

Print ISSN : 0972-8813
e-ISSN : 2582-2780

[Vol. 21(2) May-August 2023]

Pantnagar Journal of Research

(Formerly International Journal of Basic and
Applied Agricultural Research ISSN : 2349-8765)



G.B. Pant University of Agriculture & Technology, Pantnagar



ADVISORYBOARD

Patron

Dr. Manmohan Singh Chauhan, Vice-Chancellor, G.B. Pant University of Agriculture and Technology, Pantnagar, India

Members

Dr. A.S. Nain, Ph.D., Director Research, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. J.P. Jaiswal, Ph.D., Director, Extension Education, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. S.K. Kashyap, Ph.D., Dean, College of Agriculture, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. S.P. Singh, Ph.D., Dean, College of Veterinary & Animal Sciences, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. K.P. Raverkar, Ph.D., Dean, College of Post Graduate Studies, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. Sandeep Arora, Ph.D., Dean, College of Basic Sciences & Humanities, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. Alaknanda Ashok, Ph.D., Dean, College of Technology, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. Alka Goel, Ph.D., Dean, College of Home Science, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. Malobica Das Trakroo, Ph.D., Dean, College of Fisheries, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. R.S. Jadoun, Ph.D., Dean, College of Agribusiness Management, G.B. Pant University of Agri. & Tech., Pantnagar, India

EDITORIALBOARD

Members

Prof. A.K. Misra, Ph.D., Chairman, Agricultural Scientists Recruitment Board, Krishi Anusandhan Bhavan I, New Delhi, India
Dr. Anand Shukla, Director, Reefberry Foodex Pvt. Ltd., Veraval, Gujarat, India
Dr. Anil Kumar, Ph.D., Director, Education, Rani Lakshmi Bai Central Agricultural University, Jhansi, India
Dr. Ashok K. Mishra, Ph.D., Kemper and Ethel Marley Foundation Chair, W P Carey Business School, Arizona State University, U.S.A
Dr. B.B. Singh, Ph.D., Visiting Professor and Senior Fellow, Dept. of Soil and Crop Sciences and Borlaug Institute for International Agriculture, Texas A&M University, U.S.A.
Prof. Binod Kumar Kanaujia, Ph.D., Professor, School of Computational and Integrative Sciences, Jawahar Lal Nehru University, New Delhi, India
Dr. D. Ratna Kumari, Ph.D., Associate Dean, College of Community / Home Science, PJTSAU, Hyderabad, India
Dr. Deepak Pant, Ph.D., Separation and Conversion Technology, Flemish Institute for Technological Research (VITO), Belgium
Dr. Desirazu N. Rao, Ph.D., Professor, Department of Biochemistry, Indian Institute of Science, Bangalore, India
Dr. G.K. Garg, Ph.D., Dean (Retired), College of Basic Sciences & Humanities, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. Humnath Bhandari, Ph.D., IRRRI Representative for Bangladesh, Agricultural Economist, Agrifood Policy Platform, Philippines
Dr. Indu S Sawant, Ph.D., Director, ICAR - National Research Centre for Grapes, Pune, India
Dr. Kuldeep Singh, Ph.D., Director, ICAR - National Bureau of Plant Genetic Resources, New Delhi, India
Dr. M.P. Pandey, Ph.D., Ex. Vice Chancellor, BAU, Ranchi & IGKV, Raipur and Director General, IAT, Allahabad, India
Dr. Martin Mortimer, Ph.D., Professor, The Centre of Excellence for Sustainable Food Systems, University of Liverpool, United Kingdom
Dr. Muneshwar Singh, Ph.D., Project Coordinator AICRP- LTFE, ICAR - Indian Institute of Soil Science, Bhopal, India
Prof. Omkar, Ph.D., Professor, Department of Zoology, University of Lucknow, India
Dr. P.C. Srivastav, Ph.D., Professor, Department of Soil Science, G.B. Pant University of Agriculture and Technology, Pantnagar, India
Dr. Prashant Srivastava, Ph.D., Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, University of South Australia, Australia
Dr. Puneet Srivastava, Ph.D., Director, Water Resources Center, Butler-Cunningham Eminent Scholar, Professor, Biosystems Engineering, Auburn University, U.S.A.
Dr. R.C. Chaudhary, Ph.D., Chairman, Participatory Rural Development Foundation, Gorakhpur, India
Dr. R.K. Singh, Ph.D., Director & Vice Chancellor, ICAR-Indian Veterinary Research Institute, Izatnagar, U.P., India
Prof. Ramesh Kanwar, Ph.D., Charles F. Curtiss Distinguished Professor of Water Resources Engineering, Iowa State University, U.S.A.
Dr. S.N. Maurya, Ph.D., Professor (Retired), Department of Gynecology & Obstetrics, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. Sham S. Goyal, Ph.D., Professor (Retired), Faculty of Agriculture and Environmental Sciences, University of California, Davis, U.S.A.
Prof. Umesh Varshney, Ph.D., Professor, Department of Microbiology and Cell Biology, Indian Institute of Science, Bangalore, India
Prof. V.D. Sharma, Ph.D., Dean Academics, SAI Group of Institutions, Dehradun, India
Dr. V.K. Singh, Ph.D., Head, Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi, India
Dr. Vijay P. Singh, Ph.D., Distinguished Professor, Caroline and William N. Lehrer Distinguished Chair in Water Engineering, Department of Biological Agricultural Engineering, Texas A&M University, U.S.A.
Dr. Vinay Mehrotra, Ph.D., President, Vinlax Canada Inc., Canada

Editor-in-Chief

Dr. Manoranjan Dutta, Head Crop Improvement Division (Retd.), National Bureau of Plant Genetic Resources, New Delhi, India

Managing Editor

Dr. S.N. Tiwari, Ph.D., Professor, Department of Entomology, G.B. Pant University of Agriculture and Technology, Pantnagar, India

Assistant Managing Editor

Dr. Jyotsna Yadav, Ph.D., Research Editor, Directorate of Research, G.B. Pant University of Agriculture and Technology, Pantnagar, India

Technical Manager

Dr. S.D. Samantray, Ph.D., Professor, Department of Computer Science and Engineering, G.B. Pant University of Agriculture and Technology, Pantnagar, India

PANTNAGAR JOURNAL OF RESEARCH

Vol. 21(2)

