Journal of

Entomology

ISSN 1812-5670

Academic
Journals Inc.

www.academicjournals.com

OPEN ACCESS Journal of Entomology

ISSN 1812-5670
DOI: 10.3923/je.2016.98.103

Research Article

Evaluation of Five Essential Plant Oils as a Source of Repellent and Larvicidal Activities Against Larvae of *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae)

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Abstract

To determine the repellent and larvicidal activities of five essential plant oils such as citriodora oil (*Corymbia citriodora* var. C.), citronella oil (*Cymbopogon nardus* var. L.), clove oil (*Syzygium aromaticum* L.), Gaultheria oil (*Gaultheria procumbens* L.) and lemongras oil (*Cymbopogon citratus*) against *Tribolium castaneum*. Repellent and larvicidal activities of citriodora, citronella, clove, gaultheria and lemongras oils were tested against *T. castaneum*. Significant effect has been observed in all tested essential oils compared to control, even though citriodora oil shows more significant than other four oils. Citriodora oil was recorded maximum repellent activity (95.24%) and larval mortality (81.86%) against larvae of *T. castaneum* at 20 µL mL^{-1}. This plant oil showed potential to be used as bio-pesticides in the management of *T. castaneum* pest.

Key words: Citriodora, citronella, clove, gaultheria, lemongras, larvicidal, repellent and *Tribolium castaneum*

Received: December 03, 2015 Accepted: March 04, 2016 Published: April 15, 2016

Citation: A. Jeyasankar, V. Chennaiyan and T. Chinnamani, 2016. Evaluation of five essential plant oils as a source of repellent and larvicidal activities against larvae of *Tribolium castaneum* (herbst) (Coleoptera: Tenebrionidae). J. Entomol., 13: 98-103.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Stored products of agricultural and animal origin are attacked by more than 600 species of beetle pests, 70 species of moths and about 355 species of mites causing quantitative and qualitative losses (Rajendran, 2002) and insect contamination in food commodities is an important quality control problem of concern for food industries. The red flour beetle, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) is a cosmopolitan, polyphagous and major secondary pest of stored grain products throughout the world (Garcia *et al*., 2005; Jemaa *et al*., 2012) and is generally found in grain, flour, peas, beans, nuts, dried fruits, spices and even dried museum specimens (Weston and Rattlingourd, 2000; Pugazhvendan *et al*., 2009). Adults and larvae of both species are serious economic pests that cause quantitative and qualitative losses in tropical and sub tropical regions (Rees, 2004).

Synthetic insecticides have been used for a long time to control stored product insect pests. Synthetic insecticides, such as melathion, pirimiphos-methyl, chlorpyrifos-methyl, deltamethrin and the fumigant phosphine are presently the main products used to protect stored grains from insects (Bond, 1984; Islam *et al*., 2009). The control of flour beetle and other pests of stored products by the use of chemical insecticides have serious drawbacks, such as the environmental pollution, insect's resistance, high mammalian toxicity and increasing cost of application (Jeyasankar and Jesudasan, 2005; Murugan, 2006; El-Kamali, 2009; Sousa *et al*., 2009).

Among other approaches to substitute conventional pesticides in integrated pest management programs (pheromones, monitoring and organic production), the developing of new pesticides from natural resources, such as undamaged native plants “Botanical pesticides” has been attempted in the past (Isman, 2005). Plant products have been successfully exploited as insecticides, insect repellents and antifeedants (El Nadi *et al*., 2001; Owusu *et al*., 2007; Islam *et al*., 2009; Islam, 2010; Jeyasankar *et al*., 2014). Monoterperoids found in essential oils are known neurotoxins (Stamopoulos *et al*., 2007) and most of them are volatile, thus offering the prospect of their use against stored product pests. Essential oils obtained from Eucalyptus, marjoram, pennyroyal and rosemary have shown insecticidal activity against *Pediculus humanuscapitis* De Geer (Yang *et al*., 2004). Essential oils derived from more than 75 plant species have been evaluated for fumigant toxicity against stored product insects so far (Rajendran and Srianjini, 2008).

