JJBS

Volume 7, Number 1, March .2014
ISSN 1995-6673
Pages 49 - 55

Jordan Journal of Biological Sciences

Newbouldia laevis (Seem) as an Entomocide Against *Sitophilus oryzae* and *Sitophilus zeamais* Infesting Maize Grain

Olaniyi C. Ogungbite* and Emmanuel A. Oyeniyi

Department of Biology, Federal University of Technology, P.M.B 704, Akure, Nigeria.

Received: October 21, 2013 Revised: November 26, 2013 Accepted: November 30, 2013

Abstract

This study was conducted under laboratory conditions at temperature of 28±2^{o}C and relative humidity 75±5% to investigate the entomocidal flurry of *Newbouldia laevis* against *Sitophilus oryzae* and *Sitophilus zeamais* infesting maize grain in storage. The powders of stem and root of *N. laevis* were prepared at 0.1, 0.2, 0.3, 0.4 and 0.5g dosages, while their extracts were prepared at 1, 2, 3, 4 and 5% concentrations. The control experiments were also set up. None of the powders of stem and root of this plant was able to achieve complete mortality of the two insects within 96h of application, except for the root powder which was able to achieve 100% mortality of *S. oryzae* at 0.5g dosage only. Only the root extract at 4% was able to achieve complete weevils mortality within 96h and its effect was significantly different (p<0.05) from the extracts of the stem except at 4 and 5% concentration of stem extract. The fiducial limits showed that a lower concentration of root extract was needed to cause 50% mortality in *S. zeamais* (0.00-1.64 %) when compared to the concentration needed for *S. oryzae* (0.10-1.72 %). Both the stem and root extracts of the plant were more effective than their powders. The powders and the extracts of this plant either reduced or prevented the emergence of adult weevils and inhibit the developmental period of the insects. The powders and the extracts of *N. laevis* also reduced or prevented the weight loss of the treated maize grains. Therefore, with the result obtained in this research, both the powder and extract of *N. laevis* root and stem could go a long way in the quest of providing alternative wherewithal to the use of chemical insecticides for protecting maize grain in storage. Root extract of *N. laevis* could, however, offer more protection against *S. oryzae* and *S. zeamais* infesting maize grain than its stem extracts.

Keywords: Entomocide, Plant Extract, *Newbouldia laevis*, *Sitophilus oryzae, Sitophilus zeamais*, Adult Emergence, Weight Loss.

1. Introduction

Crop protection plays a vital and integral role in ensuring food security in a particular country. In many developing countries, security of food has been threatened due to infestation of their farm produce by many stored product insect pests starting from the field to storage where it is more pronounced. Loss of stored grains which amounts to 5-10% in the temperate countries and 20-30% in the tropical zones has been associated with the infestation by many stored product insect pests (Dubey *et al.*, 2008; Rajashekar and Shivanandappa, 2010). Maize, one of the major staple foods of the world, has been attacked by a wide range of insect pests including beetles, weevils and moths.

In recent decades, controlling many of these destructive insect pests has profoundly relied upon the use of synthetic chemical insecticides (Akinkurolere, 2007; Akinneye and Ogungbite, 2013), which has been reported to have many cons that impede their widespread use nowadays. These include high cost of procurement, pest resurgence and resistance, poisonous residue accumulation in foods, risks of user's contamination, effect on both human and environmental health (Ashamo and Akinnawonu, 2012; Akinneye and Ogungbite, 2013). Public awareness of the adverse effects of the synthetic chemical insecticides has called for the urgent need to look for safer alternatives that could comparably contend with chemical insecticides in action both preferably and adequately.

In order to obviate the use of these synthetic chemical insecticides, research studies have been focused on the plant kingdom as a new tool of controlling insect pests of stored products. Prior to the discovery and commercial success of the synthetic chemical insecticides in the late 1930s and early 1940s, botanical base insecticides have remained important weapons in the farmers armory in managing the insect pests of their farm produce (Forim *et al.*, 2012). Hitherto, in spite of the effectiveness of many botanical insecticides, their insecticidal activity is yet to be comparable to many synthetic chemical insecticides; and the once that are believed to be comparable with chemical insecticides have not commanded more than 1% of the global insecticide market (Isman, 2000;

* Corresponding author. e-mail: olaniyi2oguns@gmail.com.

Begum *et al.*, 2013) because they are believed to live for a short period of time and to lose their potency over time (Oruonye and Okrikata, 2010). Therefore, there is still a need to search for other plant species which could have high efficacy against stored product insect pests.

Sitophilus oryzae and *Sitophilus zeamais* are important stored product insect pests of maize, whose infestations have brought about diminution of the quality and the marketability of this grain. *Newbouldia laevis* is a medicinal plant whose insecticidal effect has been proved against *Callosobruchus maculatus* infesting cowpea seeds (Ashamo *et al.*, 2013). This study, therefore, investigates *N. laevis* (Seem) as an entomocide against *S. oryzae* and *S. zeamais* infesting maize grain.

