Bionatura
Latin American Journal of Biotechnology and Life Sciences

Article

Efficiency and economic feasibility of using Neonicotinoids against Flat-headed borer *Chrysobothris affinis* (Fabricius, 1794) (*Buprestidae: Coleoptera*) infesting Jujube orchards in Basra Province, Iraq

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Available from. http://dx.doi.org/10.21931/RB/2023.08.04.57

ABSTRACT

A field study evaluated the efficiency and economic feasibility of using three Neonicotinoids to control Flat-headed borers infesting Jujube orchards in Basra Province during 2020 and 2021. The insecticides tested were Acetamiprid, Imidacloprid and Thiamethoxam, with recommended field application rates. This study showed that Acetamiprid and Imidacloprid provided the best protection to jujube trees, reflected in the high average efficiency (88.70% and 93.40%, respectively). Acetamiprid and Thiamethoxam enhanced the production, with an average of 60.10 and 60.00 kg/tree, respectively, compared to 39.50 kg of the check trees. Thus, the study showed the highest economic return from controlling the flat-headed borers using Acetamiprid and Thiamethoxam (5714900 and 5676500 dinars/ dunum, respectively). In contrast, the economic returns of Imidacloprid were 5082900 Iraqi dinars/ dunum. These results confirmed that the high economic feasibility was related to the efficacy of the low-cost insecticides in reducing the fruit infestation rate and increasing the yield.

Keywords: Buprestidae; Insecticides; flat-headed borers; Economic visibility; Neonicotinoids.

INTRODUCTION

Jujube tree (*Ziziphus* spp., Family: Rhamnaceae) is an evergreen fruit tree that grows in tropical, subtropical and warm temperate regions [1]. There are many cultivars in Iraq, including Tuffahi, Zaitooni and Hindi (*Z. mauritiana*), and Bambawi, Malasi and wild cultivars (*Z. spinachristi*) [2]. Jujube plantations spread mainly in the central and southern regions of Iraq; recently, they have been planted on a large scale in Basra Province due to the economic importance of these trees to smallholder farmers; there are around 146,720 trees in an area of 5,675 Iraqi dunams (Department of Horticulture-Basra, Ministry of Agriculture, 2021). The Tuffahi cultivar is the most desirable to consumers and farmers due to its high productivity and good fruit quality. [3]. The fruit of these trees is distinguished by its high nutritional value, as it contains many carbohydrates, ascorbic acid (vitamin C), and amino acids. [3,4].

Jujube trees are affected by several pests causing economic damage, such as *Tarucus rosaceus* (Lycaenidae: Lepidoptera) [5], and Jujube fruit fly *Carpomya incomplete* and *C. vesuviana* (Tephritidae: Diptera), which leads to fruit damage and fall, and consequently the lack of production as a result of infestation [6]. In recent years, Jujube trees have been infested with flat-headed borers *Chrysobothris affinis* (Buprestidae: Coleoptera) in Basra Province; this important pest caused significant economic damage to the trees [7].

Flat-headed borers infested more than 700 species of trees in North America [8]. These beetles attack the trunks of fruit, shade and ornamental trees, causing significant economic losses; it can cause a rapid decline in economically significant trees during severe infestations [9,10]. Most flathead borers can survive in the cold winter, as the glycerin accumulates in the larvae; the insect has one generation per year [11,12].

Flat-headed borers infesting different host trees are controlled by several insecticides, such as pyrethroids [13,14] and Neonicotinoids, which can reduce the damage of the infestations [14]. Neonicotinoid Insecticides are very applicable in controlling flat-headed borers; they can be effectively sprayed or soil-treated, including pellets, seed dressing, or injection [15]; several Neonicotinoids, such as Imidacloprid, against several borers, such as the flat-headed apple-tree borer, *Chrysobothris femorata* (Olivier) [16]. Also, Soil-treated insecticides (Imidacloprid and Thiamethoxam) were used against *C. femorata* (Olivier) infesting red maple (*Acer rubrum* L.) [13]. Neonicotinoids are systemic pesticides that move between plant tissues and provide protection for all parts of the plant; the mode of action of these insecticides includes the ability to bind with Nicotine Acetylcholine receptors (nAChRs), causing failure of the transmission of nerve impulses, paralysis and death within a few hours [17,18]. This study aimed to assess the efficiency of neonicotinoids against flat-headed borers infesting Jujube orchards and determine the economic feasibility of using these insecticides.

