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Research Article

Palm oil formulation as 34 % mayonnaise and evaluation of its biological efficacy against citrus mealybug, *Planococcus citri* under laboratory and field conditions

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Abstract

The use of environmentally friendly pesticides using palm oil derivatives as palm oil methyl ester (PME) carrier solvents has been reported. PME-based glyphosate isopropylamine nanoemulsion in the water against weeds has been the subject of numerous studies as well as palm oil methyl ester molluscicidal against golden apple snails. This study's major goal was to formulate palm oil in an appropriate formulation form and assess its insecticidal effectiveness against citrus mealybug, *Planococcus citri*. Palm oil was formulated as 34% oil in water emulsion (O/W) (mayonnaise). The new mayonnaise formulation successfully passed all physical and chemical testing requirements set out by pesticide organizations for (O/W) emulsions. Under laboratory conditions, it was biologically evaluated against nymphs and adults of the citrus mealybug, *Planococcus citri,* with serial concentrations. It had considerable insecticidal activity against all study stages, although the impact on nymphs was significantly greater than that on adults. This was evident from its LC_{50} values, which were 53.52 and 58.58 mg/ml for nymphs and adults, respectively. The citrus mealybug, *Planococcus citri,* in its adult, nymphs, and gravid stages, was tested using the new palm oil 34% mayonnaise formulation in the field. The highest mortality percentages were seen in the nymphs, followed by adults and then the gravid stage. After additional research, the newly developed palm oil formula might be employed to combat the citrus mealybug, *Planococcus citri*.

Keywords: Formulation, Mayonnaise, Palm oil, *Planococcus citri*

INTRODUCTION

Mealybugs are harmful insect pests that attack various horticultural and agricultural crops, including grapevine, citrus, mango, and coffee (Arshad *et al.,* 2015). So far, mealybugs have been classified into 74 families and 175 genera (Ben-Dov, 2007).The polyphagous species, citrus mealybug or *Planococcus citri*, is found throughout the world's geographical zones. Its classification is Class Insecta, Order Hemiptera, Family Pseudococcidae, Genus *Planococcus,* and species Citri (Asiedu *et al.,* 2014).

The citrus mealybug, *Planococcus citri*, is the most widespread polyphagous and frequently the most damaging species in its family. The citrus mealybug, *Planococcus citri*, is widely distributed worldwide and has been deemed an economically significant pest in several crops (Silva *et al.,* 2015). The nymphs and females harm host plants with their piercing-sucking mouthparts, which they utilize to suck sap and take nutrients. As a result, the plants frequently exhibit diminished vigor and become stunted, deformed, or yellowed. They exude honeydew, which serves as a medium for developing fungi that cause black sooty mold (Elkady, 2013). *P. citri* displayed varying degrees of preference for citrus, guava, and grape (Ahmed and Abd-Rabou, 2010).

Around 69 species, including (*Mangifera indica* L.), are farmed in Egypt, particularly in the Ismailia Governorate (Anacardiaceae). Unfortunately, a heavy infestation of mealybugs, such as the *Planococcus citri* (Risso), significantly damages mango trees in all areas and decreases mango productivity (Mokhtar, 2022). Although female mealybugs acquire cushiony scales on their dorsal side, which decreases their exposure to the uptake of insecticides, mealy bugs have a cryptic character, making their management difficult and difficult ineffectual (Arshad *et al.,* 2015). Numerous issues that were not anticipated when synthetic pesticides were first introduced have been brought on by their use. Chemical pesticides prevent the coccinellid predator (CP), one of the biological control agents for citrus mealybug control (CM). Profenofos, Methidathion, Chlorpyrifos, Fenpropathrin, and Methomyl are just a few of the several pesticides that have been used to suppress CM (Aheer *et al.,* 2009). Yet, they have been found to be detrimental to coccinellid beetles (Lo *et al.,* 2009, Ahmadi and Amiri-Besheli, 2015).

