	16.58 (4.10)[b]	27.18 (5.30)[b]	32.72 (5.71)[d]	25.49 (5.03)
T_4-Green manuring - cowpea	17.31 (4.19)[b]	27.67 (5.28)[b]	31.74 (5.63)[c]	25.47 (5.03)
T_5-Green manuring - sunnhemp	17.73 (4.24)[b]	29.89 (5.30)[bc]	33.34 (5.77)[e]	26.65 (5.1)
T_6 –Fertilizer 600g N+ 200g P+100g K	24 (4.92)[c]	32.22 (5.69)[c]	36.36 (6.02)[f]	31.86 (5.54)
SEd±	0.14	0.3	0.29	
CD (P=0.05)	0.3	0.64	0.32	

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

Efficacy of certain new insecticides

Evaluation of new insecticides, viz. thiomethoxam @ 0.008%, acetamiprid @ 0.007%, imidacloprid @ 0.009% (soil and foliar application), abamectin @ 0.0006% and spinosad @ 0.015% (foliar application) against ACP indicated all the treatments recorded significantly low ACP population than control irrespective of year and days after treatment. Of the treatments, at 7 DAT foliar application of thiamethoxam @ 0.008% in spring 2010, soil application of thiamethoxam @ 0.008% in spring 2011 and foliar application of imidacloprid @ 0.009% in spring 2012 recorded significantly

Table 3 Effect of soil and foliar application of certain insecticides against Asian citrus psyllid (*Diaphorina citri*) population during spring 2010, 11 and 2012

Treatment	ACP population/5 cm twig											
	7 DAT				14 DAT				21 DAT			
	2010	2011	2012	Pooled mean	2010	2011	2012	Pooled mean	2010	2011	2012	Pooled mean
T_1–Thiamethoxam	16.58	12.16	24.3	17.68	11.33	6.66	9.7	9.23	3	3.66	4.2	3.62
SA @ 0.008%	(4.11)^{bc}	(3.55)^{a}	(4.93)^{b}	(4.18)	(3.43)^{bc}	(2.66)^{a}	(3.09)^{b}	(3.06)	(1.87)^{a}	(2.02)^{a}	(2.05)^{a}	(1.98)
T_2–Acetamiprid	18.41	22.16	33.2	24.59	12	15.83	26.16	17.99	17.83	11.33	15.2	14.78
SA @ 0.007%	(4.34)^{c}	(4.72)^{b}	(5.75)^{e}	(4.93)	(3.51)^{cd}	(4.02)^{d}	(5.09)^{e}	(4.2)	(4.28)^{d}	(3.43)^{bc}	(3.90)^{g}	(3.87)
T_3–Imidacloprid	14.08	28.16	28.8	23.68	10.5	20.33	11.33	14.05	7.88	8.5	6.7	7.69
SA @ 0.009%	(3.77)^{abc}	(5.35)^{b}	(5.36)^{d}	(14.48)	(3.30)^{bc}	(4.56)^{e}	(3.36)^{c}	(3.74)	(2.88)^{c}	(3.00)^{bc}	(2.60)^{c}	(2.82)
T4–Abamectin	10.16	18.5	36.8	21.82	5.08	10.5	15.2	10.26	4.75	8.66	12.1	8.5
FA @0.0006%	(3.23)^{ab}	(4.35)^{ab}	(6.06)^{g}	(4.54)	(2.34)^{a}	(3.31)^{bc}	(3.75)^{d}	(3.13)	(2.29)^{b}	(2.96)^{abc}	(3.48)^{f}	(2.91)
T_5–Spinosad	18.5	18.83	37.2	24.84	17.08	12.66	26.2	18.64	7.16	9	18.2	11.45
FA @0.015%	(4.34)^{c}	(4.36)^{ab}	(6.09)^{g}	(4.93)	(4.16)^{d}	(3.62)^{c}	(4.92)^{e}	(4.23)	(2.75)^{c}	(3.07)^{bc}	(4.26)^{h}	(3.36)
T_6–Thiamethoxam	8.75	15.16	25.8	16.57	4.25	7.66	7.7	6.53	3.5	5.5	5.6	4.86
FA @ 0.008%	(3.00)^{a}	(3.95)^{ab}	(5.08)^{c}	(4.01)	(2.17)^{a}	(2.84)^{ab}	(2.74)^{a}	(2.58)	(1.99)^{ab}	(2.41)^{ab}	(2.37)^{b}	(2.25)
T_7–Acetamiprid	17.33	13.33	34.2	21.62	10.41	11	11.0	10.8	4.83	9.33	8.7	7.62
FA @ 0.007%	(4.21)^{bc}	(3.68)^{a}	(5.84)^{f}	(4.57)	(3.29)^{bc}	(3.38)^{c}	(3.31)^{c}	(3.32)	(2.28)^{b}	(3.13)^{bc}	(2.96)^{e}	(2.79)
T_8–Imidacloprid	12.25	13.16	12.8	12.73	7.41	7.58	7.6	7.53	3.25	8	7.3	6.18
FA @ 0.009%	(3.52)^{abc}	(3.67)^{a}	(3.56)^{a}	(3.58)	(2.80)^{ab}	(2.83)^{a}	(2.74)^{a}	(2.79)	(1.93)^{ab}	(2.88)^{ab}	(2.70)^{d}	(2.5)
T_9–Control	22.16	38.66	46.5	35.77	17.83	56	56.0	43.27	20.75	58.66	56.7	45.37
	(5.66)^{d}	(6.25)^{c}	(6.81)^{h}	(6.24)	(5.21)^{e}	(7.51)^{f}	(7.48)^{f}	(6.73)	(5.55)^{e}	(6.54)^{d}	(7.53)^{i}	(6.54)
SEd±	0.47	0.39	0.33		0.33	0.24	4.17		0.17	0.43	0.05	
CD (P=0.05)	1	0.83	0.24		0.7	0.51	1.13		0.36	0.94	0.23	

