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Review

Activity of essential oils as a biorational alternative to control coleopteran insects in stored grains

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The essential oils have been widely used as antiparasitical, bactericidal, fungicidal, antivirus and insecticidal. On the other hand the main method to control insect pest is using synthetic pesticides, but the development of insect resistance to this products, the high operational cost and environmental pollution have created the need for developing alternative approaches to control many insects pest, and in this sense the essential oils are an alternative to control many insects. This work is a review for the last five years, which shows the main essential oils from 30 botanical families with activity against coleopterans insect pest in stored grains. It was found that 22 species belong to the family Lamiaceae 17 of Asteraceae and 10 of Myrtaceae

Key words: Insecticidal, fumigant, repellent, antifeedant, activity, alternative.

INTRODUCTION

Insects are one of the major causes of grain losses during stored (Scotti, 1978). Crops loss due to insect pests varies between 10 and 30% for major crops (Ferry et al., 2004). Management of agricultural pests over the past half century has been largely depending on the use of synthetic chemical pesticides for field and post-harvest protection of crops. However, these synthetic insecticides are toxic and show adversely effects to the environment by contaminating soil, water and air, and the extensive use of these compounds has led to the development of resistance in several species, vast destruction of beneficial organisms.

In addition the documentation of negative environmental and health impact of synthetic insecticides and increasingly stringent environmental regulation of pesticides (Isman, 2000) have resulted in growing interest in research concerning the possible use of plant extracts as alternatives to synthetic insecticides. Not only might certain secondary metabolites of the plants origin be source of new pesticides, also botanical derivatives may be more environmentally benign than synthetic chemicals. Over 2000 species of plants are known to possess some insecticidal activities (Klocke, 1989). The essential oils are natural, volatile and complex compounds, its characteristic odour are formed by secondary metabolites in plants. In the nature those compounds plays an important role in the protection of the plants against bacteria, fungi, virus, insects and others herbivores. They also may attract some insects to favour the dispersion of pollens and seeds, or repel undesirable others (Bakkali et al., 2008).

There are very complex natural mixtures and can contain about 20 to 60 compounds at different concentrations, characterized by two or three major components at fairly high concentrations (20 to 70%) compared to others components present in trace amounts. Generally, these major components determine the biological properties of the essential oils. The components include two groups of distinct biosynthetical origin (Pichersky et al., 2006). The main group is composed of terpenes and terpenoids and the other of aromatic and aliphatic constituents, all characterized by low molecular weight

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(Bakkali et al., 2008).

Commercially plant essential oils are used in four primary ways: as pharmaceutical, as flavor enhancers in many food products, as odorants in fragrances, and as insecticides (Pushpanathan et al., 2006). The activities of essential oil are being investigated including their action as fumigants, repellents, antifeedants and insect growth regulators (Weaver and Subramanyam, 2000). These studies showed that essential oils and their constituents may have potential as alternative to currently used fumigants (Tunc et al., 2000). The aims of this paper were to review the biological activities of essentials oils against insect pest of stored grains, and their potential as a biorational alternative to control those pests.

Bostrichidids insects

The mortality of *Rhyzopertha dominica* (Coleoptera: Bostrichidae) was 100% for global oil (0 to 90 min), when *Mentha spicata* (Lamiaceae) essential oil was used. The composition of oil was determined. The main constituents of the oil were 79.9% carvone and 4.3% 1,8-cineole (Khalfi et al., 2006). Also the repellency to was evaluated for the essential oils from *Afromomum melegueta* (Zingiberaceae) seeds and *Zingiber officinale* (Zingiberaceae) rhizomes which were evaluated against *R. dominica* in a four-armed airflow olfatometer. Ten microlitre of both oils significantly repelled the beetles when tested singly and in combination with 5 g winter wheat grains (Ukeh, 2008). Also the essential oil was tested from *Origanum glandulosum* (Lamiaceae) against *R. dominica*, toxicity test showed that insect mortality increased with the concentration used, and the main components from this oil were thymol, carvacrol, p-cymene and γ-terpinene (Khalfi et al., 2008).

Bruchids insects

The essential oils from *Artemisia annua, Artemisia scoparia, Artemisia selengensis* and *Artemisia sieversiana* (Asteraceae) were tested against *Callosobruchus chinensis* (Coleoptera: Bruchidae). The four essential oils showed strong fumigant and contact activity, the major activity was obtained with *A. selengensis* oil (Yuan et al., 2007). On the other side Upadhyay et al. (2007) tested fourteen essential oils from *Anethum graveolense* (Apiaceae), *Azadirachta indica* (Meliaceae), *Cinnamomum cassia* (Lauraceae), *Cleome gynandra* (Cleomaceae), *Cuminum cyminum* (Apiaceae), *Carum copticum* (Apiaceae), *Cymbopogon narudus* (Poaceae), *Eugenia aromaticum* (Myrtaceae), *Foeniculum vulgarae* (Apiaceae), *Illicium verum* (Schisandraceae), *Nigella sativa* (Ranuculaceae), *Piper nigrum* (Piperaceae), *Prunus amygdalus* (Rosaceae), and *Terminalia avicenioides* (Combretaceae) against *C. chinensis*. The oils of the first seven plants were toxic to the beetle as their LC_{50} values were 1.05, 1.25, 1.05, 1.10, 1.15, 0.90 and 0.85 µl, respectively. These oils inhibited oviposition and showed repellent activity.