May-August, 2023

CONTENTS

Evaluation of seed quality parameters in forage oat (<i>Avena sativa</i> L.) germplasm HARSHITA NEGI, VAIBHAV BIST, AKIRTI BALLABH and BIRENDRA PRASAD	129
Mepiquat Chloride: An effective plant growth regulator to improve growth and productivity of rice in North-Western Himalayan region of India S. K. YADAV, D. K. SINGH, KIRTI SHARMA, PRATIMA ARYA, SUPRIYA TRIPATHI and YOGESH SHARMA	135
Performance of Integrated Nutrient Management for yield and Net Income of lentil (<i>Lens culinaris Medik</i>) KUMARI ANJALI and HIMANSHU VERMA	141
Potential and scope of Agarwood (<i>Aquilaria malaccensis</i> lamk.) cultivation in India SNEHA DOBHALL, DURGA BAHUGUNA, REETIKA BINJOLA, GARIMA BHATT, RAJ KUMAR, AYUSH JOSHI, KANICA UPADHYAY and NEELAM CHAUHAN	145
Effect of transplanting date on incidence of insect pests of rice R. DOGRA and A. K. PANDEY	154
Measuring the antixenosis responses of <i>Spodoptera litura</i> larvae to different soybean germplasms by leaf choice method ASHUTOSH and NEETA GAUR	170
Long term efficacy of different herbal fumigants against <i>Rhyzopertha dominica</i> (Fabricius) and <i>Tribolium castaneum</i> (Herbst) DEEPA KUMARI and S. N. TIWARI	174
Screening of different combinations of <i>Trichoderma harzanium</i> and <i>Pseudomonas fluorescens</i> for growth promotion activity in rice plants under glass house conditions SAPNA, BHUPESH CHANDRA KABDWAL and ROOPALI SHARMA	186
Role of Fungal Effector Proteins for Disease Expression in Plants HINA KAUSAR, GEETA SHARMA and BHAGYASHREE BHATT	191
Effect of biostimulants and biofertilizer on performance of rose cv. Rose Sherbet LOLLA RACHANA, V. K. RAO and D. C. DIMRI	203
A Review-Tomato quality as influenced by preharvest factors H.N. PRASAD, BANKEY LAL, SUNITA BHANDARI, RAKESH BHARGAVA, VIPUL PRATAP SINGH and ANSHU KAMBOJ	209
Effect of ZnO Nanoparticles on Macronutrients Content of <i>Pleurotus sajor-caju</i> (Oyster Mushroom) LEEMA and H. PUNETHA	218
Nutritional, sensory and shelf-life analysis of pearl millet-based value-added biscuits enriched with <i>jamun</i> seed powder SAVITA, AMITA BENIWAL, VEENU SANGWAN and ASHA KAWATRA	224
Quality characteristics of low salt functional chicken meat patties incorporated with Barnyard Millet DEEPSHIKHA SINGH, ANITA ARYA, P. PRABHAKARAN, P.K. SINGH, SHIVE KUMAR, N.C. HAHN and A.K. UPADHYAY	234

Effect of supplementation of tulsi (<i>Ocimum sanctum</i>) leaf powder on growth performance in commercial broiler	239
SURAJ GAJANAN MADAVI, RAJKUMAR1, KARTIK TOMAR, SHIWANSHU TIWARI, D.S. SAHU, S.P. YADAV and GULAB CHANDRA	
Combating antimicrobial resistance through gene silencing	246
BEENU JAIN, ANUJ TEWARI, ANUPRIYA MISRA and YASHOVARDHAN MISRA	
Effect of aluminium nano particles on humoral immune response of wistar rats	256
SHODHAN K.V, SEEMA AGARWAL and R S CHAUHAN	
Effect of nano zinc on body weight and behaviour of Wistar rats	262
ABHIVYAKTI PATHAK, SEEMA AGARWAL and R.S. CHAUHAN	
The growth potential of thermophilic Campylobacters on various culture media	267
NAWAL KISHOR SINGH, A. K. UPADHYAY, MAANSI, AMAN KAMBOJ and AJAY KUMAR	
Meta-analysis of rabies diagnostic tests in dogs	271
A. K. UPADHYAY, R. S. CHAUHAN, MAANSI and N. K. SINGH	
Growth Performance of <i>Schizothorax richardsonii</i> fingerlings with different feeding strategies	274
TOSHIBAA, DIKSHA ARYA, SUMIT KUMAR, H.C.S BISHT and N.N. PANDEY	
Observation of fish mortality in the mudflat of Siruthalaikadu Creek, Palk Bay, Southeast Coast of India	279
ABINAYA R, KANISHKAR A and SAJEEVAN MK	
Physiochemical properties of pretreated tomato powder from different drying technique	282
SHRADDHA SETHI and NEERAJ SETHI	
A Review: Energy analysis of different fodder crop production in India	290
RAHUL KUMAR YADAV, RAVI PRATAP SINGH, ANIL KUMAR and SAURABH KUMAR SINGH	
A review on current scenario of paddy straw management machineries: Viable solution for in-situ residue management	297
VISHNU JI AWASTHI, RAJ NARAYAN PATERIYA, ABHISHEK MISHRA, KETAN BHIBHISHAN PHALPHALE and ABHINAV KUMAR	
Field evaluation of Tractor-Operated Pneumatic Planter for maize crop planting	305
AMIT KUMAR, JAYAN P R and VISHNU JI AWASTHI	
Assessing flood inundation for breach of Jamrani Dam, Uttarakhand using HEC-RAS 2D	314
JYOTHI PRASAD, LOVEJEET SINGH and SHIVA PRASAD H.J	
Attitude and constraints faced by the beneficiaries of Pradhan Mantri Krishi Sinchayee Yojana in Garhwal region of Uttarakhand	320
TRIPTI KHOLIA and ARPITA SHARMA KANDPAL	
Effectiveness of participatory newsletter on honey production: A study in Nainital district of Uttarakhand	327
MALIK, AAFREEN, ANSARI, M.A. and AMARDEEP	
Food habits of farm women and their haemoglobin level	322
REETA DEVI YADAV, S.K. GANGWAR, CHELPURI RAMULU and ANUPAMA KUMARI	

Long term efficacy of different herbal fumigants against *Rhyzopertha dominica* (Fabricius) and *Tribolium castaneum* (Herbst)

DEEPA KUMARI* and S. N. TIWARI

Department of Entomology, College of Agriculture, G. B. Pant University of Agriculture and Technology, Pantnagar-263145 (U.S. Nagar, Uttarakhand)

*Corresponding author's email Id: deepa5227@yahoo.co.in

ABSTRACT: Laboratory experiments were conducted to study the long-term efficacy of 141 formulations of herbal fumigants against *Rhyzopertha dominica* and *Tribolium castaneum*. The herbal fumigants were formulated by compounding the essential oils of *Mentha arvensis*, *Mentha piperita*, *Mentha spicata*, *Cymbopogon winterianus*, *Eucalyptus citriodora*, *Curcuma longa* and *Pinus roxburghii* at different concentrations. All seven essential oils were studied at 0.20 and 0.40 per cent (v/w) while their two, three, four, five, six and seven component combinations were evaluated at 0.20, 0.14, 0.10, 0.08, 0.07 and 0.06, per cent (v/w) each. Some other formulations such as *M. piperita* + *C. longa*, *M. piperita* + *P. roxburghii*, *C. longa* + *P. roxburghii*, *C. longa* + *M. arvensis* and *P. roxburghii* + *M. arvensis* were also evaluated at 0.10+0.10 per cent each while *C. longa* + *M. arvensis* and *P. roxburghii* + *M. arvensis* were tested at 0.30+0.10 per cent against both the insects. The test insects were reared on the grain treated with different formulations. The number of progenies produced by 10 adult insects were counted after 469 and 446 days, in case of *R. dominica* and *T. castaneum*, respectively. Inhibition of progeny by test formulation was calculated by using the number of adults emerged in treated and untreated grain. No adult of *R. dominica* emerged in any of the treatment after 469 days while 386 adults emerged from untreated grain. In case of *T. castaneum*, 153.3 adults emerged from untreated grain after 446 days while treated grain did not permit any adult. The results indicated that all the formulations of herbal fumigants completely checked the progeny production of both the insects for more than a year.

