



Eco-friendly organic management of rust red flour beetle, *Tribolium castaneum* (Herbst) under stored conditions

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Summary

The results showed that neem leaf powder was the most effective treatment with a record of the highest mean adult mortality of 67.22 per cent and also exhibited the lowest weight loss of 0.67 per cent after 60 days of treatment. It was followed by powders of Eucalyptus (58.89% & 0.87%) and Tulsi (51.11% & 0.80%). The least effectiveness of turmeric rhizome powder against the pest recording minimum adult mortality and maximum weight loss of 30.56% and 1.07% per cent respectively was noticed control against adult mortality (30.56 %), grain weight loss and adult emergence owing to *T. castaneum*. As a result, 1.5 g/100 g of grains of neem leaf powder can be recommended as a safe control method against *T. castaneum* in stored wheat. The overall mean adult mortality of *T. castaneum* in fenvalerate was 72.78 per cent. When it came to treating *T. castaneum* with some inert materials, boric acid treatment was the most effective showed the 100 percent adult mortality, followed by coal ash (71.67 %) and cow dung ash (63.33 %) after 5 days of storage. There was minimum grain weight loss and least adult emergence was recorded in the treatment of coal ash and cow dung ash. Whereas sawdust resulted in the least effective treatment with mean adult mortality of (35.56 %), there was maximum adult emergence seen.

JAE 2022, Vol 14

Received: 10 Sept. 2022

Accepted: 15 Oct. 2022

Published: 05 Nov. 2022

<https://doi.org/10.53911/JAE.2022.14216>

JAE.2022.14216

Associate Editor: Dr. B. L.

Jakhar

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Keywords: *Tribolium castaneum* (Herbst); plant powders; inert materials, adult mortality, grain weight loss

INTRODUCTION

Cereals play a pivotal role to satisfy the global food demand of the growing population for dietary energy, protein, and micronutrients. The major cereal crops are rice, maize, and wheat, but sorghum, millets, oats and rye are important in some regions and wheat is India's prime staple food which is placed second after rice. Wheat is the most widely grown food crop in the world, which ranks first in terms of area and production in the world. Wheat (*Triticum aestivum* Linnaeus) is known as the "KING OF CEREALS". It is mainly consumed in the northern and north-west parts of the country. Wheat is the major cereal crop occupying an eminent place in our country'. Production of wheat during 2019-20 is estimated with a record of 107.18 million tonnes. Uttar Pradesh is the top wheat producing state in India, followed by Haryana, Punjab, and Madhya Pradesh. Wheat is consumed in numerous forms, viz., roti/chapati,

halwa, sweet meat, etc. and also in most of the urban areas in the nation, it is a major ingredient in such foods as bread, biscuits, pancakes, pasta and pies, pastries, pizza, cakes, cookies, doughnuts, beer, vodka, boza (a fermented beverage), and breakfast cereals etc., is increasing at a fast rate. Being rich in proteins, vitamins, and carbohydrates, it provides a balanced food diet to millions of people every day.

There are approximately 200 species of insects and mites attacking stored grains and stored products. In most of the Coleopteran insects (weevil and beetles) viz., Rust red flour beetle, *Tribolium spp.*, Rice weevil, *Sitophilus oryzae* (Linnaeus), Lesser grain borer, *Rhizopertha dominica* (Fabricius), Saw-toothed grain beetle, *Oryzaephilus surinamensis* (Linnaeus), Khapra beetle, *Trogoderma granarium* (Everts), Cigarette beetle, *Lasioderma serricorne* (Fabricius), Groundnut bruchid beetle, *Caryedon serratus* (Olivier), Pulse beetle, *Callosobruchus chinensis* (Linnaeus), are the most vital insects damaging the stored products excessively. Apart from damage and feed they contaminate more, not useful for consumption. These attacks reduced both the quantity and food value of the stored seeds.

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The rust red flour beetle, *Tribolium castaneum* (Herbst) is considered a major pest of stored grain.¹ The principal stored grain pest of wheat is rust-red flour beetle which is a cosmopolitan and most serious pest. These beetles are found in granaries of wheat, cereals, mixed cake, dried flowers and pet food, seeds, chocolate, meal, spices, nuts etc., In some tropical countries, these losses are as high as 30%.² The rust red flour beetle may be present in large numbers in infested grain. The adults are attracted to light but go towards cover when disturbed. Normally, these beetles have been found inside infested grain products, but sometime also found in cracks and crevices where grain may have spilt. They are attracted to grain with high moisture content and can cause a grey tint to the grain they are infesting.³ The beetles give off a distasteful odour, and their presence encourages mould growth in grain. The larvae destroy 12.5-14.60 per cent of the individual seeds and during their development, some 88 grains are attacked by per larva. It leads to a considerable loss in the number of grains and reduces their viability.⁴ In two species of confused flour beetle, the last four segments of antennae are gradually enlarged towards the tips, whereas the rust-red flour beetle last three segments of the antennae are abruptly enlarged to form a club. These are small beetles with reddish brown. These are found in temperate areas but will survive the winter in protected places, especially with central heat.⁵ The eggs are white, slender larvae are creamy yellow to light brown in colour. The pupae are lighter in colour, white to yellowish.