Numerous insecticides had thus failed to control the mealybugs. Pesticide treatments must be repeated several times since the available pesticides on the market might not be sufficient to control mealybugs if applied just once. Insecticide resistance might arise as a result of this circumstance. Additionally, different insecticide classes offer various active ingredients, and if insecticide resistance emerges, their effectiveness may be diminished (Venkatesan *et al.,* 2016). Chlorpyrifos, as an example of a synthetic pesticide, has been recognized as one of the field's most widely used and successful insecticides for controlling scale insects (mealybugs and armoured scales) (Mansour *et al.,* 2018, Attia *et al.,* 2018, Satar *et al.,* 2013). Despite having a high toxicity against mealybugs in general, chlorpyrifos has some drawbacks, such as negative effects on non-target natural enemies and insect pollinators as well as the emergence of resistance in scale insects (Mansour *et al.,* 2018, Urlacher *et al.,* 2016).

The baseline investigation for the evolution of resistance in *Planococcus citri* to organophosphates and insect growth regulators is presented by Mruthunjayaswamy *et al.* (2019) with indications of a favorable link between detoxifying enzymes and pesticides. Since mealybugs have a very low to low level of pesticide resistance, appropriate steps should be implemented to stop the emergence of this resistance.

Materials or eco-friendly pesticides are a great substitute for synthetic pesticides to lessen harmful effects on both human health and the environment. Discovering and commercializing natural compounds as green pesticides is an attractive and successful effort attracting attention due to the shift towards green chemical processes and the ongoing requirement for new crop protection agents with innovative modes of action. The term "Green Pesticides" refers to all kinds of eco-friendly and useful pest control products that can help to lower the pest population and boost food output (Mohan *et al.,* 2011).

The use of eco-friendly pesticides using palm oil methyl ester (PME) carrier solvents, such as PME-based glyphosate isopropylamine nanoemulsion in water (EW) against weeds, (e.g., *Eleusine indica*) (Jiang *et al.,* 2011), palm oil methyl ester molluscicidal against golden apple snails (*Pomace canaliculata*) (Massaguni and Latip, 2015), and EW of mixed triclopyr butoxyethylester and glyphosate isopropylamine in palm oil methyl ester based emulsifier for weed control (Raman *et al.,* 2014) has been the subject of several research. Furthermore, Sharri *et al.* (2021) reported field findings for creating an *Aedes* mosquito nanoemulsion pesticide for thermal fogging based on palm oil. When used to kill *Ae. aegypti*, the oil-in-water nanoemulsion insecticides Nano EW8 and Nano EW3 were stable and effective.

Oil droplets are dispersed in a continuous aqueous phase to form an oil-in-water (O/W) emulsion (e.g., milk, mayonnaise, and vinaigrette). Lipophilic actives are delivered using these emulsions (e.g., phytosterols). Water droplets make up the dispersed phase of a W/O emulsion, and oil makes up the bulk phase. Because oils comprise the bulk phase and have additional stabilizing mechanisms, the latter emulsions present more difficulties than O/W emulsions. Multiple polar components (such as water, protein, or polysaccharides) and non-polar ingredients (such as oil, emulsifiers) may be present in an emulsion utilised in various food and non-food purposes, which may substantially impact their formation and stability. Emulsions are complicated systems involving different molecular interactions that depend on both phases' physical and chemical characteristics (Romero-Peña, 2021).

The major objective of this research was to identify new active compounds with plant origins, formulate them for commercial use, and assess their effectiveness against the citrus mealybug, *Planococcus citri*, to introduce new formulas for use in the pest control sector.

MATERIALS AND METHODS

Tested chemicals

a) Palm oil was supplied by Agricultural Development Markets, Nadi El Seid St., Dokki, Giza.

b) Surface active agents were provided by EL-Gomhoria Chemicals Company Cairo, Egypt.

Physico-chemical properties of mayonnaise main components

Active ingredient

a) **Solubility:** Using volume of distilled water, ethanol, acetone, xylene, and DMF, one gram of the substance was assessed for total solubility or miscibility at 20 °C (Nelson and Fiero, 1954). Using the equation below, the percent solubility was determined. A

Percent solubility = W/V x 100 Eq. 1

[Where; W= weight of active ingredient, V= solvent volume for complete solubility].

b) **Free acidity or alkalinity**: It was evaluated utilizing the technique recommended by the WHO (1979).

