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Research Article

ANTIFEEDANT ACTIVITY OF FOUR PLANT ESSENTIAL OILS AGAINST MAJOR STORED PRODUCT INSECT PESTS

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ABSTRACT

Experiments were carried out in the laboratory to determine antifeedant activity of four plant essential oils of *Rabdosia rugosa* (Wall. ex Benth), *Zanthoxylum armatum* (DC.), *Artemisia maritima* (L.) and *Colebrookea oppositifolia* (Sm.) against four stored product insect pests viz. *Tribolium castaneum* (Herbst.), *Sitophilus oryzae* (L.), *Stegobium paniceum* (L.) and *Plodia interpunctella* (Hubner). Feeding deterrence indices (FDI) showed that the plant essential oils had antifeedant action against the four insect pests at different concentrations. *R. rugosa* and *Z. armatum* oil at a high concentration of 300 µl/g resulted in 5.22 ± 0.21 and 6.42 ± 0.32% grain damage as compared to 70.32 ± 0.28% damage under control and FDI of 86.17 ± 0.25 and 85.71 ± 0.27% was recorded for *T. castaneum* followed by *S. oryzae* with a FDI of 70.58 ± 0.21 and 67.68 ± 0.19% and grain damage of 15.42 ± 0.12 and 16.31 ± 0.21% as compared to 85.36 ± 0.09% grain damage in control for similar concentrations of above oils. *A. maritima* oil at 100 µl/g showed 76.31 ± 0.16% FDI followed by *C. oppositifolia* oil obtaining 75.11 ± 0.35% feeding deterrence against *T. castaneum* whereas 65.99 ± 0.32% and 65.46 ± 0.14% FDI was obtained for similar concentrations of these oils against *S. oryzae*. FDI of 62.82 ± 0.32 and 60.03 ± 0.26% was observed for *R. rugosa* and *Z. armatum* oil at 300 µl/g against *S. paniceum* followed by 64.97 ± 0.14 and 53.35 ± 0.18% against *P. interpunctella* for similar concentration of oils. The present study indicated that *R. rugosa* and *Z. armatum* were highly effective followed by *A. maritima* and *C. oppositifolia* against all the insect pest.

Keywords: Essential oils; Antifeedant activity; Deterrence, Grain damage; Insect pests

INTRODUCTION

Stored grain insect pests can cause reductions in weight, quality, commercial value and seed viability. Seventy-five percent of these insects are Coleopterans and the most damaging species of storage insects are in the genera Sitophilus and Tribolium (Marsans, 1987; Khan and Selman, 1988; Pinto et al., 1997). *S. paniceum* is the most extensively distributed insect pest causing serious damages to stored products (Can et al., 2004; Guilin and Wangxi, 1996). Indian meal moth, *P. interpunctella* (Lepidoptera: Pyralidae), is a serious pest of stored products like grains, seeds, flour and other milled products and has a universal distribution (Nansen et al., 2004). The use of chemical agents to prevent or control insect infestations has been the main method of grain protection, since it is the simplest and most cost-effective means of dealing with stored product pests (Hidalgo et al., 1998). Although effective, their repeated use for decades has disrupted biological control by natural enemies and led to resurgence of stored-product insect pests (Brower et al., 1995), sometimes resulted in the development of resistance (Champ and Dyte, 1977; Subramanyam and Hagstrum, 1995; White and Leesch, 1995), had undesirable effects on non-target organisms, and fostered environmental and human health concerns (Brown, 1978; Hayes and Laws, 1991; White and Leesch, 1995). Much effort has, therefore, been focused on plant-derived materials as potential sources of commercial insect-control agents (Hill and Schoonhoven, 1981; Coats et al., 1991; Konstantopoulou et al., 1992). The biggest impetus for the growth of biopesticides comes from the growing awareness by farmers of the value of integrated pest management as a more environmentally sound, economical, safer and a selective approach to crop protection (Menn, 1996). A large number of plant-derived substances possess various physiological and behavioral activities against stored-product insects. These include toxic, repellent and antifeedant effects (Amason et al., 1989; Grainge and Ahmed, 1988; Jacobson, 1990). Pesticides based on plant essential oils or their constituents have demonstrated efficacy against a range of stored product pests, domestic pests, blood feeding pests and certain soft bodied agricultural pests, as well as against some plant pathogenic fungi responsible for pre and post-harvest diseases. They may be applied as fumigants, granular formulations or direct sprays with a range of effects from lethal toxicity to repellence and oviposition deterrence in insects. These features indicate that pesticides based on plant essential oils could be used in a variety of ways to control a large number of pests. Essential oils, which are volatile oils from plants and their constituents, have been shown to be a potent source of botanical pesticides (Singh and Upadhyay,

