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Field Evaluation of Insecticidal Activity of Aqueous *Azadirachta indica* L. Leaf Powder Against *Aulacuspis tubercularis* Newsteed (Homoptera: Diaspididae) on Mango (*Mangifera indica* L.) in East Wollega Zone, Ethiopia †

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† Presented at the 1st International Electronic Conference on Entomology (IECE 2021), 1–15 July 2021; Available online: https://iece.sciforum.net/.

Citation: Fita Gursha, T.; Degaga, E.G.; Wakgari, M.; Wo/Tsadike, K. Field Evaluation of Insecticidal Activity of Aqueous *Azadirachta indica* L. Leaf Powder Against *Aulacuspis tubercularis* Newsteed (Homoptera: Diaspididae) on Mango (*Mangifera indica* L.) in East Wollega Zone, Ethiopia, in Proceedings of the 1st International Electronic Conference on Entomology, 1–15 July 2021, MDPI: Basel, Switzerland, doi:10.3390/IECE-10608.

Published: 6 July 2021

Abstracts: Among the many tropical fruits, mango (*Mangifera indica* L.) has been identified as the most important from socio-cultural, commercial and environmental aspects. It is grown in more than 100 countries. *Aulacuspis tubercularis* Newsteed (Homoptera: Diaspididae) commonly known as white mango scale, is a serious insect pest of mango in many mango growing countries including Ethiopia. *Aulacuspis tubercularis* introduced to Ethiopia a decade ago; there was none successful technologies towards its control, which enabled the pest to invade the whole country resulting in 50-100% crop losses. The current study was conducted to know the efficacy of aqueous Neem, *Azadirachta indica* L. (A. Juss) leaf powder in the management of *A. tubercularis* under field condition. Field experiments were conducted at Arjo Gudetu and Uke experimental sites of East Wollega zone. The treatments were different spray concentrations prepared from aqueous *A. indica* leaf powder. These were 0.05, 0.1 and 0.15mg/ml of water. Treatments started after complete infestation was observed and continued for 3 times at 10 days interval. The experiment was laid out in a randomized complete block design in four replications. Mortality count was recorded 10 days after 1st, 2nd and 3rd treatment applications. The results obtained revealed that aqueous *A. indica* leaf powder at 0.15 concentration significantly ($p<0.05$) reduced the population of *A. tubercularis* at both experimental sites. Male adults and nymphs were more affected than the females. The use of aqueous *A. indica* leaf powder led to significant population reduction of *A. tubercularis* and its impact. Hence, the product can be recommended for the management of *A. tubercularis*.

Keywords: Adult males and females; crawlers; efficacy; management; treatments; white mango scale

1. Introduction

Among the many tropical fruits, mango (*Mangifera indica* L.) has been identified as the most important from a socio-cultural, commercial and environmental point of view [1]. Mango is grown in more than 100 countries. Among these, more than 65 countries each produce more than 1,000 metric tones' per year which played an important role in the lives of many, not only by being rich in nutrients, but also as a source of livelihood for millions of people in the tropics [2]. The total world production of mangoes in 2018 was over 55.38 million metric tones' with area coverage of 5.75 million hectares [3]. Apart from India, other major mango producing countries are China, Mexico, Thailand, Indonesia, Pakistan, Philippines, Nigeria, Brazil, Peru, Australia, South Africa, Malaysia and Venezuela [4]. Because of its attractive appearance and the very pleasant test of selected cultivars, mango is claimed to be the most important fruit of the tropics and has been named as a 'king' of fruits'. The fruit contains almost all the known vitamins and many essential minerals [5].

Mango is one of the most widely grown among the fruit crops cultivated in Ethiopia preceded only by banana in terms of economic importance, of which most of the productions come mainly from the Rift Valley, south western and western Ethiopia [6]. Annual mango production in Ethiopia is 133,704.93 t with area coverage of 19,497.92 ha and its production is 6.86 tones ha^{-1} [7], which accounts for about 0.18% of the world production. Mango production in Ethiopia is constrained by a number of factors of which damage by *Aulacaspis tubercularis* Newstead (Homoptera: Diaspididae) is the most important one [8, 9]. At high level of infestations, *A. tubercularis* causes losses ranging from 50 to 100% [10]. *A. tubercularis* is believed to have originated from Asia [11]. The global dispersal of this pest could have occurred through the movement of plant parts.

A. tubercularis was first detected in Ethiopia in 2010 infesting mango plants in western parts of the country, East Wollega Zone [12], from where it was distributed to different parts of the country [8, 9].

Neem tree, *Azadirachta indica* L. is a tropical plant that is well known for its pesticidal properties [13]. *A. indica* an evergreen plant having leaves year round. The fruits and seeds can only be available once in a year. The fact that concentrated Azadirchatin presented in the seeds many of the pest control program depends on the seeds. However, seasonality of the seed availability pushed stakeholders to look for other pest control options like use of synthetic pesticides, which have so many negative effects. As Azadirchatin also present in the leaf with low concentration, the current experiment tested the efficacy of aqueous *A. indica* leaf powder for management of *A. tubercularis.*

2. Materials and Methods

2.1. Description of the Study area

The field evaluation of aqueous *A. indica* leaf powder was conducted in East Wollega Zone of Guto Gida district, Uke Kersa Administrative kebele (09°18.908'N, 036°31.473'E) and Digga District, Arjo Gudatu kebele (09°02.225'N, 036°15.013'E) from March 2018 to May 2018. The selected districts represent mango producing agro-ecological zones. The ecological zones of the two districts are lowlands (wet kolla), wet midlands (weyna dega) and Highlands (wet dega) (Table1). Diga district represented midland and lowland ecologies and it received moderate rainfall. Guto Gida received high to moderate rainfall and represented the high to low altitude areas. Elevation of Diga district ranges from 1250 to 2300 meters above sea level (m.a.s.l), while that of Guto Gida district is from 1350 m.a.s.l. to 2900 m.a.s.l.

