RESEARCH ARTICLE Legume Research- An International Journal, Volume 44 Issue 6: 667-672 (June 2021)

Fumigant Activity of Four Plant Powders against Cowpea Weevil, *Callosobruchus maculatus* (Fabricius) (Coleoptera: Chrysomelidae) in Stored Adzuki Bean

Muhammad Bayu Mario[1,2], Ludji Pantja Astuti[2], Jue-Liang Hsu[1], Lekhnath Kafle 10.18805/LR-533

ABSTRACT

Background: Cowpea weevil, *Callosobruchus maculatus* (Fabricius) (Coleoptera: Chrysomelidae) is one of most common species pest that attack various types of beans in the storage. Plant-based insecticides are considered as good candidates as alternatives to methyl bromide and phosphine for controlling pest in storage. Plenty of reports about plant powder as grain protectant, conversely a little information on plant powder as fumigant had been reported. This study was designed to observe the effects of plant powders of clove, holy basil, lemongrass and turmeric as fumigant on the biological parameters of *C. maculatus* under laboratory conditions.

Methods: Experiments were conducted on plant powders against biological parameters of cowpea weevil. No choice test method was followed to assess the bioefficacy of the four natural fumigants on adult longevity, fecundity, F_1 progeny, bean damage and weight loss of bean under completely randomized design (CRD).

Result: Fumigant toxicity of four plant powders (clove, holy basil, lemongrass and turmeric) varied amongst doses. Clove powder showed significantly lower adult longevity, fecundity of female, number of F_1 progeny, bean damage and weight loss of bean at 1 g and 3 g dose per container. Major volatile organic compounds (VOCs) in clove powder were eugenol (48.64%) and caryophyllene (43.09%) identified by solid phase microextraction followed with gas chromatography and mass spectrometry (SPME-GC/MS). These two major constituents might explain the fumigant toxic activities of clove powder towards *C. maculatus* biological parameters.

Key words: Adult longevity, Clove, Cowpea weevil, Eugenol, Natural product, Plant powder, SPME-GC/MS, Volatile organic compound.

INTRODUCTION

Cowpea weevil, *Callosobruchus maculatus* (Fabricius) (Coleoptera: Chrysomelidae) is major pest that cause serious damages to storage beans in most of tropical countries. This insect has been categorized into primary pest that adequate to penetrate and infest of undamaged grains. Furthermore, the insect being internal feeder immature stage developes inside the bean (Singh, 2017; Rees, 2004) causing weight loss, seed germination reduction, contamination, heating of commodity, quality loss and mould growth (Rees, 2004). This pest can attack many bean species, not just in storage facility but also before harvest (Prevett, 1961; Hagstrum *et al*., 2013).

Plant-based insecticides are considered as good candidates as alternatives to methyl bromide and phosphine for controlling pest in storage (Athanassiou *et al*., 2014). The major traits of the plant-based pesticides, *viz*. relatively effective, biodegradable and considerably low mammalian toxicity, made them highly desirable environmentally friendly alternatives (Athanassiou *et al*., 2014). As much 1,079 plants species have been described as botanical pesticide and 866 species of them possess toxicities, repellencies, physiological and deterrent effects against insects (Prakash and Rao, 1997). Plenty of natural products have been used as pest control agents, but most of them are using liquid formulations (plant extract or essential oil) as fumigant and solid formulations (powder) as contact insecticide or grain protectant (Adedire and Akinneye, 2004; Boeke *et al*., 2004: Hernandez-Lambraño *et al*., 2015). Plenty of reports about plant powder as grain protectant, conversely a little information on plant powder as fumigant had been reported (Weaver *et al*., 1994).

This study was designed to observe the effects of plant powders of clove, holy basil, lemongrass and turmeric as

Department of Tropical Agriculture and International Cooperation, National Pingtung University of Science and Technology, 1 Shuefu Road, Neipu, Pingtung 912, Taiwan (ROC).

[1]Department of Biological Science and Technology, National Pingtung University of Science and Technology, 1 Shuefu Road, Neipu, Pingtung 912, Taiwan (ROC).

[2]Department of Plant Pest and Disease, Faculty of Agriculture, University of Brawijaya, Jalan Veteran, Malang 65145, Indonesia.