Control of these relies heavily on the use of synthetic insecticides and fumigants. But their widespread use has led to some serious problems including the development of insect strains resistant to insecticides, toxic residues on stored grains, toxicity to consumers and increasing costs of claim, environmental contamination, harmfulness to non-target organisms etc.^{6, 23} Pimentel et al.⁷ reported that the phosphine resistance was shown by *T. castaneum*, *R. dominica*, *O. surinamensis*. In analysis of these problems, several insecticides have either been banned or restricted in their use. For example, the use of organophosphates was decreased, because of increasing resistance incidence in stored-product insects against these chemicals.^{8, 25}

For developing an effective management strategy against pests, we need to go for safe alternatives like plant powders and inert materials etc. Botanicals have low mammalian toxicity, easy to use, biodegradable and moreover no harm to the environment. Over 120 plants and plant products can be used to control stored grain

insect pests.^{9, 24} Inert materials are chemically inactive, with no toxicity and local availability. Inert dust absorbs the waxy layer of insects, dehydrating them to death. So, in view of the above aspects, the present research work on eco-friendly organic management of rust red flour beetle, *T. castaneum* under stored conditions was made.

Materials and Methods

Several laboratory experiments were conducted during 2019- 2020 in the Entomology Department, College of Agriculture, Central Agricultural University, Imphal to study the post-harvest management of the rust-red flour beetle, *Tribolium castaneum* (Herbst). The materials, methods and procedures used for the experimentations are briefly described below:

Rearing of *T. castaneum* for the experiments

The initial culture of *T. castaneum* was started by collecting adult beetles from the infested rice grains of nearby godowns. Adults were introduced to a plastic bottle containing the wheat flour. At top portion of the bottle was covered with a muslin cloth and tied with rubber bands to prevent adults from escaping. These plastic bottles were kept under non-invasive laboratory conditions. The stock culture was maintained at room temperature and then newly emerged young beetles were used throughout the period of experimental investigation. The detail concerning materials used and the method employed during the period of investigation are described objective-wise briefly as under.

Effect of certain plant powders on *T. Castaneum*

Powders of six indigenous plants all at a single dose (@1.50 g/100g seeds) were tested on the seeds of the wheat variety 'Sonalika'. Twenty pairs of 10 days old adults of *T. castaneum* were released into the plastic bottles (200 ml capacity) containing 100 g treated separately with different plant powder and then kept under room conditions. The experiment was replicated three times.

Preparation of botanical powders

The leaves of neem, *Azadirachta indica* A.Juss; eucalyptus, *Eucalyptus globulus* Labill, tulsi, *Ocimum sanctum* Linnaeus; and guava, *Psidium guajava* Linnaeus free from any other pesticide application were collected from College farm, and rhizomes of turmeric, *Curcuma longa* Linnaeus; ginger, *Zingiber officinale* Rosc. were obtained from the local farmers who harvested from the organic fields (Table 1). The locally collected plant parts of six plants were cut into small pieces and dried under shade conditions for a week. The shade-dried plant parts were ground with the help of an electrical grinder/ mortar

and pestle. Then, the ground materials were passed through a 30mesh sieve to get a fine powder, and preserved under dry and shade conditions for experimentation.

Table 1: List of the indigenous plant species evaluated in powder forms against *T. castaneum*

S. No.	Common & scientific name	Family	Local name	Plant part used
1.	Neem, <i>Azadirachta indica</i> A. Juss	Meliaceae	Neem	Leave
2.	Eucalyptus, <i>Eucalyptus globulus</i> Labill.	Myrtaceae	Nashik	Leave
3.	Turmeric, <i>Curcuma longa</i> Linnaeus	Zingiberaceae	Yaingang	Rhiome
4.	Ginger, <i>Zingiber officinale</i> Rosc.	Zingiberaceae	Shing	Rhizome
5.	Tulsi, <i>Ocimum sanctum</i> Linnaeus	Lamiaceae	Tulasi	Leave
6.	Guava, <i>Psidium guajava</i> Linnaeus	Myrtaceae	Pungdon	Leave

There were 8 treatments with four leaf powders and two rhizome powders along with a commercial insecticide Fenvalerate 0.4 D (as a check) and an uncontrolled (without any treatment) (Table 2). Hundred (100) gm of healthy and disinfested grains of wheat variety 'Sonalika' was taken in plastic bottles, and then each bottle was mixed with botanical powders at the rate of 1.50 gm /100 gm grains. The experimentation was conducted by using

CRD replicated three times. There were altogether 8 treatments viz., Fenvalerate 0.4 D at the rate of 0.30 gm/ 100 gm of grains was treated as a check. One untreated control was maintained without mixing the botanical powder. Freshly emerged 10 pairs of adult beetles were released in each plastic bottle. Bottles were covered with muslin cloth and tied with rubber bands.

Table 2: Details of the treatments used in the experiment

Treatment (Plant powder)	Plant parts used	Dosage (g/100 g grain)
T ₁ =Neem	Leave	1.50
T ₂ =Eucalyptus	Leave	1.50
T ₃ =Turmeric	Rhizome	1.50
T ₄ =Ginger	Rhizome	1.50
T ₅ =Tulsi	Leave	1.50
T ₆ =Guava	Leave	1.50
T ₇ =Fenvalerate 0.4 D (Check insecticide)	-	0.30
T ₀ = Untreated control	-	-

Effect of some inert materials on the population of *T. castaneum*

Seven inert materials were evaluated for their efficacy against *T. castaneum* on stored wheat grains (Table 3). There were 8 treatments with seven inert materials along

with an uncontrol (without any treatment). The details of the various inert materials used are given below. There were eight different treatments comprising seven inert materials and one untreated control (Table 3).

Table 3: Details of inert materials used

Treatment (Inert materials)	Dosage (g/100 g grains)
T ₁ =Paddy straw	1.50
T ₂ =Paddy husk ash	1.50
T ₃ = Cow dung ash	1.50
T ₄ =Coal ash	1.50
T ₅ =Saw dust	1.50
T ₆ =Sand dust	1.50
T ₇ =Boric acid	1.50
T ₀ =Untreated control	Without any treatment

Preparation of inert materials

Paddy straw was collected from our college field and Paddy husk ash was obtained from nearby rice mill. Cow dung pallets were collected from the college farm and it was burnt to get the ash. Coal ash was obtained from the kitchen. Saw dust was also collected from the carpentry workshop.

