Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

Journal of Entomology and Zoology Studies

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2019; 7(3): 278-283

Received: 27-03-2019
Accepted: 30-04-2019

Ranjeet Kumar
Post Graduate Department of Entomology, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

PS Pandey
Assistant Director General (Education planning & Home Science) ICAR, New Delhi, India

SN Tiwari
Department of Entomology, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Correspondence
Ranjeet Kumar
Post Graduate Department of Entomology, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

Fumigant toxicity of essential oil based formulations against three stored product coleoptera in stored wheat

Ranjeet Kumar, PS Pandey and SN Tiwari

Abstract
The Laboratory Experiment were conducted to develop economically feasible, ecologically compatible and safe formulations based on essential oils against three stored product coleoptera e.g. *Sitophilus oryzae, Rhyzopertha dominica* and *Tribolium castaneum.* The highly effective essential oils of *Calistemon citrinus, Chenopodium botrys, Cinnamomum tamala, Artemisia annua, Citrus reticulata, Curcuma longa, Lantana camara, Murraya koenigii* and *Pinus roxburghii* were used at 0.2 percent and their two component formulations at 0.1 percent each and three component formulations at 0.07 percent each and four component formulations at 0.05 percent each formulated and tested for their fumigant toxicity against *Sitophilus oryzae, Rhyzopertha dominica* and *Tribolium castaneum.* The all tested essential oil based formulations either alone or in two, three and four component formulations were found highly effective against *Sitophilus oryzae, Rhyzopertha dominica* and *Tribolium castaneum*. The tested essential oil based formulations were completely suppressed the feeding and breeding of three stored product coleoptera. The all tested essential oil based formulations did not affect the germination quality of wheat seed.

Keywords: *Sitophilus oryzae, Rhyzopertha dominica, Tribolium castaneum,* Essential oil

Introduction
In the recent years, the use of essential oils derived from aromatic plants as low risk insecticides has increased considerably owing to their popularity with organic farming and environmentally conscious consumers. Essential oils are secondary metabolites that plants produce for their own needs other than nutrition. Generally they are complex mixture of 20-60 organic compounds that provides characteristic odour and flavor to leaves, flowers, fruits, seeds, bark and rhizomes [1]. Several essential oils have anti-parasitical, bactericidal, fungicidal, virucidal and insecticidal properties [1, 7]. Essential oil from more than seventy five plant species belonging to different families, such as Anacardiaceae, Apiaceae, Araceae, Asteraceae, Brassicaceae, Chenopodiaceae, Cupressaceae, Graminaceae, Lamiaceae, Lauraceae, Liliaceae, Myrtaceae, Pinaceae, Rutaceae and Zingiberaceae have been studied for fumigant toxicity against several insect pests of stored grain [7]. Stored-product insects cause serious postharvest losses, estimated up to 10 percent in developing countries but they also contribute to contamination of food products through the presence of live insects, insect products such as chemical excretions or silk, dead insects and insect body fragments, general infestation of storage structures, and accumulation of chemical insecticide residues in food, as well as human exposure to dangerous chemicals as a result of pest control efforts against them. In India, only aluminum phosphide and methyl bromide are available for fumigation of food grain. The use of aluminum phosphide is restricted by law while methyl bromide needs special infrastructures for its use. On the basis of above mentioned fact the present study was taken up to evaluate fumigant toxicity of essential oils based formulations against three stored product coleoptera in stored wheat.

Material and Methods
Culture of the insects
Pure culture of *Sitophilus oryzae, Rhyzopertha dominica* and *Tribolium castaneum* were developed in the Biological Oxygen Demand incubator maintained at 27$^{\circ C}$ ± 1 temperature and 70 ± 5 percent relative humidity. Plastic jars of 1.0 kg capacity were used for rearing purpose. At the center of the lid a hole of 1.8 cm diameter was made and covered with 30 mesh copper

wire net to facilitate aeration in the jar. The adults of *Sitophilus oryzae* L (Coleoptera: Curculionidae), *Rhyzopertha dominica* (Coleoptera: Bostrichiidae) were reared on the graded and untreated grain of wheat variety DBW-14 while *Tribolium castaneum* reared on its flour with five percent yeast powder. Before use, grain was disinfested in the oven at 60° C for 12 hrs. After disinfestation the moisture content of the grain was measured and raised to 13.5 per cent by mixing water in the grain. The quantity of water required to raise the optimum moisture content was calculated by formula as described by [6].