Corresponding Author: Lekhnath Kafle, Department of Tropical Agriculture and International Cooperation, National Pingtung University of Science and Technology, 1 Shuefu Road, Neipu, Pingtung 912, Taiwan (ROC). Email: kafle@mail.npust.edu.tw

How to cite this article: Mario, M.B., Astuti, L.P., Hsu, J.L. and Kafle, L. (2021). Fumigant Activity of Four Plant Powders against Cowpea Weevil, *Callosobruchus maculatus* (Fabricius) (Coleoptera: Chrysomelidae) in Stored Adzuki Bean. Legume Research. 44(6): 667-672. DOI: 10.18805/LR-533.

Submitted: 21-10-2019 **Accepted:** 25-01-2021 **Online:** 07-04-2021

fumigant on the biological parameters of *C. maculatus* under laboratory conditions.

MATERIALS AND METHODS

Insect diet

Kaohsiung-9 variety of adzuki bean obtained from Pingtung and Donggang Farmer's Association Taiwan was used for rearing and further experimentation after cold sterilization as per Heinrichs *et al*. (1985) and Astuti *et al*. (2019).

Insect rearing

Inoculative insect culture was obtained from the Taiwan Agricultural Research Institute (TARI) in Taichung, Taiwan. Adzuki bean (100 g) was put in plastic container (Ø=6.5 cm, h=5 cm), then infested with unsexed 50 adults of *C. maculatus*. The lid of plastic containers was covered by nylon mesh. Eggs laid were allowed to develop inside the beans and emerged adults were collected for experimental purpose. Adults infestation were removed after all adults were dead.

Natural fumigants oreparation

Four kinds of herbs were respective plant parts such as buds (clove), leaves (holy basil), stems (lemongrass) and rhizomes (turmeric) were separated from other parts and shade-dried in laboratory conditions (27±2°C, 60% RH) for seven days (Tapondjou *et al*., 2002). Dried herbs were ground into powder using an electric blender and sieved using a 0.84 mm (20 mesh) sieve by sieve shaker for several minutes. The herbs were put into a tea bag (5×4 cm) in 1 and 3 g/container, separately.

Volatile organic compounds (VOCs) analysis

Volatile organic compounds analysis on four natural fumigants were done at the Department of Biological Science and Technology, National Pingtung University of Science and Technology, Taiwan. This analysis was aimed to identify and determine of relative amounts of the VOCs from each fumigants. Samples were analyzed with solid-phase microextraction and gas chromatography-mass spectrometry (SPME-GC/MS) method as described by Cozzolino *et al.* (2016).

Insect biology test

The experiment was conducted during August-September 2018 at Integrated Pest Management and Urban Entomology Laboratory, National Pingtung University of Science and Technology, Taiwan. No choice test method was followed to assess the bioefficacy of the four natural fumigants on adult longevity, fecundity, F_1 progeny, bean damage and weight loss of bean under completely randomized design (CRD) consisted of four fumigants (treated), positive control (without fumigant) and negative control (without fumigant and insect infestation) by replicating six times. Plastic container (Ø=6.5 cm, t=5 cm, v=±140 mL) filled with 30 g of adzuki bean was transferred with 15 pairs (0-24 hours old) of adults (Adedire and Akinneye, 2004; Righi-Assia *et al*., 2010; Regmi *et al*., 2012; Astuti *et al*., 2018) sexing the adult by elytral pattern (Beck and Blumer, 2014). The lid of plastic container was hermetically sealed with parafilm to prevent volatile escaping from the plastic container and it placed in laboratory conditions (27±2°C, 60% RH).

Adult mortality was assessed daily by counting the dead adults which paved way to arrive adult longevity. Insects were considered as dead if appendages (*i.e*. legs and antennae) did not move when touched with a paint brush for a minute (Hernandes-Lambraño *et al*., 2015). All dead adults were removed from the container.

Fecundity were counted by the eggs attached on surface of all beans after death of all released adults. Fecundity reduction was calculated and compared to control using the following formula (Gusmão *et al*., 2013):

$$\text{Fecundity reduction (\%)} = \left(\frac{Nc\text{-}Nt}{Nc}\right)\times 100$$

Whereas
Nc = Number of eggs (fecundity) on control.
Nt = Number of eggs (fecundity) on treatment.

