



## Effects of Balanite (*Balanites aegyptiaca*) and Neem (*Azadirachta indica*) Oils against the Tropical Warehouse Moth (*Ephestia cautella*) in Stored Maize

Malgwi, A. M.,\* Medugu, M. A. and Shehu, A

Department of Crop Protection, Faculty of Agriculture, Modibbo Adama University,  
P.M.B 2076 Yola, Adamawa State, Nigeria

### Abstract

*Ephestia cautella* (Walker) is an important storage pest of maize. The control of this insect relies heavily on the use of synthetic insecticides. This leads to environmental hazards, toxicity to non-target organisms and development of resistant strains of insect pests. Therefore, in this study laboratory bioassays were conducted by treating 100 g of maize grains with different concentrations of neem and desert date oils (10, 15, 20 and 25 ml/l) and Dichlorvos (DDVP) (10 ml/l) as standard reference product. Data were collected on contact toxicity by grain treatment, effects on progeny production, grain damage, weight loss, germination and palatability test. The persistence of the oils and DDVP were also tested. Each treatment was replicated three times in a completely randomized design (CRD). The data obtained were analyzed using ANOVA. The results indicated that Dichlorvos, neem and desert date oils significantly ( $P<0.05$ ) caused mortality of adults and reduced progenies emergence. There was no emergence on grains treated with the oils at 30 ml/l and some of the adults emerged were deformed and hence can affect their survival and reproductive ability. Consequently, the oils also significantly ( $P<0.05$ ) reduced the grain damage and weight loss. The oils remained effective for 9 weeks with percent mean damage of 8.67% and 5.13 % on grains treated with neem and desert date oils, respectively, at 20 ml/l as against the control with 68.10 % damage. The oils were also found to have no effects on seed germination with 90 to 93.33 % and 86.67 to 91.67 % percent germination were recorded on neem and desert date treated grains, respectively. Palatability of the treated grains was not affected by the oils after three (3) months storage. It was therefore shown that The effectiveness of neem oil is nothing new or that to be proven neem and desert date oils significantly ( $P<0.05$ ) reduced infestation of maize grains and provided good protection to maize grains and could therefore be considered as a substitute for DDVP and other synthetic insecticides.

**Keywords:** Maize, *Azadirachta indica*, *Balanites aegyptiaca*, *Ephestia cautella*, Dichlorvos.

---

\*Correspondence email:  
annamalgwil@gmail.com

### INTRODUCTION

Maize (*Zea mays* L., Family; Poaceae) is an important cereal grain widely cultivated in

the tropics for human consumption, as feed for livestock and poultry, as a raw material for many industrial products and for soil nitrogen enrichment (Badu-Apraku and Fakorede, 2006; Hanna, 2018). Maize is the most important cereal in the world after wheat and rice with regard to areas of cultivation and total production (Malgwi and Dunuwel, 2013). It is an important crop in the domestic economy of Nigerians and is also the most important staple food for resource-poor smallholders in Africa, providing food and income to millions of people (Tefera, 2012). The production of maize cuts across all the ecological zones of the country, although the intensity of cultivation and production differ in these zones. The main producing countries in Africa as of 2020 are South Africa (15.3 million tonnes), Nigeria (12 million tonnes), Ethiopia (10.02 million tonnes) and Egypt (7.5 million tonnes) (FAO, 2022a). One of the major constraints to the increased and sustainable production of maize is its susceptibility to infestation by insect pests both in the field and during storage (Falak *et al.*, 2003). Insect infestation of maize grains and its products during storage causes considerable loss due to tunneling activity of larvae of *Tribolium castaneum* (Herbst), *T. confusum* (Jacquelin du Val), *Plodia interpunctella* (Hubner), *Sitophilus zeamais* (Mots.), *Sitotroga cerealella* (Oliver), *Ephestia cautella* (Walker) and *Prostephanus truncatus* (Horn) among others (Oni, 2011).

The tropical warehouse moth *Ephestia cautella* (Walker) is primarily distributed in tropical and subtropical climates where it is often the most important stored product pest in non-arid areas (Akol *et al.*, 2001). The larvae of *E. cautella* attack the grain germ, moving from grain to grain and consuming these parts. Contamination of the infested commodity also occurs from the large

quantity of webbing which is spun over its surface (Akol *et al.*, 2001). Their frass, faeces and bad odour also results into serious contamination of the grains. To reduce these losses, certain control measures must be taken. Insect pest control in stored produce normally relies heavily on the use of fumigants and residual contact insecticides (Obeng-Ofori, 2007 and Shehu *et al.*, 2010). The implications of these are serious problems of toxic residues, health and environment hazards, development of insecticide resistant insect strains, increasing cost of application and erratic supply of safer chemicals in the developing countries due to foreign exchange constraints (Obeng-Ofori, 2007). The need to find materials that effectively protect stored produce, that are readily available, affordable, pest specific, less prone to pest resistance and resurgence, relatively less poisonous to man, beneficial organisms and less detrimental to the environment had stimulated interest in the development of alternative control strategies and re-evaluation of traditional botanical pest control agents (Grzywacz, 2013).

Plant derived pesticides are effective against many pests as antifeedants, repellents or toxicants and are less hazardous (Obeng-Ofori, 2007 and Grzywacz, 2013). Seed extracts from neem tree (*Azadirachta indica* A. Juss.) and desert date (*Balanites aegyptica* L. Delile.) have attracted special interest of Entomologists and Phytochemists throughout the world (Yadav and Panghal, 2010; Obeng-Ofori, 2007). Neem products are broad spectrum in activity and are known to affect over 300 species of insects as well as mites, nematodes, fungi, bacteria and few viruses (Obeng-Ofori, 2008). Extracts from several parts of *B. aegyptiaca* were shown to exhibit antifeedants and molluscidal activities against variety of pests and steroidal saponin is believed to be the main cause behind these activities (Chothani and Vaghasiya, 2011). In

spite of the highly positive benefits derived from the use of the neem products, their utilization as pesticide is limited in Africa (Obeng-Ofori, 2007), desert date have also received limited recognition from research and development community (Okia *et al.*, 2011). Therefore, in this study, laboratory bioassays were used to evaluate the efficacy of neem and desert date oils in the control of the tropical warehouse moth, *E. cautella* on stored maize grains.

## MATERIALS AND METHODS

### Experimental Site

Laboratory experiments were conducted at Entomology Laboratory, Department of Crop Protection, Faculty of Agriculture, Modibbo Adama University, Yola, Nigeria. The geographical coordinate of the Laboratory is located on latitude 9°20'49"N and longitude 12°29'41"E (Google compass, 2022). The work was conducted at room temperature and relative humidity range of 32 - 35°C and 55 to 75%, respectively starting from October, 2021 to April, 2022.

### Experimental Materials

Materials used for the study were neem seed oil, desert date oil, Dichlorvos (2, 2-dichlorovinyl phosphate; DDVP), glass jars, poultry mash (wheat bran + honey + glycerine + yeast), maize and millet grains, liquid soap, petri-dish, aspirator, white filter paper, micro pipette, rubber band, white cloth, ovum, sieve, hand lens, refrigerator and digital weighing scale.

### Rearing of *Ephestia cautella*

The Tropical warehouse moth (*Ephestia cautella*) was obtained from preserved parent stock in the laboratory of the Department of Crop Protection, Faculty of Agriculture, Modibbo Adama University, Yola. The insects were reared on poultry mash (FAO,

2022b). The mash (wheat bran + honey + glycerine + yeast) was placed in a 1 litre glass jar. Semovita was added to increase the rate of larval growth. Sub cultures were made using millet grains as back up cultures to ensure surplus number of larvae when needed. Before culturing, the poultry mash, millet grains and glass jars were sterilized at 60°C for 3 hours so as to kill any possible spores, insect eggs and other organisms surviving on them (Allotey and Azaleclor, 2000). Using aspirator, 30 unsexed *E. cautella* adults were picked from the parent stock and were used to infest the mash in each glass jar. The glass jars were covered with perforated lid but sealed with a mesh to facilitate ventilation. The jars were kept on trays smeared with oil so as to prevent insects or mites from crawling into the cultures. The introduced adult *E. cautella* were removed using aspirator after four days of oviposition. The emerging adults of two to three days old were used for the experiment (Shehu *et al.*, 2010).

