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Post-oviposition Effect of Slow Release Pelletized Edible Essential Oils on Cowpea Seed Bruchid, *Callosobruchus maculatus* (F.) (Coleoptera: Chrysomelidae) Infesting Some Legume Grains

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ABSTRACT

The evaluation of insecticidal efficacy of three slow release pelletized edible essential oils (SRPEEOs) extracted from clove, Syzygium aromaticum (L.), West African Black pepper (WABP) (Piper guineense Schumm et Thonn) and Ginger (Zingiber officinale (Roseoe) on the bean bruchid, Callosobruchus maculatus infesting some legumes. The research was carried out on under ambient laboratory conditions (27º C±2 and RH70 %) at the Agronomy Laboratory of Faculty of Agriculture (Shabu-Lafia Campus), Nasarawa State University, Keffi. Evaluation of the SRPEEOs on legume varieties on biological determination of treatments applied as after infestation (TAI) tests. All the treatments were replicated three times and the experiments were laid out in Complete Randomized Block Design. Data analyses were carried out using Statistix 10 analytical package in a two-way factorial analysis. All data were transformed before analyses. The use of the three SRPEEPs at the rates of 1.0 g/5 g seed significantly (p≤0.05) inhibited oviposition and prevented emergence of bruchids in all the legume varieties tested at TA1. The three SRPEEOs were very effective to confer protection on the legume

varieties against infestation by the bruchid, hence, serve as an alternative to synthetic pesticides when used at the rate of 1 g/5 g (100 g/50 kg bag), especially, to repel colonization of legumes.

Keywords: Post-oviposition, Legumes, Slow release pelletized edible essential oils.

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INTRODUCTION

The word legume comes from the Latin word legumen which can be translated to mean "seeds harvested inpods" (Vasconcelos *et al*., 2020). According to Singh and Singh (1992). In many parts of the world (Canada, Bangladesh or India), the world pulse is used when referring to legume grains, especially those with low content in fats. Legumes or pulses have been known to farmers since the Neolithic revolution, from the very onset of farming practices by mankind (Huebbe and Rimbach, 2020). In agriculture, the legume family (Fabaceae) is second in importance only to the cereals (Poaceae) (Maphosa and Jideani, 2017). With reference to the area of harvested land and total world production, more than 650 million tons of grain legumes were produced on 240 million ha as at 2011 (FAOSTAT, 2016). Grain legumes provide one-third of the plant protein and a similar proportion of the vegetable oil used for human consumption (Graham and Vance, 2003). The amino acid composition of legumes are reported to complement that of cereals and root crops (Wang *et al.,* 2003), perhaps explaining why the two groups were domesticated together (Gepts, 2004).

Legumes are also important forage crops in temperate and tropical regions (Singh *et al*., 2019), and provide essential minerals for the consumer (Grusak, 2002). Among the pulses, cowpea, Soya bean, Bambara groundnut and pigeon pea are the most common and important legume crops in the world (Mahdi and Rahman, 2008). Pulses have a prominent place in daily diet as a rich source of vegetable protein, minerals and vitamin B. They are of special significance to the people in developing countries who may not always afford animal protein in adequate quantities (Singh, 2017). Legumes have been widely recognized as an important sources for fortification of wheat-based traditional bakery products, such as biscuits.

Legumes have been reported to be rich in secondary metabolites, such as polyphenols, alkaloids, and saponins, which are important defense compounds to protect the plant against herbivores and pathogens and act as signaling molecules between the plant and its biotic environment (Ndakidemi and Dakora, 2003; Ku *et al*., 2020). These secondary metabolites have been suggested to protect the human consumer against some cancer related causal organisms (Madar and Stark, 2002) and have some benefits in the treatment of diabetes (Jenkins *et al*., 2003). Further to these, legumes have been reported to reduce blood cholesterol.