Surface active agents

a) **Surface tension**

For solutions containing 0.5 percent (W/V) surface active agent, it was evaluated using a Du-Nouy tensiometer, according to ASTM D-1331 (2001).

b) **Hydrophilic-lipophilic balance (HLB):** The solubility of surfactant in water serves as a good approximation of its hydrophilic-lipophilic balance (Lynch and Griffin, 1974).

c) **Critical micelle concentration (CMC)**: The concentration of the tested surfactants at which the solution's surface tension does not decrease as the concentration of the tested surfactant increases (CMC) was determined using the methodology described in (Osipow, 1964).

d) **Free acidity or alkalinity:** It was determined as before.

Mayonnaise formulation

a) **Emulsion stability test**: According to CIPAC MT 36 (2007), five ml of the formulation are combined with standard water to produce 100 ml of the aqueous emulsion.

b) **Accelerated storage**: According to CIPAC MT 46 (2007), put about 50 ml of the formulation in a bottle, add polyethylene inserts, and place the uncapped container with its contents in the oven at 54 ^{0}C.

Spray solution

a**) Surface tension**: It was done as stated before.

b) **Viscosity**: According to ASTM D-2196 (2005) viscosity was examined using a Brookfield viscometer model DVII+Pro and measured in centipoise.

c) **Electrical conductivity and pH**: The electrical conductivity and pH were measured using a Cole-Parmer pH/Conductivity meter 1484-44, where mhos is the unit of electrical conductivity measurement (Dobrat and Martijn, 1995).

Bioassay

Source of the citrus mealybug *(P. citri)*

P. citri insect cultures were obtained from the citrus orchard at the Agriculture Research Center (A. R. C.), Dokki, Giza, Egypt for use in laboratory experiments. Randomly chosen samples were taken from each of the four cardinal directions (East, West, North and South). In paper bags, the leaves were delivered to the lab where they were kept at a temperature of about 25±1°C and a relative humidity of 65±1%. *P. citri* was recognized in the lab by the mealybug and scale insect department. Agriculture Research Center, Plant Protection Research Institute.

Laboratory experiment

Four different concentrations of formulated palm oil (5, 10, 15, 20 mg/ml) were tested in laboratory bioassays against mealybug *Planococcus citri* nymphs and adults together.

In spray toxicity assay, orange tree leaves that weren't infested were picked out and put in petri dishes (9 cm diameter, 1cm height). Thirty mealybug nymphs and thirty adult mealybugs were placed together on each leaf in Petri dishes. Then, 1 ml of the new formula's tested concentrations was sprayed for 5 seconds over each dish, leaf, and *P. citri* individual. The dishes were allowed to dry at room temperature and covered. For each treatment, three replications were carried out. Petri dishes used were then placed in a lab environment and checked for mortality after 24, 48, and 72 hours. Control insects were just exposed to water spray.

Field experiment

This study was carried out on an orange orchard that was *P. citri* infested at the Agriculture Research Center (A. R. C.) - horticulture research institute, Giza, Egypt. The selected area (about 350 m2) was divided into four portions, with three receiving sprays of the tested oil formulation at three different concentrations (58.5, 117 and 234 mg/ml) and the fourth receiving a control spray with water. Each sprayed area was split into three replicates. After spraying in all directions and at every level of the tree, samples of 10 infected leaves from each tree (10 leaves X 3 trees) (30 leaves for each replicate X 3 replicates) totaled 90 leaves. The same numbers were selected from the untreated trees (control). As a pre-treatment count, 90 leaves from each treatment and control area were also taken before spraying. Paper bags were used to store these samples, which were then brought to a lab for examination. For the live stages (nymph and adult female stages), data from the pre-treatment, control, and post-treatment samples were collected in order to determine the population reduction %. After 2, 4, and 6 weeks following spraying, three post-treatment counts were performed.

Statistical analysis

Using Abbott formula (1925), the mortality percentage was corrected. The LC_{50} values were determined using the LdP-line program. ANOVA was used to statistically analyze the data from all experiments analyze the data from all experiments statistically, and Duncan's Multiple Range Test was used to compare the means at ($P<0.05$). The software program Costat was used for all statistical analysis.

