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# Effect Of Nanoparticles On Some Biological Aspects Of The Lesser Grain Borer Beetle Rhyzopertha Dominica (Fab.) (Coleoptera: Bostrichidae)

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**ABSTRACT**

Lesser grain borer Rhyzopertha dominica (Fab.) (Coleoptera: Bostrichidae). It is one of the harmful and dangerous pests that attack stored crops, especially wheat, and because it feeds on a very important crop for all peoples of the world, it has become very important to develop methods of control for this insect away from the use of dangerous chemical pesticides. In this study some nanoparticles were used (ZnONPs, AgNPs and SeNPs) with different concentrations (250, 500, 750, 1000) ppm. These materials showed a significant effect on the life aspects of the insect. The average number of eggs was 185 in the treatment of AgNPs, while the average number of eggs was 201.46 and 191.8 in the two treatments of ZnONPs and SeNPs, respectively. The incubation period for eggs was 10.2 days in the treatment of AgNPs, while the incubation period for eggs was 8.93 and 9.35 days in the two treatments of ZnONPs and SeNPs, respectively. AgNPs had a significant effect on the duration of the larval stage, reaching 19.53 days, and the duration of the larval phase in the two treatments of ZnONPs and SeNPs was 18.33 and 18.46 days, respectively. As for the pupal stage, the period was 4.73 days in the treatment of AgNPs, 3.86 days in the treatment of ZnONPs, and 4.26 days in the treatment of SeNPs, the nanomaterials had a clear effect on the killing rate, as the killing rate in the adults of Rhyzopertha dominica reached 100% after 9 Days from the start of this experiment.

**Keywords**: Lesser grain borer, nanoparticles, Silver nanoparticles, Zinc nanoparticles, Selenium nanoparticles

## Introduction

Insects are considered among the pests of stores that are very harmful because they cause health damages such as allergens, skin ulceration, or respiratory damage through their residues on infected grains (Crombie, 1941). It was found that some flour beetles secrete quinines which act as carcinogens in laboratory animals. These pests lead to an increase in storage humidity, which leads to the growth of fungi that are harmful to the health of the consumer, One of the very harmful insects is the Lesser grain borer beetle, Rhyzoperta dominica (Fabricius, 1792), because it causes a significant decrease in the weight, quality and economic value of those infected grains (Bashir, 2002), if it works on contaminating the grains with its sloughed skins and the remains of dead insects and their faeces as well as gaining an unpleasant smell It is acceptable and causes great losses because it has strong jaws that dig inside the grain, in addition to that its larvae dig inside the grain and feed on its contents, leaving nothing but the peels (Duong, 2006).

Wheat is an annual plant of the species (F: Poaceae), and it is considered the main food for many peoples of the world, and it covers large parts of the surface of the global as it takes the largest area of any other food crop (. Jafer and Annon, 2018). One of the most important pests that affect stored wheat grains are insects. Its nutrition is on these grains, as its effect is not limited to the loss, but rather effectively affects the quality of the grains, as well as the damage exceeding the contamination of stored grains with the remnants of these insects and their shedding skins(Ghorpadie and Thyagarajan, 1980), Therefore, the process of storing and preserving seeds from the risk of infection with insect pests is a global strategic goal for all societies since creation because it is related to the food security requirements of these peoples.

Also, the stored materials, especially grains, are of great economic importance to the citizens of many peoples (Longstaff and Starick, 1989). From an economic point of view, the infestation of grain by insects leads to a loss of the weight of those seeds as well as to a reduction in their germination rate, as the losses caused by pests that affect the stored grain amounted to one billion dollars per year in the United States of America from the value of agricultural products, which is estimated at 25 billion dollars (Chanbang et al, 2008). It also consumes more than it needs in its food, in addition to its ability to pierce dry grains, which is difficult for most other insects to pierce and feed on. This insect is one of the important pests in Iraq, as it causes great losses as a result of its food on grains (David et al, 2002).

There are several methods for controlling warehouse insects, including the biological method, in which the parasites that have previously been raised in laboratories and prepared as pupae or adults are released and released repeatedly. In this process, eggs and larvae of stored pests are targeted, as in the Trichogramma sp. Where it can parasitize on a wide range of eggs of the Indian flour moth and Mediterranean flour moth and produces these parasites(Rouhani et al, 2012). A disadvantage of this method is that it is difficult for non-professionals to accomplish biological control given the many variables involved and the specialized knowledge of pests, biological factors, and environmental conditions that are often necessary for success. It in turn becomes a pest (Immaraju, 1998).

As well as chemical control, which is the use of a group of chemicals that work to kill pests or prevent them from multiplying, which ultimately leads to a reduction in their numbers. Chemical control is one of the traditional methods of pest control, as pesticides have shown good effectiveness and a high ability to kill insect pests, but these pesticides are a short-term solution to the pest problem. However, the unsafe use of pesticides has led to extensive damage to human health and the environment, as pesticides are one of the most common causes of poisoning around the world (Roberts and Reigart, 2013), and the excessive use of pesticides leads to the emergence of resistance in insect pests and the emergence of their residues in Crops, soils, high toxicity to animals and increased production cost (Hamed et al, 2012). One of the chemicals used in chemical control is phosphine. It was used during the thirties of the last century on a global scale as a fumigant and pesticide against storehouse and grain insects because of its effective cycle, cheapness and ease of use. However, high levels of resistance to phosphine were recorded by stored grain pests, especially Minor grain borer The beginning was in Bangladesh and more recently in India and tropical countries and in eastern Australia a clear resistance to phosphine began in the insect population (White and Lambkin, 1990) and using genetic techniques was identified the location of two genes conferring this trait. Because of these problems and because of the environmental concern associated with the accumulation of these pesticides in food crops and water sources, there was a need to develop efficient, safe and economical methods for controlling stocking insects.