Despite these advantages, the cowpea seed bruchid, *Callosobruchus maculatus* Fab. (Coleoptera: Chrysomelidae: Bruchinea) has been reported to be a major store pest of economic importance infesting stored legumes (cowpea, Bamabara nut, lima bean, lentil, green gram and black gram) (Park *et al*., 2003). *C. maculatus* is a cosmopolitan polyphagous field-to-store pest in most tropics and subtropical parts of the world (Booth *et al*., 1990; Bagheri, 1996). This bruchid is reported to be the most damaging pest of legume seeds and grains as its larva infest grain legumes (Srinivasan *et al*., 2008). Insect infestation is a major contributor to quality deterioration of durables legumes. The larvae are the most destructive stage in the life cycle of the bruchid as the adult do not feed (Gbaye and Holloway, 2011). Aboua *et al.* (2010) reported that *C. maculatus* larvae that feed inside cowpea seeds can cause up to 80% weight loss after six months of storage. Botanical insecticides, including powders, extracts and essential oils have been used to protect crops for many years (Isman, 2006), some of which may be plant derived bio-ticides with significant roles in the traditional storage methods in many parts of Africa (Bekele and Hassanali, 2001).

Some plants are reputed to possess compounds such as terpenoids, alkaloids and phenols that have been reported to have various effects against insect pests including toxicity, antifeedants, repellants, growth inhibition and feeding deterrence (Divekar *et al*., 2022). Various essential oils have been reported to play significant roles in protecting stored grains against insect infestations (Regnault-Roger, 1997; Bakkali *et al*., 2008; Pérez *et al*., 2010). Products from edible spices particularly oils, have been screened for their efficacy in suppressing stored product pests without constituting threats to farmers and the environment, mainly because they do not add to the weight of the produce, unlike with use of powders, ash, or leaves (Ajayi and Lale, 2000). Monoterpenoids found in essential oils are known neurotoxins and most of them are volatile thus, act as fumigants. The use of formulated edible essential oils (EEOs) as pellets to cause slow release are scantily reported (Etonihu *et al*., 2008). However, there is need to explore the possibility of formulating and determining the efficacy of slow release of pelletized EEOs to form slow release pelletized edible essential oil (SRPEEO) when used as protectants of grains and seeds of stored products.

Pesticides can be classified in terms of active ingredient, emulsion, fumigant, impregnates, pheromones, phytotoxicity, solution and suspension (Cardarelli, 2018). Also, Pesticides are available in various "formulations". Formulations include pellets, dusts, gels, granules, liquids, aerosols, wettable powders, concentrates, and pre-mixed solutions (Libs and Salim, 2017). Most of the active ingredients of existing pesticides are high-activity, water-insoluble organic compounds (Syafrudin *et al*., 2021). It is usually necessary to add auxiliary ingredients such as carriers, solvents, emulsifiers, and dispersing agents to prepare various types of formulations (Ghormade *et al*., 2011). Therefore, using advanced carrier materials and loading methods to improve the effectiveness and utilization of pesticides, as well as reducing the residual pollution in non-target areas and environments, has become a scientific problem in modern agriculture that needs to be urgently solved.

The formulated essential oils in the form of SRPEEOs was therefore, evaluated on cowpea seed bruchid, *Callosobruchus maculatus* (F.), infesting five legume varieties, cowpea (*Vigna unguiculata* (L.) Walp.), Lima beans (*Phaseolus lunatus* L.), soya beans (*Glycine max* L.), Bambara groundnut (*Vigna subterranea* (L.) Verd.) and pigeon pea (*Cajanus cajan* (L.) Millsp.) under laboratory conditions in Lafia, Nasarawa State, Nigeria.

MATERIALS AND METHOD

1.1 Experimental Site

The study was carried out in the laboratory of the Department of Agronomy, Faculty of Agriculture (Shabu-Lafia Campus), Nasarawa State University, Keffi.

Insect culture

An infested cowpea seeds (var. Kananade) was used to raise the initial culture of the cowpea seed bruchid, *C. maculatus* in the laboratory. Infested cowpea seeds were raised inside a 500 ml transparent Kilner jar and covered with muslin cloth held in place with a rubber band till the emergence of adults (Ajayi and Lale, 2000). Cowpea seed bruchid was allowed to oviposit for a period of 10 days before all living and dead insects were removed. The culture was left until emergence of adults from the culture. Gravid adult female *C. maculatus* as described by Singh and Pandey (2001) that emerged from the initial stock were collected with the aid of a pooter and re-infested on a pristine cowpea seeds for new emergence. This was carried out for five consecutive generations until the insects acclimatized and the populations were found to be sufficient to commence the experiment.