MATERIALS AND METHODS

Description of the Experiment Site

The experiment was carried out in seven orchards planted with Jujube trees in the Shatt Al-Arab district, southeast of Basra province (E 65932 N 87892, E 65975 N 87797, E 66041 N 87652, E66139 N 87916, E 66192 N 87835, E 66216 N 87717, E 65992 N 87734). Each orchard has 4 dunums; the Jujube tree cultivar (Tuffahi) is identical in size, age, and irrigation method. Each dunum contains 80 Jujube trees, and the distance between one tree and another is 4 meters.

Insecticides

Three Neonicotinoid insecticides (Acetamiprid, Imidacloprid and Thiamethoxam) were applied in two ways: spraying and soil drenching (Table 1) two times (10/5/2021 and 10/6/2021). Each insecticide was applied individually in different orchards. Overall, six treatments (3 insecticides and 2 applications) and the check treatment were carried out individually at the seven above private orchards. The spraying application was done using a 100-liter sprayer (Turkish-made), and the homogeneity of the spraying process was considered on all parts of the tree so that the spray covered all parts at a rate of 10-15 liters of solution per tree. However, a 20-liter watering plastic can was used in the soil drench treatments; to increase the efficiency of the pesticide absorption process, basins were made surrounding the trees to ensure the spread of the pesticide solution on all the tree roots.

Chemical name	Trade name	active ingredient % a.i	Formulation	Concentration of formulation (ml or g/ L)	Price (ID/ 1 L or Kg)	Company
Acetamiprid	Mospilan	20	S.P.	50	70000	Nippon Soda
Imidacloprid	Confidor	20	SL	50	100000	Bayer
Thiamethoxam	Actara	25	G.P.	50	80000	Syngenta

Table 1. Neonicotinoid insecticides used in the study and the use rate to control flat-headed borers.

Data Collection

Ten jujube trees in each orchard were sampled at the end of the growing season of 2020 and 2021. The infestation rates of flat-headed borers (*C. affinis*) were recorded in each Jujube orchard (treatment). The infestation rate (equation 1) of the pest was determined based on the symptoms of infestation on the trees (the presence of holes, dead branches, the presence of traces and feeding tunnels for larvae and gummy secretions), as well as cutting the branches that have symptoms and dissecting them and noting the presence of larvae inside the branches. The insecticide efficiency was calculated according to the Henderson-Tilton formula (2)

$$\text{Infestation rate} = \frac{\text{The number of infested trees}}{\text{Total number of trees}} \text{ X } 100 \qquad (1)$$

$$\text{Corrected \%} = \left(1 - \frac{\text{n in Co before application X n in T after application}}{\text{n in Co after application X n in T before application}}\right) \text{X } 100 \qquad (2)$$

Where, n = insect population, T= Treated, Co= control

Calculating the economic feasibility of using the pesticide

The production cost was calculated as follows:

The productivity of one dunum was calculated without the costs of application, harvesting and marketing by randomly selecting the productivity of 5 trees from each treated orchard and untreated orchard.

$$\text{The productivity of a dunum without control cost average production of one tree X number of Jujube trees pe}$$
$$\text{X average price of one kilogram during the season} \qquad (3)$$

Estimation of the cost of flat-headed borer's control:

The costs of the control process were calculated for each treatment according to the [19-21] method; the price of the insecticide was calculated as follows:

$$\text{Cost of insecticide applied (Quantity of insecticide applied (L) X insecticide concentration for 100 L of water}$$
$$\text{X price of 1 g or ml of the insecticide) / 100} \qquad (4)$$

The cost of inputs related to control for each application, including labor wages, was 50,000 Iraqi dinars for controlling 4 dunums, in addition to the cost of a 100 litres-sprayer of 10,000 Iraqi dinars.

