



Bioefficacy of some ground plant powders against the seed beetle, *Callosobruchus maculatus* (Coleoptera: Chrysomelidae) in storage

Oabile L Tlale, Bamphitlhi Tiroesele, Goitseone Malambane, Mitch M Legwaila

Faculty of Agriculture, Department of Crop and Soil Sciences, Botswana University of Agriculture and Natural Resources, Gaborone, Botswana

Abstract

The seed beetle, *Callosobruchus maculatus* (Coleoptera: Chrysomelidae) is a cosmopolitan field and storage pest of stored grain in several parts of Africa. Its control in storage is mainly founded on the application of synthetic grain protectants. The use of synthetic insecticides to control stored produce pests has raised serious environmental and human health concerns. A laboratory study was undertaken to evaluate the effect of peppermint (*Mentha piperita* L.), garlic (*Allium sativum* L), fever tea (*Lippia javanica*) and marigold (*Tagetes minuta*) ground plant powders on oviposition, adult emergence and survival of *Callosobruchus maculatus* on stored beans (*Phaseolus vulgaris*) at the Botswana University of Agriculture and Natural Resources (BUAN). The experiment was laid out in a Complete Randomized Design with three replicates. Previous studies on the effects of bioactive plants on behavioral and biological makeup of pests were taken into consideration. The study revealed differences in the mean and percentage repellency, mortality and adult emergence of *C. maculatus* on the treated beans. Garlic was found to be the most oviposition deterrent followed by fever tea and marigold. Peppermint was the most effective at inhibiting adult emergence followed by fever tea, garlic and marigold. Marigold and peppermint ground powders were the most toxic to *C. maculatus* beetles. This study found that garlic, peppermint, fever tea and marigold can offer effective control of *C. maculatus*, and prevent serious damage to stored beans. Extended durations of exposure and constant re-application may help increase the efficacy of plant powders.

Keywords: *Mentha piperita*, *Allium sativum*, *Lippia javanica*, *Tagetes minuta*, bio-efficacy, *Callosobruchus maculatus*, *Phaseolus vulgaris*

Introduction

Common bean, *Phaseolus vulgaris* L. (Fabaceae) is the most important legume crop in the world, and among the most consumed pulse crops in Botswana (Mangole *et al.*, 2023; Porch, 2013) [30]. It is a primary source of nutrition for millions of people because of its high protein and energy content (Astaraki *et al.*, 2025; Mashiqa *et al.*, 2019) [4, 25]. Beans are an excellent source of important minerals, vitamins and dietary fibre (Mojica & de Mejía, 2015; Maiti & Singh, 2007) [22, 26] for lower socio-economic households in most developing countries. However, its production has been on the decline in most developing countries due to drought, heat stress, low yielding grains, high susceptibility to diseases, unavailability of locally bred improved cultivars and damages by insect pests (Katungi *et al.*, 2017) [16]. The attack by pests during storage is one of the most common constraints, which cause significant losses (Mutari *et al.*, 2021; Estelle *et al.*, 2018) [9, 27]. Insects cause quantitative losses through consumption of the grain or qualitative losses through contamination from excrements and molts (Silva & Costa, 2016) [35]. Major storage pests of the common bean include the rusty grain beetle (*Cryptolestes ferrugineus* Steph.), the Saw-toothed grain beetle (*O. surinamensis* Linn.), the cowpea weevil (*Callosobruchus maculatus* F.), the Mexican bean weevil (*Zabrotes subfasciatus* B.), and the Common bean weevil (*Acanthoscelides obtectus* S.) (Beneke *et al.*, 2010) [5]. *C. maculatus* is the primary seed beetle pest in Botswana that causes heavy quantitative and qualitative losses to beans in storage. Severe infestations of *C. maculatus* can result in losses of up to 100%, rendering

