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# Molluscicidal Activity and Repellency of some Inorganic Fertilizers against Terrestrial Snail, *Theba pisana* (Müller), Infesting Citrus Trees in Northern Areas, Egypt

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ABSTRACT. In the present study, five inorganic fertilizer compounds: superphosphate, potassium sulfate, ammonium sulfate, ferrous sulfate and copper sulfate were chosen and formulated in solution form of 1.5% (w/v) with an adhesive substance (Arab Gum). Their efficacy as repellent and/or toxic agents against the terrestrial *Theba pisana* snails was investigated. The infested Citrus trees with *T. pisana* snails were divided into four groups. The percentage decrease in the infested snail numbers were calculated after 1,2,3,4,5, and 6 weeks post treatment. The total percentage decrease in the snail numbers (% decrease in the snail numbers after 6 weeks plus the % mortality of the snail numbers at the end of the experiment) were also calculated.

The results showed that there were significant differences between all treatments at ($p < 0.01$). Copper sulfate was shown to be the most effective compound exhibiting 100% decrease in the total number of infested snails in the first and second groups. Potassium sulfate was less successful followed by ferrous sulfate.

## Introduction

Terrestrial white garden snails *Theba pisana* (Müller) are considered to be one of the most common dangerous species in the delta region, especially in northern areas of Egypt. They are also known as destructive pests, causing severe damage to vegetables, ornamentals and citrus trees[1-8].

The use of specific molluscicides as well as other compounds including carbamates, oxime carbamates, organophosphorous, inorganic metal compounds, and inorganic fertilizers is considered the most effective measure for controlling terrestrial gastropods[2-21].

Control of terrestrial snails and slugs by contact molluscicides is potentially more efficient than the bait-delivery method currently used for control[14]. The use of inorganic fertilizers as barriers and/or poisons against terrestrial snails is met with the problem that, such compounds are not stable when they are sprayed on the plants by using spray techniques. This may be due to the washing up by the effect of the rain fall or by the irrigation water.

The aim of the present study is to investigate some common inorganic fertilizers which are already used as nutrients for different crops and plants, as barriers and/or poisons against terretrial *Theba pisana* snails applying them in a safe way, based on the use of an adhesive substance such as Arab Gum prepared in glass distilled water and used as spray solutions. This may protect the citrus from snail infestations and in the same time avoid the health hazards and environmental pollution.

## Materials and Methods

### *Experimental Animals*

The white garden *Theba pisana* (Müller) snails, which commonly infest Citrus trees in El-Montaza gardens, Alexandria, Egypt.

### *Chemicals*

Five inorganic fertilizer compounds were chosen, they were:

1. Calcium superphosphate $Ca_3 (PO_4)2$ (10%P).
2. Potassium sulfate $K_2SO_4$ (48-52% $K_2O$).
3. Ammonium sulfate $[(NH_4)_2 SO_4]$ (20.6% Nitrogen).
4. Ferrous sulfate $FeSO_4. 7H_2O$ (20% Iron).
5. Copper sulfate $CuSO_4. 5H_2O$ (25%Copper).

### *Preparation of the Formulated Fertilizer Solutions*

Each formulated fertilizer solution (1.5% w/v) was prepared, by dissolving or suspending it in 5% Arab Gum solution (5 gram Arab Gum dissolved in 100 ml glass distilled water).

### *The Experiments*

The infested Cirtus trees with *Theba pisana* (Müller) snails which were planted in El-Montaza gardens in Alexandria, Egypt were chosen randomly. All trees were nearly uniform in size (130-150 cm height). They were divided into four groups. Each group was replicated. The first group (Group I) was treated for one application by spraying 50 cm high of the tree trunks from the base by using the inorganic fertilizer formulations after removing the infesting snails from each tree. The removed snails were collected and put on the ground under each tree. The second group (Group II) was treated for three applications (at two week intervals) using the same method as described in the first group. The third group (Group III) was treated once without removing the infested

snails. The fourth group (Group IV) was treated for three applications (at two week intervals) without removing the snails infestion. In the third and fourth groups 50 cm height of the tree trunks from the base were treated in addition to every aggregation site of the snails. Control groups were treated with 5% w/v Arab Gum solution free of inorganic fertilizer compounds.