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1993). The present study was carried out in the laboratory to determine antifeedant activity of four plant essential oils of *Rabdosia rugosa* (Wall. ex Benth), *Zanthoxylum armatum* (DC.), *Artemisia maritima* (L.) and *Colebrookea oppositifolia* (Sm.) against four stored product insect pests viz. *Tribolium castaneum* (Herbst.), *Sitophilus oryzae* (L.), *Stegobium paniceum* (L.) adults and larvae of *Plodia interpunctella* (Hubner).

MATERIALS AND METHODS

Extraction of essential oils

Essential oils were extracted from leaves of *R. rugosa*, *Z. armatum*, *A. maritima* and *C. oppositifolia* collected from the local areas of Shimla district of Himachal Pradesh, India. The leaves were dried in shade at room temperature (30 ± 5□) and grounded by domestic mixer. The dried powdered material was hydro-distilled in Clevenger apparatus. Conditions of extraction were: 50 g of air-dried sample in 1:10 plant material/water volume ratio for 4 hrs distillation. Oil yield (2.9% w/w) was calculated on a dry weight basis.

Test insects

Laboratory cultures of *P. interpunctella*, *T. castaneum*, *S. oryzae* and *S. paniceum* were maintained at 28 ± 2°C

and 68 ± 2% relative humidity. Adult insects of *T. castaneum*, *S. oryzae* and *S. paniceum* were reared on wholemeal wheat flour plus brewer's yeast (19:1) and larvae of *P. interpunctella* was reared on a diet of 80% ground rice, 10% glycerin, 5% yeast in plastic containers (30 cm length × 20 cm width × 8 cm height). Mouth of the containers was covered with fine mesh cloth for ventilation as well as to prevent escape of the insects.

Antifeedant activity of essential oils

The bioassay experiment was conducted for evaluating essential oils as potential seed protectants against *T. castaneum*, *S. oryzae*, *S. paniceum* (5-10 day old) adults and larvae (16 day old) of *P. interpunctella*. To determine antifeedant activity of essential oils a no-choice test was carried out as described by *Huang et al. (2002)* and *Gomah (2011)* with some modifications. 1 ml of prepared concentrations of 100 and 300 µl of essential oils dissolved in methanol and 1 ml solvent alone as control were applied on to a 5 g grinded mixture of pulses and rice kernels. The treated mixture of food media were placed in Petri dishes after evaporating the solvent. 10 adults of *T. castaneum*, *S. oryzae*, *S. paniceum* and larvae of *P. interpunctella* were transferred to each pre-weighed food media in Petri dishes. After feeding for 72 hrs under laboratory conditions food media was re-weighed and mortality of insects was recorded. Nutritional indices and weight loss were calculated as previously described by Mahdi (2008) and Huang et al. (2002).

Weight loss (%WL)=(IW-FW) × 100/ IW, where the IW is the initial weight and FW is the final weight.

Feeding Deterrence Index was calculated by (Isman et al. 1990; Huang Ho et al. 2003) using the formula,

FDI (%)=(C–T)/(C+T) × 100, where C is weight loss of control rice kernels and T is weight loss of treated rice kernels.

