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# MANAGEMENT OF WHITE MANGO SCALE (*Aulacaspis tubercularis*) IN ASSOSA DISTRICT, BENISHANGUL GUMUZ REGION, WESTERN ETHIOPIA

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**Abstract:** The research was initiated to develop a strategy for the management of white mango scale (*Aulacaspis tubercularis*). Field experiment was conducted to evaluate the effect of Imidacloprid 20SL, Dimethoate 40%EC, White oil extract, Pruning, Imidacloprid 20SL + Pruning, Dimethoate 40%EC + Pruning and White oil extract + Pruning against white mango scale insect. The experiments were arranged in Randomized complete block design with three replications. The results indicates that all the treatments significantly ($p<0.05$) reduced infestation of white mango scale and gave higher yield over the control. Imidacloprid 20 SL + pruning treatment was the most significantly effective which also provide a promising alternative cost to producers against white mango scale insect pest than other treatments. Further study on other management tactics which are compatible with cultural practices and reduced dose of insecticide as a part of integrated pest management strategy is mandatory.

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## 1 Introduction

Mango is a member of the family Anacardiaceae within the genus Mangifera which consists of over 25 species. Among the several species of mango, Mangifera indica is the only species grown commercially on large scale (Griesbach, 2003). Mango originated in tropical Asia and is currently distributed across all tropical and subtropical lowland areas throughout the world (Dirou, 2004; Okoth *et al*., 2013; Ubwa *et al*., 2014 and Crane *et al*., 2017). Mango is one of the most cherished fruits, not only for its flavour and taste, but also for its nutritional value. Mango is a good source of vitamin A and C, and is rich in carbohydrates, potassium and phosphorus (Griesbach, 2003 and Nabil *et al*., 2012). Mango serves as a fruit crop and as a subsistence crop for family farms. As it ripens at the end of the dry season and at the start of the rainy season, the mango is a fundamental source of nutrition for rural populations (Vayssières *et al*., 2012). Mango is traditionally grown in Ethiopia primarily for family consumption and local markets, but some emerging modern farms have started to produce mango for both local and export markets (Chala *et al*., 2014). Ethiopia exports mango to Djibouti, Saudi Arabia, Yemen, Sudan and the United Arab Emirates (Bezu *et al*., 2014).

Benishangul Gumuz Region is one of the potential mango producing areas. The regional farmers about 37% hold mango trees producing on 2,151.96 hectare of land coverage. However the productivity of mango trees remains very low; not more than 5.45 ton/ha as compared to the national average yields of 7 ton/ha (CSA, 2019). Also the productivity in the country is very low compared to the crop potential, about 20-30 ton/ha (Griesbach, 2003; Tiwari and Baghel, 2014). The low productivity mainly related with traditional way of production and the outbreak of diseases (mango anthracnose and powdery mildew) and insect pest such as white mango scale, fruit flies, mango seed weevil, mites, thrips, mealybugs and scale insects (Griesbach, 2003 and FAO, 2010; Hussen and Yimer, 2013 and Chala *et al*., 2014). Among these insect pests of mango, white mango scale (*Aulacaspis tubercularis Newstead*) is the most important of hard scale insects which is reported to have damaged mango in various parts of the world (SRA, 2006; Germain *et al*., 2010 and Abo-Shanab, 2012).

Infestation of mango by WMS insect pest in Ethiopia was first reported in 2010 in a mango orchard owned by Green Focus Ethiopia Ltd. (Dawd *et al*., 2012) which used to import mango seedlings from India and hence it is deduced that the insect pest probably entered Ethiopia accidently on imported seedlings. Within one-year of first record, WMS (white mango scale) was reported to have dispersed 100 km west and to northern and central Ethiopia, with the infested area in the north being about 1,500 km away from the place of initial infestation (Fita, 2014 and Ayalew *et al*., 2015).

Mango production in western Ethiopia is highly constrained by WMS. The damage of WMS induced panic and frustration in Western Ethiopia for the loss in crop production and indirect sociological consequences, since mango plantation serves as shade for animals and conference hall for the people, in addition to generating income and serving as food in the region. The insect has become a growing concern among various government organizations and civil societies and communities. The problem is no more regarded as economic one as it has social, environmental, and other repercussions (Hailu *et al*., 2014; Djirata and Getu, 2015).

The WMS insect pest morphological description is opaque white female armour which is circular, flat, thin and often wrinkled and Exuviae is near the margin, and is yellowish-brown, with a median black ridge, forming a dark distinct median line; Male armours are small, white, sides nearly parallel and distinctly tricarinate and crawlers are deep bright brick red (Hamon, 2016). The pest reproduces during both dry and wet seasons (Halteren, 1970). WMS is a sucking insect that poses severe threat to mango plantations in various mango growing countries (Labuschagne *et al*., 1995; Pena *et al*., 1998; Nabil *et al*., 2012; Juárez-Hernández *et al*., 2014). The damage caused by WMS includes yellowing of leaves, appearance of conspicuous pink blemishes on mature and ripe fruits, and dieback of the plant (El-Metwally *et al*., 2011; Abo-Shanab 2012). Infestation in young trees may lead to excessive fall off leaves, retarded growth and death of the whole plant (Nabil *et al*., 2012). The development of conspicuous blemishes on mango fruit skin which was infested by WMS markedly damages mango fruit export potential and eventually leads to economic loss (USDA, 2006 and 2007). According to the information obtained from farmers, they used to harvest up to 10 quintal of fruits per tree before the occurrence of this new insect pest. But the fruit yield reduced to 2-3 quintal per tree or may not be obtained at all due to the heavy infestation of white mango scale (Dawd *et al*., 2012).

Different literatures were indicated for management of WMS such as a recommendation of applaud and white oil extract by Ambo Plant Protection Research Centre (Hailu *et al*., 2014). Mineral oils such as Diver®, CAPL2® and super masrona® and insecticide such as Deltametrine and pyrethrin in Kenya; chloropyrifos, methidathion, Dimethoate 40%EC, Movento, Folimat 500SL, D-C-Tron and Closer insecticides showed different effectiveness in reducing the insect number (Howard, 1989; Findlay, 2003; Abo-Shanab, 2012; Ayalew *et al*. 2015; Djirata, 2017). However Insecticides currently in use against WMS in the infested mango orchards are insecticides recommended for the control of armoured scales such as the red scale (*Aonidiella auranti*) on citrus in the early 1980s (Abate, 1994; Azerefegne *et al*., 2009). Djirata (2017) reported that limited report of experiments performed regarding insecticide screening against WMS insect pest in Ethiopia since the insect introduced in the country has been less than a decade. Therefore, the objective of this research was to evaluate the effective management methods on WMS at Assosa district in Benshungul-Gumuz Region, Western Ethiopia.

## 2 Materials and Methods

### 2.1 Description of the experimental site

Field experiments were conducted at Assosa district in Assosa Administrative Zone, woreda-1 ketena-5, Ethiopia (Figure 1). The specific experimental site lies at $10^0$3’22’’ - $10^0$3’16’’N latitude and $34^0$33’18’’ - $34^0$33’20’’E longitude and a mean altitude of 1554 meter above sea level. The site is located in Assosa poly technique mango orchard which was selected purposively by looking accessible uniform size mango trees, naturally infested by WMS (white mango scale) and easy access to road for day to day follow up of the site. It is 687 Km far from Addiss Abeba. The average annual rainfall is 900-1200 mm and the annual ambient temperature varies from 21-31°C (NMA, 2015).

