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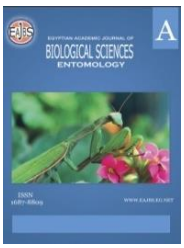

Efficacy of Certain Inorganic Salts, as A Wood Preservative, on Bamboo Beetle, *Dinoderus minutus* Fab., (Coleoptera: Bostrychidae)

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ABSTRACT

The protective and remedial effect of certain inorganic salts on powder post beetle, *Dinoderus minutus* Fab., infesting bamboo wood revealed that intact and infested bamboo wood cuttings treated with different concentrations of each copper sulfate and sodium fluoride gave 100% protection and reduction of infestation when used copper sulfate at concentration 12% ($12x10^4$ppm), while sodium fluoride gave 100% protection and infestation reduction at concentration 8% ($8 x10^4$ppm). The number of entrance and emergence holes decreased with the increase of salt concentrations which indicates to death of different stages of beetles inside treated bamboo wood by the appropriate concentration of salt used.

The amount of consumed and lost wood from infested bamboo wood decreased with the increasein salt concentration. The percentages of lost bamboo wood varied from 5.09 % to 38.1% for copper sulfate at concentrations between 12% and 0.25%, while the percentages of loss wood rangedbetween4.7% to 25% at concentrations 8% and 0.25% respectively for sodium fluoride.

INTRODUCTION

The small powder post beetles (Anobiidae, Bostrychidae, Lyctidae) are serious pests to many various species of wood because they reduce the infested wood to flour-like powder. These boring insects infest the used wood in different forms and sizes such as furniture, desks, piers poles, fencing, bridges, scaffoldings, beams, steps and decorative purposes; besides other several uses. Various studies carried out on certain powder post beetles by some authors such as Halal & El-Sebay (1981), Batt (2000),Haggag& Batt (2000), Borowski &Węgrzynowicz (2012), Batt & Ahmed (2013), Watanabe *et al.* (2020) and Rainho *et al.* (2022).

Bamboo powder post beetle, *Dinoderus minutus* (Coleoptera: Bostrychidae) is one of the borers that cause economic losses in infested bamboo wood. Damage occurs by burrowing larvae and adults into the sap and heartwood, as shown in Photo (1). In Egypt, this borer attacked bamboo wood, Nour (1963) and Moussa (1977), while Mohamad (2002) recorded *D. minutus* on the bamboo wood, palm and guava trees.

Some wood types are resistant to infestation with borers, while others are susceptible to several species of borers, the last species can be protected by insecticides or preservatives, or physical methods. Wood preservatives are now accepted, as some of the most effective treatments, for the protection of wood against insects and fungi.

Certain authors studied the effect of some preservatives on the infestation with various wood borers. El-Sebay (1995) studied the effect of boron against the two powder post beetles, *Lyctus africanus* Lesne and *Sinoxylon sudanicum* Lesne on cuts of Poinciana wood. Treated wood by some materials, such as disodium octaborate and boric acid appeared resistant to termites (Vorono *et al.*, 2003; Usta *et al.*,2009). Also, the using inorganic salts such as, zinc chloride, copper sulfate, sodium fluoride and borax against the dry wood termite *Cryptotermes brevis* Walker were studied (Moein and Farrg (1977), Abdel Malak (1999) and Abdel Malak (2002)). Whereas, Abd El-Latif *et al.* (2014) used chromated copper arsenate as the wood preservative to prevent the infestation with subterranean termite, *Psammotermes hybostoma* Desneux to some different woods (poinciana, willow, mulberry, casuarina and poplar) for two years at Fayoum governorate. Likewise treated wood with chromated copper arsenate gave high resistance against the infestation by *L.africanus* beetle for 4years (Ali and Hashim 2019)

The aim of this work is to study the effectiveness of some inorganic salts on toxicity (mortality), infestation (entrance & emergence), the preservation and amount of lost wood (consumed weight) by bostrychid powder post beetle, *D. minutus* on bamboo wood cuttings.