Mortality % = (1 – n in treatment after treatment / n in control after treatment) x 100 Eq. 2

Where; n= Insect population

Henderson and Tilton equation (1955) was used to assess the reduction percentages for each stage as follows:

Reduction% = (1 - (n in Co before treatment) X (n in T after treatment) / (n in Co after treatment) X (n in T before treatment) * 100 Eq. 3

Where: n = Insect population, T = treated, Co = control

The acquired data was statistically analyzed using the Microsoft Office Excel Program version 2016 to compute "F values" and L.S.D to identify the significant differences between the examined palm oil formulation concentrations and between the various stages of the investigated pest *P. citri*.

RESULTS AND DISCUSSION

Formulation part

The physicochemical attributes of palm oil are displayed in Table 1. It demonstrates total insolubility in aqueous solvents such as water, dimethylformamide (DMF), and ethanol but only poor solubility in acetone and xylene as their respective percentages were 1.25 and 0.05. Additionally, palm oil had an alkaline property resulted from its free alkalinity measured as a percentage of sodium hydroxide (6.37). The active ingredient's physical and chemical characteristics primarily define not only the type of formulation on which it may be formulated but also the kind of additives to apply in this formulation (FAO/WHO Meeting, 2002; Abd-Alla and Hamouda, 2021). These findings were in agreement with those of Hamouda *et al.,* 2022, who said that the physical and chemical characteristics of the active ingredients and the surface active agents utilized in the formulation procedures must be completely compatible.

The physico-chemical characteristics of the recommended surfactants are shown in Table 2. Surfactant A demonstrated total insolubility in both aqueous and organic solvents, whereas surfactant B demonstrated medium solubility in water and complete solubility in DMF, acetone, and xylene. Surfactant C demonstrated an observed degree of solubility in water and complete solubility in DMF, acetone, and xylene. The HLB values for all tested surfactants were larger than 13, and the relative critical micelle concentrations for surfactants A, B, and C were 0.3, 0.2, and 0.5, respectively. Additionally, all of them displayed lower surface tension values than water, with respective values of 50, 36, and 39.2 dyne/cm compared to water's 72 dyne/cm. surfactant A only demonstrated an alkaline property based on its free alkalinity assessed as sodium hydroxide percentage (2.94), but surfactants B and C demonstrated an acidic nature based on their respective free acidity values of 0.49 and 0.196 measured as a sulfuric acid percentage. To choose the best surfactant to be used in the formulation procedures, the physico-chemical properties of the investigated surface active agents have been thoroughly evaluated to choose the most compatible surfactant with active ingredient (Griffin, 1954).

The physico-chemical characteristics of the palm oil 34% mayonnaise formulation before and after accelerated storage are displayed in Table 3. Before storage, 100% spontaneous emulsification in hard and soft water was demonstrated by the new formulation. In addition, it demonstrated total emulsion stability with no oil or cream layer separation or precipitation in either soft

Table 1. Physical and chemical properties of palm oil as an active ingredient

Solubility % (W/V)					Free alkalinity as % NaOH
Water	DMF	Ethanol	Acetone	Xylene	
N.S*	N.S	N.S	1.25	0.05	6.37

N.S*: Not soluble

Table 2. Physical and chemical properties of the tested surface active agents

Surface active agents	Solubility % (W/V)				HLB	CMC	Surface tension Dyne/cm	Free alkalinity as NaOH %	Free acidity as H_2SO_4 %
	Water	DMF	Ace-tone	Xy-lene					
Surfactant A	N.S*	N.S	N.S	N.S	> 13	0.3	50	2.94	-
Surfactant B	50	100	100	100	> 13	0.2	36	-	0.49
Surfactant C	20	100	100	100	> 13	0.5	39.2	-	0.196

or hard water. Additionally, it demonstrated an alkaline property as indicated by the sodium hydroxide percentage (0.0098), as well as low levels of foam in the two types of water tested. The new mayonnaise formulation demonstrated complete emulsion stability with no oil or cream layer separation or precipitation, no foam in either of the two types of water utilized, and relatively the same values for all evaluated chemical and physical characteristics after accelerated storage. The free alkalinity evaluated after accelerated storage exhibited a noticeable change, however the new formula demonstrated an alkaline property both before and after accelerated storage. Results collected before and after accelerated storage demonstrated the new mayonnaise formulation's ability to retain its physico-chemical properties under various circumstances (El-Sharkawy *et al.,* 2020).