The cost of inputs unrelated to control, including harvesting and transportation wages, was calculated using the following equation:

$$\text{Cost of inputs unrelated to control} = \text{Cost of harvesting} + \text{Cost of transportation} \quad (5)$$

The worker's wages = 25,000 Iraqi dinars/day; the cost of transporting 1000 kg of fruits = 50000 Iraqi dinars.

The average price of one kilogram of Jujube fruits of a Tuffahi Cultivar from the beginning to the end of the season is 4000 Iraqi dinars.
The economic return of using the insecticide per dunum was calculated according to the following equation:

$$\text{Economic return} = \text{Yield\_Price per controlled dunum} - (\text{the cost of the insecticide application} + \text{Yield\_Price per check dunum}) \quad (6)$$

Statistical analysis
The data were tested using analysis of variance (ANOVA), and means were compared using a Least Significant Difference (L.S.D.) test at $P \leq 0.05$.

RESULTS

Efficiency of Insecticide

The results of Table (2) showed that there were significant differences in the efficiency of the insecticides against flat-headed borers infesting jujube trees; the highest rate of efficiency was 93.40% of Imidacloprid, followed by Acetamiprid and Thiamethoxam with a rate of 88.70% and 83.30%. Also, the results indicated no significant differences between the application ways (spraying and soil drenching).

Insecticide	Efficiency of Insecticide %		Mean
	Spraying	Soil drench	
Acetamiprid	84.00±3.71	82.70±5.39	83.35±4.51
Imidacloprid	91.90±3.55	94.80±3.11	93.40±3.28
Thiamethoxam	87.60±7.14	89.8±3.82	88.7±5.59
Mean	87.80±5.01	89.1±4.37	
L. S. D (0.05)	NS		9.36

Interaction (insecticide X application) = N.S.

Table 2. Efficiency of Neonicotinoid insecticides against flat-headed borers.

Production

The results of Table (3) showed that there were significant differences between the productivity of the controlled Jujube trees compared to the check trees; the highest rate of production per tree for the pesticide Acetamiprid and Thiamethoxam were 60.10 and 60.00 kg/tree, respectively; however, the production of the trees controlled by Imidacloprid was 58.10 kg/tree, compared to 39.50 kg of the check trees; the results also

showed that there were no significant differences in the productivity of trees depending on the application ways (spraying and Soil-drench); The production of the trees were 55.60 and 53.25 kg/tree, respectively.

Insecticide	Production (Kg/tree)		Mean
	Spraying	Soil drench	
Acetamiprid	62.00±1.52	58.20±1.77	60.10±1.79
Imidacloprid	53.80±3.02	62.40±3.34	58.10±3.21
Thiamethoxam	61.20±1.59	58.80±1.68	60.00±1.65
Check	45.40±3.40	33.60±2.56	39.50±3.08
Mean	55.60±4.45	53.25±4.95	
L. S. D (0.05)	2.014		2.848

Interaction (insecticide X application) = 4.028

Table 3. Shows the productivity of trees in the treated and untreated jujube orchards.

Economic Feasibility

Results of the economic feasibility of using neonicotinoids against flat-headed borers infesting Jujube orchards (Table 4) indicated Imidacloprid recorded the highest cost of pest control, with an average of 97,500 Iraqi dinars per dunum, followed by Thiamethoxam and Acetamiprid, with an average of 81,500 and 73,500 Iraqi dinars per dunum, respectively. The study also showed that the highest economic return resulting from controlling the borer using Acetamiprid (5714900 dinars/ dunum), while the economic returns of Thiamethoxam and Imidacloprid were 5676500 and 5082900 Iraqi dinars/ dunum, respectively.

Insecticide	Insecticide efficiency (%)	Cost of insecticide/ 2 seasons	Application frequency	Application Cost (I.D.)	Production (kg/dunum)	Yield_ Price (I.D./dunum)	Economic return (I.D./dunum)
Acetamiprid	83.35	56,000	2	73,500	4808	19,232,000	5,714,900
Imidacloprid	93.40	80,000	2	97,500	4648	18,592,000	5,082,900
Thiamethoxam	88.70	64,000	2	81,500	4800	19,200,000	5,676,500
Check					3160	12,640,000	

Table 4. Economic feasibility of neonicotinoids-controlled flat-headed borers infesting Jujube orchards.