2. Materials and Methods

2.1. Insect Culture

The culture of *S. oryzae* and *S. zeamais* was obtained from an infested maize grain at Food Storage Research Laboratory, Federal University of Technology, Akure, Nigeria. This was reared on non-infested clean maize grains obtained from Agricultural Development Project (ADP) Akure, Nigeria. The experiment was setup in the laboratory at temperature of 28±2°C and relative humidity of 75±5%.

2.2. Collection of Plant Materials and Maize Seeds

Different parts of *N. laevis* were collected from Oke-Odo Aratunsin area of Akure, Ondo State, Nigeria. Collected plants were taken to Natural History Museum Obafemi Awolowo University, Ile-Ife for identification. The yellow variety of maize grains, used for the experiment, was obtained from the Agricultural Development Project (ADP), Akure, Nigeria. The seeds were cleaned of foreign matter and disinfested by being kept in a freezer at -5°C for 7 days. They were then air-dried to avoid mouldiness of the grains.

2.3. Preparation of Plant Powder and Extracts

The plant parts (stem bark and root bark) used were collected fresh and sun dried. The plant parts were ground into fine powder using electric blender and the powders were further sieved to pass through 1mm^2 perforations before being stored in separate plastic containers with tight lids for subsequent use. 0.1, 0.2, 0.3, 0.4 and 0.5g of the powders were weighed using Metler beam weighing balance. To prepare the extract, twenty grams of each pulverized plant materials (stem bark and root bark) was put in a muslin cloth and transferred into the thimble and extracted with methanol in a soxhlet apparatus. The extraction was carried out for 3-4 hr depending on the plant material. The extraction was terminated when the solvent in the thimble became clear. Then, the thimble was removed from the unit and the solvent recovered by distilling in the soxhlet extractor. The resulting extracts contained both the solvent and the oil. The solvent was separated from the oil using rotary evaporator, after which the oil was exposed to air so that traces of the volatile solvents evaporate, leaving the oil extract. This is important so as to avoid making false concentrations.

From this main stock solution, different concentrations of 1, 2, 3, 4 and 5% oil concentrations were made. A concentration of 1% was made by diluting 0.1ml of plant extract in 9.9ml of methanol (solvent). 2% concentration was made by diluting 0.2ml of plant extract in 9.8ml methanol. Also, 3%, 4% and 5% concentration was made by diluting 0.3ml, 0.4ml and 0.5ml of the plant extract with 9.7ml, 9.6ml and 9.5ml of the solvent respectively. The various concentrations were made using small glass bottles and graduated syringes. After each dilution, the syringe was rinsed with the solvent while different syringes were used for different plant part extracts.

2.4. Effect of N. Laevis on Mortality, Adult Emergence and Weight Loss

2.4.1. Plant Powder

Twenty grammes of the maize grains were weighed into 250ml plastic containers. Plant powders weighing 0.0g (control), 0.1g, 0.2g, 0.3g, 0.4g and 0.5g was weighed and thoroughly mixed with the maize seeds inside the plastic containers using glass rod. The experiment was set up in a complete randomized design and each treatment was replicated five times. Ten pairs of *S. zeamais* and *S. oryzae* were separately introduced into those treated maize grains immediately and weevil mortality was assessed at 72 and 96 h post treatment. Both dead and live insects were removed on the fourth day and experiments were left for 42days to allow for emergence of F1 generation and the number of adult emerged was counted. Inhibition rate (%IR) in adult emergence was calculated using the method described by Tapondju *et al.* (2002). The weight loss of the stored

$$\%IR = \frac{C_n - T_n}{C_n} x \frac{100}{1}$$

grains was calculated using the formula below:

Where C_n is the number of insects that emerged in the control treatment and T_n is the number of adult

$$\%\text{weight loss} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} x \frac{100}{1}$$

insects that emerged in the treated grains

2.4.2. Oil Extracts

20g of maize gains was weighed into 250ml plastic containers and 1ml of plant extracts concentration of 1, 2, 3, 4 and 5% was separately mixed with the maize and was left for 1hr to ensure the escape of the methanol solvent. Two control experiments were set up, one with solvent alone and one with neither solvent nor extract (untreated control). Ten pairs of 0-24 adult insects were introduced into containers with treated grains and were arranged in a complete randomized design and each treatment was replicated five times. Adult mortality was observed after 72 and 96h of application. Both dead and live insects were removed on the fourth day and experiments were left for 42 days to allow for emergence of F_1 generation and the number of adult emerged was counted. %IR and the weight loss of the stored grains were calculated using the formula described above

2.5. Statistical Analysis

All the data obtained were subjected to one-way analysis of variance at 5% significant level and means were separated with New Duncan's Multiple Range Tests using SPSS version 17. Also data, obtained from weevil's mortality, were subjected to regression analysis to calculate the LD_{50} of the powders and LC_{50} of the extracts using probit analysis (Finney, 1971).

