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CONTENTS

Long term efficacy of some essential oils against *Rhyzopertha dominica* (Fabricius) and *Sitophilus oryzae* (Linnaeus)

NIDHI TEWARI and S. N. TIWARI

Department of Entomology, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar-263 145 (U.S. Nagar, Uttarakhand)

ABSTRACT: The long-term efficacy of some essential oils was studied against Lesser grain borer, *Rhyzopertha dominica* and Rice weevil, *Sitophilus oryzae* at 0.40%(v/w) under laboratory condition. After 6 months storage, essential oils of *Mentha arvensis*, *M. piperita, M. spicata, Pinus roxburghii, Cymbopogon winterianus, Eucalyptus globulus, Curcuma longa, M. citrata* and *P. graveolens* were found to be highly effective by inhibiting 91.9 to 100.0 per cent progeny of *R. dominica*. On the other hand, the oils of *E. citriodora* and *C. flexuosus* became least effective due to 7.5 and 59.1 per cent suppression of progeny after 6 months. Treatment of grain with essential oils of *M. arvensis, M. piperita, M. spicata, P. roxburghii, C. winterianus, E. globulus, C. longa, M. citrata* and *P. graveolens* suppressed 97.3, 99.2, 99.1, 98.2, 96.8, 99.5, 98.9, 94.3 and 89.7 per cent infestation of this insect, respectively, after 6 months storage. The oils of *M. arvensis, M. piperita, M. spicata, P. roxburghii, C. winterianus, E. globulus, C. longa*, *M. citrata* and *P. graveolens also* suppressed 97.2, 99.2, 99.1, 98.3, 98.7, 98.6, 95.6 and 89.8 per cent weight loss after 6 months storage. The oils of *M. arvensis, M. piperita, M. spicata, P. roxburghii, C. winterianus, E. citriodora* and *E. globulus* were also highly effective against *S. oryzae* after 2, 4 and 6 months storage due to 90.1 to 100.0 per cent inhibition of progeny. Except *C. winterianus,* all these oils were also highly effective in reducing the infestation and weight loss of grain due to *S. oryzae* after 4 and 6 months storage. The result indicated that essential oils were highly effective against *R. dominica* and *S. oryzae* for 6 months and they can be used for protection of grain in short to medium term storage.

Key words: Essential oils, fumigant toxicity, long term efficacy, lesser grain borer, rice weevil, *Rhyzopertha dominica*, *Sitophilus oryzae*

Lesser grain borer, *Rhyzopertha dominica* (F.) and Rice weevil, *Sitophilus oryzae* (L.) are major insect pests of stored cereals in many countries (CABI, 2021) in which their management is dominated by use of insecticides and fumigants which are not suitable for use in on farm and consumer level storage due to various reasons. In the past six decades numerous attempts have been made to investigate non-chemical tools for the management of these insects and much advancement has been made in the exploration of phytochemicals, many of which have been found to be highly effective against these insects due to their contact, anti-feedant, repellent and fumigant action (Grainge and Ahmed, 1988; Shaaya *et al.,* 1990; Shaaya *et al.,* 1997; Rajendran and Sriranjini, 2008). Nowadays much emphasis is being given to plant essential oils that have been investigated to possess potent fumigant action which may be utilized for the management of these insect pests. Review of literature indicates that most of the studies have focused on identification of essential oils possessing fumigant action and characterization of active ingredients (Tripathi *et al.,* 2002; Tewari and Tiwari, 2008; Geetanjly *et al.*, 2016; Gangwar and Tiwari, 2017; Kumar and Tiwari, 2017a; 2017b; Kumar and Tiwari, 2018a; 2018b; Joshi and Tiwari, 2019; Sharma and Tiwari, 2021a; 2021b; Geetanjly and Tiwari, 2021) and only a few studies have been directed towards investigating their capability in protection of grain in long term storage (Kumar *et al.*, 2019).

