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Effect of plant oils and insecticides impregnated packaging materials on *Rhyzopertha dominica* (Fab.) in stored barley

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Abstract
Investigations on "Effect of plant oils and insecticides impregnated packaging materials on *Rhyzopertha dominica* in stored barley**"** were conducted at Department of Entomology, S.K.N. College of Agriculture, Jobner during 2016 and 2017. The bags (plastic fiber and gunny) impregnated with deltamethrin 2.8 EC (0.075%) was found most effective to reduce adult emergence, grain damage and weight loss by *R. dominica* in barley grains, followed by malathion 50 EC (0.1%), delatmethrin (0.05%), neem oil (10.0%), deltamethrin (0.025%), malathion (0.075%) castor oil (10.0%) and neem oil (7.5%).

Keywords: Barley, *Rhyzopertha dominica,* plant oils, insecticides

Introduction
Barley (*Hordeum vulgare* (Linn.) is an important *Rabi* season cereal crop after wheat in northern India. It is grown throughout the state of Rajasthan, but Jaipur district holds the pioneer position both in area and production, which is grown for brewing, human consumption and cattle feed. In India, it has occupied an area of 2.95 million hectares with an annual production of 8.59 million tons (Anonymous, 2014) [1]. However, Rajasthan occupied 0.31 million hectares area with an annual production of 0.94 million tonne (Anonymous, 2014) [2]. Post harvest losses to barley grains in different ecological zones have been estimated from zero to 25 percent (Mookherjee *et al.*, 1968) [3]. In India, barley in storage is heavily infested by a number of insect pests. Among these, the lesser grain borer, *Rhyzopertha dominica* (Fab.) (Bostrichidae: Coleoptera) causes considerable damage. (Campbell and Sinha, 1976) [4] This pest was recorded as a major pest in all the districts of Rajasthan (Bhargava and Choudhary, 2007) [5]. The original home tract of *R. dominica* is said to be India (Pruthi and Singh, 1950) [6]. It feeds on a variety of stored products like cereals, pulses, groundnut kernels, other edible substances and grocery stores and as such it is considered one of the important pests of stored grains. It not only cause post harvest losses in terms of quantity but also affect the quality through depletion of specific nutrients and contamination with uric acid and excreta. Therefore in the present investigations plant oils impregnation of packaging materials, effect of solar energy and different storage structures has been evaluated to find out their effectiveness against the incidence of *R. dominica* in stored barley.

Materials and Methods
The packaging materials (Plastic fibre bags and Gunny bags of 20 x 18 cm) were impregnated separately with different concentrations of test oils and insecticides. The solution of oils was also made with acetone. The untreated control was maintained for comparison. The treated bags with each treatment were dried in shade for 24 hrs and were filled with 350 g of sterilized barley grains, replicated thrice and kept in a room for 6 months with *R. dominica* infested stock to have the natural infestation. Periodic inspection (at monthly interval) of the grains in the bags was done to record natural infestation. The number of adults and damaged grains were recorded by visual count. The adult were discarded every month after taking the observations. The observations were recorded up to 180 days of storage. The grain weight was recorded by excluding the frass. The percent data on grain damage, weight loss and germination were transformed in to angular values (arc sine √percentage) and number of insects into log x+ 1 values for analysis of variance.

Results and Discussion

The effect of plant oils *viz.*, castor, neem, mustard (5, 7.5 and 10%) and insecticides *viz.*, malathion 50 EC (0.05, 0.075 and 0.1%) and deltamethrin 2.8 EC (0.025, 0.05 and 0.075%) impregnated packaging materials (plastic fiber bags and gunny bags) were evaluated against *R. dominica* in stored barley. The observations on adult emergence, grain damage and weight loss were recorded at monthly interval.

Adult emergence in plastic fiber bag

The data presented in table 1 revealed that all the treatments were found significantly superior over untreated control up to 180 days of storage in impregnated plastic fiber bags; however significant difference existed among them. The adult (F_1) emergence was not recorded up to 60 days of storage in all the treatments.

After 90 days of treatment, the adult emergence was also not observed in the bags treated with deltamethrin 2.8 EC 0.05 and 0.075 percent, malathion 50 EC 0.075 and 0.10 percent, neem oil 5.0 and 10.0 percent, castor oil 5.0 and 10.0 percent and mustard oil 10.0 percent. The minimum adults emerged from bags treated with deltamethrin 2.8 EC 0.025 percent (0.67) and malathion 50 EC 0.05 percent (1.0), which differed significantly. The maximum adults emerged from bags treated with mustard oil 5.0 percent (2.67) and castor oil 5.0 percent (2.33) and both were at par with each other however, significantly superior to untreated control (5.67). The other treatments were moderately effective with respect to adult emergence (Table 1).

The adult emergence was not observed in the bag treated with deltamethrin 2.8 EC 0.075 percent even after 120 days of treatment. The minimum adult emergence was recorded in the bags treated with deltamethrin 2.8 EC 0.05 percent (1.0), malathion 50 EC 0.1 percent (1.0) and neem oil 10.0 percent (1.00), these were found statistically at par with each other. The maximum adult emergence was observed in mustard oil 5.0 percent (5.0) followed by castor oil 5.0 percent (4.67), both were at par with each other and significantly superior to untreated control (10.67).