Table 1. Description of the main Agro-ecological zones of the study districts.

Districts	Agro-ecological zone	Altitude (m.a.s.l.)	Mean temp. (0°C)	Rainfall (mm)
Guto Gida	Highland	2300-3200	12-18	2244.3
	Midland	1500-2300	18-25	2071.6
	Lowland	500-1500	Over 25	1516.9
Diga	Midland	1500-2300	18-27	1754.8
	Lowland	500-1500	>25	1663.6

Source: A Guideline for Development Agents on Soil and Water Conservation in Ethiopia [14] and NMA of Ethiopia

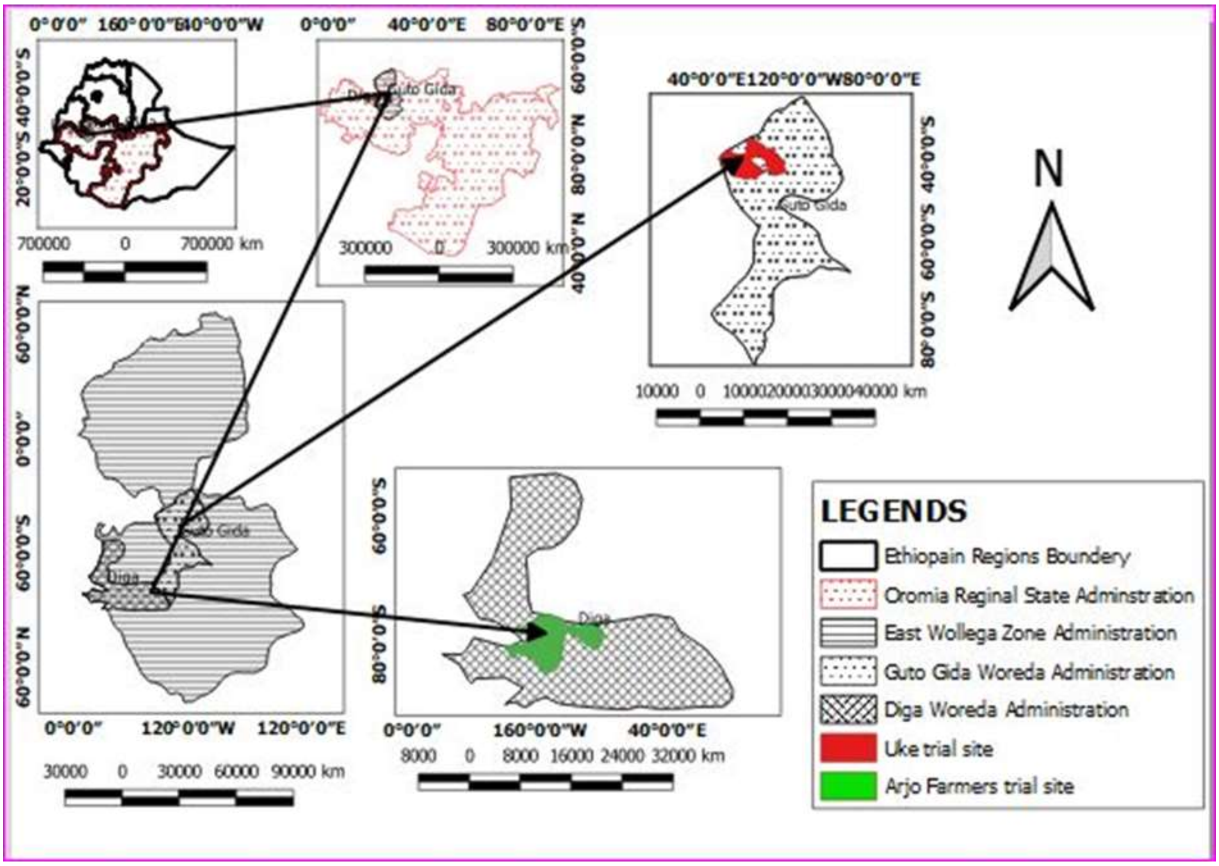

Figure 1. **S**tudy Area for field evaluation of aqueous *A. indica* leaf powder against *A. tubercularis* in East Wollega Zone of Guto Gida and Diga District at Uke Kersa kebele and Arjo Gudetu, respectively.

