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Development of a Predictive Equation for Optimizing Systemic Pesticide Injection in Date Palm (Phoenix dactylifera L.) Trunks for Effective Pest Management

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Abstract

One type of chemical management utilized via injection to manage insect pests infesting trees, such as date palm pests, is systemic insecticides. However, depending on how much poison is required to penetrate the tree's tissue and reach the intended insect, the control's effectiveness could not be sufficient. Additionally, the suggested dosage varies based on the tree's size. As a result, a formula that can be used to determine the quantity of pesticide required for each tree depending on the palm tree's length and diameter (size) is provided below. The following were components of the formula: Am is the quantity of pesticide required, F is a constant, V is the size of the trunk, and Q is the recommended dose by the manufacturer. The formula was evaluated theoretically to calculate the quantity of pesticide required for each palm tree depending on the trunk's length and diameter. It was then tested in the field to evaluate the efficacy of the pesticide dose determined using the method. The dubas bug Ommatissus lybicus and palm borers of the species Oryctes were treated with three distinct systemic insecticides: Tiam, Tiamethoxam 25%, Radical, Imidacloprid 20%, and Mospilan, Acetameprid 20%. The findings showed that as trunk length and diameter grow, more insecticide is required to manage the two insect pests. Consequently, 1.50 g, 1.98 ml, and 2.49 g of pesticides were determined to be required to suppress the bores in trees with a trunk length of 3 m and a diameter of 0.50 m for Tiam, Radical, and Mospilan, respectively. In trees with a height of 9 m and a diameter of 0.5 m, the doses of the three pesticides were raised to 4.49 g, 5.69 ml, and 7.48 g, respectively. In terms of field applications, the efficacy of the estimated dosages for each insecticide on borers of the genus Oryctes was comparable, but it varied depending on the insecticide and targeted pest, reaching 97.77% for Mospilan in trees with a trunk length of 9 m and a diameter of 5.0 m. Regarding the Dubas insect, O. lybicus bug, Mospilan also had the greatest death rate of 92.00% on trees with a diameter of 0.5 m and a trunk length of 9 m. The results of this study showed that the proposed equation is highly reliable and is suitable for estimating the appropriate dose of systemic pesticide to be injected into palm trees based on measurements of trunk

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lengths and diameters (i.e., their size). They can also be used as integrated management strategies to address other palm pests, including matches, red palm weevils, palm dubas, and scale insects. The proposed formula represents an innovative, environmentally friendly approach to palm pest control in a safe and sustainable manner.

Keywords
Equation, systemic insecticide, injections, date palms, Oryctes ,Ommatissus lybicus

