Repellent activity of some essential oils against two stored product beetles *Callosobruchus chinensis* L. and *C. maculatus* F. (Coleoptera: Bruchidae) with reference to *Chenopodium ambrosioides* L. oil for the safety of pigeon pea seeds

Abhay K. Pandey · Uma T. Palni · N. N. Tripathi

Revised: 8 November 2012 / Accepted: 9 November 2012 / Published online: 4 December 2012
© Association of Food Scientists & Technologists (India) 2012

Abstract Essential oils from 35 aromatic and medicinal plant species of Gorakhpur Division (U. P., India) were evaluated for their repellent activity against pulse bruchids *Callosobruchus chinensis* L. and *C. maculatus* F. of stored pigeon pea seeds. The oil concentration was at 0.36 µl/ml. Out of 35 essential oils, *Adhatoda vasica* Ness and *Chenopodium ambrosioides* L. oils showed absolute (100 %) insect repellency. *Chenopodium* oil exhibited 100 % mortality for both the test insects at 10 µl concentration (LD_{50} =2.8 µl for *C. chinensis* & 2.5 µl for *C. maculatus*) and more toxic than *Adhatoda* oil (LD_{50} =6.8 µl for *C. chinensis* & 8.4 µl for *C. maculatus*). During in vivo evaluation, 0.29 and 0.58 µl/ml of *Chenopodium* oil significantly enhanced feeding deterrence in insects and reduced the seed damage as well as weight loss of fumigated pigeon pea seeds up to 6 months of storage as compared to control set. Thus, *Chenopodium* oil can be used as an effective option of commercial fumigants for the storage of pigeon pea seeds against pulse bruchids.

Keywords Essential oils · *Callosobruchus* spp · Pigeon pea seeds · *Chenopodium ambrosioides*

Introduction

Deterioration of pulses provoked by insects accounts for considerable loss of economic importance at international level. The bruchid, *Callosobruchus* species (Coleoptera: Bruchidae) is a cosmopolitan field-to-store pest ranked as the principal post harvest pest (Dongre et al. 1993). It causes substantial quantitative and qualitative loss, manifested by seed perforation, reduction in weight, market value and germinability of seeds. About 10–40 % of the total annual production valued at billions of US dollars are lost annually alone to *Callosobruchus* species in tropical countries (Ukeh and Mordue 2009). In order to manage the deterioration, more and more synthetic fumigants are being used, but unfortunately they posed various side effects on human health like carcinogenicity, teratogenicity, hormonal imbalance etc. (Unnikrishnan and Nath 2002). With the limitations on the use of current pest control methods, there is scope for the discovery of safe, non-polluting, bio-rational pest management technologies for stored products. The use of botanical pesticides in pulse protection has a long account (Verma and Dubey 1999; Rajendran and Srianjini 2008) and there are a number of bibliographic records on the use of essential oils from different plants against stored product insect pests by researchers in developing countries were found (Rajapakse and Vaneben 1997; Kim and Ahn 2001; Rajashekar et al. 2010; Devi and Devi 2011; Jaya et al. 2012). So far, the effect of plant essential oils on *Callosobruchus* species has been investigated using fumigant toxicity (Park et al. 2003), repellent activity (Mishra et al. 2002; Radha and Murugan 2011) as well as antifeedant activity (Kumar et al. 2008).

Pigeon pea (*Cajanus cajan* L. Millsp) is a legume of semiarid tropics. It is cultivated in more than 25 tropical

A. K. Pandey (✉) · N. N. Tripathi
Bacteriology and Natural Pesticide Laboratory,
Department of Botany, DDU Gorakhpur University,
Gorakhpur 273009 Uttar Pradesh, India
e-mail: abhaykumarpandey.ku@gmail.com