Procurement of Essential oils

The essential oils selected for the study were extracted from the locally available plants by steam distillation with Clevenger Apparatus in Department of Entomology Laboratory Mandan Bharti Agriculture College, Agwanpur, Saharsa, Bihar Agricultural University, Sabour. The essesntial oil of *Pinus roxburghii* was purchased from local market. The extracted and purchased essential oils were kept in refrigerator at 4 ˚C till experiment.

Preparation of grain

All experiments on *Sitophilus oryzae, Rhyzopertha dominica* and *Tribolium castaneum* were conducted on graded and untreated wheat seed variety DBW-14. Before use, the grain was disinfested and raised moisture content to 13.5 percent as rearing conditions. To ensure the even distribution of water, the grain was spread on a platform and water was sprayed on it by hand sprayer. The grain was then mixed thoroughly and closed in polythene bag for a week for equilibration of moisture content of grain. The Experiments were conducted at same as rearing condition.

Effect of essential oil on germination of wheat

Samples were drawn from experiment to record the effect of different essential oils based formulations on germination of wheat. Germination test was done as per protocol of [2].

Fumigant toxicity of Essential oil based formulations

The experiments were conducted in laboratory at 27±1 °C temperature and 70±5 per cent relative humidity on wheat variety DBW-14 (13.5 per cent moisture content). Five hundred gram of wheat grain was filled in 1000 ml capacity of plastic jars. Each treatment was replicated three times. In the study nine highly effective essential oils and their s were used for formulating multi-ingredient compositions as per details given several possible formulations were used. After filling the wheat seed in plastic vial 20 adults (0-7 days old) of *R. dominica*, *S. oryzae* or *T. castaneum* were released in each plastic jars. Measured quantity of essential oil based formulations was soaked on absorbing mat after which it was inserted in the jars which was closed to air tight. After closing the lid the jars were sealed with the help of paraffin wax strips and kept for twelve months thereafter observations were taken.

Result and Discussion

The fumigant toxicity of essential oil based formulation against three stored product coleoptera in stored wheat is presented in table 1. The highly effective essential oils of *Calistemon citrinus*, *Chenopodium botrys*, *Cinnamomum tamala*, *Artemisia annua*, *Citrus reticulata, Curcuma longa, Lantana camara*, *Murraya koenigii* and *Pinus roxburghii* were used at 0.2 percent and their two component formulations at 0.1 percent each and three component formulations at 0.07 percent each and four component formulations at 0.05 percent each formulated and tested for their fumigant toxicity against *Sitophilus oryzae, Rhyzopertha dominica* and *Tribolium castaneum.* The all tested essential oil based formulations either alone or in two, three and four component formulations were found highly effective against *Sitophilus oryzae, Rhyzopertha dominica* and *Tribolium castaneum*. The tested essential oil based formulations were completely suppressed the feeding and breeding of three stored product coleoptera as compare to untreated control. The essential oil of *Curcuma longa* at 0.2 percent inhibits 99.33 and 98.66 percent population of *Sitophilus oryzae* and *Rhyzopertha dominica* respectively. [4] Evaluated fumigant toxicity of essential oil of *C. sieberi* (Myrtaceae) against *S. oryzae*, *T. castaneum* and *R. dominica* and suggested the oil act as potent fumigant against tested insects. [9] Tested fumigant toxicity of essential oil from cumin (*Cuminum cyminum*) against eggs of two stored product insects, *T. confusum* and *Ephestia kuehniella,* it caused100 % mortality. Bio- efficacy of leaf oil of Curry leaf plant *Murraya koenigii* (Rutaceae) was evaluated against *C. chinensis* [5]. The essential oils of *Murraya koenigii, Citrus reticulata*, *Calistimone citrinus* either alone at 0.2 percent or two component combinations found highly effective against *S. oryzae* and *R. dominica* [3].