After 150 days of treatment, the minimum number of adults emerged in deltamethrin 2.8 EC 0.075 percent (1.0), followed by malathion 50 EC 0.1 percent (1.33) and neem oil 10 percent (1.33), former proved superior to letter to treatments significantly and the maximum number of adults emerged in mustard oil 5.0 percent (8.67) and castor oil 5.0 percent (7.33), both were at par with each other at 0.01 percent level (CD= 0.01%) and significantly superior to untreated control (13.67). The other treatments were moderately effective with regards to adult emergence.

Even after 180 days of treatment, the minimum adult emergence was recorded from bags treated with deltamethrin 2.8 EC 0.075 percent (1.67) and malathion 50 EC 0.05 percent (2.00), which were statistically at par with each other. The next effective group of treatments with minimum adult emergence was deltamethrin 2.8 EC 0.05 percent (2.67), followed by neem oil 10 percent (2.67), castor oil 10 percent (3.0), neem oil 7.5 percent (3.0), deltamethrin 2.8 EC 0.025 percent (3.0) and malathion 50 EC 0.075 percent (3.0), these treatments differed non significantly with each other. The maximum adult emergence was recorded from bags treated with mustard oil 5.0 percent (9.67) which was statistically at par with castor oil 5.0 percent (9.0). The other treatments were moderately effective. The results are fully conformity with Kakde *et al.*(2014) [6] who reported that gunny bags impregnated with neem oil (10.0%) and mustard oil (10.0%) provided complete protection over adult emergence of *R. dominica*. Similarly, Ramamurthy and Venugopal (1997) [7] noted that gunny bags impregnated with neem oil at 3.0 percent was effective in avoiding the *S. cerealella* damage. Muhammad *et al.* (2005) [8] observed that penetration of stored insects reduced in neem oil (10.0%) impregnated packaging materials Similarly, Naga *et al.* (2011) [9] and Sharma (2013) [10] also reported that impregnation of gunny and cloth bags with plant oils were found effective in reducing the infestation of *T. castaneum* and *T. granarium*.

Adult emergence in gunny bags

The data presented in table 2 revealed that all the treatments were found significantly superior over untreated control up to 180 days of storage in impregnated gunny bags; however significant differences existed among them. The adult (F_1) emergence was not recorded up to 60 days of storage in all the treatments.

After 90 days of treatment, the adult emergence was not found in the bags treated with deltamethrin 2.8 EC 0.05 and 0.075 percent, malathion 50 EC 0.1 percent, neem oil 10.0 percent and castor oil 10.0 percent. The minimum numbers of adults emerged from bags treated with malathion 50 EC 0.05 percent (1.0) and mustard oil 10.0 percent (1.0), which were statistically at par with each other. The next group of effective treatments with minimum adults emergence were malathion 50 EC 0.075 percent (2.33), followed neem oil 7.5 percent (2.67), these treatments were statistically at par with each other. The maximum adults emerged from bags treated with mustard oil 5.0 percent (7.67) and castor oil 5.0 percent (7.33), which were at par with each other. The other treatments were moderately effective with respect to adult emergence.

After 120 days of treatment, the adult emergence was not found in the bags treated with deltamethrin 2.8 EC 0.075 percent. The minimum adult mergence was recorded in the bags treated with deltamethrin 2.8 EC 0.05 percent (1.33), followed by malathion 50 EC 0.1 percent (1.67) and neem oil 10.0 percent (1.67), these treatments were found statistically at par with each other. The maximum adult emergence was observed in mustard oil 5.0 percent (11.67%), followed by castor oil 5.0 percent (10.33), which were at par with each other. The rest of treatments were moderately effective (Table 2).

Even after 150 days of bag treatment, the minimum number of adults emerged in deltamethrin 2.8 EC 0.075 percent (2.33) and malathion 50 EC 0.1 percent (2.67), both were statistically at par each other. The maximum number of adults emerged in mustard oil 5.0 percent (19.0) and castor oil 5.0 percent (17.0), which differed non significantly with each other. The other treatments observed to be moderately effective.

After 180 days of treatment, the minimum adult emergence was recorded from bags treated with deltamethrin 2.8 EC 0.075 percent (4.67), followed by deltamethrin 2.8 EC 0.05 percent (6.0) and malathion 50 EC 0.05 percent (6.67), later two were significantly at par with each other. The next group of effective treatments was neem oil 10.0 percent (10.33), followed by malathion 50 EC 0.075 percent (11.0) and deltamethrin 2.8 EC 0.025 percent (11.0), these treatments were statistically at par with each other. The maximum adult emergence was recorded from bags treated with mustard oil 5.0 percent (28.0) and castor oil 5.0 percent (24.33), both were at par with each other. The other treatments were moderately effective.