N. N. Tripathi
e-mail: nijendratripathi@rediffmail.com

U. T. Palni
Department of Botany, D. S. B. Campus, Kumaun University,
Nainital 263002 Uttarakhand, India

and sub-tropical countries of the world (Reddy et al. 1993). It is a major source of protein and other essential nutrients like lysine, riboflavin, thiamine, niacin, and iron in the areas where it is cultivated. India is the world's largest producer of pigeon pea and accounts 75 % of total worldwide production. India produces about 2.0–2.5 million tonnes of pigeon pea yearly. Major losses of pigeon pea during storage by pulse beetles affect overall production by Indian farmers. This loss is expected to be 7–10 % at the farm to market level and 4–5 % at market and distribution level (Anonymous 2011). This loss constitutes 12–16 million tonnes of grain for which average annual per capita utilization is approximately 15 kg. North-eastern Uttar Pradesh is ideal for pigeon pea cultivation, but due to high humidity and warm storage conditions there is decrease in shelf life of pigeon pea seeds during storage due to infestation caused by *Callosobruchus* species such as *C. chinensis* and *C. maculatus*. Therefore, the present study was performed to evaluate repellent activity of some essential oils isolated from aromatic plants of Gorakhpur Division (U.P., India) against aforesaid pests of pigeon pea seeds in order to find some effective botanicals. Insecticidal activity of more potent oils and in vivo preservation of pigeon pea seeds with most active oil were also investigated.

Materials and methods

Insect rearing

Rearing of the both *Callosobruchus* species was carried out separately in glass containers at Bacteriology and Natural Pesticide Lab, Department of Botany, DDU Gorakhpur University, Gorakhpur under the environment conditions of 28 ± 2 °C and 75 ± 5 % RH (Shukla et al. 2007). To obtain newly emerged bruchids of same generation, 40 adults were released in a container having 250 g of pigeon pea seeds covered by a muslin cloth. The insects emerged after 3–4 weeks were used during the entire experiments.

Essential oil extraction

Thirty five indigenous aromatic and medicinal plant species were procured from Gorakhpur Division (U.P., India) during 2008–2009, and identified with the help of Flora Gorakhpurensis (Srivastava 1976) as well as by matching their specimens lodged in the herbarium of BSI (NRC) Dehradun. Essential oils from fresh parts of collected plant species (300 g each) were extracted separately using Clevenger's apparatus at 90 ± 2 °C for 4 h. Each essential oil was dried over anhydrous sodium sulphate and was stored at 4 °C in clean glass vial for further experimentation.

Repellency bioassay

Essential oils were assessed for their repellent activity against insects *Callosobruchus chinensis* and *C. maculatus* following the method of Tripathi and Kumar (2007) using 'Y' tube Olfactometer separately. Requisite amount of the oil (0.36 µl/ml) from each plant was soaked in cotton swab and introduced in one arm of 'Y' tube of Olfactometer separately. Water soaked cotton swab was placed in other arm as control set. 20 individuals of each test insects were obtained from reared culture, and introduced separately into basal arm of 'Y' tube Olfactometer in 4 batches at interval of 10 min each to avoid mutual interference. The repellent activity of oil was recorded in terms of per cent repellency (Per cent repellency = $\frac{NC - NT}{NC} \times 100$, where NC and NT are number of individual in control and treatment arms of Olfactometer respectively) after 30 min of interval.

Insecticidal bioassay

The insecticidal activity of potent oils was determined against *C. chinensis* and *C. maculatus* following Kumar et al. (2008). Different amounts of oil (5, 10 and 20 µl) were soaked in filter paper discs (10 mm diam) separately and pasted on inner surface of the cover of the pre-sterilized Petri plates containing 5 g of pigeon pea seeds along with a group of ten insects. Similarly, a control set was also maintained without oil. In order to get tidal nature of the oil, the insect revival was observed after transferring them onto fresh Petri plates. Experimental set up for both the insects was done separately. The incubation temperature was at 28 ± 2 °C and 75 ± 5 % RH. The per cent mortality of insects was recorded at interval of 24 h of exposure.

In vivo toxicity of *Chenopodium ambrosioides* oil against pulse bruchids

Experiment was conducted following the method of Shukla (2009). To find out practical applicability of *Chenopodium* oil as fumigant for the protection of pigeon pea seeds from insect infestation, freshly harvested pigeon pea seeds of local variety (Ramarhara) were collected from village of Gorakhpur district during 2009–2010 in polyethylene bags. The moisture content of the seeds was determined by oven drying method. Different amounts of *Chenopodium* oil were soaked in cotton swabs so as to procure concentrations of 0.29 and 0.58 µl/ml and introduced separately in pre-sterilized gunny bags and glass containers (35 cm diameter × 16 cm) with 1 kg of pigeon pea seeds for fumigation. Likewise two other sets were prepared by treating pigeon pea seeds with synthetic fumigants (aluminium phosphide and ethylene dibromide, purchased from market) for comparison purpose. The non fumigated seeds were kept as control set. Each set was kept in triplicates.