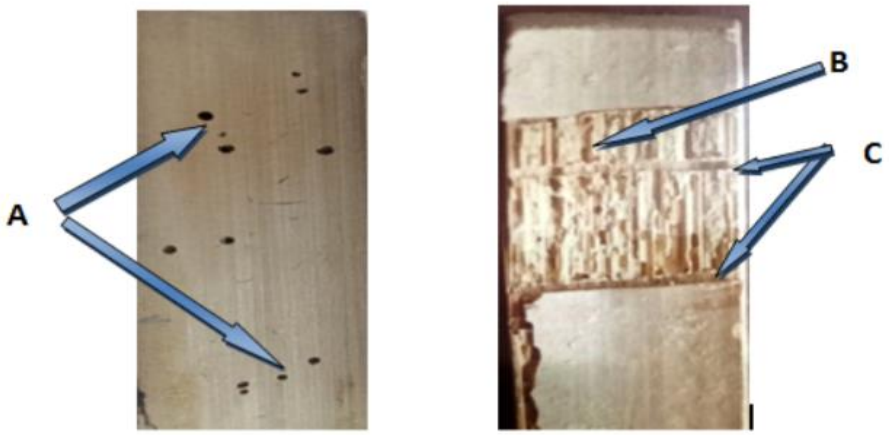

Photo 1: Infested bamboo wood with *D. minutus.*
A. Entrance and Exit holes of beetle. B. Larval tunnels. C. Adults tunnels.

MATERIALS AND METHODS

The sound and infested stems of bamboo trees with powder post beetles *Dinoderus minutus* Fab., were collected from bamboo tress (*Bambusa arundinacea* Willd.) cultivated at Orman garden, Giza governorate, the cuttings were transferred separated to Wood Borers Laboratory at Plant Protection Research Institute, ARC., Giza governorate. All intact and infested bamboo stems were divided into cuttings. These cuttings were separately put in wired cages under laboratory conditions (29.7°C average temperature and 46.8%RH); the infested cuttings were continuously examined until the beetles emerged.

The tested solution for copper sulfate (CuSo4), and sodium fluoride (NaF) were prepared under different concentrations, therefore 20grams of each tested salt were dissolved in 100ml distilled water to obtain the concentration $20x10^4$ppmthen various concentrations for each salt prepared and tested to study the different effects of these salts, the tested

concentrations were 0.25,0.50,1,2,4,6 and 8% for sodium fluoride salts as well as to concentrations 10 and 12% for copper sulfate salts.

The infested bamboo cuttings were used as a source to obtain the beetles, the intact cuttings were used to study the infestation (entrance and emergence beetles) for this purpose every10 intact cuttings (of about 10 cm length, 3mm diameter and 0.7mm thickness) were dipped for 15 minutus in one of the tested concentrations of different salt solutions and left to dry for 48 hours under laboratory condition. Each treated cutting was placed in a glass vessel (15cm x 6cm) and offered to twenty couples of beetles, then covered with muslin cloth and fixed with rubber bands. As well as another ten cuttings were left untreated as a control.

The numbers of entrance and emergence holes were recorded; the percentages of infestation reduction at different concentrations for copper sulfate and sodium fluoride salts were calculated by Abbott's formula (1925).

The percentages of lost wood (loss ratio %) or consumed wood for bamboo cuttings by *D.minutus* beetles and larva feeding were determined, for that the ten treated bamboo cuttings were weighed before the infestation and after the emergence of all beetles for the new generation and remove the powder resulting from infestation. The effects of different concentrations of tested salts were determined.

Statistical Analysis: The obtained data were statistically analyzed by using SAS (2001).

RESULTS AND DISCUSSION

A. Influence of Inorganic Salts on the Infestation:

1. Influence of Copper Sulfate:

1.1. The Number of Entrances and the Emergence Holes:

Data on the number of each entrance and emergence holes obtained from the attack of *D.minutus* beetles on bamboo cuttings treated by copper sulfate as well as the percentages of reduction resulting from the effect of copper sulfate at different concentrations were illustrated in Table(1).