Clove oil obtained from *Syzygium aromaticum* Linn. (Myrtaceae) are commonly used as a spice in cigarette called kretek in Indonesia (Merr and Perry, 2011). About 85% of cloves powerful taste is imparted by the chemical eugenol. Citronella oil obtained from *Cymbopogon nardus* var. Linn (Poaceae) and it contain a source of perfumery chemicals, such as citronella and geraniol (Lawless, 1995). Citriodora oil taken from *Corymbia citriodora* var. *citriodora* (Myrtaceae) is commonly used in perfumery and insect repellents (Lawless, 1995). Gaultheria oil obtained from *Gaultheria procumbens* Linn. (Ericaceae) used in anti-inflammatory properties and is used in Chinese herbal medicine for the treatment of rheumatoid arthritis, swelling and pain (Zhang *et al*., 2011). Lemongras oil obtained from *Cymbopogon citratus* (Poaceae) included above 45 species of grasses. No study has been reported concerning the activity of this five essential tested oils as repellent and larvicidal against these stored product insects. So, this study discussed about repellent and larvicidal effect of five essential oils against *T. castaneum.*

MATERIALS AND METHODS

Collection of plant oils: Clove (*Syzygium aromaticum* Linn.), citronella (*Cymbopogon nardus* var. Linn.), citriodora (*Corymbia citriodora* var. *citriodora*), Gaultheria (*Gaultheria procumbens* Linn) and lemongras (*Cymbopogon citratus*) were purchased from Tamil Nadu Government Co-operative Super Market, Cherring cross, Udhagamandalam, The Nilgiris, Tamil Nadu, India and collected oils were used for bioassay against larvae of *T. castaneum*.

Culture of test organism: *Tribolium castaneum* larvae was collected from infested grains purchased from local market in Musiri, Tamil Nadu, India and brought to the laboratory. The culture was established using wheat flour in a plastic container of 25×10 cm and maintained at room temperature 30±2°C and relative humidity of 70-75%. Sieving the culture separated the 4th instar larva and the larvae were used for subsequent experiment. The culture was continuously maintained in the containers throughout the study period.

Repellent activity: Repellent activity contained in the five essential oils were studied according to method adopted by Talukder and Howse (1994). Petridishes (9 cm dia) were used for the repellency test. Test solutions were prepared by dissolving different concentrations (5, 10, 15 and 20 μL) of each oil in 1 mL distilled water. Whatman No. 1 filter paper (8 cm dia) was cut into two and each solution was applied to half of a filter paper as uniform as possible by using micro pipette. The other half of the filter paper was treated with distilled water alone. The oil treated and distilled water untreated halves were dried to evaporate the solvent completely. Treated and untreated halves were attached with staple pins and placed in the glass petri dish. About 10 No. of 4th instar larvae of *T. castaneum* were released at the centre of the filter paper disc and then sealed tightly. Five replicates were set for each concentration. Observation of the No. of larva present on both the treated and untreated halves were recorded after 30 min for 2 h of experiment setting (30, 60, 90 and 120 min). The data were expressed as Percentage Repulsion (PR) by using the following equation (Talukder and Howse, 1994):

$$PR = \frac{NC-NT}{NC+NT} \times 100$$

where, PR is percentage repellency, NC is No. of larvae on control portion, NT is No. of larvae on treated portion.

The average values was then classified according to repellency classes from 0-V, where 0 = <0.1, Class I = 0.1-20, Class II = 20.1-40, Class III = 40.1-60, Class IV = 60.1-80 and Class V = 80.1-100%, respectively (McGovern *et al*., 1977).

