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LABORATORY AND FIELD STUDIES ABOUT EFFECTIVENESS OF SOME SYSTEMIC INSECTICIDES AGAINST DATE PALM TREE BORERS (RHINOCEROS BEETLE), ORYCTES SP. (COLEOPTERA: SCARABAEIDAE)

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September 2023

We certify that we have read this thesis and that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science

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ABSTRACT

LABORATORY AND FIELD STUDIES ABOUT EFFECTIVENESS OF SOME SYSTEMIC INSECTICIDES AGAINST DATE PALM TREE BORERS (RHINOCEROS BEETLE), ORYCTES SP. (COLEOPTERA: SCARABAEIDAE)

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The study's goal was to find out how well three second-generation neuro-active insecticides from the Neonicotinoids class work at getting rid of palm rhinoceros (Oryctes genus) pests and to choose the best way to get rid of them. Three neuro-active insecticides from the Neonoctoniods class were identified: Mospilan (Acetamiprid 20%), Tiam WG (Thiamethoxam 25%), and Radical (Imidacloprid 20%). Laboratory tests were conducted in the laboratories of Al-Nahrain University/Faculty of Biotechnology, and field tests were conducted in palm groves in southern Baghdad in 2021 and 2022. The laboratory tests were conducted in two treatments: direct spraying of larvae and larvae-food treatment. In the field tests, three different treatments were applied. These were direct spraying on the top of the palm tree, trunk injection, and soil irrigation. The laboratory tests involved the combination of pesticides with water at different concentrations. In particular, Mospilan was mixed at concentrations of 0.5 g/L and 1 g/liter of water, and Tiam at concentrations of 0.3 g/L and 0.6 g/L of water. Finally, Radical was mixed at water concentrations of 0.38 ml/L and 0.76 ml/L for direct spraying of larvae and larval-bait treatment, respectively. In field tests, Mospilan was applied at application doses of 0.5 g/L and 1 g/L, Tiam at 0.3 g/L and 0.6 g/L, and Radical at 0.38 ml/L and 0.76 ml/L at 5 liters of solution per tree. In the tree trunk injection experiments, for Mospilan, 20 ml of solution was applied at a water concentration of 1 g/2 ml per palm tree, and for Tiam, 20 ml of solution was applied at a water concentration of 1 g/3 ml per palm tree. For Radical, 20 ml of solution was used at a water concentration of 1 ml/1.5 ml per tree. In soil irrigation experiments, Mospilan

1g/5L, Tiam 1g/7L, and Radical 1ml/3.8L were applied at a water concentration of 50 liters per palm tree. Only dead larvae were counted in the laboratory experiments. However, for the field experiments, both dead and live larvae were counted. The laboratory results showed that all three pesticides tested were effective when used on larvae by direct spraying or during food processing and were effective in the range of 96%–100% for both low and high concentrations. However, when treated with different concentrations, a significant difference in the time taken for larvae to start dying was observed. Larvae treated with low concentrations of pesticides started to die after 12 days, while larvae treated with high concentrations of pesticides took only 2 days to die. When used in direct spraying on palm trees in field experiments, the pesticides showed no efficacy. The ratio of dead to live larvae was similar in all treatments, including the comparison treatment. When higher doses of pesticides were used, there was no appreciable effect on the insect, similar to the results obtained at lower concentrations and in the control treatments. The mortality values obtained for Radical, Tiam, and Mospilan were 0.34%, 3.7%, and 5.2%, respectively. When higher concentrations were used, these values were 3.7%, 4.6%, and 8.5%, respectively. As for the stem injection and soil irrigation experiments, both Mospilan and Tiam showed high efficacy in killing larvae in the stem injection experiments, with mortality values of 91.7% and 100%, respectively. In soil irrigation experiments, the mortality values for Mospilan and Tiam were 90.1% and 100%, respectively. Radical showed a lower efficacy compared to the other two pesticides, with an efficacy of 64% and 65.4% in both injection and soil irrigation treatments, respectively.

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Keywords: Radical, Tiam, Mospilan, Larvae, Oryctes, Palm trees

ÖZET

HURMA AĞAÇ KURDU (GERGEDAN BÖCEĞİ), ORYCTES SPP (COLEOPTERA: SCARABAEIDAE)'YE KARŞI BAZI SİSTEMİK İNSEKTİSİTLERİN ETKİNLİĞİ ÜZERİNE LABORATUVAR VE SAHA ÇALIŞMALARI

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Bu çalışmanın amacı, Neonikotinoidler sınıfından üç ikinci nesil nöro-aktif insektisitin palmiye gergedanı (Oryctes cinsi) zararlıları ile mücadelede kullanılabilirliğinin belirlenmesi ve zararlının kontrolünde kullanılabilecek en iyi yöntemin seçilmesidir. Neonoctoniodler sınıfından üç nöro-aktif insektisit belirlenmiştir: Mospilan (Acetamiprid %20), Tiam WG (Thiamethoxam %25) ve Radical (Imidacloprid %20). Laboratuvar testleri Al-Nahrain Üniversitesi/Biyoteknoloji Fakültesi laboratuvarlarında, saha testleri ise 2021 ve 2022 yıllarında Bağdat'ın güneyindeki palmiye bahçelerinde gerçekleştirilmiştir. Laboratuvar testleri, larvalara doğrudan püskürtülmesi ve larva-yiyecek muamelesi olmak üzere iki şekilde gerçekleştirilmiştir. Saha testlerinde ise üç farklı uygulama yapılmıştır. Bunlar; palmiye ağacının tepesine doğrudan püskürtme, gövdeye enjekte etme ve topraktan sulamadır. Laboratuvar testleri, pestisitlerin farklı konsantrasyonlarda su ile kombinasyonunu içermiştir. Özellikle, Mospilan 0,5 g/L ve 1 g/litre su konsantrasyonlarında, Tiam 0,3 g/L ve 0,6 g/L su konsantrasyonlarında karıştırılmıştır. Son olarak, Radical larvaların doğrudan püskürtülmesi ve larva-yem muamelesi için sırasıyla 0,38 ml/L ve 0,76 ml/L su konsantrasyonlarında karıştırılmıştır. Saha testlerinde, Mospilan, 0,5 g/L ve 1 g/L, Tiam 0,3 g/L ve 0,6 g/L, Radikal ise 0,38 ml/L ve 0,76 ml/L uygulama dozlarında ağaç başına 5 litre çözelti olacak şekilde uygulanmıştır. Ağaç gövdesine enjeksiyon deneylerinde ise; Mospilan için, palmiye ağacı başına 1g/2ml su konsantrasyonunda 20 ml çözelti, Tiam için, palmiye ağacı başına 1g/3ml su konsantrasyonunda 20 ml çözelti uygulanmıştır. Radikal için ise , ağaç başına 1 ml/1,5 ml su konsantrasyonunda 20 ml çözelti kullanılmıştır.

Topraktan sulama deneylerinde ise Mospilan 1g/5L, Tiam 1g/7L ve Radical 1ml/3,8L su konsantrasyonunda palmiye ağacı başına 50 litre olacak şekilde uygulanmıştır. Laboratuvar deneylerinde sadece ölü larvalar sayılmıştır. Ancak saha deneyleri için hem ölü hem de canlı larvalar sayılmıştır. Laboratuvar sonuçları, test edilen üç pestisitin de larvalar üzerine doğrudan püskürtme yoluyla ya da gıdaların işlenmesi sırasında kullanıldığında etkili olduğunu ve hem düşük hem de yüksek konsantrasyonlar için %96-%100 aralığında etkin olduğunu göstermiştir. Bununla birlikte, farklı konsantrasyonlarla muamele edildiğinde, larvaların ölmeye başlaması için geçen sürede önemli bir fark gözlenmiştir. Düşük konsantrasyonlarda pestisitlerle muamele edilen larvaların ölümü 12 gün sonra başlarken, yüksek konsantrasyonlarda pestisitlerle muamele edilen larvalar için bu süre sadece 2 gün olarak belirlenmiştir. Saha deneylerinde palmiye ağaçlarının üzerine doğrudan püskürtmede kullanıldığında, pestisitler hiçbir etkinlik göstermemiştir. Ölü ve canlı larvaların oranı karşılaştırma uygulaması da dahil olmak üzere tüm uygulamalarda benzer özellik göstermiştir. Daha yüksek dozlarda pestisit kullanıldığında, daha düşük konsantrasyonlarda ve kontrol uygulamalarında elde edilen sonuçlara benzer şekilde, böcek üzerinde kayda değer bir etki görülmemiştir. Radical, Tiam ve Mospilan için elde edilen ölüm değerleri sırasıyla %0,34, %3,7 ve %5,2 olmuştur. Daha yüksek konsantrasyonlar kullanıldığında, bu değerler sırasıyla %3,7, %4,6 ve %8,5 olmuştur. Gövde enjeksiyonu ve toprak sulama deneylerine gelindiğinde, hem Mospilan hem de Tiam, sırasıyla %91,7 ve %100'lük ölüm değerleriyle gövde enjeksiyonu deneylerinde larvaları öldürmede yüksek etkinlik göstermiştir. Toprak sulama deneylerinde ise Mospilan ve Tiam için ölüm değerler sırasıyla %90,1 ve %100 olarak bulunmuştur. Radical hem enjeksiyon hem de toprak sulama uygulamalarında sırasıyla %64 ve %65,4'lük bir etkinlikle diğer iki pestisite kıyasla daha düşük bir etkinlik göstermiştir.

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Anahtar Kelimeler: Radikal, Tiam, Mospilan, Larvalar, Oryctes, Palmiye ağaçları

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Noor Mohammed Sakran SAKRAN
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CONTENTS

LIST OF SYMBOLS

$g.mol^{-1}$	Gram per mol
km	Kilometer
L	Liter
ml	Milliliter
mm	Millimeter
%	Percent

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1. INTRODUCTION

The order Palmales includes several types of palm trees: date palm, cocnut palm, oil palm, and Washingtonia palm and the genus *Phoenix* includes several species, including the date palm *Phoenix dactylifera* L., the sugar palm *Phoenix sylvestris*, and the ornamental palm *Phoenix canariensis*. These species are similar in some characteristics (Al-Dabbagh 1969). The date palm, *P. dactylifera,* which belongs to the Palmaceae family, is considered one of the trees of economic importance found in Mesopotamia. It was known to the Sumerians and Babylonians, as traces of these trees were found in the land of Babylon, whose age extends to about four thousand years before Christ, as it was mentioned in the Code of Hammurabi, and the Assyrians revered four religious rites, one of which was the date palm (Al-Baker 1972, Al-Naemi and AlAmir 1980). It was also mentioned in holy books (the Qur'an, the Bible, and the Torah). Wrigley (1995) indicated that the date palm has been known in the history of Mesopotamia since ancient times. Johnson et al. (2013) indicated that the oldest trace of the existence of the date palm in Mesopotamia dates to 6000 years ago. Dates are considered one of the oldest and most important food crops produced in Iraq. The cultivation of date palm trees *(P. dactylifera*) spreads to most of the governorates of Iraq (Hanoush 2013), and it is considered the most widespread and productive in the countries of the Arab world. Dates play an essential role in national food security, in addition to being used as a raw material in many food and processing industries (Shbana and Zayed 2006).

All parts of the palm trees are exposed to infection with one or more types of insect pests and mites in palm groves, which affect their vitality and production both quantitatively and qualitatively (Al-Azzawi 1972). There are 132 types of insect pests affecting *P. dactylifera L.* grown all over the world (Ali et al. 2017). Palm rhinocero is one of the insect pests that cause severe damage to palm trees, leading to their weakness, lack of production, stem breakage, and sometimes death (Khalaf et al. 2010). It is also a carrier of some pathogens. Date palms are attacked by three rhinoceros: *Phonapate frontalis* targeting palm leaf, the longhorn *Jebusaea sp*. targeting palm stem, followed by the species *J. hammerschmidtii* and *J. perseca*. And the single-horned of the genus *Oryctes sp.,* followed by several species: *O. elegans, O. sinaicus*, and *O. agamemnon*, followed by the two sub-species: *O. a. arabicus* and the root rhienoceros, *O. a. matthiesseni* (Al-Saadi 2014; Khalaf and Mahmoud 2021; Khalaf and Alrubiae, 2015). The two species, *O. elegans* and *O. agamemnon*, are widespread in Arab Gulf countries such as the Kingdom of Saudi Arabia, Iraq, the United Arab Emirates, Oman, and other countries (Bedford *et al*. 2015). Controlling this insect is exceedingly difficult due to its concealment in the trunk of palm trees and the inability of the pesticide to reach it when used in direct spraying methods. For controlling this pest, this study was proposed, which aims to:

1. Surveying palm borers belonging to the genus Oryctes in orchards south of Baghdad.
2. Determining the infestation rate in the above-mentioned orchards.
3. Selecting three different neuro-active pesticides with different active substances and different origins.
4. The use of three experimental methods (direct spraying on the top of the palm tree, injection in the trunk, and watering through soil) to determine which is more effective in controlling the pest.
5. Evaluation of the effectiveness of laboratory-selected pesticides by direct spraying on larvae and by treating larvae with food.
6. Determining the efficiency of the best pest management methods in the fields, such as direct spraying on the top of the palm tree, injection into the trunk, or watering through the trunk.
7. Choosing the best pest control methods that reduce pollution in the environment and food.
8. Determining the best pesticidal concentrations that cause high pest killing at the lowest concentration.