The containers were made airtight and stored in a seed storage cabinet in laboratory at 28 ± 2 °C and 75 ± 5 % RH for 6 months. Efficacy of the oil and synthetic fumigants in control of pigeon pea seed's infestation was assessed by weight loss, seed damage (Parkin 1956) and by calculating feeding deterrence index (Isman et al. 1990).

Statistical analysis

All the experiments were carried out in triplicates and data were subjected to standard deviation. Data were also

subjected to analysis of variance ($p<0.05$) and the means were separated using Duncan's multiple range test. Probit analysis was used for the estimation of LD_{50} .

Results and discussion

During insect repellent activity a considerable variation in repellent activity among oils and insect species was observed. On one hand *Adhatoda* and *Chenopodium* oils exhibited 100 % repellency against test insects by contrast,

Table 1 Insect repellent activity of essential oils of aromatic plants of Gorakhpur Division

Plant species (essential oils) ^a	Part used	Family	Per cent repellency	
			<i>Callosobruchus chinensis</i> L.	<i>C. maculatus</i> F.
<i>Adhatoda vasica</i> Ness	L	Acanthaceae	100±0.00 ^b	100±0.00 ^b
<i>Aegle marmelos</i> (L.) Corr	„	Rutaceae	52.2±1.2	45.0±1.5
<i>Anisomeles indica</i> (L.)Kuntz	L	Lamiaceae	83.3±0.58 ^b	78.1±0.58 ^b
<i>Annona squamosa</i> Linn.	„	Annonaceae	40.0±2.0	34.8±2.6
<i>Ashphodelus tenuifolius</i> Cav.	W	Liliaceae	34.0±2.0	9.0±0.82
<i>Azadirachta indica</i> A. Juss	L	Meliaceae	60.9±1.0	71.4±1.0
<i>Callistemon lanceolatus</i> (R.Br)DC	L	Myrtaceae	69.6±1.1	59.4±2.0
<i>Chenopodium ambrosioides</i> Linn.	T	Chenopodiaceae	100±0.00 ^b	100±0.00 ^b
<i>Chrysanthemum indicum</i> (L)DC	„	Asteraceae	50.0±2.0	64.0±1.0
<i>Citrus aurantium</i> Linn	„	Rutaceae	26.7±1.5	60.9±1.0
<i>Cleome gynandra</i> (L.) Briq.	L	Capparidaceae	73.9±1.0 ^b	43.3±1.5
<i>Cotula anthemoides</i> Linn.	„	Asteraceae	44.4±1.5	40.0±4.5
<i>Curcuma aromatica</i> Salisb.	L	Zingiberaceae	45.5±1.7	55.0±1.0
<i>Cyperus triceps</i> (Rottb.)Endl.	W	Cyperaceae	21.3±1.5	20.5±2.0
<i>Erigeron bonariensis</i> Linn	„	Asteraceae	30.0±1.7	63.6±1.2
<i>E. canadensis</i> Linn	„	„	42.8±1.7	62.5±1.0
<i>Gynura crepidioides</i> Benth.	T	„	34.6±1.0	5.8±1.0
<i>Hygrophila difformis</i> Linn.	„	Acanthaceae	79.2±1.2 ^b	75.0±1.0
<i>H. pinnatifida</i> Dalz.	„	„	13.8±0.21	21.7±2.3
<i>Lawsonia inermis</i> Linn.	„	Lythraceae	7.0±0.52	30.0±2.0
<i>Leucas cephalotes</i> Spreng.	W	Lamiaceae	75.0±1.0 ^b	45.8±1.5
<i>Melia azedarach</i> Linn.	T	Meliaceae	31.0±1.0	59.1±1.0
<i>Murraya koenigii</i> Spreng.	L	Rutaceae	36.0±1.0	3.0±0.52
<i>M. paniculata</i> (L)Jack	„	„	31.6±0.57	30.0±1.5
<i>Piper longum</i> Linn.	„	Piperaceae	47.8±1.0	52.2±1.1
<i>P. methysticum</i> Linn.	„	„	34.5±1.0	56.5±1.2
<i>P. sylvaticum</i> Roxb.	„	„	33.3±1.0	65.2±0.58
<i>Pogostemon heyneanus</i> Benth.	„	Lamiaceae	47.4±1.1	52.2±2.0
<i>P. plectranthoides</i> Desf.	„	„	38.8±1.2	59.1±1.0
<i>Psidium guajava</i> Linn.	„	Myrtaceae	45.5±1.0	50.0±1.5
<i>Putranjiva roxburghii</i> Wall.	„	Euphorbiaceae	56.5±0.58	40.0±1.0
<i>Saraca indica</i> Linn.	„	Caesalpiniaceae	58.3±2.0	57.9±1.2
<i>Syzygium cumini</i> (L)Skeels	„	Myrtaceae	37.5±1.6	53.3±2.5
<i>Tagetes erecta</i> Linn.	„	Asteraceae	31.6±0.57	20.0±2.0
<i>Xanthium strumarium</i> Linn.	„	„	80.0±1.5 ^b	31.8±1.0