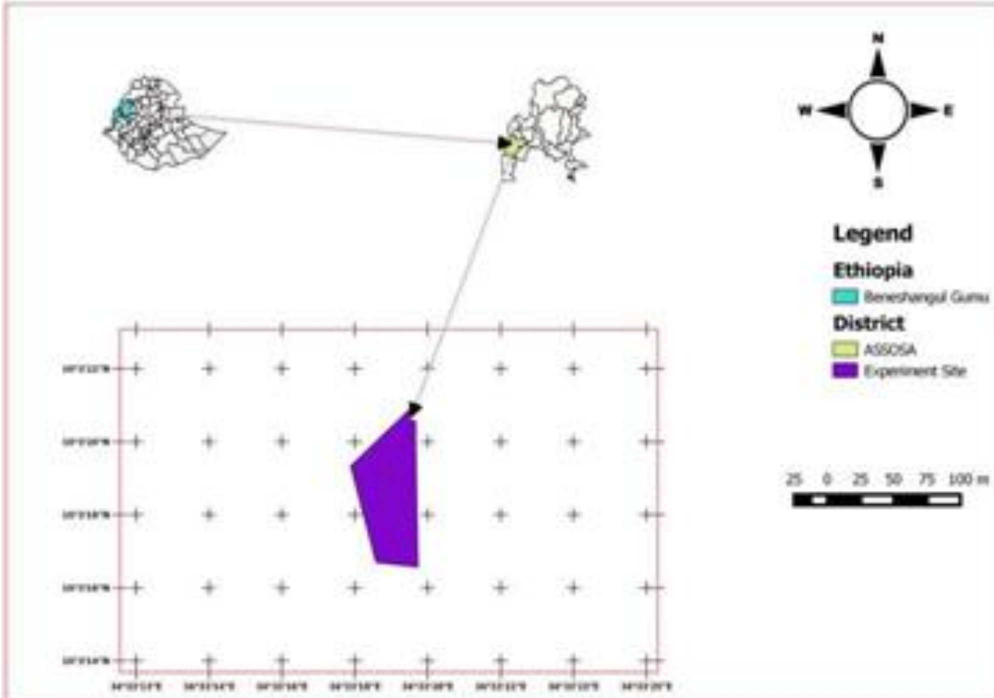


**Figure 1:** Location map of the experimental site

### 2.2 Experimental materials

Field experiment was conducted to evaluate the effective management option of eight treatments such as Imidacloprid 20SL, Dimethoate 40% EC, white oil extract, pruning, Imidacloprid 20SL + Pruning, Dimethoate 40% EC + Pruning, white oil extract + Pruning and untreated control. Imidacloprid 20SL 0.8ml per 1 liter of water dosage rate was used for this experiment. First 5 liters of water was filled in the sprayer tank and then 4ml of Imidacloprid 20SL was added and well shaked and then sprayed for a single mango tree (Varghese, 2000). Dimethoate 40%EC 0.75 ml per 1 liter of water dosage rate was used for this experiment. First 5 liter of water was filled in the sprayer tank and then 3.75 ml Dimethoate 40%EC was added and well shaked and then sprayed for a single mango tree (MoA, 2016). White oil extract was prepared by taking an empty plastic bottle, pure edible oil (Trade name: Sekina) was poured in a 250ml cup and mixed with 62.5ml of hand dish wash liquid detergent (Trade name: BEKAS Sine) and shaked well finally turned to white. The sprayer tank was first filled by 5 liter of water and then 10ml from prepared white oil per 1 liter of water calculated a total of 50ml of white oil was added and mixed well and used for a single mango tree for this experiment (https:// www. organicgardener.com.au/ blogs/home-made-pest-remedies, retrieved on 01 June 2018). Average water requirement used for spray was 5 liters per tree. Pruning was done for 12 randomly selected mango trees by removal of undesirable vegetative parts, crowded branches, insect-infested and diseased branches, leaves, flowers and other plant parts. Small branches were cut first followed by large branches and all debris was removed to clean the surroundings (Williams *et al*., 2009).

**Table 1:** Dose and formulation of insecticides

| Insecticide | Active ingredient | Dosage rate | Mode of application | Source |
|---|---|---|---|---|
| Gain 20 SL | Imidacloprid 20 SL | 0.8ml / 1 Liter of water | Foliar spray | Chemtrade International |
| Agro-Thoate 40% EC | Dimethoate 40% (W/V) | 0.75 ml / 1 Liter of water | Foliar spray | Chemtrade International |
| White oil extract | | 10ml / 1 Liter of water | Foliar spray | Home made |

**2.3** Treatments, experimental design and procedures

Mango trees selected for pruning were treated during August 1-15/2018 before the flower induction and right after harvest before spray and spray was taken place during active stage of mango flowering stage (Williams *et al.*, 2009). Mango trees were sprayed three times with the interval of two weeks during December 15-30/2018 and January 15/2019 after 11:00 hour using motorized knapsack sprayer and an untreated check were maintained for comparison purposes. In this experiment Dimethoate 40% EC and Imidacloprid 20SL are systemic insecticides and home-made white oil treatments were arranged separately as well as in combination with pruning cultural control method as a management tactics.

The experimental were arranged in randomised complete block design (RCBD) with three replications. The treatments were eight and three mango trees per treatments were used as three replications in each treatment. A total number of 24 mango trees were used in this experiment. Uniform size, same age (16 years old age) and cultivar mango trees (Kent) were selected for experimental unit. Drift problem was protected by using breaker of a plastic cover of the neighbouring mango trees canopy during spraying. The control was wetted three times with sterile water to avoid moisture difference between treatments. All agronomic practices were kept the same among the treatments during experimental period.

**Table 2:** Treatment types for the experiment

| Treatment Code | Treatment Application Rate |
|---|---|
| (T1) | Imidacloprid 20SL@4ml/5 Liter water |
| (T2) | Dimethoate 40% EC@3.75ml/5 Liter water |
| (T3) | White oil extract @50ml l/5Liter water |
| (T4) | Pruning |
| (T5) | Imidacloprid 20SL@4ml/5Liter water + pruning |
| (T6) | Dimethoate 40% EC @3.75ml/5 Liter water + pruning |
| (T7) | White oil extract @50ml l/5 Liter water + pruning |
| (T8) | Untreated Control @ 5 Liter water |

2.4 Data collection for the experiment

Experimental data from the treated and untreated control were collected randomly three from lower, four from middle and three from top of canopy a total of ten sample leaves and 30 sample leaves from each treatment. The mean number of WMS population (sum of live nymph and adult) per 10 leaves before and after the treatments application were taken as the methodology used by Ayalew *et al.*, 2014 and Djirata *et al.*, 2017. Mean number of WMS population per 10 leaves prior to treatment application and Mean number of insects from post treatment was used to assess efficacy of the suggested management option.

The average mango fruit number and yield in Kilo gram per tree per treatment was determined during March and April at harvest. During each sampling time the marketable quality of the fruits was subjectively assessed and judged using a 1-9 rating scale with 1=unusable, 3=unsalable (poor), 5=fair, 7=good, 9=excellent to evaluate the fruit quality. The size, color, firmness surface defects, sign of pest and shrinkage were used as visual parameters for the rating. Fruits that received a rating of five and above were considered marketable while those rated less than five were considered unmarketable (Mohammed *et al*., 1999).