2. LITERATURE REVIEW

2.1 The Economic Importance of Date Palm

The order of palmales includes several types of palms: date palm, coconut palm, oil palm, and ornamental *Washingtonia palm*. These species have some characteristics among themselves (Al-Dabbagh 1969). The date palm, *Phoenix dactylifera*, is one of the most important fruit trees of economic importance in the countries of the Arab world, especially Iraq, where it is acclimatized in its middle and south (Al-Baker et al., 1972; Al-Deeb, 1999; Soltani, 2011). Dates are considered one of the oldest and most important food crops produced in Iraq, and the cultivation of date palm trees (*P. dactylifera*) is widely spread in most of the provinces of Iraq: Baghdad, Basra, Maysan, Dhi Qar, Wasit, Qadisiyah, Muthanna, Najaf, Holy Karbala, Babel, Anbar, Diyala, and Salah al-Din. Basra, Holy Karbala, Babel, Baghdad, and Diyala are considered among the main provinces in the production of dates of commercial varieties that include Al-Zahdi, Al-Khastawi, Al-Sayer, Al-Khadrawi, Al-Brim, Al-Dairi, Al-Maktoum, Al-Tebarzel, and Al-Barhee (Hanush, 2013). The number of date palms in Iraq reached 32 million trees in 1963, constituting 32% of the world's production (Abdul Hussein 1963; Al-Baker 1972). And because of negligence and pest manifestations, Iraq lost more than half of its date palm trees, leaving 15,300,762 palm trees left with an annual production of 618.8 thousand tons. The Zahdi variety represents 54.7% of the total production, followed by the Khastawi, Khadrawi, Al-Sayer, and other varieties (Directorate of Agricultural Statistics, 2017). In 2017, the number of palm trees in Iraq reached 20,342,958 palm trees, of which 15,300,762 are productive. In 2018, the number of palm trees decreased and reached 19,913,787 palm trees, including 15,139,076 productive palm trees, indicating a loss of 429,171 palm trees in total. And the highest number of palm trees is found in the governorates of Diyala, Babel, and Baghdad, which reached 3791127, 2747134, and 2483890, respectively, of which the percentage of productive trees was 61.3%, 69.6%, and 72.1%, respectively (Directorate of Agricultural Statistics 2018).

The date palm, *P. dactylifera*, is considered the most widespread and productive tree in the Arab countries and dates play a fundamental role in national food security in addition to being used as raw materials in many food manufacturing and processing industries (Shabana and Zayed 2006).

All parts of palm trees are at risk of being infected by one or more types of insect pests and mites in palm groves, which affect their vitality and production in quantity and type (Al-Azzawi 1972).

2.2 Economic Entomology, Secondary, and Rare Insects Found on the Date Palm

There are 132 species of insect pests associated with the date palm, *P. dactylifera L.*, cultivated all over the world. These species are divided into eight insect orders and 30 families, in addition to one order of mites, followed by nine families, in addition to one rank of acarus (mite), followed by nine families. Of these insect pests, 52 species were recorded on the palm fronds, 26 on the roots and trunk, and 27 on stored dates. Out of the 52 recorded species, Coleoptera represent 41%, 20% are Homoptera, 12% are Lepidoptera, and 16% are mites and spiders. Although the number of pest species affecting date palms is high, only a few of these species are considered major pests of economic importance (Ali *et al*. 2017). Both Kaakeh (2021) and Ali (2017) indicated that insect pests are generally divided into three levels in terms of economic importance, which are as follows:

2.1.1 Key pests

Thesee insects that infect the crop, are present at high population densities, and cause damage to it. These require continuous monitoring, surveillance, and the conduct of pest control measures.

2.2.2 Occasional (miner) pests

These insects are present on the crop with low population densities every year but start increasing their population density as a result of certain circumstances, such as a disturbance in the agricultural ecosystem or other factors. This causes economic losses and requires pest control measures. Surveillance and monitoring are needed for this kind of pest, as it appears in irregular periods extending to three years in some cases.

2.2.3 Infrequent pests

These insects exist at a low population density and are not affecting the growth and production of the crop most of the time. This type of pest is classified as one of the latent types of potential pests that can turn into important pests when the appropriate conditions are available for them. Therefore, pests (insects) that attack or infect palm trees and their fruits are divided as follows:

A. Root insects

- Primary: termites are several species of the family Termitidae.
- Secondary*: Gryllotalpa gryllotapa* carob.

B. Trunk insects

- Primary: long-horned palm stems borers *Jebusaea hammerschmidtii*, unicorn borers of the genus *Oryctes*, red palm weevil *Rhynchophorus ferrugineus*.
- Secondary: Palm offshoot borer *Strategus julianus*.
  Rare: the bark beetle *Xyleborus perforans*, giant palm borer *Dinapate wrightii*

C. Frond and podaxis insects

- Primary: *Oryctes elagans*, the palm stem borer, the single-horned beetles *Oryctes agamemnon*, including the Arabian rhinoceros beetle *O. a. arabicus*, *Phonapate frontalis*, Dubas palm insect *Ommatissus lybicus*, giant date palm mealybug *Pseudaspidoproctus hyphaeniacus*, Citrus mealybug *Planococcus citri*, and Parlatoria date scale insect *Parlatoria blanchardi*.
- Secondary: *Perindus binudatus* leafhopper, *Maconellicoccus hirsutus*, mealybug *Nipaecoccus viridis*, green scale insect *Fiorinia phoenicis*, red scale insect *Phoenicoccus marlatti*, Yellow scale insect *Aonidiella orientalis*, green borer scale insect *Plamaspis phoenicis*, and *Julodis fimbriata.*
- Seasonal: Desert locust, *Schistocerca gregaria*.
- Rare: tree locust *Anacridium melanorhodon arabafrum*, cicada insect *Platypleura Arabica*.

D. Insects taste and fruits

- Primary: the lesser date moth *Batrachedra amydraula*, the greater date moth *Arenepses sabella*, and the palm flower weevil *Derelomus sp*.
- Secondary: Palm pollen beetle, *Pseudomalegia sp.* Pomegranate fruit butterfly *Deudorix livia*, Date seed Beetle *Coccotrypes dactyliperda*, yellow wasp, *Polistes gallicus*; red wasp *Vespa orientalis.*

2.3 Types of Borers That Attack Date Palms and the Damage They Cause

Palm borers are one of the pests that cause severe damage to palm trees, leading to their weakness, lack of production, stem breakage, and sometimes death (Khalaf et al. 2010), and they are carriers of some pathogens. Date palms are attacked by three borers: the palm leaf borer *Phonapate frontalis*, the longhorn palm stem borer *Jebusaea sp.* of the species *J. hammerschmidtii* and *J. perseca*, and the single-horned palm borers of the genus *Oryctes sp.* of several species: *O. elegans, O. sinaicus,* and *O. agamemnon* of two species: the Arabian rhinoceros beetle, *O. a. arabicus,* and the root borer *O. a. matthiesseni* (Al-Saadi at al 2014).

Palm borers of the genus Oryctes (Scarabaeidae: Dynastinae: Coleoptera): Globally, there are about 44 species of palm borers that belong to the genus Oryctes (Coleoptera: Scarabaeidae) (Table 2.1). Four of them are spread in the Arab region and are called rhinoceros: the palm borer *Oryctes elegans*, the Arabian rhinoceros beetle *O. agamemnon arabicus*, *O. sahariensis* borers, and *O. sinaicus* borers (Aljboory 2007, Bedford 1976, Bedford et al. 2015).

The two species *O. elegans* and *O. agamemnon* are the most widespread in the Arab Gulf countries, such as the Kingdom of Saudi Arabia, Iraq, the United Arab Emirates, Oman, and the rest of other countries (Bedford et al. 2015). The type *O. agamemnon arabicus* was recorded by Khalaf et al. (2013) in Iraq in 2013, and was previously believed to be of the species *O. elegans* recorded in 1911. The adults of the *O. agamemnon arabicus* species are taxonomically different from the adults of the *O. elegans* species, and the presence of this insect was particularly associated with date palms. (Khalaf et al. 2014) showed that this insect infects all parts of the date palm tree from bottom to top, including the outer parts of the stem and the green parts of the palm. It was also shown that the larval stage is the cause of the main damage to the date palm. Oryctes borers cause severe damage to the fronds and the trunk by digging a network of tunnels inside the trunk, causing the trunk to break when high winds blow and creating free space for pathogen infections. Different palm varieties have a different degree of sensitivity to the infections caused by this genus of borers (Bedford et al. 2015).

Borers of the genus Oryctes coexist with the borers *J. hammerschmditii*, and the dominance in population density in the orchards infected with the genus *Jebusaea* and *Oryctes* is reversed in favor of one of them. This happens despite their single activity peak, which is in June and July, respectively. Where the population density of the genus *Oryctes* is higher than that of *J. hammerschmditii* in the south of the Al-Ahsa region in the Kingdom of Saudi Arabia, it spans from March to August. However, the genus *Oryctes* is active in Iraq during July and August, and its presence period extends from

April to the end of September. Infestation with the longhorn palm stem borer is chronic and develops slowly, which helps attract insects of the genus Oryctes, causing secondary infection of the palm (Bedford *et al.* 2015).

Table 2.1 Types of palm borers belonging to the genus Oryctes, which are widespread in the countries of the world

• *Oryctes agamemnon* Burmeister, 1847 • *Oryctes amberiensis* Sternberg, 1910 • *Oryctes anguliceps* Fairmaire, 1901 • *Oryctes ata* Semenov & Medvedev, 1932 • *Oryctes augias* (Olivier, 1789) • *Oryctes boas* (Fabricius, 1775) • *Oryctes borbonicus* Dechambre, 1986 • *Oryctes capucinus* Arrow, 1937 • *Oryctes centaurus* Sternberg, 1910 • *Oryctes cherlonneixi* Dechambre, 1996 • *Oryctes chevrolatii* Guérin-Méneville, 1844 • *Oryctes colonicus* Coquerel, 1852 • *Oryctes comoriensis* Fairmaire, 1893 • *Oryctes congonis* Endrödi, 1969 • *Oryctes curvicornis* Sternberg, 1910 • *Oryctes dollei* Fairmaire, 1897 • *Oryctes elegans* Prell, 1914 • *Oryctes erebus* Burmeister, 1847 • *Oryctes forceps* Dechambre, 1980 • *Oryctes gigas* Laporte de Castelnau, 1840 • *Oryctes gnu* Mohnike, 1874 - Malaysian rhinoceros beetle • *Oryctes gracilis* Prell, 1934 • *Oryctes heros* Endrödi, 1973 • *Oryctes hisamatsui* Nagai, 2002 • *Oryctes latecavatus* Fairmaire, 1891	• *Oryctes mayottensis* Dechambre, 1982 • *Oryctes minor* Waterhouse, 1876 • *Oryctes monardi* Beck, 1942 • *Oryctes monoceros* (Olivier, 1789) - African rhinoceros beetle • *Oryctes nasicornis* (Linnaeus, 1758) - type species (as *Scarabaeus nasicornis* L.: the European rhinoceros beetle) • *Oryctes nudicauda* Arrow, 1910 • *Oryctes ohausi* Minck, 1913 • *Oryctes owariensis* Beavois, 1807 • *Oryctes politus* Fairmaire, 1901 • *Oryctes proxilus* Wollaston 1864 • *Oryctes pyrrhus* Burmeister, 1847 • *Oryctes ranavalo* Coquerel, 1852 • *Oryctes rhinoceros* (Linnaeus, 1758) - Asiatic rhinoceros beetle • *Oryctes richteri* Petrovitz, 1958 • *Oryctes sahariensis* de Miré, 1960 • *Oryctes simiar* Coquerel, 1852 • *Oryctes sjoestedti* Kolbe, 1905 • *Oryctes tarandus* (Olivier, 1789) • *Oryctes vicinus* Gahan, 1900

2.4 Infestation and Damage Caused by Borers of the Genus Oryctes

Oryctes borers infect date palm trees in many palm-growing areas in Arab countries and other countries around the world (Bedford et al. 2015). The adults make tunnels in the trunk and create a network of tunnels that cause a gap in the trunk of the palm tree, which leads to its breaking and falling in high winds (Khalaf and Al-Taweel 2015). Adult borers appear during April and reach the highest population density during the months of June and July under the conditions of Iraq. As for the larvae, they exist during the period from June until the end of March or the beginning of April for the next season. The spread of the Arabian rhinoceros beetle, *O. a. arabicus*, in the orchards of Baghdad was recorded. And in Wasit Province, two of these borers were recorded, which are the Arabian rhinoceros beetle and the date palm borer. In Basra, four species of this genus were recorded (Khalaf and Al-Taweel, 2015). Infection with these borers causes weakness of the palm tree and favors a place for pathogen infection, leading to breakage of the trunk, falling of the tree, and death in cases of severe (Bedford *at al.* 2015; Khalaf 2018).

Khalaf et al. (2015) showed that the larvae of this genus are usually located inside the stems of palm trees and under the fronds, and their presence is concentrated in the head of the palm tree in the lower rows of the bases of the fronds. The presence of a number of larvae feeding from one place inside the stem of a weak palm tree causes a large hole inside the stem, and such stems break either because of the presence of the large hole or because of the wind (Bedford *et al.* 2015). The larvae prefer the moist tissues of the palm tree, and the larvae are also found between the fronds and fibers in the head of the palm tree and between the offshoots around the mother tree. And Khalaf (2015) showed the existence of differences between palm varieties in the degree of their sensitivity to infection with this genus from borers and that numerical density differs between palm-growing areas in Iraq, where there is dominance of one of the species or absence of some of them.

Khalaf and Al-Taweel (2014) showed that date palm trees of all ages are exposed to infection with Oryctes borers and that the old trees (older than 30 years) were more severely infected than the middle and young trees. They also studied the severity of infections in palm groves, where the severity fluctuated between one area and another. Borers caused severe damage to the palm trees, leading to their breaking during high winds due to the network of tunnels that the larvae make in the trunk of the affected palm.

2.5 Parts of the Palm Affected by the Borers of the Genus Oryctes

Bedford et al. (2015) showed that date palm tree borers belonging to the genus Oryctes attack most parts of the date palm tree, infecting the aerial roots at the base of the trunk near the soil surface in young date palms (4–10 years) due to the presence of a suitable place for the insect between the layers of the fronds near the soil surface, but such infections do not occur in middle-aged (10–20 years old) and elderly (more than 20 years old) palm trees. The insect infects the middle of the trunk of middle and old palm trees, and this does not occur in young trees because there is no long trunk exposed to infection. As for the top of the trunk (the area of the old frond) and the crown of the palm tree from the bottom, no injury was recorded in the new palms, but severe injury was recorded in the middle-aged and advanced-aged palms. No damage was observed on the upper part, fronds, and bracts of both young and mature palm plants. This pest attacks the bottom parts of the palm near the roots at the surface of the soil and the upper crown of the palm tree. It works in an interlocking network of tunnels that weaken the whole palm tree and lead to the breakage of the trunk and the falling of the trees when high winds blow. It also weakens the young trees in the area of contact of the trunk with the soil, or yellows and stiffens the crown of the palm tree (Khalaf et al., 2014; Soltani, 2011). Palm trees are the only host of this pest that attacks the palm, which forms a network of larval tunnels overlapping to form a wide hole in the trunk, which later leads to a sudden collapse due to high winds (Bedford et al. 2015).

2.6 Description and Life Cycle of Palm Borers of the Genus Oryctes.

Soltani (2012) and Khalaf et al. (2014) studied the biology of a species of palm borer belonging to the genus *Oryctes* under laboratory conditions and showed the description and life roles of the Arabian rhinoceros beetle *Oryctes agamemnon arabicus*.