2.2. Preparation of aqueous A. indica leaf powder

Well-matured leaves of *A. indica* were collected from neem trees found in Dire Dawa town. The leaves were washed thoroughly with water at its fresh stage before drying to remove any dirt or other undesirable accumulations on the leaves, which may reduce the efficacy of the final product or may harm the equipment during processing. Then, the leaves were dried under shade on plastic sheets placed on wooden benches for good circulation of air until complete green drying. The dried leaves were crushed and stored in cotton cloth. Following [15] procedure the dried *A. indica* leaf was ground gently by electric grinder (Model SZJ-830 'S SAYONA Patirrier DELUXE COFFEE and SPICE GRINDER 220-240V 50-60HZ') to produce fine powder. Following [16] procedure, the leaf powder was kept in a cotton cloth bags and then the readymade powder was measured to make up a volume of 1 liter of 5, 10 and 15% aqueous solution, respectively. Then the measured leaf powders were added into plastic bucket containing 15 l of pure water, mixed very well and stored overnight in the plastic buckets. The aqueous leaf powder was poured into muslin pouch cloth and filtered. Soap with no detergent was added at the rate of 1ml/liter as an emulsifier to the pure filtrate of aqueous *A. indica* leaf powder to stick on the leaf surface of mango plants [15].

2.3. Field design and treatment application

The field experiment was carried out to evaluate the efficacy of aqueous *A. indica* leaf powder for the control of *A. tubercularis* on mangoes under field condition. The treatments were 0.05, 0.10 and 0.15 ml of the filtrates. Distilled water was used as a negative control for comparison. The concentrations were calculated using the following formula $C_1V_1=C_2V_2$, where C_1 and C_2 represent initial and final concentration, respectively and V_1 and V_2 represent initial and final volume, respectively [16].

The experiment was designed in a Randomized Complete Block design in four replications. An experimental field of three blocks consisting of fifteen mango plants occupying an area of 840 m^2 (40m x 24m) was used for the experiment. A block size was 280 m^2 having 5 mango plants. A plot consists of 1 mango plant. Spacing between plants and rows were 7m and 8m, respectively. Similar age and size mango plants were considered for the experiment. The mango plants used for the experiment were not treated with pesticides at least for the last two years. Cultural practices such as hand weeding and mowing were used for weed control. Pre test calibration of the sample treatment carried out to their respective plots (trees) for determination of the amount of water used as the carrier.

Accordingly, 12 l of water was used for each plant. A manually calibrated 'Knapsack Sprayer Thailand made (Jacto16 HD400) was used for treatment application. Treatment application started on April 20, 2018 when the infestation of *A. tubercularis* reached climax (almost 90-100% infestation from the lower canopy leaves) and repeated every 10 days for three times. Spraying of the aqueous *A. indica* leaf powder carried out in the afternoon at 3:30 pm to reduce loss of the chemicals due to evaporation.

2.4. Data collection

From the sampled mango tress, twelve leaves from each tree plucked following the four cardinals from top, middle and lower canopies of each tree at 1st, 3rd and 6th days after treatment application and kept in a paper bag, labeled and taken to the School of Veterinary laboratory, Wollega University. The number of dead adults and crawlers of *A. tubercularis* after spray were counted under dissecting microscope (WESCO®, Valencia, CA). The dead adults and crawlers (nymphs) data converted into percentage mortality. Pre- and post-spray counts of the adults and crawlers per leaf were also recorded from the sampled leaves and the reduction in infestation (efficacy %) was computed following Henderson and Tilton [17] equation;

Percent (%) efficacy = [1- (Ta/Ca x Cb/Tb)] x 100 (1)

Where,

'Tb' is infestation in treated plot prior to treatment application;

'Ta' is infestation in treated plot after treatment application

'Cb' is infestation in control plot prior to treatment application

'Ca' is infestation in control plot after treatment application

Any change in color and texture of leaves due to probable phytotoxicity of the tested aqueous *A. indica* leaf powder was recorded. Results of mortality were presented as percentage mortality, with correction for untreated (control) mortality using Abbott's formula [18] as follows;

Mortality % = O.M.T – M.C/100– M.C x 100 (2)

Where; O.M.T = Observed mortality in treatment; M.C = Mortality in control.

A. tubercularis were considered as dead if there is a change in color (cloudy or blackish), dried and empty, and no movement of appendages when rubbed with fine brush.

2.5. Data analysis

The Mixed Procedure Repeated-measure with restricted maximum likelihood (REML) models was employed for analysis of variation between experimental units [19]. Tukey's Honestly Significant Difference (HSD) method was used for mean ($P<0.05$) separation [20]. The data were then subjected to Probit analysis. MS Excel worksheet based on Finney's method of probit analysis was used for LC_{50} and LC_{95} data analysis [21] and the confidence limits were determined by logistic regression based on the concentrations of probit-mortality [22].

3. Results

Results of mortality of sessile *A. tubercularis* due to different concentrations of aqueous *A. indica* leaf powder at Uke and Arjo Gudetu are shown in Table 2. Mortality of sessile *A. tubercularis* increases significantly (p<0.0001) with an increase in the concentration of *A. indica* leaf powder water extract. The highest mean percent mortality of *A. tubercularis* with three times treatment applications recorded with 15% concentration, while the lowest was with 5% concentration at both experimental sites.

Table 2. Effect of three round application of aqueous *A. indica* leaf powder on mean (±SE) percent mortality of *A. tubercularis* at Uke and Arjo Gudetu.