**2.5 Data analysis**

Mean number of live nymph and adult of WMS per ten leaves per tree per treatment were taken and subjected to analysis. The treatment effect on WMS population and mortality were analysed using a general linear model (PROC GLM). Count data of WMS was subjected to square root transformation ($\sqrt{X}$) and mortality percentages data was subjected to arcsine/angular transformation before analysis to stabilize the variance. Homogeneity of variance of the sample was tested using levene's test before and after data transformation ($p > .05$) (Gomez and Gomez, 1984 and SAS Institute, 2009). The data were reported in the text using the back transformed values.

Percent reduction in WMS population over control was worked out after each treatment using Abbott's (1925) formula of mortality correction.

$$\text{Mortality correction} = \left(1 - \frac{\text{n in T after treatment}}{\text{n in Co after treatment}}\right) * 100$$

Where n in T = Population in the treated plot after treatment; n in Co = Population in control after treatment

The treatment effect on average fruit number and yield in Kilo gram per tree per treatment were taken and subjected to analysis by using the methods described by Gomez and Gomez (1984) using a general linear model (PROC GLM). Whenever the F-test was significant, significant means were separated by Fisher's Least Significant Difference (LSD) at 5% or 1% error level. For two group means *t*-test was used for comparison using PROC TTEST at 5% or 1% error level (Gomez and Gomez, 1984 and SAS Institute, 2009). Microsoft Excel was used for data summary.

### 2.6 Cost-benefit analysis

Cost-benefit analysis using partial budget analysis was subjected to agricultural business (CIMMYT, 1988). Marginal analysis as used within this context is a procedure for calculating marginal rates of return between treatments, proceeding in a stepwise manner from a lower-cost treatment to the next higher-cost treatments, and comparing marginal rates of return to acceptable minimum rates of return. The minimum acceptable rate of return without asking producers what they considered to be a reasonable rate of return, researchers noted that experience and empirical evidence suggest that a rate between 50% and 100% seems adequate. If the technology is new and requires learning new skills, then the upper-bound should be used. In cases where switching technologies simply represents an adjustment, then the lower-bound may be acceptable. An alternative approach to estimating the minimum rate of return is to double the rate of interest charged by the lending institution. In this context as the experiment was new for the recommendation domain, the upper bound 100% was used as minimum rate of return for selecting profitable treatments.

The marginal rate of return was computed as the marginal net benefit (i.e. the change in net benefits) divided by the marginal cost (i.e. the change in costs), expressed as a percentage.

$$\text{MRR} = \frac{\text{DNI}}{DIC}$$

The "net benefits" of different treatments were determined by first calculating the "gross field benefit" and the "total costs that vary" in switching treatments. The gross field benefit for each treatment was obtained by multiplying the "adjusted yield" by the farm gate price. The adjusted yield was represented by a fraction of 0.9 of the average marketable yield which obtained under an experimental condition. The farm gate price used in the analysis was the price that the producer receives less any harvesting and marketing costs. The price of mango fruits was based on the average farm gate price of fruit between March and April, obtained from personal communication with mango fruit producers around Assosa main market and '*Gulit*' which were the nearest market to the experiment site. The total costs that vary for each treatment was computed as the sum of ONLY those costs that were expected to change by using another treatment. The net benefit for a given treatment was then obtained by subtracting the total cost from the gross field benefit. The dominance analysis was done by sorting the treatment sum on the basis of costs from the lowest to the highest, together with their respective net benefit. The conclusion of a marginal analysis was also checked by using the concept of ''residual'' which was calculated by subtracting the return that farmers require (the minimum rate of return multiplied by the total costs that vary) from the net benefits.

## 3 Results

### 3.1 Effects of treatments on white mango scales population

The pre-treatment observation on WMS population 333.33(18.23) to 370(19.22) per ten leaves per tree, which was statistically insignificant which indicated uniform distribution of the pest among different treatments. The observations were recorded on WMS population with 14th day's interval of post first, post second and post third spray application (Table 3).

The data revealed that after first spray mean WMS population ranged from 141.33(11.88) to 407(20.16) per ten leaves per tree in different treatments were highly significantly different (*F*= 2 44, $p < .01$). The lowest WMS population were observed in Imidacloprid 20SL+pruning treatment 141.33(11.88) compared to other treatments (Figure 2). The comparative WMS population among treatments against WMS at fourteenth_day after first spraying found in descending order were untreated Control 407(20.16), Pruning 285.33(16.86), White oil extract 267.67(16.35), Dimethoate 40% EC 261.33(16.14), Imidacloprid 20SL 252.67(15.84), White oil extract + pruning 251(15.8), Dimethoate 40% EC + pruning 222.67(14.89) and Imidacloprid 20SL+pruning 141.33(11.88) respectively. All the treatments were significantly different from untreated control. White oil extract + pruning 251(15.8) and Imidacloprid 20SL 252.67(15.84) which were found to be at par with each other. White oil extract 267.67(16.35) and Dimethoate 40% EC 261.33(16.14) which were found to be at par with each other (Table 3).


**Figure 2:** Effect of application of treatments on white mango scale A) Untreated Control B) Imidacloprid 20SL+ pruning

The data revealed that after second spray the mean WMS population ranged from 89.33(9.44) to 447.67(21.14) per ten leaves per tree in different treatment were highly significantly different (*F*= 68.62, *p* < 0.01). The lowest WMS population was observed in Imidacloprid 20SL + pruning treatment 89.33(9.44) compared to other treatments. The comparative WMS population among treatments at fourteenth_day after second spraying found in descending order were Control 447.67(21.14), Pruning 234(15.24), White oil extract 224(14.93), Dimethoate 40% EC 184.33(13.52), Imidacloprid 20SL 163(12.63), White oil extract + pruning 161.33(12.58), Dimethoate 40% EC + Pruning 138.67(11.68) and Imidacloprid 20SL+ pruning 89.33(9.44) respectively. All the treatments were significantly different from untreated control. Pruning 234(15.24) and White oil extract 224(14.93) which were found to be at par with each other. Imidacloprid 20SL 163(12.63) and White oil extract + Pruning 161.33(12.58) which were found to be at par with each other (Table 3).