DAT, days after treatment; SA, soil application; FA, foliar application

Figures in parentheses are square root transformed values.

Values followed by same letter in a column are not significantly different (P=0.05)

low ACP population but was at par with foliar application of abamectin @ 0.0006%, foliar and soil application of imidacloprid @ 0.009% during 2010 and foliar application of all the test insecticides during 2011. At 14 DAT, foliar application of thiamethoxam @ 0.008% during 2010, foliar application of imidacloprid @ 0.009% during 2011 and 12 recorded significantly low ACP population but was par with foliar application of abamectin @ 0.0006% and imidacloprid @ 0.009% during 2010 and foliar application of thiamethoxam @ 0.008% during 2011 and 12. At 21 DAT, soil application of thiamethoxam @ 0.008% recorded significantly low ACP population (3-4.2 population/5 cm twig) than other treatments irrespective of year but was at par with foliar application of thiamethoxam @ 0.008% (3.5-5.5 population/5 cm twig) and imidacloprid @ 0.009% (3.25-8.0 population/5 cm twig) during 2010 and 11(Table 3).

The results indicated that soil and foliar application of thiamethoxam @ 0.008% and foliar application of imidacloprid @ 0.009% were effective in checking the ACP population up to 21 days after treatment (foliar application). The results are in agreement with Rogers and Shawer (2007) and Childers and Rogers (2005) who reported soil application of the two neonicotinoid insecticides imidacloprid and thiamethoxam provided the greatest reduction in psyllid populations. Therefore, soil application of thiamethoxam @ 0.008% may well be given priority over foliar application of the same in ACP management due to its safety to biocontrol agents of ACP which are not directly targeted as the case with foliar application.

The present study generated useful information on ACP population reduction through various management aspects, viz. breaking water stress on 1 January, 6 m × 6 m spacing, application of vermicompost @ 10 kg/tree and soil application of thiamethoxam @ 0.008% which may well be taken into consideration while developing pest management modules against ACP in Nagpur mandarin orchards of central India.

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