Nanoparticles represent a new generation of environmental remediation technologies that can offer a cost-effective solution to some of the most challenging environmental clean-up problems: insects. Nanoparticles help produce a variety of insecticides (Rouhani et al, 2012). Nanotechnology has made a global impact through remarkable achievement in medicine, engineering, biological and agricultural sciences. Nano applications in the agricultural field represent one of the most important mechanisms to reach modern farming methods, which is summarized in the low economic cost necessary to treat epidemic diseases that affect various crops such as grains, as well as increasing the efficiency of manufactured fertilizers with low material cost and the resistance of the agricultural product to different environmental conditions. Nano-technologies and tools such as nanotubes, nanoparticles, and even nanocapsules are examples of the uses of disease detection and treatment, to enhance the absorption of plant nutrients (Sondi and Slopeak, 2004).

Nanoparticles can be used specifically to reduce damage to plant tissues. Nanomaterials offer great opportunities in the field of agriculture due to their unique physical and chemical properties. The interaction of nanoparticles with plants leads to many physiological and morphological changes. The researchers found that there are two types of negative and positive response of nanoparticles to plant growth depending on the properties of nanomaterials and the method of application. Nano science and technology are applied in the management of plant pests and diseases (Mohsen et al, 2017), as the control of nanomaterials has recently received great attention, specifically using them as pesticides in many studies to test their efficiency in combating many crop pests and disease vectors, mainly mosquitoes and ticks. However, accurate information about the mechanism of action These materials against insects are still limited (kaoud et al, 2013), however, many studies have proven the effectiveness of nanomaterials in combating some storehouse insects.

**Materials and Methods**

Lesser grain borer was isolated from infected wheat from the 18 to 25 of October 2020. Adult insect was diagnosed at the Natural History Research Center and Museum - University of Baghdad. The infected seeds were placed in plastic bottles of 1000 ml capacity, their cups were sealed with a muslin with good ventilation, and placed in the incubator at a temperature of 32 ±2 °C and relative humidity 70%±5 . a number of adults (♂ + ♀) about 200 adults were isolated and distributed in plastic bottles with a capacity of 1000 ml. Uninfected wheat seeds (Jihan category) were placed at a rate of 300 g / bottle. After two weeks, the adults were removed to obtain members of the new generation. The insect cultures were renewed after each generation and as needed. Wheat seeds that were not treated with insecticides or chemicals were obtained from the local market in Hawija district and before infesting the seeds with insects, they were manually cleaned to remove foreign matter and the samples were placed in the freezer at -20 temperature for 24 hours to eliminate any possible infection (Russo and Garzia, 2017).

**Nanomaterials used in this study**

The nanoparticles used in this study were purchased locally from Scientific market in Baghdad governorate as follows:

1- Zinc Oxide Nanoparticles(ZnONPs): It is a white powder with a size of 50 nm and purity of 99.5% manufactured by US Research nanomaterials, Inc.

2- AgNPs (AgNPs): It is a black powder with a size of 20 nm and a purity of 99.9% manufactured by Hongwu International Group Ltd.

3- Silenium Nanoparticles (SeNPs): It is a black powder with a size of 50 nm and purity of 99.5% manufactured by Hongwu International Group Ltd.

**Productivity**

To determine the effect of nanoparticles on the productivity of Lesser grain borer healthy wheat seeds were cleaned and sterilized in the freezer at -20°C for 24 hours, soaked in 10 ml of the substance and for all nanoparticles. The seeds were later dried on filter paper at room temperature. The seeds were distributed in 9 cm Petri dishes for 5 g / dish, with three replications for each concentration as well as control treatment, Five pairs of newly hatched insect ( 5 ♂ +5 ♀) were introduced in each dish, The lid a plate with porous cloth to provide good ventilation for insect, and placed in the incubator at a temperature of 32 ° C . The relative humidity was set at 70 + 5%, The percentage of productivity were calculated by applying Abbott formula later (kaoud et al, 2013), Average number of out coming insect and average number of Laid eggs were calculated in all treatment sample as well as control (Tabu et al, 2018):

$$\text{Productivity \%} = \frac{\text{Av. Number of outcoming insects}}{\text{Av. Number of laid eggs}} \times 100$$

**Incubation period of eggs, duration of the larval stage and the duration pupal stage.**

Ten gm. of crushed wheat seeds placed in size 9 cm Petri dishes. Crushed wheat grains of the aforementioned size are the best food medium for obtaining lesser grain borer pupae, a 5 newly hatched pairs ( 5 ♂ + 5 ♀) were introduced and placed in the incubator at a temperature of 32 ° C . The relative humidity was set at 70 + 5%, with daily monitoring, Three days later, the insects were removed dish and only 10 eggs left in each plate and re incubated. Under the anatomical microscope (Olympus MH, Japan).

**statistical analysis**

The results were statistically analyzed as a factorial experiment according to a completely randomized design using the SAS - V9 program, and the means were compared using the Least Significant Difference ( LSD ) test at a level of significance of 0.05 % .

**Mortality**

Wheat seeds were placed in plastic bottles in 250 ml at 30 g/bottle for each concentration of the studied concentrations. Five newly hatched pairs of insect were introduced (5♂ + 5♀) in each container placed in the incubator at a temperature of 32°C, and relative humidity was set at 70 + 5%, The number of dead insects was calculated from 1 - 12 days. the percentage of mortality was calculated according to following formula: (Hill, 2002).

$$\text{Mortality \%} = \frac{\text{Av. Number of dead insects}}{\text{Total number of insects}} \times 100$$

**Results and discussion**

**Characterize of nanoparticles**

The nanoparticles used in this study were Characterize using SEM. The size and shape were determined from SEM images. The results showed average is 50, 34 , 56 for ZnNPs وAgNPs and SeNPs respectively (Fig. 1, 2 and 3).