### Extraction of Neem and Desert Date Oils

The oils were prepared as described by Akinjide, (2019); Obeng-Ofori, (1999) and Oluwale *et al.* (2015) with some modifications. The neem and desert date fruits and seeds were obtained from Potiskum town of Yobe State where the seeds were in abundance and used for many purposes. To produce oils, ripe fruits and seeds collected were cleaned by washing in ordinary water and rubbing with the palms to remove the skin of the fruits. The cleaned seeds were then dried by spreading in the sun to reduce the moisture content. This is followed by removing unwanted materials such as stones and dirt by hand picking (Oluwale *et al.*, 2015). The seeds were decorticated in a mortar or lightly cracked on grinding stone so that the outer husks are freed from the inner seed. The husks were

then removed by winnowing and hand picking. The decorticated seeds were sun dried for three to five hours, lightly roasted and grinded using grinding machine. The paste was then poured into a pot (on fire) and stirred. A little hot water was added time to time as the stirring continues and after some time, the oil begin to settle at the top. Approximately 0.5 L water per 4 kg of kernel was added. The oil was scooped away and the dough was kneaded and pressed firmly for several minutes over a grinding stone until the oil oozed out and flow to the tip of the grinding stone for collection in a small bowl. The oils were kept under room temperature until needed.

#### **Phytochemical Composition Analysis of Desert Date oil**

The Phytochemical composition analysis of the desert date and neem oil used for the experiment was conducted at Central Laboratory, Modibbo Adama University, Yola, Adamawa State.

#### **Bioassay of Effects of Neem and Desert Date Oils *E. cautella***

The neem and desert date oils were applied as a mixture in which the oils were dissolved in water with liquid soap as emulsifier (Adarkwa *et al.*, 2008). Four different concentrations of neem and desert date oils (10, 15, 20, and 25 ml/l) each, Dichlorvos (2, 2-dichlorovinyl phosphate; DDVP at 10 ml/l), a widely used insecticide approved for stored product protection in Nigeria was used as standard reference (positive control) and untreated grain as negative control were used in the experiments. One centiliter (1 cl) of each solution was used to treat 1 kg of maize grains. Each treatment was replicated three times in a Completely Randomized Design (CRD). Thus each experiment has a total of ten treatments replicated three times.

#### ***Mortality of Ephestia cautella on treated maize grain***

The method adopted by Shehu *et al.* (2010) was used in conducting this experiment, where 100 grams of maize grains were placed in five glass jars each. The grains were treated with four different concentrations of neem, desert date oils (10, 15, 20 and 25 ml/l) and DDVP (10 ml/l). The control was treated with water only. Twenty (20) adults *E. cautella* of 2-3 days old of mixed sexes were introduced to infest the maize grains. The jars were then covered with white thin cloth held with rubber bands. Each treatment was replicated three times in a completely randomized design. Dead insects in the treatments were counted after 24, 48, 72 and 96 hours. Data was corrected on percentage mortalities using Abbott's 1925 formula where control mortality is up to five percent as adopted by Boateng and Kusi (2008) and Rahman and Talukder (2006).

$$Cm = Pt - Pc/100 - Pc.$$

Where:

Cm = Corrected mortality;

Pt = Percentage mortality on treatment;

Pc = Percentage mortality on control.

Percent mortality was computed as follows:

$$\text{Mortality (\%)} = Nd/N \times 100.$$

Where:

Nd = Number of dead insect;

N = number of introduced insects.

#### ***Progeny assessment***

In this experiment, method adopted by Maina and Lale (2004) was used where 20 adult unsexed 2 to 3 days old *E. cautella* were introduced into ten glass jars containing 1 00 g of maize grains treated with four different concentrations of neem and desert date oils (10, 15, 20 and 25 ml/l) each and Dichlorvos

(10 ml/l) and the control. Each treatment was replicated three times and arranged in a completely randomized design. The set up was left undisturbed for period of six (6) weeks. The adult *E. cautella* that emerged (dead and living) in both treated and control jars were counted and recorded.

### **Damage Assessment**

Damage assessment was carried out by taking samples of grains from each jar [i.e. grains with insect's emergence hole(s)] at 12 weeks after treatment infestation. The number of damaged (grains with characteristic holes) and undamaged grains were counted and weighed.

### **Weight loss of maize grains**

Percentage weight loss was calculated using count and weigh method described by Lale (2002) as adopted by Shehu *et al.* (2010).

$$\% \text{ weight loss} = \frac{UNd - DNu}{U(Nd + Nu)} \times 100$$

Where:

- U = Weight of undamaged grains in the sample;  
 Nu = Total number of undamaged grains in the sample;  
 Nd = Number of damaged grains in a sample; D = Weight of damaged grains in the sample.

### **Damage of maize grains**

Percent damage was also computed as;

$$\text{Damage (\%)} = \frac{Nd}{N} \times 100$$

Where:

- Nd = Number of damaged grains;  
 N = Total number of grains in a sample.

### **Seed Germination Test of Maize Grains**

The germination test adopted by Rahman and Talukder (2006) was used in testing the

viability of the neem and desert date oils treated seeds.

Twenty (20) seeds from each jar at the fourth set after 12 weeks of treatment use for persistency test were placed on moist cotton wool in Petri dishes. The dishes were kept under laboratory conditions for 10 days and germinated seeds were counted from first to last day of germination

### **Palatability Test of Maize Grains**

The sensory method adapted by Katherene *et al.* (2017) and Ilesanmi and Gungula (2011) with little amendments were used to evaluate the palatability of the treated and untreated maize grains. One kilogram (1 kg) of maize grains were separately treated with neem and desert date oils at concentrations of 10, 15, 20 and 25 ml/l each and Dichlorvos at 10 ml/l while the control seeds were treated with water only. The treated and control seeds were air-dried for 6 hours and stored for three months. After 3 months, a little water was sprinkled on the grains and then transferred into a mortar for pounding to remove the bran. The grains were then washed, sun dried, ground in to flour and cooked to form dough (*Tuwo*). Ten (10) panel members consisted of male and female students were randomly selected from University community. During tasting sessions, one "bite-sized" piece of each food was served at an appropriate temperature for consumption to members of the trained panel to taste the food samples and give scores on the basis of flavor, color and taste. Participants were given 2 minutes to taste and rate each food, and take a sip of water prior to the presentation of the next food.

Palatability was assessed using a standard five-point scale as follows:

- 1 = disliked much;  
 2 = disliked moderately;  
 3 = indifferent;

4 = liked moderately;  
5 = liked much.

The order of presentation of the samples to the judges was randomized. Foods from untreated maize grains were used as control. The test results were expressed as numerical values and treated statistically.

### Data Analysis

Data obtained from the experiments on effects of neem and desert date oils on the adult *Ephesia cautella*, progeny production, persistency and palatability of treated grains were subjected to Analysis of Variance (ANOVA) suitable for CRD using SAS software, 9.4 version (SAS institute, Cary,

NC, USA). Significantly different means were separated using New Duncan Multiple Range Test (NDMRT)  $P \leq 0.05$ .

## RESULTS

### Phytochemical Composition of Desert Date Oil

The result for phytochemical composition of Desert date oil is shown in Table 1. The result revealed the presence of saponins, alkaloids, flavonoids, tannins, steroids, glycosides and volatile oils, while phenols, terpenoids and anthraquinones were absent. The quantitative compositions of the chemicals were also presented in Table 1.

**Table 1:** Phytochemical Composition of Desert Date Oil

Phytochemical (g/100g)	Observation	Quantitative Mean
Alkanoids	+	0.338
Flavonoids	+	0.414
Tannins	+	0.766
Saponins	+	0.540
Steroids	+	0.317
Glycocides	+	1.884
Volatile fatty acids	+	1.564
Esters	+	0.707
Acid values (mgkoh/g)	+	2.656
Phenols	-	-
Terpenoids	-	-
Anthraquinones	-	-

+ = Positive (Available in the oil); - = Negative (Not available in the oil).