Observations recorded

The adult mortality was recorded at 5, 10 and 15 days after their release in each treatment. Per cent weight

losses were also recorded after 30 and 90 days of the release. Per cent weight loss of grains was calculated by weighing of grains after sieving of frass, which is due to insect damage. After weight loss was calculated, the containers were kept separately for adult emergence (population build up). Observation on adult emergence was made at 30 and 90 days after treatment. Ninety days after the release, total number of adults emerged in each treatment were counted. The adult mortality, grain weight losses and adult emergence were determined by following formula:

$$\text{Per cent adult mortality} = \frac{\text{Number of adults died}}{\text{Total Number of adults released (20)}} \times 100$$

$$\text{Per cent grain weight loss} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

Where,

Initial weight = weight of original wheat grains

Final weight = weight of infested wheat grains

$$\text{Per cent adult emergence} = \frac{\text{Number of adults emerged from hatched eggs}}{\text{Total Number of eggs hatched (100)}} \times 100$$

Results and Discussion

The substantial findings of laboratory experiments conducted in the Department of Entomology, College of Agriculture, Central Agricultural University, Imphal during 2020-2021 to investigate the eco-friendly management of rust red flour beetle, *Tribolium castaneum* (Herbst) under stored conditions. The significant findings are briefly outlined and discussed below:

Evaluation of botanical powders against *T. castaneum* on stored wheat

Some of the botanical powders like neem, eucalyptus, turmeric, ginger, tulsi and guava were tested with the dose of 1.5 g/100 g grains as a grain protectant property against *T. castaneum* in wheat grains under laboratory conditions. The efficacy of these botanicals was determined based on adult mortality, weight loss and adult emergence.

Effect on adult mortality of *T. castaneum*

Among all botanical powders, neem leaf powder showed a maximum adult mortality rate of 67.22 per cent. The treatment without any control recorded the least adult mortality (2.22 %). The results of remaining botanical

powders viz., eucalyptus leaf powder (58.89 %), tulsi leaf powder (54.44 %), ginger rhizome powder (51.11 %), guava leaf powder (47.22 %) significantly par with each other and at last turmeric rhizome powder (30.56 %). The chemical-based treatment fenvalerate which is used as a check recorded (72.78 %) the highest adult mortality rate of all botanical powders (Table 4 & Fig. 1). The present findings seem to be consistent with other research of Britto et al.¹⁰ reported that the antifeedant properties of some medicinal plants such *Azadirachta indica*, *Zingiber officinale*, *Ocimum sanctum* on the adult of *Tribolium castaneum*. The mortality rate in adults of *T. castaneum* treated with plant extracts or powder was studied. It has been stated that the tested medicinal plant possessed antifeedant properties and these plants may be exploited for controlling insects and pests. Whereas Rajapakse¹¹ estimated the neem leaf powder at 2 DAT and 4 DAT mean mortality against *C. maculatus*. Oyegoke et al.¹² and Gupta¹³ observed that the repellent properties of *Ocimum sanctum* against *Tribolium castaneum* in the laboratory, mortality increased with increase in concentration, with highest mortality (63.5%) observed with 0.5 g *O. sanctum*. Iram et al.¹⁴ reported that the leaves of *Psidium guajava* have a toxic effect on adult *T. castaneum*.

Table 4: Efficacy of some botanical powders on adult mortality of *Tribolium castaneum*

Botanical powder	Dosage (g/100g grains)	Per cent adult mortality of <i>T. castaneum</i>			
		5 DAT	10 DAT	15 DAT	Pooled mean
T ₁ =Neem powder	1.5 g	53.33 (46.91)	61.67 (51.76)	86.67 (68.86)	67.22 (55.84)
T ₂ =Eucalyptus powder	1.5 g	43.33 (41.16)	56.67 (48.83)	76.67 (65.95)	58.89 (50.38)
T ₃ =Ginger powder	1.5 g	36.67 (37.25)	48.33 (44.04)	68.33 (55.77)	51.11 (45.69)
T ₄ =Turmeric powder	1.5 g	21.67 (27.71)	28.33 (32.14)	41.67 (40.20)	30.56 (33.35)
T ₅ =Tulsi powder	1.5 g	43.33 (41.16)	51.67 (45.96)	68.33 (55.77)	54.44 (47.63)
T ₆ =Guava powder	1.5 g	41.57 (40.20)	43.33 (41.16)	56.67 (48.84)	47.22 (43.40)
T ₇ =Fenvalerate 0.4 D	0.30 g	58.33 (49.80)	76.67 (61.22)	83.33 (65.95)	72.78 (58.99)
T ₀ =Untreated control	-	0 (0.00)	0 (0.00)	6.67 (14.76)	2.22 (4.92)
SE(m)±	-	0.93	1.15	1.48	2.53
CD at 5%	-	2.79	3.47	4.44	7.16

Figures in the parentheses are angular transformed values

Data represented are the mean of three replications

Effect on grain weight loss

At the end of 90 days, all the botanical powders proved to be significantly effective on the adult emergence of *Tribolium castaneum* over the untreated control (57.67 %). However, the highest adult emergence (42.67 %) was marked in the turmeric leaf powder, followed by ginger rhizome powder (34.33 %) and guava leaf powder 28.67 per cent. Fenvalerate used as a check records the lowest adult emergence with a value of 11 per cent, followed by

neem leaf powder at 20.67 per cent. The remaining two botanical powders of tulsi and eucalyptus recorded the same value of (26 %). The treatments of guava, eucalyptus and tulsi were par with one another. Untreated control > turmeric leaf powder > ginger rhizome powder > guava leaf powder > eucalyptus > tulsi leaf powder > neem leaf powder was the chronological order of efficiency of some botanical powders based on adult emergence after 90 days of storage (Table 5 & Fig. 1).