Tewari and Tiwari (2021a) reported that essential oils of *Curcuma longa, Cymbopogon winterianus, Eucalyptus citriodora, E. globulus, Mentha arvensis, M. citrata, M. piperita, M. spicata, Pelargonium graveolens, Pinus roxburghii* were highly effective against *R. dominica* at 0.4 per cent concentration (v/w). In another study the essential oils of *Cymbopogon flexuosus, C. winterianus, E. citriodora, E. globulus, M. piperita*, *M. spicata and P. roxburghii* were also found to be highly effective against *S. oryzae* at the same concentration (Tewari and Tiwari, 2021b). In these studies the efficacy of

the essential oils was studied only for one generation due to which they may not be considered for protection of grain unless their high efficacy persists in long term storage. In the present study, an attempt was made to investigate the long-term efficacy of above-mentioned essential oils against *R. dominica* and *S. oryzae* in long term storage.

MATERIALS AND METHODS

The experiments were conducted in Post Harvest Entomology Laboratory of Department of Entomology, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. Pure culture of *R. dominica* and *S. oryzae* was developed on grain of wheat variety UP-2565 in 1 kg plastic jar having a circular hole of 1.8 cm diameter in the lid which was covered with 30 mesh copper wire net. The rearing was done in BOD incubator at 30+1^{0}C temperature and 70+5 per cent relative humidity. Before use, the grain was disinfested in the oven at 60^{0}C for 12 hrs after which its moisture content 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 the formula described by Pixton (1967). After mixing the water in the grain it was kept in closed polythene bag for a week for moisture equilibration. The grain was then filled in plastic jar and 100 adults were released in each jar which was then kept in incubator. First generation adults (0-7 days old) were used for experimental purpose.

Essential oils selected for the study were collected from the Medicinal and Aromatic Plants Research and Development Centre, Pantnagar and Central Institute of Medicinal and Aromatic Plants, Field Station, Pantnagar. The oils of *Mentha arvensis* (mint), *M. piperita* (peppermint), *M. spicata*(spearmint), *Pinus roxburghii* (pine), *Eucalyptus citriodora* (Nilgiri), *E. globulus* (eucalyptus) and *Cymbopogon winterianus* (citronella) were used for evaluation against *S. oryzae* while *Curcuma longa* (turmeric), *C. flexuosus* (lemon grass), *M. citrata* (Bergamot mint) and *Pelargonium graveolens* (geranium) oil were also included in the study against *R. dominica.* The long-term fumigant toxicity of all the oils was studied at 0.40 per cent (v/w).

The experiment was conducted in a control room at 30±1°C temperature and 70±5 per cent relative humidity in air tight plastic jar of 250 g capacity on wheat grain of variety UP 2565 having 13.5 per cent moisture content. The long term efficacy of essential oils was evaluated on the basis of effect of oil on population build up of *R. dominica* and *S. oryzae* and per cent infestation and weight loss of grain after 2, 4 and 6 month storage. Each treatment was replicated three times and three sets of each treatment were prepared for recording observation at different intervals. After filling 250 g wheat grain in plastic jar, 20 adults of *R. dominica* or *S. oryzae* were released in it. Required quantity of essential oil was soaked on 7 cm paper discs (What Man No. 42 filter paper) which was then inserted in the grain filled in jar. After treatment the lid of the jar was closed and sealed by paraffin film strip to make it completely airtight. After 2, 4 and 6 month storage three jars comprising three replication of each treatment were opened to count the number of adults emerged and the number of healthy and infested grain to calculate per cent infestation and per cent weight loss.

The per cent infestation in grain was calculated by using the formula:

$$\text{Per cent infestation} = \frac{Nd}{Nu + Nd} \times 100$$

Per cent weight loss was calculated by using the formula described by Adams and Schulten (1976).

Per cent weight loss =

$$\frac{(Wu \times Nd) - (Wd \times Nu)}{Wu\ (Nd + Nu)} \times 100$$

where,
Wu= weight of undamaged grain;
Wd= weight of damaged grain;
Nu= number of undamaged grain;
Nd= number of damaged grain

Data was analyzed in two factor completely randomized design after suitable transformation.