The essential oil from *Cymbopogon schoenanthus* (Poaceae) showed development inhibition in all stages of *Callosobruchus maculatus* (Coleoptera: Bruchidae). The concentration of 33.3 µl/l caused 100% of mortality of adults which was observed within 24 h of exposure to the oil and the development newly laid eggs and neonate larvae was also inhibited. However, the oil had variable efficacy against the bruchid instars developing inside the seeds-5-day-old larvae (63% LI and 37% LII) of *C. maculatus* (Ketoh et al., 2005). Another essential oil from *Hyptis spicigera* (Lamiaceae) were tested on *C. maculates*. Essential oil had a dose-dependent insecticidal effect while sub lethal doses were only repellent to adults, also reduced oviposition eggs viability with increasing doses. Essential oil was lethal to larvae developing within cowpea seeds, but oil activity was age-dependent, younger instars being more susceptible (Sanon et al., 2006). The activity of the essential oils of *Cymbopogon martini* (Poaceae), *Piper aduncum, Piper hispidinervium* (Piperaceae), *Melaleuca sp.* (Myrtaceae), and *Lippia gracilis* (Verbenaceae) and fixed oils of *Helianthus annuus* (Asteraceae), *Sesamum indicum* (Pedaliaceae), *Gossypium hirsutum* (Malvaceae), *Glycine max* (Fabaceae) and *Caryocar brasiliense* (Caryocaraceae) were studied against *C. maculatus* in cowpea grains. These oils were used at 10, 20, 30, 40 and 50 ml/20 g. A mortality of 100% was obtained with essential oils of *C. martinii, P. aduncum* and *L. gracillis* at all concentrations; *P. hispidinervium* at 30 to 50 ml/20 g and *Melaleuca sp* at 40 and 50 ml/20 g. The reduction in viable eggs and emerged insects was approximately 100%, except for *Melaleuca* sp. Low levels of mortality was observed with all fixed oils, but markedly reduced the number of viable eggs and emerged insects (Pereira et al., 2008). The fumigant activity of *Carum copticum* (Apiaceae) and *Vitex pseudo-negundo* (Lamiaceae) essential oils against eggs, larvae and adults of *C. maculatus* was tested. The lethal concentration of the essential oil to kill 50% of the population (LD_{50}) for egg, larvae and adult was found to be 0.90, 1.01 and 2.5 µl L^{-1} air of *C. copticum* oil, followed by 2.20, 8.42 and 9.39 µl/L air essential oil of *V. pseudo-negundo*, respectively, *C. copticum* oil was almost more toxic than *V. pseudo-negundo* on all growth stages of *C. maculatus* (Sahaf and Moharramipour, 2008). The activity of essential oils extracted of *Ageratum conyzoides* (Asteraceae), *Citrus aurantifolia* (Rutaceae) and *Melaleuca quinquenervia* (Myrtaceae) was tested by fumigation on the flightless form of the *C. maculatus*. Concentration of 6.7, 10, 16.7 and 33.3 µl/L were evaluated at a temperature of 27.5 ± 0.2°C and at a relative humidity of 80.3 ± 1.6%. These oils presented an insecticidal activity and induced, in the females of *C. maculatus*, a very significant reduction of lying (4.79 ± 0.75 with *C. aurantifolia*, 3.75 ± 0.28 with *A. conyzoides* and 1.81 ± 0.53 with *M. quinquenervia* at the lower concentration (6.7 µl/L) compared to that in the control (51.23 ± 0.32). The essential oils of *M. quinquenervia* with the LC_{50}=3.09 µl/l was more effective than that of *A. conyzoides* (8.05 µl/L) and *C. aurantifolia* (6.89 µl/L) (Nondenot et al., 2010).

Chrysomelids insects

The toxicity of essential oil of *P. aduncum*, was tested against *Cerotoma tingomarianus* (Coleoptera: Chrysomelidae). The toxicity of the oil to *C. tingomarianus* was high with: LC_{50} of 0.06 ml/cm^2 and LD_{50} of 0.002 ml/mg of the insect. For contact (filter-paper) applications, the mortality was nearly 100% at oil concentrations of 1%. Oil concentrations of 2.5 and 5% reduced the foliar consumption by the beetles. Contact application of the oil showed insecticidal effects at concentration of 0.04%. In case of topical application, this oil caused physiological problems, when used at concentrations higher than 2.5% (Fazolin et al., 2005).

The insecticidal activity and the effects on progeny production of the essential oil from *Clausena anisata* (Rutaceae) and a mixture of clay and essential oil (aromatized clay powder) on *Acanthoscelides obtectus* (Coleoptera: Chrysomelidae) were evaluated. Contact toxicity assayed by coating on bean grains showed that both caused mortality of the insect and it was dose dependant. The aromatized clay powder was more toxic (LC_{50} = 0.069 µl/g grain) than the pure essential oil (LC_{50} = 0.081 µl/g grain). The aromatized clay powder as well as essential oil considerably reduced the F1 progeny insect production. The essential oil evoked moderated repellent action and high fumigant toxicity against adults of the insect (Ndomo et al., 2008).

Twenty two components were identified from the essential oils of leaves and stems of *Croton grewioides* (Euphorbiaceae), with predominance of phenylpropanoid compounds, whose principal component was (E)-anethole. Other major components in the leaf oil were methyl eugenol and (E)-methyl isoeugenol, and in the stem oil were (E)-methyl isoeugenol, cadelene and methyl eugenol.

The insecticidal activity of the oils was evaluated against Mexican bean weevils, *Zabrotes subfasciatus* (Coleoptera: Chrysomelidae), resulting in a LD_{50} for the leaf oil, which was 3.4 times less than that obtained from the stem oil (Silva et al., 2008).

Curculionids insects

Essential oils from eight plants: *Hypericum scabrum* (Hypericaceae), *Hyssopus officinalis* (Lamiaceae), *Micromeria fruticosa* (Lamiaceae), *Origanum acutidens* (Lamiaceae), *Satureja hortensis* (Lamiaceae), *Tylenchorhynchus vulgaris, Salvia limbata,* and *Salvia nemorosa* (Lamiaceae) were tested against *Sitophilus granarius* (Coleoptera: Curculionidae) adults. The average mortality rates with a concentration of 10 µl of these essential oils were approximately 74, 66, 73, 4, 12, 7, 10 and 14% for *S. granarius*. Mortality rate increased with the concentration of the essential oils and their exposure period (Yildrim et al., 2005). Rozman et al. (2006) studied the essential oils of *Lavandula angustifolia* (Lamiaceae), *Laurus nobilis*, *Rosmarinus officinalis, and T. vulgaris,* 1,8-cineole, camphor, eugenol, linalool, carvacrol, thymol, borneol, bornyl acetate and lynalyl acetate were isolated. The compounds were tested (each at 0.1 µl/720 ml) against *S. granarius* L. on stored wheat. This insect showed very high susceptibility to all the compounds after 24 h exposure, with average mortalities of 96.5 to 100%. Farinograph analyses showed that the compounds of essential oils had no negative effect on dough properties.