T twig, l leaf, w whole part

^aoil concentration- 0.36 µl/ml, n=3

^bSignificantly different at $p<0.05$

Table 2 Insecticidal activity of *A. vasica* and *C. ambrosioides* oils against pulse bruchids

Essential oils	Oil concentration (μl)	Pulse bruchids			
		<i>Callosobruchus chinensis</i>		<i>C. maculatus</i>	
		Per cent mortality	LD ₅₀ value (μl)	Per cent mortality	LD ₅₀ value (μl)
<i>A. vasica</i>	5	43.6±0.57 ^c	6.8	34.6±0.39 ^c	8.4
	10	69.6±1.2 ^b		64.5±1.5 ^b	
	20	82.3±2.0 ^a		79.6±1.7 ^a	
<i>C. ambrosioides</i>	5	86.6±0.00 ^a	2.8	93.3±0.00 ^a	2.5
	10	100±0.00 ^a		100±0.00 ^a	
	20	100±0.00 ^a		100±0.00 ^a	

n=3, Within individual row values with different superscript are significantly different with each other at *p*<0.05

some essential oils viz., *Lawsonia inermis* (7 %) for *C. chinensis* and *Ashphodelus tenuifolius* (9 %), *Gynura crepidioides* (5.8 %), *Murraya koenigii* (3 %) for *C. maculatus* showed poor repellency (<10 %). The essential oils of *Anisomeles* and *Hygrophila* showed more than 75 % insects repellency against both insect species while *Xanthium* oil showed 80 % repellent activity for *C. chinensis* only (Table 1). This differentiation of toxicity among the oils may be due to differences in their chemical constituents present in oils. Using same pathogens, Tiwari et al. (1998) recorded 100 % repellency of *Cinnamomum zeylanicum* at 0.004 % concentration for *C. chinensis*. The repellent activity of *Placanthus grandifolius* was 84 % for *C. maculatus* (Mikolo et al. 2009). These variations in repellency may be due to variation of host range of *Callosobruchus* species. The repellent plants may contain certain active volatile compounds that elicit antifeedant behaviour by the visiting insects.

During insecticidal bioassay, *Adhatoda* and *Chenopodium* oils applied at dose of 5 μl caused significant (*p*<0.05) mortality of test insects within 24 h treatment as compared to control set (Table 2). *Chenopodium* oil was more toxic towards both insects than *Adhatoda* oil and exhibited 100 % mortality at 10 μl. Table also shows that LD₅₀ values of *Chenopodium* oil were 2.8 μl for *C. chinensis* & 2.5 μl for