beans unfit for human consumption and for sowing (Allotey *et al.*, 2011) [2]. In Botswana, the control of *C. maculatus* relies on the use of synthetic grain protectants which are viewed to be effective, quick and secure. However, synthetic grain protectants have several disadvantages which include; undesirable effect on produce and the environment, toxicity to humans and animals, presence of residues on the commodity, and resistance development in pests (Rajkumar *et al.*, 2020; Singh, 2017) [31, 36]. These negative outcomes have necessitated the search for more eco-friendly control methods such as the use of ground plant powders as grain protectants (Sarwar, 2013) [34]. Although ground plant powders have been used as grain protectants by traditional African communities for decades (Kiri *et al.*, 2024; Yadav *et al.*, 2022) [18, 39], few studies have been undertaken to determine the efficacy of plant-based grain protectants in Botswana. It is essential to identify effective ground plant powders that can be recommended for use by farmers as components of an integrated pest management strategy against *C. maculatus* in storage. In the current study, selected ground plant powders were evaluated for their effectiveness against *C. maculatus* on stored common bean (*Phaseolus vulgaris*) with a view to generate bio-efficacy data for use with other integrated storage pest management practices.

Materials and Methods

This experiment was carried out in the Entomology laboratory, Department of Crop and Soil Sciences at Botswana University of Agriculture and Natural Resources (BUAN) (24°34' 25"S, 25°95'0"E; altitude: 998 m).

C. Maculatus culturing

C. maculatus were reared in the Entomology laboratory at 25°C - 32°C, 30 – 50% RH during summer, following Kestenholz *et al.* (2007) [17]. The beetles that were used in the experiment were collected from the laboratory stock culture on Tswana cowpeas. 1kg of black-eyed cowpeas was used as a medium for culturing the *C. maculatus*. The black-eyed cowpeas were then disinfected by keeping them in the refrigerator at temperature of 0 °C for seven days. The 1kg of the black-eyed cowpeas was then placed in 1litre plastic jar and hundred adults of mixed female and male (50:50 proportion) of *C. maculatus* collected from the stock culture was placed on the beans. The glass jar was covered with a muslin cloth for the seed beetles not to escape and also for aeration. The adult *C. maculatus* were left for a week under laboratory conditions to mate and lay eggs. As soon as the oviposition was observed, the adult *C. maculatus* were removed from the glass jar using a 2 mm sieve. The eggs were then left in the glass jar to develop until emergence of new adult beetles. A day after emergence, the adults was sexed by observing the shape of abdomen and markings on elytra. Males have a rounded abdomen with a more consistently patterned elytra, and a consistently pale abdominal tip, while females have a more oval-shaped abdomen with distinct “eye” marks on the elytra and two dark stripes on the tip of the abdomen (Arnold *et al.*, 2012) [3]. The emerged adults were then used for the experiments.

Insect Identification

C. maculatus were identified under the dissecting microscope using insect identification keys, and then counted separately using a digital hand counter before use in the bioassay.

Preparation of plant powders

Garlic and peppermint were bought from the local markets, marigold was collected from a local garden and fever tea was collected from a local farm. Plant powders were obtained by thoroughly rinsing the plant vegetative part (clove, flowers or leaves) in distilled water thrice to remove dirt, and then dried at room temperature in the Entomology laboratory for 7 days. The plant materials were then oven dried at 60 ± 1°C for 48 hours and each were preserved in their own clear airtight bottle which was then placed in a refrigerator at 4 ± 2°C.

Experimental set up

Bean seeds were used to test the efficacy of the plant powders in controlling *C. maculatus*. The experiment was laid out in a Complete Randomized Design with three

replicates. 50 g of seeds for was placed into individual rearing jars, and 4 g of each plant powder was then introduced into rearing jars of the seeds. The glass jars were shaken for three minutes to ensure even distribution of the plant powders. All the feeding jars were artificially infested with ten pairs of *C. maculatus* adults of 1 to 2 days old which were collected from seed beetle culturing jar. The feeding jars were covered with a muslin cloth so that beetles would not escape and were left in the Entomology laboratory to mate. For the control treatment, no plant powder was added.

The adults were allowed to oviposit on the beans for ten days before they were removed and discarded. The experiment was terminated after 50 days. Oviposited eggs were counted, recorded, and kept until adult emergence. Parameters that were recorded for the purpose of assessing the effectiveness of treatments were; the number of eggs oviposited, number of adults emerged and the number of dead beetles per treatment.