Egg: The egg is oval in shape and white in color, with an average length of 2.9 mm and a width of 2.15 mm. The average incubation period is 13.2 days.

Larvae: The larva is curved in shape, its color is creamy white, and its body contains brown hairs. The head has very strong jaws. It has the ability to bite and grind pieces of soft tissue from fronds within hours and turn it into a powder that resembles peatmoss. It has three pairs of legs that vary in length: the first pair is 6 mm, the second pair is 7 mm, and the third pair is 9 mm. Both sides of the larval body contain 9 pairs of light-brown circular spots (thought to be respiratory openings), one pair of which is on the first thoracic ring, and 8 pairs on the ventral rings. The larva excretes black feces in the form of clumps of oval shape, larger than the size of a grain of wheat. The larva goes through three stages, and when it is fully grown, it lives inside a nest that it makes from palm tissue and the crumbs of fronds surrounding it for the purposes of pupation. The fully developed larva is 76.8 mm long and 16.1 mm wide from the middle of the body, and its weight is 7.80 grams. The average period of its development into a pupal is 196 days.

Pupa: The pupal is formed at the beginning of its stage inside the skin of the larva and makes a T-shaped incision to exit from the skin of the larva. The pupal is white in the first hours of its formation and turns to a light-brown color gradually; its length is 39.2 mm; its width from the middle of the body is 27.4 mm; its weight in the first two days is 3.24 grams; and the duration of its development as an adult is 29 days.

Adult: The adult emerges from the skin of the pupa, and its color at the beginning of its emergence is reddish, gradually turning to brown-black during the first day of emergence. Its body is elongated and has a length of 39.4 and 33.6 mm, a middle body width of 16.4 and 13.4 mm, and an average weight of 2.79 and 2.00 grams for both males and females, respectively. The male is distinguished from the female by the presence of a long horn in the middle of the head, 4.75 mm long and of a diameter of 1.4 mm at the base and 1.05 mm at the end. As for the female, the horn is very short or vestigial, with an average length of 1.30 mm. The adult contains a concavity at the top of the first thoracic ring. This concavity is characterized by the presence of two bumps at the end in the male, while in the female it contains one bump (Fig. 12). The area of this spot in the male is larger than the female, and its average dimensions are 7.4, 10.05 mm, and 4.51, 7.13 mm in the male. and female, respectively. The wings in the male are larger than the female, and one of the taxonomic characteristics of this species is that the front leg in adults contains three lateral appendages. The duration of development of the egg, larva, and pupal in *O. agamemnon arabicus* differs from the development period of the three stages mentioned in *O. elegans*, in which the total duration ranged from 293–329 days, and is also different from the development period in *O. rhinoceros* (Soltani 2011).

2.7 Integrated Control of Palm Borers of the Genus Oryctes

A successful control program for any pest must rely on an integrated management program that includes all or most of the integrated control factors, and to establish a management strategy for palm borers, it must include a system of knowledge of the field survey of this pest and its behavior in order to limit its damage. The main objective of integrated control projects for palm borers is to find new methods or improve existing methods so that they lead to the development of management systems for palm borers that are economically and environmentally acceptable and acceptable in the management system for these pests (Khalaf and Mahmoud 2021).

Khalaf (2018) implemented a program to control palm borers belonging to the genus Oryctes in orchards in central Iraq. The program included the following aspects of integrated control:

- Manual collection of larvae occurs during the months of January and March, when temperatures range between zero and 15 degrees Celsius.
- Cutting anguish and dry fronds: during the months of January and March, when temperatures range between zero and 15 degrees Celsius, preferably after rain.
- Optical traps powered by solar energy equipped with lamps with a wavelength of 350–420 nm (for monitoring and control or mass trapping): during the period from May until the beginning of September, when temperatures range between 35 and 50 degrees Celsius.
- Semi-chemicals (pheromones), whether for monitoring and control purposes or for large-scale hunting for adults, occur during the period from May until the beginning of September, when temperatures range between 35 and 50 degrees Celsius.
- Biological elements (nematodes and entomopathogenic fungi): during the month of November, coinciding with the presence of borers in the larval stage of the last larval instars, where temperatures ranged between 20 and 30 degrees Celsius.
- Chemical control (systemic pesticides): after the end of harvesting the crop in conjunction with the presence of the borers in the larval stage.

2.8 Chemical Control of Palm Borers

The chemical control of palm borers is considered difficult due to the size and height of palm trees on the one hand and because of the behavior of the insect by hiding inside the tissues of the trunk of the palm tree on the other hand, especially at the larval stage (Bedford et al., 2015). In Tunisia, Gharib (1970) used a bait of bran with an insecticide in the head of the palm tree, and Soltani (2010) used the method of dipping the offshoots in the insecticide to avoid infection with borers. In Iraq, experiments were carried out on comparing the effectiveness of three systemic chemical pesticides by direct spraying on the top of the palm tree, and it did not show any effectiveness in killing the larvae of the borers of the genus *Oryctes* (ICARDA 2011). In the United Arab Emirates, chemical control is not recommended, but it is applicable in certain cases, such as soil treatment when no optical traps are available and organic and mineral fertilizer treatment with pesticides before and after use and treatment of infected roots.

As for Al-Deeb and Khalaf (2015), they showed the possibility of using chemical pesticides to control the long-horned palm stem borer *Jebusaea hammerschmidtii* by immersing the trunk of the palm with the pesticide or by injecting into the trunk in the same way that was used to control the red palm weevil *Rhynchophorus ferrugineus*, as it was shown that it is not possible to rely on chemical control because of the behavior of the destructive larval role by hiding inside the tissues of the trunk of the palm tree, where it is not exposed to the direct effect of pesticides.

2.9 Chemical Pesticides and Methods of Their Use

It is common in orchards to use pesticides by traditional methods, whether by spraying or immersing the soil, and although they are useful in treating pests and reducing their harm, they can have many side effects (Perry *et al.,* 1991). These risks include environmental pollution and its impact on the user and consumer. Direct foliar spraying of pesticides is the most common method of application, but its efficiency is limited due to the losses caused by the drift of pesticides, especially large trees, and sometimes spraying works near homes or prohibited places (Aćimović *et al.* 2016; Wise *et al*., 2014). While Pimentel and Levitan (1986) and Pimentel (1995) showed that estimates indicate that only 0.1% of the pesticides applied in the United States of America reach the target pests, the remaining percentage represents environmental pollution, which causes losses for farmers and has a major impact on the environment. Thus, this calls for a search for safer and more promising alternative methods (Aimovi *et al.* 2014). From this, the method of injecting pesticides into the trunks of many trees is considered one of the most promising, which reduces environmental impacts and reduces the drift of pesticides towards non-targeted places. This method can be used in orchards, forests, gardens, and parks (Coslor *et al.* 2018; Doccola *et al.* 2012; Ferracini and Alma 2018; Kobza *et al.* 2011). In this method, pesticides will be transported and transmitted through transport vessels to the locations of the target pests, avoiding access to the outer parts of the trees or dispersing the pesticide outside the plant (Fettig 2013). Biological control agents and growth regulators can also be used by injection into the stem to control fungi, insects, nematodes, and phytoplasmas. Thus, it is considered an environmentally friendly method (Aimovi *et al.,* 2015; Byrne *et al.,* 2012; Hu and Wang, 2016; Percival and Boyle, 2005).

2.10 History and Recent Developments in the Use of Pesticides by Injection into Tree Trunks

Injecting chemicals into tree trunks has a long history and varying results. Over the centuries, attempts have been made using this method, but none have been successful. In the fifth century, Leonard da Vinci was the first to try to inject arsenic and toxic substances into the trunk of apple trees through holes and tunnels in order to make the fruits toxic (Roach 1939; Stoddart and Dimond 1949). Experiments were conducted during the nineteenth century that developed the use of this method. In 1853, Hartig was the first to use this method for injecting liquid into a tree trunk through a container located outside the trunk. Sachs (1894) injected iron salts to treat deficiencies in some elements. During the 1990–2000 period, a lot of research was conducted on injecting pesticides into tree trunks to treat many insects and diseases, especially borers such as *Agrilus planipennis* (Grimalt *et al*. 2011) and the longhorn beetle *Anoplophora glabripennis* (Ugine et al. 2013). This method was also used to treat the red palm weevil, *Rhynchophorus ferrugineus*, in Central Asia, North Africa, and Europe (Burkhard *et al.* 2015). It was also used in Asia and Europe to treat the nematode *Bursaphelenchus xylophilus*, which causes wilting (Sousa et al. 2013).

2.11 Tools and Supplies Used in the Injection Process.

The methods of injecting pesticides into the trunk are still developing, but they tend to be used on a large scale thanks to technological advances in devices and injection equipment. The required equipment to accomplish this is an injection port, an injection tool, syringes, pesticides, or a pressurized capsule designated for that. There are two ways for injecting: either through an outer container connected to the trunk from which the solution flows or through a hole of diameter ranging from 2 to 9.5 mm (University of Padova 2011). The depth of the hole varies according to the needs and the morphology of the tree. The pesticide is pushed either naturally or with a specific force of pressure.

2.12 Systemic Pesticides

Doccola et al. (2009) showed that imidacloprid and emamectin benzoate are systemic pesticides that have an effect on some insect pests. The pesticide Imidacloprid is from the group of neonicotinoids that have the ability to move through the tissues of the plant after application and cause disruption of the nerve impulses of the targeted insects, causing them to die (Fossen 2006). As for emamectin benzoate, it is derived from abamectin, which is a natural product resulting from the fermentation of the soil by the bacterium *Streptomyces avermitilis*. Its mode of action is to paralyze the function of connecting neurons in insects, stopping the functioning of the cell, eventually disturbing the resulting nerve impulses, and leading to paralysis and death (USEPA 2009). The action of injecting systemic pesticides into tree trunks is relatively simple and quick. The chemical components can take from a few hours to weeks to reach all parts of the treated tree, depending on the properties of the pesticide and the characteristics of the tree (Doccola et al. 2009). However, this depends on the percentage of pesticide dilution and the health and size of the tree (McWain and Gregory 1973; Doccola et al. 2009).

2.13 What is A Neonicotinoid

It is a new class of pesticides chemically related to nicotine, and the name literally means (new insecticides similar to nicotine." Nicotine pesticides act on certain types of receptors in the synapse and are more toxic to invertebrates, such as insects, than to mammals, birds, and other higher organisms. (Texas A&M Agrilife Extension 2016).

One of the aspects that made neonicotinoid insecticides more popular in insect control is their solubility in water, which allows them to be placed in the soil and the ability of plants to absorb them, and thus their applications reduce the risk of their drift from the target site. There are several types of neonicotinoid pesticides, and the first one used was imidacloprid, which is common in insect control. Bayer Advanced Garden Insecticides produced it. It is used as a spray on plants and is often effective at piercing and sucking insects when applied to the soil. There is another product, Dinotefuran (Safari), which is more soluble in water and very effective on insects that feed on sap. In addition, it is very effective against some beetles, fleas, and insects that infect pets, as well as against some wood pests, flies, and cockroaches. And since this pesticide belongs to the group of neonicotinoids, its active substance must be one of the following substances:

- Acetamiprid
- Clothianidin
- Dinotefuran
- Imidacloprid
- Nitenpyram
- Thiocloprid
- Thiamethoxam

Despite what was indicated as having low toxicity to some beneficial insects, including bees, some recent research indicated that this claim has become questionable, as research indicated that through contamination of pollen and nectar with neonicotinoid pesticides used in agriculture, even though these low levels of exposure do not kill bees even with direct exposure, it may affect the ability of some bees to search for the source of nectar and remember the location of flowers, or weaken their ability to find the location of the hive. Therefore, it is preferable to use these pesticides in the evening in areas with the presence of bees (Texas A&M Agrilife Extension 2016).

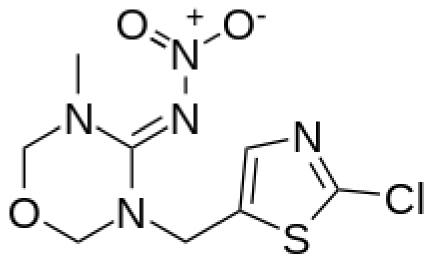
2.14 Thiamethoxam

Thiamethoxam is a second-generation systemic insecticide belonging to the class Neonicotinoids. In 1991, Cipa-Geigy (now Syngenta) developed this pesticide. This broad-spectrum pesticide enters plants quickly and spreads to every part of the plant, including pollen, where it prevents insect feeding (Maienfisch 2001). It can be absorbed by insects via the stomach through feeding, direct contact, or trachea. This compound hinders the transmission of neurotransmitters between nerve cells via acetylcholine receptors in the nervous system and ultimately paralyzes the insects' muscles (Syngenta 2006). This compound improves plant activity by triggering physiological reactions within the plant, allowing the plant to thrive during conditions of heat stress, drought, low soil PH, wounds, pests, wind, cold, and viruses. The selective toxicity of thiamethoxam is due to its effect on acetylcholine receptors in insects. The Food and Agriculture Organization of the United Nations has evaluated that this pesticide has a moderate third-category danger to humans and is harmful if swallowed. It does not cause skin or eye irritation and does not cause any mutations in the human body. It is non-toxic to fish and algae, moderately toxic to birds, severely toxic to fleas, acutely toxic to bees, and harmful if swallowed. (FAO 2000).

Some chemical and physical properties of thiamethoxam are as follows (Sigma – Aldrich 2010):

- Chemical formula: $C_8H_{10}ClN_5O_3S$

{3-[(2-Chloro-1,3-thiazol-5-yl)methyl]-5-methyl-1,3,5-oxadiazinan-4-ylidene}nitramide}



- EC Number: **428-650-4, 604-921-4**
- Molar Mass: **291.79 g.mol^{-1}**
- Density: **1.57 g/ cm^3**
- Solubility in water: **4.1 g/L**

2.15 Acetamiprid

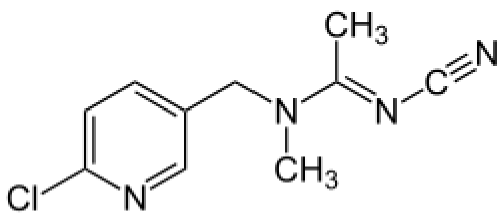
It is an organic compound and an odorless systemic insecticide from the neonicotinoid group that was introduced for use in the early 1990s. Its synonyms include Mospilan, Intruder, and other names, and it is produced under several trade names (Yao *et al.* 2006). This pesticide was developed by the Nippon Soda Company. It is used to control sucking insects on vegetable crops, citrus fruits, pomegranates, grapes, cotton, and ornamental plants. It is used to control fruit fly larvae that infect cherry trees, as well as to control some household insects such as fleas (Brunet *et al.* 2005).