RESULTS AND DISCUSSION

Effect of essential oils on population buildup of *R. dominica* and infestation of grain

The effect of essential oils on population buildup of *R. dominica* after 2, 4 and 6 month storage is presented in Table 1 which indicates that significantly higher adult emergence was recorded in untreated control as compared to different treatments during all the observations. All the essential oils were highly effective after 2 months storage because they suppressed 92.6 to 100.0 per cent progeny of *R. dominica* during this period. Significant reduction in fumigant toxicity of *E. citriodora* was recorded after 4 months storage as its efficacy reduced to 55 per cent. Some reduction in efficacy of *C. flexuosus* and *P. graveolens* was also noticed during this observation due to which they became moderately effective by inhibiting 89.1 and 87.1 per cent progeny. Rest of the oils remained highly effective during this observation. More or less similar trend was recorded after 6 months storage during which essential oils of *M. arvensis*, *M. piperita, M. spicata, P. roxburghii, C. winterianus, E. globulus, C. longa, M. citrata* and *P. graveolens* retained their efficacy by inhibiting 91.9 to 100.0 per cent progeny of *R. dominica*. On the other hand, the oils of *E. citriodora* and *C. flexuosus* became least effective due to 7.5 and 59.1 per cent suppression of progeny, respectively.

The effect of essential oils on the infestation of grain is presented in Table 2 which indicates that infestation was very low in grain treated with *M. arvensis, M. piperita, M. spicata, P. roxburghii, C. winterianus, E. globulus, C. longa* and *P. graveolens*. In case of *E. citriodora* and *C. flexuosus* per cent infestation increased from 11.19 to 60.40 and 3.62 to 54.35 between 4 and 6 month storage, respectively. As compared to these treatments the rate of increase was very high in untreated control in which infestation increased from 15.84 to 54.27 per cent. The study indicated that most of the oils were highly effective against *R. dominica* at 0.4 per cent due to appreciable reduction in per cent infestation after 6 month storage. Treatment of grain with essential oils of *M. arvensis, M. piperita, M. spicata, P. roxburghii, C. winterianus, E. globulus, C. longa* and *M. citrata* caused 97.3, 99.2, 99.1, 98.2, 96.8, 99.5, 98.9 and 94.3 per cent inhibition while *P. graveolens* caused 89.7 per cent inhibition after six months. On the other hand, *E. citriodora* and *C. flexuosus* oils were not found effective as more infestation was found in grain treated with these as compared to untreated control after 6 month storage. Most of the essential oils suppressed the loss in weight due to infestation of *R. dominica (*Table 3). However, *E. citriodora* and *C. flexuosus* failed to check any weight loss which increased from 17.73 to 91.29 and 6.09 to 88.89 per cent after 4 to 6 months storage, respectively. In case of untreated control, weight loss increased from 22.30 to 90.48 per cent during this period. The oils of *M. arvensis, M. piperita, M. spicata, P. roxburghii, C. winterianus, E. globulus, C. longa* , *M. citrate* and *P. graveolens* showed high efficacy at 0.4 per cent by suppressing 97.2, 99.2, 99.1, 98.3, 98.7, 98.6, 95.6 and 89.8 per cent weight loss after 6 months storage. On the other hand the oils of *E. citriodora* and *C. flexuosus* failed to check the loss in weight due to infestation of *R. dominica.*

Effect of essential oils on population buildup of *S. oryzae* and infestation of grain

The fumigant toxicity of essential oils against *S. oryzae* is presented in Table 4 which indicates that all the oils of *M. arvensis, M. piperita, M. spicata, P. roxburghii, C. winterianus, E. citriodora* and *E. globules* were highly effective against this insect after 2, 4 and 6 months storage due to 90.1 to 100.0 per cent inhibition of progeny. On the other hand very high adult emergence was recorded in untreated control which reached to 576.3 after 6 months storage. Table 5 indicates that all the oils except *C. winterianus* were also highly effective in reducing the infestation of grain after 4 and 6 months storage. The essential oil of *C. winterianus* was moderately effective in reducing the infestation as it suppressed 79.2 and 88.6 per cent infestation after 4 and 6 months, respectively. The weight loss was very high in untreated control as compared to treated grain (Table 6), however, not much difference in weight loss was observed between 4 and 6 month in all the