Treatment concentration (%)	Experimental sites	
	Uke	Arjo Gudetu
5	53.95 ± 0.68c	50.93 ± 0.23c
10	65.48 ± 0.68ab	64.56 ± 0.23ab
15	72.28 ± 0.66a	73.16 ± 0.23a

*Means followed by the same letter (s) within a column are not significantly different from each other at 5% level, Tukey's studentized range test (HSD).

The effect of frequency of application and days after treatment application of aqueous *A. indica* leaf powder on percent mean mortality of *A. tubercularis* at Uke and Arjo Gudetu are shown in Table 3. The highest mean percent mortality of *A. tubercularis* was recorded 30 days after third round treatment applications, while the lowest was recorded at first round (10 days after) treatment application at both experimental sites.

Table 3. Mean (±SE) percent mortality of sessile *A. tubercularis* at different frequency of application and days after treatment application.

Treatment Concentration %	Frequency of treatment application	DAT Application	Experimental sites	
			Uke	Arjo Gudetu
5	1st	10	32.58± 0.64d	30.81± 0.22d
	2nd	10	45.85± 0.64c	49.28± 0.22c
	3rd	10	52.08± 0.60b	60.82± 0.22b
10	1st	20	55.75± 0.61c	50.89± 0.38c
	2nd	20	66.77± 0.61b	63.31± 0.38b
	3rd	20	75.31± 0.61a	71.79± 0.38a
15	1st	30	73.12± 0.80c	71.08.± 0.44b
	2nd	30	83.43± 0.80ab	81.08± 0.44ab
	3rd	30	89.06± 0.80a	87.18± 0.44a

*Means followed by the same letter (s) within a column are not significantly different from each other at 5% level, Tukey's studentized range test (HSD); DAT= Days after treatment.

Mean percent mortality of female, male and crawlers of *A. tubercularis* due to application of aqueous *A. indica* leaf powder at Arjo Gudetu and Uke are shown in Table 4. The highest mean percent mortality happened to the crawlers followed by males and females in that order.

Table 4. Percent mean (±SE) mortality of *A. tubercularis* on different sexes and stages due to different treatments application of aqueous *A. indica* leaf powder at Uke and Arjo Gudetu.

Concentration %	Sex and stages of *A. tubercularis*	Experimental sites	
		Uke	Arjo Gudetu
5	Male	40.63± 0.53d	43.11± 0.33d
	Female	19.36± 0.53f	21.97± 0.34f
	Crawlers	48.98± 0.51c	51.72± 0.34c
10	Male	57.48± 0.77b	55.34± 0.50b
	Female	37.27± 0.77e	35.46± 0.50e
	Crawlers	67.95± 0.78ab	64.25± 0.50ab
15	Male	70.06± 0.82a	69.58± 0.52a
	Female	51.09± 0.82b	48.30± 0.52b
	Crawlers	76.98 ± 0.83a	77.33± 0.52a

Means followed by the same letter (s) within a column are not significantly different from each other at 5% level,Tukey's studentized range test (HSD).

The effect of contact toxicity of aqueous *A. indica* leaf powder against *A. tubercularis* is shown in Table 5. The LC_{50} values of aqueous *A. indica* leaf powder at Arjo Gudetu against sessile *A. tubercularis* at 1st, 2nd and 3rd times treatments were 15.36, 8.93 and 5.06 mg/100 ml, respectively, while the Chi Square (X^2) values after 1st, 2nd and 3rd treatments were 117.99, 155.41 and 212.70, respectively. The LC_{50} values of aqueous *A. indica* leaf powder at Uke site against sessile *A. tubercularis* at 1st, 2nd and 3rd times treatments were 28.16, 11.43 and 4.90 mg/100 ml, respectively, while the Chi Square (X^2) for 1st, 2nd, and 3rd round treatments were 94.80, 65.58 and 267.49, respectively.

Table 5. Comparison of LC50 and LC95 of aqueous *A. indica* leaf powder at Uke and Arjo Gudetu experimental sites against *A. tubercularis.*

Experimental sites	DAT	LC50 (μg/ml)	LL-UL	LC95 (μg/ml)	LL-UL	Slope ± SE	(X2)
Uke	10	28.2	22.0–36.0	752.5	298.7–1895.9	4.46±0.98	94.8c
	20	11.4	10.84–12.1	67.3	53.8– 83.99	4.82±0.97	65.6c
	30	4.9	4.49–5.34	34.2	28.5– 41.03	5.46±0.92	267.5a
Arjo Gudetu	10	15.4	13.98–1687	153.9	102.1–231-8	4.66±0.98	118.0b
	20	8.9	8.25–9.7	174.9	103.6–295.1	5.01±0.96	155.4b
	30	5.1	4.49–5.7	79.5	54.8–115.4	5.33±0.95	212.7ab

DAT=Days after treatment; LC=Lethal Concentration; LL=Lower limit; UL= Upper Limit; LC_{50} and LC_{95} values are expressed as percentage (n=360); SE=Slope of the concentration-mortality regression line ± standard error; x^2= Pearson's Chi-square value. *Implies that the X^2 values are significant by Tukey's HSD test at $p \leq 0.05$ levels and therefore a heterogeneity factor is used in the calculation of the confidence interval.