Acetamiprid is a nicotine-like substance that interacts with the body in a manner similar to that of nicotine. It is a natural insecticide from which many human-made insecticides are derived. It interacts with acetylcholine receptors (nACh-R) that are located in the dendrites of all neurons in the brain, spinal cord, and ganglia. It is highly toxic to insects and less toxic to mammals (Kimura-Kuroda et al. 2012).

Some chemical and physical properties of acetamiprid are as follows (Yao et al. 2006):

- Chemical formula: $C_{10}H_{11}ClN_4$

N-[(6-chloro-3-pyridyl)methyl]-N'-cyano-N-methyl-acetamidine



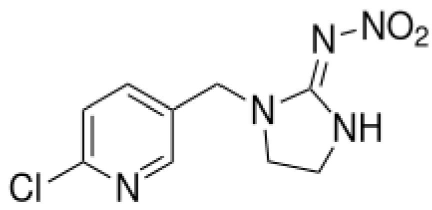
- Molar mass: 222.678 g.mol^{-1}
- Density: 1.17 g/cm^3

2.16 Imidacloprid

A systemic insecticide belongs to the group of chemicals called neonicotinoids that act on the nervous system of insects by interfering with stimuli in their nervous system by blocking the nicotinergic neuronal pathway by blocking acetylcholine receptors. It prevents the transmission of impulses between the nerves, which leads to paralysis of the insect and eventually death, and it is effective through contact and ingestion (Extension Toxicology Network 2012). Imidacloprid binds more strongly to the receptors of neurons in insects than in mammals, so it is more toxic to insects than to mammals. Since 1999 until 2018, this pesticide has been one of the most widely used pest control pesticides in the world. Bayer CropScience is the company that makes it. This pesticide can be used through soil, injection into tree trunks, or foliar spraying. It is available in several granular and liquid formulations, is used to combat a wide range of pests, and is toxic to birds and bees (Casida 2018).

Some chemical and physical properties of imedacloprid are as follows (Extension Toxicology Network 2012):

- Chemical formula: $C_9H_{10}ClN_5O_2$



N-{1-[(6-Chloro-3-pyridyl)methyl]-4,5-dihydroimidazol-2-yl}nitramide

- Molar mass: 255.661 g.mol^{-1}
- Solubility in water: 0.51 g/L (20 °C)

2.17 The Use of Systemic Pesticides by Injection in the Trunk and Watering

There were several tests done on the use of systemic pesticides like emamectin benzoate, imidacloprid, dinotefuran, spinosad, chlorantraniliprole, and abamectin in the trunks of apple trees in the spring and fall. Samples of pollen and nectar were taken during flowering time in the following spring to compare the seasonal timing of the accumulation of pesticides in parts of the flower, and their concentrations were within the permissible limit for that. Bhandari and Cheng (2016) applied the systemic pesticides Imidacloprid and Emamectine Benzoate to the trunk of Chinese banyan, Ficus microcarpa trees, to control two Hymenoptera wasps: the wasp affecting Ficus microcarpa leaves, Josephiella microcapae, and the stem wasp, Josephiella sp. Imidacloprid gave protection to the trees from infection with these wasps for a period of 18 months after the treatment, compared to 14 months when using the pesticide Emamectine Benzoate and that the use of pesticides injected into the trunk can be a feasible strategy for controlling the stem and leaf wasps that infect Ficus microcarpae trees. Grosman et al. (2002) conducted experiments on the use of pesticides Emamectin benzoate alone, Imidacloprid alone, and the two together by injection into the trunk for one or two times to control the Pinus taeda L. insect that infects loblolly pine trees. The pesticides were effective in reducing the damage of the insect, gave protection to trees for a full year, and also reduced the percentage of damage to seeds and cones by 86%. Dewhurst (2006) used the method of injecting pesticides into the trunk to control insect pests that attack oil palm trees and obtained good results in reducing insect pest damage and reducing their population density. However, Gill et al. (1999) used the systemic pesticides Imidacloprid (Pointer 4% and Merit 75 WP) and Abamectin (Greyhound 1.9%) by two methods, trunk injection and watering using the fertilizer in the area around the roots, to control some sucking insects of the lace bug and obtained good results, in which the damage and the number of insects were reduced to zero compared to the control treatment. Fishel (2017) used the following pesticides, plant growth regulators, and antibiotics: Abamctin injection into the stem to control mites, Acephate injection into the stem to control insects, Azadirachtin injection to combat insects, Calcium Oxytetracycline injection as an antibiotic, Dikegulac-Sodium injection as a plant growth regulator, Dinotefuransrhdm watering and injection For insect control, Emamectine-benzoate injection for insect control, Indole-3-butyric cid injection for plant growth regulator, Mefenoxan watering fungicide, methyl Oxydemeton injection for insecticide, and Oxytetracycline hydrochloride injection for antibiotic. Bouagga et al. (2017) developed a promising technique to control the red palm weevil using mass hunting and injection of the pheromone Rhylure 700. Sunamura et al. (2021) studied the effect of two neonicotinoid insecticides (thiamethoxam and dinotefuran) on the wood borer Aromia bungii that recently invaded Japan. The insect caused a high death rate and gradually reduced its numbers when exposed to high concentrations of the two pesticides.

3. MATERIALS AND METHODS

3.1 Experimental Sites

Field experiments were carried out in two orchards of palm trees, each with an area of 2 hectares, located in the Al-Madaen region (30 km south of Baghdad), Iraq, at coordinates of Latitude 33.148939 and Longitude 44.576131 according to the Global Positioning System (GPS) during the 2021–2022 season. The orchards contain several varieties of date palm (Figure 3.1). The names of the cultivars were determined with the help of the experience of the orchard owners and those working in their service. From there, the cultivars were recorded in the orchards, as well as their ages, the average length of the trees, and the diameter of their trunk at a height of one meter above the ground. Field experiments were carried out on the Amrani cultivar. The orchard is subject to the annual periodic service works for the palms: irrigation, fertilization, with no cutting of fronds for two previous years, the fronds (leaves), and the stems for the purpose of obtaining sufficient numbers of palm borers to carry out field experiments. As for laboratory experiments, they were carried out in the laboratories of the college.

Figure 3.1 One of the palm groves in which field experiments were carried out to control the palm borer Oryctes sp. of Biotechnology/Al-Nahrain University/Iraq during 2021-2022

3.2 Climatic Conditions

The temperatures and relative humidity were recorded during the period of executing the field experiments in November, December 2021, and January 2022, using a US-made Watch Dog 2000 device. The temperature of palm trees was also measured during that period using an alcohol thermometer that was placed inside a hole with a depth of 10 cm inside the palm tree in three periods, morning, noon, and evening, in different places of the experiment grove.

3.3 Used Chemical Pesticides

Three organic pesticides of organic origin were used: neonicotinoids, Mospilan (Acetamiprid 20%), Tiam WG (Thiamethoxam 25%), and Radical (Imidacloprid 20%), with three control methods: direct spraying on the top of the palm tree, injection into the trunk, and watering with irrigation (Table 3.1).

Table 3.1 Chemical pesticides used to control palm borers of the genus Oryctes

Insecticide type	Active ingredient, Class	Company name	Mode of use	Recommended concentration	Amount for each palm
Mospilan	Acetamiprid 20% Neonicotinods	Nipon Soda,Japan	Direct spraying	50 g/ 100 L water	5 L
Mospilan	Acetamiprid 20% Neonicotinods	Nipon Soda,Japan	Stem injection	1 g/ 2ml water	20 ml
Mospilan	Acetamiprid 20% Neonicotinods	Nipon Soda,Japan	watering	1g/ 5 L water	50 L
Tiam	Thiamethoxam25% Neonicotinods	Agrichem, Australia	Direct spraying	30g/ 100L water	5 L
Tiam	Thiamethoxam25% Neonicotinods	Agrichem, Australia	Stem injection	1g/ 3ml water	20 ml
Tiam	Thiamethoxam25% Neonicotinods	Agrichem, Australia	watering	1g/ 7L water	50 L
Radical	Imidacloprid 20% Neonicotinods	Imprint Farmer China	Direct spraying	38ml/ 100L water	5 L
Radical	Imidacloprid 20% Neonicotinods	Imprint Farmer China	Stem injection	1ml/ 1.5ml water	20 ml
Radical	Imidacloprid 20% Neonicotinods	Imprint Farmer China	watering	1ml/ 3.8L water	50 L

3.4 Infestation Rate and Population Density of the Insect

The percentage of infection in the orchard was calculated by searching for the larvae of palm borers belonging to the genus Oryctes that are present under the pits of the palm (fronds) at the head of the palm tree by the ascent of the palm service worker, collecting the larvae after cutting the fronds (Figure 3.2), and placing them in a plastic bottle that the worker attaches to the palm-rising machine. Number of total trees examined, infected trees, and number of larvae for each palm in the surrounding orchards. The experimental orchard and the target cultivar for the control works and the severity of the infection were determined by examining 20 trees in each site, four in each of the four corners and four in the middle of the site (for each region, the experimental site, and the cultivar). From this, the infestation rates in the region, in the experimental orchard, and per cultivar were calculated using the following equations, according to Bedford et al. (2015). Also, the number of larvae in the palm crown was calculated in three common cultivars (Brim, Amrani, and Khadrawi) at the site of the implementation of the experiments. Therefore, five trees of each of the three cultivars were examined, from which the severity of infection and the sensitivity of each cultivar to infection by borers were determined..

- $$\text{Infestation Rate in Region} = \frac{\text{Number of infested palms (Region)}}{\text{Total number sampled in Region}} \times 100$$

- $$\text{Infestation Rate in Station} = \frac{\text{Number of infested palms (station)}}{\text{Total number sampled (station)}} \times 100$$

- $$\text{Infestation Rate in variety} = \frac{\text{Number of infested palms (Variety)}}{\text{Total number sampled (Variety)}} \times 100$$

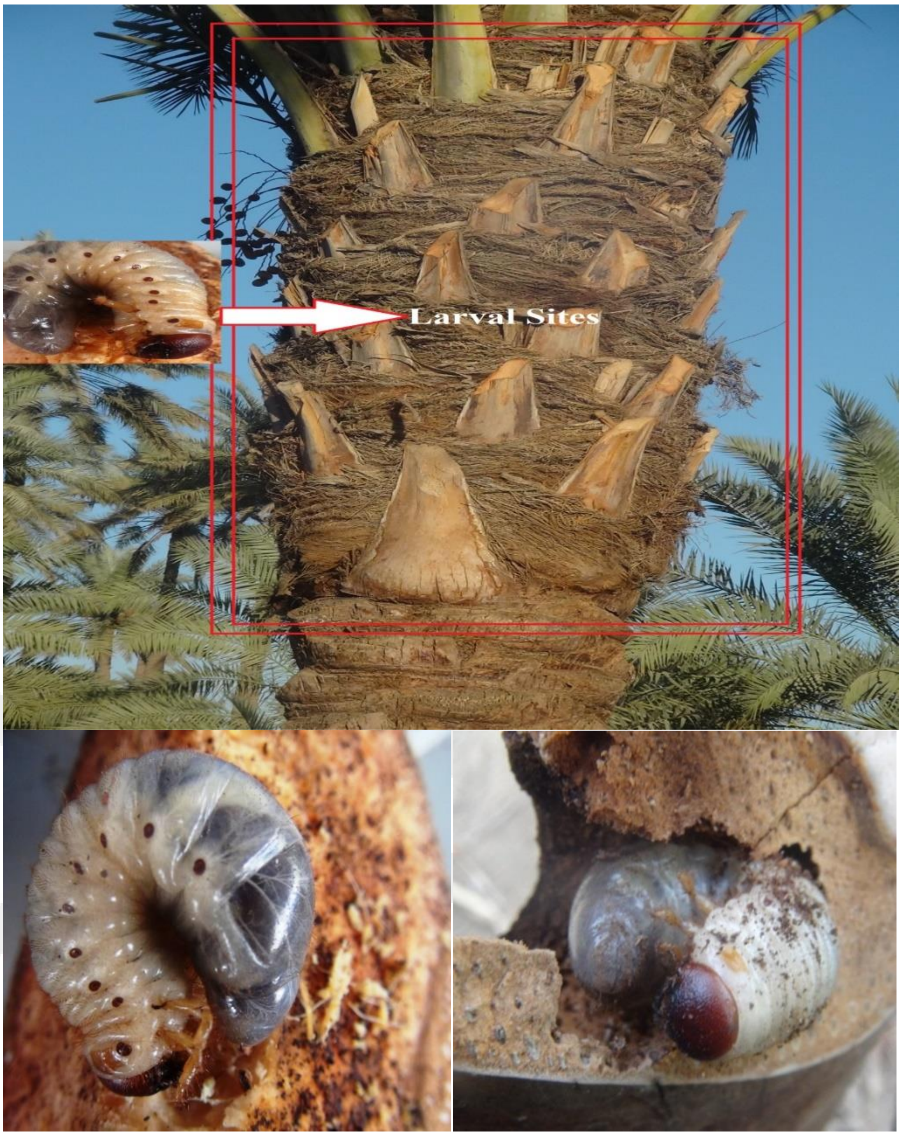


Figure 3.2 Location of the larvae of palm borers of the genus Oryctes on the palm

3.5 Insect Colony and Experimental Samples

The larvae and adults of palm borers belonging to the genus Oryctes were collected from under the fronds of the infected palm, accompanied by the palm service worker. The larvae were placed in 5-liter plastic containers and provided with natural food (fresh fronds). The food pieces were replaced when needed. Sufficient numbers of larvae and adults were collected (Figure 3.3). To carry out the experiments, the larvae collection lasted until the end of April, when the insect began entering the pupation stage under field conditions.