Larvicidal activity: For evaluation of larvicidal activity in newly moulted 4th instar larvae of *T. castaneum* were exposed to various quantities of essential oils. To study the larvicidal activity of each oils are 3 g of half broken rice was coated with different concentrations (5, 10, 15 and 20 μL) in 1 mL of distilled water placed in (9 cm dia) glass petri dish and distilled water was used as control. The oil treated and distilled water untreated was dried to evaporate the solvent completely. Ten larvae taken from laboratory culture were placed in each petri dish. Five replicates were set for each concentration and control. Mortality was recorded every 24 h for 4 days and the percentage of mortality was calculated by Abbott (1925):

$$\text{Abbott's percent corrected mortality} = \frac{\text{Mortality in treated (\%)-Mortality in control (\%)}}{\text{100-Mortality in control (\%)}} \times 100$$

Statistical analysis: Data analysis was carried out using Microsoft Excel 2007. One-way ANOVA was performed for all the experimental data from that least significant difference was calculated and the significant differences were marked with different alphabet.

RESULTS

Repellent activity of five essential oils was studied at four different concentrations (5, 10, 15 and 20 μL mL^{-1}) against *T. castaneum* larvae. Table 1 is showed remarkable repellent effects. Repellency was seen in the number of larva found in the treated oils were significantly smaller than the number in

Table 1: Repellent activity of five essential plant oils against *T. castaneum* larvae

Plant oil name	Concentration (μL mL^{-1})	Repellency rate (%) 30 (mAT)	60 (mAT)	90 (mAT)	120 (mAT)	Mean repellency rate (%)	Repellency class
Clove oil	5	16	24	12	8	15.0	I
	10	20	24	40	44	32.0	II
	15	36	48	40	48	43.0	III
	20	64	60	64	56	61.0	IV
Citronella oil	5	17.2	19.3	16	12	16.1	I
	10	36	30	28	32	31.5	II
	15	46	42	52	46.2	46.55	III
	20	72	64	56	60	63.0	IV
Citriodora oil	5	22.8	22	24.4	24	23.3	II
	10	44.8	50	45.92	49.2	47.48	III
	15	76	72	69.08	73.76	72.71	IV
	20	95.76	94	93.2	98	95.24	V
Gaultheria oil	5	18	20.8	24	22	21.2	II
	10	43.36	42.8	44	42	43.04	III
	15	66	69.2	66.8	61.84	65.96	IV
	20	80.4	81.2	81.2	78	80.2	V
Lemongrass oil	5	20	24	16	18	19.5	I
	10	34	39.2	36.4	40	37.4	II
	15	44	56	58	60	54.5	III
	20	70	72	76	66	71.0	IV
Control	0	N.D	N.D	N.D	N.D	N.D	0

ND: Not Detected, 0 = <0.1, Class I: 0.1-2, Class II: 20.1-40, Class III: 40.1-60, Class IV: 60.1-80 and Class V: 80.1-100%

Table 2: Larvicidal activity of five essential plant oils against *T. castaneum* larvae

		Exposure time (h)			
Plant oil name	Concentration (µL mL^{-1})	24	48	72	96
Clove oil	5	8.00±4.4	11.20±2.1	13.15±3.0	14.31±2.8
	10	10.86±1.7	14.74±3.2	23.00±2.5	26.12±4.1
	15	13.92±2.7	19.75±3.6	31.84±2.4	40.40±4.7
	20	16.82±4.5	28.44±1.4	38.24±3.9	52.37±4.0
Citronella oil	5	10.23±0.0	13.66±2.1	16.44±1.9	16.31±2.7
	10	11.08±2.1	15.93±3.2	24.66±2.8	28.06±1.5
	15	14.86±3.9	23.60±2.8	33.40±2.7	44.28±4.8
	20	19.33±0.8	31.81±4.5	45.02±3.6	56.00±4.3
Citriodora oil	5	13.86±3.4	15.53±5.0	18.80±1.8	21.92±2.4
	10	19.79±4.3	26.26±3.4	34.91±3.7	41.71±5.5
	15	26.60±4.1	37.17±4.1	48.66±5.4	60.11±4.1
	20	32.0±5.2	47.02±2.1	60.28±2.9	81.86±4.8
Gaultheria oil	5	11.40±2.0	14.19±3.1	16.66±1.1	18.40±2.0
	10	16.81±1.9	23.64±2.5	31.04±1.4	37.78±4.8
	15	23.13±4.5	32.0±3.00	45.44±3.8	54.64±4.0
	20	29.15±2.8	40.68±2.2	54.97±3.5	69.91±3.7
Lemongrass oil	5	9.86±1.5	12.40±2.3	14.28±2.3	17.24±2.5
	10	12.15±2.5	17.53±2.8	23.90±2.5	29.57±4.6
	15	16.46±2.6	25.86±1.7	39.06±1.4	48.57±3.1
	20	22.50±3.4	34.17±4.5	47.81±3.8	60.55±4.0
Control	0	0.00±0.0			