The physical and chemical characteristics of the spray solution affect how well the new pesticide will penetrate, abide to the treated surface, or reach the target site, ultimately leading to toxicity in the pest under study. As a result, these physical and chemical characteristics greatly influence the expected biological activity of the new formulations under field conditions. The physico-chemical features of the 34% palm oil mayonnaise formulation spray solution at field dilution rate (0.5) are displayed in Table 4. The spray solution's surface tension was 55 dyne/cm, which was lower than the water's surface tension of 72 dyne/cm. This drop in surface tension is required because it increased spreading throughout the treated surface (Pereira *et al.,* 2016). The increase in viscosity, on the other hand, is a required characteristic for spray solutions as it reduces pesticide drift and increases the formulation's stickiness on the treated surface (Spanoghe *et al.,* 2007). The new mayonnaise formulation had a high viscosity value of 2.56 cm/poise. El-Sisi *et al.* (2011) claimed that the spray solution's high electrical conductivity and low pH value would improve the insecticides' deionization, increase deposits and penetration into the treated surface, and be expected to increase pesticidal efficacy. The new mayonnaise formulation displayed these characteristics, with a high electrical conductivity value of (275 mhos) and a low pH value of 6. These results for the spray solution's chemical as well as physical features are in accordance with AbdAllah *et al.* (2022).

Biological activity

Under laboratory conditions, the biological effectiveness of the new palm oil 34% mayonnaise formulation was examined using the citrus mealybug, *P. citri* nymphs and adults. Table 5 displayed the preliminary evaluation of formulation in lab against nymphs and adults of the citrus mealybug, *P. citri*.

Under laboratory conditions, *P. citri* nymphs were exposed to a series of concentrations (5, 10, 15, and 20

Table 3. Physical and chemical properties of the new locally prepared 34 % palm oil mayonnaise formulation before and after accelerated storage

Before storage							After storage						
Spontaneous emulsification %		Emulsion stability		Foam (cm^3)		Free alkalinity as NaOH	Spontaneous emulsification %		Emulsion stability		Foam (cm^3)		Free alkalinity as NaOH
Hard	Soft	Hard	Soft	Hard	Soft		Hard	Soft	Hard	Soft	Hard	Soft	
100	100	Pass	pass	1	2	0.0098	100	100	pass	pass	-	-	0.024

Table 4. Physical and chemical properties of locally prepared 34 % palm oil mayonnaise formulation spray solution at field dilution rate.

Surface tension dyne/cm	Viscosity cm/poise	Electrical conductivity µ mhos	pH
55	2.56	275	6

Table 5. Preliminary evaluation of palm oil mayonnaise 34 % against nymphs and adults of citrus mealybug, *Planococcus citri* under laboratory conditions

Concentration mg/ml	% Mortality after days			
	Stage	1st	2nd	3rd
5	Nymphs	16.3	36.7	46.4
	Adults	13.3	40	40
10	Nymphs	33.3	70	80
	Adults	50	56.7	73.3
15	Nymphs	53.3	83.3	96.7
	Adults	53.3	76.6	86.3
20	Nymphs	73.7	86.7	100
	Adults	70	83.3	96.7
	Control	0	0	0

mg/ml) of the new palm oil 34% mayonnaise formulation to examine its effect. The percentage mortality mean and the length of treatment were directly correlated at each concentration; for example, at 5 mg/ml, the percentage mortality mean was 16.6, 43.3, and 46.6 after 1, 2, and 3 days of treatment, respectively. Similar to this, the other concentrations examined also produced results with a similar relationship between the average mortality percentage and the length of treatment; 20 mg/ml produced mortality means of 73.3, 86.6, and 100% after 1, 2, and 3 days from treatment, respectively. A new direct correlation between the increase in concentration used and the increase in the mortality percentage mean was seen for every day of treatment. The percentage mean of mortality rose from 16.6% to 33.3% to 50% to 73.3% after the first day of treatment, in accordance with the four concentrations employed. The percentage mean of mortality increased after the second day of treatment by 43.3, 70, 83.3, and 86.6%, respectively, for the same concentrations as before. Generally the highest percentage mean of mortality of nymphs of citrus mealybug, *P. citri* was obtained with the highest concentration used (20 mg/ml) and on the third day from treatment (100 %). In general, *P. citri* nymphs had the highest mean percentage mortality (100%) at the highest concentration used (20 mg/ml) and after the third day of treatment. According to Elhefny *et al.* (2019), the toxicity tests of citrus peel essential oils against nymphs and adults of *F. virgata* and *M. mangiferae* showed toxicity rates with concentration and time-dependent. The obtained results are consistent with their findings.