Key words: Essential oils, fumigant toxicity, herbal fumigants, *Rhyzopertha dominica*, stored wheat, storage insects, *Tribolium castaneum*

India is estimated to lose 14 million tonnes of food grains in storage annually worth Rs 7000 crore, of which about Rs 1300 crore is lost due to insects alone (IGSMRI, 2019). Due to limited pest control options and lack of scientific storage facilities at farmers level, we are not successful in reducing such post-harvest losses due to insect pests. In India and many other countries, phosphine is the only chemical which is recommended for use under technical supervision. Since most of the farmers don't have any training for its use and airtight storage facilities, injudicious application of this highly poisonous chemical results in to various types of health hazards in addition to development of resistance in insect pests. In such a situation, efforts are being made to find a safer alternative and over the past six decades,

many plants have been investigated for their insect control properties (Jacobson, 1975; Golob and Webley, 1980; Jacobson, 1983; Grainge and Ahmed, 1988). Many essential oils of plant origin have also shown appreciable antifeedant, ovicidal, oviposition inhibitory, repellent and fumigant toxicity against storage insects (Don- Pedro, 1996; Clemente *et al.*, 2003; Pascual and Ballesta, 2003; Singh *et al.*, 1989; Shaaya *et al.*, 1990, 1997; Tiwari, 1993; Singh and Upadhyay, 1993; Regnault-Roger, 1997; Tunc *et al.*, 2000; Tripathi *et al.*, 2002; Lee *et al.*, 2002, 2004; Ngamo *et al.*, 2007; Tewari, 2008; Rajendran and Sriranjini, 2008; Geetanjly *et al.*, 2016; Gangwar and Tiwari, 2017; Kumar and Tiwari, 2017a; 2017b; Kumar *et al.*, 2018; Joshi and Tiwari, 2019; Geetanjly and Tiwari, 2021; Tewari and Tiwari, 2021a; 2021b; 2021c; 2021d; Kumari and Tiwari, 2022a; 2022b; 2022c; Kumari and Tiwari, 2023). The review of literature indicates that majority of plants do not show appreciable activity against all the insect pest of stored grain due to which

*A part of Ph.D. thesis submitted by senior author to G.B. Pant University of Agriculture and Technology, Pantnagar; Present Address: Soban Singh Jeena University, Department of Zoology, Pt. Badri Dutt Pandey Campus, Bageshwar - 263642 (Uttarakhand).

they have very limited practical applicability.

Furthermore, their efficacy is limited for short duration due to which they cannot be used for the protection of grain in long term storage. Tewari and Tewari (2021c) studied the fumigant toxicity of seven essential oils and their 2,3,4,5,6 and 7 oil combinations against *R. dominica* and *S. oryzae*, however, they could not report the long-term efficacy of these formulations because of termination of experiment after completion of only one generation. Since most of the oils were found to be highly effective against both the insects, the present investigation was undertaken to study their long-term efficacy against *R. dominica* and *T. castaneum* for longer duration of more than one year. The study may reveal the potential of several herbal fumigants in long term protection of grain against storage insect pests.

MATERIALS AND METHODS

The experiment was conducted in Post-Harvest Entomology Laboratory of Department of Entomology, G.B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar (Uttarakhand).

Rearing of Rhyzopertha dominica and Tribolium castaneum

Pure culture of test insects was developed in the control room of laboratory at 27°C±1 temperature and 70±5% relative humidity. Plastic jars of about 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 *R. dominica* were reared on the grain of wheat variety PBW-343 while *T. castaneum* was cultured on its flour fortified with 5 per cent yeast powder. Before use, grains were 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 moisture content was calculated by using following formula as described by Pixton (1967).

$$\text{Quantity of water to be added} = \frac{W_1(M_2 - M_1)}{100 - M_2}$$

Where, W_1 =Initial weight of grains; M_1 =Initial moisture content; M_2 =Final moisture content

After mixing the water in grain it was kept in closed polythene bags for a week so that moisture content of grain could equilibrate. The grain was then filled in plastic jar and 100 adults were released in each jar after which was kept in incubator. First generation adults (0-7 days old) were used for experimental purpose.

Preparation of Grain for Experiment

All fumigation experiments on *R. dominica* and *T. castaneum* were conducted on untreated graded seed of wheat variety PBW-343. Before use, the grains were disinfested by keeping them in the oven at 60°C for 12 hrs. After disinfestation the moisture content of grain was measured and raised to 13.5 per cent by adding water in the required quantity to the grain as described in previous section. To ensure the even distribution of water, the grain was spread on a platform and water was sprayed on it using hand sprayer. The grain was then mixed thoroughly and closed in polythene bags for a week for equilibration of moisture content of grain. The grain (50g) was then filled in 100ml capacity plastic vials to perform experiment.

Procurement of Oil for Experiment

To ensure the purity and quality, the oils selected for the study were collected from the Medicinal and Aromatic Plants Research and Development Centre, Haldi and Central Institute of Medicinal and

Table 1: Scientific and common names of the plants, the essential oils of which was used for study

Sl. No.	Scientific name	Common name
1	<i>Mentha arvensis</i>	Mint
2	<i>Mentha piperita</i>	Peppermint
3	<i>Mentha spicata</i>	Spearmint
4	<i>Cymbopogon winterianus</i>	Citronella
5	<i>Eucalyptus citriodora</i>	Nilgiri
6	<i>Curcuma longa</i>	Turmeric
7	<i>Pinus roxburghii</i>	Pine

Aromatic Plants, Field Station, Nagla (Uttarakhand) and Central Institute of Medicinal and Aromatic Plants, Lucknow (Uttar Pradesh). The common and scientific name of plants, the oils used in the experiment are given in Table 1.

Experimental Details

The herbal fumigants were formulated by mixing

different essential oils as per composition and concentrations given in Table 2 and 3. The experiment was conducted in control room at $27\pm1^{\circ}\text{C}$ temperature and 70 ± 5 per cent relative humidity on wheat variety PBW-343 (13.5 per cent moisture content). Fifty-gram grain was filled in 100ml capacity plastic vial. Each treatment was replicated three times. After filling the grain in plastic vial 10 adults (0-7 days old) of *R. dominica*

Table 2: Effect of different formulations of herbal fumigants on progeny production of *R. dominica*