Table 1 : Population buildup of *R. dominica* on grain treated with different essential oils

Plant oil	Conc. % (v/w)	Month after storage						Mean
		2 month		4 month		6 month		
		Adults emerged	% inhibition	Adults emerged	% inhibition	Adults emerged	% inhibition	
M. arvensis	0.4	0.3 (0.2)	99.7	31.7 (3.5)	93.5	21.3 (3.1)	97.2	17.8 (2.3)
M. piperita	0.4	0.0 (0.0)	100.0	0.0 (0.0)	100.0	0.0 (0.0)	100.0	0.0 (0.0)
M. spicata	0.4	0.0 (0.0)	100.0	2.0 (0.7)	99.6	3.0 (0.8)	99.6	1.7 (0.5)
P. roxburghii	0.4	0.0 (0.0)	100.0	0.0 (0.0)	100.0	0.0 (0.0)	100.0	0.0 (0.0)
E. citriodora	0.4	0.0 (0.0)	100.0	219.7 (5.4)	55.0	692.7 (6.5)	7.5	304.1 (4.0)
C. winterianus	0.4	2.7 (1.2)	97.8	20.0 (3.0)	95.9	28.0 (3.3)	96.3	16.9 (2.5)
E. globulus	0.4	0.0 (0.0)	100.0	0.0 (0.0)	100.0	0.0 (0.0)	100.0	0.0 (0.0)
C. longa	0.4	0.0 (0.0)	100.0	3.0 (1.1)	99.4	2.7 (0.9)	99.6	1.9 (0.7)
C. flexuosus	0.4	4.7 (1.7)	96.2	53.3 (4.0)	89.1	306.0 (5.7)	59.1	121.3 (3.8)
M. citrata	0.4	9.3 (2.3)	92.6	12.7 (2.5)	97.4	10.3 (1.9)	98.6	10.8 (2.2)
P. graveolens	0.4	8.3 (2.2)	93.4	63.0 (4.1)	87.1	60.7 (4.1)	91.9	44.0 (3.5)
Untreated control	–	125.0 (4.8)	–	488.0 (6.2)	–	748.7 (6.6)	–	453.9 (5.9)
Mean		12.5 (1.0)	–	74.4 (2.5)	–	156.1 (2.7)	–	81.0 (2.1)
		Months		Treatment		Interaction		
S.Em±		4.1 (0.1)		8.1 (0.2)		14.1 (0.3)		
CD at 5%		11.4 (0.2)		22.8 (0.5)		39.6 (0.8)		

*Data in parentheses indicate log (X+1) transformed values

Table 2: Infestation of *R. dominica* in the grain treated with different essential oils

Plant oil	Conc. % (v/w)	Month after storage			
		4 month		6 month	
		Per cent infestation	% inhibition	Per cent infestation	% inhibition
M. arvensis	0.4	1.10 (5.97)	93.1	1.48 (6.96)	97.3
M. piperita	0.4	0.70 (4.74)	95.6	0.41 (3.61)	99.2
M. spicata	0.4	0.59 (4.31)	96.3	0.49 (3.99)	99.1
P. roxburghii	0.4	0.88 (5.31)	94.4	1.00 (5.63)	98.2
E. citriodora	0.4	11.19 (19.30)	29.4	60.40 (51.01)	0.0
C. winterianus	0.4	1.46 (6.95)	90.8	1.71 (7.52)	96.8
E. globulus	0.4	0.32 (3.24)	98.0	0.26 (2.88)	99.5
C. longa	0.4	0.90 (5.41)	94.3	0.58 (4.35)	98.9
C. flexuosus	0.4	3.62 (10.86)	77.2	54.35 (47.51)	0.0
M. citrata	0.4	1.70 (7.47)	89.3	3.09 (9.84)	94.3
P. graveolens	0.4	4.87 (12.64)	69.3	5.55 (13.60)	89.7
Untreated control	–	15.84 (23.07)	–	54.27 (47.45)	–
S.Em.±		1.42 (1.32)	–	1.56 (1.08)	–
CD at 5%		4.13 (3.86)	–	4.55 (3.16)	–

*Data in parentheses indicate angular transformed values

treatments. Treatment of grain with oils of *M. arvensis, M. piperita, M. spicata, P. roxburghii, E. citriodora* and *E. globulus* resulted in 95.4, 97.7, 95.9, 96.5, 98.2 and 96.9 per cent suppression of weight loss, respectively. The oil of *C. winterianus* was moderately effective as it checked 86.6 per cent loss in weight.