The legumes comprising cowpea (*Vigna unguiculata*), Lima bean (*Phaseolus lunatus*), soya bean (*Glycine max*), Bambara nut (*Vigna subterranea*) and pigeon pea (*Cajanus cajan*) were purchased from Lafia main market, Lafia, Nasarawa State. The legumes were carefully sorted out and only pristine grains were collected from the lot. The legume were then transferred into a double-layered polythene bag with the opening fastened with a tight rubber band to prevent any water seepage in the freezer and infestation by cowpea seed bruchid. The polythene bag containing the legumes were kept at -18^0 C for five days, this was done to disinfest the legume from harbouring eggs or larvae. After five days of cold treatment, the legumes were spread on polythene sheets on a laboratory bench and covered with screen gauze to equilibrate to atmospheric laboratory conditions, for three days. Thereafter, the legumes were packed into disinfested Kilner jars and kept on the laboratory bench (Lale and Ajayi, 1999), Ajayi and Lale (2000), until ready for use. The slow release pelletized edible essential oils from clove (*Syzgium aromaticum)*, ginger (*Zingiber officinale*) and West African black pepper (*Piper guineense*) were obtained from already prepared pellets from the National Institute for Pharmaceutical Research and Development, Pharmaceutical Technology and Raw Materials Department, Abuja, (FCT).

5 g of the legume varieties were weighed into a 100 ml glass jar and treated with slow released pelletized edible essential oils. 3-day old adults of *C. maculatus* were then introduced into each jar and allowed to oviposit for 10 days. After 10 days, all the insects were removed with a means of a pooter from the treatments and replicates. The number of eggs laid in each replicate and treatments were counted and recorded. Each treatment of the cowpea seeds (now carrying bruchid eggs) were treated with 0.0, 0.25, 0.50, 0.75 and 1.0 g of each SRPEEOs. The experiment was laid out in a Randomized Complete Block Design and replicated three times. The effect of the slow release pelletized edible essential oil on the biology of the cowpea seed bruchid was collected for first generation of bruchid emergence. And the following data were collected.

1. Adult mortality

All adults that emerged in all the treatments were counted and recorded. Adult mortality was calculated based on actual physical mortality of the adults' insect at the time of recording. The effect of edible essential oil on the mortality of adult *C. maculatus* in comparison to the mortality recorded in the control following the method described by Abbott (1925):

$$PT = \frac{Po - Pc}{100 - Po} \times 100$$

Where:

Pt = Corrected mortality (%)

Pc=Control mortality (%)

Po =Observed mortality (%)

2. Percentage Adult Emergence (PAE)

The number of adult emergence was expressed in percentages (Odeyemi and Daramola, 2000):

$$\%\text{Adult emergence} = \frac{\text{Total number of adult emergence}}{\text{Total number of eggs laid}} \times 100$$

3. Determination of percentage weight loss

Initial weight of each legume samples were taken to determine percentage weight loss following the method of Ileke *et al.* (2020):

$$\text{Percentage weight loss (PWL)} = \frac{W_1 - W_2}{W_2} \times 100$$

Where

W_1 = Initial weight

W_2 = Final weight

4. Weevil Perforation Index (WPI)

Was expressed as described by Fatope *et al.* (1995):

$$WPI = \frac{\%\text{ treated maize grains perforated}}{\%\text{ control maize grains perforated}} \times 100$$

WPI value exceeding 50 was regarded as enhancement of infestation by the beetle or negative protectability of the extract tested.

Statistical Analysis.

All other data were subjected to two-way ANOVA as the case may be and the differences between treatment means were seperated using Duncan Multiple Range Test (DMRT) at p≤0.05 % probability level, using STATISTIX 10 for students' version (2018) analytical package.