Figure 3.3 Collecting larvae and adults of palm borers of the genus Oryctes used in the experiments

3.6 Laboratory Experiments to Test the Effectiveness of Neonicotinoids

First, the direct spraying method: two experiments were carried out for this purpose, one using the concentration recommended by the manufacturing company and the other using the doubled concentration. Five larvae were sprayed directly with the pesticide according to the recommended concentration (see Table 3.1) using a hand sprayer in the same way for all replicates and treatments, then they were transferred to a 5-liter plastic container (considering that each container contains 5 replicate larvae), and they were provided with natural food (frond pieces with dimensions of approximately 5 cm). Five replicates were used for this purpose, while the control treatment was brushed with distilled water only, and the containers were placed under laboratory conditions with a temperature ranging between 25 and 30 °C, a relative humidity of 50–60%, and a lighting period of 0–24 hours (light and dark). The second experiment was carried out using the same method referred to above, but with a double concentration of pesticides. The larvae were examined on a daily basis to count the number of living and dead larvae and to record some vital parameters (larva weight, dimensions, color, and activity) until the death of all larvae, the stage of immobility, or reaching adulthood. Five replicates were used for each pesticide treatment and comparison, and from them, the killing rate and pesticide efficacy (corrected killing values) were calculated using Henderson-Telton's formula in laboratory experiments and Schneider-Orelli's formula in field experiments, according to Puntener (1981):

1- Henderson-Telton's Formula:

$$\text{Corrected\%} = \left(1 - \frac{\text{n in Co before treatment} \times \text{n in T. after treatment}}{\text{n in Co after treatment} \times \text{n in T. before treatment}}\right) \times 100$$

n= insect population, T = treated, Co = control

2- Schneider-Orelli's Formula:

$$\text{Corrected\%} = \left(\frac{\text{mortality\% in treated plot - mortality\% in control plot}}{\text{100 – mortality\% in control plot}}\right) \times 100$$

Second, indirect spraying: The same method of direct spraying was used, but without treating the larvae with the pesticide. Rather, the food was only sprayed, and then the larvae were transferred to it later, under the same conditions of direct spraying and the same number of replications. The same previous standards were calculated, like in the direct spraying treatment.

3.7 Field Experiments to Test the Effectiveness of Chemical Pesticides

Ten trees were examined in the experimental orchard, two of which were in each corner of the orchard and two in the middle of the orchard, in order to confirm the presence of insects and their numbers.

First, the direct spraying method: 32 trees (each tree repeated) were allocated for this experiment, of which 16 were treated with the recommended concentration and the other 16 were treated with the double concentration. Four of them (replicates) were used for each of the three pesticides, and four (replicates) were used for spraying with water only for the purpose of comparison (control). Trees were marked with symbols using spray paint (Figure 3.4). Pesticides were mixed with water according to the recommended ratios (see Table 3.1) once and with a doubled concentration again. 5 liters of the pesticide solution were sprayed on the top of the palm tree using a motorized sprinkler attached to a long arm to deliver the pesticide to the top of the palm tree (Figure 3.5). Trees were examined after one month of treatment with pesticides by the worker ascending to the palm to cut the fronds and counting the number of dead and alive larvae at the top of each palm tree (repeated) for all treatments of Mospilan, Tiam, and Radical pesticides. The killing ratio and corrected values were calculated to calculate the effectiveness of each pesticide.

Figure 3.4 Marking trees in field experiments using spray paints

Figure 3.5 The method of direct spraying on the head of the palm tree to control the palm borers of the genus Oryctes

Second, the method of injecting pesticides into the trunk: four trees (each tree repeated) were allocated for each pesticide treatment, and four other trees were control (water only) without pesticide use. A hole was made in the trunk of the palm tree with a diameter of 10 mm and a depth of 100 mm at a height of 1 m above the ground and at an angle of 45 degrees from the trunk. For this purpose, a drill with the same measurements as the above hole was used (Figure 3.6). The pesticides were mixed according to the recommended proportions (Table 3.1) and injected into the hole with a syringe with a pressure of 1 bar, and the holes were closed with silicone. After a month of treatment, the trees were examined by ascending to cut fronds and counting the number of dead and alive larvae at the top of each palm tree (repeated) for all pesticide treatments: Mospilan (Acetamprid 20%), Tiam (Tiamethoxam 25%), and Radical (Imidacloprid 20%). Then, from that, the killing ratio and corrected values were calculated to calculate the effectiveness of each pesticide.

Figure 3.6 Testing the efficacy of systemic insecticides by injection method in the trunk of palm trees against palm borers of the genus Oryctes

Third, method of watering: Four trees (each tree repeated) were allocated for each pesticide treatment and four other trees for control (water only) without pesticide use. A circular hole was made around the tree, 25 cm deep and 1 m away from the trunk (Figure 3.7), and pesticides were mixed according to the recommended proportions (Table 3.1), and 50 liters of the pesticide solution were placed in the hole. After a month of treatment, the trees were examined by ascending to cut fronds and counting the number of dead and live larvae at the top of each palm tree (repeated), and for all pesticide treatments, Mospilan (Acetamprid 20%), Tiam (Tiamethoxam 25%), and Radical (Imidacloprid 20%). Then, from that, the killing ratio and corrected values were calculated to calculate the effectiveness of each pesticide.

Figure 3.7 Testing the efficiency of systemic pesticides using watering method against palm borers of the genus Oryctes

3.8 Experimental Design, Statistical Analysis and Pesticide Efficacy Calculation

The randomized complete block design (RCBD) was used when executing the field experiments and the completely randomized design (CRD) was used when executing the laboratory experiments. The Genstat5 program was used to do statistical analysis of the results. The Duncan multinomial test with a probability of 5% was used to find the significant differences between the pesticide treatments (Duncan 1955). The analysis of variance table and the Henderson-Tilton formula were used to correct the killing values and the effectiveness of pesticides under laboratory conditions, and Schneider-Orelli's formula, according to Puntener (1981) to correct the killing values and the effectiveness of pesticides in the field.

4. RESULTS AND DISCUSSION

4.1 Experimental Orchards and Palm Varieties

The results of the field survey in the orchards in which the field experiments were carried out show that there are several varieties of date palm, which are the most common in the region (Brim, Omrani, Barhee, Khadrawi, Zohdi, and Maktoum). Trees were identified by the experience of the owners of orchards and workers in the service of palm trees. The results of measuring the dimensions of the trees of the variety that was used in the implementation of the experiments showed that the trees are of medium age (30–35 years), with an average length of 7-9 m and a trunk diameter of 60–65 cm. Experiments on old palms and high-trunk trees were avoided for the sake of ensuring accuracy and for the ease of recording data. The Omrani variety (Usta Omran) was adopted, as it is one of the most common varieties in the experimental area.

4.2 Climatic Conditions during the Field Experiments Implementation Period

The results in Table 3 indicated that the temperatures and relative humidity in the orchards during the period of executing the experiments for the months of November and December 2021 and January 2022 were 22.5, 12.0, and 8.0 degrees Celsius, and relative humidity was 40%, 55%, and 70% for each, respectively. While the temperatures recorded inside the trunk of the palm ranged between 22 and 28 degrees Celsius throughout the period of implementation of the experiments, this indicates that the palm trees have the ability to maintain temperatures within a medium range and are little affected by external conditions. This may be attributed to the size of the trunk of the palm tree and the outer layer surrounding it: dead, thick stems (the bases of the fronds), and fibers that act as an insulating layer between the trunk of the palm tree and its outer periphery.

Table 4.1 Temperature and relative humidity during the implementation of field experiments in Baghdad orchards

Month-year	Temperature °C				Relative humidity		
	High	Low	Average	Inside the trunk	High	Low	Average
November-2021	18	27	22.5	28 - 24	20	60	40
December-2021	4	20	12.0	26 - 22	45	65	55
January-2022	1	15	8.0	24 - 22	65	75	70

4.3 Infection Rate of Date Palm Trees With Borers of The Genus Oryctes

The results of calculating the infection rate in the orchards of the area surrounding the experimental site and the orchards of the site and the class in which the field experiments were carried out showed that the infection rate was 85%, 95%, and 100% for each of the region's orchards and the orchards of the experiment and the Umrani variety, respectively, by using the equations for calculating the infection rates with palm borers according to Bedford et al. (2015):

1- In the experimental area

$$\text{Infestation Rate in Region} = \frac{\text{Number of infested palms (Region)}}{\text{Total number sampled in Region}} \times 100$$

$$\text{Infestation Rate in Region} = \frac{17}{20} \times 100 = 85\%$$

2- Experiments carried out in the orchards

$$\text{Infestation Rate in Station} = \frac{\text{Number of infested palms (station)}}{\text{Total number sampled (station)}} \times 100$$

$$\text{Infestation Rate in Station} = \frac{19}{20} \times 100 = 95\%$$

3- In the Umrani category (Usta Umran)

$$\text{Infestation Rate in variety} = \frac{\text{Number of infested palms (Variety)}}{\text{Total number sampled (Variety)}} \times 100$$

$$\text{Infestation Rate in variety (Omrani)} = \frac{20}{20} \times 100 = 100\%$$

Table 4 also showed that there were differences between date palm cultivars in how easily they got infected and how well they fought off infection by palm borers of the genus Oryctes. The cultivar Prim was the most likely to get infected, followed by the cultivar Amrani, and finally the cultivar Khadrawi was the least likely to get infected. The difference was indicated through the index of calculating the number of larvae present in the head of the palm tree (Figure 4.1), where the average was 14.8, 8.4, and 3.8 larvae/tree for each of the cultivars Prim, Amrani, and Khadrawi, respectively. The statistical analysis showed that the three cultivars had different levels of infection with the borers of the genus Oryctes. The Prim cultivar had a severe infection, the Amrani cultivar had a moderate infection, and the Khadrawi cultivar had a mild infection. This may be due to the state of preference and lack of preference resulting from the characteristics of the tissues of each class, and this is identical to what was found by Khalaf et al. (2010), which showed that the cultivar Prim is the most preferred cultivar for the borers of the genus Oryctes, compared to the cultivar Tbarzel, the most resistant to it, as it recorded a number of larvae at an average of 12.7, 11.7, and 4.2 larvae per tree for each of the cultivars Prim, Amrani, and Tbarzel, respectively. It also showed the existence of a relationship between the nature of the tissue of the bases of the fronds under which the larvae hide and feed, so there was an inverse relationship between the weight of the stalk and the number of larvae present in the head of the palm tree. It was explained that the number of larvae in the head of the palm tree was 12.7, 11.7, and 4.2 larvae/tree for each of the cultivars Prim, Amrani, and Tbarzel, respectively, and the weight of one frond was 475, 788, and 1656 gm/frond for each of them, respectively. It was shown that the frond tissue of the Brim variety is light and semi-spongy and cuts easily compared to the variety Tbarzel, whose frond texture was tough and hard and cut with difficulty, which makes the Brim variety more favorable for injury and a food source for borers of the genus Oryctus, in contrast to the variety Tbarzel, whose texture is tough and rigid, which makes it resistant and less preferable to borers of the genus Oryctus.

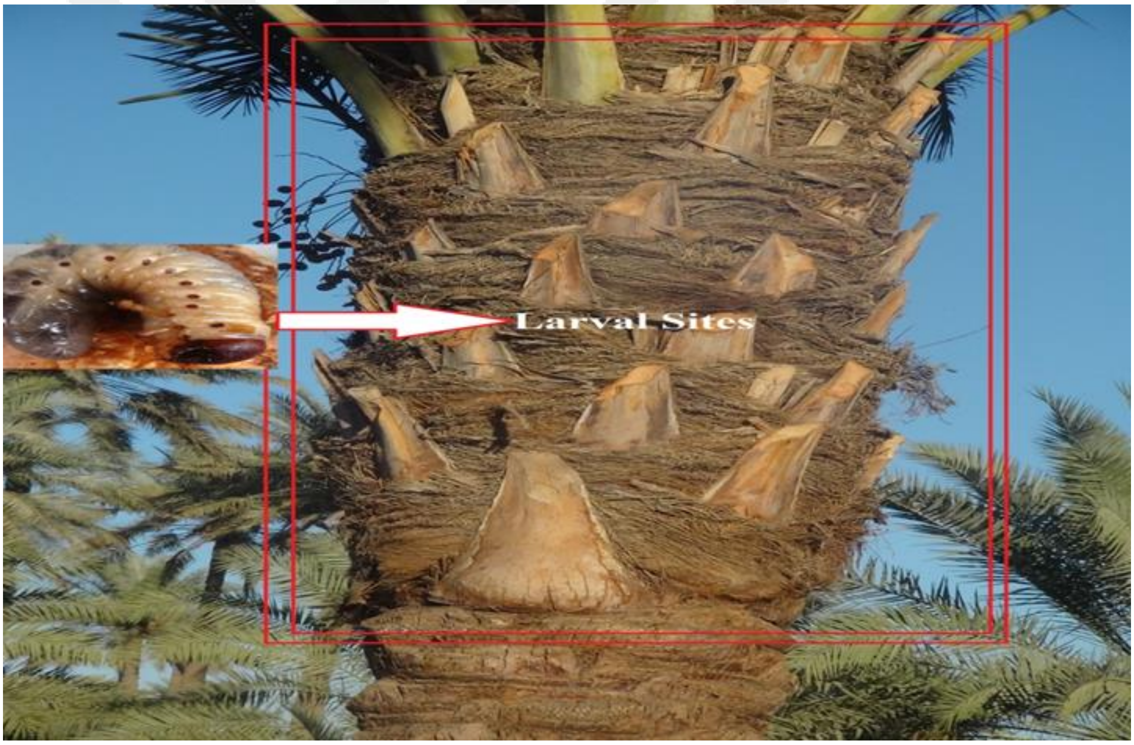


Figure 4.1 Location of the larvae of Oryctes borers in middle-aged palm trees

Averages followed by the same letters and the same column are not significantly different according to Duncan's multiple range test and under a probability of 5%.

Table 4.1 Susceptibility of some date palm cultivars to infection with palm borers of the genus Oryctes under Baghdad orchard conditions in 2022

Cultivar	Number of trees	Number of larvae in tree head		Severity	Resistance
		Total	Average		
Brim	5	74	14.8 c	Severe	Very sensitive
Umrani	5	42	8.4 b	Average	Sensitive
Khadrawi	5	19	3.8 a	Mild	Resistance

4.4 Insect Laboratory Colony

After the periodic collection of the larvae of palm borers belonging to the genus Oryctes, which were reared on the natural food medium (soft palm frond), sufficient numbers were provided (Figure 4.2) to carry out laboratory experiments to determine the effectiveness of pesticides. The larvae were of recent ages and were monitored daily. The larvae of this genus are large in size; their dimensions and weight are presented in Table 4.3. The larval age of this genus ranges from 197–227 days, depending on the temperature (Soltani et al., 2008; 2012).