3. Results

3.1. Effect of stem and root powders of N. laevis on mortality of S. oryzae and S. zeamais

Table 1 presented the percentage mortality observed in *S. oryzae* and *S. zeamais* exposed to stem and root powder of *N. laevis*. Irrespective of the plant powder, weevil mortality increased with the increase in the dosage of the plant powder and the exposure time. However, significant differences (p<0.05) existed among the mortality values of *S. oryzae* and *S. zeamais*. Likewise, there was a significant difference (p<0.05) in the adult mortality of both weevils treated with both plant powder when compared to control. Generally, mortality values, observed in *S. zeamais*, were observed to be lower than those observed in *S. oryzae* and 100% mortality was only achieved in *S. oryzae* exposed to root powder of *N. laevis* at 0.5g/20g of maize grains after 96 h.

Table 1. Percentage mortality of *S. oryzae* and *S. zeamais* on maize seeds treated with plant powders of *N. laevis*

Plant material	Dosages (g)	Mean % mortality ± SE (hours)			
		S. oryzae		*S. zeamais*	
		72	96	72	96
Stem	0.1	30.00± 0.58^{b}	50.00 ± 0.58^{b}	26.20± 0.33^{b}	33.30± 0.88^{b}
	0.2	53.20± 0.88^{c}	69.00 ± 0.73^{c}	46.70±0.28^{c}	53.33± 1.45^{c}
	0.3	63.30 ± 0.67^{c}	80.00±0.58^{c}	53.28± 0.88^{c}	70.00 ± 0.00^{d}
	0.4	74.20± 0.33^{cd}	86.70±1.33^{cd}	66.40± 0.88^{cd}	76.70 ± 0.33^{de}
	0.5	78.67± 0.33^{cd}	93.30± 0.33^{cd}	76.70± 0.24^{d}	88.00 ±0.28^{e}
Root	0.1	46.00± 0.66^{b}	53.00± 0.68^{b}	35.00± 0.55^{b}	41.00± 0.58^{b}
	0.2	52.00 ± 0.93^{b}	62.00 ± 0.75^{b}	47.00 ± 0.60^{b}	56.00± 0.66^{c}
	0.3	69.00 ± 0.73^{c}	77.00 ± 1.36^{c}	56.00± 0.66^{b}	78.00± 1.22^{d}
	0.4	88.00 ± 0.75^{d}	99.00 ± 0.20^{c}	76.00 ± 1.07^{bc}	88.20± 0.63^{de}
	0.5	93.00 ± 0.40^{d}	100.00 ± 0.00^{c}	81.00 ± 0.80^{c}	94.00 ± 1.29^{e}
Control	0.0	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}

Means followed by the same letter along the column are not significantly different (P>0.05) using New Duncan Multiple Range Test.

3.2. Effect of stem and root extracts of N. laevis on mortality of S. oryzae and S. zeamais

The mortality of weevils treated with extracts of stem and root of *N. laevis* is presented in Table 2. The percentage of weevil mortality, observed in both *S. oryzae* and *S. zeamais*, was significantly different (p<0.05) from the controls with or without methanol solvent. Significant differences also existed among percentage mortality values at different concentrations of stem and root extracts in both weevils. Generally, weevil mortality increased with the increase in exposure time and concentration of stem or root extract. However, regardless of the exposure time, root extract achieved higher percentage mortality (53-100%) in both weevils at each of the concentrations when compared to stem extract (40.30-100%). This shows that the root extract was more toxic to both weevils when compared to stem extract.

Table 2. Percentage mortality of *S. oryzae* and *S. zeamais* on maize seed treated with extracts of *N. laevis*