Data Collection

Oviposition and number of eggs hatched

A magnifying glass and dissecting microscope were used to count the eggs sticking on the surface of the beans. The number of larvae emerging from eggs were also counted.

Adult emergence and mortality

The adults that emerged from the seeds were counted daily. Both dead and living emerged adults were recorded. After recording the beetles, they were then discarded. This continued daily for the duration of the experiment. The beetles observed and recorded on the bean samples were further differentiated into two categories, that is, those found dead and those found alive. Data were expressed as percentages.

Data Analysis

The Data collected on various parameters from the experiments were entered into Microsoft excel and statistical analysis was performed using the SAS 9.4 software package. Data was subjected to analysis of variance (ANOVA) and the means were separated using the Least Significant Difference (LSD) at P < 0.05.

Results

Table 1: Mean number of *C. maculatus* eggs oviposited, adult emergence (%), and adult mortality on beans treated with different plant powders.

Mean ± SE					
		Number of Eggs oviposited	Bruchid Adult emergence (%)	Adult Mortality (%)	Seed weight loss (%)
Treatments	Garlic	7.83 ^d ± 0.63	0.87 ^{bc} ± 0.34	0.00 ^b ± 0.00	0.00 ^b ± 0.00
	Peppermint	92.67 ^a ± 1.96	0.26 ^c ± 0.003	0.25 ^{ab} ± 0.001	0.00 ^b ± 0.00
	Fever tea	10.83 ^{cd} ± 0.66	0.73 ^{bc} ± 0.56	0.00 ^b ± 0.00	0.00 ^b ± 0.00
	Marigold	12.83 ^c ± 0.82	2.96 ^b ± 0.65	1.67 ^{ab} ± 1.29	0.67 ^{ab} ± 0.13
	Control	50.67 ^b ± 1.97	8.97 ^a ± 0.30	3.23 ^a ± 0.42	1.33 ^a ± 0.40
	F	1419.00	41.54	3.25	12.80
	P	< 0.0001	< 0.0001	0.0213	< 0.0001
	LSD	2.784	1.61	2.24	0.476

Means within the same column followed by the same small letter do not differ significantly, (P<0.05)

The results of the study in table 1 show that the treatments were significantly different in the average number of eggs laid ($F_{(4, 40)} = 1419$, $P < 0.0001$). The average number of eggs laid for the treatments ranged between 7.83 to 92.67%. Samples treated with garlic were observed to have the lowest mean number of eggs, followed by fever tea with a mean of $10.83 \pm 0.66\%$, marigold with a mean of $12.83 \pm 0.82\%$, control with mean of $50.67 \pm 1.97\%$, and then peppermint having significantly the highest mean with $92.67 \pm 1.96\%$. These findings showed that fever tea and marigold treatments were not significantly different in eggs laid. Garlic and fever tea did not differ in the number of eggs laid, as they recorded the lowest number of eggs oviposited.

The mean number of adults emerged for treatments garlic, fever tea and marigold were significantly different ($F_{(4, 40)} = 41.54$, $P < 0.0001$) from the control treatment. Garlic and Fever tea did not significantly differ from peppermint in percentage adult emergence. The average adult emergence percentage ranged from 0.26% to 8.97%. Peppermint caused the lowest mean percentage adult emergence ($0.26 \pm 0.003\%$) followed by fever tea ($0.73 \pm 0.56\%$), garlic ($0.87 \pm 0.34\%$), and then marigold with $2.96 \pm 0.65\%$.

The study also investigated the comparisons of treatment on percentage adult mortality. The percentage adult mortalities for peppermint and marigold and control significantly different ($F_{(4, 40)} = 3.25$; $P < 0.05$). Marigold was the most toxic to *C. maculatus* adults causing mortality of $1.67 \pm 1.29\%$, followed by peppermint with a mortality average of $0.25 \pm 0.001\%$. Garlic and fever tea powders did not show any acute toxicity to *C. maculatus* adults over the entire duration of the bioassay.

It has been revealed from this study that treatments significantly differed in percentage seed weight loss ($F_{(4, 40)} = 12.80$, $P < 0.0001$). Treatments with garlic, peppermint and fever tea did show any percentage seed weight loss (0.00 ± 0.00). These three treatments did not differ significantly from one another. In addition, they were significantly different from marigold which showed a higher level of seed weight loss (0.67 ± 0.13). The control treatment recorded a seed weight loss percentage of 1.33 ± 0.40 .

