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Control of the white mango scale *Aulacaspis tubercularis* (Hemiptera: Sternorrhyncha: Diaspididae) with systemic soil drenching insecticides and pruning in greater than ten years old mangos in western Ethiopia

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ABSTRACT

The white mango scale insect (WMS), *Aulacaspis tubercularis* Newstead, 1906 is a key pest of mango in Ethiopia, which has been spreading throughout the country since its introduction in 2010. Evaluation of the efficacy of two systemic soil drenching insecticides (thiamethoxam 25 % WG and imidacloprid 35 % SC) independently, and in combination with tree management (pruning) for the control of the WMS was conducted under field conditions in western Ethiopia in two locations in 2018 and 2019. Randomized complete block designs with three replications were used for the experiments. In the first site, all treatments resulted in scale populations that were significantly lower than the control (1086 crawlers and females per leaf). Thiamethoxam 25 % WG at 12 g/tree + pruning resulted in the lowest number of the WMS after the second treatment (43.5 per leaf) followed by thiamethoxam 25 % WG at 18 g/tree + pruning, which was statistically similar. In the second site, imidacloprid 35 % SC + thiamethoxam 25 % WG at 18 g/tree + pruning, resulted in the lowest mean number of the WMS (31.1 per leaf) followed by thiamethoxam 25 % WG at 12 g/tree + pruning (61.4 per leaf). This treatment also gave the highest percentage reduction in number of the WMS compared to the WMS counting before treatment application. This study has shown that use of systemic insecticides and pruning are promising control tactics for the WMS. Cost implications and effects of the insecticides on the natural enemy complex and residual toxicity in fruits need to be evaluated.

KEYWORDS: *Aulacaspis tubercularis*, white mango scale, pest management, pruning, systemic insecticides, *Mangifera indica*.

INTRODUCTION

The white mango scale insect (WMS), *Aulacaspis tubercularis* Newstead, 1906 (Hemiptera: Sternorrhyncha: Diaspididae), became a key pest of mango after it was introduced to Ethiopia in 2010 (Mohamed *et al*. 2012). The pest has spread to all mango producing regions of Ethiopia during the last 10 years (Fita 2014; Gashawbeza *et al*. 2015; Ofgaa *et al*. 2019). All the growth stages of mango plant from seedling to mature trees are attacked and damage symptoms include yellowing

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of leaves, twigs and fruits, and die-back (Ofgaa *et al*. 2016). If infestation occurs at the seedling stage, the whole plant can die; mature plants exhibit decreased fruit bearing, defoliation, poor blossoming and reduced juice content in fruit (Abo-Shanab 2012). Infestation by the WMS also deprives the plant of active photosynthetic leaf area by causing yellowing of the leaves, lowers productivity and causes serious declines in mango production in many countries (Miller & Davidson 1990; USDA 2006; Germain *et al*. 2010; Abo-Shanab 2012). In addition to Ethiopia, the WMS is an important mango pest in Africa (Benin, Côte d'Ivoire, Egypt, The Gambia, Ghana, Guyana, Kenya, Liberia, Madagascar, Malawi, Mauritius, Mozambique, Sierra Leone, Seychelles, South Africa, Tanzania, Togo, Uganda, Zambia and Zanzibar), North and South America, Asia, Australia and the Caribbean Islands (El-Metwally *et al*. 2011; Nabil *et al*. 2012; García *et al.* 2016; CABI 2018).

The WMS control measures include the use of insecticides, cultural practices and biological control by parasitoids and predators (Daneel & Joubert 2009; Abo-Shanab 2012; Gashawbeza *et al*. 2015). However, since most mango varieties grown in the homesteads of small holder farms are up to 20 m tall and difficult to reach by ordinary spray equipment, use of foliar insecticides against the WMS is less practical (Fita 2014; Ofgaa 2020). Moreover, health hazards to humans, domestic animals and environmental contamination are other drawbacks of foliar insecticides. In addition, controlling the WMS with foliar insecticides may require several consecutive weekly applications, yet does not guarantee effective control and can negatively impact populations of the natural enemies of the pest (Manners 2016). While pruning is a necessary and routine tree management activity that also contributes to pest control, it often requires additional measures. Neonicotinoids are classified as 'reduced risk' insecticides by the Environmental Protection Agency (EPA 2018). Use of systemic insecticides through soil drenching has been recommended for effective and efficient control of scale and other sucking insects (Miranda *et al.* 2016). The objective of this study was therefore to evaluate the efficacy of integrated application of two systemic soil drenching neonicotinoid insecticides and pruning in controlling the white mango scale.