Essential oils of *Acorus calamus* (Acoraceae) and *Syzygium aromaticum* (Myrtaceae) were evaluated against *Sitophilus oryzae* (Coleoptera: Curculionidae) as seed protector. The use of both essential oils exhibited inhibition of F1 progeny from 61.08 to 91.52%. Inhibition of the F1 progeny due to clove oil treatment ranged from 50.42 to 72.5%. When the oils were applied to the medium at the rate of 25 to 500 ppm, no insect infestation was observed at 500 ppm applications of clove and sweet flag oils (Sharma and Meshram, 2006). Also were tested the insecticidal effect and repellent activity of essential oils of, *Hyptis spicigera, Ocimum canum* (Lamiaceae), and *Vepris heterophyla* (Rutaceae) against *Sitophilus. oryzae*. The oil of *O. canum* was insecticidal with a LD_{50} of 42.9 ppm. The most repellent effect was obtained by a combination of the essential oils of *O. canum*, and *H. spicigera* (77.5%) (Ngassoum et al., 2007). Other essentials oils of *Echinops giganteus* (Asteraceae), *H. spicigera, O. canum* (Lamiaceae), *Plectranthus glandulosus* (Lamiaceae) and *Vepris heterophylla* (Rutaceae) were applied both alone and in balanced combinations on the adults of *S. oryzae* to evaluate their toxicity. All the essential oils were insecticide, except *Eubrontes giganteus*. Their LD_{50} varied from 42.91 ppm for the oil of *O. canum* to 349.8 ppm for the oil of *V. heterophylla*. Applied in balance combination, 20% of *O. canum* and 80% *E. giganteus* led to 100% mortality. *V. heterophylla*, relatively rich in oxygenated sesquiterpenes, increased the values of LD_{50}, which were higher and significantly different from the expected values (Ngamo et al., 2007).

Essential oils from *Ocimum gratissimum* (Lamiaceae) leaves and *Xylopia aethiopica* (Annonaceae) dried fruits were tested against *S. zeamais*. In this study the main components of *X. aethiopica* were β-pinene, terpinen-4-ol, sabinene, α-terpineol, 1,8-cineole, myrtenol and kaurane derivatives. In the case of the oil of *O. gratissimum* the major constituents were thymol, γ-terpinene, p-cymene, limonene, terpinolene and 1,8-cineole. The insecticidal activity was tested by putting 20 adults of *Sitophilus zeamais* with 20 g of maize grains powdered with various essential oils. The essential oils of *O. gratissimum* and *X. aethiopica* protect 74 and 93.3% of the test material against the insect population after 4 days, respectively. A direct application of oils on the test insects killed by knock down effect 85.7% of the weevil population with *O. gratissimum*, and 90.1% for *X. aethiopica*, after 48 h (Jirovetz et al., 2005).

In other study the essential oils from the whole and fruits of *X. aethiopica*, were tested on adults of this insect, one of the main pest in granaries in Cameroon. Concentration of 1 ml of essential oil per 100 g of maize was evaluated to determine weevil mortality after 24 h of exposure, after this time it was observed 100% of mortality. The main constituents of the oils were α-pinene, β-pinene, Δ-3-carene and terpinen-4-ol also were tested against *S. zeamais*. β-pinene and terpinen-4-ol were responsible for 50% of the mortality at the proportion found in the essential oil of the concerned plant part. The synergistic effect of the two compounds restored the activity observed for the crude oil (Kouminki et al., 2007).

Essential oil from *Tanaecium nocturnum* (Bignoneaceae) was tested against *S. zeamais*. The toxicity (LC_{50}) of the oil to *S. zeamais* was 14.1 ng/cm^2 and LC_{50} of 1,321.6 ng/g of the grains for contact and fumigant effects, respectively, and LD_{50} of 14.7 µg/mg of the insect for topical application. For contact and fumigant effects, the mortality rate was nearly 100% at oil concentrations of 2 and 5% (m/v) and 4 and 5% (m/v) respectively (Fazolin et al., 2007).

The chemical composition of the essential oils obtained by hydrodistillation of different tissues of *Piper capense*, *Piper guineense*, *Piper nigrum* and *Piper umbellatum* (Piperaceae) was compared. Oils from the fruits were rich in α-pinene (5.6 to 12.3%) and β-pinene (6.7 to 59.3%). They showed variable contact toxicity against *S. zeamais* with *P. guineense* being more toxic (LD_{50} = 10.0 ± 0.3 µl/g) than *P. capense* (LD_{50} = 16.1 ± 0.6 µl/g) and *P. nigrum* (LD_{50} = 26.4 ± 1.5 µl/g) (Tchoumbougnang et al., 2009).

Domestids insects

The insecticidal activity of the essential oil of the rhizomes of *Acorus calamus* at rates of 30, 50 and 70 µl was investigated against *Trogoderma granarium* (Coleoptera: Domestidae) on wheat grains. The insects showed 11.10, 22.59 and 44.70% mortality at exposure periods of 3, 5 and 7 days, respectively. Mortality reaches 22.18, 24.44 and 27.77% with 30, 50 and 70 µl oil, respectively. The population built up decreased with the increase in the rate of essential oil and exposure time (Mansoor-ul et al., 2006).

Tenebroids insects

The main biological activities of *Baccharis salicifolia* (Asteraceae) essential oil on *Tribolium castaneum* (Coleoptera: Tenebrioidae) were toxicity and repellency. The constituents of the oil were β-pinene, pulegone, α-terpineol. After 3 days β-pinene and pulegone showed the highest toxicity. The most repellent compound was α-terpineol (García et al., 2005). Also were tested the repellent, toxic and fumigant effects, as well as nutritional indices and feeding deterrent activities of the essential oil isolated from *Tagetes terniflora* (Asteraceae) against *T. castaneum* larvae and adults. On fifth instar the repellency increased with oil concentration. This oil was no found to be toxic to any stages evaluated. The essential oil deceased the growth rate at 0.4%, food utilization decreased at 0.4, 1 and 4% and had no effect on food consumption. In larvae, the essential oil had no activity on growth rate, food consumption and food utilization (Stefanazzi et al., 2006). Wang et al. (2006) tested the repellency and fumigant activity of the essential oil from *Artemisia vulgaris* (Asteraceae) against *T. castaneum*. The oil had significantly repellency at 0.6 µl/ml (v/v) and higher in a filter-paper arena test. Also it was found that at 8.0 µl/ml the mortality in adults was 100%, but with 12, 14 and 16 day larvae, mortalities were 49%, 53% and 52%, respectively. The oil had also high-fumigant activity against eggs. At concentrations of 10, 15 and 20 µl/l air and 96 h of exposure period the mortality was 100%. The essential oils from *P. nigrum* repelled significantly adults of *T. castaneum* at concentration of 0.2% (v:v). The LC_{50} values for larvae and adults of *T. castaneum* were 14.022 µl and 15,262 µl respectively. Effective concentration (EC_{50}) of *P. nigrum* oil reduce the number of larvae transformed to pupae was found to be 6.919 µl (Upadhyay and Jaiswal, 2007).