The log probit regression line calculated for Uke experimental site had the values of Y=1.189x+3.275 (X-0.498); Y=1.948x+2.88 (X-0.847) and Y=1.658X+3.894 (X-0.507) for 1st, 2nd and 3rd round treatments, respectively, (Figure 1). The log probit regression line calculated for Arjo Gudetu experimental site showed Y=1.455x+3.172 (X-0.579), Y=1.015x + 3.981 (X-0.357) and Y=1.080x+4.263 (X-0.329) for 1st, 2nd and 3^{d} round treatments, respectively, (Figure 2). At both experimental sites, the R^2 was shows significant difference for 1st, 2nd and 3rd round treatments (Figure 1&2). This indicates that the regression model had statistically significant explanatory power, which implies that by the tested concentrations (0.05, 0.1 & 0.15), the mortality caused showed statistically different values, indicating that the mortality caused at 3rd round treatment (30 days after 3rd round treatment application) was higher than the 1st and 2nd round applications. The increase in probability of mortality rates was proportionately higher at lower log concentrations than at the higher ones so that the probit regression lines were more elevated at the lower points than at the higher points.

Table 6. Toxicity (LC50 and LC95) of aqueous *A. indica* leaf powder at different concentrations on *A. tubercularis* crawlers, adult males and females 10 days after each 1st, 2nd and 3rd round treatments (n=360) at Uke and Arjo Gudetu sites.

Experimental sites	Sex/Stage of WMS	DAT	LC_{50} (μg/ml)	LL-UL	LC_{95} (μg/ml)	LL-UL	Slope ± SE	(X^2)
Uke	Crawlers	10	17.8	13.6–23.2	464.8	119.9–1802.4	4.68±0.97	0.40cd
	Female	10	49.7	25.7–96.2	1135.5	173.8–7420.4	4.15±0.99	0.00f
	Male	10	24.7	17.1–35.9	613.7	139.3–2704.1	4.51±0.98	0.51cd
	Crawlers	20	9.9	9.3–10.5	35.0	28.8–42.5	4.94±0.98	0.18e
	Female	20	17.6	13.3–23.3	563.5	124.4–2551.8	4.70±0.97	0.73c
	Male	20	11.1	10.3–12.0	54.1	39.6–73.9	4.84±0.98	3.59a
	Crawlers	30	4.8	4.4–5.2	13.1	11.8–14.4	5.67±0.86	2.61ab
	Female	30	6.8	5.7–8.2	191.1	67.5–541.2	5.15±0.95	0.48d
	Male	30	4.4	3.8–5.2	29.8	22.6–39.3	5.56±0.93	1.90b
Arjo Gudetu	Crawlers	10	10.6	9.6–11.8	92.0	54.7–158.3	4.89±0.97	0.54cd
	Female	10	24.5	18.7–32.0	231.7	98.6–554.5	4.34±0.99	0.01f
	Male	10	14.0	12.2–16.2	132.6	69.6–252.9	4.72±0.98	0.16e
	Crawlers	20	5.5	4.6–6.6	78.7	42.8–144.8	5.29±0.95	0.94c
	Female	20	18.3	14.0–23.9	422.3	118.0–1516.0	4.65±0.97	0.27e
	Male	20	7.9	6.8–9.1	150.1	64.0–352.5	5.08±0.96	0.45cd
	Crawlers	30	3.5	2.8–4.4	29.5	21.5–40.5	5.67±0.92	3.45a
	Female	30	10.2	8.8–11.8	225.6	81.1–627.5	4.94±0.96	0.69c
	Male	30	4.5	3.6–5.6	63.2	36.1–110.4	5.42±0.94	1.54b

WMS = White mango scale (*Aulacaspis tubercularis*); DAT= days after treatment; LC=Lethal Concentration; LL=Lower Limit; UL=Upper Limit; LC_{50} and LC_{95} values are expressed as percentage (n=360); SE: Slope of the concentration-mortality regression line ± standard error; x^2 = Pearson's Chi-square test. *The X^2 values within a column with the same letter (s) are not significantly different from each other by Tukey's HSD test at $p \leq 0.05$ levels.