The data revealed that after third spray mean WMS population ranged from 24(4.87) to 492.67(22.18) per ten leaves per tree in different treatment were highly significantly different (*F* = 90.81, *p* < .01). The lowest WMS population were observed in Imidacloprid 20SL + Pruning treatment 24(4.87) compared to other treatments. The comparative WMS population among treatments at fourteenth_day after third spraying found in descending order were Control 492.67(22.18), Pruning 187.33(13.52), White oil extract 165.67(12.77), Dimethoate 40% EC 92(9.44), Imidacloprid 20SL 74(8.46), White oil extract + pruning 78.67(8.74), Dimethoate 40% EC + pruning 66.33(8.013) and Imidacloprid 20SL + pruning 24(4.87) respectively. All the treatments were significantly different from untreated control. Pruning 187.33(13.52) and White oil 165.67(12.77) which were found to be at par with each other. Dimethoate 40% EC 92(9.44), Imidacloprid 20SL 74(8.46) and White oil extract + Pruning 78.67(8.74) which were found to be at par with each other (Table 3). The mean of the three spray data revealed that the mean WMS population ranged from 85(9.21) to 449.33(21.18) per ten leaves per tree in different treatment were highly significantly different (*F* = 98.63, *p* < .01). The lowest WMS population were observed in Imidacloprid 20SL + Pruning treatment 85(9.21) compared to other treatments. The comparative WMS population among treatments against white mango scale found in descending order were Control 449.33(21.8), Pruning 235.67(15.28), White oil extract 219.33(14.78), Dimethoate 40% EC 179.33(13.34), Imidacloprid 20SL 163.33(12.69), White oil extract + Pruning 163.67(12.72), Dimethoate 40% EC + Pruning 142.67(11.89) and Imidacloprid 20SL + Pruning 85(9.21) respectively. All the treatments were significantly different from untreated control. Pruning 235.67(15.28) and White oil extract 219.33(14.78) which were found to be at par with each other. Imidacloprid 20SL 163.33(12.69) and White oil extract + Pruning 163.67(12.72) which were found to be at par with each other (Table 3).

**Table 3:** Mean number of white mango scales in the experimental mango orchards

| | Mean | | | | |
|---|---|---|---|---|---|
| Treatment | PrT | PFS | PSS | PTS | MS |
| Control | 370(19.22) | 407(20.16)[a] | 447.67(21.14)[a] | 492.67(22.18)[a] | 449.33(21.18)[a] |
| Pruning | 348.33(18.64) | 285.33(16.86)[b] | 234(15.24)[b] | 187.33(13.52)[b] | 235.67(15.28)[b] |
| White oil extract | 355(18.84) | 267.67(16.35)[bc] | 224(14.93)[b] | 165.67(12.77)[b] | 219.33(14.78)[b] |
| Dimethoate | 333.33(18.23) | 261.33(16.14)[bc] | 184.33(13.52)[c] | 92(9.44)[c] | 179.33(13.34)[c] |
| Imidacloprid | 340(18.41) | 252.67(15.84)[c] | 163(12.63)[cd] | 74(8.46)[c] | 163.33(12.69)[cd] |
| White oil + pruning | 358.33(18.9) | 251(15.8)[c] | 161.33(12.58)[cd] | 78.67(8.74)[c] | 163.67(12.72)[cd] |
| Dimethoate+ pruning | 351.67(18.72) | 222.67(14.89)[d] | 138.67(11.68)[d] | 66.33(8.013)[cd] | 142.67(11.89)[d] |
| Imidacloprid + pruning | 353.33(18.78) | 141.33(11.88)[e] | 89.33(9.44)[e] | 24(4.87)[d] | 85(9.21)[e] |
| Mean | 351.3(18.7) | 261.1(15.99) | 205.3(13.9) | 147.6(10.99) | 204.8(13.89) |
| $SE_m$ | 4.4(0.11) | 5.8(0.17) | 6.8(0.25) | 9.2(0.34) | 6.4(0.21) |
| LSD | 21.8(059) | 28.7(0.85) | 33.46(1.27) | 45.44(1.68) | 31.77(1.064) |
| CV% | 3.53(1.79) | 6.28(3.044) | 9.31(5.199) | 17.58(8.72) | 8.86(4.37) |
| Sign.difference | ns | ** | ** | ** | ** |

Values given in parenthesis are square root transformed values; Values in each column of the same letter are not significantly different; $SE_m$= Standard error of mean; LSD=Least Significant Difference; CV=Coefficient of Variation; * significant at P < .05; ** significant at .01; ns=Non_significant; PrT=Pre_Treatment WMS count/10 leaves, PFS=Post First Spray WMS count/10 leaves, PSS=Post Second Spray WMS count/10 leaves, PTS=Post Third Spray WMS count/10 leaves, MS=mean WMS count/10 leaves after all spray

### 3.2 Effects of treatments on white mango scales mortality

The WMS mortality percentage over control was worked out after each treatment using Abbott's (1925) formula of mortality correction (Table 4). The mortality percentage of WMS fourteen days after the first application was highly significantly different among treatments ($F$ = 136, $p$ <0.01). The highest mortality percentage was observed in Imidacloprid 20SL+ pruning treatment 65(53.73) compared to other treatments. The comparative mortality percentage among treatments in descending order were Imidacloprid 20SL + pruning 65(53.73), Dimethoate 40%Ec + pruning 45.33(42.27), White oil extract + pruning 38.67(38.42), Imidacloprid 20SL 38.33(38.18), Dimethoate 40%EC 36(36.9), White oil extract 34(35.5), Pruning 30.33(33.3) and Control 0(0.33) respectively. All the treatments were significantly different from untreated control. Dimethoate 40%EC + pruning 45.33(42.27) and White oil extract + pruning 38.67(38.42) which was found to be at par with each other. Dimethoate 40EC 36(36.9) and White oil extract 34(35.5) which were found to be at par with each other.

The mortality percentage of WMS fourteen_days after the second application were highly significantly different among treatments ($F$= 167, $p$ < .01). The highest mortality percentage was observed in Imidacloprid 20SL + pruning treatment 80(63.44) compared to other treatments. The comparative mortality percentage among treatments in descending order were Imidacloprid 20SL + pruning 80(63.44), Dimethoate 40%EC+ pruning 69(56.3), Imidacloprid 20SL 64(53.1), White oil extract + pruning 64(53.3), Dimethoate 40%EC 59(50.2), White oil extract 50(45.0), Pruning 47.67(43.7) and Control 0(0.33) respectively. All the treatments were significantly different from untreated control. Imidacloprid 20SL 64(53.1) and White oil extract + pruning 64(53.3) which were found to be at par with each other. White oil extract 50(45.0) and Pruning 47.67(43.7) which were found to be at par with each other.

The mortality percentage of WMS fourteen_days after the third application were highly significantly different among treatments ($F$ = 168.1, $p$ < .01). The highest mortality percentage was observed in Imidacloprid 20SL + pruning treatment 95(77.12) compared to other treatments. The comparative mortality percentage among treatments in descending order were Imidacloprid 20SL + pruning 95(77.12), Dimethoate 40%EC + pruning 87(69.1), Imidacloprid 20SL 85.33(67.7), White oil + pruning 84.67(67.1), Dimethoate 40% EC 81.67(64.9), White oil extract 66(54.5), Pruning 62.33(52.4) and Control 0(0.33) respectively. All the treatments were significantly different from untreated control. Dimethoate 40%EC + pruning 87(69.1), Imidacloprid 20SL 85.33(67.7), White oil extract + pruning 84.67(67.1) and Dimethoate 40%EC 81.67(64.9) which were found to be at par with each other. White oil extract 66(54.5) and Pruning 62.33(52.4) which were found to be at par with each other.

Mortality percentages of WMS showed a progressive increase from first spray to third spray application for all treatments compared to untreated control. The progressive increase of mortality percentage of each treatments Imidacloprid 20SL + pruning, Dimethoate 40%EC + pruning, Imidacloprid 20SL, White oil extract + pruning, Dimethoate 40%EC, White oil extract and Pruning were 65 to 95, 45.33 to 87, 38.33 to 85.33, 38.67 to 84.67, 36 to 81.67, 34 to 66 and 30.33 to 62.33 respectively.