In other research the chemical composition of essential oil of *V. heterophylla* collected in Mokolo and Meri, two localities from Cameroon was evaluated. The oil from Meri has sabinene, E-caryophyllene, α-humulene, elemol and germacrene. The oil from Mokolo has E-cariophyllene and safole. The volume of essential oil killing half of the *T. castaneum* population tested (VL_{50}) were 49.44 µl from Mokolo and 61.2 µl from Meri (Ngamo et al., 2007). Also the repellent, toxic and developmental inhibitory activity of the essential oils from *Trachyspermum ammi* (Apiaceae), *Anethum graveolens* (Apiaceae) and *Nigella sativa* (Ranunculaceae) against *T. castaneum* were tested. The three essential oils repelled the adults of the insect at low concentrations in the filter paper repellency assay, the LC_{50} of *T. ammi*, *A. graveolens* and *Nigella sativa* essential oils against larval stages of the insect were 11.62, 14.78 and 9.46 µL respectively. The essential oils reduced the oviposition potential and increased the developmental period of the insect. Fumigation of these essential oils inhibited development of larvae to pupae and the pupae to adults and also resulted in the deformities in the different developmental stages of the insect (Chaubey, 2007). Another work showed that the compounds trans-anethol, thymol, eugenol and cinnamaldehyde presents in many plant essential oils were evaluated for contact and fumigant toxicity against adult and larvae from 10 and 18 days old of *T. castaneum*, cinnamaldehyde and eugenol were highly effective when applied for highest exposure time of 48 h at the lowest dose.

At the highest dose level of 0.288 mg cm^{-2} and lowest exposure time of 6 h, trans-anethol achieved 100% mortality of 10 day old larvae as contact toxicity, whereas highest dose of 115.38 and 6.153 mg L-1, thymol and eugenol achieved only 36.66 and 30% of 10 day old larvae and adult as fumigant toxicity. Against 18 day old larvae, eugenol and cinnamaldehyde achieved 100% of mortality after exposure for 48 h, even with the highest dose volume (Mondal and Khalequzzaman, 2010).

On the other side the fumigant toxicity of essential oils of *Laurus nobilis* (Lauraceae) and *R. officinalis* (Lamiaceae) was evaluated against all development stage of the beetle *Tribolium confusum* (Coleoptera: Tenebrionidae).

The major component of both oils was 1,8-cineole. The two essential oils were toxic to all stages of the insect. When eggs were exposed to 172.6 mg, 65% mortality was observed and the pupae were the most resistant (Isikber et al., 2006). Te flower essential oil of *Anacyclus cyrtolepidioides* (Asteraceae) pomel showed Insecticidal activity against *T. confusum* using direct contact application method (Zardi-Bergaoui et al., 2008).

Toxicity of essential oils from *P. aduncum*, *P. hispidinervium* and *T. nocturnum* was evaluated against larvae of *Tenebrio molitor* (Coleoptera: Tenebrionidae). All essential oils possessed insecticidal activity against this insect but the responses varied depending on the oil concentration and method of exposure. LC_{50} values were 0.045, 0.033 and 1.515 ml/cm^2 for *P. aduncum*, *P. hispidinervium* and *T. nocturnum* oils respectively, for the filter paper studies.

For topical effect, The LD_{50} values were 0.000025, 0.009 and 0.000015 ml/mg of the insect, respectively (Fazolin et al., 2007).

Two or more insect orders

Effectiveness repellency and toxicity of the essential oils of *Cymbopogon winterianus* (Poaceae), *Cinnamomum camphora, Matricaria chamomile* (Asteraceae), *Mentha viridis* (Lamiaceae), *P. amygdalus*, *R. officinalis* and *Simmondsia chinensis* (Simmondsiaceae) were evaluated against *Oryzaephilus surinamensis* (Coleoptera: Cucujidae) and *T. castaneum*. 100% mortality of *O. surinamensis* was obtained with the treatment with the essential oils from *M. viridis*, *M. chamomila* and *C. camphora* at concentration more than 0.5%. The treatment of 1.0% of *P. amygdalus* or *C. winterianus* gave complete mortality of *T. castaneum* after two weeks of exposure. *R. officinalis* oil was the least toxic to both insect. An increase of mortality was observed for most of the essential oils with increasing time exposure. *M. chamomila* exhibited high repellency of 81.94 and 84.73% at 1.0% concentration against *O. surinamensis* and *T. castaneum*, respectively (Al-Jabr, 2006). The essential oil from seeds of jojoba, *Simmondasia chinensis* (Simmondasiaceae) grown in Kerman (South-eastern part of Iran) was obtained by steam distillation, and it was used for efficacy on the repellency of two important stored products insects, *O. surinamensis* and *C. maculates*. The purity of used essential oil was 0.97 and the experiments were done at 0.2 ml concentration at 30 replications, by using y-shape Olfactometer and Loschiavo methods. The repellency of jojoba oil was 21.41 ± 3.44 and 11.07± 4.01 for *C. maculates* and 18. 75 ± 0.31 and 12.74 ± 1.28 for *O. surinamensis* by using y-shape Olfactometer and Loschiavo methods, respectively (Kheradmand et al., 2010).

Antifeedant and ovipositional activities of essential oil, agnuside and viridiflorol, obtained from the leaves of *Vitex negundo* (Lamiaceae) were tested against *C. chinensis* and *S. oryzae*. Essential oil was effective at concentrations with both species from 0.062 to 0.5%. Agnuside and viridiflorol were antifeedant against *S. oryzae* at 0.25% and up to 0.58 and 1.69% (Rana et al., 2005).

The effects of the essential oils *Eucalyptus citriodora, Eucalyptus globulus* and *Eucalyptus staigerana* (Myrtaceae) on oviposition and number of emerged insects of *Z. subfasciatus* and *C. maculates* was tested. The concentrations were 5, 10, 15, 20 and 25 oil µl/0.0017 m^3. The essential oils reduced the percentage of viable eggs and emerged insects of the two coleopterans species (Brito et al., 2006).

Essential oils from leaves of *Artemisia princeps* (Asteraceae) and *Cinnamomum camphora* (Lauraceae) were tested as repellent and insecticidal against *Bruchus rugimanus* (Coleoptera: Bruchidae) and *S. oryzae*. Both oils showed activities, however, their mixture (1:1) exhibited much better repellent effect at concentrations from 250 to 1000 µg/g and insecticidal activity at concentration ≥1000 µg/g against the two beetles. The oils from both plants applied individually were significantly toxic to seed germination of wheat at 500 µg/ml (Liu et al., 2006).