RESULTS

The result in Table 1 shows the interactive effect on treatment and concentrations of the slow release pelletized essential oils SRPEEOs on *C. maculatus*. The results indicated significant differences ($p \leq 0.05$) among the treatments and concentrations on number of eggs. The highest number of eggs were obtained when treated with SRPEEOs of Clove at 0.0 g (166.83), while the lowest number of eggs laid was obtained with WABP at 1.0 g (145.61). Also, significant differences ($p \leq 0.05$) were observed on percentage mortality, with the highest mortality obtained with SRPEEOs of Ginger at 0.50 g (0.11 %), while the lowest mortalities were obtained with Clove at 0.75 g (0.02%). Significant differences ($p \leq 0.05$) were also observed among emerged adults. The highest level of percentage adult emergence (PAE) was obtained when treated with SRPEEOs of WABP at 0.0 g (69.06 %), while the lowest PAE was obtained with Clove at 1.0 g (6.29%).

Results in Table 1 also indicated that there were significant differences ($p \leq 0.05$) between treatments and concentrations on weight loss. The highest percentage weight loss (PWL) was observed with SRPEEOs of Clove at 0.0 g (75.83 %), while the lowest was obtained on West African black pepper at 1.0 g (11.83%). Results in Table 1 further indicates significant differences ($p \leq 0.05$) among weevil perforation index (WPI), with the highest obtained with SRPEEOs of Clove with at 0.0 g (65.29 %), while the lowest WPI was obtained with WABP at 1.0 g (6.15%).

Table 1:Post-oviposition interactive effects on treatments and concentrations of slow release pelletized essential oils against *Callosobruchus maculatus*

Treatment	Concentration	No. of Eggs Laid	% Mortality	% Adult Emerged	% Weight loss	% Weevil perforation Index (WPI)
Clove	0	166.83^{a}	0.03^{d}	67.11^{a}	75.83^{a}	65.29^{a}
WABP	0	161.17^{ab}	0.03^{d}	69.06^{a}	75.82^{a}	64.01^{a}
Ginger	0	155.89^{bcde}	0.02^{d}	67.86^{a}	75.49^{a}	64.94^{a}
WABP	0.25	147.94^{def}	0.10^{ab}	29.04^{b}	54.06^{b}	35.47^{c}
Clove	0.25	158.22^{abc}	0.07^{abcd}	26.39^{c}	52.06^{bc}	38.91^{b}
Ginger	0.25	147.56^{def}	0.09^{abc}	25.59^{c}	49.98^{c}	38.04^{b}
Clove	0.5	145.72^{f}	0.07^{abcd}	17.21^{d}	40.84^{d}	21.76^{e}
WABP	0.5	145.61^{f}	0.07^{abcd}	16.43^{d}	39.68^{d}	18.94^{f}
Ginger	0.5	147.22^{ef}	0.11^{a}	16.73^{d}	36.15^{e}	23.81^{d}
WABP	0.75	149.00^{def}	0.04^{cd}	10.89^{e}	20.47^{g}	10.54^{i}
Clove	0.75	155.22^{bcde}	0.02^{d}	9.82^{e}	20.40^{g}	14.21^{g}
Ginger	0.75	154.56^{bcdef}	0.05^{bcd}	10.21^{e}	28.09^{f}	12.45^{h}
Ginger	1	156.44^{bcd}	0.05^{bcd}	7.00^{f}	16.00^{h}	6.60^{j}
WABP	1	150.56^{cdef}	0.06^{abcd}	6.34^{f}	11.83^{i}	6.15^{j}
Clove	1	154.17^{bcdef}	0.05^{abcd}	6.29^{f}	12.33^{i}	6.17^{j}
SE		4.62	2.84	1.03	1.38	0.89
LSD		9.10	5.60	2.04	2.71	1.75

Means with the same letter in the column are not significantly different at 5% level of probability using DNMRT ($p \leq 0.05$)

WABP = West African Black Pepper
% Mortality = Percentage Mortality
% Adult Emergence = Percentage Adult Emergence
% Weight Loss = Percentage Weight Loss
% Weevil Perforation Index (WPI) = Percentage Perforation Index
SE = Standard Error.
LSD = Least Significant Difference

The results in Table 2 shows the interactive effect between treatments and varieties of the SRPEEOs on *C. maculatus*. The results indicated that there were significant differences ($p \leq 0.05$) among the treatments and varieties on number of eggs. The highest number of eggs was obtained when treated with SRPEEOs of Clove on Cowpea (176.60), while the lowest number of eggs was obtained with WABP on Lima bean (123.33). Results in Table 2 further indicated significant differences ($p \leq 0.05$) in percentage mortality, with the highest mortality obtained when treated with Ginger on Soya bean (0.10 %), while the lowest mortality was obtained with WABP on Lima bean (0.4%).