**Table 4:** Mortality percentage of white mango scales in response of treatments in the experimental mango orchards

| Treatment | Mean | | |
|---|---|---|---|
| | First spray mortality % | Second spray mortality % | Third spray mortality % |
| Imidacloprid + Pruning | 65(53.73)[a] | 80(63.44)[a] | 95(77.12)[a] |
| Dimethoate + Pruning | 45.33(42.27)[b] | 69(56.3)[b] | 87(69.1)[b] |
| Imidacloprid | 38.33(38.18)[c] | 64(53.1)[bc] | 85.33(67.7)[b] |
| White oil +Pruning | 38.67(38.42)[b] | 64(53.3)[bc] | 84.67(67.1)[b] |
| Dimethoate | 36 (36.9)[cd] | 59(50.2)[c] | 81.67(64.9)[b] |
| White oil | 34(35.5)[cd] | 50(45.0)[d] | 66(54.5)[c] |
| Pruning | 30.33(33.3)[d] | 47.67(43.7)[d] | 62.33(52.4)[c] |
| Control | 0(0.33)[e] | 0(0.33)[e] | 0(0.33)[d] |
| Mean | 35.97(34.8) | 54.22(45.7) | 70.3(56.6) |
| $SE_m$ | 1.3(0.8) | 1.5(0.9 ) | 1.9(1.14 ) |
| LSD | 6.49(3.97) | 7.34(4.5) | 9.24(5.6) |
| CV% | 10.31(6.5) | 7.73(5.7) | 7.51(5.7) |
| Sign.difference | ** | ** | ** |

Values given in parenthesis are angular transformed value; Values in each column of the same letter are not significantly different; $SE_m$= Standard error of mean; LSD=Least Significant Difference; CV=Coefficient of Variation; * significant at P < .05; ** significant at .01; ns=Non_significant

### 3.3 Effects of treatments on mango fruit number and yield (kg/tree)

The mean marketable fruit number ranged from 43.33 to 262 per tree in different treatments were highly significantly different ($F$ = 23.68, $p < .01$). The lowest marketable fruit number was untreated control (43.33) compared to other treatments. The comparative marketable fruit number among treatments found in descending order were Imidacloprid 20SL + pruning (262), Dimethoate 40%EC + pruning (170.67), Imidacloprid 20SL (145.33), White oil extract + pruning (142.33), Dimethoate 40%EC (137.33), White oil extract (115.67), Pruning (112), untreated control (43.33) respectively. Imidacloprid 20SL (145.33), White oil extract + pruning (142.33) and Dimethoate 40%EC (137.33) which were found to be at par with each other. White oil extract (115.67) and Pruning (112) which were found to be at par with each other (Table 5).

The mean unmarketable fruit number ranged from 83.33 to 176.67 per tree in different treatments were highly significantly different ($F$= 6.46, $p < .01$). The lowest unmarketable fruit number was Imidacloprid 20SL + pruning treated 83.33 compared to other treatments. The comparative marketable fruit number among treatments found in descending order were untreated control (176.67), Pruning (154.67), White oil extract (147),White oil extract + pruning (144.67), Dimethoate 40%EC (132.67), Dimethoate 40%EC+pruning (130), Imidacloprid 20SL (122.33), and Imidacloprid 20SL+pruning (83.33) respectively. Pruning (154.67), White oil extract (147) and White oil extract + pruning (144.67) which were found to be at par with each other. Dimethoate 40%EC (132.67), Dimethoate 40%EC + pruning (130) and Imidacloprid 20SL (122.33) which were found to be at par with each other (Table 5).

The mean total fruit number ranged from 345.33 to 220 per tree in different treatments were significantly different ($F$= 3.66, $p < 0.05$). The lowest total fruit number was untreated control 220 compared to other treatments. The comparative total fruit number among treatments found in descending order were Imidacloprid 20SL + pruning (345.33), Dimethoate 40%EC + pruning (300.67), White oil extract + pruning (287), Dimethoate 40%EC (270), Imidacloprid 20SL (267.67), Pruning (266.67), White oil extract (262.67) and untreated control (220) respectively. Dimethoate 40%EC (270), Imidacloprid 20SL (267.67), Pruning (266.67) and White oil extract (262.67) which were found to be at par with each other (Table 5).

The mean marketable fruit yield ranged from 10.83 to 65.5 per tree in different treatments were significantly different ($F$= 23.68, $p$ < .01). The lowest marketable fruit yield was untreated control (10.83) compared to other treatments. The comparative marketable fruit yield among treatments found in descending order were Imidacloprid 20SL + pruning (65.5), Dimethoate 40%EC + pruning (42.67), Imidacloprid 20SL (36.33), White oil extract + pruning (35.58), Dimethoate 40%EC (34.33), White oil extract (28.92), Pruning (28), untreated control (10.83) respectively. Imidacloprid 20SL (36.33), White oil extract + pruning (35.58) and Dimethoate 40%EC (34.33) which were found to be at par with each other. White oil extract (28.92) and Pruning (28) which were found to be at par with each other (Table 5).

The mean unmarketable fruit yield ranged from 20.83 to 44.17 per tree in different treatments were significantly different ($F$ = 6.46, $p$ < 0.01). The lowest unmarketable fruit yield was Imidacloprid 20SL + pruning treated (20.83) compared to other treatments. The comparative unmarketable fruit yield among treatments found in descending order were untreated control (44.17), Pruning (38.67), White oil extract (36.75), White oil extract + pruning (36.17), Dimethoate 40%EC (33.17), Dimethoate 40%EC +pruning (32.5), Imidacloprid 20SL (30.58), and Imidacloprid 20SL + pruning (20.83) respectively. Pruning (38.67), White oil extract (36.75) and White oil extract + pruning (36.17) which were found to be at par with each other. Dimethoate 40%EC (33.17), Dimethoate 40%EC + pruning (32.5) and Imidacloprid 20SL (30.58) which were found to be at par with each other (Table 5).

The average total fruit yield ranged from 55 to 86.33 per tree in different treatments were significantly different ($F$= 3.66, $p$ < 0.05). The lowest total fruit yield was untreated control 55 compared to other treatments. The comparative total fruit yield among treatments found in descending order were Imidacloprid 20SL + pruning (86.33), Dimethoate 40%EC + pruning (75.17), White oil extract + pruning (71.75), Dimethoate 40%EC (67.5), Imidacloprid 20SL (66.92), Pruning (66.67), White oil extract (65.67) and untreated control (55) respectively. Dimethoate 40%EC (67.5), Imidacloprid 20SL (66.92), Pruning (66.67) and White oil extract (65.67) which were found to be at par with each other (Table 5).