Table 5: Effect of plant powders on per cent weight loss of grains due to *Tribolium castaneum* as influenced by different botanical powders at 30 and 60 DAT

Botanical powder	Dosage (g/100g grains)	Per cent weight loss of grains	
		30 DAT	60 DAT
T ₁ =Neem powder	1.5 g	0.31 (0.80)	0.67 (1.09)
T ₂ =Eucalyptus powder	1.5 g	0.18 (0.83)	0.78 (1.13)
T ₃ =Ginger powder	1.5 g	0.40 (0.95)	0.87 (1.18)
T ₄ =Turmeric powder	1.5 g	0.79 (1.14)	1.07 (1.26)
T ₅ =Tulsi powder	1.5 g	0.28 (0.89)	0.80 (1.15)
T ₆ =Guava powder	1.5 g	0.68 (1.09)	0.86 (1.17)
T ₇ =Fenvalerate 0.4 D	0.30 g	0.09 (0.77)	0.55 (1.03)
T ₀ =Untreated control	-	0.89 (1.18)	1.86 (1.54)
SE(m)±	-	0.01	0.03
CD at 5%	-	0.03	0.09

Figures in the parentheses are square root transformed values;
Data represented are the mean of three replications

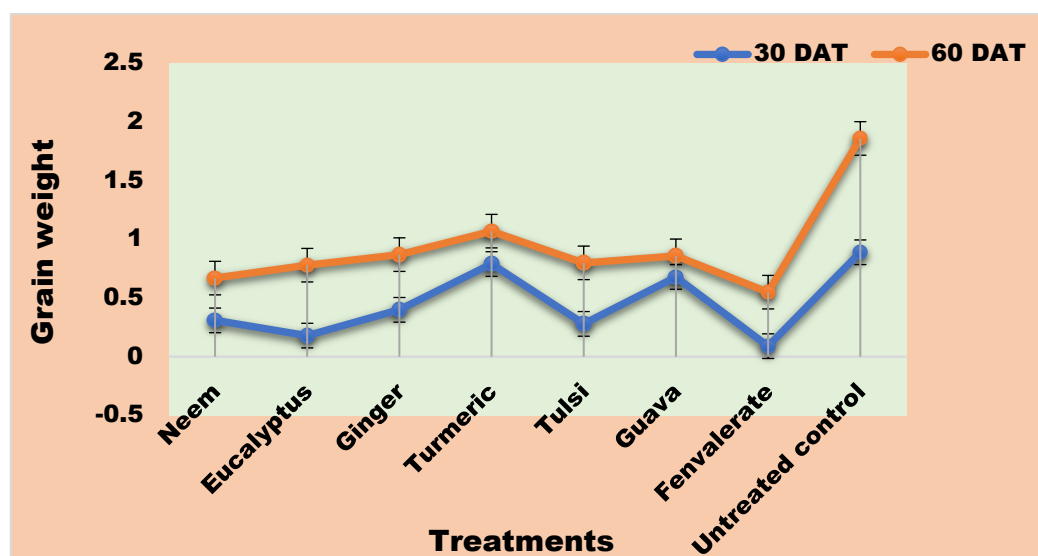


Figure 1: Graphical representation on the effect of plant powders on per cent weight loss at 30 and 60 DAT

Effect on adult emergence

At the end of 90 days of observation, all the botanical powders proved to be significantly effective on the adult emergence of *Tribolium castaneum* over the untreated control (57.67 %). However, the highest adult emergence (42.67 %) was marked in the turmeric leaf powder, followed by ginger rhizome powder (34.33 %) and guava leaf powder 28.67 per cent. Fenvalerate used as a check records the lowest adult emergence with a value of 11 per cent, followed by neem leaf powder at 20.67 per cent. The remaining two botanical powders of tulsi and eucalyptus recorded the same value of (26 %). The treatments of guava, eucalyptus and tulsi were par with one another.

Untreated control > turmeric leaf powder > ginger rhizome powder > guava leaf powder > eucalyptus = tulsi leaf powder > neem leaf powder was the chronological order of efficiency of some botanical powders based on adult emergence after 90 days of storage (Table 6 & Fig. 2). Pereira & Wohlgemuth¹⁵ reported that neem seed and neem leaves effectively reduced the productivity of all the beetle screened and adult emergence of *S. cerealella* and *E. cautella*. Prakash et al.¹⁶ tested the plant products and said the multiplication of *S. cerealella* and *R. dominica* was prevented. Yadav and Tiwari¹⁷ took chopped neem leaves and ajwain seed powder with minimum adult emergence of 12 % and 11.67 per cent.

Table 6: Effect of botanical powders on adult emergence of *Tribolium castaneum*

Botanical powder	Dosage (g/100g grains)	Per cent adult emergence of <i>T. castaneum</i>		
		¹ 15 DAT	² 45 DAT	³ 90 DAT
T ₁ =Neem powder	1.50 g	0.00 (0.71) ¹	7.34 (2.80) ¹	20.67 (27.03) ²
T ₂ =Eucalyptus powder	1.50 g	0.00 (0.71)	10.00 (3.24)	26.00 (30.57)
T ₃ =Ginger powder	1.50 g	0.00 (0.71)	15.67 (4.03)	34.33 (35.87)
T ₄ =Turmeric powder	1.50 g	0.00 (0.71)	12.00 (3.54)	42.67 (40.78)
T ₅ =Tulsi powder	1.50 g	0.00 (0.71)	8.00 (2.92)	26.00 (30.65)
T ₆ =Guava powder	1.50 g	0.00 (0.71)	13.34 (3.72)	28.67 (32.37)
T ₇ =Fenvalerate 0.4 D	0.30 g	0.00 (0.71)	5.00 (2.34)	11.00 (19.36)
T ₀ =Untreated control	-	0.00 (0.71)	22.67 (4.81)	57.67 (49.41)