Discussion

The current study revealed that the tested plant powders were effective against *C. maculatus* when applied to beans in storage. The results obtained in this present study indicate garlic powder possesses oviposition deterrent properties against *C. maculatus* followed by Fever tea and then marigold powders. These results are consistent with Ishag *et al.* (2018) [15] who found that garlic extracts inhibit oviposition by damaging the insects' reproductive system or altering their behavior by obscuring detection of hosts. Peixoto *et al.* (2015) [29] reported that fever tea possesses strong insect repellent and oviposition deterrent properties towards several storage pests. Cosmas *et al.* (2012) [6] and Weaver *et al.* (1994) [38] documented anti-oviposition effects of marigold on *C. maculatus* adults and suggested that marigold might have reproduction sterility properties on *C. maculatus* adults.

Although *C. maculatus* adults in this study oviposited significantly higher amounts of eggs on peppermint treated seeds, peppermint achieved the lowest adult emergence percentage compared to all other treatments. This result

suggests that peppermint possesses strong ovicidal and/or larvicidal properties against *C. maculatus*. This is a particularly welcome finding because the number of larvae on the food commodity, which are the most damaging life stage, would be reduced. Reproduction or oviposition from emerging adults would also be reduced. The findings of the present study agree with a study by Loolai (2017) [21], in which peppermint was very effective in killing the larvae of black carpet beetle and cigarette beetle. Kumari *et al.* (2014) [19] also reported high ovicidal properties of peppermint against the pulse beetle. The strong ovicidal and larvicidal properties of peppermint powder are attributable to the presence of the chemical compound menthone which has been found to possess strong contact toxicity against Pear Psylla nymph and larvae (Li and Tian, 2020) [21]. Fever tea had the second lowest adult emergence followed by garlic, and marigold suggesting the presence of ovicidal and/or larvicidal properties. These findings are in agreement to those of Ho *et al.* (1996) [13] who reported that garlic caused mortality of *T. castaneum* eggs and larvae, with eggs being more susceptible than larvae. Ahmed *et al.* (2019) [1] and Ishag *et al.* (2018) [15] observed that garlic reduced hatching and revealed ovicidal effects on several insect eggs. Garlic extracts have been shown to cause egg shells of storage pests to harden making it hard to hatch (Gurusubramanian & Krishna, 1996) [12]. Elango *et al.* (2009) [8] reported that marigold possessed strong ovicidal activity against *Anopheles subpictus*. Marigold has been reported to have an anti-feedant effect on the maize weevils (*Sitophilus zeamais*) affecting maize in storage (Cosmas *et al.*, 2012) [6]. The larval mortality achieved with fever tea treatment might be due to *C. maculatus* larvae being unable to feed because of antifeedant, repellent and toxic effects of fever tea powder. This observation is consistent with findings of Manenzhe *et al.* (2004) [23], who reported that fever tea possessed repellent, toxic, and antifeedant effects on *B. brassicae* and *T. evansi*. Id *et al.* (2020) [14] recorded a significant mortality on both *L. hesperus* and *B. tabaci* adults following treatments marigold. Marigold has also been documented to be very effective in killing *Sitophilus zeamais* weevils (Cosmas *et al.*, 2012) [6]. Weaver *et al.* (1994) [38] reported marigold plant to have strong insecticidal compounds in its flowers, roots and the leaves. Peppermint has been found to be toxic to *Tribolium castaneum*, *Rhizopertha dominica* and *Drosophila suzukii* (Renkema *et al.*, 2016; Ukeh & Umoetok, 2011) [33, 37]. Reda *et al.* (2010) [32] reported the presence of monoterpene compounds in peppermint which are highly toxic when they penetrate insect cuticle or the respiratory system. Peppermint powder has been reported to block the spiracles of insects, thus impairing respiration leading to death (Getahun & Wondimu, 2020) [11]. Reda *et al.* (2010) [32] also reported that peppermint causes suffocation and inhibition of various biosynthesis processes of the insects. Garlic and Fever tea treatment did not record any mortality of beetles; however, the beetles were observed to be less active. This result might be due to the less duration of exposure to the plant powders. Getahun & Wondimu (2020) [11] and Gereziher & Gofitshu (2016) [10] in similar studies observed that the efficacy of the plant powders increased with the duration of exposure. The beetle mortality in the control treatment might be due to disturbances or genetic weaknesses (Cosmas *et al.*, 2018).