**Table 5:** Mean number of mango fruit and yield per tree in response of treatments in experimental mango orchards

| Treatment | Fruit mean (Number/per tree) | | | Fruit Yield mean (kg/tree) | | |
|---|---|---|---|---|---|---|
| | Marketable | Unmarketable | Total | Marketable | Unmarketable | Total |
| Imidacloprid + Pruning | 262$^{a}$ | 83.33$^{c}$ | 345.33$^{a}$ | 65.5$^{a}$ | 20.83$^{c}$ | 86.33$^{a}$ |
| Dimethoate+ Pruning | 170.67$^{b}$ | 130$^{b}$ | 300.67$^{ab}$ | 42.67$^{b}$ | 32.5$^{b}$ | 75.17$^{ab}$ |
| Imidacloprid | 145.33$^{bc}$ | 122.33$^{b}$ | 267.67$^{bc}$ | 36.33$^{bc}$ | 30.58$^{b}$ | 66.92$^{bc}$ |
| White oil + Pruning | 142.33$^{bc}$ | 144.67$^{ab}$ | 287$^{b}$ | 35.58$^{bc}$ | 36.17$^{ab}$ | 71.75$^{b}$ |
| Dimethoate | 137.33$^{bc}$ | 132.67$^{b}$ | 270$^{bc}$ | 34.33$^{bc}$ | 33.17$^{b}$ | 67.5$^{bc}$ |
| White oil | 115.67$^{c}$ | 147$^{ab}$ | 262.67$^{bc}$ | 28.92$^{c}$ | 36.75$^{ab}$ | 65.67$^{bc}$ |
| Pruning | 112$^{c}$ | 154.67$^{ab}$ | 266.67$^{bc}$ | 28$^{c}$ | 38.67$^{ab}$ | 66.67$^{bc}$ |
| Control | 43.33$^{d}$ | 176.67$^{a}$ | 220$^{c}$ | 10.83$^{d}$ | 44.17$^{a}$ | 55$^{c}$ |
| Mean | 141.1 | 136.4 | 277.5 | 35.3 | 34.1 | 69.4 |
| SEm | 7.8 | 6.6 | 11.5 | 1.9 | 1.9 | 2.7 |
| LSD | 38.41 | 32.54 | 56.91 | 9.6 | 8.13 | 14.23 |
| CV% | 15.54 | 13.62 | 11.71 | 15.54 | 13.62 | 11.71 |
| Sign.difference | ** | ** | * | ** | ** | * |

Values in each column of the same letter are not significantly different; $SE_m$= Standard error of mean; LSD=Least Significant Difference; CV=Coefficient of Variation; * significant at P < .05; ** significant at .01; ns=Non_significant

Cost benefit analysis Partial budget analysis for white mango scale management experiment: Table 6 illustrates the partial budget analysis of treatments. ETB18/Kg was used as farm gate price. Adjusted yield, total costs that vary and net benefit was done for each treatment

**Table 6:** Partial budget analysis for white mango scale management experiment

| | Treatments | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Item | Contro | Prunin | White | Dimeth | White | Imidacl | Dimetho | Imidaclo |
| Average yield (kg/tree) | 10.83 | 28 | 28.92 | 34.33 | 35.58 | 36.33 | 42.67 | 65.5 |
| Adjusted yield (kg/tree) | 9.747 | 25.2 | 26.028 | 30.897 | 32.022 | 32.697 | 38.403 | 58.95 |
| Gross field benefits (ETB/tree) | 175.446 | 453.6 | 468.50 | 556.146 | 576.396 | 588.546 | 691.254 | 1061.1 |
| cost of insecticide (ETB/tree) | 0 | 0 | 0 | 3.94 | 0 | 9.36 | 3.94 | 9.36 |
| cost of white oil (ETB/tree) | 0 | 0 | 10.3 | | 10.3 | 0 | 0 | 0 |
| Cost of labor to apply insecticide (ETB/tree) | 0 | 0 | 0 | 90 | 0 | 90 | 90 | 90 |
| Cost of sprayer rental (ETB/tree) | 0 | 0 | 40 | 60 | 40 | 60 | 60 | 60 |
| Cost of labor to apply white oil (ETB/tree) | 0 | 0 | 30 | 0 | 30 | 0 | 0 | 0 |
| Cost of labor for pruning (ETB/tree) | 0 | 75 | 0 | 0 | 75 | 0 | 75 | 75 |
| Total costs that vary (ETB/tree) | 0 | 75 | 80.3 | 153.94 | 155.3 | 159.36 | 228.94 | 234.36 |
| Net benefits (ETB/tree) | 175.446 | 378.6 | 388.20 | 402.206 | 421.096 | 429.186 | 462.314 | 826.74 |

Dominance analysis for white mango scale management experiment: Table 7 illustrates Dominance analysis between treatments. In moving from the lowest to the highest, there were no 'dominated' treatments obtained which costs more than the previous. Therefore all treatments were taken in to MRR analysis.

**Table 7:** Dominance analysis for white mango scale management experiment

| Treatment | Total costs that vary (ETB/tree) | Net benefits (ETB/tree) | Dominancy |
|---|---|---|---|
| Untreated Control | 0 | 175.446 | |
| Pruning | 75 | 378.6 | No |
| White oil extract | 80.3 | 388.20 | No |
| Dimethoate 40% EC | 153.94 | 402.206 | No |
| White oil extract + pruning | 155.3 | 421.096 | No |
| Imidacloprid 20SL | 159.36 | 429.186 | No |
| Dimethoate 40% EC + pruning | 228.94 | 462.314 | No |
| Imidacloprid 20SL+ pruning | 234.36 | 826.74 | No |

Marginal analysis for WMS management experiment: Table 8 illustrates calculating the MRR between treatments. The MRR by switching from untreated control to pruning treatment was 270.87%, well above the minimum. Hence, a 270.87% MRR in switching from untreated control to pruning treatment implied that for each ETB invested in the new treatment, the producer can expect to recover the 1ETB invested plus an additional return of 2.7087ETB. Therefore pruning was certainly a worthwhile alternative to the untreated control.

The MRR by switching from pruning to white oil extract treatment the marginal rate of return was 181.21%, also well above the minimum. Hence, a 181.21% MRR in switching from pruning to white oil treatment implied that for each ETB invested in the new treatment, the producer can expect to recover the 1ETB invested plus an additional return of 1.8121ETB, and therefore white oil was certainly a worthwhile alternative to pruning management option.

The MRR by switching from white oil to Dimethoate 40%EC treatment the was 19.014%, and below the minimum. Hence, a 19.014% MRR in switching from pruning to white oil treatment implied that for each ETB invested in the new treatment, the producer can expect to recover the 1ETB invested plus an additional return of 0.19014ETB which was less than white oil treatment. Therefore Dimethoate 40%EC treatment had been eliminated from consideration.

The MRR by switching from Dimethoate 40%EC to white oil + pruning treatment was 1388.97% and above the minimum rate of return which seems profitable. However the MRR by switching from white oil to white oil + pruning was 43.86%, below the minimum. Hence, a 43.86% MRR in switching from white oil to white oil + pruning implied that for each ETB invested in the new treatment, the producer can expect to recover the 1ETB invested plus an additional return of 0.4386ETB which was less than white oil treatment. Therefore white oil + pruning had been eliminated from consideration.

The MRR by switching from white oil + pruning to Imidacloprid 20SL treatment the was 199.26%, well above the minimum, which seems profitable however the MRR by switching from white oil to Imidacloprid 20SL treatment was 51.85%, below the minimum. Hence, a 51.85% MRR in switching from white oil to Imidacloprid 20SL treatment implied that for each ETB invested in the new treatment, the producer can expect to recover the 1ETB invested plus an additional return of 0.5185ETB which was less than white oil treatment. Therefore Imidacloprid 20SL treatment had been eliminated from consideration.