Plant material	Concentrations (%)	Mean % mortality ± SE (hours)			
		S. oryzae		*S. zeamais*	
		72	96	72	96
Stem	1	43.30±0.33[b]	53.30±1.45[b]	40.30±0.33[b]	56.30± 0.24[b]
	2	63.30±0.33[c]	68.00±0.58[c]	54.70±0.24[bc]	66.30± 1.00[bc]
	3	66.70±0.88[c]	83.30±0.67[d]	59.30±0.88[c]	74.00 ± 0.80[cd]
	4	76.70±0.33[cd]	90.40±0.22[de]	72.00±0.24[cd]	89.78 ± 2.03[e]
	5	86.70±1.33[d]	100.00±0.00[e]	83.20±0.67[de]	100.00 ± 0.00[e]
Root	1	53.30±1.45[b]	53.00± 0.68[b]	60.00± 0.53[c]	67.24± 0.88[bc]
	2	66.24±0.28[c]	62.00 ± 0.75[bc]	68.30 ± 0.44[cd]	79.00± 0.33[cd]
	3	83.30±0.67[d]	77.00 ± 1.36[cd]	86.00± 0.67[e]	88.00± 0.24[de]
	4	96.70±0.30[e]	100.00 ± 0.00[e]	98.26 ± 0.22[e]	100.00 ± 0.00[e]
	5	100.00 ± 0.00[e]	100.00 ± 0.00[e]	100.00 ± 0.00[e]	100.00 ± 0.00[e]
Treated control		0.00±0.00[a]	2.00±0.33[a]	2.24±0.88[a]	2.24±0.88[a]
Untreated control		0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]

Means followed by the same letter along the column are not significantly different ($P>0.05$) using New Duncan Multiple Range Test.

3.3. Lethal dose (LD_{50}) and lethal concentrations (LC_{50}) of N. laevis powder and extract in S. oryzae and S. zeamais after 72 h

Table 3 shows that lower amounts of root powder and extract of *N. laevis* were needed to achieve 50% mortality in both weevils when compared to the amount required using stem powder and extract. This shows that the root of this plant material was more toxic than the stem. Also, higher amount of stem powder, root powder and stem extract of *N. laevis* were needed to kill 50% of *S. zeamais* when compared to the amount needed for *S. oryzae*. However, fiducial limits revealed that a lower amount of root extract was needed to cause 50% mortality in *S. zeamais* (0.00-1.64) when compared to the amount needed for *S. oryzae* (0.10-1.72). This further revealed that *S. oryzae* were more susceptible to stem and root powder as well as stem extract, while *S. zeamais* insects were, however, more susceptible to root extract.

Table 3. Lethal dose (LD_{50}) and lethal concentration (LC_{50}) of *N. laevis* powders and extracts required to achieve 50% mortality in *S. oryzae* and *S. zeamais* after 72 hours post treatment

Insect	Plant powder		Plant extract	
	LD_{50}(gm)		LC_{50}(%)	
	Stem	Root	Stem	Root
S. oryzae	0.19	0.14	1.32	1.09
	(0.16-0.22)	(0.01-0.22)	(0.95-1.62)	(0.10-1.72)
S. zeamais	0.23	0.19	1.61	0.96
	(0.20-0.27)	(0.10-0.27)	(1.22-1.95)	(0.00-1.64)

Values in parenthesis represent 95% fiducial limits.

3.4. Adult emergence, Inhibition rate (%IR) in adult emergence of S. oryzae and S. zeamais and weight loss in maize grains treated with N. laevis powders

Table 4 reveals more *S. oryzae* (33.24%) and S. *zeamais* (37.21%) emerged from the control maize grain which was significantly higher ($p<0.05$) than those observed in the treated maize grains. Weevil's emergence in the treated maize grains also decreased with increasing dosage of both plant powders. However, significantly fewer ($p<0.05$) *S. oryzae* and *S. zeamais* emerged from the maize grains treated with root powder when compared to those treated with stem powder. Percentage reduction in F1 progeny also increased with the increase in the dosage of stem and root powder of *N. laevis*; this was significantly different ($p<0.05$) from that of control. Regardless of the weevil used to infest the maize grains, high percentage reduction in F1 progeny, which ranges from 89.85-100%, was observed in maize grains treated with root powder of *N. laevis* when compared to their counterpart treated with stem powder of this plant material which ranges from 81.60-89.29%. 100% reduction in F1 progeny was, however, observed only at 0.4g and 0.5g of root powder/20g of maize grains infested with *S. oryzae*. But for maize grains infested with *S. zeamais*, 100% reduction was only observed at 0.5g of root powder/20g of maize grains. Weight loss in control maize grains was significantly higher ($p<0.05$) than in the treated maize grains. Significant differences also existed among maize grains treated with both plant parts powders and infested with both weevils. Generally, weight loss in maize grains reduced with increasing stem and root powder of *N. laevis*. No weight loss was, however, observed at 0.4 and 0.5g of root powder/20g of maize grains infested with *S. oryzae* and 0.5g of root powder/20g of maize grains infested with *S. zeamais*.

Table 4. Number of adult emergence, inhibition rate (%IR) in adult emergence of *S. oryzae* and *S. zeamais* and weight loss in maize grains treated with *N. laevis* powders.