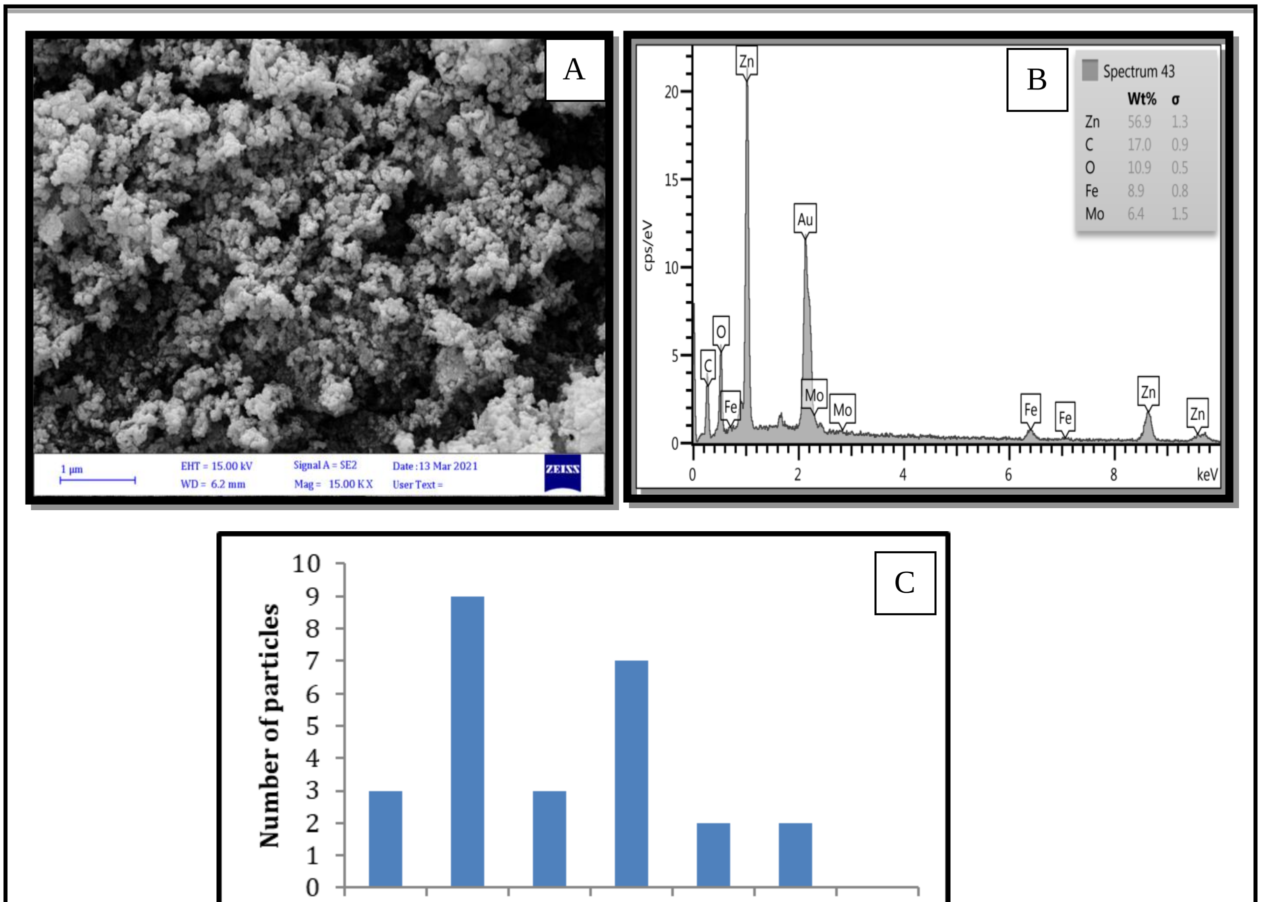
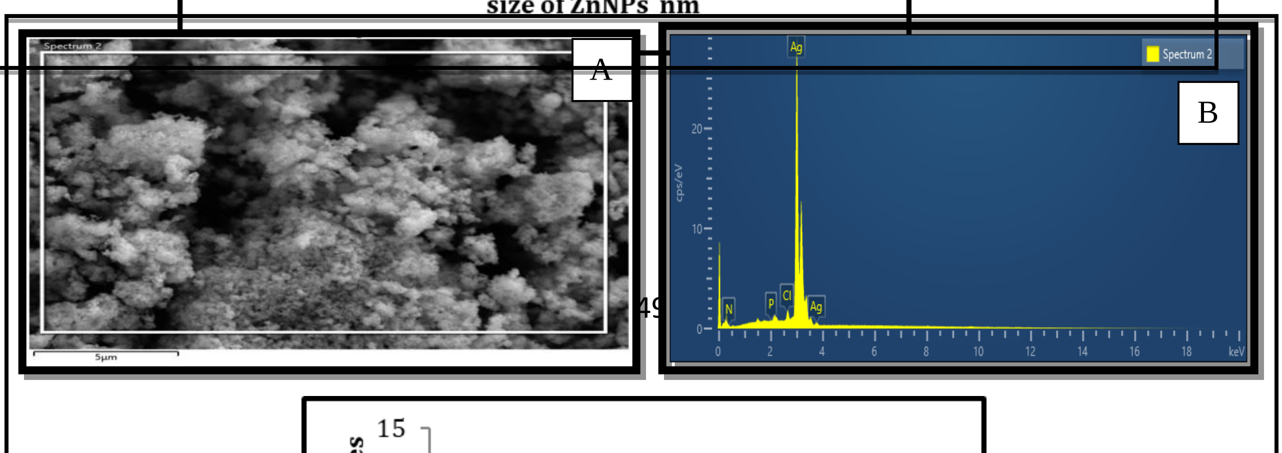