The MRR by switching from Imidacloprid 20SL treatment to Dimethoate 40%EC + pruning was 47.61%, below the minimum and also by switching from white oil to Dimethoate 40%EC + pruning the MRR was 49.85, below the minimum. Hence, a 49.85% MRR in switching from white oil to Dimethoate 40%EC + pruning treatment implied that for each ETB invested in the new treatment, the producer can expect to recover the 1ETB invested plus an additional return of 0.4985ETB which was less than white oil treatment. Therefore Dimethoate 40%EC + pruning treatment had been eliminated from consideration.

The MRR by switching from Dimethoat 40%EC e + pruning to Imidacloprid 20SL+ pruning treatment was 6723.72%, well above the minimum which seems unrealistic since which was seen from not profitable treatment. But by switching from white oil to Imidacloprid 20SL + pruning treatment the MRR was 284.65%, also well above the minimum. Hence, a 284.65%, MRR in switching from white oil to Imidacloprid 20SL+ pruning treatment implies that for each ETB invested in the new treatment, the producer can expect to recover the 1ETB invested plus an additional return of 2.8465ETB which was greater than white oil treatment. Therefore Imidacloprid 20SL + pruning treatment was certainly a worthwhile alternative to all management option. Therefore white oil and pruning should be considered as second and third alternative to producers.

Researchers should continue to experiment white oil, pruning and Imidacloprid 20SL + pruning treatment which seems to be a promising alternative to producers white mango scale management. Dimethoate 40%EC, white oil + pruning, Imidacloprid 20SL and Dimethoate 40%EC + pruning treatments gave higher marketable yield and statistically significant different from pruning and white oil treatment but their costs were such that they did not provide an acceptable rate of return. However Imidacloprid 20SL + pruning treatment costs higher compared with all other treatment but gave higher yield and acceptable rate of return.

**Table 8:** Marginal analysis for white mango scale management experiment

| Treatment | Total costs that vary (ETB/tree) | Net benefits (ETB/tree) | Marginal rate of return(MRR)% | |
|---|---|---|---|---|
| Untreated Control | 0 | 175.446 | | |
| | | | → 270.87% | |
| Pruning | 75 | 378.6 | | |
| | | | → 181.21% | |
| White oil extract | 80.3 | 388.20 | | |
| | | | → 19.01 | |
| Dimethoate 40% EC | 153.94 | 402.206 | | |
| | | | → 1388.9 | |
| White oil extract + pruning | 155.3 | 421.096 | | **43.9** |
| | | | → 199.26 | |
| Imidacloprid 20SL | 159.36 | 429.186 | | **51.9** |
| | | | → 47.61 | |
| Dimethoate 40% EC + pruning | 228.94 | 462.314 | | **49.8** |
| | | | → 6723.7 | |
| Imidacloprid 20SL + pruning | 234.36 | 826.74 | | **284.6** |

Residual analysis for white mango scale management experiment: Table 9 illustrates the computation of residual of treatments. The treatments were arranged in order from lowest to highest total costs that vary. Since producers will be interested in the treatment with the highest residual. The treatment with highest residual was Imidacloprid 20SL + pruning treatment and the second and third highest residual were white oil and pruning respectively which was the same conclusion reached in the previous MRR analysis.

**Table 9:** Residual analysis for white mango scale management experiment

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Treatment | Total costs that vary (ETB/tree) | Net benefits (ETB/tree) | Return required [100%*(1)] ETB/tree | Residual [(2)-(3)] ETB/tree |
| Untreated Control | 0 | 175.446 | 0 | 175.446 |
| Pruning | 75 | 378.6 | 75 | 303.6[c] |
| White oil extract | 80.3 | 388.20 | 80.3 | 307.904[b] |
| Dimethoate40% EC | 153.94 | 402.206 | 153.94 | 248.266 |
| White oil extract+ pruning | 155.3 | 421.096 | 155.3 | 265.796 |
| Imidacloprid 20SL | 159.36 | 429.186 | 159.36 | 269.826 |
| Dimethoate40% EC + pruning | 228.94 | 462.314 | 228.94 | 233.374 |
| Imidacloprid 20SL+ pruning | 234.36 | 826.74 | 234.36 | 592.38[a] |

a / The first Maximum residual b / The second Maximum residual c / The third Maximum residual

## 4 Discussion

White mango scale is a sucking and hard scale which secrete tough waxy protective covering coat attached to the plant surface while the insect is free within the cover (Varshney *et al*., 2002; Moharum, 2012 and Mark *et al*., 2019). Also the insect pest reproduces during both dry and wet seasons, and produce five to six generations per year, at a maximum day time temperature of 26°C and night time minimum temperature of 13°C ; and also overlapping generations throughout the year and reached peak population during the flowering time of spring and harvesting period in western wellega area (Halteren, 1970; Miller and Davidson, 2005 and Hailu *et al.*, 2014). Therefore the armour of the insect which used for protection from natural enemies and insecticide penetration and also its overlapping generation throughout the year made this insect pest difficult to control.

Different literatures and countries experience indicated that management of white mango scale using applaud, white oil extract, mineral oils such as Diver®, CAPL2® and super masrona®, insecticide such as Deltametrine and pyrethrin in Kenya, chloropyrifos, methidathion, Dimethoate 40%EC, Movento, Folimat 500SL, D-C-Tron and Closer insecticides showed different effectiveness in reducing the insect number (Howard, 1989; Findlay, 2003; Abo-Shanab, 2012; Hailu *et al*., 2014; Ayalew *et al*. 2015; Djirata, 2017). However in our country there were a limited literature and recommendation for the white mango scale management since the insect introduced in the country not more than a decade. Therefore this experiment was used different management option such as systemic insecticide, white oil extract and pruning each separately and systemic insecticide and white oil extract each in combination with pruning as management tactics. All the management tactics were highly significant effectiveness as compared with untreated control.

However the treatments were showed that different effectiveness in decreasing population number of white mango scale and in increasing mortality percentage and mango fruits and yields. The treatments against white mango scale population found in descending order were (Pruning at par with White oil extract) > (Dimethoate 40% EC) > (Imidacloprid 20SL at par with White oil extract + Pruning) > (Dimethoate 40% EC + Pruning) > (Imidacloprid 20SL + Pruning) respectively. The treatments against mortality percentage found in descending order were (Imidacloprid 20SL + pruning) > (Dimethoate 40%EC + pruning), (Imidacloprid 20SL), (White oil + pruning and Dimethoate 40% EC at par with each other) > (White oil extract at par with Pruning) respectively. Fruit number and yield among treatments found in descending order were (Imidacloprid 20SL + pruning) > (Dimethoate 40%EC + pruning) > (White oil extract + pruning) > (Dimethoate 40%EC, Imidacloprid 20SL, Pruning, White oil extract at par with each) other respectively.