Plant materials	Dosage (g)	*S. oryzae*			*S. zeamais*		
		Mean number of adult emergence±S.E	%IR	(%)Weight loss	Mean number of adult emergence	%IR	(%)Weight loss
Stem	0.1	7.93 ± 0.44^{d}	81.60 ± 0.08^{b}	9.00 ± 0.58^{c}	8.10 ± 0.08^{ef}	73.62 ± 0.01^{b}	9.78 ± 0.39^{d}
	0.2	5.74 ± 1.33^{c}	83.79 ± 1.43^{b}	8.60 ± 0.40^{c}	7.50 ± 1.55^{e}	77.08 ± 0.22^{b}	9.60 ± 1.33^{d}
	0.3	4.44 ± 2.03^{c}	86.00 ± 0.33^{b}	7.67 ± 0.33^{bc}	4.87 ± 3.02^{d}	82.30 ± 0.02^{c}	7.96 ± 0.24^{c}
	0.4	4.02 ± 0.34^{c}	86.95 ± 1.77^{b}	7.33 ± 0.67^{bc}	4.56 ± 0.53^{d}	85.82 ± 1.02^{c}	7.58 ± 4.01^{c}
	0.5	3.97 ± 2.88^{c}	89.29 ± 0.33^{bc}	6.11 ± 1.06^{b}	4.29 ± 1.48^{d}	88.37 ± 2.36^{cd}	6.11 ± 1.06^{bc}
Root	0.1	2.70 ± 0.34^{b}	89.85 ± 1.17^{bc}	9.43 ± 1.32^{c}	2.89 ± 0.23^{c}	89.40 ± 0.01^{cd}	9.54 ± 0.03^{d}
	0.2	2.10 ± 1.28^{b}	92.00 ± 0.32^{cd}	6.28 ± 0.33^{b}	2.47 ± 0.13^{c}	91.49 ± 0.22^{d}	7.13 ± 1.04^{c}
	0.3	0.13 ± 0.01^{a}	99.98 ± 0.01^{d}	4.67 ± 2.88^{b}	1.44 ± 2.04^{b}	95.04 ± 1.67^{d}	5.78 ± 0.23^{bc}
	0.4	0.00 ± 0.00^{a}	100.00 ± 0.00^{d}	0.00 ± 0.00^{a}	1.00 ± 0.33^{ab}	97.86 ± 2.24^{e}	3.86 ± 0.33^{b}
	0.5	0.00 ± 0.00^{a}	100.00 ± 0.00^{d}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	100.00 ± 0.00^{e}	0.00 ± 0.00^{a}
Control	0.0	33.26 ± 2.06^{e}	0.00 ± 0.00^{a}	73.30 ± 0.01^{d}	37.21 ± 2.45^{g}	0.00 ± 0.00^{a}	81.32 ± 0.28^{e}

Means followed by the same letter along the column are not significantly different ($P>0.05$) using New Duncan Multiple Range Test.

3.5. Adult emergence, Inhibition rate (%IR) in adult emergence of S. oryzae and S. zeamais and weight loss in maize grains treated with N. laevis extracts

Table 5 shows there was a significantly higher ($p<0.05$) adult emergence of both weevils in maize grains of treated and untreated control when compared to grains treated with stem and root extracts of *N. laevis.* Adult emergence decreased with the increase in concentration of plant part extract irrespective of the plant part extract used. However, grains treated with root extract and infested with both weevils showed a lower adult emergence than those treated with stem extract of *N. laevis.* No weevil emerged at 4 and 5% of stem extract/20g of maize grains infested with *S. oryzae* and 5% of stem extract/20g of maize grains infested with *S. zeamais.* Likewise, no weevil emerged at 3, 4 and 5% of root extract/20g of maize grains infested with *S. oryzae* and *S. zeamais*. Percentage reduction in F1 progeny of both weevils increased with increase in concentration of both extracts and 100% reduction in F1 progeny was observed at 4 and 5% of stem extract/20g of maize grains infested with *S. oryzae* and 5% of stem extract/20g maize grains infested with *S. zeamais*. At 3, 4 and 5% of root extract/20g of maize grains infested with both weevils; 100% reduction was also observed in progeny development. Weight loss in maize grains of treated and untreated control was significantly higher ($p<0.05$) than in the maize grains treated with extract of *N. laevis*. Weight loss at 4 and 5% of stem extract/20g of maize grains infested with both weevils was significantly lower ($p<0.05$) when compared to weight loss at 1, 2 and 3% respectively. Likewise, weight loss at 3, 4 and 5% of root extract/20g of maize grains infested with *S. oryzae* was also significantly lower than at 1 and 2%. But, no significant different ($p>0.05$) existed among the weight loss observed in maize grains treated with root extract and infested with *S. zeamais*.

Table 5. Number of adult emergence, inhibition rate (%IR) in adult emergence of *S. oryzae* and *S. zeamais* and weight loss in maize grains treated with *N. laevis* extracts.