SE(m)±	-	0.09	0.92
CD at 5%	-	0.28	2.77

¹Figures in the parentheses are square root transformed values;

²Figures in the parentheses are angular transformed values;

Data represented are mean of three replications

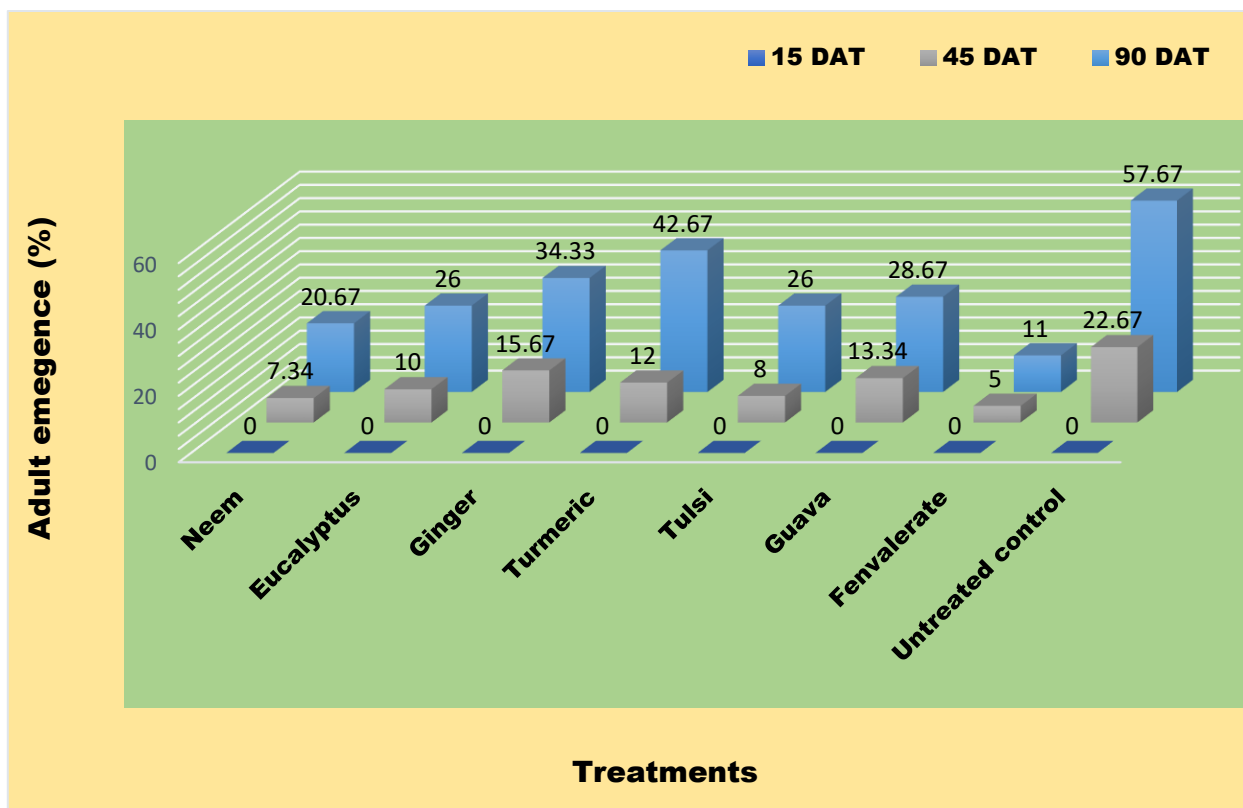


Figure 2: Effect of some botanical powders on adult emergence of *Tribolium castaneum*

Evaluation of some inert materials against *T. castaneum* on stored wheat

Some of the inert materials like paddy straw, paddy husk ash, cow dung ash, coal ash, sawdust, sand dust and boric acid were tested with the dose of 1.5 g/100 g grains as a grain protectant property was evaluated against *T. castaneum* in wheat grains under laboratory conditions. These inert materials were estimated based on adult mortality, weight loss as well as adult emergence.

Effect on adult mortality of *T. castaneum*

Cow dung ash had the highest adult mortality over all the inert material treatments recording 81.11 per cent mortality. The treatment with any control recorded the least adult mortality (5.56 %). The results of remaining inert materials viz., coal ash (78.33 %), paddy husk ash (68.89 %), sand dust (53.89 %), and at last saw dust (35.56 %). Among all the treatments of inert material, there was a considerable difference between some of them those were cow dung ash and coal ash par with each other, sand dust and paddy straw par with each other (Table 7 & Fig. 3). In the overall mean the results of the study were similar to the Kumar¹⁸ who studied the adult mortality of