Management of white mango scale using pruning as cited by Williams et al. (2009) was one of the method of pest management on mango trees by removal of undesirable vegetative parts, crowded branches, insect-infested and diseased branches, leaves, flowers and other plant parts. Therefore the mango trees were pruned during the vegetative stage soon after mango fruits harvest. The white mango scale was relatively decreased its population and increased its mortality than untreated control during 1st, 2nd and 3rd count, respectively. Therefore the management using pruning helps free sun light penetration in the mango canopy which forces white mango scale population to the lower canopy and under shade area and some might be killed by the direct sunlight which helps to decrease the infestation status. Integrated management tactics using white oil extract, Imidacloprid 20SL and dimethoate 40%EC each with pruning operation were increased the effectiveness of white mango scale control since pruning increased the penetration for the spray. Literature reported by Cunningham (1989) post-harvest pruning was an effective control measure and also helps the penetration of chemical sprays through the tree canopy. In addition Bautista-Rosales et al. (2013) who stated that pruning was significantly reduced the number of females per leaf and Lal and Mishra (2007) reported that pruning used as cultural management for obtaining quality yield by reducing incidence of pests and disease occurs due to high relative humidity.

Pruning decreased mango fruits number during the first year soon after pruning which kept increasing in the successive years (Lal *et al*., 2000). However in this experiment as the pre-treatment data showed that white mango scale natural infestation was similar infestation status which means comparatively similar dead leaf, twigs and branches which was unproductive and used for harbouring the pest which in turn contribute infestation of the newly emerged leaf. Therefore avoiding of such dead tree parts which was not used for fruit baring did not affect the yield obtained per tree rather than these tree parts used for harbouring the pest as shelter for further infestation while the newly emerged leaf. So in this case the yield was compensated comparatively with other unpruned treatments.

Management of white mango scale using white oil extract was significantly effective compared with untreated control. White oil extract was prepared by taking an empty plastic bottle, pure edible oil (Trade name: Sekina) was poured in a 250ml cup and mixed with 62.5ml of hand dish wash liquid detergent (Trade name: BEKAS Sine) and shaked well finally turned to white. White oil extract of 50 ml per 5 liter water mixed well and used for a single mango tree for this experiment (https:// www. organicgardener.com.au/ blogs/home-made-pest-remedies, retrieved on 01 June 2018). Since the white oil extract was used for suffocating and dried out the white mango scale results a decreased population. Different literature indicated that white oil extract used for white mango scale management. As cited by Hailu *et al*. (2014) that Assosa Agricultural research institute recommended white oil extract for control of white mango scale. Others literature by Muegge *et al*. (2019) reported that scale insects are suffocated by oils and dried out by insecticidal soaps. Insecticidal soaps disrupt the waxy cuticle or "skin" of the insect, which eventually causes the insect to dry out or desiccate and die. In addition Prasannath (2016) supports to use such type of botanical control due to biodegradable nature, systemicity after application, capacity to alter the behaviour of target pests and favourable safety profile. Management of white mango scale using pruning and white oil extract at par with each other and effective compared with untreated control but less effective compared with white oil extract with pruning management tactics.

In this experiment Imidacloprid 20SL was used for the management of white mango scale. Experiments conducted by Varghese (2000) on mango varieties, Alphanso and Bangampalli showed that imidacloprid recommendation dosage between 0.2 to 0.8 ml/liter was found effective. Therefore for this experiment 0.8ml of Imidacloprid 20SL per 1 liter of water dosage 4ml per 5 liters of water was sprayed for a single mango tree. Mango white scale insect population highly significant decreased while using Imidacloprid 20SL as compared with pruning, white oil extract, Dimethoate 40%EC and Dimethoate 40%EC+pruning. However it was insignificant mortality percentage compared with Dimethoate 40%EC+pruning, white oil+pruning and Dimethoate 40%EC but highly significant mortality percentage compared with white oil and pruning. The effect of Imidacloprid 20SL with pruning operation was highly significant effectiveness compared with all other treatments. Literature by Hegde and Nidagundi, 2009 and Patil *et al*. (2009) reported that Imidacloprid is a new class of insecticide and its potency against sucking insect is well reported in different countries of the world. Studies by Kencharaddai and Balikai (2012) and Joshi and Sharma (2009) showed that imidacloprid gives an outstanding result against sucking insects. Also Robson *et a*l. (2007) and Shi *et al*. (2011) stated that imidacloprid is comparatively safer than other conventional insecticides and once it is applied, the action continued for a longer period. On the other hand, the action of imidacloprid persisted at least up to day 10 which raises the possibility that once it enters into the plant system, the imidacloprid remains comparatively for a longer period of time and also supports as this imidacloprid is comparatively less toxicity to human and environment. However Imidacloprid 20SL is registered for the control of aphids (Macrosiphum euphorbiae) on potatoes in Ethiopia (MoA, 2016).

In this experiment Dimethoate 40%EC was sprayed for the management of white mango scale. In this experiment based on 0.75 ml of Dimethoate 40%EC per 1 liter of water dosage rate 3.75 ml per 5 liter of water per a single mango tree was used for spray (MoA, 2016). Management of white mango scale using Dimethoate 40%EC was highly significant effectiveness as compared with white oil extract and pruning in decreasing population number and increasing mortality percentage. However it was insignificant moratlity percentage variation as compared with Dimethoate 40%EC+pruning, Imidacloprid 20SL and white oil extract+pruning. In the case of white mango scale population number reduction management using Dimethoate 40%EC with pruning operation was highly significant effectiveness as compared with Dimethoate 40%EC without pruning management tactics. Management using Dimethoate 40%EC with pruning operation in the case of population number reduction was highly significant effectiveness as compared with other treatements excluding Imidacloprid 20SL+pruning treatment. However it was insignificant mortality percentage variation as compared with Dimethoate 40%EC without pruning management tactics. In general management of white mango scale using Dimethoate 40%EC and Dimethoate 40%EC with pruning management tactics were highly significant effectiveness as compared with untreated control. Study by Swaminathan *et al*. (2010) who reported that dimethoate was effective in reducing the effect of sucking insect pest and earlier study by Howard (1989) showed that dimethoate 40%EC was used for control of white mango scale. Dimethoate is organo phosphate class which is now in modern crop protection is not recommended due to its hazardous nature to water, soil, environment and human health compared with neonicotinoides new type insecticides like imidacloprid. In general management of white mango scale using white oil extract, imidacloprid 20SL and dimethoate 40%EC integrating with pruning increases the effectiveness which in lined with Cunningham (1989) and Andrew (2016) who reported post-harvest pruning is an effective control measure which helps the penetration of chemical sprays through the tree canopy. In the case of cost wise effectiveness white oil, pruning and Imidacloprid 20SL + pruning treatment seems to be a promising alternative to producers for white mango scale management. Management with Dimethoate 40%EC, white oil + pruning, Imidacloprid 20SL and Dimethoate 40%EC + pruning treatments gave higher marketable yield and statistically highly significant different from pruning and white oil treatment but their costs were such that they did not provide an acceptable rate of return. However in this experiment Imidacloprid

20SL + pruning treatment costs higher compared with all other treatment but gave higher yield and acceptable rate of return.

## 5 Conclusions

Results of the present study indicated that integrated application of Imidacloprid 20 SL with pruning of mango tree was the most effective method for management of white mango scale. Furthermore this study revealed that application of Imidacloprid 20 SL + pruning treatment provides a promising cost effective alternative to producers against white mango scale insect pest. Since Imidacloprid 20SL is ecologically safe insecticide compared to Dimethoate 40%EC; therefore it is more preferable for white mango scale insect pest management. Further detail study on other management tactics such as biological control, host resistances which are compatible with cultural practices and reduced dose of insecticide as a part of integrated pest management strategy is mandatory to come with sustainable strategy for management of white mango scale and increase productivity of mango.

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