Plant materials	Conc. (%)	*S. oryza*			*S. zeamais*		
		Mean number of adult emergence	%IR	(%)Weight Loss	Mean number of adult emergence	%IR	(%)Weight loss
Stem	1	5.25 ± 2.57^{e}	86.42 ± 2.08^{b}	6.82 ± 1.44^{d}	8.10 ± 0.08^{ef}	73.62 ± 0.01^{b}	7.25 ± 0.01^{d}
	2	3.74 ± 1.28^{d}	88.36 ± 1.22^{b}	5.96 ± 4.20^{cd}	7.50 ± 1.55^{e}	77.08 ± 0.22^{b}	6.25 ± 2.01^{d}
	3	1.22 ± 4.01^{c}	92.24 ± 3.34^{c}	4.67 ± 0.01^{c}	4.87 ± 3.02^{d}	82.30 ± 0.02^{b}	4.98 ± 0.67^{c}
	4	0.00 ± 0.00^{a}	100.00 ± 0.00^{d}	0.00 ± 0.00^{a}	0.58 ± 0.24^{ab}	97.44 ± 4.01^{c}	2.42 ± 2.67^{ab}
	5	0.00 ± 0.00^{a}	100.00 ± 0.00^{d}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	100.00 ± 0.00^{c}	0.00 ± 0.00^{a}
Root	1	1.70 ± 1.33^{c}	95.67 ± 1.33^{cd}	2.74 ± 2.88^{b}	1.98 ± 1.33^{c}	93.74 ± 2.44^{c}	2.73 ± 0.01^{ab}
	2	0.52 ± 1.28^{ab}	97.82 ± 0.02^{d}	2.14 ± 0.01^{b}	0.58 ± 4.13^{ab}	97.44 ± 0.28^{c}	0.60 ± 3.01^{a}
	3	0.00 ± 0.00^{a}	100.00 ± 0.00^{d}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	100.00 ± 0.00^{c}	0.00 ± 0.00^{a}
	4	0.00 ± 0.00^{a}	100.00 ± 0.00^{d}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	100.00 ± 0.00^{c}	0.00 ± 0.00^{a}
	5	0.00 ± 0.00^{a}	100.00 ± 0.00^{d}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	100.00 ± 0.00^{c}	0.00 ± 0.00^{a}
Untreated control		33.26 ± 2.06^{f}	0.00 ± 0.00^{a}	73.30 ± 0.01^{e}	37.21 ± 2.45^{g}	0.00 ± 0.00^{a}	81.32 ± 0.28^{d}
Treated control		34.78 ± 1.33^{f}	0.00 ± 0.00^{a}	73.89 ± 0.10^{e}	35.82 ± 1.55^{g}	0.00 ± 0.00^{a}	78.67 ± 2.67^{d}

Means followed by the same letter along the column are not significantly different ($P>0.05$) using New Duncan Multiple Range Test.

4. Discussion

The use of plant materials as a protectant against stored product pests is a common practice mostly in many developing countries of the world. This practice has been suggested as one of great hope for controlling stored product pests (Singh, 2011) due to several limitations associated with the use of synthetic insecticides and fumigants. As a result, several powders and extracts of different plants have been shown to possess insecticidal activity against stored product pests (Ileke and Olotuah, 2012; Akinneye and Ogungbite, 2013; Ashamo *et al*., 2013).

In this study, both the powders and extracts of *N. laevis* were observed to cause adult mortality and reduced adult emergence and progeny development of both weevils. They also reduced weight loss of maize grains treated with this plant material. However, the efficacy depended on the plant part used (stem or root), dosage or concentration of *N. laevis* and exposure time. Stem and root extracts were also observed to be more effective than the powders and this may be linked to the presence of more bioactive compounds in the methanolic extracts of this plant when compared to the powder. Powder and extract of *N. laevis* root also proved to be more effective in controlling both weevils than the stem as revealed by their $LD_{50}$and LC_{50} values. This can be corroborated by the findings of Ashamo and Akinnawonu (2012) in which the efficacy of different plant oils were found to be effective than their powders. It was also noted that the root extracts were more effective than the stem extracts. This result agreed with the work of Ashamo *et al*. (2013) in which the root extract of *N. laevis* was found to be more effective than the extracts of its leaf and stem in controlling *Callosobruchus maculatus* on cowpea. The high mortality effect of these *N. laevis* oil extracts and powders could be due to the inability of the insects to feed on the maize grain that have been coated with these oils and powders thereby leading to their starvation. The oils and powders of this plant may have also disrupted the normal respiratory activities of these insects leading to the asphyxiation and subsequent death (Ashamo *et al.,* 2013).