Figure 4.2 Nurturing of larvae of palm borers of the genus Oryctes on natural food (palm fronds) under laboratory conditions

Table 4.2 Some morphological characteristics of the larvae of palm borers of the genus Oryctes

Trait	Features
Shape	Arched
Color	Creamy white
The length of the larva in the last stage	69.21 mm (Average)
Width from the middle of the body	15.72 mm
Weight	6.91 g (Average)

4.5 Laboratory Experiments

Direct spraying on larvae method: The results in Table 4.4 indicate that the effectiveness of the pesticides in killing the larvae of palm borers belonging to the genus Oryctes began after 10, 11, and 14 days for Mospilan, Tiam, and Radical, respectively, when using the pesticides at the minimum concentration recommended by the manufacturers. Then, it reached the highest killing rate during days 13, 14, and 15 after treatment with the Mospilan pesticide, and the killing percentage during those days was 24%, 24%, and 24%, respectively. As for Tiam pesticide during days 12, 13, 14, and 15, the killing percentage was 20%, 20%, 28%, and 24%, respectively, compared to Radical, which gave the highest killing rate during days 15, 16, 17, and 17 after treatment with a killing percentage of 16%, 12%, 20%, and 24%. As for the required period to kill all the larvae, it was 26 days, as the pesticides gave efficacy of 100%, 96%, and 100% for Mospilan, Tiam, and Radical, respectively. However, when doubling the concentration of pesticides, the time needed to show the effectiveness of pesticides in killing larvae decreased significantly compared to using the lowest concentration of pesticides. The effectiveness of pesticides began after the second day of treatment and continued during days 3, 4, 5, 6, 7, and 8 after treatment, with a killing rate of 12%, 20%, 16%, 20%, 24%, and 8% in Mospilan, respectively (Table 4.5). As for Tiam, its effectiveness began at the same time as Mospilan, and its efficacy reached 8%, 32%, 28%, 24%, and 4% on days 3, 4, 5, 6, and 7 after treatment, respectively. As for Radical, it showed delayed effectiveness compared to Mospilan and Tiam. Its effectiveness began after a week of treatment and reached 24%, 16%, 20%, 12%, and 24% during days 8, 9, 10, 11, and 12 after the treatment, respectively (Table 4.5), where the final effectiveness of the pesticides reached 100% and 95.8% and 100% for Mospilan, Tiam, and Radical pesticides, respectively.

Table 4.4 The effectiveness of three neonicotinoids on the larvae of palm borers belonging to the genus Oryctes by using the method of direct spraying on the larvae when used at the lowest concentration under laboratory conditions

Days after treatment	Number of used larvae	**Treatment and Concentration**										
		Control (water)		Mospilan 0.5g/L water			Tiam 0.3g/L water			Radical 0.38ml/L water		
		Active substance										
		---------		Acetamiprid 20% Neonicotinods			Thiamethoxam 25% Neonicotinods			Imidacloprid 20% Neonicotinods		
		Number of dead larvae										
		Dead larvae	**Kill %**	**Dead larvae**	**Kill %**	**Efficancy %**	**Dead larvae**	**Kill %**	**Efficancy %**	**Dead larvae**	**Kill %**	**Efficancy %**
1	**25**	0	0	0	0	0	0	0	0	0	0	0
2	**25**	0	0	0	0	0	0	0	0	0	0	0
3	**25**	0	0	0	0	0	0	0	0	0	0	0
4	**25**	0	0	0	0	0	0	0	0	0	0	0
5	**25**	0	0	0	0	0	0	0	0	0	0	0
6	**25**	0	0	0	0	0	0	0	0	0	0	0
7	**25**	0	0	0	0	0	0	0	0	0	0	0
8	**25**	0	0	0	0	0	0	0	0	0	0	0
9	**25**	0	0	0	0	0	0	0	0	0	0	0
10	**25**	0	0	0	0	0	0	0	0	0	0	0
11	**25**	0	0	**1**	**4**	**4**	0	0	0	0	0	0
12	**25**	0	0	**1**	**4**	**4**	**5**	**20**	**20**	0	0	0
13	**25**	0	0	**6**	**24**	**24**	**5**	**20**	**20**	0	0	0
14	**25**	0	0	**6**	**24**	**24**	**7**	**28**	**28**	**1**	**4**	**4**
15	**25**	0	0	**6**	**24**	**24**	**6**	**24**	**24**	**4**	**16**	**16**
16	**25**	0	0	**2**	**8**	**8**	0	0	0	**3**	**12**	**12**
17	**25**	0	0	0	0	0	0	0	0	**5**	**20**	**20**
18	**25**	0	0	0	0	0	0	0	0	**6**	**24**	**24**
19	**25**	0	0	0	0	0	**1**	**4**	**4**	**2**	**8**	**8**
20	**25**	0	0	**1**	**4**	**4**	0	0	0	0	0	0
21	**25**	0	0	0	0	0	0	0	0	0	0	0
22	**25**	0	0	0	0	0	0	0	0	0	0	0
23	**25**	0	0	0	0	0	0	0	0	**1**	**4**	**4**
24	**25**	0	0	**1**	**4**	**4**	**1**	**4**		0	0	0
25	**25**	0	0	0	0	0	0	0	0	**2**	**8**	**8**
26	**25**	0	0	**1**	**4**	**4**	0	0	0	**1**	**4**	**4**
Net killing %	**---**	**0**	**0**	**25**	**100**		**24**	**96**		**25**	**100**	
Efficiency	**----**	**---**	**---**			**100**			**96**			**100**

The value of the least significant difference (LSD) for the number of dead larvae: 0.3140.

Table 4.5 The effectiveness of three neonicotinoids on the larvae of palm borers belonging to the genus Oryctes by using the method of direct spraying on the larvae when used at the highest concentration under laboratory conditions

Days after treatment	Number of used larvae	Treatment and Concentration										
		Control (water)		Mospilan 0.5g/L water			Tiam 0.3g/L water			Radical 0.38ml/L water		
		Active substance										
		---------		Acetamiprid 20% Neonicotinods			Thiamethoxam 25% Neonicotinods			Imidacloprid 20% Neonicotinods		
		Number of dead larvae										
		Dead larvae	**Kill %**	**Dead larvae**	**Kill %**	**Efficancy %**	**Dead larvae**	**Kill %**	**Efficancy %**	**Dead larvae**	**Kill %**	**Efficancy %**
1	**25**	0	0	0	0	0	0	0	0	0	0	0
2	**25**	0	0	0	0	0	0	0	0	0	0	0
3	**25**	0	0	**3**	**12**	**12**	**2**	**8**	**8**	0	0	0
4	**25**	0	0	**5**	**20**	**20**	**8**	**32**	**32**	0	0	0
5	**25**	0	0	**4**	**16**	**16**	**7**	**28**	**28**	0	0	0
6	**25**	0	0	**5**	**20**	**20**	**6**	**24**	**24**	**1**	**4**	**4**
7	**25**	0	0	**6**	**24**	**24**	**1**	**4**	**4**	0	0	0
8	**25**	0	0	**2**	**8**	**8**	0	0	0	**6**	**24**	**24**
9	**25**	0	0	0	0	0	0	0	0	**4**	**16**	**16**
10	**25**	0	0	0	0	0	0	0	0	**5**	**20**	**20**
11	**25**	0	0	0	0	0	0	0	0	**3**	**12**	**12**
12	**25**	0	0	0	0	0	0	0	0	**6**	**24**	**24**
13	**25**	0	0	0	0	0	0	0	0	0	0	0
14	**25**	0	0	0	0	0	0	0	0	0	0	0
15	**25**	0	0	0	0	0	0	0	0	0	0	0
16	**25**	0	0	0	0	0	0	0	0	0	0	0
17	**25**	0	0	0	0	0	0	0	0	0	0	0
18	**25**	**1**	**4**	**1**	0	0	0	0	0	0	0	0
19	**25**	0	0	0	0	0	0	0	0	0	0	0
20	**25**	0	0	0	0	0	0	0	0	0	0	0
21	**25**	0	0	0	0	0	0	0	0	0	0	0
22	**25**	0	0	0	0	0	0	0	0	0	0	0
23	**25**	0	0	0	0	0	0	0	0	0	0	0
24	**25**	0	0	0	0	0	0	0	0	0	0	0
25	**25**	0	0	0	0	0	0	0	0	0	0	0
26	**25**	0	0	0	0	0	0	0	0	0	0	0
Net killing %	**---**	**1**	**4**	**25**	**100**		**24**	**96**		**25**	**100**	
Efficiency	**----**					**100**			**95.8**			**100**

The value of the least significant difference (LSD) for the number of dead larvae: 0.3045

The results in Tables 4.4 and 4.5 indicate that all three pesticides were effective, but they differed in the duration of their killing of larvae. When using the lowest recommended concentration, it took a longer time compared to when doubling the concentration, at which point the effectiveness of the pesticides began after two days of treatment. On the other hand, the radical pesticide took longer than the two pesticides, Mospilan and Tiam, to start showing its effectiveness for both lower and higher concentrations. This may be due to the combination of pesticides or the difference between the nature of the effect of the active substances of the three pesticides, which are acetamiprid 20%, thiamethoxam 25%, and imidacloprid 20% for Mospilan, Tiam, and Radical, respectively. Faster effectiveness when increased concentrations were used might be due to the large body of the larva, which had an average weight of 6.91 grams and a length of 69.21 mm, which requires larger concentrations of the pesticide to show faster effectiveness. Experiments carried out by FAO (2000) showed that thiamethoxam (25% moved faster in plant tissues. This compound improves plant activity by triggering physiological reactions within the plant, allowing the plant to be active during conditions of heat stress, drought, low soil acidity, damage, pests, wind, cold, and viruses. This provides a faster effect, and the selective toxicity of thiamethoxam is due to its effect on acetylcholine receptors in insects. Conversely, acetamiprid interacts with the body in a manner similar to nicotine and is a natural insecticide that interacts with acetylcholine receptors (nACh-R), which are located in the dendrites of all neurons in the brain, spinal cord, ganglia, and muscle connections. It is highly toxic to insects and less toxic to mammals (Kimura-Kuroda *et al.* 2012). As for Imidacloprid, it has the ability to move through plant tissues after application and causes disruption of the nerve impulses of the targeted insects, causing them to die (Fossen 2006). This could explain the differences between pesticides in the mechanism of their onset of effectiveness as well as the difference in the composition of pesticides manufactured by different companies. . These results support what was found by Grosman et al. (2002), who conducted experiments on the use of the pesticide Imidacloprid by injecting it into the trunk one or two times to combat the *Pinus taeda L.* insect that infects loblolly pine trees. The pesticide was effective in reducing insect damage, gave protection to trees for a full year, and reduced the percentage of damage to seeds and cones by 86%. These results are also consistent with those found by (Amirzade et al. 2014) in a laboratory study on the effect of three neonicotinoid pesticides Acetamiprid, Thiamethoxam and Imidacloprid on the insect *Pistachio psylla, Agonoscena pistaciae*, it was found that the value of LC50 varies according to the age of the larvae, and as the larvae advanced in age, they needed a higher pesticide concentration, as the LC50 values reached: 56.35 mg/L, 60.75 mg/L and 138.21 mg/L for each of Thiamethoxam, Acetamiprid and Imidacloprid respectively, which indicates that the two pesticides Thiamethoxam and Acetamiprid were more effective than the pesticide Imidacloprid when compared by the amount of pesticide used. The pesticides Thiamethoxam and Acetamiprid reached LC50 values when they were used at a lower concentration than the pesticide Imidacloprid, and this matches what we have reached, where the concentration of the pesticide Radical (Imidacloprid) was higher than the two pesticides Mospilan (Acetamiprid) and Tiam (thiamethoxam), according to Table 3.1. In addition to that, the pesticide Radical took longer than the rest of the pesticides to start showing its effect on the larvae.

Larval food treatment: The results showed in Table 4.6 that the effectiveness of the pesticides in killing the larvae of palm borers belonging to the genus Oryctes began after 12, 13, and 15 days for Mospilan, Tiam, and Radical, respectively, when using the pesticides at the minimum concentration recommended by the manufacturers. Then, it reached the highest killing rate during days 12, 13, 14, and 15 after treatment with Mospilan, with killing percentages during those days of 20%, 24%, 24%, and 24%, respectively. As for the Tiam pesticide, it was during days 13, 14, 15, and 16 after the treatment, with a killing percentage of 24%, 24%, 24%, and 16%, respectively, compared to the Radical pesticide, which gave the highest killing rate during days 16, 17, 18, 19, and 20 with a killing percentage of 20%, 16%, 20%, 8%, and 24%, respectively. The period required to kill all the larvae was 25–26 days, when the pesticides gave efficacy of 100%, 100%, and 96% for each of Mospilan, Tiam, and Radical, respectively. As for the period required to kill all the larvae, it lasted 25–26 days, as it was given. When the concentration of pesticides was doubled, the period required to show the effectiveness of the pesticides in killing the larvae decreased significantly compared to when the lowest concentrations of pesticides were used. The effectiveness of the pesticides began after the third day of treatment and continued during days 4, 5, 6, 7, 8, and 9 after treatment, with a killing percentage of 4%, 24%, 28%, 24%, 16%, and 4% in Mospilan, respectively (Table 4.7). As for Tiam, its effectiveness began at the same time as Mospilan, and its efficacy reached 32%, 24%, 20%, 20%, and 4% on days 4, 5, 6, 7, and 8 after treatment, respectively. As for Radical, it showed delayed effectiveness compared to Mospilan and Tiam. Its effectiveness began after eight days of treatment and reached 12%, 24%, 28%, 28%, and 4% during days 9, 10, 11, 12, and 13 after treatment, respectively (Table 4.7), where the final effectiveness of the pesticides reached 100% and 95.8% for Mospilan, Tiam, and Radical pesticides, respectively. Table 10 shows that the killing rate and the effectiveness of the three pesticides did not change when they were used, whether at the lowest or highest concentration, and in both the method of direct spraying on the larvae or the treatment of the larvae's food, but there was a difference in the beginning of effectiveness. The pesticides began to be effective after 11–12 days when used at the lowest concentration, compared to three days when used at the highest concentration, except for Radical, whose effectiveness began late after nine days of treatment. However, all three pesticides showed high efficacy, ranging between 96 and 100%, but they differed among themselves in the beginning of efficacy in killing larvae for both the lowest and highest concentrations. From there, we can use pesticides at a lower concentration in order to achieve an economic aspect and reduce environmental pollution, taking into consideration the waiting time for the pesticides to start their action. The results of the daily monitoring of the larvae treated either by direct spraying or food treatment indicated that the larvae stopped feeding and lacked movement after treatment with pesticides, but it took a period of several days until they died. This might be explained by the large size and weight of the larvae, according to Table 4.6. (Matsuda et al. 2001; Miller and Denholm 2007) indicated that neonicotinoids, including thiamethoxam, acetamiprid, and imidacloprid, act on the insect nervous system by binding to choline receptors in neurons. This mode of action prevents neurotransmission, leading to general weakness of the nervous system and eventually death. This is what we found during this research, as pesticides caused lethargy in larvae and cessation of feeding. Also, Gaber et al. (2015) indicated in a study conducted to determine the effectiveness of the pesticides Thiamethoxam, Acetamiprid, and Imidacloprid on a cotton insect that these pesticides proved highly efficient against a cotton insect and caused a reduction in the population density of the insect ranging between 73 and 96%, and their effect lasted for 21 days after the treatment. This is consistent with the results that have been reached.