### Mortality of *E. cautella* in Treated Grain

Toxicity to *Ephesia cautella* increased with increasing dosage of neem and desert date oils applied on grains and time (Table 2). After 24 hours, the highest percent mean mortality (100%) was recorded on grains treated with DDVP and the lowest (13.33%) was recorded on grains treated with lowest concentration of neem oil (10 ml/l). No

mortality was recorded on the control. There was significant difference ( $P \leq 0.05$ ) between mortality caused by the oils and the DDVP, with mean mortality on neem (13.33-26.67%), desert date (16.67-30%) and DDVP (100%). There was no significant difference ( $P \leq 0.05$ ) between the control (0%) and different concentrations of neem oil 13.33-16.67%) except 25 ml/l (26.67%) but the

difference was significant between the control and Desert date oil (26.67-30%) except the lowest concentration (10 ml/l) with 16.67%. After 48 hours, all treatments caused significantly ( $P \leq 0.05$ ) higher mortality (43.33-100%) than untreated grain (0%), the difference was also significant between DDVP (100 %) and different concentrations of neem oil (43.33-73.33%), but the difference was not significant between DDVP (100 %) and Balanite oil (83.33-93.33%) except the lowest concentration (10 ml/l) with 63.33 mortality. After 72 hours, the difference ( $P \leq 0.05$ ) was not significant between DDVP (100%) and

different concentrations of the oils (83.33-100%) except the lowest concentration of the oils (neem 60.00% and balanites 80.00%). Highest concentrations of 25 ml/L of neem and desert date oils caused mortality of 93 % and 100%, respectively to *E. cautella* after 96 hours of treatment.

The overall best performance was recorded on DDVP (10 ml/l) and its significantly different from the oils. Neem and desert date oils (25 ml/l) performed best among the different concentrations of the oils. But there is no significant difference between the different levels of the oils (Table 2).

**Table 2:** Percentage Means Mortality of *E. cautella* in Treated Grains

Treatments (ml/l)	Percent (%) mean mortality with time (hrs.)			
	24	48	72	96
<b>Control (0.0)</b>	0.00 <sup>c</sup>	0.00 <sup>f</sup>	0.00 <sup>d</sup>	3.33 <sup>d</sup>
<b>Neem Oil</b>				
10	13.33 <sup>bc</sup>	43.33 <sup>e</sup>	60.00 <sup>c</sup>	63.33 <sup>c</sup>
15	16.67 <sup>bc</sup>	60.00 <sup>de</sup>	83.33 <sup>ab</sup>	86.67 <sup>ab</sup>
20	16.67 <sup>bc</sup>	73.33 <sup>bcd</sup>	83.33 <sup>ab</sup>	86.67 <sup>ab</sup>
25	26.67 <sup>b</sup>	70.00 <sup>cd</sup>	90.00 <sup>ab</sup>	93.33 <sup>ab</sup>
<b>Desert Date Oil</b>				
10	16.67 <sup>bc</sup>	63.33 <sup>cde</sup>	80.00 <sup>b</sup>	80.00 <sup>b</sup>
15	30.00 <sup>b</sup>	83.33 <sup>abc</sup>	93.33 <sup>ab</sup>	100.00 <sup>a</sup>
20	26.67 <sup>b</sup>	96.67 <sup>a</sup>	100.00 <sup>a</sup>	100.00 <sup>a</sup>
25	30.00 <sup>b</sup>	93.33 <sup>ab</sup>	100.00 <sup>a</sup>	100.00 <sup>a</sup>
<b>DDVP</b>	100.00 <sup>a</sup>	100.00 <sup>a</sup>	100.00 <sup>a</sup>	100.00 <sup>a</sup>
CV (%)	22.33	17.35	11.32	10.77
Pr> F	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Means in same column with the same alphabets are not significantly different at  $P \leq 0.05$  using New Duncan Multiple Range Test of mean separation.

CV = Coefficient of Variation.

### Effects of Neem and Desert Date Oils on Progeny Production

Results for effects of neem and desert date oils on *Ephestia cautella* progeny production is summarized in Table 3. Neem and desert date oils drastically reduced the emergence

of adult insects when treated grains were infested with *E. cautella* (Table 3). The highest number of progeny emergence (56.67) was recorded on untreated grains. There was complete inhibition (0.00 %) of progeny emergence on grains treated with

different concentrations of the oils (15, 20 and 25 ml/l) and DDVP, however few emerged on the ones treated with lowest concentration (10 ml/l) of neem and balanite oils which had 4.0 and 5.0 progenies respectively. There was significant difference ( $P \leq 0.05$ ) between the number of progenies emerged on grains treated with different concentrations of the oils (0.00 - 5.00 %) and the control (56.67) and also between the lowest concentrations (10 ml/l) of the oils (neem, 4.0 and Balanite, 5.0) and DDVP (0.0), but no significant difference between the higher concentration of the oils (15, 20 and 25 ml/l) and DDVP (10 ml/l) on *E. cautella* was observed. Some of the adults of *E. cautella* that emerged were deformed (Table 3).

### Damage Assessment

Results for damage caused by *Ephestia cautella* to maize grams treated with different concentrations of neem and desert date oils are summarized in Table 3. Neem and desert date oils gave high protection to treated grains against damage by *E. cautella* compared to untreated grains (Table 3). No damage (0.00 %) was observed on grains treated with neem and desert date oils (15 and 20 ml/l) while 25.81 and 2.93 damage were observed on grains treated with the lowest concentration (10 ml/l) of neem and balanite oils respectively. There was significant difference between the damage recorded on all treatments (0.00 - 25.81 %) and the control (71.02 %), but no significant difference was observed between the different concentrations of the oils (0.0 - 2.93 %) and DDVP (0.00 %), except the lowest concentration (10 ml/l) of neem oil (25.8 %). Weight loss of 0.0 - 6.64 % were observed on grains treated with different concentrations of neem oil and 0.0 - 0.73 % on desert date oil after 2 months of storage compared to untreated grains with up to

27.03 %. There was significant difference ( $P \leq 0.05$ ) between the grain protection made by oil treatments (0.0-6.64%) and the control (27.03%) but no significant difference between the protectant ability of the oils (0.0-6.64%) and DDVP (0.00%) was observed.

Dichlorvos DDVP (10 ml/l), desert date oil (15 ml/l) and neem oil (15 ml/l) performed equally without damage (0.00 %) on the treated grains.

**Table 3:** Effect of Neem and Desert date oils on Mean number of progeny emergence and losses caused by *E. cautella* to Stored Maize Grains

Treatments (ml/l)	Mean number of progeny	Percent damage	Percent weight loss
Control (0.0)	56.67 <sup>a</sup>	71.02 <sup>a</sup>	27.03 <sup>a</sup>
<b>Neem Oil</b>			
10	4.00 <sup>b</sup>	25.81 <sup>b</sup>	6.64 <sup>b</sup>
15	0.00 <sup>c</sup>	0.00 <sup>c</sup>	0.00 <sup>b</sup>
20	0.00 <sup>c</sup>	0.00 <sup>c</sup>	0.00 <sup>b</sup>
25	0.00 <sup>c</sup>	1.33 <sup>c</sup>	0.94 <sup>b</sup>
<b>Desert Date Oil</b>			
10		2.93 <sup>c</sup>	0.73 <sup>b</sup>
15	0.00 <sup>b</sup>	0.00 <sup>c</sup>	0.00 <sup>b</sup>
20	0.00 <sup>c</sup>	0.00 <sup>c</sup>	0.00 <sup>b</sup>
25	0.00 <sup>c</sup>	0.00 <sup>c</sup>	0.00 <sup>b</sup>
<b>DDVP</b>	0.00 <sup>c</sup>	0.00 <sup>c</sup>	0.00 <sup>b</sup>
CV (%)	19.55	18.84	25.06
Pr > F	< 0.0001	< 0.0001	< 0.0001

Means in same column with the same alphabets are not significantly different at  $P \leq 0.05$  using New Duncan Multiple Range Test of mean separation.

CV = Coefficient of Variation.