S. No.	Component	Conc. % (v/w)	No. of adults emerged	Percent Inhibition	Days after fumigation
1	<i>M. arvensis</i>	0.2	0.0±0.0	100	469
2	<i>M. piperita</i>	0.2	0.0±0.0	100	469
3	<i>M. spicata</i>	0.2	0.0±0.0	100	469
4	<i>C. winterianus</i>	0.2	0.0±0.0	100	469
5	<i>E. citriodora</i>	0.2	0.0±0.0	100	469
6	<i>C. longa</i>	0.2	0.0±0.0	100	469
7	<i>P. roxburghii</i>	0.2	0.0±0.0	100	469
8	<i>M. arvensis</i>	0.4	0.0±0.0	100	469
9	<i>M. piperita</i>	0.4	0.0±0.0	100	469
10	<i>M. spicata</i>	0.4	0.0±0.0	100	469
11	<i>C. winterianus</i>	0.4	0.0±0.0	100	469
12	<i>E. citriodora</i>	0.4	0.0±0.0	100	469
13	<i>C. longa</i>	0.4	0.0±0.0	100	469
14	<i>P. roxburghii</i>	0.4	0.0±0.0	100	469
15	<i>M. arvensis</i> + <i>M. piperita</i>	0.2+0.2	0.0±0.0	100	469
16	<i>M. arvensis</i> + <i>M. spicata</i>	0.2+0.2	0.0±0.0	100	469
17	<i>M. arvensis</i> + <i>C. winterianus</i>	0.2+0.2	0.0±0.0	100	469
18	<i>M. arvensis</i> + <i>E. citriodora</i>	0.2+0.2	0.0±0.0	100	469
19	<i>M. arvensis</i> + <i>C. longa</i>	0.2+0.2	0.0±0.0	100	469
20	<i>M. arvensis</i> + <i>P. roxburghii</i>	0.2+0.2	0.0±0.0	100	469
21	<i>M. piperita</i> + <i>M. spicata</i>	0.2+0.2	0.0±0.0	100	469
22	<i>M. piperita</i> + <i>C. winterianus</i>	0.2+0.2	0.0±0.0	100	469
23	<i>M. piperita</i> + <i>E. citriodora</i>	0.2+0.2	0.0±0.0	100	469
24	<i>M. piperita</i> + <i>C. longa</i>	0.2+0.2	0.0±0.0	100	469
25	<i>M. piperita</i> + <i>P. roxburghii</i>	0.2+0.2	0.0±0.0	100	469
26	<i>M. spicata</i> + <i>C. winterianus</i>	0.2+0.2	0.0±0.0	100	469
27	<i>M. spicata</i> + <i>E. citriodora</i>	0.2+0.2	0.0±0.0	100	469
28	<i>M. spicata</i> + <i>C. longa</i>	0.2+0.2	0.0±0.0	100	469
29	<i>M. spicata</i> + <i>P. roxburghii</i>	0.2+0.2	0.0±0.0	100	469
30	<i>C. winterianus</i> + <i>E. citriodora</i>	0.2+0.2	0.0±0.0	100	469
31	<i>C. winterianus</i> + <i>C. longa</i>	0.2+0.2	0.0±0.0	100	469
32	<i>C. winterianus</i> + <i>P. roxburghii</i>	0.2+0.2	0.0±0.0	100	469
33	<i>E. citriodora</i> + <i>C. longa</i>	0.2+0.2	0.0±0.0	100	469
34	<i>E. citriodora</i> + <i>P. roxburghii</i>	0.2+0.2	0.0±0.0	100	469
35	<i>C. longa</i> + <i>P. roxburghii</i>	0.2+0.2	0.0±0.0	100	469
36	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i>	0.14 E	0.0±0.0	100	469
37	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. winterianus</i>	0.14 E	0.0±0.0	100	469
38	<i>M. arvensis</i> + <i>M. piperita</i> + <i>E. citriodora</i>	0.14 E	0.0±0.0	100	469
39	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. longa</i>	0.14 E	0.0±0.0	100	469
40	<i>M. arvensis</i> + <i>M. piperita</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	469
41	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. winterianus</i>	0.14 E	0.0±0.0	100	469

42	<i>M. arvensis</i> + <i>M. spicata</i> + <i>E. citriodora</i>	0.14 E	0.0±0.0	100	469
43	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. longa</i>	0.14 E	0.0±0.0	100	469
44	<i>M. arvensis</i> + <i>M. spicata</i> + <i>P. roxburghii</i>	0.14E	0.0±0.0	100	469
45	<i>M. arvensis</i> + <i>C. winterianus</i> + <i>E. citriodora</i>	0.14 E	0.0±0.0	100	469
46	<i>M. arvensis</i> + <i>C. winterianus</i> + <i>C. longa</i>	0.14 E	0.0±0.0	100	469
47	<i>M. arvensis</i> + <i>C. winterianus</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	469
48	<i>M. arvensis</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.14 E	0.0±0.0	100	469
49	<i>M. arvensis</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	469
50	<i>M. arvensis</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	469
51	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i>	0.14 E	0.0±0.0	100	469
52	<i>M. piperita</i> + <i>M. spicata</i> + <i>E. citriodora</i>	0.14 E	0.0±0.0	100	469
53	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. longa</i>	0.14 E	0.0±0.0	100	469
54	<i>M. piperita</i> + <i>M. spicata</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	469
55	<i>M. piperita</i> + <i>C. winterianus</i> + <i>E. citriodora</i>	0.14 E	0.0 ± 0.0	100	469
56	<i>M. piperita</i> + <i>C. winterianus</i> + <i>C. longa</i>	0.14 E	0.0 ± 0.0	100	469
57	<i>M. piperita</i> + <i>C. winterianus</i> + <i>P. roxburghii</i>	0.14 E	0.0 ± 0.0	100	469
58	<i>M. piperita</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.14 E	0.0 ± 0.0	100	469
59	<i>M. piperita</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.14 E	0.0 ± 0.0	100	469
60	<i>M. piperita</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.14 E	0.0 ± 0.0	100	469
61	<i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i>	0.14 E	0.0 ± 0.0	100	469
62	<i>M. spicata</i> + <i>C. winterianus</i> + <i>C. longa</i>	0.14 E	0.0 ± 0.0	100	469
63	<i>M. spicata</i> + <i>C. winterianus</i> + <i>P. roxburghii</i>	0.14 E	0.0 ± 0.0	100	469
64	<i>M. spicata</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.14 E	0.0 ± 0.0	100	469
65	<i>M. spicata</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.14 E	0.0 ± 0.0	100	469
66	<i>M. spicata</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.14 E	0.0 ± 0.0	100	469
67	<i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.14 E	0.0 ± 0.0	100	469
68	<i>C. winterianus</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.14 E	0.0 ± 0.0	100	469
69	<i>C. winterianus</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.14 E	0.0 ± 0.0	100	469
70	<i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.14 E	0.0 ± 0.0	100	469
71	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i>	0.1 E	0.0 ± 0.0	100	469
72	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>E. citriodora</i>	0.1 E	0.0 ± 0.0	100	469
73	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. longa</i>	0.1 E	0.0 ± 0.0	100	469
74	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
75	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. winterianus</i> + <i>E. citriodora</i>	0.1 E	0.0 ± 0.0	100	469
76	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. winterianus</i> + <i>C. longa</i>	0.1 E	0.0 ± 0.0	100	469
77	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. winterianus</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
78	<i>M. arvensis</i> + <i>M. piperita</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.1 E	0.0 ± 0.0	100	469
79	<i>M. arvensis</i> + <i>M. piperita</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
80	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
81	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i>	0.1 E	0.0 ± 0.0	100	469
82	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>C. longa</i>	0.1 E	0.0 ± 0.0	100	469
83	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
84	<i>M. arvensis</i> + <i>M. spicata</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.1 E	0.0 ± 0.0	100	469
85	<i>M. arvensis</i> + <i>M. spicata</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
86	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
87	<i>M. arvensis</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.1 E	0.0 ± 0.0	100	469
88	<i>M. arvensis</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
89	<i>M. arvensis</i> + <i>C. winterianus</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
90	<i>M. arvensis</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
91	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i>	0.1 E	0.0 ± 0.0	100	469
92	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>C. longa</i>	0.1 E	0.0 ± 0.0	100	469
93	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
94	<i>M. piperita</i> + <i>M. spicata</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.1 E	0.0 ± 0.0	100	469
95	<i>M. piperita</i> + <i>M. spicata</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
96	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
97	<i>M. piperita</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.1 E	0.0 ± 0.0	100	469