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Introduction

The method of injecting systemic pesticides, into the trunks of trees, is one of the effective tools which approved to be effective applications in controlling insect pests such as aphids, scale insects, stem and branches borers attacking trees in public gardens, parks, and fruit trees in orchards (Shang et al., 2024). This method is characterized by the rapid entry of the pesticide into the carrier vessels and widely translocated in plant tissues, as a safe application toward natural flowers pollinators (Wu et al., 2019). Studies indicate that the dose of the pesticide that is used for injecting the tree depends on the size of targeted tree, which inturn depends on the diameter and length of stem from the ground to the top. The recommended amount of insecticide is calculated according to the trunk diameter of trunk and the number of injection site to determine the amount of pesticide for each injection site to obtain the total amount of pesticide needed (Coslor et al., 2019). Another previous study, (VanWoerkom, 2012), recommended that injection method is efficient and would assist the efforts of controlling insects that infect fruit trees. However, this method is still need more development to be applied on a base of large scale which depend on the technological progress in the manufacturing technology of injection devices and equipment. There are two mechanisms for injection, either by making a hole and pressing the solution, or by using an external container attached to the stem from which the solution flows, the diameter of the hole ranges from 2 to 9.5 mm (El Aissaoui, 2015). While, the depth of the hole varies according to the purpose and the morphology of the target tree, the pesticide is deliverd in to the trunk either automatically or by using a specific pressure tool (Archer et al., 2022). Studies indicated that systemic pesticides from the Neonicotinoid group have the ability of translocation through the plant tissues to reach the target pests (Fossen, 2006; Alobidy & Alebady, 2023). Another study (Al-Jboory, 2007), indicated that the use of Actara 25 WG by injection to control Dubas bug Ommatissus lybicus on date palm was effective in reducing the population density and damage of this insect. Other studies also indicated that neonicotinoid systemic insecticides are very effective in controlling dubas bug and borers when used by injection in palm trunks (Khalaf and Alrubiae 2016). The application of systemic pesticides have additional benefits that can be achieved when used by injection or by drenching, these benefits are as the following: It can be applied accurately towards the target pest without drift to the soil or wind, it can be used in places where the soil conditions are not suitable for conventional control practices or trees that grow in excessively moist, sandy, compacted or restricted soils, have limited impact on non-target organisms or sensitive environments, it can be used effectively against, bores, leaf miners and sucking insects such as whiteflies, aphids and scale insects...etc (Fishel et al., 2022). Previous studies (Li & Nangong, 2022; Dhannoon Alobidy & Mohammed Alebady, 2024) showed that the injection technique is a promising method, accurate and environmentally friendly practice that has achieved high effectiveness in terms of combating the target pest and safety in terms of its impact on the environment and public health, however there is a need to identify specialized chemicals that can be used by injection and suitable to different kinds of trees or pests in order to reduce damages which may happened to trunks, in addition to the need for developing of highly efficient automatic equipment to be used in this manner. The development of an-efficient and precise injection devices, a reliable integrated pest management platform along with mechanisms of detection, prevention, treatment practices, environmental monitoring, techniques of artificial intelligence, all are representing a promising tools for reliable sustainable agriculture (Li et al., 2025). However, more work is still needed to find a reliable method by which the required amount of pesticide can be determined for the use by injection to control pests that live within the plant tissues. According to this approach and due to the importance of determining the appropriate dose suitable for type of each tree and target pest, the current study was carried out with the aim of designing a equation for calculating the optimum pesticide doses that can be used for combating palm borers and dubas bug with the possibility of applying the devised formula to determine pesticide doses required for other agricultural pests infecting Palm trees such as other species of red palm weevil , dust mites and scale insects.

Materials And Methods

Proposed formula and elements

A number of tests were carried out that included series of calculations related to determining the required dose of the pesticide based on the height and diameter of the palm trunk. The formula was designed as the following: :

VI = C × TV × RID

VI= Volume of insecticide per palm tree

C = constant factor (8.478)

The constant factor was determined through a number of steps, starting with the hypothesis and trials , testing of hypothesis , application of the hypothesis and then verifying the accuracy of the data, until the best results were reached in combating the target pest. Then, the constant factor is implemented as an essential element in the formula for all calculations related to estimating the pesticide dose according to the length and diameter of the trunk of palm tree.

VI = volume for palm trunk (volume of cylinder) = (3.14 x n2 x h) per meter

RID= the Company's recommended insecticide dose (ml per liter)

Note: The trunk diameter was calculated according to the fronds bases cutting

Sites of the field experiments:

Experiments concerning the application of the proposed formula were conducted in palm orchards in Al-Madaen region (30 km south of Baghdad). Experiments were directed toward controlling palm borers belonging to genus Oryctes .The second site was in orchards located in Al-Suwaira/Wasit (60 km south of Baghdad) and experiments were directed for controlling the Dubas bug and borers.

Application of the formula:

5 palm trees (replicates) were allocated for each treatment, selected according to intended length and diameter of each tree, and the treatments were carried out as the following:

1.Using the systemic insecticide (Tiam, Thiamethoxam 25%). At the dose recommended by the manufacturer ,30 g per 100 liters of water

2.Using the systemic insecticide (Radical, Imidacloprid 20%) at the dose recommended by the manufacturer: 38 ml per 100 liters

3.Using the systemic insecticide (Mospilan, Acetameprid 20%) at the dose recommended by the manufacturer ,50 g per 100 liters

As for palm trees selected according to Lengths and diameters of trunks, they were allocated as the following:

 A palm tree with a height of 3 meters to the developing top and a trunk diameter of 0.50 meters
 A palm tree with a height of 3 meters to the developing top and a trunk diameter of 0.60 meters
 A palm tree with a height of 6 meters to the developing top, and a trunk diameter of 0.50
 A palm tree with a height of 6 meters to the developing top and a trunk diameter of 0.60 meters
 A palm tree with a height of 9 meters to the developing top and a trunk diameter of 0.60 meters
 A palm tree with a height of 9 meters to the developing top and a trunk diameter of 0.60 meters.