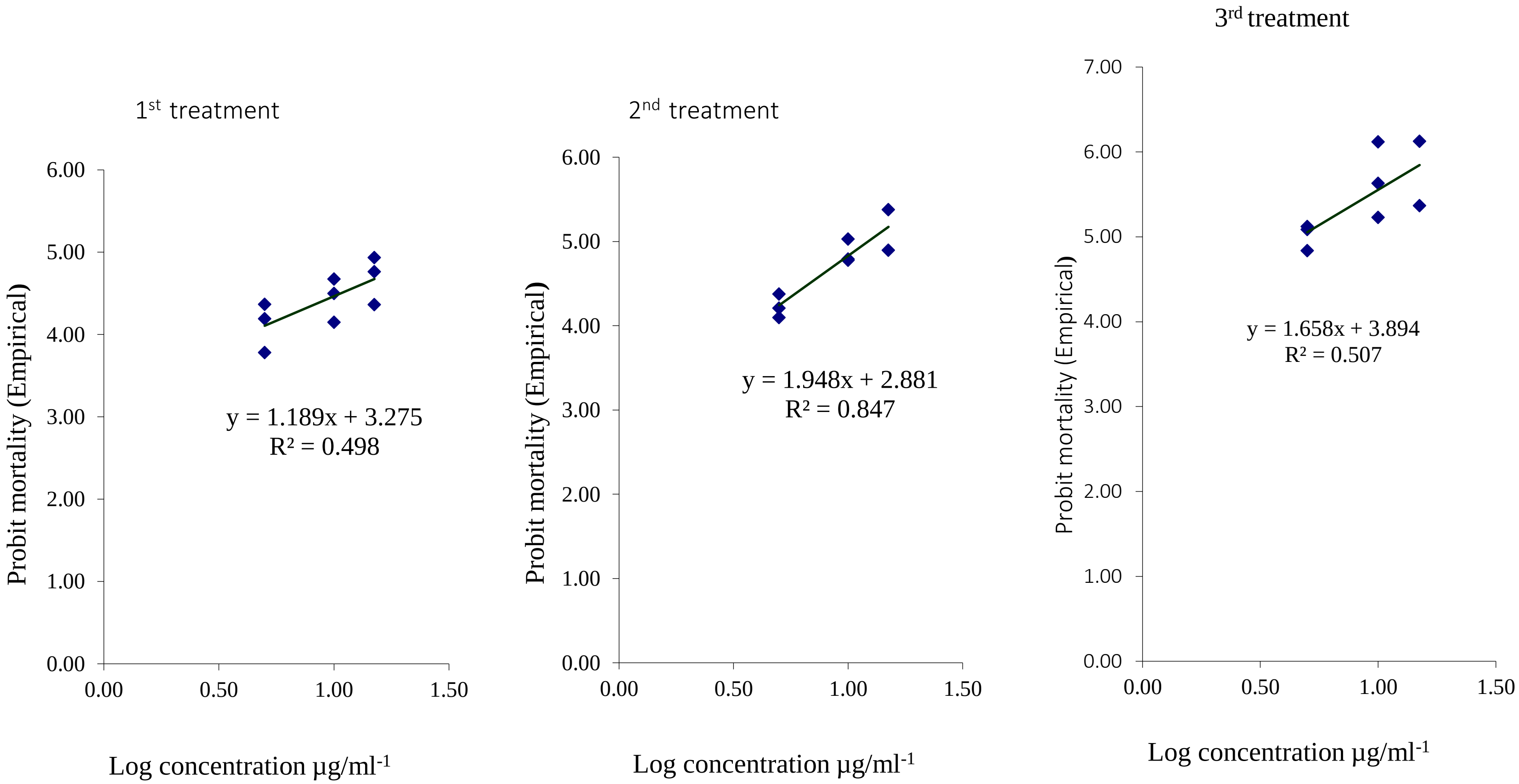

Figure 1. The log probit regression line for aqueous *A. indica* leaf powder against sessile *A. tubercularis* (crawlers, adult females and males) *after* 1st, 2nd & 3rd round treatment at Uke.