Essential oil of Sweet Annie, *Artemisia annua* (Compositae) evaluated by [8] against *T. castaneum* and *C. maculatus* at 1 percent showed adult repellent and with adult emergence of *T. castaneum*. [9] Tested fumigant toxicity of essential oil from cumin (*Cuminum cyminum*) against eggs of two stored product insects, *T. confusum* and *Ephestia kuhniella*, it caused 100 percent mortality.

The effect of essential oil based formulation on infestation, weight loss and germination of wheat is presented in table 2 which indicates that after twelve months of storage the percent infestation, percent weight loss did not affected by the tested essential oil based formulations against three stored product coleoptera. The percent germination of treated wheat seed is also very high.

The present study concludes that the essential oil based formulations completely suppressed the feeding and breeding of *Sitophilus oryzae*, *Rhyzopertha dominica* and *Tribolium castaneum*. The tested essential oil based formulations did not affect the germination quality of wheat.

Table 1: Adult emerged and percent inhibition of *S. oryzae, R. dominica* and *T. castaneum* after twelve months of treatment with essential oil based formulations

Essential oil based formulations	Con.%	*Sitophilus oryzae*		*Rhyzopertha dominica*		*Tribolium castaneum*	
		After twelve months of storage					
		Adults emerged	Percent inhibition	Adults emerged	Percent inhibition	Adults emerged	Percent inhibition
Calistemon citrinus	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
Chenopodium botrys	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
Cinnamomum tamala	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
Artemisia annua	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00

Citrus reticulata	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
Curcuma longa	0.2	1.0 (0.4)	99.33	2.0 (0.4)	98.66	0.0 (0.0)	100.00
Lantana camara	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
Murraya koenigii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
Pinus roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. citrinus +C. botrys	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. citrinus +C. tamala	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. citrinus+ A. annua	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. citrinus + C. reticulata	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. citrinus + C. longa	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. citrinus +L. camara	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. citrinus + M. koenigii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. citrinus + P. roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. botrys + C. tamala	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. botrys +A. annua	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. botrys + C. reticulata	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. botrys +C. longa	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. botrys + L. camara	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. botrys + M. koenigii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. botrys + P. roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. tamala+ A. annua	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. tamala + C. reticulata	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. tamala + C. longa	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. tamala + L. camara	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. tamala + M. koenigii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. tamala + P. roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
A. annua + C. reticulata	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
A. annua + C. longa	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
A. annua + L. camara	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
A. annua + M. koenigii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
A. annua +P. roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. reticulata + C. longa	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. reticulata+L. camara	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. reticulata+ M. koenigii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. reticulata +P. roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. longa +L. camara	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. longa +M. koenigii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. longa + P. roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
L. camara + M. koenigii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
L. camara+ P. roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
M. koenigii + P. roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. citrinus +C. botrys+ C. tamala	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. citrinus + A. annua+ C. reticulata	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. citrinus + C. longa+ L. camara	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. citrinus + M. koenigii+ P. roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. botrys+ C. tamala+ A. annua	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. botrys +C. reticulate + C. longa	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. botrys + L. camara+ M. koenigii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. tamala + A. annua+ C. reticulata	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. tamala+ C. longa+ L. camara	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. tamala + M. koenigii+ P. roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
A. annua+ C. reticulate + C. longa	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
A. annua+ L. camara+ M. koenigii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. reticulate + C. longa+ L. camara	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. reticulate + M. koenigii+ P. roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. longa + L. camara+ M. koenigii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
L. camara+ M. koenigii+ P. roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. citrinus +C. botrys+ C. tamala+ A. annua	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. citrinus +C. botrys+ C. tamala+ C. reticulata	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. citrinus +C. botrys+ C. tamala+ C. longa	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. citrinus +C. botrys+ C. tamala+ L. camara	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. citrinus +C. botrys+ C. tamala+ M. koenigii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. citrinus +C. botrys+ C. tamala+ P. roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. botrys+ C. tamala+ A. annua+ C. reticulata	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. botrys+ C. tamala+ A. annua+ C. longa	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. botrys+ C. tamala+ A. annua+ L. camara	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. botrys+ C. tamala+ A. annua+ M. koenigii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. botrys+ C. tamala+ A. annua+ P. roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00