C. maculatus and were less than *Adhatoda* oil (LD₅₀=6.8 μl for *C. chinensis* & 8.4 μl for *C. maculatus*).

Naturally occurring compounds can affect the physiology of insects or modify their behaviour. Either the compounds in the vapour phase (volatile) or non-volatile compounds can affect insects to change their behaviour. Those compounds can impede development, kill insects or cause losses in fecundity or viability of egg production and, therefore, reduce the number of offspring. They may act by ingestion, cuticle contact or fumigant action (Radha and Murugan 2011). It has investigated that the insecticidal constituents of many plant essential oils are terpenoids. Due to their high volatility they have fumigant activity that might be of importance for controlling stored-product insects. Recently, chemical analysis of *Chenopodium* oil revealed that oil was mixture of α-terpinene (37.7 %), *p*-cymene (16.7 %), limonene (1.9 %), isoascaridole (2.5 %) and ascaridole (38.03 %) as major constituents (Pandey et al. 2012). In present study, *Chenopodium* oil exhibited greater insecticidal activity with regard to both insect species than *Adhatoda* oil. Moreover, *C. ambrosioides* oil also reported to exhibit ovipositional, ovicidal and antifeedant properties (Pandey et al. 2011) against *Callosobruchus* species in our earlier research. The toxic effect of *C. ambrosioides* oil could be attributed to presence of chemical constituents such as

Table 3 Per cent weight loss & seed damage of 6 months stored pigeon pea seeds treated with *Chenopodium* oil and synthetic fumigants

Treatment	Concentration in μl/ml	Per cent weight loss		Per cent seed damage		FDI index (%)	
		Gunny bag	Glass container	Gunny bag	Glass container	Gunny bag	Glass container
Aluminium phosphide (56 %)	0.29	25.0±0.5 ^c	14.0±0.00 ^b	28.0±2.0 ^c	21.6±1.2 ^c	16.6±0.57 ^d	33.3±1.3 ^c
	0.58	14.0±0.25 ^b	5.0±0.29 ^b	16.0±1.1 ^c	18.9±1.0 ^c	42.8±0.94 ^c	69.7±3.1 ^b
Ethylene dibromide (83 %)	0.29	6.0±0.24 ^b	6.0±0.00 ^a	10.0±0.00 ^b	8.0±1.15 ^b	70.7±2.2 ^b	64.7±1.2 ^b
	0.58	4.0±0.0 ^a	0.00±0.00 ^a	5.0±0.90 ^b	0.00±0.00 ^a	79.5±1.1 ^a	100±0.00 ^a
Control		35.0±1.0 ^d	28.0±1.8 ^c	41.0±2.0 ^d	38.0±1.8 ^d		

n=3, Within individual row values with different superscript are significantly different with each other at *p*<0.05, FDI % (Feeding Deterency Index) = $C - T \times 100 / C + T$, where C and T is the weight loss in control and fumigated sets respectively, Weight loss and seed damage were nil and FDI index was 100%^a in all cases for both concentrations (0.29 and 0.58 μl/ml) of *Chenopodium* oil

α -terpinene, *p*-cymene, limonene, ascaridole and isoascaridole. These terpenic compounds act as the fumigant in *Chenopodium* oil which might have broad insecticidal activity. These constituents were also reported as insecticidal agents against several other stored-product beetles by earlier researchers (Tapondjou et al. 2002; Kim et al. 2003). This indicates that the active ingredients of botanicals which are responsible for the toxicity of the plant kill the insects gradually. Thus, the activity of the oil seems likely to be due to the synergistic effect of major and minor components present in it.

Chenopodium oil showed its efficacy in control of pest infestation of pigeon pea seeds during 6 months of storage. It significantly protected pigeon pea seeds from storage pests by decreasing weight loss and seed damage than control sets, exhibiting 100 % feeding deterrence. The seed samples of control sets exhibited presence of *C. chinensis* and *C. maculatus*. The weight loss and seed damage of control sets due to bruchids were 35 & 48 % when stored in gunny bags and 28 & 38 % when stored in glass containers respectively (Table 3). Among synthetic fumigants, ethylene dibromide showed its effectiveness than aluminium phosphide.