The obtained results showed that each of the entrance and emergence holes decreased with the increase of salt concentration, while the percentages of infestation reduction increased with the increase of copper sulfate concentration, the minimum concentration (0.25×10^4ppm) appeared 6.17% reduction for the number of entrance holes and gave 8.90% reduction for the number of emergence holes, the highest concentrations 10×10^4ppm and 12×10^4ppm showed that 93.83% and 100% reduction for the number of entrance holes, while these concentrations gave 100 reductions for the number of emergence holes. These results were compatible with obtained data by Batt & Ramadan (2017) who found a reduction in the number of entrance and emergence holes of *Ennesdesmus trispnosus* Oliv. Beetles, in infested palm fronds cuttings were increased with the increase of copper sulfate salt concentrations.

1.2. Mortality Percentages:

Mortality percentages of *D.minutus* beetles subjected to bamboo cuttings treated by dipping in different concentrations of copper sulfate were determined by bioassay for toxicity of salt solution at various times (Fig. 1).

The effect of different concentrations of copper sulfate affecting *D.minutus* beetles indicated that simple effect on mortality percentage for small concentrations even 6×10^4ppm concentration, the mortality percentage attained 86% at 10×10^4ppm concentration, while this percentage reached 100% mortality at 12×10^4ppm concentration at the times of 5to 7 days. So the concentration 12×10^4ppm can be used to protect the bamboo wood from infestation by *D.minutus* beetles. The obtained results of the effect of copper sulfate on *D.*

minutus beetles agree with obtained results by Salmen and Sayed (1990) who showed that 10% of copper sulfate or borax salts inhibited the activity of *P.hybostoma* termite for a period ranging from 6 to 12 months. Whereas Moein and Farrag (1997) found that the mortality percentage of *Cryptoterms brevis* Desneux termite recorded at 8.33% at a concentration of 0.5% of copper sulfate after two days and reached 83.33% after 28 days Furthermore, they showed that the concentration 5% gave 68.89% mortality after 2 days and increased to 100%mortaity after 21days. As well Mohamed (2013) found that the lowest percentage of mortality for *Lyctus linearis* Goeze was 7% recorded at a concentration of 2% of copper sulfate while the highest mortality percentage was recorded at 100% at a concentration of 12%. Also, Batt & Ramadan (2017) found that the mortality percentages for *E. trispnosus* recorded100% at a concentration of 12% of copper sulfate salt.

Statistical analysis for obtained data from the effect of copper sulfate concentrations on each mortality percentage, reduction of entrance and emergence holes indicated high significant differences (P = 0.0001), Table (5).

Table 1: Influence of copper sulfate salt on the infestation of bamboo cuttings with *D. minutus* beetles.

Concentration	Number of entrance holes		Number of emergence holes	
Percent (ppm)	Mean± Sd	Reduction %	Mean± Sd.	Reduction %
0.25 (0.25×10^4)	7.7 ±1.14	6.17	47.1 ± 1.78	8.90
0.50 (0.50×10^4)	6.8 ± 0.93	16.05	42.7 ± 2.87	17.41
1 (1×10^4)	6.3 ± 1.34	22.22	38.7 ± 1.85	25.15
2 (2×10^4)	5.7 ± 1.95	29.63	34.5 ± 2.20	33.27
4 (4×10^4)	3.9 ± 1.09	51.85	23.7 ± 2.08	54.16
6 6×10^4	3.5 ± 1.07	56.79	19.7 ± 1.9	61.90
8 8×10^4	1.8 ±1.2	77.78	9.8 ± 1.6	81.05
10 10×10^4	0.5 ± 0.86	93.83	0.0 ± 0.0	100
12 12×10^4	0.0 ± 0.0	100	0.0 ± 0.0	100
Check	8.1 ± 0.46	-	51.7. ± 0.98	-