Table 4.6 The effectiveness of three neonicotinoids on the larvae of palm borers belonging to the genus Oryctes by using the larval food treatment method when used at the lowest concentration under laboratory conditions.

Days after treatment	Number of used larvae	**Treatment and Concentration**										
		Control (water)		Mospilan 0.5g/L water			Tiam 0.3g/L water			Radical 0.38ml/L water		
		Active substance										
		---------		Acetamiprid 20% Neonicotinods			Thiamethoxam 25% Neonicotinods			Imidacloprid 20% Neonicotinods		
		Number of dead larvae										
		Dead larvae	**Kill %**	**Dead larvae**	**Kill %**	**Efficancy %**	**Dead larvae**	**Kill %**	**Efficancy %**	**Dead larvae**	**Kill %**	**Efficancy %**
1	**25**	0	0	0	0	0	0	0	0	0	0	0
2	**25**	0	0	0	0	0	0	0	0	0	0	0
3	**25**	0	0	0	0	0	0	0	0	0	0	0
4	**25**	0	0	0	0	0	0	0	0	0	0	0
5	**25**	0	0	0	0	0	0	0	0	0	0	0
6	**25**	0	0	0	0	0	0	0	0	0	0	0
7	**25**	0	0	0	0	0	0	0	0	0	0	0
8	**25**	0	0	0	0	0	0	0	0	0	0	0
9	**25**	0	0	0	0	0	0	0	0	0	0	0
10	**25**	0	0	0	0	0	0	0	0	0	0	0
11	**25**	0	0	0	0	0	0	0	0	0	0	0
12	**25**	0	0	**5**	**20**	**20**	0	0	0	0	0	0
13	**25**	0	0	**6**	**24**	**24**	**6**	**24**	**24**	0	0	0
14	**25**	0	0	**6**	**24**	**24**	**6**	**24**	**24**	0	0	0
15	**25**	0	0	**6**	**24**	**24**	**6**	**24**	**24**	**1**	**4**	**4**
16	**25**	0	0	**1**	**4**	**4**	**4**	**16**	**16**	**5**	**20**	**20**
17	**25**	0	0	0	0	0	**1**	**4**	**4**	**4**	**16**	**16**
18	**25**	0	0	0	0	0	0	0	0	**5**	**20**	**20**
19	**25**	0	0	0	0	0	**1**	**4**	**4**	**2**	**8**	**8**
20	**25**	0	0	0	0	0	0	0	0	**6**	**24**	**24**
21	**25**	0	0	0	0	0	0	0	0	0	0	0
22	**25**	0	0	0	0	0	0	0	0	0	0	0
23	**25**	0	0	0	0	0	0	0	0	0	0	0
24	**25**	0	0	0	0	0	0	0	0	**1**	**4**	**4**
25	**25**	0	0	**1**	**4**	**4**	**1**	**4**	**4**	0	0	0
26	**25**	0	0	0	0	0	0	0	0	**1**	**4**	**4**
Net killing %	**---**	**0**	**0**	**25**	**100**		**25**	**100**		**24**	**96**	
Efficiency	**----**					**100**			**100**			**96**

The value of the least significant difference (LSD) for the number of dead larvae: 0.3001

Table 4.7 Efficacy of three neonicotinoids on larvae of palm borers belonging to the genus Oryctes using the larval diet method when used at the highest concentration under laboratory conditions

Days after treatment	Number of used larvae	Treatment and Concentration										
		Control (water)		Mospilan 0.5g/L water			Tiam 0.3g/L water			Radical 0.38ml/L water		
		Active substance										
		---------		Acetamiprid 20% Neonicotinods			Thiamethoxam 25% Neonicotinods			Imidacloprid 20% Neonicotinods		
		Number of dead larvae										
		Dead larvae	Kill %	Dead larvae	Kill %	Efficancy %	Dead larvae	Kill %	Efficancy %	Dead larvae	Kill %	Efficancy %
1	**25**	0	0	0	0	0	0	0	0	0	0	0
2	**25**	0	0	0	0	0	0	0	0	0	0	0
3	**25**	0	0	0	0	0	0	0	0	0	0	0
4	**25**	0	0	**1**	**4**	**4**	**8**	**32**	**32**	0	0	0
5	**25**	0	0	**6**	**24**	**24**	**6**	**24**	**24**	0	0	0
6	**25**	0	0	**7**	**28**	**28**	**5**	**20**	**20**	0	0	0
7	**25**	0	0	**6**	**24**	**24**	**5**	**20**	**20**	0	0	0
8	**25**	0	0	**4**	**16**	**16**	**1**	**4**	**4**	0	0	0
9	**25**	0	0	**1**	**4**	**4**	0	0	0	**3**	**12**	**12**
10	**25**	0	0	0	0	0	0	0	0	**6**	**24**	**24**
11	**25**	0	0	0	0	0	0	0	0	**7**	**28**	**28**
12	**25**	0	0	0	0	0	0	0	0	**7**	**28**	**28**
13	**25**	0	0	0	0	0	0	0	0	**1**	**4**	**4**
14	**25**	0	0	0	0	0	0	0	0	0	0	0
15	**25**	0	0	0	0	0	0	0	0	0	0	0
16	**25**	0	0	0	0	0	0	0	0	0	0	0
17	**25**	0	0	0	0	0	0	0	0	0	0	0
18	**25**	1	4	0	0	0	0	0	0	0	0	0
19	**25**	0	0	0	0	0	0	0	0	0	0	0
20	**25**	0	0	0	0	0	0	0	0	0	0	0
21	**25**	0	0	0	0	0	0	0	0	0	0	0
22	**25**	0	0	0	0	0	0	0	0	0	0	0
23	**25**	0	0	0	0	0	0	0	0	0	0	0
24	**25**	0	0	0	0	0	0	0	0	0	0	0
25	**25**	0	0	0	0	0	0	0	0	0	0	0
26	**25**	0	0	0	0	0	0	0	0	0	0	0
Net killing %	**---**	**1**	**4**	**25**	**100**		**25**	**100**		**24**	**96**	
Efficiency	**----**					**100**		**100**				**95.8**

The value of the least significant difference LSD for the number of dead larvae: 0.956

Table 4.8 Comparison of the killing rates caused by three neonicotinoids in the larvae of palm borers of the genus Oryctes when treated with different methods under laboratory conditions

Days after treatment	Direct spraying on larvae Kill %						Larvae food treatment Kill %					
	Lowest concentration			Highest concentration			Lowest concentration			Highest concentration		
	M	**T**	**R**	**M**	**T**	**R**	**M**	**T**	**R**	**M**	**T**	**R**
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	12	8	0	0	0	0	0	0	0
4	0	0	0	20	32	0	0	0	0	4	32	0
5	0	0	0	16	28	0	0	0	0	24	24	0
6	0	0	0	20	24	4	0	0	0	28	20	0
7	0	0	0	24	4	0	0	0	0	24	20	0
8	0	0	0	8	---	24	0	0	0	16	4	0
9	0	0	0	---	---	16	0	0	0	4	---	12
10	0	0	0	---	---	20	0	0	0	---	---	24
11	4	0	0	---	---	12	0	0	0	---	---	28
12	4	20	20	---	---	24	20	0	0	---	---	28
13	24	20	20	---	---	---	24	24	0	---	---	4
14	24	28	4	---	---	---	24	24	0	---	---	---
15	24	24	16	---	---	---	24	24	4	---	---	---
16	8	0	12	---	----	---	0	16	20	----	---	---
17	0	0	20	----	----	----	4	4	16	----	---	---
18	0	0	24	----	----	----	0	0	20	----	---	---
19	0	4	8	----	----	----	0	4	8	----	---	---
20	4	0	0	----	----	----	0	0	24	----	---	---
21	0	0	0	----	---	----	0	0	0	---	---	---
22	0	0	0	---	---	---	0	0	0	---	---	---
23	0	0	4	---	---	---	0	0	0	---	---	---
24	4	4	0	---	---	---	0	0	4	---	---	---
25	0	---	8	---	---	---	4	4	0	---	---	---
26	4	---	4	---	---	---		---	4	---	---	---
Total killing %	**100**	**100**	**100**	**100**	**96**	**100**	**100**	**100**	**100**	**100**	**100**	**96**

M = Mospilan, T = Tiam, R = Radical

4.6 Field experiments

Method of direct spraying on trees: The results in Table 4.9 indicated that there was no effect of the three pesticides on the larvae when used by direct spraying on the top of the palm tree at concentrations of 50 ml/100 liters of water, 30 ml/100 liters of water, and 37 ml/100 liters of water for each of the Mospilan, Tiam, and Radical, respectively, with a quantity of 5 liters of solution on top of each tree. The pesticides gave a very low killing rate of 12.50%, 11.11%, and 8.00% for Mospilan, Tiam, and Radical, respectively, and these values are close to the natural death rate of larvae under field conditions, which is 7.69%, where the corrected killing values indicated 5.2%, 3.7%, and 0.34% for Mospilan, Tiam, and Radical, respectively. The results of the statistical analysis also showed that there were no significant differences between the pesticides in the average number of larvae killed, which was 1.00, 0.75, and 0.50 dead larvae per tree. And there were no significant differences between the average number of dead larvae for the three pesticides and the comparison treatment, which amounted to 0.50 dead larvae per tree. This confirms the ineffectiveness of pesticides when used in this way and at the recommended concentrations. The results also showed that the average number of larvae ranged between 5-7 larvae at the top of each tree, as shown in Figure 4.3. Therefore, another experiment was carried out by increasing the concentration of pesticides and using a doubled concentration in order to ascertain the reasons for the decrease in the effectiveness of pesticides. Is it due to the lack of concentration used or to the method of treatment used? When used in direct spraying on the larvae of palm borers of the genus Oryctes, (Table 4.10) demonstrated that increasing the concentration of pesticides had no effect on their effectiveness. When the concentration was doubled to 100 ml/100 liters of water, 60 ml/100 liters of water, and 76 ml/100 liters of water for Mospilan, Tiam, and Radical, respectively, it gave a very low killing rate of 13.89%, 10.25%, and 9.38%. And a corrected killing rate of 8.51%, 4.64%, and 3.72% for each of the Mospilan, Tiam, and Radical pesticides, respectively, which confirms that there is no increase in the effectiveness of pesticides when the concentration used is doubled. The results of the statistical analysis also showed that there were no significant differences between the average number of dead larvae among the three pesticides on the one hand, as well as with the comparison study on the other hand, where the average number of dead larvae per tree was 0.50, 1.25, 1.25, and 0.75 for each comparison study for Mospilan, Tiam, and Radical, respectively, when the number of larvae ranged between 7-9 per tree. These results are consistent with what was found by Khalaf and Alrubaei (2016), who showed that the two systemic pesticides Confidor 200SL (Imidacloprid) and Actara 240SC (Thiamethoxam) in field studies on the Arabian Rhinoceros Beetle (*Oryctes agamemnon arabicus*) had no effect when used by direct spraying on top of the palm tree. Because a dead layer of fronds and fibers surrounds the trunks of palm trees, it's possible that these systemic pesticides' ineffectiveness when applied directly to trees is due to the pesticide's inability to absorb into the tissues of the outer palm tree. In addition, the new leaflets have a layer of white powder on them, and the respiratory stomata are present on the lower surface of the leaflet. Moreover, it has a small number and is immersed in the fabric. This is also confirmed by Mannion's (2019) mention that it is not recommended to use neonicotinoids by foliar spraying because they do not last long. It also confirms the results of McCullongh et al. (2011), who used emamectin benzoate as trunk injections, imidacloprid as trunk injections, and dinotefuran as a surface spray to control Agrilus planipenus, which causes severe damage to the trunks of ash trees *Fraxinus spp*. in the state of Michigan in the USA. It was found that the treated trees trunks by surface spraying with pesticides had a number of larvae similar to the control treatment.