Grain damage in plastic fiber bag

The data presented in table 3 revealed that all the treatments were found significantly superior over untreated control up to 180 days of storage in impregnated plastic fiber bags; however a significant difference existed among them. The grain damage was not recorded up to 60 days of storage in all the treatments including untreated control.

After 90 days of storage, the grain damage was not observed in the bags impregnated with deltamethrin 2.8 EC 0.05 and 0.075 percent, malathion 50 EC 0.1 percent, neem oil 10.0 percent and castor oil 10.0 percent. The minimum grain damage was found in deltamethrin 2.8 EC 0.025 percent (1.33%), followed by mustard oil 10 percent (1.67%), malathion 50 EC 0.075 percent (2.33%) and neem oil 7.5 percent (2.67%), the former two and later two treatments were at par with each other, respectively. The maximum grain damage was registered in bags treated with mustard oil 5.0 percent (6.67%) and castor oil 5.0 percent (6.33%), which was at par with each other. The moderately effective treatments were mustard oil 5.0 percent (4.0%), followed by castor oil 7.5 percent (4.0%), neem oil 5.0 percent (4.33%) and mustard oil 7.5 percent (4.33%), however, these treatments were statistically at par with each other (Table 3).

Even after 120 days of storage, grain damage was not found in bags impregnated with deltamethrin 2.8 EC 0.075 percent. The minimum grain damage was recorded in deltamethrin 2.8 EC 0.05 percent (1.67%), followed by malathion 50 EC 0.1 percent (2.00%), neem oil 10.0 percent (3.0%), castor oil 10.0 percent (3.0%) and daltamethion 2.8 EC 0.025 percent (3.33%), the former two and later three treatments were at par with each other. The maximum grain damage was recorded in bags treated with mustard oil 5.0 percent (10.0%) and castor oil 5.0 percent (9.33%), both the treatments were at par with each other. The rest of the treatments were moderately effective.

After 150 days of treatment, the minimum grain damage was exhibited by deltamethrin 2.8 EC 0.075 percent (1.33%) and deltamethrin 2.8 EC 0.05 percent (2.33%). This was followed by malathion 50 EC0.1 percent (4.0%), deltamethrin 2.8 EC 0.025 percent (4.33%) and neem oil 10.0 percent (4.67%) which were statistically at par with each other. The maximum grain damage was observed in mustard oil 5.0 percent (16.33%), followed by castor oil 5.0 percent (14.33%) and mustard oil 7.5 percent (14.0%), later two treatments were at par with each and superior to untreated control (22.67%). The rest of the treatments showed moderate effectiveness (Table 3).

After 180 days of bag treatment, the minimum grain damage was exhibited by treatment of deltamethrin 2.8 EC 0.075 percent (2.67%). This was followed by deltamethrin 2.8 EC 0.05 percent (4.33%), malathion 50 EC 0.1 percent (4.67%) and neem oil 10.0 percent (5.0%). Later three treatments were statistically at par each other. The maximum grain damage (22.67%) was found in mustard oil 5.0 percent which was at par with castor oil 5.0 percent (21.67%). This was followed by mustard oil 7.5 percent (16.67%), neem oil 5.0 percent (15.67%), castor oil 7.5 percent (15.0%), and malathion 50 EC0.05 percent (15.0%), in which former to and letter for were statistically at par with each other and significantly superior to untreated control (27.67%). The other treatments exhibited moderate grain damage.

Grain damage in gunny bags

The data presented in table 4 revealed that all the treatments were found significantly superior over untreated control up to 180 days of storage in impregnated gunny bags; however significant difference existed among them. The grain damage was not recorded up to 60 days of storage in all the treatments including untreated control.

After 90 days of storage the grain damage was not exhibited by the treatments of deltamethrin 2.8 EC 0.05 (0.075%) percent, malathion 50 EC 0.1 percent, neem oil 10.0 percent and castor oil 10.0 percent. The minimum grain damage was found in deltamethrin 2.8 EC 0.025 percent (2.0%), followed by neem oil 7.5 percent (2.33%), mustard oil 10.0 percent (3.33%) and malathion 50 EC 0.075 percent (4.0%), only former two were at par with each other. The next effective treatments were neem oil 5.0 percent (6.67%), mustard oil 7.5 percent (6.33%) and malathion 50 EC 0.05 percent (6.33), however these treatments were statistically at par each other. The maximum grain damage was observed in bags treated with mustard oil 5.0 percent (8.0%) and castor oil 5.0 percent (7.67%), both these treatments were at par with each other. The other treatments were moderately effective with regard to the grain damage (Table 4).

After 120 days of bag impregnation, the minimum grain damage was observed in deltamethrin 2.8 EC 0.075 percent (1.00%), followed by malathion 50 EC 0.1 percent (2.33%), deltamethrin 2.8 EC 0.05 percent (2.33%) and neem oil 10.0 percent (3.00%), the later three were found at par with each other. The maximum grain damage was recorded in bags treated with mustard oil 5.0 percent (13.00%) and castor oil 5.0 percent (11.67%), which were at par with each other. The rest of the treatments showed moderate effectiveness.