F_1 progeny were examined daily and dead adults if any inside of the beans were removed manually. F_1 progeny reduction was calculated and compared with control using the following formula (Kedia *et al*., 2015):

$$F_1 \text{ progeny reduction (\%)} = \left(\frac{Nc\text{-}Nt}{Nc}\right)\times 100$$

Whereas
Nc = Number of F_1 progeny on control.
Nt = Number of F_1 progeny on treatment.

Bean damage was calculated by observing emergence holes on the surface of beans using the following formula (Kedia *et al*., 2015):

$$\text{Bean damage (\%)} = \left(\frac{Tb\text{ -}Nud}{Tb}\right)\times 100$$

Whereas
Tb = Total number of beans (damaged and undamaged).
Nud = Number of beans undamaged (bean with single or more holes counted as a bean damage).

Weight loss was calculated by the difference of weight before experiment started and the end of experiment and was calculated using the following formula (Kedia *et al*., 2015):

$$\text{Weight loss (\%)} = \left(\frac{WI\text{ - }WE}{WI}\right)\times 100$$

Whereas
WI = Weight of beans at intial of experiment.
WE = Weight of beans at the end of experiment (negative control was used as correction factor to calculate at the end of each treatment).

Consumption reduction was observed by the difference of weight loss of beans on control and treatment and was calculated using the following formula (Kedia *et al*., 2015):

$$\text{Consumption reduction (\%)} = \left(\frac{Wc\text{ - }Wt}{Wc}\right)\times 100$$

Whereas
Wc = Weight loss of beans on control.
Wt = Weight loss of beans on treatment.

Table 1: Volatile compounds of clove, holy basil, lemongrass and turmeric powder detected by SPME-GC/MS analysis.

Volatile compound	RT (min)	% Area			
		Clove	Holy basil	Lemongrass	Turmeric
Eucalyptol	14.65	-	3.14	-	7.19
β-Ocimene	15.36	-	0.90	-	-
trans-β-Terpineol	16.25	-	0.12	-	-
Linalool	17.52	-	1.25	0.21	-
α-Terpineol	21.08	-	-	-	0.45
Estragole	21.49	-	87.13	5.51	4.73
β-Citral	22.28	-	0.14	24.20	0.31
Geraniol	22.78	-	-	0.88	-
Lavandulol	23.13	-	-	2.24	-
α-Citral	23.77	-	0.19	28.88	0.46
Bornyl acetate	24.29	-	0.24	-	-
Anethole	24.33	0.73	-	-	-
Hydroxycineyl acetate	26.14	-	0.11	-	-
Eugenol	26.80	48.64	-	0.71	-
Cyclosativene	27.12	-	-	0.30	-
α-Copaene	27.38	1.32	-	-	-
Geranyl acetate	27.49	-	-	0.68	-
β-Elemene	27.80	-	0.43	1.22	0.44
Methyleugenol	28.18	-	1.44	-	-
(Z)-β-Caryophyllene	28.74	-	-	8.52	-
Caryophyllene	28.92	43.09	0.14	-	1.77
α-Bergamotene	29.21	-	1.74	3.88	0.97
Alloaromadendrene	29.57	-	-	0.13	-
(Z)-β-Farnesene	29.87	-	-	-	1.63
Humulene (α-Caryophyllene)	29.91	3.38	0.43	-	-
β-Panasinsene	29.96	-	-	0.39	-
Bicyclosesquiphellandrene	30.08	-	0.21	-	-
D-Germacrene	30.68	-	0.84	3.69	-
α-Curcumene	30.74	-	-	-	7.75
4,11-selinadiene	30.76	-	-	1.62	-
δ-Selinene	30.88	-	-	1.07	-
Eremophilene	31.03	-	-	0.33	-
γ-Elemene	31.13	-	0.52	-	-
Zingiberene	31.15	-	-	3.57	-
α-Zingiberene	31.24	-	-	-	35.22
α-Bulnesene	31.32	-	0.15	0.59	-
β-Bisabolene	31.57	-	-	0.63	4.64
α-Amorphene	31.66	-	0.43	1.43	-
Acetyl eugenol	31.76	2.08	-	-	-
δ-Cadinene	31.83	0.24	-	0.46	-
β-Sesquiphellandrene	32.08	-	0.09	0.78	20.18
α-Gurjunene	32.24	-	-	0.43	-
Elixene	33.01	-	-	-	0.42
Selina-6-en-4-ol	34.89	-	-	6.85	-
β-Maaliene	36.03	-	-	0.51	-
Ar-Turmerone	36.06	-	-	-	3.68
α-Turmerone	36.22	-	-	-	6.93
Germacrone	36.82	-	-	-	0.32
β-Turmerone	37.10	-	-	-	2.56
Total (%)		99.48	99.64	99.71	99.65