The percentage decrease of the infested snail numbers for each group was calculated after 1,2,3,4,5 and 6 weeks post treatment. In addition, at the end of the experiments the total percentage decrease (The percentage decrease in the snail numbers after six weeks plus the percentage mortality of the collected snail numbers at the end of the experiment) of the infested snail numbers were calculated, and compared to control group.

### *Statistical Analysis*

Statistical analysis for the obtained data were made by using General Linear Model procedure and Least Significant Difference (L.S.D.) at 0.05 as a level of significance[22].

## Results and Discussion

Formulated solutions (1.5% w/v of superphosphate, potassium sulfate, ammonium sulfate, ferrous sulfate and copper sulfate were tested for their molluscicidal activity and/or repellancy effect against *Theba pisana* (Müller) snails under field conditions.

Results presented in Table (1) illustrate the data obtained from trees treated for one application with the different formulated fertilizer solutions after removing the snails from them (Group I). Results showed that, there are no significant differences between the time intervals post treatment, while there are significant differences between different treatments at ($P < 0.01$) as compared to control group. The highest percentage decrease (100%) in the snail numbers were found in the case of trees treated with copper sulfate followed by 68.23% and 58.43% decrease in the case of trees treated with ferrous sulfate and potassium sulfate respectively. In case of treatment with superphosphate and ammonium sulfate no significant decrease in the snail numbers were exhibited. Copper sulfate exhibited 100% decrease in the snail infestation because of its repellency effect and it provided an excellent barrier to prevent snail access to the trees.This finding concerning the effect of copper sulfate agree with the results obtained in some of the previous studies made by[17,11,15,17,23-25]. Copper acts on the external epithelium of the foot, mantle and resulting in the rupture of epidermal cells so allowing blood seepage and facilitating bacterial infection[15]. Copper sulphate was still effective for a long time even after the end of the season. Ferrous sulfate exhibited 74.13% reduction in the snail numbers after six weeks post treatment. However, in general most metal salts are not effective as stomach poison because of the molluscs fail to eat sufficient metal compound to be lethal[19].

In the case of trees treated for three applications after removing the infestion snails (Group II) Table (2). Results indicated that, there are significant differences at ($P < 0.01$) between different time intervals in the percentage decrease of the snail numbers, whereas, the highest percentage decrease in snail numbers are 66.81% and 68.64% after

five and six weeks post treatments respectively. On the other hand, the lowest percentage decrease was 46.41% after two weeks. The aforementioned decrease may be due to the fact that at the beginning, the snails tried to infest the tree trunks in access numbers, but after they were exposed to contact action of the tested compounds they started to move down leaving the trees to avoid the molluscicidal action of the compounds. Results also showed that, all different treatments exhibited significant reduction at ($P < 0.01$) in snail numbers as compared to the control group. Copper sulfate exhibited the highest percentage decrease (100%) followed by potassium sulfate (68.18%). Generally speaking, we can conclude from the results presented in Table (1) and Table (2) that, the best results were exhibited by copper sulfate followed by ferrous sulfate and potassium sulfate.

TABLE 1. The % decrease of infested *Theba pisana* (Müller) snail numbers after removing the infested snails from citrus trees (Group I) and treated with different formulated fertilizer solutions in a single application.

| Time intervals post treatment (Weeks) | % decrease of *Theba pisana* snail numbers/tree | | | | | | Mean (%) |
|---|---|---|---|---|---|---|---|
| | Control (%) | Superphosphate (%) | Potassium sulfate (%) | Ammonium sulfate (%) | Ferrous sulfate (%) | Copper sulfate % | |
| 1 | 33.04 | 33.71 | 46.62 | 52.37 | 61.63 | 100 | 54.56[d] |
| 2 | 26.28 | 5.25 | 43.90 | 11.79 | 59.70 | 100 | 41.15[a] |
| 3 | 20.86 | 18.19 | 46.62 | 1.19 | 68.41 | 100 | 42.54[a] |
| 4 | 11.61 | 31.93 | 60.66 | 13.24 | 72.31 | 100 | 48.29[a] |
| 5 | 4.88 | 38.80 | 76.40 | 27.86 | 73.22 | 100 | 53.53[a] |
| 6 | 3.63 | 41.83 | 76.40 | 29.21 | 74.13 | 100 | 54.20[a] |
| Mean (%) | 16.71[c] | 28.29[c] | 58.43[b] | 22.61[c] | 68.23[b] | 100[a] | 49.05 |