Essential oil vapours from *Origanum acutidens* (Lamiaceae) were tested against the adults of *Lasioderma serricorne* (Coleoptera: Anobiidae), and *S. granarius.* The amounts of essential oil were 2, 4, 6 and 8 µl/L air. The mortality was 100% at 2 µl/L air within 96 h in all life stages tested. Although the essential oil of *O. acutidens* was found to be effective against all tested insect species (Caglar et al., 2007).

The essential oil of *C. martini* was an effective repellent against the beetles, *C. chinensis* and *T. castaneum*. The oil also affected oviposition, adult development, and mortality of *C. chinensis* in cow peas. The *C. martini* oil used as fumigant did not affect viability, germination, and seeding growth of gram (garbanzo bean) (Rajesh et al., 2007).

In a fumigation chamber adult of *S. oryzae* and *R. dominica* were exposed to essential oils of *Geranium sp*. (Geraniaceae), *Cymbopogon* sp. (Poaceae) and *Mentha* sp. (Lamiaceae) at different concentrations. 100% mortality of *S. oryzae* was observed with *Mentha* oil at all concentrations with no progeny production and grain damage. The order of toxicity was *Mentha* followed by *Geranium* and *Cymbopogon*. Also 100% mortality of *R. dominica* was observed in *Mentha* oil where *Geranium* and *Cymbopogon* caused nearly of 25% mortality at the same dose (Michaelraj et al., 2007).

The insecticidal activity of the essential oil isolated from *Salvia hydrangea* (Lamiaceae), was evaluated against adults of *S. granarius* and *T. confusum*, the major pest of wheat, the oil showed 68.3 and 75.0% mortality respectively (Kotan et al., 2008).

Chemical composition and fumigant toxicity of essential oil from *Perovskia abrotanoides* (Lamiaceae) against *S. oryzae* and *T. castaneum* was determined. The predominant components in the oil were camphor (28.38%) and 1,8-cineole (23.18%). Fumigant toxicity was tested against 1 to 7 days-old adults of the insects. The mortality was increased with concentrations of 32, 161, 322, 483 and 645 µl/l air and with exposure time from 2 to 15 h. The oil at 322 µl/l air caused 100% mortality of *S. oryzae* and *T. castaneum* within 13 and 7 h exposure, respectively (Arabi et al., 2008).

Fumigant toxicity of essential oils of *Cymbopogon flexuosus* (Poaceae), *Geranium viscosissimum* (Geraniaceae) and *M. piperita* was evaluated against adult of *S. oryzae* and *R. dominica* in a fumigant chamber. At 48 h exposure 100% mortality of the *S. oryzae* was recorded at 100 and 150 µl/250 ml of peppermint oil.

Also 100% mortality was observed with *R. dominica* at doses of 50, 100, 150 and 200 µl/250 ml in hatching was observed with the three oils (Michaerraj et al., 2008).

The major chemical components of the oil of fresh leaves of *Pyrenacantha staudtii* (Icacinaceae) were tetradecanoic acid (22%), hexanoic acid, α-phellandrene (13%), and citronellol (7%). This work also revealed significant insecticidal activity of the essential oil of 80 and 60% against adults of *R. dominica* and *T. castaneum*, respectively (Falodun et al., 2009).

Essential oils of 3 genotypes of *Tagetes minuta*, six of *Tagetes patula* and 15 of *Tagetes erecta* (Asteraceae) were tested as fumigant and contact toxicity against *C. maculatus, S. oryzae* and *T. castaneum*. The three genotypes more toxic, one of each plant species were evaluated for adult toxicity, oviposition deterrence, and ovicidal and population reduction activities. The oils of *T. minuta* and *T. patula* induced 100% adult mortality for all three insect species at concentrations of 50,000 ppm and 500 µg/insect, in fumigant and contact toxicity bioassays, respectively. The essential oil of *T. minuta* deterred oviposition in *T. castaneum* by 81% and suppressed its egg hatchability by 91% at concentrations of 70,000 ppm on filter paper (Alok et al., 2005).

Essential oil of *Artemisia sieberi* (Asteraceae) was tested against *C. maculatus, S. oryzae* and *T. castaneum.* On the basis of the LC_{50}, *C. maculatus* was killed faster than *S. oryzae* and *T. castaneum*. Also persistence of half-life time of the oil for *C. maculatus* was longer than the other two insects. However, the essential oil was more repellent to *T. castaneum* than *C. maculatus, S. oryzae*. Twenty nine compounds in the oil were identified. The main constituents of the oil were chrysanthenone, camphor, 1,8-cineole, camphene, borneol, cyclohexanol acetate, trans-pinocarveol, p-cymene and trans-piperitol. The oil was applied one to seven day old adults of the insects. The LC_{50} of the oil was 1.64 µl/l to *C. maculates,* 4.41 µl/l to *S. oryzae* and 20.31 µl/l to *T. castaneum*. The mortality was increased when oil concentration and exposure time were increased. The concentration of 1.85 µl/l and exposure time of 24 h was enough to obtain 100% mortality of the three insects (Negahban et al., 2006).

Some components of essential oils of, *Lavandula angustifolia* (Lamiaceae), *L. nobilis, R. officinalis,* and *Thymus vulgaris* (Lamiaceae) are: 1,8-cineole, camphor, eugenol, linalool, carvacrol, thymol, borneol, bormylacetate and linalyl acetate. They were evaluated for fumigant activity against adults of *R. dominica*, *S. oryzae* and *T. castaneum*. 1,8-cineole, borneol and thymol were highly effective against *S. oryzae* when applied 0.1 µl/720 ml volume.

For *R. dominica* camphor and linalool were highly effective and produced 100% mortality in the same conditions. Against *T. castaneum* no oil compounds achieved more than 20% mortality after exposure for 24 h. However after 7 days exposure, the mortality was higher than 70% (Rozman et al., 2007). The major components of essential oil from *Prunus domestica* (Rosaceae) were, 2-(4-nitrophenyl) acetamide, 3-hydroxy-4-methyl pentanoic acid ethyl ester, 4-hyfroxy-3-methoxy benzene-acetic acid, octanoic acid 1- methyltridecyl ester and 6-methoxy-2-[4-hydroxybenzylidene]coumaran-3-one. The oil was toxic towards *Callosobruchus analis* (Coleoptera: Bruchidae), *R. dominica, S. oryzea,* and *T. castaneum* (Ahmed et al., 2007). The essential oils from *Eucalyptus camaldulensis, Eucalyptus intertexta* and *Eucalyptus sargentii* (Myrtaceae) were tested against three major stored-product beetles, *C. maculatus*, *S. oryzae* and *T. castaneum*. The mortality of 1 to 7 day old adults of the insects increased with concentration from 37 to 926 µl/l air and with exposure time from 3 to 24 h. The LC_{50} values of *Eucalyptus* essential oils tested in this study were ranged from 2.55 to 33.50 µl/l air (Negahban and Moharramipour, 2007).