Figure 1. characterization of ZnNPs: A- Scanning electron micrograph. B- Absorbance. C- rate of particle size



C

Figure 2. characterization of AgNPs:  A- Scanning electron micrograph.  B- Absorbance. C- rate of particles size

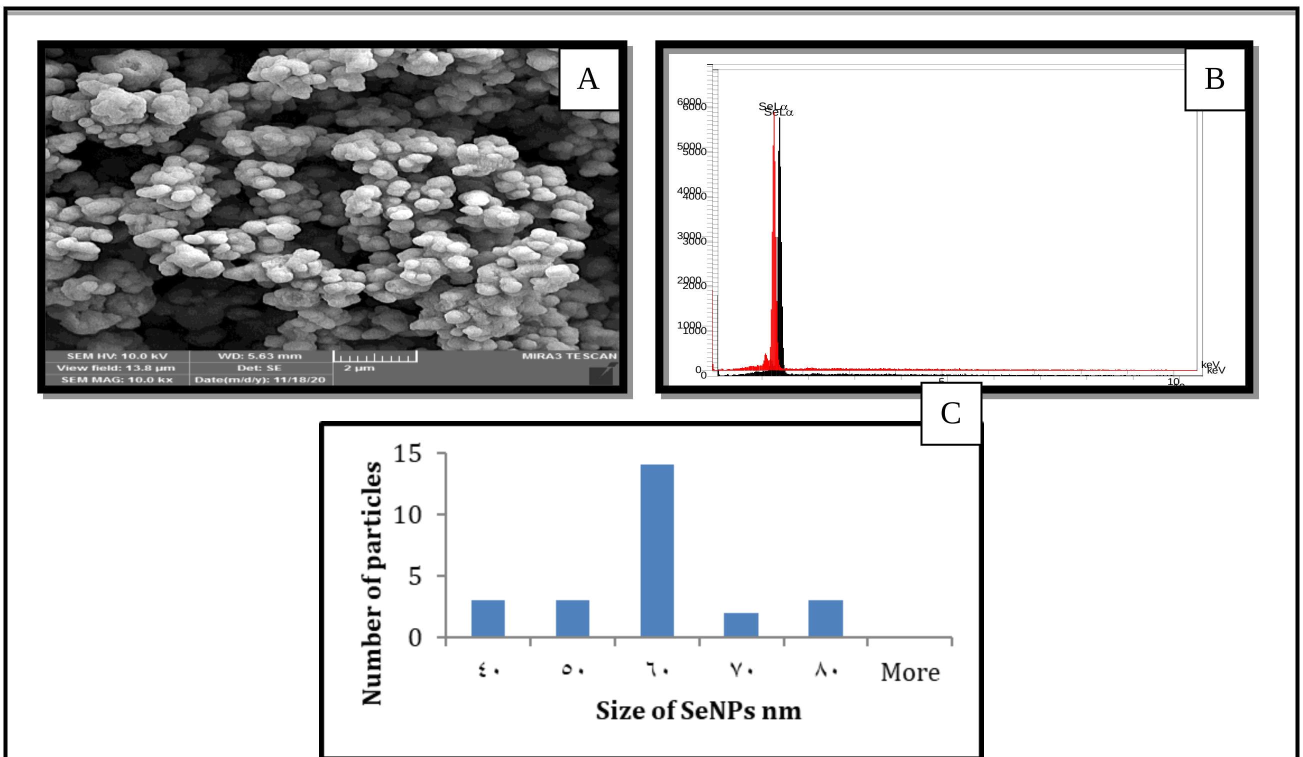



Figure 3. characterization of  SeNPs:  A- Scanning electron micrograph.  B- Absorbance. C- rate of particles size

**Effect of nanoparticles on the productivity**

The results of table (1) show that AgNPs were more influential on the average number of eggs laid, which amounted 185 eggs, compared to ZnNPs and SeNPs, which averaged 201.46 and 191.8, respectively. The results in the same table indicate the superiority of AgNPs in its impact on the number of insects, which amounted to 127.26 insects, compared to ZnNPs, which had an average number of exiting insects of 154.66 insects, and SeNPs, which had an average number of exiting insects of 134.8 insects.  The results also showed that the productivity rate reached 56.4% when using AgNPs, while the productivity rate when using ZnNPs was 67.99% and 59.03% when using SeNPs. The reason for the decrease in the number of insects emerging from seeds treated with high concentrations of nanoparticles is due to the decrease in the number of eggs laid on those seeds.

Concerning the effect of the concentrations, the results showed that the concentrations had an opposite effect with the average number of eggs laid and the average number of outgoing insects, and the concentration was 1000 ppm. The effect was the greatest, as the number of eggs laid was 103.66 eggs, while the number of eggs laid in the control treatment was 345 eggs. In addition to the fact that the number of exited insects at the same concentration mentioned was 29.66 insects, while the number of exited insects in the control treatment was 334.66. The productivity at the same mentioned concentration amounted to 28.27%, while it was 97.00% in comparison. The reason for the decrease in the number of eggs laid by the adults of lesser grain borer with the increase in concentrations may be due to the fact that this increase may lead to a shortening of the lifespan of the adults and consequently a short period of laying eggs, which leads to a decrease in the number of eggs laid.