The volume of insecticide needed to be injected into the trunk of each palm was calculated, according to the mentioned parameters in the proposed equation.

Injection of pesticides:

Five trees (replicates) were allocated for each insecticide treatment and five other trees were used for comparison (treated with water alone). A hole was made in the palm trunk with a diameter of 10 mm and a depth of 100 mm, at a height of 1 m from the surface of the ground and at an angle of 45 degrees from the trunk. The amount of insecticide was mixed with water, according to the dose determined by the proposed formula, and then injected into the hole by a syringe with a pressure of 1 bar, The holes were closed by silicone. One of the insecticides was applied as a direct spray on the tree for one of the heights in each treatment for comparison purpose. Readings concerning the borers belonging to the genus Oryctes were taken after one month of treatment. The work was done with assistance of well-trained worker who climbed the tree and cut the bases of fronds for collecting larvae of borers found under the bases of fronds for each treatment The number of dead and live larvae was counted for each palm (replicate) and for all treatments. This activity was excited during the period of November 2021-December 2022, The experiments concerning the control of Dubas bug were undertaken during the fall generation 2021 and the spring generation 2022, coinciding with rate of egg hatching ranging between 50 - 60%. - The readings were taken after three weeks of treatment. The number of live nymphs in six leaflets(wickers), (two of them from the first third of the frond, two rom the middle and two from the terminal of the frond), was counted in four fronds representing the four directions taken from the middle rows of fronds for each treatment (Byrne et al., 2014).

Experimental design, statistical analysis, and calculation of pesticide efficacy

The experiment were conducted according to the Randomized Complete Block Design (RCBD) and the results were statistically analyzed using the Genstat5 program, analysis of variance and Schneider-Orelli's formula (Puntener, 1981) for correcting the percentages of mortalities and the effectiveness of insecticides in the field.

Results And Discussion

Calculation of pesticide dose based on length and diameter of each tree.

First experiment: using the systemic insecticide (Tiam, Thiamethoxam 25%). at the concentration recommended by the manufacturer (30 g per 100 liters of water) . Results obtained according to the suggested equation ,(VI = C × TV × RID), were as the following:

 A palm tree with a height of 3 meters reaching to the top of the tree, and a trunk diameter of 0.50m
VI= 8.478 x [3.14 x (0.25) 2 x 3] x 0.3
VI= 8.478 x [3.14 x 0.0625 x 3] x 0.3
VI= 8.478 x 0.58875 x 0.3
Vi= 1.50 g per tree

 A palm tree with a height of 3 meters to the top of tree, and a trunk diameter of 0.60 meters
VI= 8.478 x [3.14 x (0.30) 2 x 3] x 0.3
VI = 8.478 x [3.14 x 0.09 x 3] x 0.3
VI= 8.478 x 0.8478 x 0.3
VI= 2.16 ml per tree

 A palm tree with a height of 6 meters to the top of the tree, and a trunk diameter of 0.50 meters
VI= 8.478 x [3.14 x (0.25) 2 x 6] x 0.3
VI= 8.478 x [3.14 x 0.0625 x 6] x 0.3
VI= 8.478 x 1.1775 x 0.3
Vi= 2.99 ml per tree

 A palm tree with a height of 6 meters to the top of the tree, and a trunk diameter of 0.60 meters
VI= 8.478 x [3.14 x (0.30) 2 x 6] x 0.3
Vi= 8.478 x [3.14 x 0.09 x 6] x 0.3
VI= 8.478 x 1.6956 x 0.3
VI= 4.31 ml per tree

 A palm tree with a height of 9 meters to the top of tree, and a trunk diameter of 0.50 meters
VI= 8.478 x [3.14 x (0.25) 2 x 9] x 0.3
VI= 8.478 x [3.14 x 0.0625 x 9] x 0.3
VI= 8.478 x 1.76625 x 0.3
VI= 4.49 ml per tree

 A palm tree with a height of 9 meters to the top of tree, and a trunk diameter of 0.60 meters
VI= 8.478 x [3.14 x (0.30) 2 x 9] x 0.3
VI= 8.478 x [3.14 x 0.09 x 9] x 0.3
VI= 8.478 x 2.5434 x 0.3
VI= 6.48 ml per tree

The second experiment

The systemic insecticide Radical, Imidacloprid (20%) was used at the concentration recommended by the manufacturer (38 ml per 100 liters.). The results are as the following:

- A palm tree with a height of 3 meters reaching to the top of tree, and a trunk diameter of 0.50 meters

VI= 8.478 x [3.14 x (0.25) 2 x 3] x 0.38
VI= 8.478 x [3.14 x 0.0625 x 3] x 0.38
VI= 8.478 x 0.58875 x 0.38
VI= 1.98 ml per tree

- A palm tree with a height of 3 meters to the top of tree, and a trunk diameter of 0.60 meters

VI= 8.478 x [3.14 x (0.30) 2 x 3] x 0.38
VI = 8.478 x [3.14 x 0.09 x 3] x 0.38
VI= 8.478 x 0.8478 x 0.38
VI= 2.73 ml per tree

- A palm tree with a height of 6 meters to the top of tree, and a trunk diameter of 0.50 meters

VI= 8.478 x [3.14 x (0.25) 2 x 6] x 0.38
VI= 8.478 x [3.14 x 0.0625 x 6] x 0.38
VI= 8.478 x 1.1775 x 0.38
VI= 3.79 ml per tree

- A palm tree with a height of 6 meters to the top of tree, and a trunk diameter of 0.60 meters

VI= 8.478 x [3.14 x (0.30) 2 x 6] x 0.38
VI= 8.478 x [3.14 x 0.09 x 6] x 0.38
VI= 8.478 x 1.6956 x 0.38
VI= 5.46 ml per tree

- A palm tree with a height of 9 meters to the top of tree, and a trunk diameter of 0.50 meters

VI= 8.478 x [3.14 x (0.25) 2 x 9] x 0.38
VI= 8.478 x [3.14 x 0.0625 x 9] x 0.38
VI= 8.478 x 1.76625 x 0.38
VI= 5.69 ml per tree

- A palm tree with a height of 9 meters to the top of tree, and a trunk diameter of 0.60 meters

VI= 8.478 x [3.14 x (0.30) 2 x 9] x 0.38
VI= 8.478 x [3.14 x 0.09 x 9] x 0.38
VI= 8.478 x 2.5434 x 0.38
VI= 9.19 ml per tree

The third experiment*:*

The use of the systemic insecticide (Mospilan, Acetameprid 20%). At the concentration rate recommended by the manufacturer (50 g per 100 liters of water)

- A palm tree with a height of 3 meters reaching to the top of tree, and a trunk diameter of 0.50 meters

VI= 8.478 x [3.14 x (0.25) 2 x 3] x 0.5
VI= 8.478 x [3.14 x 0.0625 x 3] x 0.5
VI= 8.478 x 0.58875 x 0.5
VI= 2.49 g per tree

- A palm tree with a height of 3 meters to top of tree, and a trunk diameter of 0.60 meters

VI= 8.478 x [3.14 x (0.30) 2 x 3] x 0.5
VI = 8.478 x [3.14 x 0.09 x 3] x 0.5
VI= 8.478 × 0.8478 × 0.5
VI= 3.59 g per tree

- A palm tree with a height of 6 meters to the top of tree, and a trunk diameter of 0.50 meters

VI= 8.478 x [3.14 x (0.25) 2 x 6] x 0.5
VI= 8.478 x [3.14 x 0.0625 x 6] x 0.5
VI= 8.478 x 1.1775 x 0.5
VI= 4.99 g per tree

 A palm tree with a height of 6 meters to top of tree, and a trunk diameter of 0.60 meters
VI= 8.478 x [3.14 x (0.30) 2 x 6] x 0.5
VI= 8.478 x [3.14 x 0.09 x 6] x 0.5
VI= 8.478 x 1.6956 x 0.5
VI= 7.19 g per tree
 A palm tree with a height of 9 meters to the top of tree, and a trunk diameter of 0.50 meters
VI= 8.478 x [3.14 x (0.25) 2 x 9] x 0.5
VI= 8.478 x [3.14 x 0.0625 x 9] x 0.5
VI= 8.478 x 1.76625 x 0.5
VI= 7.48 g per tree
 A palm tree with a height of 9 meters to the top of tree, and a trunk diameter of 0.60 meters
VI= 8.478 x [3.14 x (0.30) 2 x 9] x 0.5
VI= 8.478 x [3.14 x 0.09 x 9] x 0.5
VI= 8.478 x 2.5434 x 0.5
VI= 10.78 g per tree