MATERIALS AND METHODS

Field sites

The experiment was conducted in two locations in the West Shewa Zone of the Oromia Region in western Ethiopia in two consecutive years (2018 and 2019). The sites are owned by farmers who grow mango around their homesteads for consumption and market under rain-fed conditions. No specific management practices are applied by the farmers. The study was carried out at early flowering and at fruit setting stages. Different rates of thiamethoxam 25 % WG (Spark® 250 WG Jiangsu Agro-Chemicals Co. Ltd., China) with and without pruning were used for site I, while different rates of thiamethoxam 25 % WG and imidacloprid 35 %

SC (Confidence 350 SC Trust Chem. Co. Ltd., China) with and without pruning were used for site II. Doddo variety of mango trees of the same age (>10 years) and similar size were randomly selected for both sites. Each tree served as a plot. The experimental design was Randomized Complete Block with three replications. Trenches of approximately 10 cm depth were dug around each tree at one-metre distance from the trunk. Each dose of thiamethoxam 25 % WG and imidacloprid 35 % SC was dissolved in one liter of water. Drenching was done by pouring the dissolved insecticides along the trench after irrigating each tree using watering cans for five consecutive days. The trenches were filled with soil after treatment application. Drenching was done twice in a growing season (each year) on each of the same mango trees used as treatments in both years. Both insecticides and pruning were applied on the same date. The first and second pruning and drenching of the first year were conducted on January 29, 2018 and May 21, 2018 respectively. Similarly, the first and second applications of the second year were conducted on January 22, 2019 and April 24, 2019 respectively.

Data collection and analysis

Twelve leaves were randomly picked from each of the four cardinal directions (i.e. east, west, south and north) from the upper, middle and lower canopy of the trees before each treatment application and after two consecutive months after each application. The collected samples were placed in labelled polyethylene bags pierced for aeration and transported to Ambo Agricultural Research Center laboratory for further examination. Counting of life stages (females and crawlers) of the WMS on the upper and lower surfaces of the leaves was conducted using a stereo microscope. Live females were distinguished from dead ones by removing the scale armor with a needle and checking for the existence of haemocoel and movement (reaction) of the insect. Live crawlers were distinguished from the dead by their movement.

Test of homogeneity of variance (HoV test) was done with Bartlet method to decide if data could be combined over years. All count data were transformed using square root transformation method. Analysis of variance with transformed data was done with SAS software, version 9.1 (Cary NC, USA), but only means of untransformed data are presented and when ANOVA results were significant, they were followed by Least Significant Different (LSD) mean separation.

RESULTS

Site I

There was a significant difference in the overall mean number of the WMS (both crawlers and females) between the two years. Fewer mean WMS (200 per leaf) were observed in 2019 compared to 2018 (539.6 per leaf) after the second treatment application (Table 1). The results also showed that all the treatments were significantly lower than the control (1085.6 per leaf). The thiamethoxam 25 % WG at 12 g/tree + pruning resulted in the lowest number of the WMS (43.5 per leaf) after the second spray followed by thiamethoxam 25 % WG at 18 g/tree + pruning,

Table 1. Mean treatment effect on number of crawlers and females of the white mango scale pre-treatment, 60 days after treatment (DAT) of each of the first and second application of treatments as combined over years (2018 & 2019) at Tullu-sengota site I.

	Mean number of WMS (crawlers and females) per leaf		
	Pretreatment	**60 DAT (1st treatment)**	**60 DAT (2nd treatment)**
Year 1 (2018)	321.2 ± 7.2	385.5a ± 109.3	539.6a ± 244.6
Year 2 (2019)	254.1 ± 9.5	210.11b ± 31.2	200.1b ± 63.5
LSD	–	1.25	1.74
thiamethoxam 25 % WG at 6 g/tree	282.2 ± 13.7	418.1b* ± 43.0	779.9b ± 81.1
thiamethoxam 25 % WG at 12 g/tree	296.4 ± 13.7	171.7cd ± 19.5	123.2d ± 7.6
thiamethoxam 25 % WG at 18 g/tree	299.0 ± 27.7	471.5a ± 96.5	334.5c ± 72.3
thiamethoxam 25 % WG at 6 g/tree + pruning	299.3 ± 12.8	228.4c ± 16.8	137.1d ± 7.7
thiamethoxam 25 % WG at 12 g/tree + pruning	298.4 ± 40.3	96.0e ± 6.2	43.5e ± 6.2
thiamethoxam 25 % WG at 18 g/tree + pruning	259.5 ± 24.9	144.7cd ± 15.1	85.3de ± 4.8
Control	278.5 ± 26.3	554.3a ± 47.9	1085.6a ± 188.8
**LSD	–	2.3	3.2
CV	8.00	12.1	16.8

*Different letters in a column show significant differences. **LSD based on transformed data.