As for the interaction between nanomaterials and their concentrations, the results showed that AgNPs at a concentration of 1000 ppm. The most influential in the number of eggs laid and the number of excreted insects, as the number of eggs was 97 eggs. The number of excreted insects was 21.33, with a productivity of 21.99% while the concentration was 250 ppm. ZnNPs had the least effect on the number of eggs laid, which amounted to 262.33 eggs, and the least effect on the number of outside insects, which amounted to 215 insects, with a productivity of 81.95%. The superiority of AgNPs used in the study could be due to the fact that these particles inhibit the host's odor chemoreceptors and prevent them from laying eggs. These results are in line with the findings of ( Malaikozhunda and Vinodhinib,2018).

From the above results, it is clear that nanomaterials have a clear effect on the productivity of the lesser grain borer, as the largest average number of eggs was 201.46 eggs in the ZnNPs treatment, while the average number of eggs was 345 eggs in the comparison treatment. The highest rate of 154.66 insects was in the ZnNPs treatment, while the average number of exited insects in the control treatment was 344.66 insects. The reason for the reduction in productivity may be the death of the larvae inside the seeds due to the small size of these nanoparticles and their high ability to penetrate into the insect’s body through the holes. This may be due to the fact that the effect of nanomaterials has reached the ovaries and eggs, which in turn affects the fertility of adult females. This is consistent with what is mentioned (Benelli, 2018) that AgNPs have an effect on the main genes in the insect, which in turn reduces protein synthesis and affects the secretions of the gonads, leading to reproductive failure as shown by (Kamil et al, 2017) that the fruit fly D. melanogaster when eating AgNPs during the adult stage for a short or long period have a detrimental effect on survival and lifespan and affect the future size of ovaries and their ability to lay eggs by adults, and that these negative effects are transmitted to subsequent generations. This was explained by the fact that AgNPs affect the release of the ecdysone hormone, which is responsible for the development of ovaries, which in turn leads to the formation of a small ovary that lacks eggs and thus weakens the reproductive ability of females.

**Table 1 Effect of nanoparticles on Productivity**

| The rate of nanomaterial effect | number of eggs | The number of outgoing insects | Productivity |
|---|---|---|---|
| **ZnNPs** | 201.46 [a] | 154.66 [a] | 67.99 [a] |

| | | | | |
|---|---|---|---|---|
| **AgNPs** | | 185.00 $^{c}$ | 127.26 $^{c}$ | 56.40 $^{c}$ |
| **SeNPs** | | 191.80 $^{b}$ | 134.80 $^{b}$ | 59.03 $^{b}$ |
| **LSD 5 %** | | 3.19 | 2.59 | 0.13 |
| **Effect rate of nanomaterials concentration** | | | | |
| **0** | | 345.00 $^{a}$ | 334.66 $^{a}$ | 97.00 $^{a}$ |
| **250** | | 241.55 $^{b}$ | 181.22 $^{b}$ | 74.69 $^{b}$ |
| **500** | | 152.77 $^{c}$ | 98.33 $^{c}$ | 64.08 $^{c}$ |
| **750** | | 120.77 $^{d}$ | 50.66 $^{d}$ | 41.65 $^{d}$ |
| **1000** | | 103.66 $^{e}$ | 29.66 $^{e}$ | 28.27 $^{e}$ |
| **LSD 5 %** | | 4.127 | 3.3504 | 0.175 |
| **Interaction between nanomaterials and their concentrations** | | | | |
| **ZnNPs** | **0** | 345.00 $^{a}$ | 334.66 $^{a}$ | 97.00 $^{a}$ |
| | **250** | 262.33 $^{b}$ | 215.00 $^{b}$ | 81.95 $^{b}$ |
| | **500** | 162.00 $^{d}$ | 116.66 $^{e}$ | 72.01 $^{d}$ |
| | **750** | 127.66 $^{f}$ | 65.00 $^{h}$ | 50.91 $^{h}$ |
| | **1000** | 110.33 $^{h\ i}$ | 42.00 i j | 38.06 $^{j}$ |
| **AgNPs** | **0** | 345.00 $^{a}$ | 334.66 $^{a}$ | 97.00 $^{a}$ |
| | **250** | 227.66 $^{c}$ | 157.00 $^{d}$ | 68.96 $^{e}$ |
| | **500** | 141.33 $^{e}$ | 83.33 $^{g}$ | 58.96 $^{g}$ |
| | **750** | 114.00 $^{h\ g}$ | 40.00 $^{j}$ | 35.08 $^{k}$ |
| | **1000** | 97.00 $^{j}$ | 21.33 $^{k}$ | 21.99 $^{m}$ |
| **SeNPs** | **0** | 345.00 $^{a}$ | 334.66 $^{a}$ | 97.00 $^{a}$ |
| | **250** | 234.66 $^{c}$ | 171.66 $^{c}$ | 73.15 $^{c}$ |
| | **500** | 155.00 $^{d}$ | 95.00 $^{f}$ | 61.28 $^{f}$ |
| | **750** | 120.66 $^{f\ g}$ | 47.00 $^{i}$ | 38.95 $^{i}$ |
| | **1000** | 103.66 $^{I\ j}$ | 25.66 $^{k}$ | 24.76 $^{l}$ |
| **LSD 5 %** | | 7.14 | 5.80 | 0.303 |

**Effect of nanomaterials on the incubation period of eggs, the duration of the larval stage and the duration of the pupae stage of lesser grain borer**

The results in Table (2) show the effect of nanomaterials on the incubation period of eggs, as we note that AgNPs recorded the highest effect in prolonging the incubation period, which amounted to 10.2 days, while there was no significant difference between the effect of both ZnNPs and SeNPs, as their average effect was 8.93 and 9.33 days, respectively. The interaction between the materials and their concentrations showed that there were no significant differences between ZnNPs and SeNPs at the two concentrations of 250 ppm and 500 ppm. The rate of the effect of nano-Zn at a concentration of 250 ppm reached 8 days and the same rate was for SeNPs at the same concentration, and the effect of ZnNPs was equal to that of SeNPs at a concentration of 500 ppm which reached 8.66 days, while there were significant differences at the two concentrations of 750 ppm and 1000 ppm between the same two substances. They showed the superiority of nanoparticles of selenium, as the incubation periods reached 10.66 and 11.66 days, respectively.