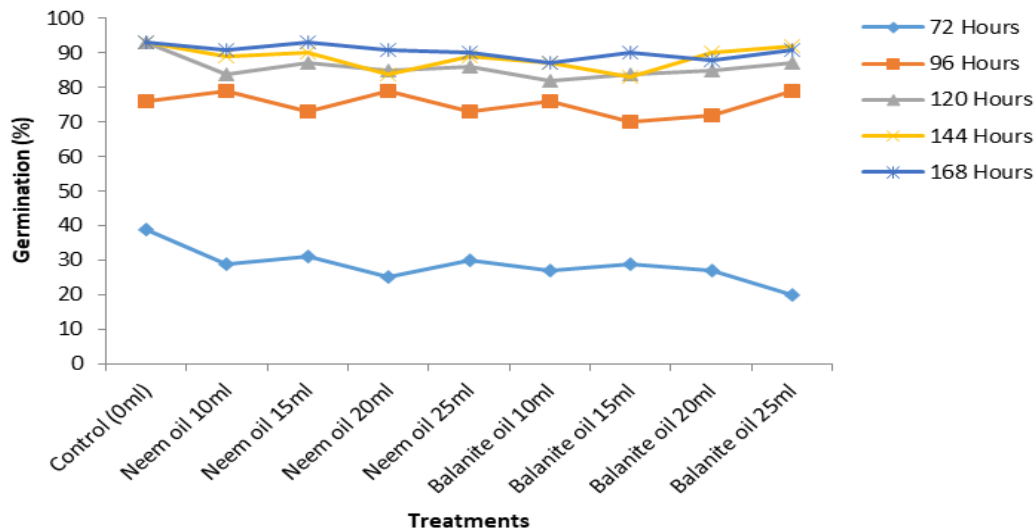
### Germination Test of Treated Grains

Results for effects of neem and desert date oils on germination of treated maize are summarized in Figure 1. Neem and desert date oils did not show any negative effect on viability of treated maize grain. Germination



started after three days on all treated samples as well as the control. The highest percent mean germination (36.67 %) was recorded on control and the lowest (18.33) was recorded on grains treated with neem oil (20 ml/l) in which the latter has the highest germination percentage on the fourth day. However, 65 to 80 % germination was recorded on all samples on the fourth day. On the seventh day, 83.33 to 93.33 % germination was recorded on all samples. There was no significant difference ( $P \leq 0.05$ )

between germination of the seeds treated with different concentration of the oils and the control. There was also no significant difference between the percent germination recorded on grains treated with DDVP and the control. In all cases, germination started on day three and continues steadily up to the seventh day after which no germination was recorded. In each day, there was no significant difference ( $P \leq 0.05$ ) in germination among the treatments.



**Figure 1:** Effects of Neem oil, Desert Date Oil and DDVP on Germination of Maize seeds

#### 4.12 Effects of Neem and Desert Date Oils on Palatability of Treated Maize

The result of the panelists ratings of palatability with respect to taste, color and flavor are shown in table 4. The panelists ratings with respect to taste reveal that the lowest rating of 3.5 was recorded from the samples treated with DDVP. The best taste rating of 4.4 was recorded from sample treated with Desert date oil (10 ml/l). There was no significant difference between the taste of food from treated grains (3.50-4.40) and the control (4.20). There was also no

significant difference among the different concentration of the two oils.

The acceptability in terms of flavor of the food samples made from treated maize grains cooked after three (3) months of storage was rated and presented in Table 4. The lowest flavor rating (3.8) was recorded from sample samples treated with Neem oil (20 and 25 ml/l) and DDVP. The best rating of 4.4 was recorded from sample treated with Desert date oil (20 ml/l). There was no significant difference ( $P \leq 0.05$ ) between the flavor of food from all the treated samples (3.80 -4.40)

and the control (4.30). There was also no significant difference ( $P \leq 0.05$ ) among the different concentrations of the two oils.

Table 4 also shows the panelists color ratings and the result reveals that there is no significant difference ( $P \leq 0.05$ ) between the treated samples (3.70-4.30) and the control (4.0).

The result for the overall acceptability in terms of sensory attributes of the treated samples stored for 3 months shows that the

overall acceptability ratings of samples treated with neem oil (20 ml/l) and DDVP were the lowest (3.87) compared to the other samples. The panelist rated samples treated with desert date oil (15 and 25 ml/l) as the best in overall acceptability (4.23). There was however no statistically significant difference ( $P \leq 0.05$ ) between the control (4.17), DDVP (3.87) and samples treated with various concentrations of neem and desert date oils (3.87-4.23).

**Table 4:** Effects of Neem and Desert date Oils on Palatability of Treated Maize

Treatments (ml/l)	Palatability Parameters			
		Color	Flavor Taste	Acceptability
<b>Control (0.0)</b>	4.00 <sup>a</sup>	4.30 <sup>a</sup>	4.20 <sup>ab</sup>	4.17 <sup>a</sup>
<b>Neem Oil</b>				
10	3.70 <sup>a</sup>	4.40 <sup>a</sup>	4.10 <sup>ab</sup>	3.90 <sup>a</sup>
15	4.10 <sup>a</sup>	4.20 <sup>a</sup>	3.90 <sup>ab</sup>	3.90 <sup>a</sup>
20	3.80 <sup>a</sup>	3.80 <sup>a</sup>	4.00 <sup>ab</sup>	3.87 <sup>a</sup>
25	4.30 <sup>a</sup>	3.80 <sup>a</sup>	4.00 <sup>ab</sup>	4.07 <sup>a</sup>
<b>Desert Date Oil</b>				
10	4.10 <sup>a</sup>	3.80 <sup>a</sup>	3.90 <sup>ab</sup>	3.97 <sup>a</sup>
15	4.20 <sup>a</sup>	4.10 <sup>a</sup>	4.40 <sup>ab</sup>	4.23 <sup>a</sup>
20	4.10 <sup>a</sup>	4.40 <sup>a</sup>	4.10 <sup>ab</sup>	4.03 <sup>a</sup>
25	4.30 <sup>a</sup>	4.20 <sup>a</sup>	4.30 <sup>ab</sup>	4.23 <sup>a</sup>
DDVP	4.30 <sup>a</sup>	3.80 <sup>a</sup>	3.50 <sup>ab</sup>	3.87 <sup>a</sup>
CV (%)	18.95	20.87	2024	6.47
Pr> F	<0.7412	<0.6350	<0.4975	<0.5042

Means in same column with the same alphabets are not significantly different at  $P \leq 0.05$  using New Duncan Multiple Range Test of mean separation.

CV = Coefficient of Variation

## DISCUSSIONS

The results of phytochemical screening test of the desert date kernel oil revealed the presence of saponins, alkaloids, flavonoids, tannins, steroids, glycosides and volatile oils, while phenols, terpenoids and anthraquinones were absent. These findings agree with similar studies reported by several researchers (Datti *et al.*, 2020; Ya'u *et al.*, 2020); Yadav and Panghal 2010; Chothani

and Vaghasiya, 2011; Al-Thobaiti and Abu-Zeid, 2018 and Selouka *et al.*, 2020). Presence of saponin can contribute to the insecticidal activities of desert date oil. Chapagain *et al.* (2008) reported that saponin extracts from *B. aegyptiaca* kernel was found to have high insecticidal effects. Chothani and Vaghasiya, (2011) also reported that extracts from several parts of *B. aegyptiaca* were shown to exhibit insecticidal activities

against variety of pests, and steroidal saponin is believed to be the main caused behind these activities. Saponin extracts from *B. aegyptica* kernel was found to have high larvicidal effects on mosquitos (Chapagain *et al.*, 2008). Extracts from several parts of *B. aegyptiaca* were shown to exhibit anti-feedants and mollucidal activities against variety of pests and steroidal saponin is believed to be the main caused behind these activities (Chothani and Vaghasiya, 2011). Katunku *et al.*, (2014) reported that saponins that is found in *E. aromatica* affect the respiratory system of insects due to their deterrent action. Saponins have many health benefits which might have accounted for some of the reported therapeutic ability of *Balanites aegyptiaca* kernel, including anti-inflammatory, anti-diabetic, anti-HIV, anti-atherosclerotic, hepatoprotective and hypolipidemic effects (Egbuna and Ifemeje, 2015). A mixture of steroidal saponins (balanitin-6 (28) and balanitin-7 (72) isolated from *B. aegyptiaca* kernels demonstrated appreciable anticancer effects in human cancer cell lines (Chothani and Vaghasiya, 2011). Saponins isolated from *B. aegyptiaca* showed significant anti-inflammatory, antinociceptive activity in the carrageenin-induced edema and acetic acid-induced antioxidant action in rats (Chothani and Vaghasiya, 2011; Murthy *et al.*, 2021). Saponin extract from fruit kernel of *B. aegyptiaca* was tested against larvae of the three mosquito species (*Anopheles arabiensis*, *Culex quinquefasciatus*, and *A. aegypti*), and  $LC_{50}$  and  $LC_{90}$  values were determined. The Saponin extract shows larvicidal effects on the mosquitoes. The larvae of *Anopheles arabiensis* were found to be more susceptible than *Culex quinquefasciatus* and *A. aegyptica* (Chothani and Vaghasiya, 2011; Murthy *et al.*, 2021). The pure saponin extracted from the *Balanite* fruits mesocarp have been reported as

hypoglycemic agent and inhibit *Escherichia coli* growth when tested on albino rats (Murthy *et al.*, 2021).