the control. Higher concentration (20 µL mL^{-1}) of all oils showed higher repellency in *T. castaneum* larvae. Data pertaining to the above experiment clearly revealed that maximum repellent activity was recorded in citriodora oil 95.24% on *T. castaneum* larvae at 20 µL mL^{-1} concentration compared to control. Following descending order shows the repellency of other four oils in *T. castaneum* larvae at concentration (20 µL mL^{-1}) Gaultheria oil (80.2%)> lemongrass oil (71%)> citronella oil (63%)> clove oil (61%), respectively.

Larvicidal activity of five essential oils were tested against *T. castaneum* larvae at four different concentrations. Data pertaining to the larvicidal activity of the selected plant oils was presented in Table 2. The results indicating that variation among the plant oils tested against the selected insect pest. Toxicity increase with increasing concentration, exposure period and insect species, indicated that larvae were significantly susceptible to the five essential oils after 24-96 h of treatment. Larvicidal activity caused maximum toxicity was recorded in citriodora oil 81.86% at the rate of 20 µL mL^{-1} concentration. Gaultheria oil showed 69.91% mortality at 96 h after treatment. Whereas lemongrass oil, citronella oil and clove oils showed moderate activity compared with citriodora oil. One-way analysis of variance (ANOVA) followed by Least Significant Difference (LSD) test showed statistical significance ($p<0.05$) compared to control.

DISCUSSION

Plant products having considerable potential as insecticidal compounds are gaining tremendous importance in recent years. Approximately two-thirds to three-quarters of the world's population rely on medicinal flora as their main source of medicines (Anonymous, 2000). Many studies were reported on the insecticidal activity of essential oils against rust-red flour beetle and dried bean beetle (Shaaya *et al*., 1991; Pemonge *et al*., 1997; Papachristos and Stamopoulos, 2004; Mondal and Khalequzzaman, 2006; Chaubey, 2007; Islam *et al*., 2009).

In the present investigation larvae of *T. castaneum* were found to be significantly repellant at concentration of 20 µL mL^{-1} of citriodora oil in compared with other four oils and control. These results are consistent with the earlier reports repellent activity of plant derived essential oils, such as bael (*Aegle marmelos*), dhaniya (*Corriandrum sativum*), laung (*Schyzygium aromaticum*) and orange (*citrus reticulata*) against *Sitophilous oryzae* and *T. castaneum*. Highest repellant activity was observed in *S. aromaticum* against *S. oryzae* (90%) and *T. castaneum* (90%) (Mishra and Tripathi, 2011). Mahmoodavand and Shakarami (2014) noticed repellency effect of essential oils and powders of *Mentha longifolia*, *Thymus daenensis*, *Achillea wilhelmisii* and *Artemisa haussknechtii* against adults of *T. castaneum* and *T. confusum*. The essential oil of *M. longifolia* exhibited significantly stronger repellency effects as at 0.9 µL oil concentration caused 86.7 and 80% repellency of *T. castaneum* and *T. confusum*, respectively. Caballero-Gallerdo *et al*. (2012) indicated that adult beetles of *T. castaneum* were repelled significantly by essential oils of *Cymbopogon martini*, *C. flexuosus* and *Lippia origanoides*.

Citronella oil also used to mosquito repellent qualities has been verified by research (Kim *et al*., 2005). Moore *et al*. (2007) also reported that use of essential oil of lemongrass as a repellent in *Anopheles darlingi* and *Anopheles arabiensis*.