DISCUSSION

Determining the efficiency and net benefit of insecticide usage is fundamental to optimum use decisions and, therefore, insecticide regulation. The pest control frameworks provide an exciting pattern to model the economic feasibility of insecticides that are kept in practical work. Due to the previously slight concurrence regarding the right state of the pest control procedure, economists must work with entomologists to reach suitable usable forms that determine pest control and net benefits. In this study, the efficacy and economic feasibility of three Neonicotinoids (Acetamiprid Imidacloprid and Thiamethoxam) against flat-headed borers infesting Jujube trees was investigated; all the applied Neonicotinoids were efficient in decreasing the infestation rates of the borer on Jujube orchards. The highest production rates per tree were recorded for the pesticides Acetamiprid and Thiamethoxam; however, the lowest production was noticed on the trees controlled by Imidacloprid compared to the check trees. Imidacloprid recorded the highest cost of borer's

control, while the low-cost insecticide was Acetamiprid; however, the highest economic return resulting from controlling the borer using Acetamiprid, while Imidacloprid caused the lowest economic returns.

Many studies indicated the efficiency of Imidacloprid against different flat-headed borers; the flat-headed apple-tree borer, *C. femorata* (Olivier), was controlled by using Imidacloprid; this study indicated that this insecticide would be sufficiently compelling to uptake from the soil treatment and thus be well protected from flat-headed borer attack [16]. Also, soil-drench Neonicotinoids Imidacloprid and Thiamethoxam can support multi-year *C. femorata* management, increasing maple tree growth [14]. Neonicotinoids are systemic insecticides that protect plants from pests [22] due to their ability to transfer mainly through tissue Xylem, and the systemic properties of these pesticides give the ability to be distributed evenly in all parts of the plant [23,24].

The insecticide group is used to control insect pests by applying (soil treatment) or by spraying the vegetative parts; they are characterized by their systemic properties protecting treated plants for sufficient time; they work as contact and stomach poisons [25]. Although there were no significant differences between the application ways (spraying and soil-drench) of the insecticides depending on the results of this investigation, some studies indicated the disadvantages of tree sprays are that they must be treated at least two times annually. However, soil application-neonicotinoid could be applied only once at the start of the growing season [14].

CONCLUSIONS

The study showed that Neonicotinoids could be effectively sprayed or soil-treated against the flat-headed borers infesting Jujube orchards in Basra Province; Acetamiprid had a high rate of efficiency, reducing the damage of the infestation of the borer and increasing the production. That is reflected in the highest economic return resulting from controlling the borers. These results confirmed that the high economic feasibility was related to the efficacy of the low-cost insecticides in reducing the fruit infestation rate and increasing the yield.

Author Contributions: Conceptualization, A.M.M. and A.A.; methodology, A.M.M. and A.A.; software, A.M.M.; validation, A.M.M. and A.A.; formal analysis, A.M.M. and A.A.; investigation, A.M.M. and A.A.; resources, A.M.M. and A.A.; data curation, A.M.M.; writing—original draft preparation, A.M.M.; writing—review and editing, A.A.; visualization, A.A.; supervision, A.A.; project administration, A.A. Both authors have read and agreed to the published version of the manuscript.

Acknowledgments: The authors are very much thankful to the staff of the Natural History Museum at the University of Baghdad for confirming the I.D. of the species. Also, the authors thank the growers who let us conduct this study in their orchards.

Conflicts of Interest: The authors declare no conflict of interest

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Received: 26 September 2023 / Accepted: 15 April 2023 / Published:15 December 2023

Citation: Alderawii, M. M.; Alyousuf, A.; Efficiency and Economic Feasibility of using neonicotinoids against Flat-headed borers *Chrysobothris affinis* (Fabricius, 1794) (Buprestidae: Coleoptera) infesting Jujube orchards in Basra Province, Iraq. Revis Bionatura 2023;8 (4) 57. http://dx.doi.org/10.21931/RB/2023.08.04.57