The biological effectiveness of the new 34% mayonnaise formulation developed from palm oil is shown in Table 7 for adults of the citrus mealybug, *Planococcus citri*, in lab using the same serial concentrations as in the case of nymphs. The collected data revealed two direct correlations, the first being between an increase in treatment period and an increase in the average mortality percentage throughout all concentrations. After 1, 2, and 3 days of treatment, 10 mg/ml produced percentage mortality means of 43.3, 56.6, and 73.3%. The second was the gradual direct increase in concentration and the rise in the percentage mean of mortality, with the percentage mean of mortality increasing from 41 to 73.3 to 86.6 to 96.6 after one, two and three days from treatment, which corresponds to the used concentrations of 5, 10, 15, and 20 mg/ml, respectively. In the end of the experiment, it was discovered that the maximum concentration employed (20 mg/ml) caused a percentage mean of mortality of 96.6 percent after three days of treatment. The observed results were in agreement with those published by Elhefny *et al.,* (2023), who found that the three essential oils' Thyme, *Thymus vulgaris* L., Flaxseed, *Linum usitatissimum* L., and Lemon, *Citrus limon* L. insecticidal toxicity against *Ferrisia virgata* adults depended on both time and concentration.

Table 8 displays the LDP line parameters for citrus mealybug, *Planococcus citri*, nymphs and adults after treatment with palm oil 34% mayonnaise under laboratory conditions. After the first, second, and third day of treatment, the lethal concentrations (LC_{50}) values for nymphs were 12.93, 6.57, and 5.35 ppm. The LC_{50} values for adults were 12.12, 7.12, and 5.85 ppm on the first, second, and third day of treatment. The LC_{50} values for nymphs were lower than those for adults, indicating greater biological activity, except on the first day

Table 6. Effect of new palm oil 34 % mayonnaise formulation against nymphs of citrus mealybug, *Planococcus citri* under lab. conditions

Concentration mg/ml	% Mortality means after days		
	1	2	3
5	16.6	43.3	46.6
10	33.3	70	80
15	50	83.3	96.6
20	73.3	86.6	100
control	0	10	10

Table 7. Effect of new palm oil 34 % mayonnaise formulation against adults of citrus mealybug, *Planococcus citri* under laboratory conditions

Concentration mg/ml	% Mortality means after days		
	1	2	3
5	13.3	40	41
10	43.3	56.6	73.3
15	50	76.6	86.6
20	63.3	83.3	96.6
Control	0	10	0

Table 8. LDP line parameters for nymphs and adults of citrus mealybug, *Planococcus citri* resulted from treatment with palm oil 34 % mayonnaise under lab. conditions

Stage	Days	LDP line parameters		
		LC_{50}	LC_{90}	Slope
Nymphs	1st	12.93 10.04 16.27	38.06 34.13 65.99	2.7343 ± 0.1552
	2nd	6.57 5.93 7.16	21.26 19.36 23.79	2.5130 ± 0.1531
	3rd	5.35 4.85 5.81	13.37 12.40 14.57	3.2226 ± 0.1954
Adults	1st	12.12 90.94 15.47	37.50 33.95 69.54	2.6138 ± 0.1525
	2nd	7.12 6.37 7.81	27.72 24.56 32.24	2.1720 ± 0.1456
	3rd	5.85 2.67 6.71	21.74 19.30 49.24	2.2500 ± 0.1553

Table 9. Effect of new palm oil 34 % mayonnaise formulation against nymphs of citrus mealybug, *Planococcus citri* under field conditions