Similarly, after 150 days of bag impregnation, the minimum grain damage was exhibited by deltamethrin 2.8 EC 0.075 percent (2.33%), followed by deltamethrin 2.8 EC 0.05 percent (3.33%) and malathion 50 EC 0.1 percent (4.0%) where, later two were statistically at par with each other. The maximum grain damage was found in mustard oil 5.0 percent (21.67%), castor oil 5.0 percent (19.67%), which were statistically at par with each other. The rest of the treatments were showed moderate effectiveness.

After 180 days of bag impregnation, the minimum grain damage was recorded in deltamethrin 2.8 EC 0.075 percent (4.67%), followed by deltamethrin 2.8 EC 0.05 percent (8.33%), malathion 50 EC 0.1 percent (11.67%) and neem oil 10.0 percent (13.67%), however, latter two treatments were at par with each other. The maximum grain damage was recorded in the mustard oil 5.0 percent (29.0%), which was at par with castor oil 5.0 percent (27.33%) and mustard oil 7.5 percent (26.33%). The next effective group of treatments were castor oil 7.5 percent (24.0%), followed by neem oil 5.0 percent (22.00%) and malathion 50 EC 0.05 percent (21.33%), which were statistically at par with each other. The other treatments exhibited moderate effectiveness. The present findings are in fully agreement with Naga *et al.* (2011) who reported minimum weight loss caused by *T. castaneum* in cloth and plastic fibre bags impregnated with neem seed kernel extract, neem oil, castor oil at 10.0 percent and malathion at 0.1 percent. The results are also in conformity with Meena *et al.*, (2010) [11] who observed nil weight loss in wheat flour caused by *T. castaneum* in the cloth bags impregnated with NSKE 10.0 percent up to 150 days and mustard oil 10.0 percent up to 75 days like wise Sharma (2013) [12] reported neem oil most effective for impregnation of gunny and cloth bags. Kakde *et al*., (2014) reported that gunny bags impregnated with neem oil 10.0 percent and mustard oil 10.0 percent provide complete protection of grains to *R. dominica.* The results are in partially conformity with *those of* Kaur and Sharma (2015) [13].

Weight loss in plastic fiber bags

The data presented in table 5 revealed that all the treatments were found significantly superior over untreated control up to 180 days of storage in impregnated plastic fiber bags, however significantly difference existed among them. The weight loss was not recorded up to 60 days of storage in all the treatments including untreated control.

After 90 days of storage in impregnated bags, the weight loss was not observed in deltamethrin 2.8 EC (0.025, 0.05 and 0.75%), malathion 50 EC (0.075 and 0.1%), neem oil (7.5 and 10%), castor oil (7.5 and 10%) and mustard oil (10.0%). The minimum weight loss was recorded in the treatment of malathion 50 EC 0.05 percent (1.33%), followed by neem oil 5.0 percent (1.67%) and mustard oil 7.5 percent (1.67%), later two were at par with each other. The maximum weight loss was found in castor oil 5.0 percent (2.0%), which was at par with mustard oil 5.0 percent (2.0%).

After 120 days of impregnation of bags, the weight loss was not recorded in deltamethrin 2.8 EC 0.05 and 0.75 percent, malathion 50 EC 0.1 percent and neem oil 10.0 percent. The minimum weight loss was found in deltamethrin 2.8 EC 0.025 percent (0.67%), followed by malathion 50 EC 0.075 percent (1.0%) and neem oil 7.5 percent (1.0%) where letter two treatments were at par with each other. The maximum weight loss was occurred in mustard oil 5.0 percent (4.0%) and castor oil 5.0 percent (3.67%), which were statistically at par with each other. The other treatments exhibited moderate effectiveness.

After 150 days of storage in impregnated bags. The minimum weight loss was registered in deltamethrin 2.8 EC 0.075 (1.67%) and 0.05 percent (2.00%), malathion 50 EC 0.1 percent (2.0%) and neem oil 10.0 percent (2.0%). These treatments were at par with each other. The maximum weight loss was registered in mustard oil 5.0 percent (8.0%) and castor oil 5.0 percent (7.33%), which were statistically at par with each other. The rest of the treatments were moderately effective with regard to weight loss in barley due to *R. dominica* infestation (Table 5).

After 180 days of bag impregnation, the minimum weight loss was recorded in the deltamethrin 2.8 EC 0.075 percent (2.33%), followed by deltamethrin 2.8 EC 0.05 percent (3.67%), malathion 50 EC 0.1 percent (4.0%) and neem oil 10.0 percent (4.0%), later three treatments were statistically at par with each other. The maximum weight loss was registered in mustard oil 5.0 percent (14.0%) and castor oil 5.0 percent (13.67%), both were statistically at par with each other. The other treatments were moderately effective.

Weight loss in gunny bags

The data presented in table 4.6 revealed that all the treatments were found significantly superior over untreated control up to 180 days of storage in impregnated gunny bags, however significantly differences existed among them. The weight loss was not recorded up to 60 days of storage in all the treatments including untreated control.