➢ Means not sharing the same letter are significantly different at ($P < 0.01$).
➢ $L.S.D._{(0.05)} = 15.478$.

Data presented in Table (3) illustrate the percentage decrease in the infested snail numbers after the trees were treated without removing the infested snails from them (Group III). Results showed that, there are significant differences at ($P < 0.01$) in percentage decrease between time intervals post treatments. Whereas, the highest percentage decrease (9.6%) resulted at the end of the sixth week as compared to control group. In addition, there were significant differences between different treatments at ($P < 0.01$), whereas the highest value (10.67%) resulted from treatment with copper sulfate, followed by ferrous sulfate which exhibited 6.12% decrease in snail numbers. Superphosphate, potassium sulfate and ammonium sulfate showed no significant differences compared to control group. Their values are 1.11%, 0.0% and 2.31% respectively.

TABLE 2. The % decrease of infested *Theba pisana* (Müller) snail numbers after removing the infested snails from citrus trees (Group II) and treated with different formulated fertilizer solutions for three applications at two week intervals.

| Time intervals post treatment (Weeks) | % decrease of *Theba pisana* snail numbers/tree | | | | | | Mean (%) |
|---|---|---|---|---|---|---|---|
| | Control (%) | Superphosphate (%) | Potassium sulfate (%) | Ammonium sulfate (%) | Ferrous sulfate (%) | Copper sulfate % | |
| 1 | 25.69 | 67.27 | 61.73 | 57.58 | 47.05 | 100 | $59.88^{ab}$ |
| 2 | 5.0 | 35.12 | 48.40 | 45.64 | 34.34 | 100 | $46.41^{c}$ |
| 3 | 12.23 | 52.54 | 52.74 | 45.84 | 51.75 | 100 | $52.51^{bc}$ |
| 4 | 6.57 | 68.67 | 78.08 | 71.59 | 69.77 | 100 | $65.78^{a}$ |
| 5 | 5.10 | 72.80 | 81.88 | 69.89 | 71.20 | 100 | $66.81^{a}$ |
| 6 | 5.10 | 73.42 | 86.29 | 69.51 | 78.71 | 100 | $68.84^{a}$ |
| Mean (%) | $11.61^{c}$ | $61.63^{b}$ | $68.18^{b}$ | $60.01^{c}$ | $58.80^{b}$ | $100^{a}$ | 60.04 |

➢ Means not sharing the same letter are significantly different at ($P < 0.01$).
➢ $L.S.D._{(0.05)} = 10.244$

TABLE 3. The % decrease of infested *Theba pisana* (Müller) snail numbers without removing the infested snails from citrus trees (Group III) and treated with different formulated solutions with one application.

| Time intervals post treatment (Weeks) | % decrease of *Theba pisana* snail numbers/tree | | | | | | Mean (%) |
|---|---|---|---|---|---|---|---|
| | Control (%) | Superphosphate (%) | Potassium sulfate (%) | Ammonium sulfate (%) | Ferrous sulfate (%) | Copper sulfate % | |
| 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.47 | $0.08^{d}$ |
| 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8.46 | $1.41^{cd}$ |
| 3 | 0.0 | 0.0 | 0.0 | 0.0 | 2.71 | 9.4 | $2.02^{cd}$ |
| 4 | 4.63 | 0.59 | 0.0 | 0.0 | 4.69 | 11.28 | $3.53^{bc}$ |
| 5 | 4.63 | 2.84 | 0.0 | 0.0 | 14.21 | 13.62 | $5.88^{b}$ |
| 6 | 4.63 | 3.21 | 0.0 | 13.85 | 15.12 | 20.82 | $9.60^{a}$ |
| Mean (%) | $2.32^{c}$ | $1.11^{c}$ | $0.0^{c}$ | $2.31^{c}$ | $6.12^{b}$ | $10.67^{a}$ | 3.76 |