In the present study citriodora oil exhibited significant larvicidal activity at higher concentration. It is possible that the insecticidal property present in the selected plant compound may arrest the various metabolic activities of the larvae during the development and ultimately the larvae failed to moult and finally died. Mortality increased with increasing of both concentration and exposure period. This results coincide with the earlier findings of Khani and Asghari (2012) who noticed that insecticidal activity of essiential oils of *Mentha longifolia*, *Pulicaria gnaphalodes* and *Achillea wilhelmsii* against *T. castaneum* and *Callsobruchus maculatus*. These three oils showed strong insecticidal activity against *C. maculatus* but *M. longifolia* and *A. wilhelmsii* oils showed strong larvicidal activity against *T. castaneum*. Popovic *et al*. (2013) reported that essential oils from three plants against *T. castaneum*. Powerful larvicide and repellent effect was observed that essential oils of *Calamintha glandulosa* with concentration of 1.14% showed higher mortality rate after 24 h (56.67%), respectively. Jeyasankar (2012) already reported that antifeedant, insecticidal and growth inhibitory activities of selected plant oils on black cutworm, *Agrotis ipsilon.* Maximum percentage of insecticidal activity (86.92%) and deformities in treated larvae was recorded in gaultheria oil. Clove oil is also used to control insects, fungus, mildews in stored grains (Han *et al*., 2006; Shang and Cai, 2007). Some authors reported that citronella oil against stored grain pests Some plant extracts, essential oils or their constituents described in this review have demonstrated high efficacy against coleopteran stored products insect pests responsible for post-harvest damage.

CONCLUSION

Citriodora oil showed greater performance of larvicidal and repellent activities against *T. castaneum*. Hence, it may be suggested that the citriodora oil, can be used for controlling the insect pest, *T. castaneum*, which will replace the chemical pesticides.

REFERENCES

Abbott, W.S., 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol., 18: 265-267.

Anonymous, 2000. The complete data base of essential oil. Boelens Aroma Chemical Information Service, The Netherlands.

Bond, E.J., 1984. Manual of Fumigation for Insect Control (FAO Plant Production and Protection Paper 54). Food and Agriculture Organization of the United Nations, Rome, Italy, Pages: 432.

Caballero-Gallardo, K., J. Olivero-Verbel and E.E. Stashenko, 2012. Repellency and toxicity of essential oils from *Cymbopogon martinii*, *Cymbopogon flexuosus* and *Lippia origanoides* cultivated in Colombia against *Tribolium castaneum*. J. Stored Prod. Res., 50: 62-65.

Chaubey, M.K., 2007. Insecticidal activity of *Trachyspermum ammi* (Umbelliferae), *Anethum graveolens* (Umbelliferae) and *Nigella sativa* (Ranunculaceae) against stored-product beetle *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae). Afr. J. Agric. Res., 2: 596-600.

El Nadi, A.H., E.A. Elhag, A.A. Zaitoon and M.A. Al-Doghairi, 2001. Toxicity of three plants extracts to *Trogoderma granarium* everts (Coleoptera: Dermestidae). Pak. J. Biol. Sci., 4: 1503-1505.

El-Kamali, H.H., 2009. Effect of certain medicinal plants extracts against storage pest, *Tribolium castaneum* Herbst. Am. Eurasian J. Sustain. Agric., 3: 139-142.

Garcia, M., O.J. Donadel, C.E. Ardanaz, C.E. Tonn and M.E. Sosa, 2005. Toxic and repellent effects of *Baccharis salicifolia* essential oil on *Tribolium castaneum*. Pest Manage. Sci., 61: 612-618.

Han, Q., Q. Luo, G. Chen, S. Huang and J. Chen, 2006. Lethal effects of *Syzygium aromaticum* on the eggs and larvae of *Tribolium castaneum*. Plant Protect., 32: 60-63.

Islam, M.S., M.M. Hasan, W. Xiong, S.C. Zhang and C.L. Lei, 2009. Fumigant and repellent activities of essential oil from *Coriandrum sativum* (L.) (Apiaceae) against red flour beetle *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). J. Pest Sci., 82: 171-177.