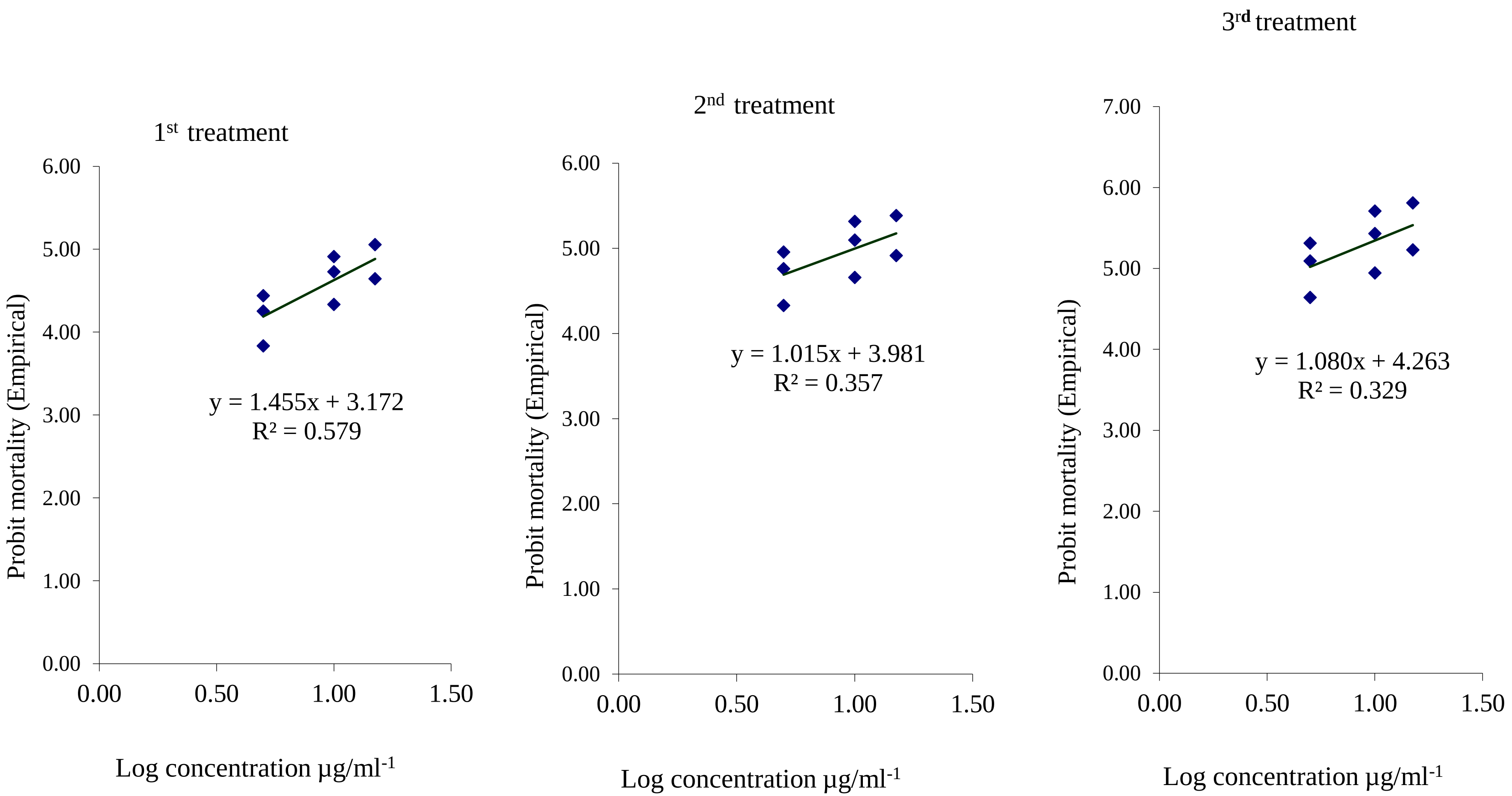

Figure 2. The log probit regression line for aqueous *A. indica* leaf powder against sessile *A. tubercularis* (crawlers, adult females and males) *after* 1st, 2nd & 3rd round treatment at Arjo Gudetu.

4. Discussion

Earlier to this study, there was no attempt to manage *A. tubercularis* using aqueous *A. indica* leaf powder solely**,** however enormous research activities conducted on *A. indica* leaf powder and gave recommendations for the control of arthropod insect pests. Moreover, the current experiment demonstrated the effectiveness of aqueous *A. indica* leaf powder in the management of *A. tubercularis.* A study by [23] mentioned that *A. indica* as an eco-friendly pest control tools', while seed setting is annually excepted in few agro ecological zones of some countries, in which two times seed setting was observed, **it** has an attractive crown of deep-green foliage available throughout the year.

The Results of the current study showed that aqueous *A. indica* leaf powder was effective against *A. tubercularis*. The mortality percentage of *A. tubercularis* with the application of aqueous *A. indica* leaf powder at Uke and Ajo Gudetu was relatively the same implying that there was no agro ecological and location differences. However, significant difference in mortality was observed between male, female and crawlers (nymphs) of *A. tubercularis* due to differences in their susceptibility to *A. indica* leaf powder water extracts**.** There was less percent reduction of adult females' population with aqueous *A. indica* leaf powder treatments at both experimental sites implying that sex and developmental stages of the pest differently respond to aqueous *A. indica* leaf powder**.** The current result agreed with the findings of [24] who reported that the formulations of "Trilogy" (the trade name for neem seed oil) against *A. tubercularis* was effective that caused 81.03 and 76.92% mortality on adults (males and females) and the nymphs, respectively. The study by [25] also reported that aqueous *A. indica* seed powder treatments cause 83 and 86% mortality at Uke and Arjo Gudetu experimental sites of east Wollega zone of Oromiya Regional state. Additionally the study by [25] also indicated that the susceptibility of adult females' were less than that of crawlers and adult males with the treatment of aqueous *A. indica* seed powder applications at both experimental sites.

This study showed that there is less percent mortality of adult females' of *A. tubercularis* with aqueous *A. indica* leaf powder treatments that might be due to the hard exuvie, which is much stronger than the wax cover of the crawlers and adult males of *A. tubercularis*. This investigation agreed with the finding of [26] who stated that the fibrous impermeable wax like scale (covering) covers the insect body providing a protective barrier against physical and chemical damage.

The results of the present work suggests that aqueous *A. indica* leaf powder at a 0.05 concentration against *A. tubercularis* may be used in preventive applications to reduce initial infestation rather than protection without causing possible phytotoxic effects on mango plants. The current study shows that the efficacy of neem leaf derivatives at 0.15 concentrations after 3rd round application causes 72.28 to 73.16% mortality at Uke and Arjo Gudetu experimental sites, respectively, on pre-adult stages of *A. tubercularis.* The results of this study indicated that the mortality of *A. tubercularis* increased with an increase in the concentrations of aqueous *A. indica* leaf powder and frequency of application. This result agreed with the findings of [27] who mentioned that the application of botanical mixture against mango scale insect, *A. tubercularis* during the year 2017 and 2018 in Egypt caused 83.60 and 72.52% reduction, respectively. This study showed that effective application of aqueous *A. indica* leaf powder including the abaxial surfaces of mango leaves gives better results for *A. tubercularis* control**.**

The lethal concentration (LC_{50} and LC_{95}) values of aqueous *A. indica* leaf powder at 10 and 15% concentrations against *A. tubercularis* showed high mortality at both experimental sites. The LC_{50} values of aqueous *A. indica* leaf powder at Uke site after 1st, 2nd and 3rd treatments application were 28.2, 11.4 and 4.9 μg/ml**.** With the same activity, at Arjo Gudetu experimental site after 1st, 2nd and 3rd treatments, the values of LC_{50} were 15.4, 8.9 and 5.1 μg/ml, respectively. The different results of the LC_{50} determination studies on sessile *A. tubercularis* may be due to the differences between treatment concentration of aqueous *A. indica* leaf powder and application round for the treatment plots. The lethal concentration analysis indicated that regression coefficient had close to one for 2nd and 3rd round application, implying that increasing the aqueous *A. indica* leaf powder treatment concentration increases its effectiveness for management of *A. tubercularis.*