Also, results in Table 2 showed significant differences ($p \leq 0.05$) on percentage adult emergence (PAE). The highest PAE was obtained when treated with WABP on Bambara nut (36.50 %), while the lowest PAE was obtained with Ginger on Lima bean (11.21%). Results in Table 2 also indicated significant differences ($p \leq 0.05$) in percentage weight loss (PWL). The highest PWL was obtained when treated Ginger on Cowpea with (50.76 %), while the lowest PWL was obtained with Clove on Soya bean (25.69 %).

Similarly, results in Table 2 indicated significant differences ($p \leq 0.05$) on percentage WPI, with the highest %WPI was obtained when treated with Ginger on Cowpea (41.64 %), while the lowest %WPI was obtained when treated with Ginger on Lima bean (10.25%).

Table 2: Post-oviposition interactive effects on treatments and varieties of slow release pelletized essential oils against *Callosobruchus maculatus*

Treatment	Varieties	No. of Eggs Laid	% Mortality	% Adult Emergence	% Weight Loss	% Weevil Perforation Index (WPI)
Clove	Cowpea	176.60^{a}	0.05^{ab}	32.98^{b}	50.44^{a}	37.46c
Ginger	Cowpea	169.60^{ab}	0.06^{ab}	32.99^{b}	50.76^{a}	41.64a
Clove	Soya bean	166.40^{bc}	0.04^{b}	13.64^{hi}	25.69^{j}	17.50h
WABP	Cowpea	166.33^{bc}	0.06^{ab}	28.95^{ef}	42.05^{de}	31.53e
WABP	Zebra bean	165.93^{bc}	0.08^{ab}	31.34^{bcd}	39.09^{ef}	34.58d
Ginger	Zebra bean	165.73^{bc}	0.06^{ab}	32.49^{b}	50.94^{a}	39.71b
Clove	Zebra bean	163.27^{bcd}	0.08^{ab}	31.55^{bc}	39.23^{ef}	38.23bc
Ginger	Pigeon pea	157.67^{cde}	0.06^{ab}	27.97^{f}	46.60^{bc}	31.86e
WABP	Pigeon pea	154.40^{de}	0.05^{ab}	29.120^{def}	41.83^{de}	29.35f
WABP	Soya bean	153.80^{de}	0.08^{ab}	15.70^{gh}	28.19^{ij}	18.25h
Ginger	Soya bean	151.60^{e}	0.10^{a}	17.39g	28.81^{i}	20.74g
Clove	Pigeon pea	151.00^{ef}	0.06^{ab}	29.70^{cdef}	46.50^{bc}	31.50d
Clove	Bambaranut	150.40^{ef}	0.06^{ab}	32.73^{b}	43.80^{cd}	37.60c
WABP	Bambaranut	141.33^{fg}	0.06^{ab}	36.50^{a}	48.11^{ab}	35.02d
Ginger	Bambaranut	138.60^{gh}	0.05^{ab}	30.83^{bcde}	42.28^{d}	30.85ef
Ginger	Lima bean	130.80^{hi}	0.04^{b}	11.21^{j}	32.21^{h}	10.25j
Clove	Lima bean	128.53^{i}	0.04^{b}	11.58^{ij}	36.09^{ef}	10.29j
WABP	Lima bean	123.33^{i}	0.04^{b}	16.51^{g}	38.19^{ef}	13.43i
SE		5.06	3.11	1.13	1.51	0.97
LSD		9.96	6.13	2.23	2.98	1.91

Means with the same letter in the column are not significantly different at 5% level of probability using DMRT ($p \leq 0.05$)

WABP = West African Black Pepper
% Mortality = Percentage Mortality
% Adult Emergence = Percentage Adult Emergence
% Weight Loss = Percentage Weight Loss
% Weevil Perforation Index (WPI) = Percentage Perforation Index
SE = Standard Error.
LSD = Least Significant Difference