➢ Means not sharing the same letter are significantly different at ($P < 0.01$).
➢ $L.S.D._{(0.05)} = 2.51$

In group IV, where trees were treated with the different tested compounds for three applications without removing the infested snails from them. The obtained results presented in Table (4) showed that, there are significant differences at ($P < 0.01$) in the percentage decrease of the infested snail numbers between different time intervals post

treatment. Whereas, the highest percentage decrease (13.%) occurred six weeks post-treatments followed by 9.6 after five weeks. Also, there are significant differences at ($P < 0.01$) between different treatments, whereas, the highest percentage decrease (16.97%) was exhibited in the case of trees treated with copper sulfate followed by ferrous sulfate which exhibit (11.08%) decrease in snail numbers compared with the control group.

TABLE 4. The % decrease of infested *Theba pisana* (Müller) snail numbers without removing the infested snails from citrus trees (Group IV) and treated with different formulated solutions for three applications at two week intervals.

| Time intervals post treatment (Weeks) | % decrease of *Theba pisana* snail numbers/tree | | | | | | Mean (%) |
|---|---|---|---|---|---|---|---|
| | Control (%) | Superphosphate (%) | Potassium sulfate (%) | Ammonium sulfate (%) | Ferrous sulfate (%) | Copper sulfate % | |
| 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.72 | 0.620[d] |
| 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 11.35 | 1.89d |
| 3 | 1.67 | 3.09 | 0.0 | 0.0 | 11.67 | 20.01 | 6.07c |
| 4 | 1.67 | 3.10 | 0.0 | 0.0 | 16.33 | 20.01 | 6.85bc |
| 5 | 1.67 | 3.61 | 0.0 | 13.64 | 16.88 | 21.79 | 9.60b |
| 6 | 1.67 | 5.15 | 0.0 | 27.92 | 21.59 | 24.95 | 13.55a |
| Mean (%) | 1.11d | 2.49d | 0.00d | 6.93c | 11.08b | 16.08a | 6.43 |

➢ Means not sharing the same letter are significantly different at ($P < 0.01$).
➢ $L.S.D._{(0.05)} = 3.03$

Results presented in Table (5) and Table (6) generally demonstrated that, there are significant differences in the percentage decrease at ($P < 0.01$) in snail numbers among different treatments as shown in Table (5), and among different time intervals as shown in Table (6) post treatment as calculated by using the combined statistical analysis between different groups. In addition, there are significant differences between the application of the tested compounds for one and three applications. Results also showed that, there are no significant differences between the number of applications and the time intervals post treatments. Significant differences at ($P < 0.01$) in the percentage decrease in the snail numbers between the groups of trees treated after removing the infested snails and that groups of trees which treated without removing the infested snails are observed.

The results illustrated in Table (5) showed that, there was a significant decrease at ($P < 0.01$ in the percentage of snail numbers among different treatments, whereas , the highest total average of the percentage decrease (56.91%) was found in case of groups of trees which were treated with copper sulfate, followed by ferrous sulfate with 36.06% decrease in snail numbers. The lowest value of the total average of the percentage decrease (22.96%) was found in case of groups of trees which were treated with ammonium sulfate, followed by superphosphate which gave 23.38% decrease in snail numbers as compared to control groups.