Statistical analysis

All the data concerning mortality were corrected by using Abbott's formula (Abbott, 1925). Tests for antifeedant activity were performed in triplicate and data presented are mean ± SE. The mean values were compared by one-way ANOVA and Tukey's multiple comparison tests using software SPSS, version 11.5.

RESULTS

Antifeedant activity of essential oils against *T. castaneum*

5.22 ± 0.21 and 6.42 ± 0.32% grain damage was observed for *R. rugosa* and *Z. armatum* oil at a high concentration of 300 µl/g as compared to 70.32 ± 0.28% damage under control and FDI of 86.17 ± 0.25 and 85.71 ± 0.27% was recorded for *T. castaneum*. *A. maritima* oil at 100 µl/g showed 76.31 ± 0.16% FDI with 9.25 ± 0.26% grain damage followed by *C. oppositifolia* oil obtaining 75.11 ± 0.35% feeding deterrence with 9.48 ± 0.18% grain damage (Table 1).

Antifeedant activity of essential oils against *S. oryzae*

R. rugosa and *Z. armatum* oil at 300 µl/g showed high FDI of 70.58 ± 0.21 and 67.68 ± 0.19% with 15.42 ± 0.12 and 16.31 ± 0.21% grain damage as compared to 85.36 ± 0.09% grain damage in control. 65.99 ± 0.32 and 58.94 ± 0.09% FDI was obtained at 100 and 300 µl/g of *A. maritima* oil while 65.46 ± 0.14 and 56.99 ± 0.26% feeding deterrence was observed by *C. oppositifolia* oil against *S. oryzae* (Table 2).

Antifeedant activity of essential oils against S. paniceum

FDI of 62.82 ± 0.32 and 60.03 ± 0.26% was observed for *R. rugosa* and *Z. armatum* oil at 300 µl/g followed by 57.71 ± 0.09 and 54.80 ± 0.13% at 100 µl/g. 19.48 ± 0.15 and 20.05 ± 0.34% grain damage was recorded at 300 µl/g of *A. maritima* and *C. oppositifolia* oil with 54.70 ± 0.28 and 50.09 ± 0.11% FDI against *S. paniceum* and 79.32 ± 0.30% grain damage in control (Table 3).

Antifeedant activity of essential oils against *P. interpunctella*

R. rugosa oil at lowest concentration of 100 µl/g showed 59.30 ± 0.18% feeding deterrency with 21.32 ± 0.13% grain damage followed by *Z. armatum* oil producing 45.93 ± 0.24 feeding deterrency with 23.16 ± 0.17% grain damage as compared to 78.26 ± 0.34% grain damage in control against *P. interpunctella*. Similarly *A. maritima* and *C. oppositifolia* oil obtained 41.71 ± 0.09 and 36.70 ± 0.30% FDI at 100 µl/g and 51.85 ± 0.28 and 46.51 ± 0.17% FDI was recorded at a concentration of 300 µl/g respectively (Table 4).

Table 1: Antifeedant activity of essential oils against *T. castaneum* (Values are mean ± SE).

Essential oils	Doses µl/g	Grain damage (%)	Weight loss (%)	FDI (%)
R. rugosa	100	7.32 ± 0.16[a]	5.42 ± 0.32[a]	78.60 ± 0.09[b]
	300	5.22 ± 0.21[b]	3.36 ± 0.26[b]	86.17 ± 0.25[c]
Z. armatum	100	8.54 ± 0.11[a]	5.56 ± 0.17[a]	78.11 ± 0.13[b]
	300	6.42 ± 0.32[b]	3.48 ± 0.21[b]	85.71 ± 0.27[c]
A. maritima	100	9.25 ± 0.26[c]	6.08 ± 0.35[c]	76.31 ± 0.16[b]
	300	6.52 ± 0.09[b]	4.24 ± 0.09[d]	82.86 ± 0.08[a]
C. oppositifolia	100	9.48 ± 0.18[c]	6.43 ± 0.16[c]	75.11 ± 0.35[b]
	300	7.05 ± 0.32[a]	4.46 ± 0.23[d]	82.05 ± 0.09[a]
Control	_	70.32 ± 0.28[ab]	45.25 ± 0.32[ab]	_

% values are mean (n=3) ± SE. The means within a column followed by same letter are not significantly different from each other according to ANOVA and Tukey's comparison tests.