Islam, M.S., 2010. Repellency of two monoterpenoids and neem oil against *Callosobruchus maculatus* (F.). Univ. J. Zool. Rajshahi Univ., 28: 41-44.

Isman, M.B., 2005. Problems and Opportunities for the Commercialization of Botanical Insecticides. In: Biopesticides of Plant Origin, Regnault-Roger, C., B.J.R. Philigene and C. Vincent (Eds.). Lavoisier, Paris, ISBN-13: 978-1898298977, pp: 283-291.

Jemaa, J.M.B., N. Tersim, K.T. Toudert and M.L. Khouja, 2012. Insecticidal activities of essential oils from leaves of *Laurus nobilis* L. from Tunisia, Algeria and Morocco and comparative chemical composition. J. Stored Prod. Res., 48: 97-104.

Jeyasankar, A. and R.W.A. Jesudasan, 2005. Insecticidal properties of novel botanicals against a few lepidopteran pests. Pestology, 29: 42-44.

Jeyasankar, A., 2012. Antifeedant, insecticidal and growth inhibitory activities of selected plant oils on black cutworm, *Agrotis ipsilon* (Hufnagel) (Lepidoptera: Noctuidae). Asian Pac. J. Trop. Dis., 2: S347-S351.

Jeyasankar, A., T. Chinnamani, V. Chennaiyan and G. Ramar, 2014. Antifeedant activity of *Barleria buxifolia* (Linn.) (acanthaceae) against *Spodoptera litura* fabricius and *Helicoverpa armigera* hubner (Lepidotera: Noctuidae). Int. J. Nat. Sci. Res., 2: 78-84.

Khani, A. and J. Asghari, 2012. Insecticide activity of essential oils of *Mentha longifolia*, *Pulicaria gnaphalodes* and *Achillea wilhelmsii* against two stored product pests, the flour beetle, *Tribolium castaneum* and the cowpea weevil, *Callosobruchus maculatus*. J. Insect Sci., Vol. 12. 10.1673/031.012.7301

Kim, J.K., C.S. Kang, J.K. Lee, Y.R. Kim, H.Y. Han and H.K. Yun, 2005. Evaluation of repellency effect of two natural aroma mosquito repellent compounds, citronella and citronellal. Entomol. Res., 35: 117-120.

Lawless, J., 1995. The Illustrated Encyclopedia of Essential Oils: The Complete Guide to the Use of Oils in Aromatherapy and Herbalism. Element Books Ltd., Shaftesbury, UK., ISBN-13: 978-1852307219, Pages: 256.

Mahmoodavand, S. and J. Shakarami, 2014. Repellency effects of essential oils and powders of four plant species on *Tribolium castaneum* (Herbst) and *T. confusum* (Du Val) (Col: Tenebrionidae). Int. J. Agric. Biosci., 3: 49-54.

McGovern, T.P., H.B. Gillenwater and L.L. McDonald, 1977. Repellents for adult *Tribolium confusum* mandelates. J. Georgia Entomol. Soc., 12: 79-84.

Merr, L. and L.M. Perry, 2011. *Syzygium aromaticum* (L.). Germplasm Resources Information Network (GRIN), ITIS Report, Beltsville, Maryland.

Mishra, B.B. and S.P. Tripathi, 2011. Repellent activity of plant derived essential oils against *Sitophilous oryzae* (Linnaeus) and *Tribolium castaneum* (herbst). Singapore J. Sci. Res., 1: 173-178.

Mondal, M. and M. Khalequzzaman, 2006. Toxicity of essential oils against red flour beetle, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). J. Bio-Sci., 14: 43-48.

Moore, S.J., N. Hill, C. Ruiz and M.M. Cameron, 2007. Field evaluation of traditionally used plant-based insect repellents and fumigants against the malaria vector *Anopheles darlingi* in Riberalta, Bolivian Amazon. J. Med. Entomol., 44: 624-630.

Murugan, K., 2006. Biopesticides as environmentally soft tool for the management of insect/mosquito vectors. Proceedings of the 4th International Symposium on Biocontrol and Biotechnology, November 27-29, 2006, Madurai, pp: 34.