Table 2. Mean percent reduction of the WMS per leaf after 1st and 2nd application at Tullu-sengota site I.

Treatment	**Before treatment**	**60 DAT (1st treatment)**	**60 DAT (2nd treatment)**
thiamethoxam 25 % WG at 6 g/tree	282	-48 (418)*	-176 (780)
thiamethoxam 25 % WG at 12 g/tree	296	42.09 (172)	58 (123)
thiamethoxam 25 % WG at 18 g/tree	299	-57.66 (472)	-12 (335)
thiamethoxam 25 % WG at 6 g/tree + pruning	299	23.69 (228)	54 (137)
thiamethoxam 25 % WG at 12 g/tree + pruning	298	67.82 (96)	85 (44)
thiamethoxam 25 % WG at 18 g/tree + pruning	260	44.24 (145)	67 (85)
Control	279	-98.98 (554)	-290 (1086)

*Values in parenthesis represent actual increase or decrease in the number of crawlers and female WMS.

which did not significantly differ from each other. The product's recommended dose (6 g/tree) of thiamethoxam 25 % WG resulted in the highest WMS numbers (779.9 per leaf) next to the control although it was significantly different from the control. The highest percentage reduction of the WMS compared to the WMS count before treatment application was observed from thiamethoxam 25 % WG at 12 g/tree + pruning (Table 2).

Site II

Two systemic soil drenching insecticides (thiamethoxam 25 % WG and imidacloprid 35 % SC) were used in this site. Data combined over the two years showed significant differences between the years. In the second year (2019) there was less mean number of the WMS (156.6 per leaf) compared to the first year (2018), with 251.8 per leaf (Table 3). In this site also, all the treatments showed significant va-

Table 3. Mean treatment effect on number of crawlers and females of the WMS pre-treatment, 60 days after treatment (DAT) of each of the first and second application of treatments as combined over years (2018 & 2019) at Tullu-sengota site II.

	Mean ± SE number WMS (crawlers and females) per leaf		
	Before treatment	**60 DAT (1st treatment)**	**60 DAT (2nd treatment)**
Year 1 (2018)	310.8 ± 8	255.2a ± 70.2	251.8a ± 108.0
Year 2 (2019)	230.4 ± 7	177.8b ± 31.0	156.6b ± 44.5
LSD	–	0.60	0.75
imidacloprid 35 % SC at 8.5 ml/tree	245.0 ± 31.3	403.3b* ± 27.8	464.5b ± 49.2
thiamethoxam 25 % WG at 12 g/tree	263.7 ± 24.1	216.6c ± 17.2	157.8c ± 5.5
Pruning only	219.7 ± 33.0	135.9ef ± 13.7	111.7d ± 7.5
imidacloprid 35 % SC at 8.5 ml/tree + pruning	264.9 ± 21.2	143.4de ± 8.7	108.2cd ± 5.2
thiamethoxam 25 % WG at 12 g/tree + pruning	299.3 ± 19.7	115.2fg ± 2.3	61.4e ± 6.7
imidacloprid 35 % SC + thiamethoxam 25 % WG at 18 g/tree	286.2 ± 20.6	170.8d ± 5.2	105.1d ± 5.8
imidacloprid 35 % SC + thiamethoxam 25 % WG at 18 g/tree + pruning	275.8 ± 25.7	99.9g ± 6.4	31.1f ± 4.4
Control	310.3 ± 38.2	447.0a ± 36.9	593.4a ± 49.4
**LSD	–	1.2	1.5
CV	9.87	7.3	10.0

*Different letters in a column show significant differences. **LSD based on transformed data.

Table 4. Mean percent reduction of the WMS per leaf after 1st and 2nd application at Tullu-sengota site II.