After 90 days of impregnation of bags, the weight loss was not found in deltamethrin 2.8 EC (0.05 and 0.75 percent), malathion 50 EC 0.1 percent, neem oil 10.0 percent and castor oil 10.0 percent. The minimum weight loss was recorded in the treatment of deltamethrin 2.8 EC 0.025 percent (1.67%), followed by malathion 50 EC 0.75 percent (2.0%) and mustard oil 10.0 percent (2.0%), which were at par with each other. The maximum weight loss was found in mustard oil 5.0 percent (5.0%) and castor oil 5.00 percent (4.67%), both were at par with each other. The rest of the treatments were moderately effective.

After 120 days of impregnation of bags, the minimum weight loss in grain was recorded in deltamethrin 2.8 EC 0.075 percent (1.33%), followed by malathion 50 EC 0.1 percent (2.0%), deltamethrin 2.8 EC 0.05 percent (2.0%) and neem oil 10.0 percent (2.0%), the former one was significantly superior over other treatments. The maximum weight loss occurred in mustard oil 5.0 percent (8.0%) and castor oil 5.0 percent (7.33%), both were at par with each other, but significantly superior to untreated control (11.33%). The other treatments were moderate for their effectiveness (Table 6).

After 150 days of impregnation of bags with different treatments, the minimum weight loss ware exhibited in deltamethrin 2.8 EC 0.075 percent (2.0%), followed by deltamethrin 2.8 EC 0.05 percent (3.33%), malathion 50 EC 0.1 percent (4.0%) and deltamethrin 2.8 EC 0.025 (4.0%), the later three were at par with each other. The next effective treatments were mustard oil 7.5 percent (9.33%), followed by castor oil 7.5 percent (9.0%), neem oil 5.0 percent (9.0%) and malathion 50 EC 0.05 percent (8.33%), which were statistically at par with each other. The maximum weight loss was registered in mustard oil 5.0 percent (12.0%) and castor oil 5.0 percent (11.33%), which were statistically at par with each other. The rest of the treatments were moderately effective.

After 180 days of bag impregnation, the minimum weight loss was recorded in deltamethrin 2.8 EC 0.075 percent (4.33%), followed by deltamethrin 2.8 EC 0.05 percent (5.0%) and malathion 50 EC 0.1 percent (5.0%). These treatments were statistically at par with each other. The maximum weight loss registered in mustard oil 5.0 percent (16.33%), followed by castor oil 5.0 percent (15.0%) and mustard oil 7.5 percent (14.33%), which were statistically at par with each other. The other treatments were moderately effective with regard to weight loss in grains due to *R. dominica* infestation.The present findings are in full agreement with Naga *et al.* (2011) who reported minimum weight loss caused by *T. castaneum* in cloth and plastic fibre bags impregnated with neem seed kernel extract, neem oil, castor oil at 10.0 percent and malathion at 0.1 percent. The results are also in conformity with Meena *et al.,* (2010) who observed nil weight loss in wheat flour caused by *T. castaneum* in the cloth bags impregnated with NSKE 10.0 percent up to 150 days and mustard oil 10.0 percent up to 75 days like wise Sharma (2013) reported neem oil most effective for impregnation of gunny and cloth bags. Kakde *et al.*, (2014) reported that gunny bags impregnated with neem oil 10.0 percent and mustard oil 10.0 percent provide complete protection of grains to *R. dominica.* The results are in partially conformity with those of Kaur and Sharma (2015).

Effect of plant oils and insecticides impregnated packaging materials on germination of barley seeds

The data on germination of barley seeds stored in plant oils and insecticides impregnated plastic fiber and gunny bag was in the range of 84.67-87.00 percent and 83.33-86.67 percent, respectively after 180 days of storage and showed statistically non-significant effect on germination (Table 7).

Table 1: Effect of plant oils and insecticides impregnated plastic fiber bags on adult (F_1) emergence of *Rhyzopertha dominica* in stored barley

S. No.	Treatments	Concentration (%)	Adult (F_1) emergence days after storage			
			90	120	150	180
1.	Castor oil	5	2.33 (0.52)	4.67 (0.75)	7.33 (0.91)	9.00 (0.99)
		7.5	0.00 (0.00)	2.33 (0.52)	5.67 (0.82)	6.67 (0.88)
		10	0.00 (0.00)	1.67 (0.42)	3.00 (0.60)	3.00 (0.60)
2.	Neem oil	5	1.33 (0.36)	3.00 (0.60)	5.67 (0.82)	5.00 (0.77)
		7.5	0.00 (0.00)	2.00 (0.47)	2.67 (0.56)	3.00 (0.60)
		10	0.00 (0.00)	1.00 (0.30)	1.33 (0.36)	2.67 (0.56)
3.	Mustard oil	5	2.67 (0.56)	5.00 (0.77)	8.67 (0.98)	9.67 (1.02)
		7.5	1.33 (0.37)	2.33 (0.52)	5.33 (0.80)	6.33 (0.86)
		10	0.00 (0.00)	2.00 (0.47)	2.67 (0.56)	3.67 (0.66)
4.	Malathion 50 EC	0.05	1.00 (0.30)	3.00 (0.60)	4.00 (0.69)	5.33 (0.80)
		0.075	0.00 (0.00)	1.33 (0.36)	2.67 (0.56)	3.00 (0.60)
		0.1	0.00 (0.00)	1.00 (0.30)	1.33 (0.36)	2.00 (0.47)
5.	Deltamethrin 2.8 EC	0.025	0.67 (0.22)	2.00 (0.47)	2.33 (0.52)	3.00 (0.60)
		0.05	0.00 (0.00)	1.00 (0.30)	1.67 (0.42)	2.67 (0.56)
		0.075	0.00 (0.00)	0.00 (0.00)	1.00 (0.30)	1.67 (0.43)
6.	Control / untreated		5.67 (0.82)	10.67 (1.06)	13.67 (1.16)	17.33 (1.26)
S. Em. ±			0.010	0.015	0.017	0.02
CD (P=0.05%)			0.04	0.04	0.05	0.05
CD (P=0.01%)			0.05	0.06	0.07	0.07