The relationship of calculated pesticide doses and the lengths of palm trunk:
Results presented in Table (1) indicate that the amount of pesticide needed for injection into trunks of palm tree varies according to the length of the trunk of each tree. The quantity of insecticide (Tiam) needed to be injected into palm stem (trunk) of 3 m, 6 m and 9 m in length was 1.50 g, 2.99 g and 4.49 g, respectively. As for the pesticide Radical pesticide the amount was1.98 ml, 3.37 ml and 4.49 ml, respectively and for Mospilam: was 2.49 g, 4.99 g and 7.48 g, respectively. These quantities were also increased as the diameter of the tree trunk increased. The quantity of insecticide needed to be injected into palm stem (trunks) with a diameter of 0.60 cm was more than that needed for trees with trunk diameter was 0.50 centimeters This difference is attributed to the increase size of the trunk. Therefore, any size increase would require an increase in the amount of insecticide needed to be injected These results supports what was mentioned by Berger and Laurant (2019), who indicated that the amount of pesticide needed for injection increases with the increase in the length and diameter of the stem of tree. They also stressed the importance of making several holes in the stems of tree stems to distribute the amount of pesticide in them, They also stressed the importance of making several holes in the stems of trees to distribute the amount of pesticides because diameter of the stems were narrow. However, in the case of palm trees, which were used in the present experiments only one holes is required and it is sufficient due to the extended trunks diameter of the palm tree.

Table 1. Calculation of insecticide amount deeded as trunk injection for the control of palm borers (Oryctes) and dubas bug based on the proposed formula

Length of Palm m L	**Diameter of palm m D**	**Size of trunk (TV) m^3 = 3.14*$(D/2)^2$ *L**	**Systemic Insecticide**	**Recommended dose) g.ml/ l (RID)**	**Constant factor (C)**	**Calculated dose, VI (g.ml/l)) based on the formula VI = C*TV*RID**
3	0.5	0.58875	Thiamethoxam 25%	0.30	8.478	1.50
	0.5	0.58875	Imidacloprid 20%	0.38	8.478	1.98
	0.5	0.58875	Acetameprid 20%	0.50	8.478	2.49
	0.6	0.8478	Thiamethoxam 25%	0.30	8.478	2.16
	0.6	0.8478	Imidacloprid 20%	0.38	8.478	2.73
	0.6	0.8478	Acetameprid 20%	0.50	8.478	3.95
6	0.5	1.775	Thiamethoxam 25%	0.30	8.478	2.99
	0.5	1.775	Imidacloprid 20%	0.38	8.478	3.79
	0.5	1.775	Acetameprid 20%	0.50	8.478	4.99
	0.6	1.6959	Thiamethoxam 25%	0.30	8.478	4.31
	0.6	1.6956	Imidacloprid 20%	0.38	8.478	5.46
	0.6	1.6956	Acetameprid 20%	0.50	8.478	7.19
	0.5	1.76625	Thiamethoxam 25%	0.30	8.478	4.49
	0.5	1.76625	Imidacloprid 20%	0.38	8.478	5.69

9	0.5	1.76625	Acetameprid 20%	0.50	8.478	7.48
	0.6	2.5434	Thiamethoxam 25%	0.30	8.478	6.48
	0.6	2.5434	Imidacloprid 20%	0.38	8.478	9.19
	0.6	2.5434	Acetameprid 20%	0.50	8.478	10.78

Efficiency of pesticides doses calculated based on proposed formula for controlling borers of the genus Oryctes and, Ommatisus lybicus.

Data presented in Table (2) and Fig. (1) show that the amount of pesticides calculated according to the proposed equation was so effective in controlling the palm borers of the genus Oryctes and the O. lybicus. The effectiveness was correlated with amount of pesticide calculated by the equation and was also influenced by increasing length and diameter of the tree. Effectiveness of the pesticides when used in trees with a trunk length of 3 m and a diameter of 0.5 m: on larvae of the genus Oryctes was 89.32%, 62.01% and 96.65% for Tiam, Radical and Mospilan respectively compared to 3.31% for injection with water alone and 2.93% for direct spraying of the insecticide Tiam on trees. The effectiveness of the three insecticides on Dubas bug O. lybicus was 87.12%, 55.02% and 90.67% for Tiam, Radical and Mospilan, respectively, compared to 5.67% for the treatment of spraying with water alone and 83.77% for direct spraying with Tiam. Against dubas bug..