Table 2: Antifeedant activity of essential oils against *S.oryzae* (Values are mean ± SE).

Essential oils	Doses µl/g	Grain damage (%)	Weight loss (%)	FDI (%)
R. rugosa	100	19.42 ± 0.33[a]	12.32 ± 0.22[b]	65.60 ± 0.19[a]
	300	15.42 ± 0.12[b]	10.23 ± 0.15[b]	70.58 ± 0.21[b]
Z. armatum	100	20.25 ± 0.27[a]	13.16 ± 0.33[b]	63.68 ± 0.17[a]
	300	16.31 ± 0.21[b]	11.43 ± 0.11[a]	67.68 ± 0.19[c]
A. maritima	100	22.42 ± 0.13[c]	15.32 ± 0.09[c]	58.94 ± 0.09[d]
	300	18.45 ± 0.22[b]	12.15 ± 0.26[a]	65.99 ± 0.32[a]
C. oppositifolia	100	23.18 ± 0.36[a]	16.25 ± 0.17[c]	56.99 ± 0.26[d]
	300	19.32 ± 0.20[b]	12.38 ± 0.08[a]	65.46 ± 0.14[a]
Control	_	85.36 ± 0.09[ab]	59.32 ± 0.26[ab]	_

% values are mean (n=3) ± SE. The means within a column followed by same letter are not significantly different from each other according to ANOVA and Tukey's comparison tests.

Table 3: Antifeedant activity of essential oils against *S. paniceum* (Values are mean ± SE).

Essential oils	Doses µl/g	Grain damage (%)	Weight loss (%)	FDI (%)
R. rugosa	100	18.32 ± 0.23[a]	13.15 ± 0.17[b]	57.71 ± 0.09[a]
	300	15.00 ± 0.09[b]	11.20 ± 0.32[b]	62.82 ± 0.32[b]
Z. armatum	100	20.05 ± 0.23[a]	14.32 ± 0.19[b]	54.80 ± 0.13[c]
	300	17.36 ± 0.17[a]	12.25 ± 0.09[a]	60.03 ± 0.26[d]
A. maritima	100	22.43 ± 0.32[c]	16.41 ± 0.32[b]	49.86 ± 0.33[bc]
	300	19.48 ± 0.15[a]	14.36 ± 0.14[b]	54.70 ± 0.28[c]
C. oppositifolia	100	23.26 ± 0.15[c]	18.10 ± 0.12[b]	46.09 ± 0.15[bc]
	300	20.05 ± 0.34[a]	16.31 ± 0.28[b]	50.09 ± 0.11[c]
Control	_	79.32 ± 0.30[ab]	49.05 ± 0.36[ab]	_

% values are mean (n=3) ± SE. The means within a column followed by same letter are not significantly different from each other according to ANOVA and Tukey's comparison tests.

Table 4: Antifeedant activity of essential oils against *P. interpunctella* (Values are mean ± SE).

Essential oils	Doses µl/g	Grain damage (%)	Weight loss (%)	FDI (%)
R. rugosa	100	21.32 ± 0.13[a]	11.32 ± 0.11[b]	59.30 ± 0.18[a]
	300	18.42 ± 0.09[b]	9.41 ± 0.21[a]	64.97 ± 0.14[a]
Z. armatum	100	23.16 ± 0.17[c]	16.41 ± 0.17[c]	45.95 ± 0.24[c]
	300	20.42 ± 0.34[a]	13.48 ± 0.32[b]	53.35 ± 0.18[d]
A. maritima	100	24.31 ± 0.21[c]	18.23 ± 0.24[c]	41.71 ± 0.09[c]
	300	21.27 ± 0.35[a]	14.05 ± 0.16[b]	51.85 ± 0.28[d]
C. oppositifolia	100	27.16 ± 0.14[d]	20.52 ± 0.21[c]	36.70 ± 0.30[bc]
	300	22.09 ± 0.25[a]	16.18 ± 0.09[c]	46.51 ± 0.17[c]
Control	_	78.26 ± 0.34[ab]	44.32 ± 0.18[ab]	_

% values are mean (n=3) ± SE. The means within a column followed by same letter are not significantly different from each other according to ANOVA and Tukey's comparison tests.