* Adult emergence was not observed up to 60 days of storage
Figures in parentheses are log X + 1 values

Table 2: Effect of plant oils and insecticides impregnated gunny bags on adult (F1) emergence of *Rhyzopertha dominica* in stored barley

S. No.	Treatments	Concentration (%)	Adult (F_1) emergence days after storage			
			90	120	150	180
1.	Castor oil	5	7.33 (0.91)	10.33 (1.05)	17.00 (1.25)	24.33 (1.40)
		7.5	5.67 (0.82)	8.00 (0.95)	12.33 (1.12)	18.00 (1.27)
		10	0.00 (0.00)	3.67 (0.66)	8.00 (0.95)	12.00 (1.11)
2.	Neem oil	5	5.00 (0.77)	7.33 (0.91)	15.00 (1.20	17.67 (1.26)
		7.5	2.67 (0.56)	3.00 (0.60)	13.67 (1.16)	13.67 (1.16)
		10	0.00 (0.00)	1.67 (0.43)	9.33 (1.01)	10.33 (1.05)
3.	Mustard oil	5	7.67 (0.93)	11.67 (1.10)	19.00 (1.30)	28.00 (1.46)
		7.5	5.67 (0.82)	9.33 (1.01)	14.00 (1.17)	23.67 (1.39)
		10	1.00 (0.30)	4.00 (0.69)	9.67 (1.02)	17.00 (1.25)
4.	Malathion 50 EC	0.05	4.00 (0.69)	5.33 (0.80)	12.00 (1.11)	16.67 (1.24)
		0.075	2.33 (0.52)	3.00 (0.60)	8.00 (0.95)	11.00 (1.07)
		0.1	0.00 (0.00)	1.67 (0.43)	2.67 (0.56)	6.67 (0.88)
5.	Deltamethrin 2.8 EC	0.025	1.00 (0.30)	3.00 (0.60)	6.67 (0.88)	11.00 (1.078)
		0.05	0.00 (0.00)	1.33 (0.37)	3.00 (0.60)	6.00 (0.84)
		0.075	0.00 (0.00)	0.00 (0.00)	2.33 (0.52)	4.67 (0.75)
6.	Control / untreated		12.33 (1.12)	15.67 (1.22)	22.67 (1.37)	35.33 (1.52)
S. Em. ±			0.01	0.01	0.02	0.02
CD (P=0.05%)			0.04	0.06	0.06	0.06
CD (P=0.01%)			0.05	0.07	0.08	0.08

* Adult emergence was not observed up to 60 days of storage
Figures in parentheses are log X + 1 values

Table 3: Effect of plant oils and insecticides impregnated plastic fiber bags on grain damage by *Rhyzopertha dominica* in stored barley

S. No.	Treatments	Concentration (%)	Grain damage (%) days after storage			
			90	120	150	180
1.	Castor oil	5	6.33 (14.55)	9.33 (17.76)	14.33 (22.22)	21.67 (27.70)
		7.5	4.00 (11.53)	6.67 (14.96)	9.00 (17.45)	15.00 (22.75)
		10	0.00 (0.00)	3.00 (9.97)	6.00 (14.17)	9.00 (17.45)
2.	Neem oil	5	4.33 (11.99)	6.67 (14.95)	12.00 (20.25)	15.67 (23.30)
		7.5	2.67 (9.39)	5.33 (13.33)	6.33 (14.56)	10.0 (18.42)
		10	0.00 (0.00)	3.00 (9.96)	4.67 (12.46)	5.00 (12.90)
3.	Mustard oil	5	6.67 (14.96)	10.00 (18.43)	16.33 (23.83)	22.67 (28.43)
		7.5	4.33 (12.00)	7.00 (15.33)	14.00 (21.97)	16.67 (24.09)
		10	1.67 (7.42)	4.33 (11.99)	6.67 (14.95)	10.33 (18.73)
4.	Malathion 50 EC	0.05	4.00 (11.52)	7.00 (15.33)	11.33 (19.65)	15.00 (22.75)
		0.075	2.33 (8.76)	5.00 (12.90)	5.00 (12.90)	9.67 (18.09)
		0.1	0.00 (0.00)	2.00 (8.13)	4.00 (11.53)	4.67 (12.48)
5.	Deltamethrin 2.8 EC	0.025	1.33 (6.62)	3.33 (10.51)	4.33 (12.01)	7.00 (15.33)
		0.05	0.00 (0.00)	1.67 (7.41)	2.33 (8.77)	4.33 (11.99)
		0.075	0.00 (0.00)	0.00 (0.00)	1.33 (6.61)	2.67 (9.39)
6.	Untreated control	-	11.33 (19.65)	15.67 (23.30)	22.67 (28.41)	27.67 (31.72)
S. Em. ±			0.27	0.40	0.50	0.60
CD (P=0.05%)			0.80	1.07	1.34	1.70
CD (P=0.01%)			1.00	1.40	1.81	2.23