Fumigant toxicity of the essential oil of the leaves of *C. flexuosus* was investigated on the progeny production of three major stored grain insects *R. dominica*, *S. oryzae* and *T. castaneum*. The oil had high effectiveness against *R. dominica* at doses of 0.4 to 1.0% (vol/wt) and *S. oryzae* at 1.0% as more than 90% of progeny was inhibited at these concentration while *T. castaneum* was less affected in fumigation test (Tewari and Tiwari, 2008).

DISCUSSION

In this work is showed 30 botanic families that were evaluated against coleopterans insects pest, from those the Lamiaceae family was the most used with 22 different species, then were Astereaceae with 17, and Myrtaceae with 10, and the others 26 families are less of 7 species. The essentials oils are used to control seven families of coleopterans insects such as: Bostrichidae, Bruchidae, Chrysomelidae, Cucujidae, Curculionidae, Domestidae and Tenebroidae.

Only 16 species of the plants of this review have the composition of their essential oils, one of the most frequently component is 1,8-cineole, which was found in 7 of these essential oils, follow for β-pinene appears at 6 and α-pinene and camphor at 5, These four compounds have been tested against some insect species and all of them showed activity (Khalfi et al., 2006; Rozman et al., 2006; Kouminki et al., 2007; Arabi et al., 2008; Tchoumbougnang et al., 2009).

The essential oils composition could be different in the same plant, for example in *Xylopia aethiopica* Kouminki et al. (2007) it was found that the main constituents were α-pinene, β-pinene, Δ-3-carene and terpinen-4-ol. While Jirovetz et al. (2005) found that main components of this plant were β-pinene, terpinen-4-ol, sabinene, α-terpineol, 1,8-cineole, myrtenol and kaurane. Both works share only β-pinene and terpinen-4-ol. This fact could be due that the plant was collected in different places.

The use of essential oils as alternative to control coleopterans insects in stored grains are a sustainable alternative because they come from natural resources. Those oils could act as a contact toxic, fumigant, repellent, antifeedant, oviposition inhibition, etc (Stefanazzi et al., 2006; Werdin-González et al., 2008), some researches have demonstrated that essential oils have neurotoxic, citotoxic, phototoxic and mutagenic action among others in different organism (Isman, 2000; Bakkali et al., 2008), and the essential oils act at multiple levels in the insects, so the possibility of generating resistance is little probable (Gutiérrez et al., 2009). For all these reasons, we can infer that the essential oils could be considered as a natural alternative in the control of stored grains insects.

REFERENCES

Al-Jabr AM (2006). Toxicity and repellency of seven plant essential oils to *Oryzaephilus surinamensis* (Coleoptera: Silvanidae) and *Tribolium castaneum* (Coleoptera: Tenebrioidae). Scientific J. King Faisal Uni., 7(1): 49-60.

Alok K, Veena P, Bhasney S, Tripathi AK, Sushil K (2005). Potential toxicity of new genotypes of *Tagetes* (astereaceae) species against stored grain insect pest. Intern. J. Trop. Inscect Sci., 25(2): 122-128.

Ahmed R, Mahmood A, Rashid F, Ahmad Z, Nadir M, Naseer Z, Kosar S (2007). Chemical constituents of seed (kernel) of *Prunus domestica* and their insecticidal and antifungal activities. J. Saudi Chem. Soc., 11(1): 121-130.

Arabi F, Moharramipour S, Sefidkon F (2008). Chemical composition and insecticidal activity of essential oil from *Perovskia abrotanoides* (Lamiaceae) against *Sitophylus oryzae*(Coleoptera: Curculionidae) and *Tribolium castaneum* (Coleoptera: Tenebrionidae). Intern. J. Trop. Insect Sci., 28(3): 144-150.

Bakkali F, Averbeck S, Averbeck D, Idaomar M (2008). Biological Effects of Essential oils-A review. Food Chem. Toxicol., 46:446-475.

Brito JP, Baptistussi RC, Funichelo M, Oliveira JEM, Bortoli SA (2006). Effect of essential oils of *Eucalyptus spp*. under *Zabrotes subfasciatus* (Both., 1833) (Coleoptera: Bruchidae) and *Callosobruchus maculatus* (Fabr., 1775) (Coleoptera: Bruchidae) in two beans species. Bol. Sanidad Veg. Plagas., 32(4): 573-580.

Caglar Ö, Calmasur Ö, Asian I, Kaya O (2007). Insecticidal effect of essential oil of *Origanum acutidens* against several stored product pests. Fresenius Environ. Bull., 15: 1395-1400.

Chaubey MK (2007). Insecticidal activity of *Trachyspermum ammi* (Umbelliferae), *Anethum graveolens* (Umbelliferae) and *Nigella sativa* (Ranunculaceae) essential oils against stored-product beetle *Tribolium castaneum* herbst (Coleoptera: Tenebrionidae) Afri. J. Agric. Res., 2(11): 596-600.

Falodun A, Siraj R, Choudhary MI (2009). GC-MS Analysis of insecticidal leaf essential oils of *Pyrenacantha Staudtii* Hutch and Dalz (Icacinaceae). Trop. J. Pharma. Res., 8(2): 139-143.

Fazolin M, Estrela JLV, Catani V, Lima MS, Alécio MR (2005). Toxicity of *Piper aduncum* oil to adults of *Cerotoma tingomarianus* Bechyné (Coleoptera: Chrysomelidae). Neotrop. Entomol., 34(3), 485-489.

Fazolin M, Estrela JLV, Catani V, Alécio MR, Lima MS (2007). Insecticidal properties of essential oils of Piper aduncum L., P. hispidinervium C. DC and Tanaecium nocturnum (Barb. Rodr.) Bur. & K, Shum against Tenebrio molitor L, 1758. Ciên. agrotec., 31(1): 113-120.

Ferry N, Edwards MG, Gatehouse JA, Gatehouse AMR (2004). Plant-insect interaction: molecular approaches to insect resistance. In: Sasaki, T., Christou P. (Eds), Biotechnol., 15: 155-161.

García M, Donadel OJ, Ardanaz CE, Tonn CE, Sosa ME (2005). Toxic and repellent effects of *Baccharis salicifolia* essential oil on *Tribolium castaneum*. Pest Manage. Sci., 61(6): 612-618.