The weight of the seeds was used to calculate seed weight loss percentage. The most effective ground plant powders

were garlic, mint and fever tea, which all recorded a zero percent reduction in seed weight due to *C. maculatus*. This suggests that seed treatments with garlic, peppermint and fever tea are adequate to protect the bean commodity from damage by *C. maculatus*. These results are welcome since farmers' objective for applying control measures to stored grain is to ensure adequate protection of the food commodity in storage. Marigold was the least effective as they recorded $0.67ab \pm 0.13$ reduction in seed weight. Although marigold recorded seed weight loss, the losses were very low to cause a reduction in profits. The results from the present study indicate that garlic, peppermint and fever tea treatment have a repellent, insecticidal, anti-oviposition properties against *C. maculatus*. These results agree with different studies which indicated garlic, peppermint and fever tea to have a protective property against some insect pests (Ahmed *et al.*, 2019; Muturi *et al.*, 2018; Peixoto *et al.*, 2015) [1, 28, 29].

Conclusion

It can be concluded from this study that garlic, peppermint, fever tea and marigold can offer effective control of *C. maculatus* on beans, and prevent serious damage to stored beans provided long exposure periods are permitted. Plant powders have lowered risk to the environment or to human and animal health, are biodegradable, and provide residue free food commodity, therefore they are suitable for use as components of integrated *C. maculatus* management program. The findings of this study should motivate extensive research and use of garlic, peppermint, fever tea and marigold for integrated *C. maculatus* management, and replace the use of synthetic grain protectants. Resource poor farmers should be encouraged to use plant powders because they are readily available. Since this study was conducted in the laboratory, further research is needed under storage conditions to validate the results obtained in the present study.

References

- Ahmed HM, Abdelbagi AO, Elaziz A, Ahmed S, Mohammed A, Hammad A. *et al.* Effects of Garlic Oils on the Fecundity Hatchability of *Callosobruchus maculatus* L. *Coleoptera*: Bruchidae. *Universal Journal of Agricultural Research*,2019;7(1):63–68.
- Allotey J, Seago M, Makate N, Mpho M. Development of *Callosobruchus maculatus* F. On some pulses in Botswana. *Journal of Applied Zoology Research*,2011;22(2):134-142.
- Arnold SEJ, Stevenson PC, Belmain SR. Odour-Mediated Orientation of Beetles Is Influenced by Age, Sex Morph. *PLoS ONE*,2012;7(11):49071. <https://doi.org/10.1371/journal.pone.0049071>
- Astaraki S, Atighi MR, Shams-bakhsh M. High-throughput sequencing revealed the symptomatic common bean *Phaseolus vulgaris* L. virome in Iran. *Sci Rep*,2025;15:1621.
- Beneke CJ. The expression inheritance of resistance to *Acanthoscelides obtectus* Bruchidae in South African dry bean cultivars. MSc Thesis. Department of Plant Sciences: Plant Breeding at the University of the Free State, 2010.
- Cosmas P, Christopher G, Charles K, Friday K, Ronald M, Belta ZM. *et al.* *Tagetes Minuta* Formulation Effect *Sitophilus Zeamais* Weevils Control in Stored Maize

Grain. *International International Journal of Plant Research*,2012;2(3):65-68.