Interestingly, repellency, insecticidal and preservative effect of *Chenopodium* oil are showing that the plants' essential oil are of great potential to be used in preservation of pulses where this *Callosobruchus* species causes severe damage and while the application of pesticides produce risk hazard to human health and environment. Thus, when essential oils are employed in a storage pest management plan, concerns regarding pesticide residue would be mitigated since some essential oil constituents taken through diet are actually not harmful, but even beneficial to human health (Haung et al. 1997). In previous investigations ascaridole, the main constituent of *C. ambrosioides* oil was found to be a potent inhibitor against in vitro development of *Plasmodium falciparum* (Pollack et al. 1990), *Trypanosoma cruzi* (Kiuchi et al. 2002) and *Leishmania amazonensis* (Monzote et al. 2006) justified its utility as non-toxicant for human beings.

Conclusion

The present study review that *C. ambrosioides* oil was found to be most toxic during repellency bioassay of 35 essential oils against *C. chinensis* and *C. maculatus*. *Chenopodium* oil holds good insecticidal property. From in vitro and in vivo trials it can be concluded that *Chenopodium* oil may be recommended as cheap, easily available and eco-friendly botanical pesticide in management of *C. chinensis* and *C. maculatus* and thus, is efficacious in protecting pigeon pea seeds and other food commodities from bruchids attack at farmer level. The results of the investigation would indicate

a significant potential for this plant as a possible source of natural insecticide that could be used as an alternative to synthetic insecticides.

Acknowledgements The authors thank to the Head, Department of Botany, DDU Gorakhpur University, Gorakhpur for providing necessary Lab. facilities, to CST UP Lucknow for financial support and to staff, BSI Dehradun for authenticating plant specimens.

References

- Anonymous (2011) Farmer surveys on post harvest loss in India, Maharashtra Hybrid Seed Company Limited
- Devi KC, Devi SS (2011) Insecticidal and oviposition deterrent properties of some spices against coleopteran beetle, *Sitophilus oryzae*. J Food Sci Technol. doi:10.1007/s13197-011-0377-1
- Dongre TK, Pawar SE, Harwalker MR (1993) Resistance to *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) in pigeon pea (*Cajanus cajan* (L.) Millsp.) and other *Cajanus* species. J Stored Prod Res 29:319–322
- Haung Y, Tan JMWL, Kini RM, Ho SH (1997) Toxic and antifeedant action of nutmeg oil against *Tribolium castaneum* (Herbst) and *Sitophilus zeamais* Motsch. J Stored Prod Res 33:289–298
- Isman MB, Koul O, Luezyński N (1990) Insecticidal and antifeedant bioactivity of neem oil and their relationship to azadirachtin content. J Agric Food Chem 38:1406–1411
- Jaya, Singh P, Prakash B, Dubey NK (2012) Insecticidal activity of *Ageratum conyzoides* L., *Coleus aromaticus* Benth. and *Hyptis suaveolens* (L.) Poit essential oils as fumigant against storage grain insect *Tribolium castaneum* Herbst. J Food Sci Technol. doi:10.1007/s13197-012-0698-8
- Kim DH, Ahn YJ (2001) Contact and fumigant activities of constituents of *Foeniculum vulgare* fruit against three coleopteran stored product insects. Pest Manag Sci 57:301–306
- Kim SI, Roh JY, Kim DH, Lee HS, Ahn YJ (2003) Insecticidal activities of aromatic plant extracts and essential oils against *Sitophilus oryzae* and *Callosobruchus chinensis*. J Stored Prod Res 39:293–303
- Kiuchi F, Itano Y, Uchiyama N, Honda G, Tsubouchi A, Nakajima-Shimada J, Aoki T (2002) Monoterpene hydroperoxides with trypanocidal activity from *Chenopodium ambrosioides*. J Natural Prod 65:509–512
- Kumar R, Kumar A, Prasad CS, Dubey NK, Samant R (2008) Insecticidal activity of *Aegle marmelos* (L.) Correa, essential oil against four stored grain insect pests. Int J Food Saf 10:39–49
- Mikolo B, Massamba D, Matos L, Bani G, Maloumbi MG, Glitho IA, Lenga A, Chalchat JC, Miller T (2009) Toxicity and repellent activity of essential oil from Waya (*Plectranthus grandifolius* Handel-Mazzetti) against *Callosobruchus maculatus* F. (Coleoptera: Bruchidae). Biopestic Int 5:52–59
- Mishra AK, Dubey NK, Singh S, Chaturvedi CM (2002) Biological activities of essential oil of *Chenopodium ambrosioides* against storage pests and its effect on puberty attainment in Japanese quail. Nat Acad Sci Lett 25:174–177
- Monzote L, Montalvo AM, Almanonni S, Scull R, Miranda M, Abreu J (2006) Activity of the essential oil from *Chenopodium ambrosioides* grown in Cuba against *Leishmania amazonensis*. Chemotherapy 52:130–136
- Pandey AK, Singh P, Tripathi NN (2011) Impact of essential oils on eggs hatchability and feeding activity of pulse beetles. J Entomol Res 35:221–225