Flavonoids sometimes serve as flavoring ingredients of spices and vegetable, but may also have anti-oxidant, anti-inflammatory, anti-microbial, anti-viral, anti-allergic, anti-cancer and anti-diarrheal effects (Egbuna and Ifemeje 2015). It was also reported that the antioxidant activities of *Balanite* oils were correlated significantly with the total phenolic and flavonoid contents (Chothani and Vaghasiya, 2011; Murthy *et al.*, 2021).

Alkaloids may be toxic at a very high amount, but are often non-toxic and may have physiological activities and hence are widely used in medicine. Lower doses of alkaloids have important pharmacological activities, such as reducing blood pressure, killing tumour cells, analgesic activity, stimulating circulation and respiration (Egbuna and Ifemeje 2015).

Tannins, the water-soluble polyphenols present in many plant foods have been reported to be responsible for decreases in feed intake, feed efficiency, growth rate and protein digestibility. However, reports have indicated some carcinogenic activities of tannins (Chung *et al.*, 1998).

Steroids are known to possess many interesting medicinal, pharmaceutical and agrochemical activities, ranging from antibacterial, hepatoprotective, anti-tumor, antihelminthic, immunosuppressive, plant-growth hormone regulator, sex hormone, cytotoxic and cardiotoxic activity (Patel and Savjani 2015).

Glycosides family has been in clinical use for many years for the treatment of heart failure and atrial arrhythmia, and they are known to have a strong direct action on the heart and support and strengthen the rate of contraction (Vaidehi and Rajesh 2016). From ancient times, humans have used glycoside-containing plants and their crude extracts as

arrow coatings, homicidal or suicidal aids, rat poisons and emetics, while in the modern times they have been adapted for the treatment of congestive heart failure and cardiac arrhythmia (Yubin *et al.*, 2014).

Volatile oils are also called essential oils and are natural metabolic secretions of plants that are considered to be true plant hormones, as well as the fluid manifestations of the immune system of the plants, since they contribute to the removal of pests, attracting pollinating agents (Monica and Loan, 2018). The most important feature of the volatile oils which gives them special economic value is their specific smell, and this forms the basis for their use in perfumery, cosmetics and the food industry. Many essential oils have special therapeutic qualities, some of which have been known and used since ancient times (Monica and Loan 2018).

Fatty acids present in *Balanite* oil contribute to its repellency effects to insects. Mokhtar *et al.* (2020) reported that the repellent effect of *Balanite* oil may be due to high quantity or quality bioactive compounds such as fatty acids. These fatty acids were reported to have strong repellency activities against mosquitoes, ticks, biting flies and bed bugs (Zhu *et al.*, 2018).

The results suggest that the seed kernel has high potentials for medicinal applications, while the kernel oil can serve as raw material for many oil related purposes. The oil can be used for human consumption, as well as in the production of industrial products like biodiesel, lubricants, soaps, shampoos and many other cosmetic products (Ya'u *et al.*, 2020).

#### **Contact toxicity of neem and desert date oils on treated grains**

The bioassay on contact toxicity of neem and desert date oils on *Ephesia cautella* was conducted by infesting the treated grains

with the insects. Maize grain treated with neem and balanites oils caused mortality to the insect. Toxicity to *E. cautella* increased with increasing dosage of neem and desert date oils applied on grains. Shehu *et al.* (2010) observed that, the developmental and reproductive effects on neem oil treated insects, causing malformation and mortality in a dose dependent manner. Also, Shehu *et al.* (2010) who reported that neem oil (5 and 7 ml/l) caused significantly ( $P \leq 0.05$ ) higher mortality to *E. cautella* than untreated grain after 48 hours. Neem and desert date oils at concentration of 25 ml/L caused mortality of 90 and 100 to *E. cautella* after 72 hours respectively. However, balanites oil was more potent than neem oil after 24 hours of treatment. Shehu *et al.*, (2010) reported that maize grain treated with neem oil at 7 ml/l caused 70 % mortality to *E. cautella* after 96 hours. Nwaogu *et al.* (2013) reported that when cowpea seeds were treated with *B. aegyptica* oil (1 ml/50 g), hundred percent (100 %) mortality of *Callosobruchus maculatus* were recorded 48 hours after infestation. Mortality in treated grain was lower on *E. cautella* than mortality caused by topical application and this could be due to the insect's habit on the grains. Most adult *E. cautella* move within the empty space above the grain level and usually settle on grain to mate and lay eggs, hence coming in contact with less oil compared to topical application. The oil showed good insecticidal potential on infested grain.

#### **Progeny Production by *E. cautella* on Treated Maize Grains**

Neem and desert date oils drastically reduced the emergence of adult insects when treated grains were infested with *E. cautella*. Adults emerged on grains treated with the lowest concentration (10 ml/l) of the oils only. This confirms a report by Shehu *et al.*, (2010) who reported that neem oil suppressed the

emergence of *E. cautella* progeny when maize grains were treated with neem oil. Dichlorvos (DDVP) significantly reduced the number of F1 progeny produced by *E. cautella* compared to the untreated seeds. Dichlorvos (DDVP) is an insecticide with rapid knock down action which instantly killed the adults of *E. cautella* on contact and also inhibited the development of eggs into adults. Neem oil is not an instant killer (Raguraman and Singh, 2008) but have strong ovicidal and antifeedant effect which inhibited the development of eggs and larvae of *E. cautella* into adults. Some of the adults of *E. cautella* that emerged were deformed. This agrees with a report by Shehu *et al.*, (2010) who confirmed that some progenies of *E. cautella* were deformed as they emerged from maize grains treated with neem oil.

When cowpea seeds were treated with *B. aegyptica* oil (1 ml/50g), hundred percent (100) mortality rates were recorded 48 hours after infestation (Nwaogu *et al.*, 2013). The authors also reported that very few eggs were laid in oil treated cowpeas with a mean fecundity of 9 to 12 eggs on *B. aegyptica* treated cowpea when compared with control cowpea which had a mean fecundity ranging from 46 to 52 eggs per female. Nwaogu *et al.*, (2013) reported that more than 50 of the total eggs laid in treated samples died at various stages of development which in turn reduced the number of progenies. Yahaya and Suleiman (2018) reported that, desert date oils effectively reduced the emergence among male bruchids from the seeds of Sokoto local variety of cowpea treated with 1.0 ml/50g. The oil has a high larvicidal effect and significantly affected the development of immature stages of the weevil (Nwaogu, *et al.*, 2013). Treatments of cowpea seeds with the mixture of neem and desert dates oils applied at the rate of 1.0 ml/50g significantly reduced the emergence

of adults of *C. maculatus* (Yahaya and Suleiman, 2018). Neem oil works as a repellent and anti-feedant and also regulates insect growth by disrupting hormone production associated with growth and moulting (Mondal and Chakraborty, 2016). It has a multi-prolonged effect, being effective on larval stages of insects (Obeng-Ofori, 2008). Neem oil also delays reproduction in pests as it causes lethal toxicity during the pupal stage leading to various morphological deformations such as malformed adults, partial ecdysis, and molt blocking, which defers and inhibits adult formation (Boulahbel *et al.*, 2015). Schmutterer (2022) has proved that azadirachtin disrupts or inhibits development of insect eggs, larvae or pupae, preventing the moulting of larvae or nymphs, disrupting mating and sexual communication, deterring females from laying eggs, sterilizing adults, poisoning larvae, thus preventing adult maturation by inhibiting the formation of chitin, the essential substance for the insect to form an exoskeleton. Extracts from several parts of *B. aegyptiaca* were shown to exhibit anti-feedants and mollucidal activities against variety of pests and steroidal saponin is believed to be the main caused behind these activities (Chothani and Vaghasiya, 2011).

Some of the adults of *E. cautella* that emerged from the grains treated with neem oil were deformed, having short and folded wings as reported by Shehu *et al.* (2010). The author reported that some adults of *E. cautella* emerged deformed and had abnormal wings, which did not fully expand after treatment of the larvae of *E. cautella* with 7 ml/l neem oil (Calneem®). Sunarti (2003) reported that application of neem oil to cocoa beans deterred larval *E. cautella* feeding by 92 and only 10 normal adult emergences was observed from the neem oil treated larvae and prevented damage and reproduction of *E. cautella* for more than 3

months storage. Schneider *et al.* (2017) reported the percentage of abnormalities in adult moth at concentrations of 0.5 to 2.0 % was up to 50 % which may be a result of morphogenetic alterations due to interferences in hormonal events. Neem oil also delays reproduction in pests as it causes lethal toxicity during the pupal stage leading to various morphological deformations such as malformed adults, partial ecdysis, and molt blocking, which defers and inhibits adult formation (Boulahbel. *et al.*, 2015).