The study revealed that essential oils of *M. arvensis, M. piperita, M. spicata, P. roxburghii, C. winterianus, E. globulus, C. longa, M. citrata* and *P. graveolens* were highly effective against *R. dominica* for 6 months as they suppressed 90 to 100 per cent population buildup, infestation and weight loss due to this insect. On the other hand, the efficacy

Table 3 : Loss in weight due to infestation of treated grain by *R. dominica*

Plant oil	Conc. % (v/w)	Month after storage			
		4 month		6 month	
		Per cent infestation	% inhibition	Per cent infestation	% inhibition
M. arvensis	0.4	1.87 (7.85)	91.6	2.55 (9.14)	97.2
M. piperita	0.4	1.20 (6.24)	94.6	0.72 (4.79)	99.2
M. spicata	0.4	0.93 (5.43)	95.8	0.85 (5.26)	99.1
P. roxburghii	0.4	1.54 (7.07)	93.1	1.58 (7.13)	98.3
E. citriodora	0.4	17.73 (24.63)	20.5	91.29 (73.06)	0.0
C. winterianus	0.4	2.51 (9.12)	88.7	3.01 (10.00)	96.7
E. globulus	0.4	0.91 (5.30)	95.9	1.03 (5.40)	98.7
C. longa	0.4	1.04 (5.49)	95.3	1.11 (6.01)	98.6
C. flexuosus	0.4	6.09 (14.16)	72.7	88.89 (70.88)	1.8
M. citrata	0.4	2.81 (9.65)	87.4	4.01 (11.37)	95.6
P. graveolens	0.4	8.32 (16.64)	62.7	9.19 (17.63)	89.8
Untreated control	–	22.30 (27.93)	-	90.48 (72.15)	-
S.Em.±		1.83 (1.52)	-	1.27 (1.35)	-
CD at 5%		5.35 (4.44)	-	3.71 (3.95)	-

*Data in parentheses indicate angular transformed values

Table 4 : Population buildup of *S. oryzae* on grain treated with different essential oils

Plant oil	Conc. % (v/w)	Month after storage						Mean
		2 month		4 month		6 month		
		Adults emerged	% inhibition	Adults emerged	% inhibition	Adults emerged	% inhibition	
M. arvensis	0.4	2.0 (0.8)	98.9	9.0 (2.3)	98.1	8.6 (2.0)	98.5	6.6 (1.7)
M. piperita	0.4	0.0 (0.0)	100.0	0.0 (0.0)	100.0	0.0 (0.0)	100.0	0.0 (0.0)
M. spicata	0.4	0.0 (0.0)	100.0	0.0 (0.0)	100.0	0.0 (0.0)	100.0	0.0 (0.0)
P. roxburghii	0.4	0.0 (0.0)	100.0	1.7 (0.8)	99.6	4.3 (1.3)	99.3	2.0 (0.7)
E. citriodora	0.4	0.0 (0.0)	100.0	48.3 (3.9)	90.1	13.3 (2.6)	97.7	20.6 (2.2)
C. winterianus	0.4	2.0 (0.9)	98.8	52.7 (4.0)	89.1	53.3 (3.7)	90.8	36.0 (2.9)
E. globulus	0.4	0.0 (0.0)	100.0	0.0 (0.0)	100.0	0.0 (0.0)	100.0	0.0 (0.0)
Untreated control	–	175.0(5.2)	–	485.7(6.2)	–	576.3(6.4)	–	412.3 (5.9)
Mean		22.4 (0.9)	–	74.7 (2.2)	–	82.0 (2.0)	–	59.7 (1.7)
		Months		Treatment		Interaction		
S.Em±		3.6 (0.1)		5.9 (0.2)		10.2 (0.3)		
CD at 5%		10.2 (0.3)		16.7 (0.4)		28.9 (0.8)		