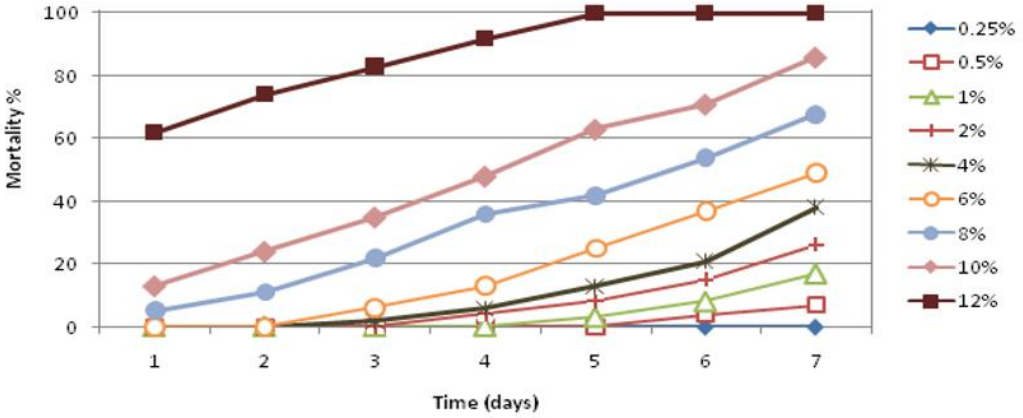

Fig. 1: Mortality percentage of *D. minutus* beetles subjected to bamboo cuttings treated at different concentrations of copper sulfate salt at various times.

2. Influence of Sodium Fluoride:

2.1. The Number of Entrances and Emergence Holes:

Obtained data from the effect of sodium fluoride salts on the numbers of entrance and emergence holes resulting from attacked *D. minutus* beetles to bamboo cuttings treated with different concentrations of sodium fluoride were illustrated in Table (2).

The results indicated that the number of entrance and emergence holes decreased with the increase of salt concentration, while the percentages of reduction increased with the increase of salt concentration. The minimum percentage of reduction at concentration 0.25 x 10^4ppm was recorded at 15.18 %for entrance holes and 27.05% for emergence holes. The highest concentration revealed that concentration 6 x 10^4ppm gave 89.24%reduction for entrance holes, while it appeared 100% reduction for emergence holes, whereas concentration 8x 10^4ppm showed a 100% reduction for each entrance and emergence hole. The obtained results agree with obtained data by Batt & Ramadan (2017) who reported that increasing the concentration of sodium fluoride works to increase the percentage of reduction for each of the entrance and emergence holes of infested palm fronds cuttings with *E. trispnosus* beetles.

2.2. Mortality Percentages:

Data on mortality percentages of *D.minutus* beetles that attacked bamboo cuttings dipping in different concentrations of sodium fluoride at various times were represented in Figure (2).

Toxicity lines of different concentrations detected that bamboo cuttings dipping in sodium fluoride at a concentration of 8 x 10^4ppm for 4 to 7 days or more gave 100% mortality, for that, the concentration of 8 x 10^4ppm sodium fluoride can beserved, as a wood preservative, to protect intact bamboo stem by dipping in these salts for 4 days or more.

The previous results agree with obtained results by Mohamed (2013) who reported that the mortality percentages for *L. linearis* were recorded at 80% and 100% at using 4% and 8% concentrations of sodium fluoride also, Batt & Ramadan (2017) found that the mortality percentages for *E.trispnosus* were reached 100% at concentration 8% of sodium fluoride. Whereas, Pan et al., (2014) appeared that mortality percentages were recorded at 100% for termite, *Reticulitermes flaviceps*during 7 days at concentrations of 0.5, 1 and 2 %. Statistical analysis for obtained data on the effect of sodium fluoride concentrations on each mortality percentage, reduction of entrance and emergence holes appeared highly significant (P = 0.0001, 0.0021 and 0.0045 respectively), Table (5).

Table 2: Influence of sodium fluoride salt on the infestation of bamboo cuttings with *D.minutus* beetles.

Concentration	Number of entrance holes		Number of emergence holes	
Percent (ppm)	Mean± Sd	Reduction %	Mean± Sd.	Reduction %
0.25 (0.25 x 10^4)	6.7 ± 1.31	15.18	35.6 ± 2.26	27.05
0.50 (0.50 x10^4)	5.8 ± 1.69	26.6	29.7 ± 2.28	39.14
1 (1 x 10^4)	4.3 ± 0.84	45.6	22.0 ± 2.96	54.91
2 (2 x 10^4)	2.8 ± 0.96	64.6	12.3 ± 1.49	74.80
4 (4 x 10^4)	1.9 ± 1.44	75.9	5.8 ± 1.4	88.11
6 (6 x 10^4)	0.85 ± 0.91	89.24	0.0 ± 0.0	100
8 (8 x 10^4)	0.0 ± 0.0	100	0.0 ± 0.0	100
Check	7.9 ± 0.46	-	48.8. ± 0.98	-