Figure 4.3 Examination of trees to record the number of live and dead larvae of palm borers of the genus Oryctes when treated with pesticides (before and after examination)

Table 4.9 The effectiveness of some neonicotinoids on the larvae of palm borers belonging to the genus Oryctes using direct spraying method with lower concentration on date palm trees

Treatment	Active substance	Concentration	The amount per tree	The number of larvae per 4 trees after one month of treatment						Killing %	Corrected kill values %
				Alive		Dead		Total			
				T	A	T	A	T	A		
Control	Only water	------	5 L / tree	24	6.00a	2	0.50a	26	6.50a	7.69	-----
Mospilan	Acetamiprid 20% Neonicotinods	50 g / 100 L water	5 L / tree	28	7.00b	4	1.00a	32	8.00b	12.50	5.2
Tiam	Thiamethoxa m 25% Neonicotinods	30 g / 100 L water	5 L / tree	24	6.00a	3	0.75a	27	6.75a	11.11	3.70
Radical	Imidacloprid 20% Neonicotinods	38 ml / 100 L water	5 L / tree	23	5.75a	2	0.50a	25	6.25a	8.00	0.34

T=Total, A=Average, Averages followed by the same letters and the same column are not significantly different according to Duncan's multiple range test and under 5% probability

Table 4.10 The effectiveness of some neonicotinoids on the larvae of palm borers belonging to the genus Oryctes using direct spraying method with higher concentration on date palm trees

Treatment	Active substance	Concentration	The amount per tree	The number of larvae per 4 trees after one month of treatment						Killing %	Corrected kill values %
				Alive		Dead		Total			
				T	A	T	A	T	A		
Control	Only water	-------	5 L / tree	32	8.00a	2	0.50a	34	8.05a	5.88	-----
Mospilan	Acetamiprid 20% Neonicotinods	100 g / 100 L water	5 L / tree	31	7.75a	5	1.25a	36	9.00a	13.89	8.51
Tiam	Thiamethoxa m 25% Neonicotinods	60 g / 100 L water	5 L / tree	36	9.00b	5	1.25a	41	10.25 b	10.25	4.64
Radical	Imidacloprid 20% Neonicotinods	76 ml / 100 L water	5 L / tree	29	7.25a	3	0.75a	32	8.00a	9.38	3.72

T=Total, A=Average, Averages followed by the same letters and the same column are not significantly different according to Duncan's multiple range test and under 5% probability

The injection method in the trunks of palm trees is: Table 4.11 shows that injecting pesticides into the trunks of palm trees killed the most Oryctes palm borer larvae, with correct killing values of 100% for Mospilan, 91.67% for Tiam, and 64.00% for Radical. And the average number of dead larvae after one month of treatment was 6.00, 5.50, and 4.00 larvae/tree for each insecticide, respectively, compared to the absence of dead larvae in the control treatment. The results also showed that the pesticides Mospilan and Tiam showed high effectiveness compared to the pesticide Radical, which showed medium effectiveness, and this may be due to the combination of the pesticide by the manufacturer or its active substance. The statistical analysis showed that the number of dead larvae after being treated with pesticides was significantly different between Radical, Mospilan, and Tiam. There were also significant differences between the three pesticides and the control treatment. (Al-Sammariae et al. 2006) indicated that thiamethoxam is a fast-moving pesticide in palm trees and is distributed in the sap, on the sides of the injection site, and in most parts of the palm tree at different heights only after one hour of injection. The findings of this study are in line with those of Ahmed et al. (2010), who assessed the effectiveness of four systemic insecticides, Confidor 200 SL, Comodor 20% SL, Rinfidor 20% SL, and Actara 25 WG (Thiamethoxam), against the *Palmapsis phoenicis* on date palm in northern Sudan using trunk injection techniques with a rate of 6, 8, and 10 g/tree for the Actara 25 WG And that by making a hole with a depth of 15 cm and a diameter of 1.5 cm at an angle of 45 degrees, the death rates were calculated after two weeks of injection and up to 12 weeks after the treatment, and it was found that the pesticides gave a high killing rate compared to the control treatment (comparison), he also did not find any residues of pesticides in the fruits when harvesting, and he obtained an increased yield of 70% compared to untreated trees. He also found that this method of control affected the rest of the insects, especially termites, except for mites. It is also economically feasible and environmentally safe for mammals. These results are also consistent with what was found by Khalaf and Alrubiae (2016), who showed that the effectiveness of the two systemic insecticides Confidor 200SL (Imidacloprid) and Actara 240SC (Thiamethoxam) in the field on the palm borer *Oryctes agamemnon arabicus*, which infects palm trees, amounted to 85% and 100% for each of them, respectively, when used as injections into the trunk with a concentration of a 40 ml solution per tree (10 ml pesticide per liter of water) of Confidor insecticide. As for the Actara insecticide, it was used with a concentration of 10 ml of solution per tree (5 ml of pesticide per 5 ml of water). Fishel (2017) showed the possibility of injecting chemicals into tree trunks at a depth of 2-4 inches in the trunk using a high-pressure injector and with a height of 18 inches above the ground, depending on the diameter of the tree trunk. The diameter of the vascular bundles in date palm trees (Figures 4.4 and 4.5), which were studied, ranged between 1080 and 1180 micrometers, which can facilitate the transfer and distribution of the pesticide in all tissues of palm trees.

Figure 4.4 Cross section of a palm tree trunk

Figure 4.5 Vascular bundles in the trunk of a palm tree

Table 4.11 Efficacy of some neonicotinoids on the larvae of palm borers belonging to the genus Oryctes using injection method in the trunks of date palm trees

Treatment	Active substance	Concentration	The amount per tree	The number of larvae per 4 trees after one month of treatment						Killing %	Corrected kill values %
				Alive		Dead		Total			
				T	A	T	A	T	A		
Control	Only water	-------	20 ml / tree	27	6.75c		0.0a	27	6.75a	00.00	----
Mospilan	Acetamiprid 20% Neonicotinods	1 g / 2 ml water	20 ml / tree	0	0.00a	24	6.00b	24	6.00a	100.00	100.00
Tiam	Thiamethoxam 25% Neonicotinods	1 g / 3 ml water	20 ml / tree	2	0.50a	22	5.50b	24	6.00a	91.67	91.67
Radical	Imidacloprid 20% Neonicotinods	1 ml / 1.5 ml water	20 ml / tree	9	1.80b	16	4.00c	25	6.25a	64.00	64.00

T=Total, A=Average, Averages followed by the same letters and the same column are not significantly different according to Duncan's multiple range test and under 5% probability

Watering through soil method: The results in Table 4.12 indicate that the method of using systemic neonicotinoid insecticides by watering through the soil to control palm borers belonging to the genus Oryctes was very effective in controlling this pest, as it had an effectiveness of 100%, 90.69%, and 65.37% for each of Mospilan, Tiam, and Radical, respectively. The average number of dead larvae after one month of treatment was 5.00, 5.25, and 3.50 larvae per tree, while the number of living larvae averaged 0.00, 0.50, and 1.75 larvae per tree, respectively, compared to the control treatment, in which the average number of living larvae was 7 larvae per tree and the dead larvae was one per tree. The results of the statistical analysis indicated that there were significant differences between the three pesticides on the one hand and the comparison treatment on the other hand, as well as significant differences between the two pesticides Mospilan and Tiam on the one hand and the Radical pesticide on the other hand. This may be due to the combination of the pesticide by the producing company or because of the effect of its active substance.

Published research indicates the possibility of using systemic insecticides by pouring them near the root zone, provided that the soil is not saturated with moisture (Fishel 2017). Regarding that, Al-Jboory et al. (2001) indicated that the use of Actara 25 WG by injection, watering, and direct spraying methods in controlling the Dubas bug *Ommatissus lybicus* that infects palm trees was effective in reducing the population density and damage to this insect, knowing that this insect is found on the outer surface of the palm fronds and not hiding inside its tissues as it is for palm borers of the genus Oryctes. The results of this research supported what was found by Al-Jboory et al. (2001) (Khalaf and Alrubiae 2016), who showed that neonicotinoid systemic pesticides are very effective in controlling some insects that infect palm trees, such as dubas and borers, when used by watering through the soil. However, Grosman and Upton (2006) evaluated the effectiveness of four systemic insecticides—dinotefuran, emamectin benzoate, fipronil, and imidacloprid—against the pine bark beetle Pinus taeda. They found that emamectin benzoate achieved high efficiency against this insect and its associated wood borers in stressed trees. As for fipronil, it was also as effective as emamectin benzoate in reducing the population density of insects after 3-5 months of injection, but the effectiveness of the pesticides was for a period of one month after injection. As for the other two pesticides, imidacloprid and dinotefuran, they were found to be ineffective in preventing the spread and infestation of the pine beetle and its associated tree borers. Here, the results of the low effectiveness of imidacloprid coincide with what we have found about the low effectiveness of the radical pesticide (whose active substance is imidacloprid) in reducing the population density of Oryctes borers that infect date palm trees.

(Fishel 2017) showed some of the benefits that can be achieved when using pesticides by both injection and watering methods, as follows:

- ❖ It can be applied accurately to the target pest without being wasted or carried away by flowing water or wind.
- ❖ It can be applied during rain or high winds because there is no drift or water flow.

- The injection method can be used in places where soil treatments are not practical, effective, or inappropriate, such as trees that grow in excessively moist, sandy, compacted, or bound soils.
- Little exposure to non-targeted organisms or sensitive environments.
- Especially useful for borers, insects that make holes, whiteflies, and aphids.
- Watering methods avoid making cuts in trees.
- The watering method does not require application equipment.

The disadvantages are:

- Injection in the trunks causes cuts that facilitate the entry of pathogens. For the trees whose wood is hard, the cuts heal quickly, but for the trees whose wood is soft, their cuts will not heal quickly.
- Injections in the trunk are sometimes expensive and require labor.
- Injections in the trunk sometimes require repeated injections.
- The amount of pesticide used in the watering method is higher than in the injection method.
- Sometimes injection equipment can be expensive.

As for the comparison between the effects of the control method on the effectiveness of pesticides, Figure 4.12 showed that the treatment by injection and watering methods was very effective compared to the method of direct spraying on trees, which did not achieve any significant effectiveness, and this confirms what was found by McCullongh et al. (2011), who used emamectin benzoate injectable, imidacloprid injectable, and dinotefuran as a surface spray to control the ash borer *Agrilus planipenus*, which causes severe damage to the trunks of ash trees.For *Fraxinus spp*. in the state of Michigan in the USA, they found that treatment by injection in tree trunks reduced the number of borers in infected trees, but treatment by surface spraying on tree trunks was not effective. They also mentioned that the effectiveness of imidacloprid was low compared to emamectin benzoate and dinotefuran.

Table 4.12 Efficacy of some neonicotinoids on the larvae of palm borers belonging to the genus Oryctes by watering in the soil of date palm trees

Treatment	Active substance	Concentration	The amount per tree	The number of larvae per 4 trees after one month of treatment						Killing %	Corrected kill values %
				Alive		Dead		Total			
				T	A	T	A	T	A		
Control	Only water	-------	50 L / tree	27	6.75c	1	0.25a	28	7.00b	3.75	----
Mospilan	Acetamiprid 20% Neonicotinods	1 g / 5 L water	50 L / tree	00	0.00a	20	5.00c	20	5.00a	100.0 0	100. 00
Tiam	Thiamethoxa m 25% Neonicotinods	1 g / 7 L water	50 L / tree	2	0.50a	21	5.25c	23	5.75a	91.30	90.6 9
Radical	Imidacloprid 20% Neonicotinods	1 ml / 3.8 L water	50 L / tree	7	1.75b	14	3.50b	21	5.25a	66.67	65.3 7

T=Total, A=Average, Averages followed by the same letters and the same column are not significantly different according to Duncan's multiple range test and under 5% probability

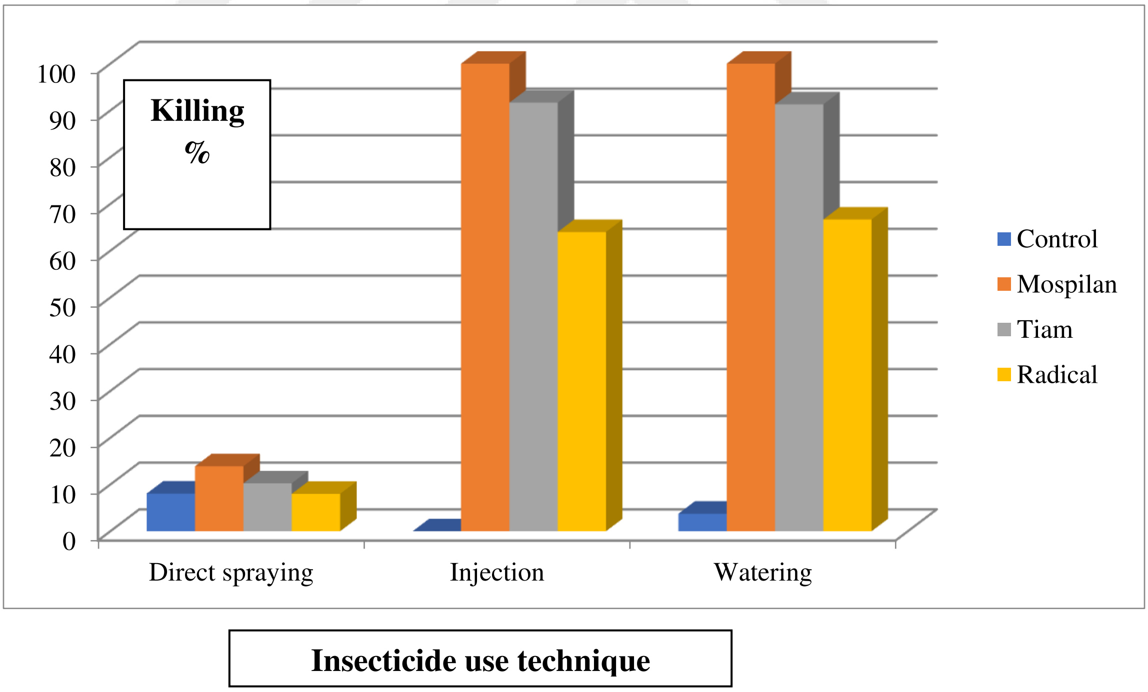


Figure 4.6 Efficacy of Mospilan, Tiam and Radical using three different methods in controlling palm borers of the genus Oryctes that infest date palm trees

5. CONCLUSION AND RECOMMENDATIONS

Conclusion:

- ❖ Palm trees are exposed to high damage due to infection with palm borers belonging to the genus Oryctes.
- ❖ Injecting Mospilan (Acetamiprid 20%), Tiam WG (25%), and Radical (Imidacloprid 20%) into the trunks of palm trees had a high effect on killing the larvae of palm borers belonging to the genus Oryctes.
- ❖ The technique of injecting pesticides into tree trunks does not require much equipment and is safe.
- ❖ The technique of injecting pesticides into the trunk and watering is highly effective in controlling palm borers and is environmentally safe.
- ❖ Injection and watering methods are less expensive and not harmful to beneficial insects.
- ❖ The method of injecting pesticides or watering was found to have an effect on the termites that infect the trunk of palm trees.
- ❖ There is no waste of pesticides because the waste is low.
- ❖ Using pesticides by injection and watering has a little impact on the environment and non-targeted pests.
- ❖ When using neonicotinoid pesticides, death of the targeted insects does not occur directly, but rather lethargy and nutrition ceasing, and after several days, death begins.
- ❖ Increasing the concentration of the pesticide does not mean an increase in killing or in the effectiveness of the pesticide; rather, it reduces the period required to eliminate the insect.

Recommendations:

- Mospilan (Acetamiprid 20%), Tiam WG (25% Thiamethoxam), and Radical (Imidacloprid 20%) can be relied upon to control palm borers within the integrated control programs for these pests.
- Conducting subsequent studies to follow up on the movement of pesticides in trees and their fading periods.
- Conducting subsequent experiments to develop an equation in which the appropriate amount of pesticide is determined in accordance with the diameter and height of the trunk of the palm tree, because the concentration of the pesticide will be diluted according to the size of the trunk of the palm tree.

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