**Table 2 Effect of nanoparticles on the Incubation period of eggs, duration of the larval stage and the duration pupal stage**

| Impact rate of nanomaterials | | Virgo period | Larval period | incubation period |
|---|---|---|---|---|
| **ZnNPs** | | 3.86 $^{b}$ | 18.33 $^{b}$ | 8.93 $^{b}$ |
| **AgNPs** | | 4.73 $^{a}$ | 19.53 $^{a}$ | 10.20 $^{a}$ |
| **SeNPs** | | 4.26 $^{ab}$ | 18.46 $^{b}$ | 9.33 $^{b}$ |
| **LSD 5 %** | | 0.48 | 0.45 | 0.47 |
| **Effect rate of nanomaterials concentration** | | | | |
| **0** | | 3.00 $^{e}$ | 16.33 $^{d}$ | 7.66 $^{e}$ |
| **250** | | 3.44 $^{d}$ | 18.11 $^{c}$ | 8.44 $^{d}$ |
| **500** | | 4.22 $^{c}$ | 19.11 $^{b}$ | 9.11 $^{c}$ |
| **750** | | 5.00 $^{b}$ | 19.66 $^{b}$ | 10.66 $^{b}$ |
| **1000** | | 5.77 $^{a}$ | 20.66 $^{a}$ | 11.55 $^{a}$ |
| **LSD 5 %** | | 0.62 | 0.59 | 0.608 |
| **Interaction between nanomaterials and their concentrations** | | | | |
| **ZnNPs** | **0** | 3.00 $^{e}$ | 16.33 $^{g}$ | 7.66 $^{f}$ |
| | **250** | 3.00 $^{e}$ | 17.66 $^{f}$ | 8.00 $^{f}$ |
| | **500** | 3.66 $^{de}$ | 18.66 $^{ef}$ | 8.66 $^{e f}$ |
| | **750** | 4.33 $^{cd}$ | 19.00 $^{de}$ | 9.66 $^{cde}$ |
| | **1000** | 5.33 $^{abc}$ | 20.00 $^{bcd}$ | 10.66 $^{bc}$ |
| **AgNPs** | **0** | 3.00 $^{e}$ | 16.33 $^{g}$ | 7.66 $^{f}$ |
| | **250** | 3.66 $^{de}$ | 19.00 $^{de}$ | 9.33 $^{de}$ |
| | **500** | 4.66 $^{bcd}$ | 20.00 $^{bcd}$ | 10.00 $^{cd}$ |
| | **750** | 6.00 $^{a}$ | 20.66 $^{ab}$ | 11.66 $^{ab}$ |
| | **1000** | 6.33 $^{a}$ | 21.66 $^{a}$ | 12.33 $^{a}$ |
| **SeNPs** | **0** | 3.00 $^{e}$ | 16.33 $^{g}$ | 7.66 $^{f}$ |
| | **250** | 3.66 $^{de}$ | 17.66 $^{f}$ | 8.00 $^{f}$ |
| | **500** | 4.33 $^{cd}$ | 18.66 $^{ef}$ | 8.66 $^{ef}$ |
| | **750** | 4.66 $^{bcd}$ | 19.33 $^{cde}$ | 10.66 $^{bc}$ |
| | **1000** | 5.66 $^{ab}$ | 20.33 $^{bc}$ | 11.66 $^{ab}$ |
| **LSD 5 %** | | 1.08 | 1.024 | 1.05 |

The results also show that the incubation period is directly affected by the concentrations, as they showed that the incubation period increases the higher the concentration. Therefore the concentration exceeded 1000 ppm at all concentrations, it reached 11.55 days. This means that nanomaterials affect the life of the lesser grain borer, and thus it can act as insecticides. These results are consistent with the findings of (Rouhani et al, 2012), showed in her study on the effect of ZnONP nanoparticles and silver AgNPs nanoparticles on the life of the southern Callosobruchus maculatus C. that these materials have prolonged the incubation period of eggs.

Results of the table (2) show that the duration of the larval stage is directly affected by the concentrations, as it was found that it increases with the concentration and the concentration exceeds 1000 ppm on all concentrations. The duration of the larval stage at this concentration was 20.66 days. The results of the effect of the substance showed a significant difference between nano silver on the one hand and nano zinc and nano selenium on the other hand, as nano silver had the most effect in prolonging the duration of the larval stage. It reached 19.53 days, while there was no significant difference between the effect of ZnNPs and SeNPs, as their average effect reached 18.33 and 18.46 days, respectively.

The interaction between the materials and their concentrations showed that there were no significant differences between ZnNPs and SeNPs at the two concentrations of 250 ppm and 500 ppm. The rate of the effect of nano-Zn at a concentration of 250 ppm reached 17.66 days and the rate of nanoparticles of selenium was the same and at the same concentration. The effect of nanoparticles of zinc was equal to that of nanoparticles of selenium at a concentration of 500 ppm which amounted to 18.66 days, while there were significant differences at concentration 1000 ppm among the nanomaterials. The results showed the superiority of AgNPs, as the duration of the larval stage reached 21.66 days.

We show in table (2) that the significant differences in the rate of effect of each of the nanomaterials used in the study, as the results showed the superiority of AgNPs, as the average duration of the pupae phase reached 4.73 days, followed by SeNPs at a rate of 4.26 days and ZnNPs at an average of 3.86 days respectively.