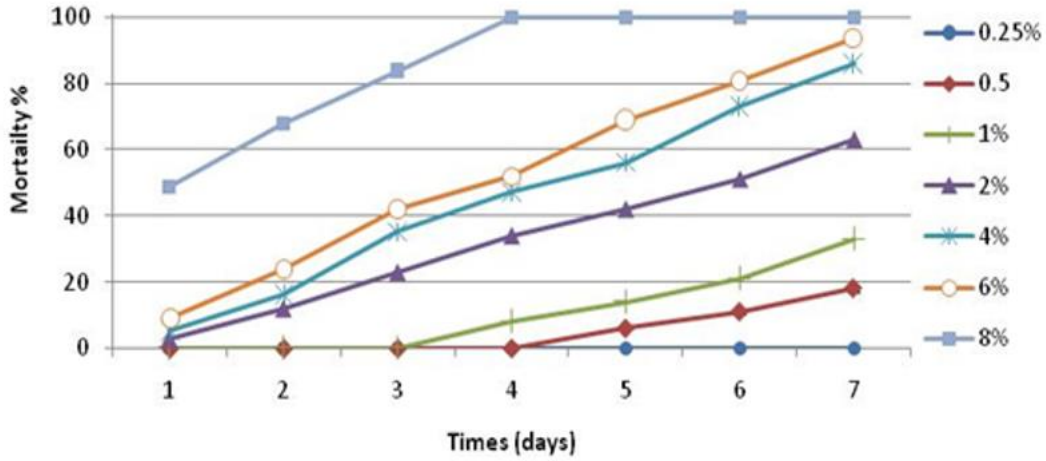

Fig. 2: Mortality percentage of *D. minutus* beetles subjected to bamboo cuttings treated at different concentrations of sodium fluoride salt at various times.

B. Influence of Inorganic Salts on Lost Wood Weight:

The amount of consumed wood (lost wood) from bamboo cuttings treated by different concentrations of mineral salts and attacked by *D.minutus* beetles and larva feeding were illustrated in Tables 3 and 4.

1- Influence of Copper Sulfate Preservative:

According to data recorded in Table (3), the lost wood weight of bamboo cuttings decreased with the increase of salt concentration, at the minimum concentration of 0.25 x 10^4ppm, the lost wood weight recorded 43.20g which detected a loss ratio of about 38.10% from wood cuttings weight, this amount of lost wood gradually decreases with concentration increase, it reaches 5.64g recorded 5.09% for loss ratio at 12 x 10^4ppm of salt concentration. This result was compatible with obtained data by Batt & Ramadan (2017) who stated that the highest weight of loss wood of infested palm frond cuttings with *E. trispnosus* beetles was 64.07g recorded at concentration.0.25 x 10^4ppm of sodium fluoride while the minimum weight of loss wood was 19.94g at a concentration of 12 x 10^4ppm of salt solution.

Analyzed data resulting from the effect of different copper sulphate concentrations

on lost wood weight showed that the simple regression was negative (b=2.820) and highly significant (P=0.0001), Table 5.

2- Influence of Sodium Fluoride Preservative:

Obtained data on lost wood from bamboo cuttings treated with different concentrations of sodium fluoride were recorded in Table (4).

The highest weight of lost wood was recorded at 29.3g representing 25% of treated wood at a concentration of 0.25 x 10^4ppm, while the minimum weight for consumed wood was 5.23g, representing 4.7% of the treated weight of bamboo wood at a concentration 8 x 10^4ppm. In this respect, Batt & Ramadan (2017) showed that the highest loss of wood of infested palm frond cuttings with *E. trispnosus* beetles was 62.87g recorded at concentration.0.25 x 10^4ppm of sodium fluoride while the minimum weight of loss wood was 19.88g at a concentration of 8 x 10^4ppm of salt solution.