* Grain damage was not observed up to 60 days of storage
Figures in the parentheses are arc sine $\sqrt{\text{percentage}}$ values

Table 4: Effect of plant oils and insecticides impregnated gunny bags on grain damage by *Rhyzopertha dominica* in stored barley

S. No.	Treatments	Concentration (%)	Grain damage (%) days after storage			
			90	120	150	180
1.	Castor oil	5	7.67 (16.05)	11.67 (19.97)	19.67 (26.29)	27.33 (31.48)
		7.5	5.33 (13.34)	8.67 (17.12)	14.33 (22.24)	24.00 (29.33)
		10	0.00 (0.00)	5.33 (13.34)	9.67 (18.11)	18.00 (25.09)
2.	Neem oil	5	6.67 (14.95)	8.67 (17.11)	15.67 (23.30)	22.00 (27.95)
		7.5	2.33 (8.73)	5.00 (12.91)	11.00 (19.35)	18.67 (25.58)
		10	0.00 (0.00)	3.00 (9.96)	6.67 (14.94)	13.67 (21.67)
3	Mustard oil	5	8.00 (16.42)	13.00 (21.13)	21.67 (27.74)	29.00 (32.57)
		7.5	6.33 (14.56)	9.00 (17.45)	14.67 (22.51)	26.33 (30.86)
		10	3.33 (10.50)	5.33 (13.33)	10.00 (18.41)	19.00 (25.82)
4	Malathion 50 EC	0.05	6.33 (14.56)	7.33 (15.69)	14.00 (21.95)	21.33 (27.49)
		0.075	4.00 (11.52)	4.67 (12.46)	10.33 (18.72)	17.33 (24.57)
		0.1	0.00 (0.00)	2.33 (8.77)	4.00 (11.53)	11.67 (19.97)
5	Deltamethrin 2.8 EC	0.025	2.00 (8.13)	5.00 (12.91)	7.00 (15.33)	15.00 (22.78)
		0.05	0.00 (0.00)	2.33 (8.77)	3.33 (10.51.)	8.33 (16.76)
		0.075	0.00 (0.00)	1.00 (5.73)	2.33 (8.77)	4.67 (12.47)
6	Untreated control		11.67 (19.97)	18.33 (25.33)	26.67 (31.07)	35.00 (36.25)
S. Em. ±			0.32	0.41	0.60	0.75
CD (P=0.05%)			0.95	1.19	1.62	2.13
CD (P=0.01%)			1.30	1.60	2.17	2.87

* Grain damage was not observed up to 60 days of storage
Figures in the parentheses are arc sine $\sqrt{\text{percentage}}$ values

Table 5: Effect of plant oils and insecticides impregnated plastic fibre bags on weight loss by *Rhyzopertha dominica* in stored barley

S. No.	Treatments	Concentration (%)	Weight loss days after storage			
			90	120	150	180
1.	Castor oil	5	2.00 (8.11)	3.67 (11.02)	7.33 (15.68)	13.67 (21.67)
		7.5	0.00 (0.00)	2.33 (8.77)	5.00 (12.91)	9.00 (17.45)
		10	0.00 (0.00)	1.33 (6.62)	3.00 (9.97)	6.33 (14.56)
2.	Neem oil	5	1.67 (7.42)	3.00 (9.96)	6.67 (14.95)	9.00 (17.44)
		7.5	0.00 (0.00)	1.00 (5.73)	4.00 (11.52)	5.33 (13.33)
		10	0.00 (0.00)	0.00 (0.00)	2.00 (8.11)	4.00 (11.52)
3.	Mustard oil	5	2.00 (8.12)	4.00 (11.53)	8.00 (16.42)	14.00 (21.97)
		7.5	1.67 (7.42)	2.67 (9.40)	5.33 (13.34)	10.33 (18.74)
		10	0.00 (0.00)	2.00 (8.12)	3.00 (9.96)	7.00 (15.32)
4.	Malathion 50 EC	0.05	1.33 (6.41)	2.67 (9.39)	7.00 (15.33)	8.33 (16.76)
		0.075	0.00 (0.00)	1.00 (5.73)	3.67 (11.02)	5.00 (12.90)
		0.1	0.00 (0.00)	0.00 (0.00)	2.00 (8.12)	4.00 (11.53)
5.	Deltamethrin 2.8 EC	0.025	0.00 (0.00)	0.67 (4.70)	4.33 (12.00)	5.33 (13.34)
		0.05	0.00 (0.00)	0.00 (0.00)	2.00 (8.12)	3.67 (11.03)
		0.075	0.00 (0.00)	0.00 (0.00)	1.67 (7.41)	2.33 (8.77)
6.	Untreated control		7.00 (15.33)	8.33 (16.76)	14.33 (22.22)	18.00 (25.08)
		S. Em. ±	0.15	0.21	0.35	0.43
		CD (P=0.05%)	0.44	0.62	0.99	1.30
		CD (P=0.01%)	0.60	0.84	1.33	1.69