As for trees with a stem (trunk) length of 6 m and a diameter of 0.5 m, a same trend was observed in term of efficacy of pesticides doses calculated according to the formula and was close to that reported for trees with stem (trunk) length of 3m.(Table 2). The effectiveness of the pesticides on the borers of Oryctes was 91.30%. 63.32% and 96.87% for Tiam, Radical and Mospilan, respectively, compared to 2.01% in the control treatment in case of injection with water alone and 1.01% for direct spraying on trees with Radical. When these insecticides used against dubas bug, the effectiveness was 85.33%, 60.88% and 91. 80% for Tiam, Radical and Mospilan compared to 4.01% for the control treatment where trees were injected with water alone and 51.66% for the treatment of direct spraying the insecticide Radical on trees.

In the case of trees with a trunk length of 9 m and a diameter of 0.5 m, the effectiveness of the pesticides on the Oryctes borers was 88.91%, 64.63% and 97.77% for Tiam, Radical and Mospilan, respectively, compared to 3.695 when injecting with water alone and 5.21% for direct spray of trees with Mospilan.(table 2) while the effectiveness on Dubas was 85.77%, 56.09% and 92.00% for Tiam, Radical and Mospilan, respectively, compared to 6.44% when injecting with water alone and 85.21% when for direct spray with on trees.

These results show that the quantities of pesticides calculated according to the proposed equation increase with the increasing length and diameter of palm trunks treated for the control of borers belonging to the genus Oryctes and dubas bug O. lybicus. The effectiveness of each pesticide used on trees of different heights was close when used by injection, bearing in mind that the larvae of borer are inside the trunks, while the dubas nymphs feed on the vegetative part (fronds and wickers), so all pesticides are ineffective in direct spraying on trees infected with borers, but they are effective against dubas infestation, The pesticides were also varied among themselves in term of their effectiveness on the two insects, and this is attributed to the active ingredient of each pesticide and the formulation method. However these results show that the proposed formula is reliable when applied to calculate the doses of pesticides based on the length and diameter of the trunk of each tree and very suitable for obtaining a constant efficacy for doses calculated according to length and diameter of trunk of each tree, Results indicated that the proposed formula can be applied in case of using chemical pesticides, biological control agents, growth stimulants, and other materials that can be used by injection as an effective tool within the integrated pest management programs applied against other species of borers infecting palm trees, including the red palm weevil and also sucking insects scale insects on date paln trees.

Previous studies (Compant et al., 2010; Berger et al., 2015) indicated the possibility of using of injecting methods for endophytic microorganisms, such as bacteria and fungi, into trunks of trees as a promising method in the field of pest management. Studies also confirm that the protection of fruit trees from diseases and insect pests is an essential part of the agricultural production system, but the development of the insecticides and fungicides used in fruit orchards was not synchronized with the development of techniques and tools of their application, as these means have not changed much in the past fifty years leading to the emergence of many environmental and health problems (VanWoerkom, 2012). However, the application methods that depend on injecting of pesticides into the trunks of tree have received increasing interest among farmers because this method is practical and environmentally safe. Where it was applied using insecticides and fungicides systematically against pests of apple trees, where a number of insecticides and fungicides were used by injection method into the trunks of tree for controlling major insect pests and fungi. The stem injection provides stable protection for a reasonable periods as well as reducing the negative effects on non-target organisms. Fruit trees, including apples, are often similar in terms of dimensions and stems length. While, palm trees show a significant variation in the length and diameter of their trunk, which leads to a difference in the size of the trunk and its content of plant juices, which may influence the concentration of the pesticide in the tissue. Therefore, there is a need for an accurate calculations to determine the amount of pesticide that must be fited with the length and trunk of the trees to be treated. Another previous study, (Coslor et al. 2019) indicated that the stem injection method is a reliable tool that deliver the pesticides inside the tree to reach the target pest, but there is a need for more research and studies to determine the effectiveness and safety toward pollinators. For this reason, several insecticides were injected for controlling some pests infecting fruit trees and to demine the pest timing of injection. Samples of nectar and pollen taken during the following spring showed that Imidacloprid was not detected in nectar or pollen when injected in spring and was detected at a level of 0.39 ng/g in pollen when injected the previous autumn. Emamectin benzoate was also not detected in nectar or pollen when injected the previous autumn but was found at 7.36 ng/g (nectar) and 1.15 ng/g (pollen) when injected in spring for the same season. The researchers identified an extensive list of injectable pesticides on apple trees and suggested that the appropriate seasonal timing of insecticide injections may reduce the risk of exposure of pollinating insect to insecticide. Other studies (Coslor et al. 2019) found that the pesticides Imidacloprid, chlorantraniliprole and emamectin benzoate were effective in controlling apple pests feeding on vegetative parts when used as injection the trunks of trees and their concentration in the fruit is less than the permitted level for residues which is extremely important for the registration of these pesticides for injection into the trunks of apple trees, Therefore this method contribute in reducing environmental risks and maintaining the safety of pollinators.