TABLE 5. The total average of % decrease in *Theba pisana* (Müller) snail numbers after and without removing the infested snails from citrus trees treated with different formulated fertilizer solutions for one and three applications.

| Type of treatment | % decrease of *Theba pisana* snail numbers/tree | | | | | | Total average of decrease (%) |
|---|---|---|---|---|---|---|---|
| | Treated trees after removing the infested snails | | | Treated trees without removing. the infested snails. | | | |
| | Treated for one application (%) | Treated for three applications (%) | Average of % decrease (%) | Treated for one application (%) | Treated for three applications (%) | Average of % decrease (%) | |
| Control | 16.71 | 11.61 | 14.16$^{d}$ | 2.32 | 1.11 | 1.71$^{d}$ | 7.94$^{d}$ |
| Superphosphate | 28.29 | 61.63 | 44.96$^{c}$ | 1.11 | 2.49 | 1.80$^{d}$ | 23.3$^{c}$ |
| Potassium sulfate | 58.43 | 68.18 | 63.31$^{b}$ | 0.000 | 0.00 | 0.00$^{d}$ | 31.65$^{b}$ |
| Ammonium sulfate | 22.61 | 60.01 | 41.31$^{c}$ | 2.31 | 6.93 | 4.61$^{c}$ | 22.96$^{c}$ |
| Ferrous sulfate | 68.24 | 58.80 | 63.52$^{b}$ | 6.12 | 11.08 | 8.60$^{b}$ | 36.06$^{b}$ |
| Copper sulfate | 100 | 100 | 100$^{a}$ | 10.67 | 16.97 | 13.82$^{a}$ | 56.91$^{a}$ |
| Mean (%) | 49.05 | 60.04 | 54.54 | 3.75 | 6.43 | 5.09 | 29.82 |

➢ Means not sharing the same letter within columns are significantly different at ($P < 0.01$).
➢ $L.S.D._{(0.05)} = 5.011$

TABLE 6. The total average of % decrease in *Theba pisana* (Müller) snail numbers after and without removing the infested snails from citrus trees treated with different formulated solutions for one and three applications at time intervals post-treatment.

| Time intervals post treatment (Weeks) | % decrease of *Theba pisana* snail numbers/tree | | | | | | Total average of decrease (%) |
|---|---|---|---|---|---|---|---|
| | Treated trees after removing the infested snails | | | Treated trees without removing. the infested snails. | | | |
| | Treated for one application (%) | Treated for three applications (%) | Average of % decrease (%) | Treated for one application (%) | Treated for three applications (%) | Average of % decrease (%) | |
| 1 | 54.56 | 59.88 | 57.22$^{a}$ | 0.08 | 0.62 | 0.35$^{e}$ | 28.79$^{cd}$ |
| 2 | 41.15 | 46.41 | 43.78$^{b}$ | 1.41 | 1.89 | 1.65$^{de}$ | 22.72$^{e}$ |
| 3 | 42.54 | 52.51 | 47.53$^{b}$ | 2.02 | 6.07 | 4.04c$^{d}$ | 25.79$^{de}$ |
| 4 | 48.29 | 65.78 | 57.03$^{a}$ | 3.53 | 6.85 | 5.29b$^{c}$ | 31.11$^{bc}$ |
| 5 | 53.53 | 66.81 | 60.17$^{a}$ | 5.88 | 9.60 | 7.74$^{b}$ | 33.95$^{ab}$ |
| 6 | 54.20 | 68.82 | 61.52$^{a}$ | 9.60 | 13.55 | 11.57$^{a}$ | 36.55$^{a}$ |
| Mean (%) | 49.05 | 60.04 | 54.54 | 3.75 | 6.43 | 5.09 | 29.82 |

➢ Means not sharing the same letter within columns are significantly different at ($P < 0.01$).
➢ $L.S.D._{(0.05)} = 5.011$

In the case of trees treated with fertilizers after removing infested snails from them (Group I and Group II) Table (5). The results showed that, copper sulfate was the most effective compound in reducing the average of the infested snail numbers (100%), followed by ferrous sulfate (63.52%) and potassium sulfate (63.31%). Also, in the case of trees without removing infested snails from them (Group III and Group IV). The results indicated that, there are significant differences at ($P < 0.01$) between different treatments in reducing the average percentage decrease of snail numbers, copper sulfate exhibited the highest value (13.82%) followed by ferrous sulfate (8.60%). In group III and IV potassium sulfate had no effect in reducing the number of the infested snails contrary to the results with Group I and Group II. This may be because the snails in the latter case were prevented from moving down and leaving the trees because of the compound effect of spraying on the trunk and on the aggregation sites of the infesting snails. Also, in the former case (Group I & Group II) it rendered high number of snails to infest the trees when it was sprayed on the tree trunks. In conclusion applications of potassium sulfate were most successful when sprayed on the trunk.