Gutiérrez MM, Stefazzi N, Werdin-González J, Benzi V, Ferrero AA (2009). Actividad fumigante de aceites esenciales de Schinus molle (Anacardiaceae) y Tagetes terniflora (Asteraceae) sobre adultos de *Pediculus humanus* capitis (Insecta; Anoplura; Pediculidae). BLACPMA, 8(3): 176-179.

Isikber AA, Alma MH, Kanat M, Karci A (2006). Fumigant toxicity of essential oils from *Laurus nobilis* and *Rosmarinus officinalis* against all the stages of *Tribolium confusum*. Phytoparasitica., 34(2): 167-177.

Isman MB (2000) Plant essential oils for pest and disease management. Crop Protection, 19: 603-608.

Jirovetz L, Buchbauer G, Ngassoum MB, Ngamo LT, Adjoudji O (2005). Combined investiagtion of the chemical composition of essential oils of *Ocimum gratissimum* and *Xylopia aethiopica* from Cameroon and their insecticidal activities against stored maize pest *Sithophilus zeamais*. Ernährung., 29(2): 55-60.

Ketoh GK, Koumaglo HK, Glitho IA (2005). Inhibition of *Callosobruchus maculatus* (F.) (Coleoptera:Bruchidae) development with essential oil extracted from *Cymbopogon schoenanthus* L. Spreng. (Poaceae), and wasp *Dinarmus basalis* (Rondani) (Hymenoptera: Pteromalidae). J. Stored Prod. Res., 41(4): 363-371.

Khalfi O, Sahraoul N, Bentahar F, Boutekedjiret C (2008). Chemical composition and insecticidal properties of *Origanum glandulosum* (Desf) essential oil from Algeria. J. Sci. Food Agric., 89(9): 1562-1566.

Khalfi O, Benyoussef E, Yahiaoui N (2006). Extraction, analysis and insecticidal activity of spearmint essential oil from Algeria against *Rhyzopertha dominica* (F.). J. Essen. oil-Bearing Plants. 9(1): 17-21.

Kheradmand K, Sadat NSA, Sabahi G (2010). Repellent effects of essential oil from *Simmondasia chinensis* (Link) against *Oryzaephilus surinamensis* Linnaeus and *Callosobruchus maculates* Fabricius. Res. J. Agri. Sci., 1(2): 66-68.

Klocke JA (1989). Plant compounds as source and models of insect-control agents. In: Hostettmann, K. (Ed.), Economic and Medicinal Plant Research. Academic Press, London, pp. 103-144.

Kotan R, Kordall S, Cakir A, Kesdek M, Kaya Y, Kilic H (2008). Antimicrobial and insecticidal activitues of essential oil isolated from Turkish *Salvia hydrangea* D.C., ex Benth. Biochem. Systemat. Ecol., 36: 360-369.

Kouminki H, Hance T, Noudjou FA, Lognay G, Malaisse F, Ngassoum MB, Mapongmetsem PM, Ngamo lST, Haubruge E (2007). Toxicity of some terpenoids of essential oil of *Xylopia aethiopica* from Cameroon against *Sithophilus zeamais* Motschulsky. J. Appl. Entomol., 131(4): 269-274.

Liu CH, Mishra AK, Tan RX, Tang C, Yang H, Shen YF (2006). Repellent and insecticidal activities of essential oils from *Artemisia princeps* and *Cinnamomum camphora* and their effect on seed germination of wheat and broad bean. Biosour. Technol., 97(15): 1969-1973.

Mansoor-Ul H, Sagheer M, Ullah E, Ahmad F, Wakil W (2006). Insecticidal activity of diferent doses of *Acorus calamus* oil against *Trogoderma granarium* (Everts). Pak. J. Agric. Sci., 43: 55-58.

Michaelraj S, Kirti S, Sharma RK (2007). Fumigation toxicity of some phyto essential oils against stored insect pests of maize. Pestic. Res. J., 19(1): 9-14.

Michaerraj S, Sharma K, Sharma RK (2008). Fumigat toxicity of essential oils against key pests of stored maize. Ann. Plant Prot. Sci., 16(2): 356-359.

Mondal M, Khalequzzaman M (2010). Toxicity of naturally occurring compounds of plant essential oil against *Tribolium castaneum* (Herbst). J. Biol. Sci., 10(1): 10-17.

Ndomo AF, Ngamo LT, Tapondjou LA, Tchouanguep FM, Hance T (2008). Insecticidal effects of the powdery formulation based on clay and essential oil from leaves of Clausena *anisata* (Willd) J.D. ex. Benth (Rutaceae) against *Acanthoscelides obtectus* (Say) Hook (Coleoptera; Bruchidae). J. Pest Sci., 81(4): 227-234.

Negahban N, Moharramipour S, Sefidkon Fl (2006). Insecticidal activity and chemical composition of *Artemisia sieberi* Besser essential oil from Karaj. Iran. J. Asia-Pacific Entomol., 9(1): 61-66.

Negahban M, Moharramipour S (2007). Fumigant toxicity of *Eucalyptus intertexta, Eucalyptus sargentii* and *Eucalyptus camaldulensis*, J. Appl. Entomol., 131(4): 256-261.

Ngamo TSL, Ngatanko I, Ngassou MB, Mapongmestem PM, Hance T (2007). Insecticidal efficiency of essential oils of 5 aromatic plants tested both alone and in combination towards *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae). Res. J. Biol. Sci., 2(1): 75-80.

Ngamo TSL, Noudjou WF, Ngassoum MB, Mapongmestsem PM, Boubakary ABA, Malaisse F, Haubruge E, Lognay G, Hance T (2007). Investigations on both chemical composition and insecticidal activities of essential oils of *Vepris heterophylla* (Rutaceae) from two localities of Northen Cameroon towards *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). Res. J. Biol. Sci., 2(1): 57-61.

Ngassoum MB, Tinkeu LSN, Ngatanko L, Tapondjou LA, Lognay G, Malaisse F, Hance T (2007). Chemical composition, insecticidal effect and repellent activity of essential oils of three aromatic plants, alone and in combination, towards *Sitophilus oryzae* L. (Coleoptera: Curculionidae). Nat. Prod. Comm., 2(12): 1229-1232.

Nondenot ALR, Seri-Kouassi BP, Kouakou KH (2010). Insecticidal Activity of Essential Oils from Three Aromatic Plants on *Callosobruchus Maculatus* F. in Côte D'ivoire. Eur. J. Sci.Res., 39(2): 243-250.