The higher efficacy of root powder and extract of *N. laevis* may be ascribed to some toxic phytochemical compounds in roots that may not be present in stem of this plant. *N. laevis* root bark had been reported to contain alkaloids, tannins, flavonoids, saponins, cyanogenetic glycosides, cardiac glycosides and phenylpropanoids (Germann *et al.,* 2006; Akerele *et al.,* 2011) while the stem barks contained tannins, flavonoids, and alkaloids (Anaduaka *et al.,* 2013). Most of these compounds had been reported for their considerable toxicity and antifeedant effect towards insects (Yang *et al*., 2006). However, the actual compound responsible for the higher insecticidal activity of root of *N. laevis* on weevils when compared to that of the stem remains to be explored.

The results of this study reveal that *S. zeamais* tolerates stem and root powder as well as stem extract more than *S. oryzae* while *S. oryzae* tolerates the root extract more than *S. zeamais*. The high tolerance of *S. zeamais* insects to the plant material might be due to the thicker exoskeleton and larger size when compared to that of *S. oryzae* (Buhler, 2013). Thicker exoskeleton in insects reduces the penetration of plant materials (Delorme *et al.,* 1988) while larger size affords them the ability to withstand the effect of a poison (Buhler, 2013).

Powders and extracts of *N. laevis* also significantly reduced or prevented the adult emergence of both weevils when compared to the control. This could be linked to the inability of the weevil eggs to develop adult due to the death of their larvae, which cannot cast off their old exoskeleton which typically remain linked to the posterior part of the abdomen (Oigiangbe *et al.,* 2010). This further suggests that *N. laevis* may have an obvious effect on the post embryonic survival of both weevils, which, in turn, prevents and significantly reduces adult emergence from treated maize grains when compared to control (Ashamo *et al.,* 2013). Also, different chemical compositions of these plants as mentioned earlier could be accountable for the inability of the adult insects to emerge as they are found to disrupt growth and reduced larva survival as well as disruption of life cycle of insects (Yang *et al.,* 2006). This result showed that both the powders and extracts of *N. laevis* had high rate of inhibition on the emergence of the adult weevils and this agreed with the work of Akinneye and Ogungbite (2013) in which the powder and extract of *Zanthoxylum. zanthoxyliodes* was found to inhibit the development of *S. zeamais.*

Powders and extracts of *N. laevis* significantly reduced or prevented the weight loss of treated maize grains. At the highest experimental dosage and concentration, the plant material completely prevented weight loss in infested maize grains with the exception of stem powder. The plant root powder and extract however reduced weight loss in infested maize grains than the stem powder and extract. This reduction in weight loss may be due to the inability of the larvae of both weevils to feed on the treated maize grains. Similar observation has been reported by Jayakumar *et al.* (2003) and Asawalam *et al.* (2007) on cowpea seeds treated with plant materials.

N. laevis is a plant with so many medicinal properties as it is used in the treatment of malaria fever, constipation coughs, tooth ache, sexually transmitted diseases and breast cancer (Iwu, 2000). The plant is readily available and it is native to tropical Africa and grows from Guinea Savannahs to dense forests, or moist and well-drained soils (Burkhill, 1984). Therefore, with the result obtained in this research, both the powder and extract of *N. laevis* root and stem could go a long way in the quest of providing alternative wherewithal to the use of chemical insecticides for protecting maize grain in storage. Root extract of *N. laevis* could however offer more protection against *S. oryzae* and *S. zeamais* infesting maize grain than its stem extracts. Further investigations is required to identify the main active compounds responsible for the higher toxicity of both powders and extracts of *N. laevis* stem and root on weevils.

References

Akerele JO, Ayinde BA and Ngiagah J. 2011. Comparative phytochemical and antimicrobial activities of the leaf and root bark of *Newbouldia laevis* Seem (Bignoniaceae) on some clinically isolated bacterial organisms. *Nig J Pharm Sci.,* **10 (2):** 8–14.

Akinkurolere RO. 2007. Assessment of the insecticidal properties of *Anhomanes difformis* (P. Beauv.) powder on five beetles of stored produce. *J Entomol.,* 4**(1):** 51-55.

Akinneye JO and Ogungbite OC. 2013. Insecticidal activities of some medicinal plants against *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidae) on stored maize. *Archiv Phytopath Plant Protect.,* **46(10):** 1206-1213.

Anaduaka EG, Ogugua VN, Egba SI and Apeh VO. 2013. Investigation of some important phytochemical, nutritional properties and toxicological potentials of ethanol extracts of *Newbouldia laevis* leaf and stem. *Afric J. Biotechnol*., **12(40):**5941-5949.

Asawalam EF, Emosairue SO, Ekeleme F and Wokocha RC. 2007. Insecticidal Effects Of Powdered Parts Of Eight Nigerian Plant Species Against Maize Weevil *Sitophilus Zeamais* Motschulsky (Coleoptera: Curculionidae). *Electro. J Environ. Agricult. Food Chem.,* **6(11):**2526-2533.