The average effect of the concentrations of nanomaterials also shows that the duration of the pupae phase is directly proportional to the concentrations. The higher the concentration, the longer the incubation period, as we notice that the concentration exceeds 1000 ppm with an average amounted 5.77 days

The interaction between the nanomaterials and their concentrations shows that there is no significant difference at the concentration of 250 ppm between AgNPs and SeNPs, where the average duration of the pupae phase reached 3.66 days. While, we notice significant differences at all other concentrations and for all nanomaterials with the superiority of AgNPs in prolonging the duration of the pupae phase. These results are consistent with the (Malaikozhunda and Vinodhinib,2018) indicating that nanomaterials have a significant effect in increasing the period of the parthenogenesis.

**Effect of nanomaterials on the lesser grain borer killing rate**

The mortality was calculated daily and from the first day of the experiment. The first day was deleted from the statistical table because no killing occurred on that day. It is noted from the results in Table (3) that there is no significant difference on the second day between any of the nanomaterials, while the results show the superiority of all from each of SeNPs and AgNPs on the third day down to the eighth day, whereas there was no significant difference between any of the nanomaterials on the ninth day of the experiment.

As for the average concentrations of nanomaterials used in the study, the results showed that the concentration exceeded 1000 ppm Since the second day of the experiment, the killing rate was 6.48%, while the killing rate on the same day was 2.77% in the comparison treatment. This superiority continues until the eighth day of the experiment, and it was noticed that the concentration exceeded 1000 ppm at a rate of 100.0%, followed by a concentration of 750 ppm at a rate of 98.14% with no significant difference between the two rates. It was noticed on the ninth day that there is no significant difference in the average killing rate for all concentrations, as all insects were killed in the workers, while the rate of killing in the comparison treatment was 47.22%. It is clear from the foregoing that the mortality is directly proportional to the concentration used.

The results of the interaction between nanomaterials and their concentrations on the second day showed the superiority of AgNPs and SeNPs at a concentration of 1000 ppm over the rest of the nanomaterials and other concentrations with killing rate at 8.33%, followed by the treatment of SeNPs at a concentration of 750 ppm