DISCUSSION AND CONCLUSION

Feeding deterrence indices (FDI) showed that the tested plant essential oils had antifeedant action against the four insect pests at different concentrations. In a related study Kumar et al. (2007) and Varma and Dubey (2001) investigated that essential oil of *Cymbopogon martinii*, *Caesulia axillaris* and *Mentha arvensis* protected stored gram and wheat from *Callosobruchus chinensis*, *S. oryzae* and *T. castaneum* for first 12 months of storage. *R. rugosa* and *Z. armatum* oil at a high concentration of 300 µl/g showed 86.17 ± 0.25 and 85.71 ± 0.27% FDI for *T. castaneum* followed by *S. oryzae* (70.58 ± 0.21 and 67.68 ± 0.19), *S. paniceum* (62.82 ± 0.32 and 60.03 ± 0.26) and *P. interpunctella* (64.97 ± 0.14 and 53.35 ± 0.18). Kumar et al. (2008) recorded 91.51, 97.26, 98.02 and 6.18% feeding deterrent index of essential oil of *Aegle marmelos* for *C. chinensis*, *Rhizopertha dominica*, *S. oryzae* and *T. castaneum* with 100% grain damage in *T. castaneum* while 7.0, 3.67 and 1.67% grain damage was found in *C. chinensis*. *R. dominica* and *S. oryza*e infested grains respectively. *A. maritima* and *C. oppositifolia* oil at 300 µl/g obtained 82.86 ± 0.08 and 82.05 ± 0.09% FDI for *T. castaneum* whereas 65.99 ± 0.32 and 65.46 ± 0.14% against *S. oryzae*. The result of present investigation are also similar to the observations of Shukla et al. (2011) who reported significant deterrent effects of essential oils of *Lippia alba* and *Callistemon lanceolatus* and their constituents on the feeding behaviour of *C. chinensis* and all the treatments showed significantly better results than the controls. Khani et al. (2013) investigated that petroleum ether extract of *Piper nigrum* and *Jatropha curcas* showed a positive dose dependent antifeedant activity and reduced consumption of rice kernels treated with both plant extract by *Corcyra cephalonica* larvae. *R. rugosa* oil at a concentration of 100 µl/g showed 59.30 ± 0.18% feeding deterrency with 21.32 ± 0.13% grain damage followed by *Z. armatum* oil producing 45.93 ± 0.24 feeding deterrency with 23.16 ± 0.17% grain damage as compared to 78.26 ± 0.34% grain damage in control against *P. interpunctella*. Least antifeedent activity was observed for *C. oppositifolia* oil towards all insect species. Essential oils inhibits locomotion which affect mating activities and sexual communication as well as deterring females from laying eggs, as well as complete suppression of the developmental stages of insects which have been reported by a number of authors (Ivbijaro and Agbaje, 1986; Ofuya, 1992; Okonkwo and Okoye, 1996; Adedire 2002). Compounds with feeding deterrents are generally toxic to insects or cause physiological disturbances of development or oviposition (Nawrot and Harmantha, 1994).