98	<i>M. piperita</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
99	<i>M. piperita</i> + <i>C. winterianus</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
100	<i>M. piperita</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
101	<i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.1 E	0.0 ± 0.0	100	469
102	<i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
103	<i>M. spicata</i> + <i>C. winterianus</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
104	<i>M. spicata</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
105	<i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0 ± 0.0	100	469
106	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i>	0.08 E	0.0 ± 0.0	100	469
107	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>C. longa</i>	0.08 E	0.0 ± 0.0	100	469
108	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>P. roxburghii</i>	0.08 E	0.0 ± 0.0	100	469
109	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.08 E	0.0 ± 0.0	100	469
110	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.08 E	0.0 ± 0.0	100	469
111	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0 ± 0.0	100	469
112	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.08 E	0.0 ± 0.0	100	469
113	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.08 E	0.0 ± 0.0	100	469
114	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. winterianus</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0 ± 0.0	100	469
115	<i>M. arvensis</i> + <i>M. piperita</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0 ± 0.0	100	469
116	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.08 E	0.0 ± 0.0	100	469
117	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.08 E	0.0 ± 0.0	100	469
118	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0 ± 0.0	100	469
119	<i>M. arvensis</i> + <i>M. spicata</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0 ± 0.0	100	469
120	<i>M. arvensis</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0 ± 0.0	100	469
121	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.08 E	0.0 ± 0.0	100	469
122	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.08 E	0.0 ± 0.0	100	469
123	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0 ± 0.0	100	469
124	<i>M. piperita</i> + <i>M. spicata</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0 ± 0.0	100	469
125	<i>M. piperita</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0 ± 0.0	100	469
126	<i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0 ± 0.0	100	469
127	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.07 E	0.0 ± 0.0	100	469
128	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.07 E	0.0 ± 0.0	100	469
129	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.07 E	0.0 ± 0.0	100	469
130	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.07 E	0.0 ± 0.0	100	469
131	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.07 E	0.0 ± 0.0	100	469
132	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.07 E	0.0 ± 0.0	100	469
133	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.07 E	0.0 ± 0.0	100	469
134	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.06 E	0.0 ± 0.0	100	469
135	<i>M. piperita</i> + <i>C. longa</i>	0.1+0.1	0.0 ± 0.0	100	469
136	<i>M. piperita</i> + <i>P. roxburghii</i>	0.1+0.1	0.0 ± 0.0	100	469
137	<i>C. longa</i> + <i>P. roxburghii</i>	0.1+0.1	0.0 ± 0.0	100	469
138	<i>C. longa</i> + <i>M. arvensis</i>	0.1+ 0.1	0.0 ± 0.0	100	469
139	<i>C. longa</i> + <i>M. arvensis</i>	0.3+ 0.1	0.0 ± 0.0	100	469
140	<i>P. roxburghii</i> + <i>M. arvensis</i>	0.1+0.1	0.0 ± 0.0	100	469
141	<i>P. roxburghii</i> + <i>M. arvensis</i>	0.3+0.1	0.0 ± 0.0	100	469
142	Untreated control	—	386.0±70.7	0	469

E= each

or *T. castaneum* were released in each vial. Measured quantity of component oil was soaked on Whatman

No. 42 filter paper disc (3.5 cm diameter) in the ratio indicated in the Table 2 and 3. The paper disc soaked

Table 3: Effect of different formulation of herbal fumigants on progeny production of *T. castaneum*

S.No.	Component	Conc. % (v/w)	No. of adults emerged	Percent Inhibition	Days after fumigation
1	<i>M. arvensis</i>	0.2	0.0±0.0	100	446
2	<i>M. piperita</i>	0.2	0.0±0.0	100	446
3	<i>M. spicata</i>	0.2	0.0±0.0	100	446
4	<i>C. winterianus</i>	0.2	0.0±0.0	100	446
5	<i>E. citriodora</i>	0.2	0.0±0.0	100	446
6	<i>C. longa</i>	0.2	0.0±0.0	100	446
7	<i>P. roxburghii</i>	0.2	0.0±0.0	100	446
8	<i>M. arvensis</i>	0.4	0.0±0.0	100	446
9	<i>M. piperita</i>	0.4	0.0±0.0	100	446
10	<i>M. spicata</i>	0.4	0.0±0.0	100	446
11	<i>C. winterianus</i>	0.4	0.0±0.0	100	446
12	<i>E. citriodora</i>	0.4	0.0±0.0	100	446
13	<i>C. longa</i>	0.4	0.0±0.0	100	446
14	<i>P. roxburghii</i>	0.4	0.0±0.0	100	446
15	<i>M. arvensis</i> + <i>M. piperita</i>	0.2+0.2	0.0±0.0	100	446
16	<i>M. arvensis</i> + <i>M. spicata</i>	0.2+0.2	0.0±0.0	100	446
17	<i>M. arvensis</i> + <i>C. winterianus</i>	0.2+0.2	0.0±0.0	100	446
18	<i>M. arvensis</i> + <i>E. citriodora</i>	0.2+0.2	0.0±0.0	100	446
19	<i>M. arvensis</i> + <i>C. longa</i>	0.2+0.2	0.0±0.0	100	446
20	<i>M. arvensis</i> + <i>P. roxburghii</i>	0.2+0.2	0.0±0.0	100	446
21	<i>M. piperita</i> + <i>M. spicata</i>	0.2+0.2	0.0±0.0	100	446
22	<i>M. piperita</i> + <i>C. winterianus</i>	0.2+0.2	0.0±0.0	100	446
23	<i>M. piperita</i> + <i>E. citriodora</i>	0.2+0.2	0.0±0.0	100	446
24	<i>M. piperita</i> + <i>C. longa</i>	0.2+0.2	0.0±0.0	100	446
25	<i>M. piperita</i> + <i>P. roxburghii</i>	0.2+0.2	0.0±0.0	100	446
26	<i>M. spicata</i> + <i>C. winterianus</i>	0.2+0.2	0.0±0.0	100	446
27	<i>M. spicata</i> + <i>E. citriodora</i>	0.2+0.2	0.0±0.0	100	446
28	<i>M. spicata</i> + <i>C. longa</i>	0.2+0.2	0.0±0.0	100	446
29	<i>M. spicata</i> + <i>P. roxburghii</i>	0.2+0.2	0.0±0.0	100	446
30	<i>C. winterianus</i> + <i>E. citriodora</i>	0.2+0.2	0.0±0.0	100	446
31	<i>C. winterianus</i> + <i>C. longa</i>	0.2+0.2	0.0±0.0	100	446
32	<i>C. winterianus</i> + <i>P. roxburghii</i>	0.2+0.2	0.0±0.0	100	446
33	<i>E. citriodora</i> + <i>C. longa</i>	0.2+0.2	0.0±0.0	100	446
34	<i>E. citriodora</i> + <i>P. roxburghii</i>	0.2+0.2	0.0±0.0	100	446
35	<i>C. longa</i> + <i>P. roxburghii</i>	0.2+0.2	0.0±0.0	100	446
36	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i>	0.14 E	0.0±0.0	100	446
37	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. winterianus</i>	0.14 E	0.0±0.0	100	446
38	<i>M. arvensis</i> + <i>M. piperita</i> + <i>E. citriodora</i>	0.14 E	0.0±0.0	100	446
39	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. longa</i>	0.14 E	0.0±0.0	100	446
40	<i>M. arvensis</i> + <i>M. piperita</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	446
41	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. winterianus</i>	0.14 E	0.0±0.0	100	446
42	<i>M. arvensis</i> + <i>M. spicata</i> + <i>E. citriodora</i>	0.14 E	0.0±0.0	100	446
43	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. longa</i>	0.14 E	0.0±0.0	100	446
44	<i>M. arvensis</i> + <i>M. spicata</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	446
45	<i>M. arvensis</i> + <i>C. winterianus</i> + <i>E. citriodora</i>	0.14 E	0.0±0.0	100	446
46	<i>M. arvensis</i> + <i>C. winterianus</i> + <i>C. longa</i>	0.14 E	0.0±0.0	100	446
47	<i>M. arvensis</i> + <i>C. winterianus</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	446
48	<i>M. arvensis</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.14 E	0.0±0.0	100	446
49	<i>M. arvensis</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	446
50	<i>M. arvensis</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	446
51	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i>	0.14 E	0.0±0.0	100	446
52	<i>M. piperita</i> + <i>M. spicata</i> + <i>E. citriodora</i>	0.14 E	0.0±0.0	100	446