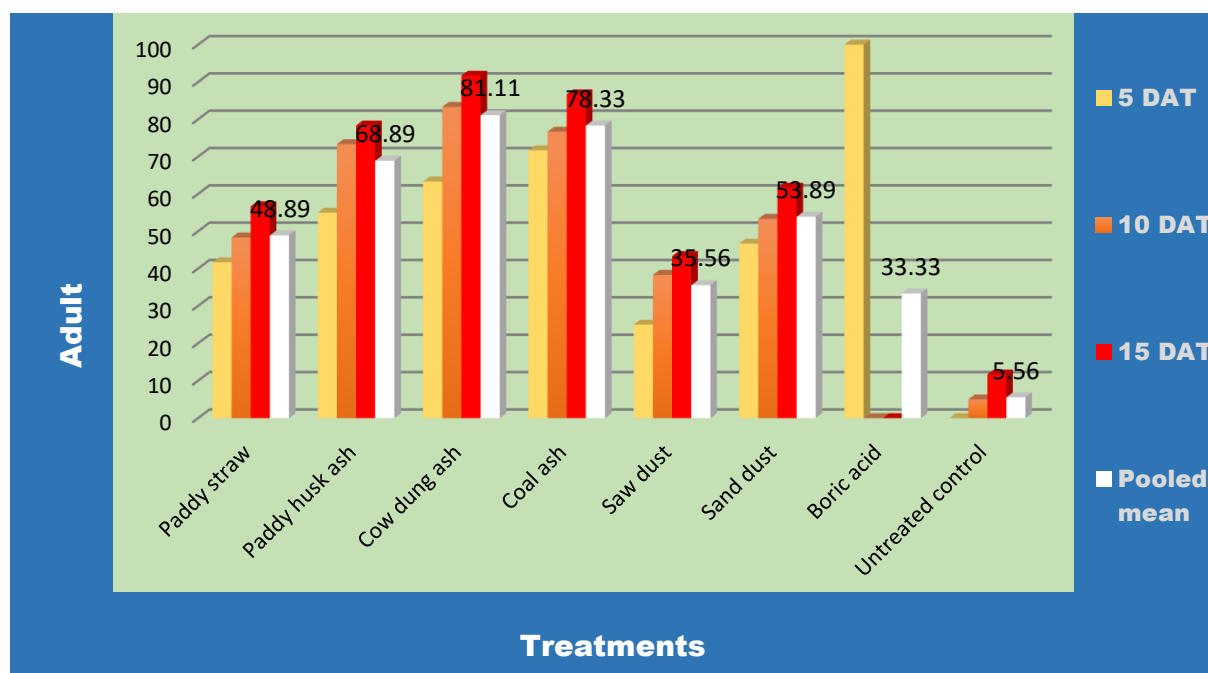
T. castaneum through inert materials, the boric acid was found to be the best among all the treatments after 7 days of storage. After 30 days of storage, cow dung ash was found to be the best treatment. While sawdust was the least effective treatment. It evaluated that 1.25 cm layer of cow dung ash at the top effectively protected seeds from *C. chinensis* in tanks and barrels. Additionally, mixing with 30 per cent wood ash was also effective against *S. oryzae* and *S. cerealella* in maize. According to Golob et al.¹⁹ restricted infestation of stored insects in maize grains admixed with wood ash, tobacco dust, sawdust and sand. Meena et al.²⁰ an experiment was conducted on the extent of damage of *C. cephalonica* in maize under different storage conditions. They reported that adult emergence of *C. cephalonica* on wood ash (33.33 %) control 90 per cent. Parkin²¹ reported that inert dust removes the wax layer on the body surface, enters the crevices in the insect cuticle and, thus causes desiccation. Dust made by powdering the vegetative parts as well as seeds of various plants have also been used in a similar manner and in some cases repellent and insecticidal properties are also found.

Table 7: Effect of inert materials on adult mortality of *Tribolium castaneum*

Inert material	Dosage (g/100g grains)	Per cent adult mortality of <i>T. castaneum</i>			
		5 DAT	10 DAT	15 DAT	Pooled mean
T ₁ =Paddy straw	1.5 g	41.67 (40.20)	48.33 (44.04)	56.67 (48.84)	48.89 (44.36)
T ₂ =Paddy husk ash	1.5 g	55.00 (47.87)	73.33 (58.93)	78.33 (62.29)	68.89 (56.36)
T ₃ =Cow dung ash	1.5 g	63.33 (52.74)	83.33 (70.11)	91.67 (73.40)	81.11 (65.42)
T ₄ =Coal ash	1.5 g	71.67 (57.86)	76.67 (61.14)	86.67 (68.66)	78.33 (62.56)
T ₅ =Saw dust	1.5 g	25.00 (29.93)	38.33 (38.24)	43.33 (41.16)	35.56 (36.44)
T ₆ =Sand dust	1.5 g	46.67 (43.09)	53.33 (46.91)	61.67 (51.76)	53.89 (47.25)
T ₇ =Boric acid	1.5 g	100 (90.00)	0.00 (0.00)	0.00 (0.00)	33.33 (30.00)
T ₀ =Untreated control	-	0 (0.00)	5.00 (12.92)	11.67 (19.89)	5.56 (10.94)
SE(m)±	-	0.56	0.55	0.69	1.89
CD at 5%	-	1.69	1.66	2.09	5.36

Figures in the parentheses are angular transformed values

Data represented are mean of three replications

**Figure 3: Efficacy of some inert materials on adult mortality of *Tribolium castaneum***

Effect on grain weight loss

The data collected on grain weight loss after two months of storage furnished in Table 8 and Figure 5 showed that weight loss of grains ranged from 2.09 to 0.22 per cent, the minimum weight loss was seen in the treatment of boric acid (0.22 %). The remaining treatments viz., sawdust (1.77 %), paddy straw (1.57 %), sand dust (0.88 %) paddy husk ash (0.78 %), coal ash (0.75 %) and cow dung ash (0.54 %) (Table 8 & Fig. 4). Chahal & Judge²²