RESULTS AND DISCUSSION

Volatile Organic Compounds (VOCs) Analysis

Of the seven VOCs identified in clove powder, the major compounds were eugenol (48.64%) and caryophyllene (43.09 %) while 20 VOCs in holy basil powder with major compound as estragole (87.13%); 27 VOCs in lemongrass with α-Citral (28.88%), β-Citral (24.20%), (Z)-β-Caryophyllene (8.52%), selina-6-en-4-ol (6.85%) and estragole (5.51%) as major ones and 18 VOCs in turmeric powder with α-Zingiberene (35.22%), β-Sesquiphellandrene (20.18%), α-Curcumene (7.75%), eucalyptol (7.19%) and α-Turmerone (6.93%) as major compounds (Table 1).

Insect Biology Test

Clove (1 and 3 g dose) powder resulted in shorter adult longevity of both sexes compared to other treatments (Table 2) besides reduced fecundity, number of F_1 progeny, bean damage and weight loss of bean due to clove (1 and 3 g dose) and holy basil (3 g dose) (Table 3 and 4). No adults (F_1 progeny) emerged in these treatments leading to healthy adzuki bean without hole. Consumption reduction ranged 83-89% in clove and holy basil highly reduced the consumption in the beans.

The major volatile compounds that detected was a possible reason that plant powder affect the biological parameters of this species. In study on the toxicity of clove powder to red imported fire ants showed 100% mortality within 6 h (Kafle and Shih, 2013). Aslam *et al*. (2002) also confirmed that clove powder admixed with chickpea exhibited the shortest time to kill 100% of *C. chinensis* and significantly reducing the number of adult emergence and weight loss. Kafle and Shih (2013) confirmed the volatile compounds (eugenol, β-caryophyllene and eugenol acetate) has high toxicity on imported fire ants. In addition, eugenol has strong contact toxicity, reduce respiration rate of treated insects by fumigant and behavior modification on walking activity of granary weevil (Plata-Rueda *et al*., 2018). Other literature stated that each of major compounds that

Table 2: Efficacy of plant powders on adult longevity of *Callosobruchus maculatus*.

Treatment	Dose (g)	Adult longevity (days)*		
		Both sexes	Male	Female
Control	-	11.09± 0.12de	11.56± 0.23d	10.62± 0.39c
Clove	1.00	2.40± 0.02a	2.22± 0.03a	2.58± 0.05a
	3.00	2.28± 0.02a	2.20± 0.03a	2.36± 0.07a
Holy basil	1.00	9.62± 0.29c	8.84± 0.44b	10.40± 0.15c
	3.00	4.18± 0.36b	3.41± 0.28a	4.94± 0.45b
Lemongrass	1.00	10.52± 0.24cd	10.62± 0.35cd	10.41± 0.32c
	3.00	10.38± 0.16cd	9.17± 0.16b	11.59± 0.27cd
Turmeric	1.00	11.56± 0.32e	10.84± 0.45cd	12.27± 0.34d
	3.00	10.42± 0.11cd	10.16± 0.25bc	10.68± 0.16c
F-value		309.47	177.44	198.49
df		45	45	45
P		< 0.001	< 0.001	< 0.001

* Mean ± SE followed by the same lower case letters within the column do not differ significantly (Tukey's HSD test; *P*< 0.05).

Table 3: Effficacy of plant powders on fecundity and F_1 progeny of *Callosobruchus maculatus*.