53	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. longa</i>	0.14 E	0.0±0.0	100	446
54	<i>M. piperita</i> + <i>M. spicata</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	446
55	<i>M. piperita</i> + <i>C. winterianus</i> + <i>E. citriodora</i>	0.14 E	0.0±0.0	100	446
56	<i>M. piperita</i> + <i>C. winterianus</i> + <i>C. longa</i>	0.14 E	0.0±0.0	100	446
57	<i>M. piperita</i> + <i>C. winterianus</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	446
58	<i>M. piperita</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.14 E	0.0±0.0	100	446
59	<i>M. piperita</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	446
60	<i>M. piperita</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	446
61	<i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i>	0.14 E	0.0±0.0	100	446
62	<i>M. spicata</i> + <i>C. winterianus</i> + <i>C. longa</i>	0.14 E	0.0±0.0	100	446
63	<i>M. spicata</i> + <i>C. winterianus</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	446
64	<i>M. spicata</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.14 E	0.0±0.0	100	446
65	<i>M. spicata</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	446
66	<i>M. spicata</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	446
67	<i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.14 E	0.0±0.0	100	446
68	<i>C. winterianus</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	446
69	<i>C. winterianus</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	446
70	<i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.14 E	0.0±0.0	100	446
71	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i>	0.1 E	0.0±0.0	100	446
72	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>E. citriodora</i>	0.1 E	0.0±0.0	100	446
73	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. longa</i>	0.1 E	0.0±0.0	100	446
74	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
75	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. winterianus</i> + <i>E. citriodora</i>	0.1 E	0.0±0.0	100	446
76	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. winterianus</i> + <i>C. longa</i>	0.1 E	0.0±0.0	100	446
77	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. winterianus</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
78	<i>M. arvensis</i> + <i>M. piperita</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.1 E	0.0±0.0	100	446
79	<i>M. arvensis</i> + <i>M. piperita</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
80	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
81	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i>	0.1 E	0.0±0.0	100	446
82	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>C. longa</i>	0.1 E	0.0±0.0	100	446
83	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
84	<i>M. arvensis</i> + <i>M. spicata</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.1 E	0.0±0.0	100	446
85	<i>M. arvensis</i> + <i>M. spicata</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
86	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
87	<i>M. arvensis</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.1 E	0.0±0.0	100	446
88	<i>M. arvensis</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
89	<i>M. arvensis</i> + <i>C. winterianus</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
90	<i>M. arvensis</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
91	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i>	0.1 E	0.0±0.0	100	446
92	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>C. longa</i>	0.1 E	0.0±0.0	100	446
93	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
94	<i>M. piperita</i> + <i>M. spicata</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.1 E	0.0±0.0	100	446
95	<i>M. piperita</i> + <i>M. spicata</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
96	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
97	<i>M. piperita</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.1 E	0.0±0.0	100	446
98	<i>M. piperita</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
99	<i>M. piperita</i> + <i>C. winterianus</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
100	<i>M. piperita</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
101	<i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.1 E	0.0±0.0	100	446
102	<i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
103	<i>M. spicata</i> + <i>C. winterianus</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
104	<i>M. spicata</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
105	<i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.1 E	0.0±0.0	100	446
106	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i>	0.08 E	0.0±0.0	100	446
107	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>C. longa</i>	0.08 E	0.0±0.0	100	446
108	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>P. roxburghii</i>	0.08 E	0.0±0.0	100	446
109	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.08 E	0.0±0.0	100	446

110	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.08 E	0.0±0.0	100	446
111	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0±0.0	100	446
112	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.08 E	0.0±0.0	100	446
113	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.08 E	0.0±0.0	100	446
114	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. winterianus</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0±0.0	100	446
115	<i>M. arvensis</i> + <i>M. piperita</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0±0.0	100	446
116	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.08 E	0.0±0.0	100	446
117	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.08 E	0.0±0.0	100	446
118	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0±0.0	100	446
119	<i>M. arvensis</i> + <i>M. spicata</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0±0.0	100	446
120	<i>M. arvensis</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0±0.0	100	446
121	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.08 E	0.0±0.0	100	446
122	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.08 E	0.0±0.0	100	446
123	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0±0.0	100	446
124	<i>M. piperita</i> + <i>M. spicata</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0±0.0	100	446
125	<i>M. piperita</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0±0.0	100	446
126	<i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.08 E	0.0±0.0	100	446
127	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i>	0.07 E	0.0±0.0	100	446
128	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>P. roxburghii</i>	0.07 E	0.0±0.0	100	446
129	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.07 E	0.0±0.0	100	446
130	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.07 E	0.0±0.0	100	446
131	<i>M. arvensis</i> + <i>M. piperita</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.07 E	0.0±0.0	100	446
132	<i>M. arvensis</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.07 E	0.0±0.0	100	446
133	<i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.07 E	0.0±0.0	100	446
134	<i>M. arvensis</i> + <i>M. piperita</i> + <i>M. spicata</i> + <i>C. winterianus</i> + <i>E. citriodora</i> + <i>C. longa</i> + <i>P. roxburghii</i>	0.06 E	0.0±0.0	100	446
135	<i>M. piperita</i> + <i>C. longa</i>	0.1+0.1	0.0±0.0	100	446
136	<i>M. piperita</i> + <i>P. roxburghii</i>	0.1+0.1	0.0±0.0	100	446
137	<i>C. longa</i> + <i>P. roxburghii</i>	0.1+0.1	0.0±0.0	100	446
138	<i>C. longa</i> + <i>M. arvensis</i>	0.1+ 0.1	0.0±0.0	100	446
139	<i>C. longa</i> + <i>M. arvensis</i>	0.3+ 0.1	0.0±0.0	100	446
140	<i>P. roxburghii</i> + <i>M. arvensis</i>	0.1+0.1	0.0±0.0	100	446
141	<i>P. roxburghii</i> + <i>M. arvensis</i>	0.3+0.1	0.0±0.0	100	446
142	Untreated control	-	153.3±71.9	0	446

E=each

with herbal fumigant was inserted in the grain filled in vial which was closed air tight. After closing the lid, the vial was sealed with the help of paraffin wax strips and cello tape. The insects were allowed to complete generations on the treated grains. The observations were recorded at 469 and 446 days after fumigation for *R. dominica* and *T. castaneum*, respectively, after which experiment was terminated as the untreated vial was completely rotten due to insect feeding. After 469- and 446-days storage each

jar was analysed to count the number of adults emerged and percent inhibition by using the formula described by Adams and Schulten (1976).