The results in Table 3 shows the interactive effect of varieties and concentrations of the SRPEEOs on *C. maculatus*. The results indicated significant differences (p≤0.05), of varieties and concentrations on number of eggs. The highest number of eggs were obtained on Zebra bean at (0.0 g), (178.00), while the lowest number of eggs were obtained on Lima bean at 0.25 g (116.11). Results also, indicated significant differences (p≤0.05) in percentage mortality, with the highest mortality obtained on Zebra bean at 0.25 g (0.12 %), while the lowest was obtained on Lima bean at 1.0 g (0.02%).
Significant differences (p≤0.05) were also observed on percentage adults' emergence (PAE). The highest PAE was obtained on Bambara nut at 0.0 g (89.26), while the lowest PAE was obtained on Lima bean at 1.0 g (3.66). Significant differences (p≤0.05) were equally observed on percentage weight loss (PWL). The highest PWL was obtained on Pigeon at 0.0 g (85.18), while the lowest PWL was obtained on Soya bean at 1.0 g (6.67). The highest %WPI was obtained on Cowpea at 0.0 g (81.55 %), while the lowest %WPI was obtained on Lima bean at 1.0 g (0.02%)

Table 3: Post-oviposition interactive effects on varieties and concentrations of slow release pelletized essential oils against *C. maculatus*

Varieties	Concentration	No. of Eggs Laid	% Egg mortality	% Adult Emergence	% Weight loss	% Weevil Perforation Index (WPI)
Cowpea	0	175.67^{abc}	0.04^{ab}	87.56^{a}	81.33^{b}	81.55^{a}
Zebra bean	0	178.00^{a}	0.03^{b}	81.87^{b}	80.91^{b}	80.92^{a}
Bambaranut	0	156.78^{de}	0.02^{b}	89.26^{a}	85.42^{a}	77.62^{b}
Soya bean	0	164.56^{bcd}	0.03^{b}	36.93^{c}	62.22^{cd}	46.39^{d}
Lima bean	0	133.67^{gh}	0.02^{b}	22.14^{ef}	59.22^{d}	22.81^{gh}
Pigeon pea	0	159.11^{de}	0.02^{b}	90.29^{a}	85.18^{a}	79.21^{ab}
Zebra bean	0.25	164.00^{cd}	0.12^{a}	29.97^{d}	50.72^{ef}	49.03^{c}
Cowpea	0.25	176.89^{ab}	0.10^{ab}	32.35^{d}	64.11^{c}	49.80^{c}
Pigeon pea	0.25	154.33^{de}	0.06^{ab}	24.68^{e}	53.98^{e}	39.29^{e}
Bambaranut	0.25	137.78^{fg}	0.08^{ab}	20.41^{fg}	58.96^{d}	49.85^{c}
Soya bean	0.25	158.33^{de}	0.12^{a}	16.72^{hi}	38.02^{j}	21.36^{h}
Lima bean	0.25	116.11^{i}	$0,06^{ab}$	19.25^{gh}	46.40^{gh}	15.51^{ijk}
Cowpea	0.5	163.56^{cd}	0.08^{ab}	19.22^{gh}	48.40^{fg}	28.76^{f}
Lima bean	0.5	120.89^{hi}	0.08^{ab}	12.24^{j}	36.22^{j}	09.05^{lm}
Soya bean	0.5	149.89^{ef}	0.10^{ab}	12.00^{jk}	19.09^{no}	14.14^{jk}
Zebra bean	0.5	165.89^{abcd}	0.08^{ab}	21.25^{fg}	43.99^{hi}	30.36^{f}