Statistical data resulting from the effect of sodium fluoride concentrations on lost wood weight appeared that the simple regression was negative (b=-1.984) and significant (P=0.0378), Table 5**.**

Table 3: Influence of copper sulfate preservative on the lost wood weight of bamboo cuttings infesting with *D. minutus* beetles.

Concentration		**Weight of cutting (g)**		**Lost wood**	
Percent (%)	ppm	Before treatment	After treatment (emergence)	Weight (g)	Loss ratio (%)
0.25	0.25 x 10^4	113.4	70.2	43.20	38.10
0.50	0.50 x 10^4	115.7	74.9	40.80	35.26
1	1 x 10^4	112.7	75.3	37.40	33.19
2	2 x 10^4	96	66.05	29.95	31.2
4	4 x 10^4	98	71.40	26.60	27.14
6	6 x 10^4	103	78.60	24.40	23.69
8	8 x 10^4	115	100.05	14.95	13
10	10 x 10^4	108	100.50	7.50	6.94
12	12 x 10^4	110.87	105.23	5.64	5.09
Infested cuttings untreated		118.6	66.7	51.90	43.8
Moisture content		114.7	109.2	5.5	4.8

Table 4: Influence of sodium fluoride preservative on the lost wood weight of bamboo cuttings infesting with *D. minutus* beetles.

Concentration		**Weight of cutting (g)**		**Lost wood**	
Percent (%)	ppm	Before treatment	After treatment (emergence)	Weight (g)	Loss ratio (%)
0.25	0.25 x 10^4	117	87.7	29.3	25
0.50	0.50 x 10^4	98.8	80.5	18.3	18.5
1	1 x 10^4	122	109.3	12.7	10.4
2	2 x 10^4	107.4	97. 6	9.8	9.1
4	4 x 10^4	113.1	106.09	7.01	6.2
6	6 x 10^4	111.3	104.96	6.34	5.7
8	8 x 10^4	111.6	106.37	5.23	4.7
Infested cuttings untreated		108.9	64.3	44.6	41.0
Moisture content		112.4	107.2	5.2	4.63

Table 5: Statistical evaluation for obtained values to impact certain salts on mortality percentages, reduction of entrance holes, reduction of emergence holes and loss of wood by *D.minutus* beetles.

Variables	Simple regression			
	b	p	b	p
	Copper sulfate		Sodium fluoride	
Mortality percentages	6.202	0.0001**	10.087	0.0001**
%Reduction entrance holes	7.804	0.0001**	9.685	0.0021**
%Reduction emergence holes	7.841	0.0001**	8.922	0.0045**
Lost wood weight	-2.820	0.0001**	-1.984	0.0378*

*: Significant **: highly Significant P = Probability

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ARABIC SUMMARY

فعالية بعض الأملاح المعدنية ـ كحافظات للخشب ـ ضد خنفساء البامبو *Dinoderus minutus* Fab., (Coleoptera: Bostrychidae).

محمد عبد الغنى بط ومعوض حسين رمضان

معهد بحوث وقاية النباتات- مركز البحوث الزراعية – ا لدقى - الجيزة – مصر

التأثير الوقائى والعلاجى لبعض الأملاح المعدنية على خنفساء *Dinoderus minutus* التى تصيب أخشاب البامبوأوضحت أن أخشاب البامبو السليمة والمصابة المعاملة بكل من سلفات النحاس وفلوريد الصوديوم أعطت 100% وقاية وخفض للاصابة بواسطة التركيز 12% لسلفات النحاس والتركيز 8% لفلوريد الصوديوم. وقد وجد أن ثقوب خروج الخنافس تتناقص بزيادة تركيز الملح المستعمل دليل على موت الأطوار المختلفة للخنافس داخل أخشاب البامبو المصابة المعاملة بالتركيز المناسب للملح المستعمل.

وقد وجد أن كمية الخشب المستهلك والمفقود من خشب البامبو المصاب تتناقص مع زيادة تركيز الملح كما وجد أن النسبة المئوية للخشب المفقود تناقصت من 5.09% إلى 38.1% لسلفات النحاس عند التركيز بين 12% ، 0.25% بينما تراوحت النسب المئوية للخشب المفقود بين 4.7% إلى 25% للتركيز 8% ، 0.25% على التوالى لفلوريد الصوديوم