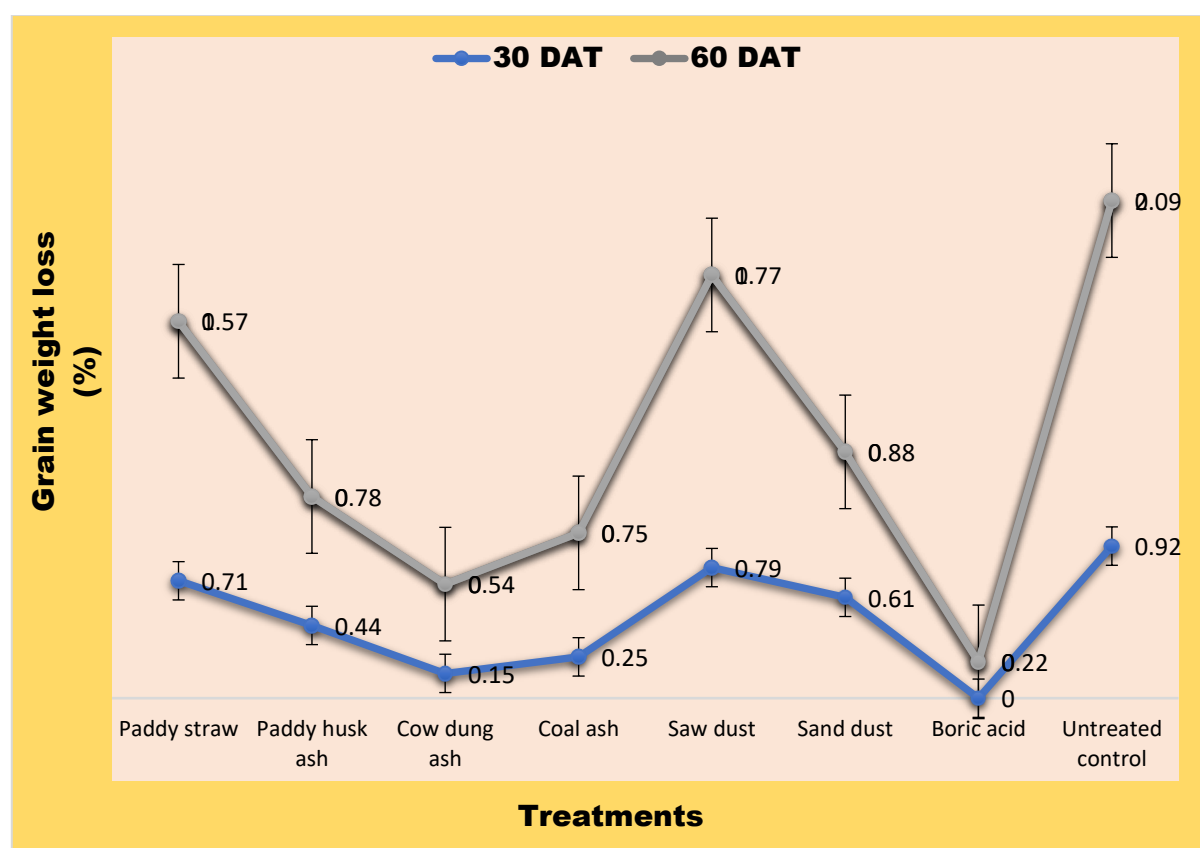
conveyed that they saw dust as a physical barrier against the khapra beetle, *Trogoderma granarium* (E.) in wheat grains. At 8 cm layer of sawdust over wheat, grains prevented the beetle attack. This finding was similar to the Yadav & Tiwari¹⁷. According to Golob et al.¹⁹ restricted infestations of stored insects in maize, grains are mixed with wood ash, tobacco dust, sawdust and sand. So far, again the uncontrol without any treatment to the grains lost a maximum weight of (2.09 %).

Table 8: Effect of inert materials on per cent weight loss of grains due to *T. castaneum* at 30 and 60 DAT

Inert material	Dosage (g/100g grains)	Per cent weight loss of grains	
		30 DAT	60 DAT
T ₁ =Paddy straw	1.5 g	0.71 (1.11)	1.57 (1.44)
T ₂ =Paddy husk ash	1.5 g	0.44 (0.97)	0.78 (1.13)
T ₃ =Cow dung ash	1.5 g	0.15 (0.81)	0.54 (1.02)
T ₄ =Coal ash	1.5 g	0.25 (0.87)	0.75 (1.12)
T ₅ =Saw dust	1.5 g	0.79 (1.14)	1.77 (1.51)
T ₆ =Sand dust	1.5 g	0.61 (1.06)	0.88 (1.18)
T ₇ =Boric acid	1.5 g	0.00 (0.71)	0.22 (0.85)
T ₀ =Untreated control	-	0.92 (1.20)	2.09 (1.61)
SE(m)±	-	0.01	0.02
CD at 5%	-	0.04	0.07

Figures in the parentheses are square root transformed values

Data represented are mean of three replications

**Figure 4: Per cent weight loss of grains due to *Tribolium castaneum* as influenced by different inert materials at 30 and 60 DAT**

Effect on adult emergence

The results recorded from the experiment on the adult emergence after three months of storage are presented in table 9 and figure 5. Here the inert material treatment of sawdust reported the highest adult emergence of *T. castaneum* was 40.67 per cent, followed by the next treatments paddy straw (31.67 %) and paddy husk ash (25.33 %). As usual, the untreated control noticed the maximum number of adult emergences 76 per cent, and the least number of adult emergences was observed in the treatment of boric acid (12.67 %). The remaining

treatments viz., cow dung ash (17 %), coal ash (21.33 %) and sand dust 22.33 per cent respectively. In the treatment of coal ash and sand dust, there was a statistically significant difference between them. After 90 days of storage, the order of adult emergence was: untreated control > saw dust > paddy straw > paddy husk ash > sand dust ≥ coal ash > cow dung ash > boric acid (Table 9 & Fig. 5). This finding further supports the idea of an association between Yadav & Tiwari¹⁷ reported that minimum adult emergence in ash powder, sand and cow dung ash was 2.00, 2.33 and 8.33 per cent. Apuli and

Villet²⁶ verified wood ash against *C. maculatus* in cowpea. The damage to seeds ranged from 63 per cent in the ash-free control to 1.3 per cent in seeds treated with 30 per cent ash. The number of progenies similarly ranged from 148 in the untreated control to 2.5 in 30 per cent ash treatment. Kittur²⁷ confirmed that cow dung ash is good

at controlling *C. chinensis* activities in red gram seeds. Ofuya²⁸ reported that wood ash was the most effective in reducing the damage done by *C. maculatus* in cowpea seeds and identified that the adult emergence was observed after 95 days of treatment.