Pigeon pea	0.5	141.00^{fg}	0.12^{a}	15.63^{i}	43.22^{hi}	21.92^{h}
Bambaranut	0.5	135.89^{g}	0.09^{ab}	18.73^{gh}	42.41^{i}	24.78^{g}
Zebra bean	0.75	161.33^{de}	0.04^{ab}	16.58^{hi}	29.00^{k}	1757^{i}
Cowpea	0.75	174.33^{abc}	0.02^{b}	10.58^{jklm}	28.22^{kl}	15.92^{ij}
Lima bean	0.75	128.56^{ghi}	0.03^{b}	8.21^{lmno}	23.24^{m}	6.23^{no}
Soya bean	0.75	155.56^{de}	0.08^{ab}	5.57^{mno}	11.83^{q}	7.10^{lmn}
Bambaranut	0.75	136.89^{g}	0.03^{b}	10.89^{jkl}	21.09^{mn}	13.62^{jk}
Pigeon pea	0.75	160.89^{de}	0.04^{b}	7.95^{mno}	24.51^{lm}	13.05^{k}
Cowpea	1	163.78^{cd}	0.05^{ab}	8.47^{lmno}	16.69^{o}	8.31^{lmn}
Zebra bean	1	155.67^{de}	0.08^{ab}	7.63^{no}	10.82^{q}	9.65^{l}
Pigeon pea	1	156.44^{de}	0.08^{ab}	6.09^{opq}	18.00^{no}	6.05^{no}
Bambaranut	1	149.89^{ef}	0.08^{ab}	7.14^{nop}	15.7^{6op}	6.59^{mno}
Soya bean	1	158.00^{de}	0.06^{ab}	4.60^{pq}	6.67^{r}	4.23^{op}
Lima bean	1	138.56^{fg}	0.02^{b}	3.66^{q}	12.40^{pq}	3.02^{p}
SE		6.53	4.02	1.60	1.95	1.25
LSD		12.86	7.91	3.16	3.84	2.47

Means with the same letter in the column are not significantly different at 5% level of probability using DNMRT ($p \leq 0.05$)

% Mortality = Percentage Mortality
% Adult Emergence = Percentage Adult Emergence
% Weight Loss = Percentage Weight Loss
% Weevil Perforation Index (WPI) = Percentage Perforation Index
SE = Standard Error.
LSD = Least Significant Difference

DISCUSSION

Results of the present study indicated the efficacy of the three SRPEEOs to deter post-oviposition by adult *Callosobruchus maculatus* when treated with Ginger, Clove and WABP on mortality, number of eggs, adult emerged, weight loss and WPI, respectively, and suppression of post-oviposition on treatments and concentrations with WABP, Ginger and Clove before infestation. These results are in consonance with the results obtained by Ajayi and Lale (2001) which showed that WABP oils inhibited the oviposition capacity of *C. maculatus* on Bambara nut infestation. They are also in tandem with the reports of Ahmed *et al.* (2010) and Campolo *et al.* (2018) which showed the efficacy of EEOs to increase as dosage concentrations increase.

The efficacy of the SRPEEOs to deter post-oviposition by adult *C. maculatus* using the

SRPEEOs manifested greatly on Soya bean, Cowpea, and Bambara nut. The results of this study conform to an extent with the reports of Opareke (2004), Adedire *et al.* (2011), Ileke and Oni (2011), who observed that certain botanicals such as WABP, *Piper guineense*, Alligator pepper, *Aframomum melegueta*, Ethiopean pepper, *Xylopia aethiopica*, ginger, *Zingiber officinale* chili pepper, *Capsicum annuum*, Cashew, *Anacardium occidentale* and spur-flower, *Plectranthus kirbii*, are effective or toxic against storage insect pests including *C. maculatus.*

The efficacy of the SRPEEOs to deter post-oviposition by adult *C. maculatus* even after showed the potency of essential oils extracted from clove, WABP and ginger to possess pesticidal properties (Asawalam *et al.*, 2007a; 2007b), Ajayi and Lale (2001a; 2001b), Ukeh *et al.*, (2012). Kafle and Shih (2013), Jairoce *et al.*, (2016), lbáñez and Blázquez, (2019), EI-Kased and El-Kersh, (2022), which assertions are in agreement with the observations made in this study, that the effect of the SRPEEOs on mortality and emergence of adults of stored product insect pests are dose dependent.

CONCLUSION

The findings from this study indicated the potency of botanical extracts in reducing *Callosobruchus maculatus* Fab. damage commonly experienced among small scale farmers. The results obtained were attributed to the insecticidal potentials of the three SRPEEOs on the cowpea seed bruchid, *C. maculatus* after infestation as the pest is considered to be a field-to-store pest. Treatment of legumes with any of these SRPEEOs as treatment after infestation (TAI) will therefore, most likely abate the population of the cowpea seed bruchid in storage.

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