Treatment	Before application	60 DAT (1st treatment)	60 DAT (2nd treatment)
imidacloprid 35 % SC at 8.5 ml/tree	245	-65 (403)	-90 (465)*
thiamethoxam 25 % WG at 12 g/tree	264	18 (217)	40 (158)
Pruning only	220	38 (136)	49 (112)
imidacloprid 35 % SC at 8.5 ml/tree + pruning	265	46 (143)	59 (108)
thiamethoxam 25 % WG at 12 g/tree + pruning	299	62 (115)	79 (61)
imidacloprid 35 % SC + thiamethoxam 25 % WG at 18 g/tree	286	40 (171)	63 (105)
imidacloprid 35 % SC + thiamethoxam 25 % WG at 18 g/tree + pruning	276	64 (100)	89 (31)
Control	310	-44 (447)	-91 (593)

*Values in parenthesis represent actual increase or decrease in the number of crawlers and female WMS.

riation from the control. However, imidacloprid 35 % SC + thiamethoxam 25 % WG at 18 g/tree + pruning resulted in the lowest mean number of the WMS (31.1 per leaf) followed by thiamethoxam 25 % WG at 12 g/tree + pruning (61.4 per leaf). This treatment also resulted in the highest percentage reduction of the WMS compared to the WMS count of the same trees before treatment application (Table 4).

DISCUSSION

The current study has shown that use of systemic insecticides as soil drench with pruning against the WMS is an effective and promising control tactic. In particular, thiamethoxam 25 % WG at 12 g/tree + pruning has been found to be an effective control measure. Use of systemic products is especially recommended for high density scale insect populations (Manners 2016). In the case of mango production in Ethiopia, most trees of the small holder farmers are very tall (up to 20 m), highly branched and often poorly managed. Use of systemic insecticides can help reach the tops of tall trees that are otherwise unreachable by ordinary spray equipment. However, this tactic has to be integrated with tree pruning practices such as regular and post-harvest pruning. The recommended rate for thiamethoxam 25 % WG is 6 g/tree (equivalent to 1.5 g a.i./tree). The present study has revealed that higher than recommended rates of thiamethoxam 25 % may be required to achieve a desired level of control. Frank (2012) evaluated the effect of thiamethoxam 25 % WG on the euonymus scale, *Unaspis euonymi* Comstock (Hemiptera: Diaspididae) (an armored scale), on the ornamental plant *Euonymus japonicus* 'Microphylla' along with other low risk insecticides, and found that it significantly reduced the number of insects on leaves at 42 and 90 DAT compared to untreated plants. However, the rate used was 2.27 g per gallon (3.79 l) for 11.4-litre pots. In the present study, thiamethoxam 25 % WG at 12 g/tree + pruning resulted in the lowest mean number of the WMS as observed at Tullu-sengota site I (Table 1). In contrast, the findings of Qureshi *et al.* (2011) who obtained lower scale insect counts using 6 g/tree and 12 g/tree indicate that although higher rates of thiamethoxam 25 % WG (12 g/tree) resulted in a lower mean number of scale insects, the efficacy was not significantly different from that of the recommended dose, i.e. 6 g/tree. These differences might have arisen from the fact that the mango trees in this study were taller (up to 14 m) compared to the mango trees (12 years old Kingston Pride variety, which is an improved variety easy to manage) used in the study by Qureshi *et al.* (2011).

On the other hand, imidacloprid 35 % SC at 8.5 ml/tree + thiamethoxam 25 % WG at 18 g/tree + pruning has given a better protection at Tullu-sengota site II indicating that the synergistic effect of these systemic insecticides may be much higher. Combined use of imidacloprid 35 % SC + thiamethoxam 25 % WG on another hemipteran insect, *Diaphorina citri* (Liviidae), has been reported to have disrupted the feeding and settling behaviour of the pest (Miranda *et al.* 2016). However, cost implications and residuals in fruits need to be further studied. To avoid extreme high rates, thiamethoxam 25 % WG at 12 g/tree + pruning, which has given the second better protection at Tullu-sengota site II, is recommended for tall trees (>14 m). In addition to these, there have been reports indicating that neonicotinoid insecticides such as thiamethoxam and imidacloprid may cause the colony collapse disease (CCD) of honey bees (Pareja *et al.* 2011; Farooqui 2013; Lu *et al.* 2014), and thus the use of these chemicals must be monitored in the presence of honey bee. The effect of the insecticides on natural enemy complex also needs to be carefully studied. In this regard, soil-applied imidacloprid to control the euonymus scale resulted in a lower than expected number of its parasitoid (*Encarsia citrina* (Craw)) that emerged from the number of available scale hosts (Rebek & Sadof 2003). Furthermore, the thiamethoxam residue on leaves of *E. japonicus* was found toxic to *Encarsia* spp. parasitoids and *Cybocephalus* spp. beetles, which are natural enemies of the armored scale (Frank 2012), prompting a cautious approach in the use of these insecticides in cases where natural enemies are involved in the integrated pest management programs.

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