Schneider *et al.*, (2017) reported that in the treatment of young pupae with higher concentrations of neem, some adults were unable to completely get rid of the exuvia, with some regions of the body remaining with parts of the old cuticle (pupa), such as wings, legs or abdomen

#### **Assessment of Damage Caused by *E. cautella* on Treated Maize**

Neem oil, desert date oil and DDVP gave high protection to treated grains against damage by *E. cautella* compared to untreated grains. Lower weight losses were observed on grain treated with different concentrations of neem oil and desert date oil after 2 months of storage compared to untreated grain with higher weight losses. Balanite oil extract significantly reduced sorghum damage by 30 (Elamin and Satti, 2013). Desert date oil gave 100 % protections to the treated grain with 0 % damage at concentration of 15 ml/l. This agrees with a report by Shehu *et al.*, (2010) who reported that neem oil (Calneem oil) gave good protection to treated grains against damage by *E. cautella* compared with untreated controls, with weight losses of 0.99-2.22 after 2 months of storage with no significant difference between Calneem® oil and Actellic. Obeng-Ofori and Dankwa (2004) reported that neem seed oil significantly reduced seed damage and the number of F<sub>1</sub> progeny produced by *C.*

*maculatus* compared to the untreated seeds. Sunarti (2003) reported that application of neem oil deterred larval *E. cautella* feeding by 92 and prevented damage by *E. cautella* to cocoa beans for more than 3 months storage. The neem oil has an antifeedant effect and also interferes with metamorphosis of the insects which in turn reduced damage by the insects (Sunarti, 2003). Lale and Mustapha (2000) also found no significant difference in the efficacy of neem seed oil and primiphos-methyl (Actellic) in reducing seed damage by *C. maculatus* in treated cowpea. Shehu *et al.*, (2010) demonstrated that maize seeds treated with neem oil at 7 ml/l remained undamaged by *E. cautella* for 10 weeks storage period.

#### **Effects of Neem and Desert Date Oils on Germination of Maize Grains**

Neem and desert date oils did not show any negative effect on viability of stored maize grain. This agrees with the findings of Saxena, (2006) who reported that application of 1 to 3 parts of neem oil per 100 parts of Bengal gram rendered complete protection against *C. chinensis* for at least 135 days, without impairing seed germination. In another report, treatments of maize with oils of neem at 10 ml kg<sup>-1</sup> reduced the germination of maize seeds (Tadesse, and. Basedow, 2005). This could be attributed to the high concentration and undiluted oil used by them.

Nukenine *et al.* (2011) reported that the rate of seed germination was not affected by NeemPro®. It protects stored grains for 4 months without affecting the seed germination power (Danga *et al.*, 2015). Nukenine *et al.*, (2013) reported similar findings where NeemAzal did not have negative effects on maize seed germination (germination rates of 92.23 at 3 g/kg to 97.77 at 12 g/kg were recorded). Danjuma *et al.*, (2019) reported that balanites powders

significantly minimized grain damage and infestation 96 days post treatment and had no effect on percent germination of maize grains when compared to controls.

### **Effects of Neem and Desert Date Oils on Palatability of Treated Maize**

The result of the panelists ratings of palatability has no adverse effects on colour, flavor and taste hence can be acceptable and used as sustainable alternatives to synthetic insecticides in maize storage especially by small holder farmers. This is in line with a report by Danjumma *et al.* (2019). The author reported that response of panelists on the effects of varying doses of different plant powders (*A. nilotica*, *C. aurantifolia*, *B. aegyptica* and synthetic pesticide (Actellic) on the colour, odour and taste of treated cooked maize seeds after 90 days of storage did not cause any significant change on palatability of the maize. Ilesanmi and Gungula (2011) also reported that the characteristic flavor of the oils was found in neem treated cowpea samples but was insignificant to alter the acceptability in terms of flavour of the treated samples.

Danjumma *et al.* (2019) reported that grain treated with varying doses of *B. aegyptiaca* recorded moderate values, without any significance difference among them. Bitter compound azadirachtin in neem discourages farmers from applying it on grains meant for consumption, but the processing work of the treated grain which involves soaking, washing and removal of bran succeeds in removing the bitter taste. Ilesanmi and Gungula (2011) affirmed that the bitter taste of neem can be completely removed if the treated cowpea is soaked for a long time in water. Stoll, (2005) also reported that to remove the bitter taste of neem oil from beans before eating they should be covered with hot water for a few minutes and drained after. Process of

producing *Naltwu* (roasted balanites seeds), involves collecting the kernel and breaking it to remove the seeds so that, women will soak the seeds in water for three days or by boiling the seeds overnight as a mechanism to remove its bitterness (Ibrahim, 2019).

The panelist rated samples treated with desert date oil (15 and 25 ml/l) as the best in overall acceptability. This is not surprising as the oil is among the locally used edible oils. Jock, (2017) reported that desert date seed oil is rich in saturated fatty acids and is used as cooking oil, its culinary quality is comparable to that of good-quality vegetable oil. There was however no significant difference ( $P \leq 0.05$ ) between the control and samples treated with various concentrations of desert date, neem and DDVP.

### **CONCLUSION**

The results obtained suggested that, there is good potential for the use of Neem and Desert date oils in stored product pest management system. The results of phytochemical screening test of the desert date kernel oil revealed the presence of only saponins, alkaloids, flavonoids, tannins, steroids, glycosides and volatile oils. Neem and Desert date oils were found to be effective against *E. cautella*. The study has shown that neem and desert elate oils contains insecticidal, anti-ovipositant, ovicidal, antifeedant and repellent properties. Contact toxicity of neem and desert date oils by topical application caused high mortality of 90 - 100% and 96.67 - 100% respectively within the first 24 hours of treatment. Contact toxicity of the oils on treated grains at concentration of 10 - 25 ml/l caused 100% mortality to larvae of *E. cautella* after 72 hours. After twenty-four (24) hours, 100% mortality to *E. cautella* adults was recorded on grains treated with desert date oil (15, 20 and 25 ml/l) and neem oil (20 ml/l).

Consequently, these treatments also significantly reduced the number of grains that were damaged through *E. cautella* infestation and caused repellency of 46.67-80% and 93.33-100% by neem and desert date oils respectively which was maintained up to four days. Complete inhibition of eggs development (100%) by the oils (20 and 25 ml/l) and strong repellent effect makes it possible for neem and desert date oils to be used before and after infestation. Repellency seems to be of primary importance as neem products control the pests by physiological disturbance, phagodeterrence and repellence more than toxicity. Pupae development was reduced and some of the adult *E. cautella* that emerged from the treated eggs, larvae and the pupae were deformed. The neem and desert date oils can protect maize grains against *E. cautella* for at least 9 weeks regardless of whether the grains were infested before treatment or not as the toxicity of the oils lasted for up to 9 weeks with percent mean damage of 8.67% on grains treated with neem oil 20 ml/l and 5.13 on grains treated with desert date oil against the control with 68.1% damage. The oils were also found to have no effects on maize seed germination at concentration of 10 - 25 ml/l. Palatability of the treated grains was not also affected by the oils after three (3) months storage. The overall acceptability rating of maize grains treated with Neem and Desert date oils (25 ml/l) were found to be 4.07 and 4.23 out of 5.0 respectively. This could become an important alternative or supplement to synthetic insecticides. Resource poor farmers can effectively use the oils to protect their grains in store. This process may be unsuitable for use in large-scale grain stores, but it is potentially valuable for household use and for protecting seeds being kept for immediate consumption and planting. The neem and desert date oils can be incorporated as a component of

Integrated Pest Management (IPM) in traditional and modern grain storage.

Further extensive studies should be carried out on the persistence and hazards that might be associated with the oils. Seasonality of neem and desert date fruits leads to inadequate supply of its seeds. Storage structures should be provided so as to make healthy seeds available throughout the year. By so doing, insecticides that effectively protect stored produce, are readily available, affordable, relatively less poisonous and less detrimental to the environment could be developed and made available to resource poor farmers.

#### ACKNOWLEDGMENT

Authors sincerely appreciate the Tertiary Education Trust Fund (TetFund) for sponsoring this research work via Modibbo Adama University, Yola.