Treatment	Dose (g)	Fecundity (eggs/female)*	Fecundity reduction (%)	F_1 progeny (adults/female)*	F_1 progeny reduction (%)
Control	-	77.67 ± 0.67d	-	13.08 ± 1.68c	-
Clove	1.00	14.34 ± 0.55a	81.53	0.00 ± 0.00a	100.00
	3.00	9.93 ± 0.63a	87.21	0.00 ± 0.00a	100.00
Holy basil	1.00	30.31 ± 3.54b	60.97	4.50 ± 0.78b	65.59
	3.00	10.02 ± 0.48a	87.10	0.00 ± 0.00a	100.00
Lemongrass	1.00	73.04 ± 1.35d	5.95	15.97 ± 0.62c	-22.09
	3.00	45.68 ± 1.07c	41.19	4.54 ± 0.34b	65.25
Turmeric	1.00	48.50 ± 1.56c	37.55	15.74 ± 0.87c	-20.39
	3.00	36.67 ± 0.62b	52.79	13.90 ± 1.10c	-6.29
F-value		293.53		75.32	
df		45		45	
P		< 0.001		< 0.001	

* Mean ± SE followed by the same lower case letters within the column do not differ significantly (Tukey's HSD test; *P*< 0.05).

(-) minus, reduction did not happen instead, F_1 progeny was higher than control.

Table 4: Efficacy of plant powders on bean damage and weight loss of bean of *Callosobruchus maculatus*.

Treatment	Dose (g)	Bean damage (%)*	Weight loss (%)*	Consumption reduction (%)
Control	-	97.01± 0.74c	24.60± 0.72d	-
Clove	1.00	0.00± 0.00a	4.05± 0.05a	83.53
	3.00	0.00± 0.00a	3.85± 0.01a	84.36
Holy basil	1.00	39.50± 4.83b	6.57± 0.66b	73.28
	3.00	0.00± 0.00a	2.70± 0.07a	89.04
Lemongrass	1.00	90.01± 0.92c	17.39± 0.52c	29.30
	3.00	35.60± 2.07b	6.38± 0.24b	74.07
Turmeric	1.00	90.49± 1.17c	18.44± 0.61c	25.01
	3.00	91.94± 1.26c	17.08± 0.39c	30.57
F-value		526.92	395.27	
df		45	45	
P		< 0.001	< 0.001	

*Mean ± SE followed by the same lower case letters within the column do not differ significantly (Tukey's HSD test; $P< 0.05$).

contained in holy basil, lemongrass and turmeric powders were responsible for inhibition of oviposition, F_1 progeny and mortality of many stored product pests (Bekele *et al*., 1996; Kim and Lee, 2014; Bossou *et al*., 2015).

Short adult longevity on clove, holy basil and lemongrass indicates that the insecticidal mode of action of the plant powder might be attributed to fumigant toxicity that penetrated the insect's body through the respiratory system (spiracles and tracheas) (Adedire *et al*., 2011; Hamza *et al*., 2016). The inability of adults to mate and oviposit their eggs within surviving adult period that lead to the reduction of fecundity and F_1 progeny numbers. Adedire *et al*. (2011) mention the botanical activities caused the disruption of locomotory insect that affected mating and ovipositing activities. Deterrent effects on F_1 progeny that emerged into adults affected the postembryonic development that performed in less or even completely no adult emergence. This might have been caused by the VOCs from plant powders which poses the ability to penetrate the eggs chorion of insect through a minute space (micropyle) that is present on the posterior pole of eggs and results in the death of embryos and/or neonate larvae (Ileke *et al*., 2014; Kedia *et al*., 2015; Zafar *et al*., 2018). At the end of the experiment, little or no bean damaged and low weight loss of bean at certain plant powders were observed due to lack of insect survival stages such as insect infestation at the beginning of the experiment, eggs and neonate larvae against VOCs.

CONCLUSION

Holy basil, turmeric and lemongrass were effective against *C. maculatus* at 3 g dose. Among all treatments, though clove powder among the four treatments at 3 g and 1 g per container were most toxic by affecting the biological parameters of test insect. Four plant powders used in this study are good candidates to use in small scale storage facility to control the one of common species insect pests that attacked beans. Even though only two plant powders (clove and holy basil) at 3 g dose inhibited population growth, while other two plant powders (lemongrass and turmeric) only at 3 g dose, could inhibit the population growth. Of all these results, the synergistic action of VOCs released from each plant powder has contributed to the insecticidal properties against *C. maculatus*. These plant powders could be a good candidate to control stored-product pests in common traditional method in rural areas or small scale storage facility beside their role as grain protectants by contact toxicity.