**Table 3 Effect of nanoparticles on the percentage of mortality**

| Impact rate of nanomaterials | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| **ZnNPs** | | 1.11 $^{a}$ | 7.77 $^{b}$ | 21.11 $^{b}$ | 35.55 $^{b}$ | 56.66 $^{b}$ | 70.55 $^{b}$ | 82.77 $^{b}$ | 89.44 $^{a}$ |
| **AgNPs** | | 3.88 $^{a}$ | 15.00 $^{a}$ | 31.11 $^{a}$ | 51.11 $^{a}$ | 68.88 $^{a}$ | 80.00 $^{a}$ | 87.22 $^{a}$ | 89.44 $^{a}$ |
| **SeNPs** | | 3.33 $^{a}$ | 12.22 $^{a}$ | 29.44 $^{a}$ | 47.22 $^{a}$ | 65.55 $^{a}$ | 78.88 $^{a}$ | 87.77 $^{a}$ | 89.44 $^{a}$ |
| **LSD 5 %** | | 3.07 | 4.14 | 5.32 | 5.32 | 4.24 | 4.14 | 2.26 | 1.60 |
| **Effect rate of nanomaterials concentration** | | | | | | | | | |
| **0** | | 2.77 $^{ab}$ | 5.55 $^{c}$ | 5.55 $^{d}$ | 13.88 $^{d}$ | 22.22 $^{d}$ | 25.00 $^{d}$ | 38.88 $^{c}$ | 47.22 $^{b}$ |
| **250** | | 0.92 $^{b}$ | 9.25 $^{bc}$ | 24.07 $^{c}$ | 44.44 $^{c}$ | 64.81 $^{c}$ | 80.55 $^{c}$ | 96.29 $^{b}$ | 100.0 $^{a}$ |
| **500** | | 0.92 $^{b}$ | 11.11 $^{b}$ | 34.25 $^{b}$ | 51.85 $^{b}$ | 72.22 $^{b}$ | 87.03 $^{b}$ | 96.29 $^{b}$ | 100.0 $^{a}$ |
| **750** | | 2.77 $^{ab}$ | 12.96 $^{b}$ | 30.55$^{bc}$ | 50.92$^{bc}$ | 73.14 $^{b}$ | 91.66 $^{b}$ | 98.14$^{ab}$ | 100.0 $^{a}$ |
| **1000** | | 6.48 $^{a}$ | 19.44 $^{a}$ | 41.66 $^{a}$ | 62.03 $^{a}$ | 86.11 $^{a}$ | 98.14 $^{a}$ | 100.0 $^{a}$ | 100.0 $^{a}$ |
| **LSD 5 %** | | 3.96 | 5.34 | 6.87 | 6.87 | 5.48 | 5.34 | 2.92 | 2.07 |
| **Interaction between nanomaterials and their concentrations** | | | | | | | | | |
| **ZnNPs** | **0** | 2.77 $^{ab}$ | 5.55 $^{d}$ | 5.55 $^{g}$ | 13.88 $^{f}$ | 22.22 $^{f}$ | 25.00 $^{f}$ | 38.88 $^{e}$ | 47.22 $^{b}$ |
| | **250** | 0.00 $^{b}$ | 8.33 $^{cd}$ | 19.44 $^{f}$ | 38.88 $^{e}$ | 58.33 $^{e}$ | 75.00 $^{e}$ | 91.66$^{cd}$ | 100.0$^{a}$ |
| | **500** | 0.00 $^{b}$ | 5.55 $^{d}$ | 25.00$^{def}$ | 41.66$^{de}$ | 63.88$^{de}$ | 77.77$^{de}$ | 88.88$^{d}$ | 100.0$^{a}$ |
| | **750** | 0.00 $^{b}$ | 8.33 $^{cd}$ | 22.22 $^{ef}$ | 36.11 $^{e}$ | 63.88$^{de}$ | 80.55$^{cde}$ | 94.44$^{bc}$ | 100.0$^{a}$ |
| | **1000** | 2.77 $^{ab}$ | 11.11$^{cd}$ | 33.33$^{b-e}$ | 47.22$^{cde}$ | 75.00 $^{c}$ | 94.44$^{ab}$ | 100.00$^{a}$ | 100.0$^{a}$ |
| **AgNPs** | **0** | 2.77 $^{ab}$ | 5.55 $^{d}$ | 5.55 $^{g}$ | 13.88 $^{f}$ | 22.22 $^{f}$ | 25.00 $^{f}$ | 38.88 $^{e}$ | 47.22 $^{b}$ |
| | **250** | 2.77 $^{ab}$ | 13.88$^{bcd}$ | 30.55$^{c-f}$ | 52.77$^{bcd}$ | 72.22$^{cd}$ | 86.11$^{bcd}$ | 97.22$^{ab}$ | 100.0$^{a}$ |
| | **500** | 2.77 $^{ab}$ | 13.88$^{bcd}$ | 33.33$^{b-e}$ | 52.77$^{bcd}$ | 72.22$^{cd}$ | 88.88$^{bc}$ | 100.00$^{a}$ | 100.0$^{a}$ |
| | **750** | 2.77 $^{ab}$ | 16.66$^{abc}$ | 36.11$^{bcd}$ | 61.11 $^{b}$ | 80.55$^{bc}$ | 100.00$^{a}$ | 100.00$^{a}$ | 100.0$^{a}$ |
| | **1000** | 8.33 $^{a}$ | 25.00 $^{a}$ | 50.00 $^{a}$ | 75.00 $^{a}$ | 97.22 $^{a}$ | 100.00$^{a}$ | 100.00$^{a}$ | 100.0$^{a}$ |
| **SeNPs** | **0** | 2.77 $^{ab}$ | 5.55 $^{d}$ | 5.55 $^{g}$ | 13.88 $^{f}$ | 22.22 $^{f}$ | 25.00 $^{f}$ | 38.88 $^{e}$ | 47.22 $^{b}$ |
| | **250** | 0.00 $^{b}$ | 5.55 $^{d}$ | 22.22 $^{ef}$ | 41.66$^{de}$ | 63.88$^{de}$ | 80.55$^{cde}$ | 100.00$^{a}$ | 100.0$^{a}$ |
| | **500** | 0.00 $^{b}$ | 13.88$^{bcd}$ | 44.44$^{ab}$ | 61.11 $^{b}$ | 80.55$^{bc}$ | 94.44$^{ab}$ | 100.00$^{a}$ | 100.0$^{a}$ |
| | **750** | 5.55 $^{ab}$ | 13.88$^{bcd}$ | 33.33$^{b-e}$ | 55.55$^{bc}$ | 75.00 $^{c}$ | 94.44$^{ab}$ | 100.00$^{a}$ | 100.0$^{a}$ |
| | **1000** | 8.33 $^{a}$ | 22.22$^{ab}$ | 41.66$^{abc}$ | 63.88$^{ab}$ | 86.11 $^{b}$ | 100.00$^{a}$ | 100.00$^{a}$ | 100.0$^{a}$ |
| **LSD 5 %** | | 6.87 | 9.26 | 11.9 | 11.9 | 9.49 | 9.26 | 5.07 | 3.58 |

which had killing rate at 5.55% with no significant difference between the two concentrations. On the third day, the results showed that AgNPs were treated with a concentration of 1000 ppm. Killing rate at this concentration was 25.00% with no significant difference between it and the treatment of selenium nanoparticles at a concentration of 1000 ppm with 22.22%, killing rate. AgNPs were treated with a concentration of 750 ppm with killing rate at 16.66%. On the fourth day, it was noticed that the superiority of the silver nanoparticle treatment at a concentration of 1000 ppm where killing rate at this concentration was 50.00% with no significant difference between it and the two treatments of selenium nanoparticles at a concentration of 500 ppm and a concentration of 1000 ppm with killing rate at 44.44% and 41.66%, respectively. On the fifth day, the results showed that AgNPs were also superior at a concentration of 1000 ppm with 75.00%, of killing rate with no significant difference between it and the treatment of selenium nanoparticles at a concentration of 1000 ppm with kill rate at 63.88%. On the sixth day of the experiment, we notice the superiority of the silver nanoparticle treatment at a concentration of 1000 ppm over most of the other concentrations. While on the seventh and eighth days, we notice that there are no significant differences between most of the concentrations used in the experiment. On the ninth day, 100% was recorded for all treatments indicating the death of all insects on that day while killing rate on the same day was 47.22% in the comparison treatment. The reason is that feeding lesser grain borer on the treated mummified grains helps these particles to enter the digestive system of the insect. Due to the high permeability of these materials, it reaches the cells of the insect, which leads cell death and DNA damage and thus the death of the insect. The results obtained are consistent with what (Kamil et al, 2017) indicated, when showed that when using nanoparticles against an insect from the mustard Lipaphis erysimi, the result was the death of 90% of the adult insect after 6 days of exposure. (Yang et al, 2009) also found that nanoparticles gave 80% kill rate against adults of T. castaneum. (Rouhani et al, 2012) reported that the percentage kill for the adults of Aphis nerii increased by growing nanoparticle concentration.

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