Concentration (mg/ml)	Reduction % after weeks		
	2	4	6
58.5	63.11	87.00	100
117	83.00	91.00	100
234	94.00	99.90	100
LSD*	7.49		
F treatment	47.96		

LSD*: Least Significance Difference

Table 10. Effect of new palm oil 34 % mayonnaise formulation against adults of citrus mealybug, *Planococcus citri* under field conditions

Concentration (mg/ml)	Reduction % after weeks		
	2	4	6
58.5	61	64	98
117	74.03	89.30	91.1
234	90	95.40	100
LSD	16.87		
F treatment	5.16		

of treatment, when the LC_{50} value for nymphs was higher than that of adults, a finding that may be explained by the incomplete growth of nymphs compared to adults and the consequent ability of the stage to tolerate the effect of the new formulation in adults rather than nymphs. The slope values after the first, second, and third days of treatment for nymphs were 2.7, 2.5, and 3.2, whereas those after the same time for adults were 2.6, 2.1, and 2.2. Nymphs had larger slope values than adults, reflecting greater biological effectiveness and sharper toxicity lines (Abd-Alla *et al.,* 2021).

Table 9 shows the impact of three different concentrations (58.5, 117, and 234 mg/ml) of a new palm oil 34% mayonnaise formulation against nymphs of citrus mealybug, *Planococcus citri* under field conditions. A direct correlation between the length of treatment and the percentage of reduction was seen for all concentrations tested. For example, 117 mg/ml exhibited 63.11, 87.00, and 100% reduction after 2, 4, and 6 weeks from treatment, respectively. Additionally, a correlation between the increase in concentration and the increase in the reduction % was discovered. Using the three previously reported concentrations, the reduction rates rose from 87.00 to 91.00 to 99.9% after four weeks of treatment, respectively. Generally, the reduction proportion was typically 87.00, 91.00, and 99.90 after 4 weeks from treatment, but 100% for all concentrations used after 6 weeks.

Table 11. Effect of new palm oil 34 % mayonnaise formulation against gravid of citrus mealybug, *Planococcus citri* under field conditions

Concentration (mg/ml)	Reduction % after weeks		
	2	4	6
58.5	60	67	93.40
117	72	88.30	100
234	90	94.7	100
LSD	7.09		
F treatment	0.67		

The new palm oil 34% mayonnaise formulation's field effectiveness against adults of the citrus mealybug, *Planococcus citri*, is shown in Table 10. The acquired data demonstrated a direct relationship between the period of treatment and the reduction percentage for all concentrations tested; 58.5 mg/ml demonstrated 61, 64, and 98% adult mortality percentages after 2, 4, and 6 weeks of treatment, respectively. Additionally, a direct correlation between concentration and reduction percentage was seen for each treatment period. For example, after 4 weeks of treatment, the percentage of reduction rose from 64.00 to 89.30 to 95.40, for 58.5, 117, and 234 mg/ml, respectively. Generally, the reduction proportion for all concentrations evaluated was often close to 100% six weeks after treatment.

The effectiveness of the new palm oil 34% mayonnaise formulation against citrus mealybug, *Planococcus citri*, gravid stage is shown in Table 11 under field conditions. As with nymphs and adults, two different direct relationships were seen. The first was between the duration of treatment and the reduction %; 117 mg/ml resulted in 72, 88.30, and 100% reduction after 2, 4, and 6 weeks from treatment, respectively. The second direct relationship was between the proportion of reduction and concentration increase. The reduction proportion rose from 60 to 72 to 90% after two weeks of treatment, corresponding to the three concentrations employed. Generally, the reduction rate attained for all used concentrations after 6 weeks of treatment was extremely close to 100%.

Conclusion

Palm oil was prepared as 34% oil in water emulsion and passed all relevant tests for oil in water emulsions. Under laboratory and field conditions, the new formulation was evaluated against the citrus mealybug, *Planococcus citri*. Under laboratory conditions, it demonstrated high biological efficacy on both nymphs and adults, however the impact was significantly stronger on nymphs than on adults. The results confirmed from field experiments showed the highest activity against nymphs, adults and then the gravid stage of the citrus mealybug, *Planococcus citri.*

Conflict of interest

The authors declare that they have no conflict of interest.

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