Table 2. Effectiveness of doses of three different systemic pesticides determined according to the proposed formula in controlling borers spp. of the genus Oryctes and Ommatisus lypicus during the fall season of 2021

Length of Palm m	Diameter of palm m	Insecticide name	Active ingredient	Recommended dose ml, gm /100 L water	Calculated insecticide amaunt	Effective on Oryctes larvae %	Effective on dubas bug %
3	0.5	water	Water (control)	----	----	3.31	5.67
	0.5	Tiam*	Thiamethoxam 25%	30 direct spray	1.50	2.93	83.77
	0.5	Tiam	Thiamethoxam 25%	30	1.50	89.32	87.12
	0.5	Radical	Imidacloprid 20%	38	1.98	62.01	55.02
	0.6	Mospilan	Acetamiprid 20%	50	2.49	96.65	90.67
	0.6	Tiam	Thiamethoxam 25%	30	2.16	88.43	84.01
	0.6	Radical	Imidacloprid 20%	38	2.73	65.90	54.11
	0.6	Mospilan	Acetamiprid 20%	50	3.59	99.01	89.23
6	0.5	water	Water (control)	----	----	2.01	4.01
	0.5	Tiam	Thiamethoxam 25%	30	2.99	91.30	85.33
	0.5	Radical**	Imidacloprid 20%	38 direct spray	1.90	1.01	51.66
	0.5	Radical	Imidacloprid 20%	38	3.79	63.32	60.88
	0.6	Mospilan	Acetamiprid 20%	50	4.99	96.87	91.80
	0.6	Tiam	Thiamethoxam 25%	30	4.31	92.06	86.44
	0.6	Radical	Imidacloprid 20%	38	5.46	62.67	57.32
	0.6	Mospilan	Acetamiprid 20%	50	7.19	100.00	90.33
9	0.5	water	Water (control)	----	----	3.65	6.44

	0.5	Tiam	Thiamethoxam 25%	30	4.49	88.91	85.77
	0.5	Radical	Imidacloprid 20%	38	5.69	64.63	65.09
	0.5	Mospilan***	Acetamiprid 20%	50 direct spray	2.50	5.21	85.21
	0.6	Mospilan	Acetamiprid 20%	50	7.48	97.77	92.00
	0.6	Tiam	Thiamethoxam 25%	30	6.48	91.55	87.65
	0.6	Radical	Imidacloprid 20%	38	9.19	67.88	59.35
	0.6	Mospilan	Acetamiprid 20%	50	10.78	98.77	89.97

***Control (direct spray Tiam)**
**** Control (direct spray Radical)**
***** Control (direct spray Mospilam)**

Conclusion

The results of the current study showed that the proposed formula was suitable in determining the amount of the injectable pesticide in the trunk of each date palm tree based on the length and diameter of the stem (trunk). The systemic insecticide, which were different in their recommended rate of use and their active ingredients, were tested in specific timing of injection. Results proved that calculated dose was adequate for injection into the palm trunk as a safe alternative to direct spraying on the trees. Tree injections can also be applied when traditional methods, such as soil and foliage treatment, are restrictive, difficult to be used or ineffective. The injection method is considered environmentally friendly, as it reduces the exposure of farm workers to pesticides, reduces the risks to the environment, as well as reducing the drift of the pesticide and its residues to other non-targeted crops and agricultural products, the impact this technique on biodiversity is limited compared to the traditional control methods. The efficiency of using the proposed formula in determining the amount of pesticides needed for injection to control palm borers and dubas confirms the possibility of farther applications in controlling other economically important pests that affect date palm trees, such as the scale insects , red palm weevil and other species of borers and scale insects, especially when the infestation is found or spread in a limited geographical area so that all infected trees in the area can be treated at the specified time.

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