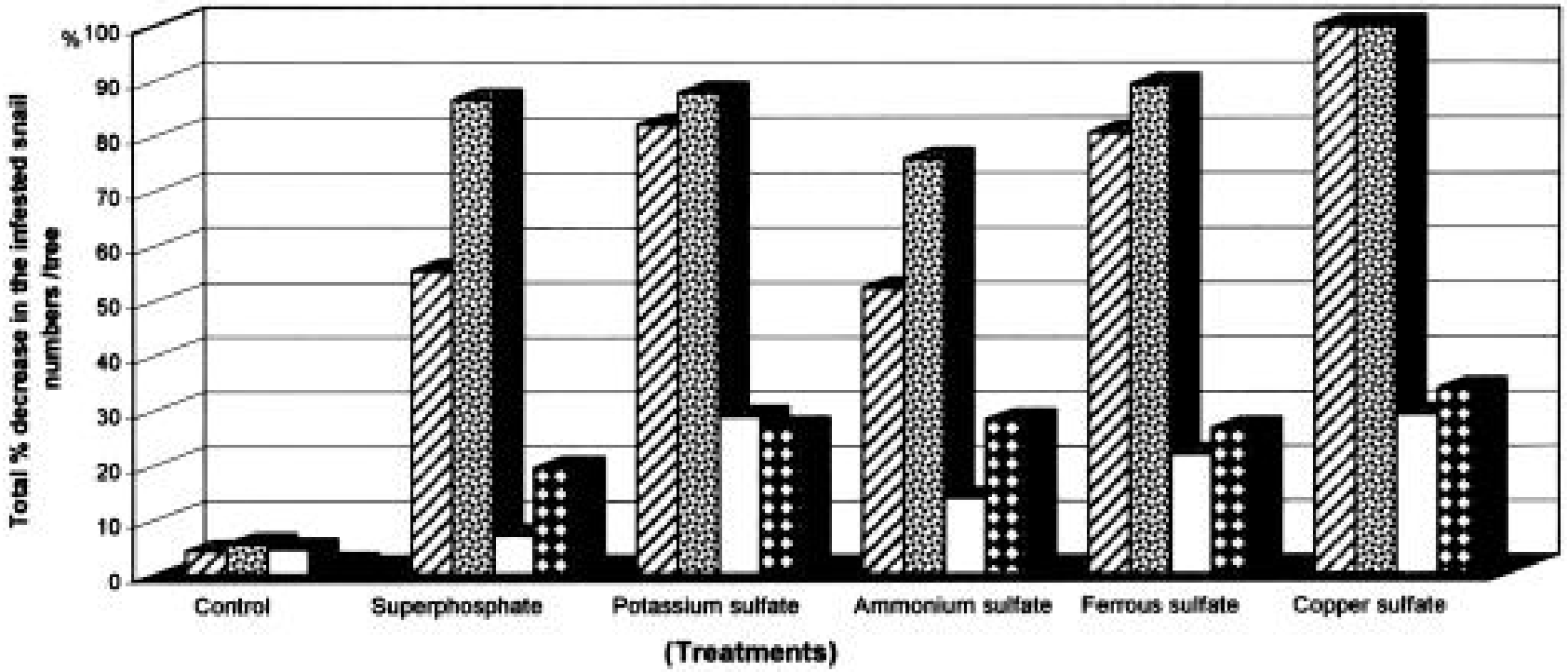
Results illustrated in Table (6) showed that, there was a significant decrease in the percentage of snail numbers among different time intervals post treatments. Whereas the highest total average of percentage decrease in snail numbers (36.55%) was found after six weeks followed by 33.95% after five weeks post treatment. Also, in Group I and II there was a significant reduction in snail numbers compared with Group III and IF. The highest average of percentage decrease in snail numbers of the Group I and Group II were 60.17% and 61.52% after five and six weeks post treatments respectively. In the Group III and Group IF the highest average of percentage decrease (7.74% and 11.57%) were found after five and six weeks respectively.