- Cosmas P, Chikuvire TJ, Kamota A, Mandumbu R, Mutsengi K, Chiripanura B. Use of Botanical Pesticides in Controlling *Sitophilus Zeamais* Maize Weevil on Stored *Zea Mays* Maize Grain. *Modern Concepts Development in Agronomy*, 2018, 1(4). MCDA.000517. DOI: 10.31031/MCDA.2018.01.000517
- Elango G, Abdul Rahuman A, Bagavan A, Kamaraj C, Abdul Zahir A, Venkatesan C. *et al.* Laboratory study on larvicidal activity of indigenous plant extracts against *Anopheles subpictus* *Culex tritaeniorhynchus*. *Parasitol Research*,2009;104:1381–1388.
- Estelle LYL, Joel AA, Azize O, Joelle T, Alexandre D. Farmer's traditional practices management methods of stored common bean *Phaseolus vulgaris* L. insect pests in the central region of Benin Republic. *Journal of Horticulture Forestry*,2018;10(8):113-126.
- Gerezihier K, Goftishu MW. Pest Management Journal of Ethiopia Plant Protection Society of Ethiopia Pest Management Journal of Ethiopia Plant Protection Society of Ethiopia. *Pest Management Journal of Ethiopia*,2016;18(19):1–21.
- Getahun D, Wondimu M. Screening of Some Botanical Insecticides against Maize Weevil, *Sitophilus Zeamais* Motschlsky *Coleoptera*. *Curculionidae*, on Maize. *Ethiopian Journal of Science Sustainable Development*, 2020, 7(1). Retrieved from <https://doi.org/10.20372/ejssdstu:v7.i1.2020.149>.
- Gurusubramanian G, Krishna SS. The effects of exposing eggs of four cotton insect pests to volatiles of *Allium sativum* Liliaceae. *Bulletin of Entomological Research*,1996;86:29–31.
- Ho SH, Koh L, Ma Y, Huang Y, Sim KY. The oil of garlic, *Azzium sativum* L. *Amaryllidaceae*, as a potential grain protectant against *Tribolium castaneum* Herbst *Sitophilus zeamais* Motsch. *Postharvest Biology Technology*,1996;9(96):41–48.
- Id JAF, Yool AJ, Spurgeon DW. Insecticidal activity of marigold *Tagetes patula* plants foliar extracts against the hemipteran pests, *Lygus hesperus* *Bemisia tabaci*. *PLoS ONE*, 2020, 1–15. <https://doi.org/10.1371/journal.pone.0233511>
- Ishag A, Mohammed A, Hammad A. Comparative assessment of the fumigant action of volatile oils from three garlic cultivars on faba bean beetle *Bruchidius incarnatus* Boh. *African Journal of Agricultural*, 2018. <https://doi.org/10.5897/AJAR2018.13538>.
- Katungi E, Mutua M, Mutari B, Makotore W, Kalemera S, Maereka E, Zulu R. *et al.* Improving bean production consumption in Zimbabwe: Baseline report. 2017. <https://core.ac.uk/reader/132691630>. Accessed 29 2020.
- Kestenholz C, Philip C, Stevenson PC, Belmain SR. *Journal of Stored Products Research*,2007;43:79–86.
- Kiri IZ, Eghosa O, Usman B, Biliyaminu A. The Use of Botanicals as Pesticides: History, Development Emerging Challenges. *Dutse Journal of Pure Applied Sciences DUJOPAS*, 2024, 10(1a).
- Kumari R, Mukherjee U, Kumar N, Kumar N. Efficacy of botanical insecticides against *Callosobruchus chinensis* L. on pigeon pea seeds. *Pest Management in Horticultural Ecosystems*,2014;20(1):41–46.
- Li J, Tian B. Peppermint Essential Oil Toxicity to the Pear Psylla Hemiptera. *Psyllidae Potential Applications*