- Pandey AK, Singh P, Palni UT, Tripathi NN (2012) In vitro antibacterial activities of the essential oils of aromatic plants against *Erwinia herbicola* (Lohnis) and *Pseudomonas putida* (Kris Hamilton). J Serb Chem Soc 77:313–323
- Park IK, Lee SG, Choi DH, Park JD, Ahn YJ (2003) Insecticidal activities of constituents identified in the essential oil from leaves of *Chamaecyparis obtusa* against *Callosobruchus chinensis* (L.) and *Sitophilus oryzae* (L.). J Stored Prod Res 39:375–384
- Parkin EA (1956) Stored product entomology (the assessment and reduction of losses caused by insects to stored food stuffs). Annu Rev Entomol 1:233–240
- Pollack Y, Segal R, Golenser J (1990) The effect of ascaridole on the in vitro development of *Plasmodium falciparum*. Parasitol Res 76:570–572
- Radha R, Murugan K (2011) Bioefficacy of plant derivatives on the repellency, damage assessment and progeny production of the cowpea weevil, *Callosobruchus maculatus* (F) (Coleoptera: Bruchidae). Internet J Food Saf 13:115–123
- Rajapakse R, Vaneben HF (1997) Potential of four vegetable oils and ten botanical powders for reducing infestation of cowpeas by *C. maculatus*, *C. chinensis* and *C. rhodanus*. J Stored Prod Res 33:59–68
- Rajashekar Y, Gunasekaran N, Shivanadappa T (2010) Insecticidal activity of the root extract of *Decalepis hamiltonii* against stored-product insect pests and its application in grain protection. J Food Sci Technol 47:310–314
- Rajendran S, Srianjini V (2008) Plant products as fumigants for stored-product insects control. J Stored Prod Res 44:126–135
- Reddy MV, Raju TN, Sharma SB, Nene YL, McDonald D (1993) Handbook of pigeon pea diseases. ICRISAT Inform Bull No 42:1–3
- Shukla AC (2009) Volatile oil of *Cymbopogon pendulus* as an effective fumigant pesticide for the management of storage-pests of food commodities. Nat Acad Sci Lett 32:51–59
- Shukla R, Srivastava B, Kumar R, Dubey NK (2007) Potential of some botanical powders in reducing infestation of chickpea by *Callosobruchus chinensis* L. (Coleoptera: Bruchidae). J Agric Technol 3:11–19
- Srivastava TN (1976) Flora Gorakhpurensis. Today & Tomorrow Printers and Publishers, New Delhi
- Tapondjou LA, Alder C, Bouda H, Fonten DA (2002) Efficacy of powder and essential oil from *Chenopodium ambrosioides* leaves as post-harvest grain protectant against six-stored products beetles. J Stored Prod Res 38:395–402
- Tiwari R, Dixit V, Bahal K (1998) Insect repellent activity of the essential oil of *Cinnamomum zeylanicum* bark. Indian Perfumer 42:68–72
- Tripathi NN, Kumar N (2007) *Putranjiva roxburghii* oil—A potential herbal preservative for peanuts during storage. J Stored Prod Res 43:435–442
- Ukeh DA, Mordue AJ (2009) Plant based repellents for the control of stored product insect pests. Biopestic Int 5:1–23
- Unnikrishnan V, Nath BS (2002) Hazardous chemicals in foods. Indian J Dairy Biosci 11:155–158
- Verma J, Dubey NK (1999) Prospective of botanical and microbial products as pesticides of tomorrow. Curr Sci 76:172–179