C. tamala+ A. annua+ C. reticulate + C. longa	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. tamala+ A. annua+ C. reticulate + L. camara	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. tamala+ A. annua+ C. reticulate + M. koenigii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. tamala+ A. annua+ C. reticulate + P. roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
A. annua+ C. reticulate + C. longa+ L. camara	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
A. annua+ C. reticulate + C. longa+ M. koenigii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
A. annua+ C. reticulate + C. longa+ P. roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. reticulate + C. longa+ L. camara+ M. koenigii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. reticulate + C. longa+ L. camara+ P. roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
C. longa+ L. camara+ M. koenigii + P. roxburghii	0.2	0.0 (0.0)	100.00	0.0 (0.0)	100.00	0.0 (0.0)	100.00
Untreated Control		221.7 (5.3)		109.7 (4.6)		68.3 (3.6)	
S. Em. ±		0.89		0.84		0.48	
CD at 5%		0.24		0.23		0.13	

Data in parenthesis indicate log (X+1) transformed values

Table 2: Effect of essential oil based formulation on infestation, weight loss and germination due to infestation of *S. oryzae, R. dominica a*nd *T. castaneum* in stored wheat

Essential oil based formulations	Con.%	*Sitophilus oryzae*			*Rhyzopertha dominica*			*Tribolium castaneum*		
		Percent Infestation	Percent Weight Loss	Percent Germination	Percent Infestation	Percent Weight Loss	Percent Germination	Percent Infestation	Percent Weight Loss	Percent Germination
Calistemon citrinus	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
Chenopodium botrys	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
Cinnamomum tamala	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
Artemisia annua	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
Citrus reticulate	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
Curcuma longa	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
Lantana camara	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
Murraya koenigii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
Pinus roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. citrinus +C. botrys	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. citrinus +C. tamala	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. citrinus+ A. annua	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. citrinus + C. reticulata	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. citrinus + C. longa	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. citrinus +L. camara	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. citrinus + M. koenigii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. citrinus + P. roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. botrys + C. tamala	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. botrys +A. annua	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. botrys + C. reticulata	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. botrys +C. longa	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. botrys + L. camara	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. botrys + M. koenigii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. botrys + P. roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. tamala+ A. annua	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. tamala + C. reticulata	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. tamala + C. longa	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. tamala + L. camara	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. tamala + M. koenigii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. tamala + P. roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
A. annua + C. reticulata	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
A. annua + C. longa	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
A. annua + L. camara	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
A. annua + M. koenigii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
A. annua +P. roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. reticulata + C. longa	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. reticulate + L. camara	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. reticulate + M. koenigii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. reticulata +P. roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. longa +L. camara	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. longa +M. koenigii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. longa + P. roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
L. camara + M. koenigii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
L. camara + P. roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
M. koenigii + P. roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. citrinus +C. botrys+ C. tamala	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. citrinus + A. annua+ C. reticulata	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. citrinus + C. longa+ L. camara	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. citrinus + M. koenigii+ P. roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. botrys+ C. tamala+ A. annua	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. botrys +C. reticulate + C. longa	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. botrys + L. camara+ M. koenigii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. tamala + A. annua+ C. reticulata	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00