The finding of this study also indicated that the botanical formulations from aqueous *A. indica* leaf-powder could replace commercial insecticides in IPM programs. The result of this study agreed with the finding of [24] who revealed that *A. indica* botanicals has an insecticidal effect for scale insect control and useful in reducing environmental pollutions. Related study by [28] reported that *A. indica* compounds has an eco-friendly insecticidal effect on some scale insects, mealy-bugs, and its response as insecticidal effect on the population of *A. tuberularis (Aulacaspis mangiferae).* A study by [28] also suggested that *A. indica* essential oils can be used potentially as an alternative source for developing bio-insecticides against scale insects. The result of different findings by [29] in the integration of neem botanical extracts and entomopathogenic fungi against Russian wheat aphid, *Diuraphis noxia* Mordvilko (Homoptera: Aphididae), revealed that the neem leaf and seed extract gave significantly higher efficacy percentage (57.82%) among the treated aphids, after 7 days application with respect to other treatments.

Related study by [24] mentioned that *A. indica* extract is a potent botanical pesticide preferred for organic agriculture that is widely used in several countries around the world today either singly or in Integrated Pest Management (IPM) or in conjunction with Synthetic pesticides. This indicates that the local people can use aqueous *A. indica* leaf powder to control the infestation of *A. tubercularis* in homestead mangoes. Therefore, the result of this study revealed that the 0.15 concentrations of aqueous *A. indica* leaf powder at three round or more frequency of application has a better impact on population reduction and potentially it can be used for the management of *A. tubercularis.*

5. Conclusion

Among the various plant products used as botanical insecticides, neem (*Azadirachta indica*) is the most studied natural insecticide and has demonstrated promise and high efficiency in pest management. The natural product formulations developed from neem (*A. indica*) have shown promise for *A. tubercularis* management and it is non-toxic, biodegradable and environmentally friendly as alternative insect pest management. In Ethiopia, the introduction of *A. tubercularis* lasts about a decade ago; there was none successful technologies towards its control, which enabled the pest to invade the whole country where mango is grown, resulting in 50-100% crop losses**.** Thus, our field experiment results suggested that aqueous *A. indica* leaf powder at 0.15 concentrations has a considerable effect on *A. tubercularis* population reduction under field conditions. Therefore, the aqueous *A. indica* leaf powder as botanical insecticide can be used for management of *A. tubercularis in* mango growing belts of the country *and may be beyond*. Thus, the use of aqueous *A. indica* leaf powder can be recommended for *A. tubercularis* management and the diversification of neem (*A. indica*) plant in mango growing areas of the country the research on its pesticidal use needs a special attention in the future research and development programs.

Data availability statement: The data presented in this study are available on request from the first author.

Authors' contributions: Temesgen F. carried out the experiments and wrote the manuscript. Prof. Emana G., Dr. Mulatu W., and Prof. Kebede W/ts all as an advisory committee members advices the principal author (researcher) throughout the work and reviews the manuscript. All authors read and approved the final manuscript for publication**.**

Author Contributions: Conceptualization, Temesgen F.,; methodology, Temesgen F., Prof. Emana G., Mulatu W., Temesgen F,; validation, Prof. Emana G., Mulatu W., Prof.

Kebede W/ts.; formal analysis, Temesgen F.; investigation, Temesgen F.; resources, Mulatu W.; data curation, Temesgen F., Prof Emana G.,; writing original draft preparation, Temesgen F.,; writing, Temesgen F., review and editing, Prof. Emana G., Mulatu W., Prof. Kebede W/ts.; validation, Temesgen F.; Prof. Emana G., Mulatu W., Prof. Kebede W/ts.; visualization, Temesgen F., Prof. Emana G.,.; supervision, Prof. Emana G., Mulatu W., Prof. Kebede W/ts.; project administration, Temesgen F.; funding acquisition, Mulatu W.,. All authors have read and agreed to the published version of the manuscript.

Funding: Ministry of Science and Higher Education (MoSHE), Haramaya University and Wollega University made financial support partly for the Doctorial grant to the principal author.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: The data presented in this study are available from the corresponding author upon reasonable request.

Ethics approval: APC is with waivers

Consent to participate: Note applicable.

Consent for publication: The author confirms that the content of the manuscript has not been published or submitted for publication elsewhere.

Informed Consent Statement: Not applicable.

Acknowledgements: Authors would like to thank Haramya University, Wollega University and Ministry of Science and Higher Education of Ethiopia (MoSHE) for financial support partly in accomplishing of this research work. Ours' sincere appreciation goes to the School of Veterinary Medicine Parasitological Lab of Wollega University for the provision of laboratory equipment for the lab work. Our appreciation also goes to Diga District of Agriculture and Natural Resource office for facilitation at Arjo Gudetu kebele and to Ato Bedasa Tolesa from Uke kebele for permitting his mango farm to be used for experimental plots.

Competing Interests: Authors have declared that no competing interests exist.

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