ACKNOWLEDGEMENT

Authors would like to thank Double Degree Program between University of Brawijaya and National Pingtung University of Science and Technology. Also to Prof. Jeng-Tze Yang for suggestions in this research and Ito Fernando, M.Sc. for laboratory assistance.

REFERENCES

Adedire, C.O. and Akinneye, J.O. (2004). Biological activity of tree marigold, *Tithonia diversifolia*, on cowpea seed bruchid, *Callosobruchus maculatus* (Coleoptera: Bruchidae). Annals of Applied Biology. 144(2): 185-189.

Adedire, C.O., Obembe, O.O., Akinkurolele, R.O. and Oduleye, O. (2011). Response of *Callosobruchus maculatus* (Coleoptera: Chysomelidae: Bruchidae) to extracts of cashew kernels. Journal of Plant Diseases and Protection. 118(2): 75-79.

Aslam, M., Khan, K.A. and Bajwa, M.Z.H. (2002). Potency of some spices against *Callsobruchus chinensis* Linnaeus. Journal of Biological Science. 2(7): 449-452.

Astuti, L.P., Mario, M.B. and Widjayanti, T. (2018). Preference, growth and development of *Oryzaephilus surinamensis* (L.) (Coleoptera: Silvanidae) on red, white and black rice in whole grain and flour form. Journal of Entomological Research. 42(4): 461-468.

Astuti, L.P., Maula, R., Rizali, A. and Mario, M.B. (2019). Effect of types inert dust to *Rhyzopertha dominica* (Fabricius) (Coleoptera: Bostrichidae) in stored rice seeds. The Journal of Experimental Life Science. 9(3): 164-169.

Athanassiou, C.G., Rani, P.U. and Kavallieratos, N.G. (2014). The Use of Plant Extracts for Stored Product Protection. In: Advances in plant biopesticides. [Singh, D. (Ed.)], Springer. New Delhi. p 131-147.

Beck, C.W. and Blumer, L.S. (2014). A handbook on bean beetles, *Callosobruchus maculatus*. National Science Foundation, Emory University, or Morehouse College. Atlanta.

Bekele, A.J., Obeng-ofori, D. and Hassanali, A. (1996). Evaluation of *Ocimum suave* (Willd) as a source of repellents, toxicants and protectants in storage against three stored product insect pests. International Journal of Pest Management. 42(2): 139-142.

Boeke, S.J., Baumgart, I.R., van Loon, J.J.A. van Huis, A., Dicke, M. and Kossou, D.K. (2004). Toxicity and repellence of African plants traditionally used for the protection of stored cowpea against *Callosobruchus maculatus*. Journal of Stored Products Research. 40(4): 423-438.

Bossou, A.D., Ahoussi, E., Ruysbergh, E., Adams, A., G. Smagghe, De Kimpe, N., Avlessi, F., Sohounhloe, D.C.K. and Mangelinckx, S. (2015). Characterization of volatile compounds from three *Cymbopogon* species and *Eucalyptus citriodora* from Benin and their insecticidal activities against *Tribolium castaneum*. Industrial Crops and Products. 76: 306-317.

Cozzolino, R., Pace, B., Cefola, M., Martignetti, A., Stocchero, M., Fratianni, F., Nazzaro, F. and De Giulio, B. (2016). Assessment of volatile profile as potential marker of chilling injury of basil leaves during postharvest storage. Food Chemistry. 213: 361-368.

Gusmão, N.M.S., de Oliveira, J.V., Navarro, D.M. do A.F., Dutra, K.A., da Silva, W.A. and Wanderley, M.J.A. (2013). Contact and fumigant toxicity and repellency of *Eucalyptus citriodora* Hook., *Eucalyptus staigeriana* F., *Cymbopogon winterianus* Jowitt and *Foeniculum vulgare* Mill. essential oils in the management of *Callosobruchus maculatus* (FABR.) (Coleoptera: Chrysomelidae, Bruchinae). Journal of Stored Products Research. 54: 41-47.