C. tamala + C. longa+ L. camara	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. tamala + M. koenigii+ P. roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
A. annua+ C. reticulate + C. longa	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
A. annua + L. camara+ M. koenigii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. reticulate + C. longa+ L. camara	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. reticulate + M. koenigii+ P. roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. longa + L. camara+ M. koenigii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
L. camara+ M. koenigii+ P. roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. citrinus +C. botrys+ C. tamala+ A. annua	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. citrinus +C. botrys+ C. tamala+ C. reticulata	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. citrinus +C. botrys+ C. tamala+ C. longa	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. citrinus +C. botrys+ C. tamala+ L. camara	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. citrinus +C. botrys+ C. tamala+ M. koenigii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. citrinus +C. botrys+ C. tamala+ P. roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. botrys+ C. tamala+ A. annua+ C. reticulata	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. botrys+ C. tamala+ A. annua+ C. longa	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. botrys + C. tamala+ A. annua+ L. camara	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. botrys+ C. tamala+ A. annua+ M. koenigii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. botrys+ C. tamala+ A. annua+ P. roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. tamala+ A. annua+ C. reticulate + C. longa	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. tamala+ A. annua+ C. reticulate + L. camara	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. tamala+ A. annua+ C. reticulate + M. koenigii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. tamala+ A. annua+ C. reticulata + P. roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
A. annua+ C. reticulate + C. longa+ L. camara	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
A. annua+ C. reticulata + C. longa+ M. koenigii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
A. annua+ C. reticulate + C. longa+ P. roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. reticulate + C. longa+ L. camara+ M. koenigii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. reticulate + C. longa+ L. camara+ P. roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
C. longa+ L. camara+ M. koenigii + P. roxburghii	0.2	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00	0.0 (0.0)	0.0 (0.0)	100.00
Untreated Control		10.49 (2.4)	0.97 (0.6)	80.62	15.24 (2.6)	0.26 (0.2)	91.00	16.21 (2.7)	0.29 (0.2)	89.00
S. Em. ±		0.12	0.92	0.69	0.19	0.73	0.47	0.16	0.89	0.63
CD at 5%		0.41	0.31	2.77	0.64	0.24	1.96	0.52	0.29	2.04

Data in parenthesis indicate log (X+1) transformed value

Acknowledgement

The authors are grateful to the Vice Chancellor and Director Research, Bihar Agricultural University, Sabour for providing necessary facilities during study.

References

1. Bakkli F, Averbeck S, Averbeck D, Idamar M. Biological effects of essential olis A Review Food and Chemical Toxicology. 2008; 46:446-475.
2. Chalam GY, Singh A, Dauglas JE. Seed testing manual. Indian Council of Agricultural Research and the National Seed Cooperation Limited, New Delhi. 1967, 67.
3. Kumar R, Tiwari SN, Vishwakarma R, Singh H, Patel DK. Fumigant toxicity of essential oil and their combination against *Rhyzopertha dominica* and *Tribolium castaneum* at different days interval in stored wheat. International Journal of Current Microbiology and Applied Sciences. 2018; 07:2621-2626.
4. Lee BH, Annis PC, Tumaallii F, Choi WS. Fumigant toxicity of essential oils from the Myrtaceae family and 1, 8-cineole against 3 major stored-grain insects. Journal of Stored Product Research. 2004; 40(5):553-564.
5. Paranagama PA, Adhikari AAC K, Abeywickrama KP, Bandara KANP. Toxicity and repellant activity of *Cymbopogon citratus* (D.C.) Stapf. and *Murraya koenigii* Sprang. against *Callosobruchus maculatus* (F.) (Coleoptera; Bruchidae). Tropical Agriculture Research and Extension. 2002; 5:22-28.
6. Pixton SW. Moisture content-its significance and measurement in stored products. Journal of Stored Product Research. 1967; 3:35-37.
7. Rajendran S, Sriranjinia V. Plant products as fumigants for stored-product insect control. Journal of Stored Product Research. 2008; 44:126-135.
8. Tripathi AK, Prajapati V, Verma N, Bahl JR, Bansal RP Khanuja SPS, Kumar S. Bioactivities of the leaf essential

oil of *Curcuma longa* (var. Ch-66) on three species of stored product beetles (Coleoptera). Journal of Economic Entomology. 2002; 95(1):183-189.

9. Tunc I, Erler F. Fumigant activity of anethole, a major component of essential oil of anise *Pimpinella anisum* L. Bulletin of OILB/SROP Turkey. 2000; 23(10):221-225