Results presented in Fig. (1) demonstrated the total percentage decrease in snail numbers (% decrease in the infested snail numbers after six weeks plus the % mortality of the snail numbers at the end of the experiment) for different treatments. Results showed that, there were significant differences at ($P < 0.01$) between different treatments. Whereas, copper sulfate exhibited significant effect in reducing the percentage decrease in snail numbers to 100% in Group I and Group II. In the case of Group III and Group IV, the total percentage decrease are 29.13% and 37.81%, respectively. Potassium sulfate was less successful than copper sulfate in this respect, exhibits a reduction of 81.82% in the snail numbers of Group I, 87.76% in Group II, 28.77% in the case of Group III and 26.6% in Group IV. This was followed by ferrous sulfate which exhibited 80.50%, 89.27%, 21.85% and 26.59% in total reduction for Group I, II, III and IV respectively.

Some investigators studied the repellancy and molluscicidal action of inorganic metal compounds such as copper sulfate, iron, zinc, ammonium carbonate and other heavy metals[7,10-12,14,16-21,26]. In spite of the success of such inorganic metals in snail control, investigators met with instability of these compounds under field conditions. This may be due to the effect of rainfall, and irrigation water, where the water can carry the metals away. This may reduce the effect of such compounds against snails.

In the present study, the use of Arab Gum as an adhesive substance succeeded in keeping the fertilizer compounds on the tree trunks for a long time. It is worth mentioning that no harmful effects were exhibited on the citrus trees by using such inorganic fertilizers.

FIG. 1. The total % decrease* in the infested *Theba pisana* (Müller) snail numbers/trees after and without removing the infested snails from the citrus trees treated with different formulated fertilizer solutions for one and three applications.




☐ Group I : Treated trees for one application after removing the infested *T. pisana* snails.

☐ Group II : Treated trees for three applications after removing the infested *T. pisana* snails.

☐ Group III : Treated trees for one application without removing the infested *T. pisana* snails.

☐ Group IV : Treated trees for three applications without removing the infested *T. pisana* snails.

*Total % decrease in the snail numbers (% decrease in the snails numbers after 6 weeks plus the % mortality of the snail numbers, at the end of the experiment).

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# الفاعليـة القاتلـة والطـاردة لبعض الأسمـدة غير العضويـة ضد قوقـع الثيـبابيسانا (مـولــر) البـري الذي يغـزو أشجـار المـوالـح في المناطـق الشماليـة بمصـر

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*المستخلص* . أختيرت في هذه الدراسة ، خمسة أسمدة غير عضوية هي السوبر فوسفات وكبريتات البوتاسيوم وكبريتات الأمونيوم وكبريتات الحديدوز وكبريتات النحاس وجهزت في هيئة محلول بتركيز ٥ , ١٪ (وزن/ حجم) مع مادة لاصقة (الصمغ العربي) . ودرست فاعليتها كمواد قاتلة أو طاردة أو الاثنتين معًا ضد قواقع الثيبابيسانا البرية . حيث قسمت أشجار الموالح المصابة بقواقع الثيبابيسانا إلى أربع مجموعات . وقد حسبت النسبة المئوية للانخفاض في أعداد القواقع بعد ١، ٢، ٣، ٤، ٥، ٦ أسابيع بعد المعاملة . كما تم حساب النسبة المئوية الكلية للانخفاض في أعداد القواقع (النسبة المئوية للانخفاض في أعداد القواقع بعد ٦ أسابيع مضاف إليها النسبة المئوية لأعداد القواقع الميتة في نهاية التجربة) .

أظهرت النتائج المتحصل عليها أن هناك اختلافات معنوية بين جميع المعاملات عند مستوى معنوية أقل من ٠١ , ٠ ووجد أن مركب كبريتات النحاس كان أكثر المركبات فاعلية في خفض العدد الكلي للقواقع في حالة المجموعة الأولى والثانية بنسبة ١٠٠٪ . أما مركب كبريتات البوتاسيوم فقد جاء في تأثيره بعد كبريتات النحاس يليه مركب كبريتات الحديدوز .