- in the Field. Journal of Economic Entomology,2020:1133:1307–1314.
21. Loolaie M, Moasefi N, Rasouli H, Adibi H. Peppermint its functionality. A Review. Archives of Clinical Microbiology,2017:8(4):54.
 22. Maiti RK, Singh VP. Advances in Common Bean Related Species, 1st ed., Agrobios International, pp. 1-2. Plant Physiol,2007:84:835-840.
 23. Manenzhe NJ, Potgieter N, Van Ree T. Composition antimicrobial activities of volatile components of *Lippia javanica*. Phytochemistry,2004:65(16):2333–2336.
 24. Mangole G, Ithuteng M, Radikgomo M, Molosiwa OO. Challenges opportunities in common bean production marketing in Botswana. Prospects farmer's perspectives. African Journal of Food Security, Agriculture, Nutrition Development,2022:22(5):20461-20479.
 25. Mashiq P, Moatshe O, Tiroesele B, Lekgari L, Molosiwa O. Response of common bean *Phaseolus vulgaris* L. genotypes to varying planting dates in Botswana. Journal of Agricultural Crop Research,2019:7(2):26-30.
 26. Mojica L, de Mejía EG. Characterization Comparison of Protein Peptide Profiles their Biological Activities of Improved Common Bean Cultivars *Phaseolus vulgaris* L from Mexico Brazil. Plant Foods for Human Nutrition,2015:70(2):105-112.
 27. Mutari B, Sibiya J, Bogweh Nchanji, E. *et al.* Farmers' perceptions of navy bean *Phaseolus vulgaris* L. production constraints, preferred traits farming systems their implications on bean breeding. a case study from South East Lowveld region of Zimbabwe. *J Ethnobiology Ethnomedicine*, 2021, 17(13). <https://doi.org/10.1186/s13002-021-00442-3>.
 28. Muturi EJ, Ramirez JL, Zilkowski B, Flor-Weiler LB, Rooney AP. Ovicidal Larvicidal Effects of Garlic Asafoetida Essential Oils Against West Nile Virus Vectors, Journal of Insect Science,2018:18(2):43.
 29. Peixoto MG, Bacci L, Fitzgerald Blank A, Araújo APA, Alves PB, Silva JHS. *et al.* Toxicity repellency of essential oils of *Lippia alba* chemotypes their major monoterpenes against stored grain insects. Industrial Crops Products,2015:71:31–36.
 30. Porch GT, Beaver JS, Debouck DG, Jackson SA, Kelly JD, Dempewolf H. *et al.* Use of wild relatives closely related species to adapt common bean to climate change. Agronomy,2013:3:433-461.
 31. Rajkumar V, Gunasekaran C, Paul CA, Dharmaraj J. Development of encapsulated peppermint essential oil in chitosan nanoparticles. characterization biological efficacy against stored-grain pest control. Pesticide Biochemistry Physiology, 2020, 170. <https://doi.org/10.1016/j.pestbp.2020.104679>.
 32. Reda FAB, Abdel Fattah H, Salim N, Atiya N. Insecticidal activity of Four Volatile Oils on Two Museum Insects Pests. Egyptian Academic Journal of Biological Sciences, F. Toxicology Pest control,2010:2(2):57-66.
 33. Renkema JM, Wright D, Buitenhuis R, Hallett RH. Plant essential oils potassium metabisulfite as repellents for *Drosophila suzukii* Diptera. Drosophilidae. Scientific Reports,2016:6:1–10.
 34. Sarwar M. Full Length Research Paper. The Inhibitory Properties of Organic Pest Control Agents against Aphid Aphididae. Homoptera on Canola *Brassica napus* L. Brassicaceae Under Field Environment. International Journal of Scientific Research in Environmental Sciences,2013:1(8):195–201.
 35. Silva TT, Costa FM. Survey of Insects that Attack Stored Bean Grains *Vigna unguiculata* L. *Phaseolus vulgaris* L. in Porto Velho, Rondônia, Brazil. EntomoBrasilis,2016:9(2):124-128.
 36. Singh S. Natural plant products - As protectant during grain storage: A review. Journal of Entomology Zoology Studies.2017:5(3):1873-1885.
 37. Ukeh DA, Umoetok SBA. Repellent effects of five monoterpenoid odours against *Tribolium castaneum* Herbst, *Rhyzopertha dominica* F. in Calabar, Nigeria. Crop Protection,2011:30(10):1351–1355.
 38. Weaver DK, Wells CD, Dunkel FV, Bertsch W, Sing SE, Sriharan S. *et al.* Insecticidal activity of floral, foliar, root extracts of *Tagetes minuta* Asterales. Asteraceae against adult Mexican bean weevils *Coleoptera*. Bruchidae. Journal of Economic Entomology,1994:87(6):1718–1725.
 39. Yadav SPS, Sharma R, Yadav B, Paudel P. History, presence, perspective of botanical insecticides against insect pests. In Advances in Agricultural Entomology, 2022, 49-69.