Pereira ACRL, Oliverira JV, Gondim Junior MGC, Cămara CAG (2008). Insecticide activity of essential and fixed oils in *Callosobruchus maculatus* (Fabr., 1775) (Coleoptea: Bruchidae) in cowpea grains *Vigna unguiculata* (L.) Walp. Ciencia Agrotec., 32(3): 717-724.

Pichersky, E., Noel, J.P., Dudareva, N., 2006. Biosynthesis of plant volatiles: nature's diversity and ingenuity. Sci.,311, 808–811.

Pushpanathan T, Jebanesan A, Govindarajan M (2006). Larvicidal, ovicidal and repellent activities of *Cymbopogan citrates* Stapf (Graminae) essential oil against the filarial mosquito *Culex quinquefasciatus* (Say) (Diptera: Culicidae). Trop. Biomed., 23: 208-212.

Rajesh K, Manisha S, Dubey NK (2007). Evaluation of *Cymbopogon martinii* oil extract for control of postharvest insect deterioration in cereals and legumes. J. Food Protect., 70(1): 172-178.

Rana VS, Rashmi, Rameshwar D (2005). Antifeedant and ovipositional activities of *Vitex negundo* leaves against *Sitophilus oryzae* and *Callosobruchus chinensis*. Shashpa., 12(2): 117-121.

Rozman V, Kalinovic I, Korunic Z (2007). Toxicity of naturally occurring compounds of Lamiaceae and Lauraceae to three stored product insect. J. Stored Prod. Res., 43(4): 349-355.

Rozman V, Kalinovic I, Liska A (2006). Insecticidal activity of some aromatic plants from Croatia against granary weevil (*Sitophilus granarius* L) on stored wheat. Cereal Res. Comm., 34: 705-708.

Sahaf BZ, Moharramipour S (2008). Fumigant toxicity of *Carum copticum* and *Vitex pseudo-negundo* essential oils against eggs, larvae and adults of *Callosobruchus maculatus*. J. Pest Sci., 81(4): 213-220.

Sanon A, Iboudo Z, Dabire CLB, Nebie RCH, Dicko IO, Monge JP (2006). Effects of *Hyptis spicigera* Lam. (Labiatae) on the behaviour and development of *Callosobruchus maculatus* F. (Coleoptera: Bruchidae), a pest of stored cowpeas. Int. J. Pest Manag., 52(2): 117-123.

Scotti G (1978). Les insectes et les acariens des céréales stokées. ITCF/AFNOR, Paris, p.238.

Sharma K, Meshram NM (2006). Bioactive of essential oils from *Acorus calamus* Linnaeus and *Syzygium aromaticum* Linnaeus against *Sitophilus oryzae* (Linnaeus) in stored wheat. Biopest. Intern., 2(2): 144-152.

Silva CGV, Zago HB, Júnior HJGS, Camara CAG, Oliveira JV (2008). Composition and insecticidal activity of the essential oil of *Croton grewioides* Baill. against Mexican bean weevil (*Zabrotes subfaciatus* Boheman). J. Essential oil Res., 20(2): 179-182.

Stefanazzi N, Gutierrez MM, Stadler T, Bonini NA, Ferrero AA (2006). Biological activity of essential oil of *Tagetes terniflora* Kunth (Astereaceae) against *Tribolium castaneum* Herbst (Insecta, Coleoptera, Tenebrionidae). Bol. Sanidad Veg. Plagas. 32(3): 439-447.

Tchoumbougnang F, Jazet DPM, Sameza ML, Fombotioh N, Wouatsa NAV, Amvam ZPH, Menut C (2009). Comparative essential oils composition and insecticidal effect of different tissues of *Piper capense* L., *Piper guineense* Schum. et Thonn., *Pipper nigrum* L. and *Piper umbellatum* L. grown in Cameroon. Afr. J. Biotech., 8(3): 424-431.

Tewari N, Tiwari SN (2008). Fumigant toxicity of lemon grass,

Cymbopogon flexuosus (D.C.) Stapf oil on progeny production of *Rhyzopertha dominica* F., *Sitophilus oryzae* L. and *Tribolium castaneum* Herbst. Environ. Ecol., 26 (4A): 1828-1830.
Tunc I, Berger BM, Erler F, Dagli F (2000). Ovicidal activity of essential oils from five plants against two stored-product insects. J. Stored Prod. Res., 36: 161-168.
Ukeh DA (2008). Bioactivities of essential oils of *Afromomum melegueta* and *Zingiber officinale* both (Zingiberaceae) against *Rhyzopertha dominica* (Fabricius). J. Entomol., 5(3): 193-199.
Upadhyay RK, Gayatri J, Neeraj Y (2007). Tocixity, repellency and
oviposition inhibitory activty of some essential oils against *Callosobruchus chinensis*. J. Appl. Biosci., 33(1): 21-26.
Upadhyay RK, Jaiswal G (2007). Evaluation of biological activities of *Piper nigrum* oil against *Tribolium castaneum*. Bull Insec., 60(1): 57-61.
Wang J, Zhou XM, Niu CY, Lei CL (2006). Repellent and fumigant activity of essential oil from *Artemisia vulgaris* to *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). J. Stored Prod. Res., 42(3): 339-347.
Weaver DK, Subramanyam B (2000). Botanicals. In: Alternative to pesticides in stored-product IPM. Ed. by Subramanyam BH, Hagstrum DW, Kluwer Academic Publishers, MA, pp 303-320.
Werdin-González JO, Murray AP, Ferrero AA (2008). Bioactividad de aceites esenciales de *Schinus molle* var. *areira* (Anacardiaceae) en ninfas II de Nezara viridula (Hemiptera: Pentatomidae). Bol San Veg., (Plagas). 34: 367-375.
Yildrim E, Kesdek M, Asian I, Calmasur O, Sahin F (2005). The effect of essential oils from eight plant species on two pests of stored product insects. Fresenius Environ. Bull., 15(1): 23-27.
Yuan HB, Shang LN, Zhao DX, Ren BZ (2007). Insecticidal activity of extracts from four species of *Artemisia* against *Callosobruchus chinensis*. J. Jilin Agric. Univ. 29(6): 612-615.
Zardi-Bergaoui A, Hammani S, Halima-Kamel MB, Sakka-Rouis L, Boussaada O, Haouas D, Mighri Z (2008). Insecticidal activities of flowerheads of *Anacyclus cyrtolepidioides* pomel growing in Tunnisia against *Tribolium confusum* du Val. J. Entomol., 5(4): 277-283.