REFERENCES

1. Adedire, C.O. (2002). Use of nutmeg, *Myristica fragrans* (Houtt) powder and oil for the control of cowpea storage bruchid. *Callosobruchus maculatus*. *Journal of Plant Diseases and Protection*., 109: 193-199.
2. Amason. J. T., Philogene, B. J. R. and Morand, F. (1989). Insecticides of Plant Origin. *American Chemical Society*. Washington, DC.
3. Brower, J. H., Smith, L., Vail, P. V., Flinn, P. W. (1995). Biological control. In: Subramanyam, B., Hagstrum, D.W. (Eds.), Integrated Management of Insects in Stored Products. *Marcel Dekker*, New York, pp. 223-286.
4. Brown, A. W. A. (1978). Ecology of Pesticides. *Wiley*, New York, 525pp.
5. Can, L., Zizhong, L., Youlian, Y. (2004). Analysis of the structure of insect community on the stored Chinese medicinal materials in Guiyang. *Journal of mountain agriculture and biology*., 23: 41-45.
6. Champ, B. R., Dyte, C. E. (1977). FAO global survey of pesticide susceptibility of stored grain pests. *FAO Plant Protection Bulletin*., 25: 49-67.
7. Coats, J. R., Karr, L. L., Drewes, C. D. (1991). Toxicity and neurotoxic effects of monoterpenoids in insects and earthworms. In: Hedin, P.A. (Ed.), Naturally Occurring Pest Bioregulators. ACS Symposium Series No. 449. *American Chemical Society*, Washington, DC., 305-316.
8. Gomah, E. N., (2011). Toxic and antifeedant activities of potato glycoalkaloids against *Trogoderma granarium* (Coleoptera: Dermestidae). *Journal of Stored Products Research*., 47: 185-190.
9. Grainge, M. and Ahmed, S. (1988). Handbook of Plants with Pest-Control Properties. *Wiley-Interscience*.
10. Guilin, L., Wangxi, D. (1996). The community quantitative characters of insects on the stored TCM materials. *Journal of Huazhong Agriculture University*., 15: 338-345.
11. Hayes Jr., J. B., Laws Jr., E. R. (1991). Handbook of Pesticide Toxicology. *Academic Press*, San Diego, 1: 496.
12. Hidalgo, E., Moore, D., Patourel, L. E (1998). The effect of different formulations of *Beauveria bassiana* on *Sitophilus zeamais* in stored maize. *Journal of Stored Products Research*., 34: 171-179.
13. Hill, J. M., Schoonhoven, A. V. (1981). The use of vegetable oils in controlling insect infestations in stored grains and pulses. *Recent Advances in Food Science and Technology*., 1: 473-481.
14. Huang Ho, S. J., Wang, K. Y., Sim, G. C. L., Ee Z, Imiyabir K. F., Yap, K., Shaari, S., Hock, G. (2003). Meliternatin: a feeding deterrent and larvicidal polyoxygenated flavone from Melicope subunifoliolata. *Phytochemistry*., 62: 1121-1124.
15. Huang, Y. S, Ho, H., Lee, H. C, Yap, Y. L. (2002). Insecticidal properties of eugenol, isoeugenol and methyleugenol and their effects on nutrition of *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae) and *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). *Journal of stored Products Research*., 38: 403-412.
16. Isman, M. B., Koul, O., Luczynski, A., Kaminskis, J. (1990). Insecticidal and antifeedant bioactivities of neem oils and their relationship to azadirachtin content. *Journal of Agriculture and Food Chemistry.,* 38: 1406-1411.
17. Ivbijaro, M.F., Agbaje, M. (1986). Insecticidal activities of *Piper guineense* and *Capsicum* species in cowpea

bruchid, *Callosobruchus maculatus. Insect science and its Application*., 7: 521-524.

18. Jacobson. M. (1990). Glossary of Plant-derived Insect Deterrents. CRC Press, Inc., Publication, New York, NY.

19. Khan, A. R., Selman, B. J. (1988). On the mortality of *Tribolium castaneum* adults treated sublethally as larvae with pirimiphos methyl, *Nosema whitei* and pirimiphos methyl-N. whitei doses. *Entomophaga*., 33: 377-380.

20. Khani, M., Awang, R. M., Omar, D., Rahmani, M. (2013). Toxicity, antifeedant, egg hatchability and adult emergence effect of *Piper nigrum L*. and *Jatropha curcas L*. extracts against rice moth, *Corcyra cephalonica* (Stainton). *Journal of Medicinal Plants Research*., 7: 1255-1262.