Ashamo MO and Akinnawonu O. 2012. Insecticidal efficacy of some plant powders and extracts against the Angoumois grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae). *Archiv Phytopath Plant Protect.,* **45 (9)**: 1051-1058.

Ashamo MO, Odeyemi OO and Ogungbite OC 2013. Protection of cowpea, *Vigna unguiculata* L. (Walp.) with *Newbouldia laevis* (Seem.) extracts against infestation by *Callosobruchus maculatus* (Fabricius). *Archiv Phytopath Plant Protect.,* **46(11):** 1295-1306.

Begum N, Shaarma B and Pandey RS 2013. *Caloptropis procera* and *Annona squamosa*: Potential alternatives to chemical pesticides. *Britis J Appl Sci Technol.,* **3(2):** 254-267.

Buhler W. 2013. Introduction to Insecticide Resistance. Pesticide Environmental Stewardship. Supported by Center for Integrated Pest Management. http://pesticidestewardship.org/ resistance/ Pages/understandingresistance.aspx. Retrieved 6th March, 2013.

Burkhill, HM. 1984. **The Useful Plants of West Tropical Africa** 2nd Edition Vol. I Families A-D Royal Botanic Gardens, KEW 686pp.

Delorme R, Fournier D, Chaufaux J, Cuany A, Bride JM, Auge D and Berge JB. 1988. Esterase metabolism and reduced penetration are causes of resistance to deltamethrin in *Spodoptera exigua* HUB (Noctuidea; Lepidoptera). *Pestic Biochem Phy*., **32:**240-246.

Dubey NK, Srivastava B and Kumar A. 2008. Current status of plant products as botanical insecticides in storage pest management. *J Biopesti.,* **1(2):**182-186.

Finney DJ. 1971. **Probit Analysis**. Cambridge University Press, Cambridge, London, 333pp.

Forim MR, Da-silva MFGF, Fernandes JB 2012. Secondary metabolism as a measurement of efficacy of botanical extracts: The use of *Azadirachta indica* (Neem) as a model. In: Perveen, F. (Ed), **Insecticides-Advances in Integrated Pest Management**. ISBN:987-953-307-780-2. pp367-390.

Germann K., Kaloga, M., Ferreira D, Marais JP. and Kolodziej H. 2006. Newbouldioside A-Phenylethanoid Glycosides from the stem bark of *Newbouldia leavis. Phytochem.,***67(8):** 805–811.

Ileke KD, Olotuah OF. 2012. Bioactivity *Anacardium occidentale* (L) and *Allium sativum* (L) powders and oil Extracts against cowpea Bruchid, *Callosobruchus maculatus* (Fab.) (Coleoptera: Chrysomelidae). *Inter J Biolo.,* **4(1):**8-13.

Isman MB. 2000. Plant essential oils for pest and disease management. *Crp Protecti,* **19:**603-608.

Iwu MM. 2000. **Handbook of Africa Medicinal Plants**. CRC Press, Inc. London p. 19.

Jayakumar M, Raja N and Ignacimuthu S. 2003. Efficacy of Crude extracts of *Hyptis suaveolens* and *Melochiacor chorifolia* on pulse beetle *Callosobruchus maculates***.** In Ignacimuthu S and Jeyaraj S (Eds), **Biological Control of Insect Pests**. Phoenix Publishing House, New Delhi, pp. 218-221.

Oigiangbe ON, Igbinosa IB and Tamo M. 2010. Insecticidal properties of an alkaloid from *Alstonia boonei* De Wild. *J Biopesti,* **3(1):**265 – 270.

Oruonye ED, Okrikata E, (2010) Sustainable use of plant protection products in Nigeria and challenges. *J Plant Breed Crop Sci.,* **2(9):**267-272.

Rajashekar Y and Shivanandappa T. 2010. A novel natural insecticide molecule for grain protection. The 10th international working conference on stored product protection. DOI:10.5073/jka.2010.425.413.

Singh, SR. 2011. Bioecological studied and control of pulse bettle *Callasobruchus chinensis* (Coleoptera : Bruchidae) on cowpea seed. .*Advanc Appl Sci. Res.,* **2(2):**295-302.

Tapondju, IA, Alder A, Fontem H and Fontem DA. 2002. Efficacy of powder and essential oil from *Chenopodium ambrosioides* leaves as post-harvest grain protectants against six stored products beetles. *J Stor Prod Res.,* **38:**395-402.

Yang Z, Zhao B, Zhu L, Fang J and Xia L. 2006. Inhibitory effects of alkaloids from *Sophora alopecuroids* on feeding,development and reproduction of *Clostera anastomosis*. *Front For China*, **1(2)**: 190-195.