* Weight loss was not observed up to 60 days of storage
Figures in the parentheses are arc sine √ percentage values

Table 6: Effect of plant oils and insecticides impregnated gunny bags on weight loss by *Rhyzopertha dominica* in stored barley

S. No.	Treatments	Concentration (%)	Weight loss (%) days after storage			
			90	120	150	180
1.	Castor oil	5	4.67 (12.46)	7.33 (15.68)	11.33 (19.64)	15.00 (22.75)
		7.5	3.00 (9.97)	5.00 (12.91)	9.00 (17.45)	13.33 (21.41)
		10	0.00 (0.00)	3.67 (11.04)	6.00 (14.17)	11.00 (19.36)
2.	Neem oil	5	4.00 (11.52)	5.67 (13.76)	9..00 (17.44)	11.00 (19.35)
		7.5	2.33 (8.77)	3.67 (11.03)	6.00 (14.16)	9.00 (17.44)
		10	0.00 (0.00)	2.00 (8.11)	4.33 (11.99)	5.67 (13.75)
3.	Mustard oil	5	5.00 (12.91)	8.00 (16.42)	12.00 (20.26)	16.33 (23.83)
		7.5	4.00 (11.53)	5.33 (13.34)	9.33 (17.78)	14.33 (22.35)
		10	2.00 (8.12)	4.00 (11.52)	7.00 (15.32)	10.67 (19.04)
4.	Malathion 50 EC	0.05	3.33 (10.50)	6.00 (14.16)	8.33 (16.76)	11.33 (19.65)
		0.075	2.00 (8.11)	4.00 (11.52)	6.00 (14.16)	8.67 (17.10)
		0.1	0.00 (0.00)	2.00 (8.12)	4.00 (11.53)	5.00 (12.91)
5.	Deltamethrin 2.8 EC	0.025	1.67 (7.42)	3.00 (9.97)	4.00 (11.53)	7.67 (16.07)
		0.05	0.00 (0.00)	2.00 (8.12)	3.33 (10.50)	5.00 (12.90)
		0.075	0.00 (0.00)	1.33 (6.61)	2.00 (8.12)	4.33 (12.00)
6.	Untreated control		8.33 (16.76)	11.33 (19.65)	15.67 (23.30)	19.33 (26.06)
		S. Em. ±	0.25	0.34	0.43	0.50
		CD (P=0.05%)	0.70	0.96	1.22	1.50
		CD (P=0.01%)	0.90	1.30	1.64	1.96

* Weight loss was not observed up to 60 days of storage
Figures in the parentheses are arc sine √ percentage values

Table 7: Effect of plant oils and insecticides impregnated plastic fibre and gunny bags on the germination of barley seeds

S. No.	Treatments	Concentration (%)	Germination (%)	
			Plastic fibre bags	Gunny bags
1	Castor oil	0.5	85.33 (68.29)	83.33 (66.52)
		1	85.67 (67.84)	84.33 (66.75)
		1.5	86.00 (68.24)	85.00 (67.39)
2	Neem oil	0.5	87.00 (70.15)	86.67 (69.77)
		1	86.00 (68.57)	85.33 (67.97)
		1.5	86.33 (69.23)	85.00 (67.98)
3	Mustard oil	0.5	86.00 (68.11)	85.67 (67.84)
		1	85.67 (67.95)	85.33 (67.67)
		1.5	87.00 (70.15)	86.00 (69.05)
4	Malathion 50 EC	0.5	86.67 (69.19)	84.67 (67.39)
		1	85.00 (67.98)	85.00 (67.98)
		1.5	84.67 (67.02)	85.00 (67.29)
5	Deltamethrin 2.8 EC	0.5	86.67 (68.82)	85.33 (67.67)
		1	86.00 (69.05)	86.00 (69.05)
		1.5	85.33 (67.97)	85.67 (68.27)
6	Untreated control		86.67 (69.19)	85.33 (67.97)
		S. Em. ±	3.90	3.75
		CD (P=0.05%)	NS	NS
		CD (P=0.01%)	NS	NS

Figures in the parentheses are arc sine √ percentage value

Conclusion

Both under artificial and natural conditions the minimum infestation of *R. dominica*, dry mass loss and grain damage were recorded in barley grains stored in metal containers followed by plastic fiber bag and polythene bags.

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