*Data in parentheses indicate log (X+1) transformed values

Table 5 : Infestation of *S. oryzae* in the grain treated with different essential oils

Plant oil	Conc. % (v/w)	Month after storage			
		4 month		6 month	
		Per cent infestation	% inhibition	Per cent infestation	% inhibition
M. arvensis	0.4	0.93	94.7	0.84	96.3
M. piperita	0.4	0.70	96.0	0.50	97.8
M. spicata	0.4	0.67	96.2	1.13	95.1
P. roxburghii	0.4	0.67	96.2	0.79	96.5
E. citriodora	0.4	3.58	97.4	1.35	94.1
C. winterianus	0.4	3.62	79.2	2.61	88.6
E. globulus	0.4	0.61	96.5	1.35	94.11
Untreated control	–	17.42	–	22.89	–
S.Em.±		0.56	–	0.62	–
CD at 5%		1.67	–	1.85	–

Table 6 : Loss in weight due to infestation of treated grain by *S. oryzae*

Plant oil	Conc. % (v/w)	Month after storage			
		4 month		6 month	
		Per cent infestation	% inhibition	Per cent infestation	% inhibition
M. arvensis	0.4	0.24	95.3	0.28	95.4
M. piperita	0.4	0.14	97.3	0.14	97.7
M. spicata	0.4	0.16	96.9	0.25	95.9
P. roxburghii	0.4	0.12	97.7	0.21	96.5
E. citriodora	0.4	0.84	83.6	0.11	98.2
C. winterianus	0.4	0.87	83.0	0.81	86.6
E. globulus	0.4	0.18	96.5	0.19	96.9
Untreated control	–	5.11	–	6.04	–
S.Em.±		0.25	–	0.58	–
CD at 5%		0.74	–	1.75	–

of *E. citriodora* and *C. flexuosus* persisted only for two months after which their inhibitory effect declined significantly against this insect. All the seven essential oils evaluated against *S. oryzae* remained effective for 6 months. The fumigant toxicity of *E. citriodora* also persisted for longer duration against this insect. The study indicates that long term efficacy of essential oils is also species specific due to which essential oils found effective against both the insects are much useful for protection of grain.

CONCLUSION

On the basis of this study, it may be concluded that essential oils of *M. arvensis*, *M. piperita, M. spicata, P. roxburghii, C. winterianus,* and *E. globules* are highly effective against *R. dominica* and *S. oryzae* at 0.40 per cent for 6 months (Fig. 1, 2 and 3). The

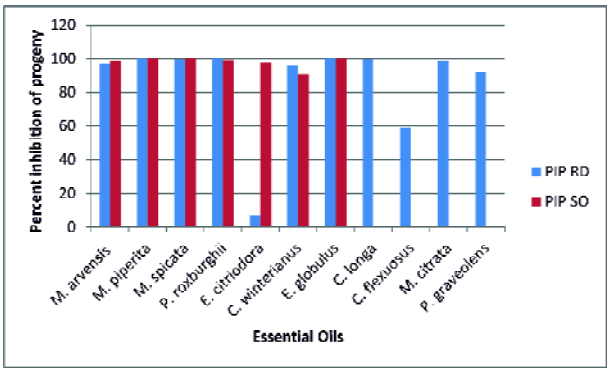

Fig 1: Per cent inhibition of progeny of *R.dominica* (PIP RD) and *S.oryzae* (PIP SO) by different essential oils

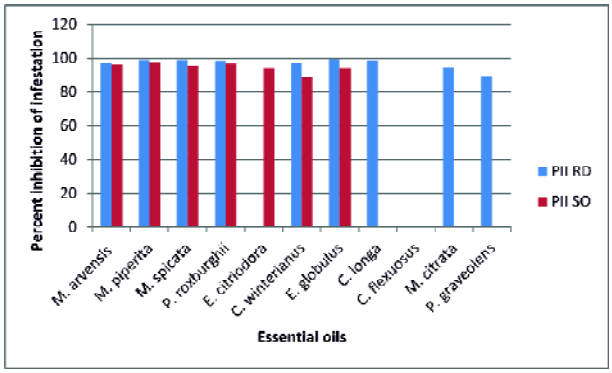

Fig 2: Per cent inhibition of infestation of *R.dominica* (PII RD) and *S.oryzae* (PII SO) by different essential oils