$$\text{Percent inhibition} = \frac{\text{Control} - \text{treated}}{\text{Control}} \times 100$$

RESULTS AND DISCUSSION

The effect of different herbal fumigants on the progeny production of *R. dominica* is presented in

Table 2 which indicates that *Mentha arvensis*, *Mentha piperita*, *Mentha spicata*, *Cymbopogon winterianus*, *Eucalyptus citriodora*, *Curcuma longa* or *Pinus roxburghii* at 0.2 or 0.4 percent or their two component combination at 0.2 percent each, three component combination at 0.14 percent each, four component combination at 0.1 percent each, five component combination at 0.08 percent each or six component combination at 0.07 percent each or seven component combination at 0.06 percent each were highly effective against this insect as they completely checked the progeny production of it. Tewari and Tiwari (2021c) also reported that different formulations of seven essential oils *M. arvensis*, *M. piperita*, *M. spicata*, *C. winterianus*, *E. citriodora*, *E. globulus* and *P. roxburghii* were effective at 0.20, 0.40, 0.14, 0.13, 0.10, 0.08, 0.07, 0.06 percent against *S. oryzae* and *R. dominica*. The combination of *M. piperita* + *C. longa* or *M. piperita* + *P. roxburghii* or *C. longa* + *P. roxburghii* or *C. longa* + *M. arvensis* or *P. roxburghii* + *M. arvensis* at 0.1 percent each were also highly effective against this insect as they completely inhibited the progeny of it. Herbal fumigant having *C. longa* + *M. arvensis* at 0.3+0.1 percent or *P. roxburghii* + *M. arvensis* at 0.3+0.1 percent was also found highly effective against *R. dominica* for 469 days. Kumari and Tiwari (2023) also reported their high efficacy of tested formulations against *Sitophilus oryzae* for 515 days except for *M. arvensis*, *C. winterianus* and *Curcuma longa* at 0.2 percent each.

The effect of different formulation of herbal fumigant on the progeny production of *T. castaneum* is presented in Table 3 which indicates that all the formulations having *M. arvensis*, *M. piperita*, *M. spicata*, *C. winterianus*, *E. citriodora*, *C. longa* or *P. roxburghii* oil at 0.2 or 0.4 percent or their two components' combinations at 0.2 percent each, three component combination at 0.14 percent each or four component combination at 0.1 percent each or five component combinations at 0.08 percent each or six component combinations at 0.07 percent each or seven component combination at 0.06 percent each, completely checked the population development of this insect up to 446 days. Herbal fumigant having *M. piperita* + *C. longa* or *M. piperita* + *P. roxburghii*

or *C. longa* + *P. roxburghii* or *C. longa* + *M. arvensis* or *P. roxburghii* + *M. arvensis* at 0.1 percent or *C. longa* + *M. arvensis* or *P. roxburghii* + *M. arvensis* at 0.3+0.1 percent were also highly effective against these insects for 446 days. Kumar *et al.* (2018) observed that herbal fumigants having *M. koenigii* + *C. reticulata*, *M. koenigii* + *C. longa*, *C. reticulata* + *C. longa* and *M. koenigii* + *C. reticulata* + *C. longa* protected the grain from infestation of *R. dominica*, *S. oryzae* and *T. castaneum* for one year without affecting the organoleptic properties of treated grain or its germination when used at 0.2%. A long-term study also indicated that essential oils of *M. arvensis*, *M. piperita*, *M. spicata*, *P. roxburghii*, *C. winterianus* and *E. globulus* were highly effective against *R. dominica* and *S. oryzae* at 0.40 per cent for 6 months (Tewari and Tiwari, 2021d).

CONCLUSION

The study revealed that all the seven essential oils of *M. arvensis*, *M. piperita*, *M. spicata*, *C. winterianus*, *E. citriodora*, *C. longa* or *P. roxburghii* at 0.20 and 0.40 per cent and their 2, 3, 4, 5, 6, 7 oil combinations at 0.14, 0.13, 0.10, 0.08, 0.07, 0.06 percent each were highly effective against *R. dominica* and *T. castaneum* up to 469 and 446 days, respectively. The formulations of essential oils having *M. piperita* + *C. longa* or *M. piperita* + *P. roxburghii* or *C. longa* + *P. roxburghii* or *C. longa* + *M. arvensis* or *P. roxburghii* + *M. arvensis* at 0.10 percent or *C. longa* + *M. arvensis* or *P. roxburghii* + *M. arvensis* at 0.30+0.10 percent were also highly effective against both the insects for the same duration. The study revealed several formulations of herbal fumigants which are highly effective against *R. dominica* and *T. castaneum*. These formulations have already been reported to be highly effective for 515 days against *S. oryzae*. Since *S. oryzae*, *R. dominica* and *T. castaneum* are the major insect pests of stored cereals in most part of India and other tropical and sub-tropical countries, these may prove to be an eco-friendly and cheap non-chemical alternative for the management of all above-mentioned pests under storage conditions. The wide availability of component plants in most of the countries may help to develop a local

alternative in most of the countries.

ACKNOWLEDGEMENTS

Authors are highly grateful to Joint Director of Medicinal and Aromatic Plants Research and Development Centre, Pantnagar (Uttarakhand) and Directors of Central Institute of Medicinal and Aromatic Plants, Field Station, Nagla (Uttarakhand) and Central Institute of Medicinal and Aromatic Plants, Lucknow (Uttar Pradesh) for providing experimental material.

REFERENCES

- Adams, J. M. and Schulten, G. G. M. (1976). Losses caused by insects, mites and micro-organisms. *In: American Association of Cereal Chemists. Postharvest Grain Loss Methods*. Slough, Pp. 83-93.
- Clemente, S., Mareggiani, G., Broussalis, A., Martino, V., Ferraro, G. (2003). Insecticidal effects of Lamiaceae species against stored product insects. *Boletín de Sanidad Vegetal*, 29: 1-8.
- Don-Pedro, K.N. (1996). Fumigant toxicity of citrus peel oils against adult and immature stages of storage insect. *Pesticide Science*, 47(3): 213-223.
- Gangwar, P. and Tiwari, S. N. (2017). Insecticidal activity of *Curcuma longa* essential oil and its fractions against *Sitophilus oryzae* L. and *Rhyzopertha dominica* F. (Coleoptera). *Indian Journal of Pure and Applied Biosciences*, 5: 912-921.
- Geetanily, Chandel, R., Mishra, V. K. and Tiwari, S. N. (2016). Comparative efficacy of eighteen essential oil against *Rhyzopertha dominica* (F.). *International Journal of Agriculture, Environment and Biotechnology*, 9(3): 353.
- Geetanily and Tiwari, S. N. (2021). Seasonal changes in yield, composition and fumigant action of essential oil of *Murraya koenigii* L. against *Rhyzopertha dominica* (F.) and *Sitophilus oryzae* (L.). *Pantnagar Journal of Research*, 19(2): 204-213.
- Golob, P. and Webley, D. J. (1980). The use of plants and minerals as traditional protectants of stored products. Report of Tropical Product Institute, No-G138, VI +32pp.
- Grainge, M. and Ahmed, S. (1988). Hand Book of Plants with Pest Control Properties. John Wiley and Sons, New York, 470p.
- IGSMRI (2019). <https://igmri.dfpd.gov.in/igmri/foodgrainstorage#:~:text=In%20India%20annual%20storage%20losses,1%2C300%20crores>
- Jacobson, M. (1975). Insecticides from plants- A review of the literature, 1953-1971. USDA Agr. Hdbk 461, ARS-USDA, Beltsville, M.D.
- Jacobson, M. (1983). Control of stored product insects with phytochemicals. Proceedings of 3rd International Working Conference on Stored Product Entomology, Manhattan, USA, Oct. 23-28, 1983, Pp 183-195.
- Joshi, R. and Tiwari, S. N. (2019). Fumigant toxicity and repellent activity of some essential oils against stored grain pest *Rhyzopertha dominica* (Fabricius). *Journal of Pharmacognosy and Phytochemistry*, 8(4): 59-62.
- Kumar, R. and Tiwari, S. N. (2017a). Fumigant toxicity of essential oil and their combination against *Rhyzopertha dominica* and *Tribolium castaneum* at different days interval in stored wheat. *Journal of Postharvest Technology*, 4 (2): S01-S05.
- Kumar, R. and Tiwari, S. N. (2017b). Fumigant toxicity of essential oils and their combination against *Sitophilus oryzae* (Coleoptera: Curculionidae) at different days interval in stored wheat. *Journal of Postharvest Technology*, 4 (2): S06-S10.
- Kumar, R., Tiwari, S. N. and Pandey, P. S. (2018). Fumigant toxicity of essential oils and their combinations on population build-up of three stored product coleoptera in stored wheat and effect on quality of wheat. 12th International Working Conference on Stored Product Protection (IWCSPP) in Berlin, Germany, October 7-11, 2018. 680-687.
- Kumari, D. and Tiwari, S. N. (2022a). Long term efficacy of seven essential oils against