21. Konstantopoulou, L., Vassilopoulou, L., Mauragani-Tsipidov, P., Scouras, Z. G. (1992). Insecticidal effects of essential oils. A study of the effects of essential oils extracted fromeleven Greek aromatic plants on *D. auraria*. *Experientia* 48: 616-619.

22. Kumar, R., Kumar, A., Prasad, C. S., Dubey, N. K., Samant, R. (2008). Insecticidal activity *Aegle marmelos* (L.) Correa essential oil against four stored grain insect pests. *Internet Journal of Food Safety*., 10: 39-49.

23. Kumar, R., Srivastava, M., Dubey, N. K. (2007). Evaluation of *Cymbopogon martini* oil extract for control of postharvest insect deterioration in cereals and legumes. *Journal of Food Protection*., 70: 172-178.

24. Mahdi, S. M. R. (2008). Insecticidal effect of some spices on *Callosobruchus maculatus* (Fabricius) in black gram seeds. *University Journal of Zoology Rajshahi University* 27, 47-50.

25. Marsans, G. (1987). Manejo y ConservacioÂ n de Granos. Ed. *Hemisferio Sur*, Buenos Aires, 266.

26. Menn, J. J. (1996). Biopesticides: Has their time come? *Journal of Environmental Science Health*., 31: 383-389.

27. Nansen, C., Phillips, T. W. (2004). Attractancy and toxicity of an attracticide for Indian meal moth, *Plodia interpunctella* (Lepidoptera: Pyralidae). *Journal of Economic Entomology*., 97, 703-710.

28. Nawrot, J., Harmatha, J. (1994). Natural products as antifeedants against stored products insects. *Postharvest News and Information*., 5: 17-21.

29. Ofuya, T. I. (1992). Oviposition deterrence and ovicidal properties of some plant powders against *Callosobruchus maculatus* in stored cowpea seeds. *Journal of Agricultural Science*., 115: 343-345.

30. Okonkwo, E. U., Okoye, W. I. (1996). The efficacy of four seed powders and the essential oils as protectants of cowpea and maize grains against infestation by *Callosobruchus maculatus* and *Sitophilus zeamais.* Nigeria International Journal Pest Management., 42: 143-146.

31. Pinto Jr, A. R., Furiatti, R. S., Pereira, P. V. S., Lazzari, F. A. (1997). Avaliac°ao de Insecticidas no Controle de Sitophilus oryzae (L.) (Coleoptera: Curculionidae), Rhyzopertha dominica (Fab) (Coleoptera: Bostrichidae) em Arroz Armazenado. *Anais da Sociedade Entomologica do Brasil* 26, 285-290.

32. Shukla, R., Singh, P., Prakash, B., Kumar, A., Mishra, P.K., Dubey, N.K., 2011. Efficacy of essential oils of *Lippia alba* (Mill.) N.E. Brown and *Callistemon lanceolatus* (Sm.) Sweet and their major constituents on mortality, oviposition and feeding behaviour of pulse beetle, *Callosobruchus chinensis L. Journal of Science Food and Agriculture*., 91: 2277-2283.

33. Singh, G., Upadhyay, R. K. (1993). Essential oils: a potent source of natural pesticides. *Journal of Scientific and Industrial Research*., 52: 676-683.

34. Subramanyam, B., Hagstrum, D. W. (1995). Resistance measurement and management. In: Subramanyam, B., Hagstrum, D.W. (Eds.). *Integrated Management of Insects in Stored Products*. Marcel Dekker, New York, 331–397.

35. Varma. J., Dubey, N.K. (2001). Efficacy of essential oils of *Caesulia axillaris* and *Mentha arvensis* against some storage pests causing biodeterioration of food commodities. *International Journal of Food Microbiology*., 68: 207-210.

36. White, N. D. G., Leesch, J. G. (1995). Chemical control. In: Subramanyam, B., Hagstrum, D.W. (Eds.), Integrated Management of Insects in Stored Products. *Marcel Dekker*, New York, 287-330.