Owusu, E.O., W.K. Osafo and E.R. Nutsukpui, 2007. Bioactivities of candlewood, *Zanthoxylum xanthoxyloides* (Lam.) solvent extracts against two stored-product insect pests. Afr. J. Sci. Technol., 8: 17-21.

Papachristos, D.P. and D.C. Stamopoulos, 2004. Fumigant toxicity of three essential oils on the eggs of *Acanthoscelides obtectus* (Say) (Coleoptera: Bruchidae). J. Stored Prod. Res., 40: 517-525.

Pemonge, J., M.J. Pascual-Villalobos and C. Regnault-Roger, 1997. Effects of material and extracts of *Trigonella foenum-graecum* L. against the stored product pests *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) and *Acanthoscelides obtectus* (Say) (Coleoptera: Bruchidae). J. Stored Prod. Res., 33: 209-217.

Popovic, A., J. Sucur, D. Orcic and P. Strbac, 2013. Effects of essential oil formulations on the adult insect *Tribolium castaneum* (Herbst) (Col., Tenebrionidae). J. Central Eur. Agric., 14: 181-193.

Pugazhvendan, S.R., K. Elumalai, P.R. Ross and M. Soundararajan, 2009. Repellent activity of chosen plant species against *Tribolium castaneum*. World J. Zool., 4: 188-190.

Rajendran, S., 2002. Post Harvest Pest Losses. In: Encyclopedia of Pest Management, Pimentel, D. (Ed.). Marcel Dekker Inc., New York, ISBN: 9781439870587, pp: 654-656.

Rajendran, S. and V. Sriranjini, 2008. Plant products as fumigants for stored-product insect control. J. Stored Prod. Res., 44: 126-135.

Rees, D., 2004. Insects of Stored Products. CSIRO Publishing, Collingwood, Australia, ISBN: 9780643102637, Pages: 192.

Shaaya, E., U. Ravid, N. Paster, B. Juven, U. Zisman and V. Pissarev, 1991. Fumigant toxicity of essential oils against four major stored-product insects. J. Chem. Ecol., 17: 499-504.

Shang, J.F. and J.P. Cai, 2007. Inhibiting action of clove extract on mildews in stored grains. J. Henan Univ. Technol. (Natl. Sci. Edn.), 28: 12-14.

Sousa, A.H., L.R.D.A. Faroni, M.A.G. Pimentel and R.N.C. Guedes, 2009. Developmental and population growth rates of phosphine-resistant and -susceptible populations of stored-product insect pests. J. Stored Prod. Res., 45: 241-246.

Stamopoulos, D.C., P. D amos and G. Karagianidou, 2007. Bioactivity of five monoterpenoid vapours to *Tribolium confusum* (du Val) (Coleoptera: Tenebrionidae). J. Stored Prod. Res., 43: 571-577.

Talukder, F.A. and P.E. Howse, 1994. Laboratory evaluation of toxic and repellent properties of the pithraj tree, *Aphanamixis polystachya* Wall and Parker, against *Sitophilus oryzae* (L.). Int. J. Pest Manage., 40: 274-279.

Weston, P.A. and P.L. Rattlingourd, 2000. Progeny production by *Tribolium castaneum* (Coleoptera: Tenebrionidae) and *Oryzaephilus surinamensis* (Coleoptera: Silvanidae) on maize previously infested by *Sitotroga cerealella* (Lepidoptera: Gelechiidae). J. Econ. Entoml., 93: 533-536.

Yang, Y.C., H.S. Lee, J.M. Clark and Y.J. Ahn, 2004. Insecticidal activity of plant essential oils against *Pediculus humanus* capitis (Anoplura: Pediculidae). J. Med. Entomol., 41: 699-704.

Zhang, D., R. Liu, L. Sun, C. Huang and C. Wang *et al*., 2011. Anti-inflammatory activity of methyl salicylate glycosides isolated from *Gaultheria yunnanensis* (Franch.) rehder. Molecules, 16: 3875-3884.