- Sitophilus oryzae* (Linnaeus), *Rhyzopertha dominica* (Fabricius) and *Tribolium castaneum* (Herbst). *Pantnagar Journal of Research*, 20(2): 221-228.
- Kumari, D. and Tiwari, S. N. (2022b). Long-term efficacy of nineteen essential oils against *Corcyra cephalonica* (Stainton), *Sitotroga cerealella* (Olivier) and *Callosobruchus chinensis* (Linnaeus). *Pantnagar Journal of Research*, 20(3): 412-424.
- Kumari, D. and Tiwari, S. N. (2022c). Long - term efficacy of some herbal fumigants against *Sitophilus oryzae* (Linnaeus), *Rhyzopertha dominica* (Fabricius) and *Tribolium castaneum* (Herbst). *Pantnagar Journal of Research*, 20(3): 425-434.
- Kumari, D. and Tiwari, S. N. (2023). The effect of different formulations of herbal fumigant on progeny production of stored grain insect pest, *Sitophilus oryzae* (Linnaeus). *Pantnagar Journal of Research*, 21(1): 45-52.
- Lee, B. H., Lee, S. E., Annis, P. C., Pratt, S. J., Park, B. S. and Tumaalii, F. (2002). Fumigant toxicity of essential oils and monoterpenes against the red flour beetle, *Tribolium castaneum* Herbs. *Journal of Asia Pacific Entomology*, 5(2): 237-240.
- Lee, B. H., Annis, P. C., Tumaalii, F. and Lee, S. E. (2004). Fumigant toxicity of *Eucalyptus blakelyi* and *Melaleuca fulgens* essential oils and 1, 8-cineole against different developmental stages of rice weevil. *Phytoparasitica*, 32(5): 498-506.
- Ngamo, T. S. L., Ngatanko, I., Ngassou, M. B., Mapongmestsem, P. M. and Hance, T. (2007). Insecticidal efficiency of essential oils of 5 aromatic plants tested both alone and in combination towards *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae). *Research Journal of Biological Sciences*, 2(1): 75-80.
- Pascual, V. M. J. and Ballesta, A. M. C. (2003). Chemical variation in an *Ocimum basilicum* germplasm collection and activity of the essential oils on *Callosobruchus maculatus*. *Biochemistry Systematics and Ecology*, 31 (7): 673-679.
- Pixton, S.W. (1967). Moisture content—its significance and measurement in stored products. *Journal of Stored Product Research*, 3: 35-37.
- Rajendran, S. and Sriranjini, V. (2008). Plant products as fumigants for stored-product insect control. *Journal of Stored Product Research*, 44: 126-135.
- Regnault-Roger, C. (1997). The potential of botanical essential oils for insect pest control. *Integrated Pest Management Reviews*, 2, 25-34.
- Shaaya, E., Ravid, U., Paster, N., Juven, B., Zisman, U. and Pissarev, V. (1990). Fumigant toxicity of essential oils against four major stored product insects. *Journal of Chemical Ecology NY*, 17(3): 499-504.
- Shaaya, E., Kostjukovski, M., Eilberg, J. and Sukprakarn, C. (1997). Plant oils as fumigants and contact insecticides for the control of stored product insects. *Journal of Stored Product Research*, 33(1): 7-15.
- Singh, D.; Siddiqui, M.S. and Sharma, S. (1989). Reproduction retardant and fumigant properties in essential oils against rice weevil (Coleoptera: Curculionidae) in stored wheat. *Journal of Economic Entomology*, 82: 727-733.
- Singh, G. and Upadhyay, R. K. (1993). Essential oils: a potent source of natural pesticides. *Journal of Scientific and Industrial Research*, 52: 676-683.
- Tewari, N. (2008). Fumigant toxicity of some essential oils against *Rhyzopertha dominica* (Fabricius) and *Sitophilus oryzae* (Linnaeus). Thesis, Ph. D, G. B. Pant University of Agriculture and Technology, Pantnagar, 302 p.
- Tewari N. and Tiwari S.N. (2021a). Effect of sixteen essential oils on the progeny production of *Sitophilus oryzae* (Linnaeus). *Pantnagar Journal of Research*, 19(2): 187-194.
- Tewari N. and Tiwari S.N. (2021b). Bio-efficacy of some essential oils as fumigant against Lesser grain borer, *Rhyzopertha dominica* (Fab.). *Pantnagar Journal of Research*, 19(2): 195-203.

- Tewari N. and Tiwari S.N. (2021c). Fumigant toxicity of some essential oils and their combinations against *Rhyzopertha dominica* (Fabricius) and *Sitophilus oryzae* (Linnaeus). *Pantnagar Journal of Research*, 19(3): 389-399
- Tewari N. and Tiwari S.N. (2021d). Long term efficacy of some essential oils against *Rhyzopertha dominica* (Fabricius) and *Sitophilus oryzae* (Linnaeus). *Pantnagar Journal of Research*, 19(3):400-407.
- Tiwari, S. N. (1993). Efficacy of some plant products as grain protectant against *Sitophilus oryzae* (L.). *Journal of Insect Science*, 6: 158-160.
- Tripathi, A.K., Prajapati, V., Verma, N., Bahl, J.R., Bansal, R.P., Khanuja, S.P.S. and Kumar, S. (2002). Bioactivities of the leaf essential oil of *Curcuma longa* (var. Ch-66) on three species of stored product beetles (Coleoptera). *Journal of Economic Entomology*, 95(1): 183-189.
- Tunc, I., Berger, B.M., Erler, F. and Dagli, F. (2000). Ovicidal activity of essential oils from five plant against two stored product insects. *Journal of Stored Product Research*, 36(2): 161-168.

Received: August 7, 2023

Accepted: August 27, 2023