Hagstrum, D.W., Klejdysz, T., Subramanyam, B. and Nawrot, J. (2013). Atlas of stored-product insects and mites. AACC International. St. Paul. 589 pp.

Hamza, A.F., El-Orabi, M.N., Gharieb, O.H., El-Saeady, A.A. and Hussein, A.E. (2016). Response of *Sitophilus granarius* L. to fumigant toxicity of some plant volatile oils. Journal of Radiation Research and Applied Sciences. 9(1): 8-14.

Heinrichs, E.A., Medrano, E.G. and Rapusas, H.R. (1985). Genetic evaluation for insectresistance in rice. International Rice ResearchInstitute. Los Banos. 354 pp.

Hernandes-Lambraño, R., Pajaro-Castro, N., Caballero-Gallardo, K., Stashenko, E. and Olivero-Verbel, J. (2015). Essential oils from plants of the genus *Cymbopogon* as natural insecticides to control stored product pests. Journal of Stored Products Research. 62: 81-83.

Ileke, K.D., Oni, M.O. and Adelegan, O.A. (2014). Laboratory assessment of some plants latex as biopesticide against cowpea bruchid, *Callosobruchus maculatus* (Fab.) [Coleoptera: Chrysomelidae]. Journal of Agricultural Science. 6(1): 123-128.

Kafle, L. and Shih, C.J. (2013). Toxicity and repellency of compounds from clove (*Syzygium aromaticum*) to red imported fire ants *Solenopsis invicta* (Hymenoptera: Formicidae). Journal of Economic Entomology. 106(1): 131-135.

Kedia, A., Prakash, B., Mishra, P.K., Dwivedy, A.K. and Dubey, N.K. (2015). Biological activities of *Cuminum cyminum* seed oil and its major components against *Callosobruchus chinensis* and *Sitophilus oryzae*. Journal of Asia-Pasific Entomology. 18(3): 383-388.

Kim, S.-I. and Lee, D.-W. (2014). Toxicity of basil and orange essential oils and their components against two coleopteran stored products insect pests. Journal of Asia-Pasific Entomology. 17: 13-17.

Prakash, A. and Rao, J. (1997). Botanical pesticides in agriculture. Lewis Publishers. Boca Raton. 476 pp.

Prevett, P.F. (1961). Field infestation of cowpea (*Vigna unguiculata*) pods by beetle of families Bruchidae and Curculionidae in Northern Nigerian. Bulletin of Entomological Research. 52(4): 635-645.

Rees, D. (2004). Insects of stored products. CSIRO Publishing. Collingwood. 181 pp.

Regmi, H., Kafle, L., Gc, Y.D. and Shih, C.J. (2012). Efficacy of natural products against *Callosobruchus chinensis* (Coleoptera: Bruchidae) in Nepal. Journal of Economic Entomology. 105(3): 1095-1099.

Righi-Assia, A.F., Khelil, M.A., Medjdoub-Bensaad, F. and Righi, K. (2010). Efficacy of oils and powders of some medicinal plants in biological control of the pea weevil (*Callosobruchus chinensis* L.). African Journal of Agricultural Research. 5(12): 1474-1481.

Singh, S. (2017). Natural plant products- As protectant during grain storage: A review. Journal of Entomology and Zoology Studies. 5(3): 1873-1885.

Tapondjou, L.A., Adler, C., Bouda, H. and Fontem, D.A. (2002). Efficacy of powder and essential oil from *Chenopodium ambrosioides* leaves as post-harvest grain protectants against six-stored product beetles. Journal of Stored Products Research. 38(4): 395-402.

Weaver, D.K., Dunkel, F.V., Potter, R.C. and Ntezurubanza, L. (1994). Contact and fumigant efficacy of powdered and intact *Ocimum canum* Sims (Lamiales: Lamiaceae) against *Zabrotes subfasciatus* (Boheman) adults (Coleoptera: Bruchidae). Journal of Stored Products Research. 30(3): 243-252.

Zafar, U., Ur-Rashid, M.M. and Shah, M. (2018). Entomotoxicity of plant powders against pulse beetle (*Callosobruchus chinensis*) on stored mung bean (*Vigna radiata*). Journal of Entomology and Zoology Studies. 6(1): 1637-1641.