#### REFERENCES

- Adarkwah, C., Obeng-Ofori, D., Buttner, C., Reichmuth, C. and Shopna, M. (2008).** Repellency and toxicity of Calneem™ Oil to *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) in stored products. First Symposium on Horticulture in Europe. University of Vienna, Austria.
- Akinjide, O. B. (2019).** Analysis of *Balanite aegyptiaca* (aduwa) Oil used as a Brake Fluid in Mechanical Brake System. *International Journal of Engineering and Technology Research*, 17: (5) 206-218.
- Akol, A. M., Chidege, M. Y., Talwana, H. A. L. and Mauremootoo, I. R. (2001).** *Cadra cautella* Walker, 1863 – Tropical Warehouse Moth. BioNET-EAFRINETUVIMA Project. Taxonomy for Development in East Africa. [https://keys.lucidcentral.org/keys/v3/eafrinet/maizepests/key/maizepests/Media/Html/Cadra cautella Walker 1863 – Tropical Warehouse Moth.htm](https://keys.lucidcentral.org/keys/v3/eafrinet/maizepests/key/maizepests/Media/Html/Cadra%20cautella%20Walker%201863%20-%20Tropical%20Warehouse%20Moth.htm). Retrieved on 13 August, 2021.



- Allotey, J. and Azeleclor, W. (2000).** Some aspects of the biology and control using Botanicals of the rice moth, *Corcyra cephalonica* (Stanton) on some pulses. *Journal of Stored Product Research*. 36(3): 235-243.
- Al-Thobaiti, S.A and Abu Zeid, I. M. (2018).** Medicinal Properties of Desert Date Plants (*Balanites aegyptiaca*) – An Overview. 12 (1): 01-12.
- Badu-Apraku, B. and Fakorede, M. A. B. (2006).** *Zea mays* L. In: Brink, M. and Belay, G. (Edts). Cereals and pulses. Plant resources of tropical Africa 1. PROT A, Wageningen, Netherlands. 297 pp.
- Boateng, B A. and Kusi, F. (2008).** Toxicity of *Jatropha* Seed Oil to *Callosobruchus maculatus* (Coleoptera: Bruchidae) and its Parasitoid, *Dinarmus basalis* (Hymenoptera: Pteromalidae). *Journal of Applied Sciences Research*. 4(8): 945-951.
- Boulahbel, B., Aribi, N., Kilani-Morakchi, S., Soltani, N. (2015).** Activity of neem oil in *Drosophila melanogaster*: toxicity and delayed effect on the progeny. *Journal of Entomology and Zoological Studies*3: 306-310.
- Chapagain, B. P., Saharan, V. and Wiesman, Z. (2008).** Larvicidal activity of saponins from *Balanites aegyptiaca* callus against *Aedes aegyptimosquito*, *Bioresources Technology*, 99: 1165-1168.
- Chothani, D. L. and Vaghasiya, H. U. (2011).** A review on *Balanite aegyptiaca* Del (desert date): phytochemical constituents, traditional uses, and pharmacological activity. *Pharmacognosy Reviews*. 5(9): 55-62.
- Chung, K. T., Wong, T. Y., Wei, C. I., Huang, Y. W. and Lin, Y. (1998).** Tannins and Human Health: A Review. *Critical Review of Food Science and Nutrition* 38(6): 421-464.
- Danga, S. P. Y., Nukenine, E.N., Fotso, G.T. (2015).** Use of NeemPro®, a neem product to control maize weevil *Sitophilus zeamais* (Motsch.) (Coleoptera: Curculionidae) on three maize varieties in Cameroon. *Agriculture and Food Security*. 4(18): <https://doi.org/10.1186/s40066-015-0039-z>
- Retrieved On 03 November, 2020.
- Danjumma, B. J., Majeed, Q. and Ibrahim, N. D (2019).** Organoleptic properties of maize Treated with the botanicals. *Journal of Entomology and Zoology Studies*, 7(4): 1320-1325.
- Datti, Y., Tijjani, Y. A., Koki, I. B., Ali, U. L, Labaran, M., Ahmad, U. U. and Tasi'u, N. (2020).** Phytochemical composition of desert date kernel (*Balanites aegyptiaca*) and the physical and chemical characteristics of its oil. *GSC Biological and Pharmaceutical Sciences*. 11(3): 197-207.
- Egbuna, C. and Ifemeje, J. C. (2015).** Biological Functions and Anti-Nutritional Effects of Phytochemicals in Living System. *IOSR Journal of Pharmacy and Biological Sciences*. 10: 10-19.
- Elamin, M. M. and Satti, A. A. (2013).** Insecticidal potentialities of *Balanites aegyptiaca* extracts against the khapra beetle (*Trogoderma granarium*). *Global Advanced Research Journal of Environmental Science and Toxicology*, 2(1): 05-10.
- Eziah, V. Y., Sackey, I., Boateng, B. A. and Obeng-Ofori, D. (2011).** Bio-efficacy of neem oil (Calneem™), a botanical insecticide against the tropical warehouse moth, *Ephestia cautella*. *International Research Journal of Agricultural Science and Soil Science*. 1(7): 242-248.
- Falak, N., Munir, H., Faridullah and Mohammad, D. (2003).** Insects Pests of Maize and their Losses. *Asian Journal of Plant Sciences*, 2: 412-414.
- Food and Agriculture Organization, (2022a).** Maize production. Top twenty producing countries. Rankings by commodity. <https://www.fao.org/faostat/en/#rankings/countries> by commodity. Retrieved on February, 2022.
- Food and Agriculture Organization (2022b).** Agris record on publication of National Resource Institute NRI (1996). A guide to insect pests of Nigerian crops: Identification, Biology and Control. Federal Ministry of Agriculture and Natural Resources, Nigeria and the Overseas Development Administration, U.K, 253pp. <https://agris.fao.org/agris->

- searc.do?recordID=GB9690016. Retrieved on 5 February, 2022.
- Grzywacz, D., Stevenson, P. C., Mushobozi, W. L., Belmain, S. and Wilson, K. (2013).** The use of indigenous ecological resources for pest control in Africa. *Food Security*, 6:71-86.
- Hanna, E. (2018).** Maize and Its Economic Importance in Nigeria. *Farmcrowdy Agribusiness*. <https://blog.farmcrowdy.com/maize-economic-importance-nigeria/>. Retrieved on 08 November, 2020.
- Ibrahim, M. B. (2019).** Sustainability and Community Development Relevance of Desert Date (*Balanites aegyptiaca*) in the Sudano-Sahelian Zone of Nigeria. *International Journal of Rural Studies*, 26(2): 1-7
- Ilesanmi J. O. and Gungula, D. T. (2011).** Effects of Neem and Moringa seed oil on cookability and palatability of cowpea grains stored for six months. *African Journal of Food Science*, 5(9): 522-528.
- Jock A. A. (2017),** Physicochemical and Phytochemical Characterization of Seed Kernel Oil from Desert Date (*Balanites aegyptiaca*). *Journal of Chemical Engineering and Bioanalytical Chemistry*, 2(1): 49-61.
- Katherine, O. B. A., Jennifer, C. L., Bruce, A. C., Malinda, M. G., Philip, A. P., Petra, E. E. and Megan, A. M. (2017).** Can the Palatability of Healthy, Satiety-Promoting Foods Increase with Repeated Exposure during Weight Loss? *Foods*, 6(2): 1-12.
- Katunku, D., Ogunwolu, E. O. and Ukwela, M. U. (2014).** Contact toxicity of *Canarium schweinfurthii* Engl. Tissues against *Callosobruchus maculatus* in stored Bambara ground nut. *International Journal of Agronomy and Agricultural Research*, 5: 20-28.
- Lale, NES (2002),** Stored-Product Entomology and Acarology in Tropical Africa. Mole Publishers, Maiduguri, Borno State, Nigeria.
- Maina, Y. T and Lale, N. E. S. (2004).** Integrated Management of *Callosobruchus maculatus* (F.) Infesting Cowpea Seeds in Storage Using Varietal Resistance, Application of Neem *Azadirachta indica* A. Juss) Seed Oil and Solar Heat. *International Journal of Agriculture and Biology*, 6 (3): 440-446.
- Mokhtar, M. M., Jianfeng, L., Du, Z. and Cheng, F. (2020).** Chemical composition and repellency activity of essential oil from desert date seeds against the red flour beetle. *International Journal of Advanced Engineering Research and Science*, 7(8): 275- 279.
- Malgwi, A. M. and Dunuwel, D. M. (2013).** Reaction of some sorghum varieties and cultivars to panicle insect pest at Yola and Kaltungo in the Sudan and Northern Guinea Savannah zone of Nigeria. *Nigerian Journal of Plant Protection*, 27 (1): 52-62.
- Mondal, E. and Chakraborty, K. (2016).** *Azadirachta indica* – A Tree with multifaceted applications: An Overview. *Journal of Pharmaceutical Science and Research*, 8(5): 299-306.
- Monica, B and Loan, S. (2018).** Essential Oils from Plants. *Journal of Biotechnology and Biomedical Science*, 1(4): 35-43.
- Murthy, H. N., Yadav, G. G., Dewir, Y. H. and Ibrahim, A. (2021).** Phytochemicals and Biological Activity of Desert Date (*Balanites aegyptiaca* (L.) Delile). *Plants*, 10 (32): 22pp.
- Nukenine E. N, Tofel, H. K, Adler, C. (2011).** Comparative efficacy of NeemAzal and local botanicals derived from *Azadirachta indica* and *Plectranthus glandulosus* against *Sitophilus zeamais* on maize. *Journal of Pest Science*. 84: 479-487
- Nwaogu, J. 1., Yahaya, M. A. and Bandiya, H. M. (2013).** Insecticidal efficacy of oil Extracts of *Balanites aegyptiaca* seeds and cashew nuts against *Callosobruchus maculatus* Fab. (Coleoptera: Bruchidae). *African Journal of Agricultural Research*. 8(25): 3285-3288.
- Obeng-Ofori, D. (1999).** Dossier information for registration of national neem pesticides in Ghana. Integrated Crop Protection Project (ICP), 81pp.
- Obeng-Ofori, D. (2007).** The use of botanicals by resource poor farmers in Africa and Asia for the protection of stored agaric products.