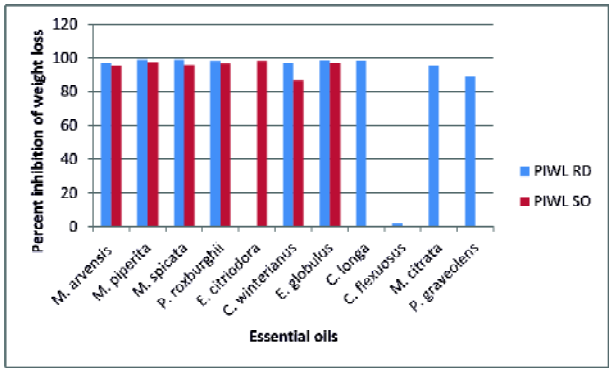

Fig 3: Per cent inhibition of weight loss due to *R. dominica* (PIWL RD) and *S. oryzae* (PIWL SO) by different essential oils

oils of *C. longa*, *M. citrata* and *P. graveolens* also showed high efficacy against *R. dominica* at above mentioned concentration for the same duration. These oils should also be evaluated against *S. oryzae* to widen their scope for use under storage condition. The fumigant toxicity of most of the essential oils

persisted at high level for six months and these oils may show highly appreciable efficacy even for longer duration and also at lower concentrations. These aspects should also be studied to make the essential oils more useful in protection of grain. Some secondary insect pests such as *Tribolium castaneum* and *Trogoderma granarium* also infest the grain in some states and countries. Extension of studies to these and other important insects may enhance their scope and acceptability.

REFERENCES

CABI (2021). Invasive Species Compendium. Wallingford, UK: CAB International. www.cabi.org/isc.

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 & Applied Biosciences*, 5: 912-921.

Geetanjly, 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.

Geetanjly 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.

Grainge, M. and Ahmed, S. (1988). Hand Book of Plants with Pest Control Properties. John Wiley and Sons, New York, 470p.

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., Pandey, P.S. and Tiwari, S.N. 2019. Fumigant toxicity of essential oil based formulations against three stored product Coleoptera in stored wheat. *Journal of Entomology and Zoology Studies*, 7(3): 278-283.

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. and Tiwari, S. N. (2018a). Fumigant toxicity of essential oils against four stored grain insect pests in stored paddy seeds. *Indian Journal of Entomology,* 80 (1): 73-77.

Kumar, R. and Tiwari, S. N. (2018b). Fumigant toxicity of essential oils against *Corcyra cephalonica* and *Sitotroga cerealella*. *Environment and Ecology,* 36 (1): 33-37.

Pixton, S. W. (1967). Moisture content—its significance and measurement in stored products. *Journal of Stored Products Research*, 3(1): 35-47.

Rajendran, S. and Sriranjini, V. (2008). Plant products as fumigants for stored-product insect control. *Journal of Stored Products Research*, 44(2): 126-135.

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.

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,*17(3): 499-504.

Sharma, J.H. and Tiwari, S.N. (2021a). Bio-efficacy of *Ageratum houstonianum* Mill. (Asteraceae) essential oil against five major insect pests of stored cereals and pulses. *Pantnagar Journal of Research,* 19(1): 40-45.

Sharma, J.H. and Tiwari, S.N. (2021b). Fumigant toxicity of alpha-pinene, beta-pinene, eucalyptol, linalool and sabinene against Rice Weevil, *Sitophilus oryzae* (L.). *Pantnagar Journal of Research,* 19(1): 50-55.

Tewari N. and Tiwari S.N. (2008). Fumigant toxicity of lemon grass, *Cymbopogon flexuosus* (D.C.) Stapf oil on progeny production of *Rhyzopertha dominica F., Sitophilus oryzae L.* and *Tribolium castaneum Herbst. Environment and Ecoogyl,* 26(4A): 1828-1830.

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.

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.

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