- Steward Postharvest Review*, 6 (5): pp 1-8.
- Obeng-Ofori, D. (2008).** Sustainable management of pests of vegetable crops in Ghana with neem bio-pesticides for food safety and environmental protection. Workshop on Agriculture and Economic Development in Sub-Saharan Africa. International Institute for the Advanced Study of Cultures, Institutions and Economic Enterprise (IIAS), Accra, Ghana. And-Economic-Development-in-Sub-Saharan-Africa, [www.IIAS.com/index.php/conferences/45-Workshop-on-Agriculture](http://www.IIAS.com/index.php/conferences/45-Workshop-on-Agriculture) Retrieved on 4th February, 2009.
- Obeng-Ofori, D. and Dankwah, J. A. (2004).** Biological effects of four protectants applied to stored Bambara groundnut against infestation by *Callosobruchus maculatus* (Fab.) (Coleoptera: Bruchidae). *Journal of the Ghana Science Association* (on line edition) 3 (8): [http://www.aiol.in\(o/viewarticle.php?id=26801](http://www.aiol.in(o/viewarticle.php?id=26801) Retrieved on 4 February, 2009
- Okia, C. A., Agea, J. G., Kimondo, James, M., Abohassan, Refaat, A. A., Okiror, P., Obua, L., Teklehaimanot, Z. (2011).** Use and management of *Balanite aegyptiaca* in drylands of Uganda. *Research journal of Biological sciences*, 6 (1): 15-24.
- Oluwole, F. A., Oumaru, M. B., and Abdulrahim, A. T. (2015).** Traditional method of neem seed oil extraction in North Eastern Nigeria: Challenges and prospects. *Continental Journal of Engineering Sciences*. 10 (1): 1-8.
- Oni, M. O. (2011).** Evaluation of seed and fruit powders of *Capsicum annum* and *Capsicum frutescens* for control of *Callosobruchus maculatus* (F.) in stored cowpea and *Sitophilus zeamais* (Motsch) in stored maize. *International Journal of Biology*, 3(2): 185-188.
- Patel, S. S. and Savjani, J. K. (2015).** Systematic Review of Plant Steroids as Potential Antiinflammatory Agents: Current Status and Future Perspectives. *The Journal of Phytopharmacology*. 4(2): 121-125.
- Raguraman, S. and Singh, D. (2008).** An Online publication of Raguraman, S. and Singh, D. (1997). Biopotentials of *Azadirachta indica* and *Cedrus deodara* oils on *Callosobruchus chinensis*. *Pharmaceutical Biology*. 35 (5): 344-348.
- Saxena, R. C. (2006). Practical applications of neem against pests of stored products. *Proceedings of Methyl Bromide Alternatives and Emissions Reduction*, pp. 110-114.
- Saxena, R. C. (2006).** Practical applications of neem against pests of stored products. *Proceedings of Methyl Bromide Alternatives and Emissions Reduction*, pp. 110-114.
- Schmutterer, H. (2022).** An Online Publication of Schmutterer, H. (1990). Properties and potentials of natural pesticides from neem tree. *Annual Review of Entomology*, 35: 271-298.
- Schneider, L. C. L., Vieira da Silva, C. and Conte, H (2017).** Toxic effect of commercial formulations of neem oil, *Azadirachta indica* A. luss., in pupae and adults of the sugarcane borer, *Diatraea saccharalis* F. (Lepidoptera: Crambidae). *Arquivos.Institute of Biology*. Sao Paulo. 84: [https://doi.org/10.1590/11808-16570\(0\)432014](https://doi.org/10.1590/11808-16570(0)432014) Retrieved on 19 February, 2021
- Selouka, M. A., Fouteye, M. M. L., Hasni, O. T., Abdelkarim, F. M. and Ali, O. M. S. B. (2020).** Phytochemicals, Antioxidant Activity and Ethnobotanical Uses of *Balanites aegyptiaca* (L.) Del. Fruits from the Arid Zone of Mauritania, *Northwest Africa Plants*. 9(401): 1-15.
- Shehu, A., Obeng-Ofori, D and Vincent, Y. E. (2010).** Biological efficacy of Calnecm 1M oil against the tropical warehouse moth *Ephestia cautella* (Lepidoptera: Pyralidae) in stored maize. *International Journal of Tropical Insect Science*. 30 (4): 207-213.
- Stoll, G. (2005).** Natural crop protection in the Tropics. Margraf Publishers Scientific Books. Second enlarged and revised edition. 377pp.
- Sunarti, C. (2003).** Oils from plants and their toxicity to cacao moth, *Ephestia cautella* (Walker) Lepidoptera. In FAO (2006) *Agris Record*, pests of plants up PH 2004001740 (Philippines), 76pp.
- Tadesse, A. and Basedow, T. (2005).** Laboratory and field studies on the effect of

- natural control measures against insect pests in stored maize in Ethiopia. *Journal of Plant Diseases and Protection*, 112(2): 156-172.
- Tefera, T. (2012).** Post-harvest losses in African maize in the face of increasing food shortage. *Food Security*. 4(2): 10-15.
- Vaidehi, P. and Rajesh, P. (2016).** The Active Constituents of Herbs and their Plant Chemistry, Extraction and Identification Methods: *Journal of Chemical and Pharmaceutical Research*. 8(4): 1423-1443.
- Yadav, J. P. and Panghal, M. (2010).** *Balanites aegyptiaca* (L.) Del. (Hingot): A review of its traditional uses, phytochemistry and pharmacological properties. *International Journal of Green Pharmacy*, 4: 140-146
- Yahaya, M. M. and Sulaiman, B. (2018).** Laboratory Assessment of the Toxic Efficacy of Selected Seed Oils against the Emergence of Cowpea Weevil (*Callosobruchus maculatus* F.) on Stored Cowpea (*Vigna unguiculata* L. Walp). *International Journal of Modern Botany*. 8(1): 1-7.
- Ya'u, D'Ahmad, T. Y., Baba, K. I., Lado, A. U., Musbahu, L., Umar, A. U. and Nura, T. (2020).** Phytochemical composition of desert date kernel (*Balanite aegyptiaca*) and the physical and chemical characteristics of its oil. *Biological and Pharmaceutical Sciences*. 11(03), 197-207.
- Yubin, J. I, Miao, Y, Bing, W. and Yao, Z. (2014).** The Extraction, Separation and Purification of Alkaloids in the Natural Medicine. *Journal of Chemical and Pharmaceutical Research*, 6(1): 338-345.
- Zhu, L. L., Cermak, S. C., Kenar, J. A., Brewer, G., Haynes, K. F. and Boxler, D. (2018).** Better than DEET repellent compounds derived from coconut oil. *Scientific Reports*, 8, 14053 <https://doi.org/10.1038/s41598-018-32373-7> Retrieved on 21 February 2021.