Table 9: Effect of some inert materials on adult emergence of *T. castaneum*

Inert material	Dosage (g/100g grains)	Per cent adult emergence of <i>T. castaneum</i>		
		¹ 15 DAT	² 45 DAT	³ 90 DAT
T ₁ =Paddy straw	1.50	0.00 (0.71)	13.00 (3.68)	31.67 (34.23)
T ₂ =Paddy husk ash	1.50	0.00 (0.71)	11.34 (3.44)	25.33 (30.22)
T ₃ =Cow dung ash	1.50	0.00 (0.71)	7.34 (2.80)	17.00 (24.31)
T ₄ =Coal ash	1.50	0.00 (0.71)	9.67 (3.19)	21.33 (27.49)
T ₅ =Saw dust	1.50	0.00 (0.71)	15.34 (3.98)	40.67 (39.62)
T ₆ =Sand dust	1.50	0.00 (0.71)	12.00 (3.54)	22.33 (28.18)
T ₇ =Boric acid	1.50	0.00 (0.71)	3.67 (2.03)	12.67 (20.80)
T ₀ =Untreated control	-	0.00 (0.71)	25.34 (5.09)	76.00 (60.70)
SE(m)±	-	-	0.09	0.57
CD at 5%	-	-	0.29	1.70

^{1,2}Figures in the parentheses are square root transformed values

³Figures in the parentheses are angular transformed values

Data represented are mean of three replications

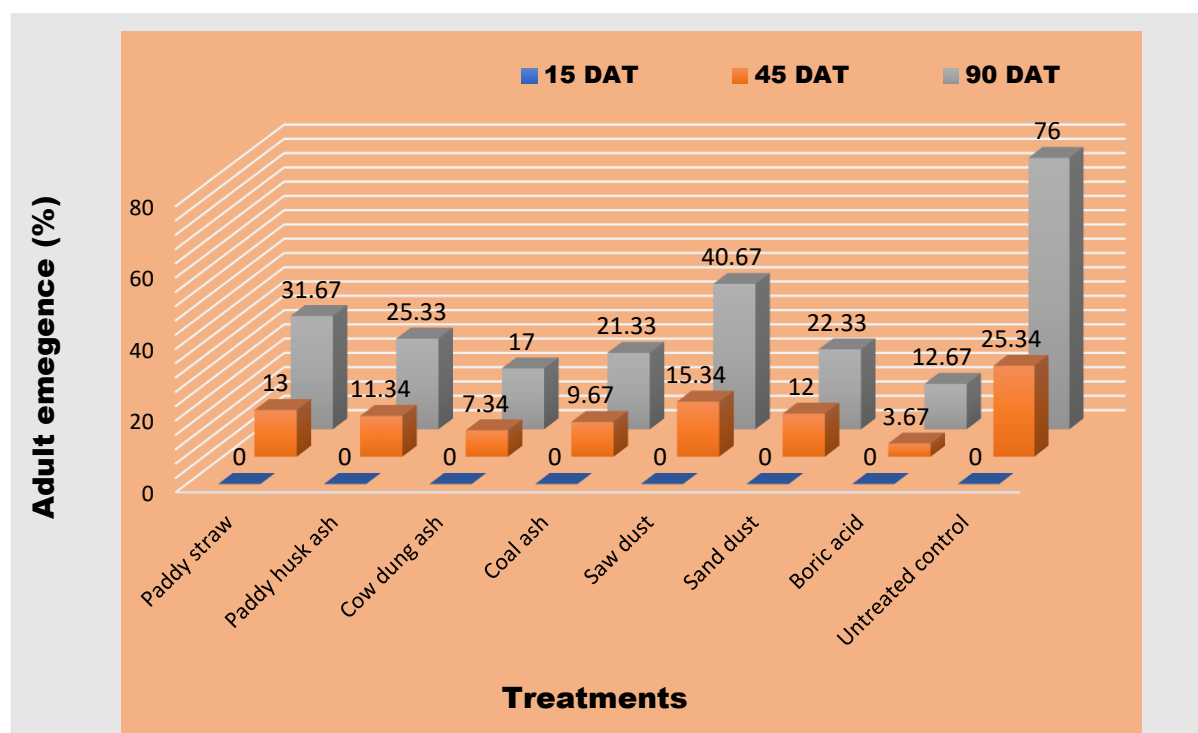


Figure 5: Effect of inert materials on adult emergence of *Tribolium castaneum*

Conclusion

It leads to the conclusion of the study that *Tribolium castaneum* (Herbst) is considered as a major pest of stored grain. The principal stored grain pest of wheat is the red flour beetle, *Tribolium castaneum* (Herbst) which is a cosmopolitan and most serious pest. These beetles are found in granaries of wheat, cereals, mixed cake, dried

flowers and pet food, seeds, chocolate, meal, spices, nuts etc. *T. castaneum* biology on preserved wheat flour was investigated. Incubation, larval development and pupal development took 5, 15, and 6 days, respectively. The entire life cycle (from birth to adult emergence) took 26 days. In the case of *T. castaneum*, it was discovered that neem leaf powder was the most effective treatment, whereas, turmeric rhizome powder was the least effective

in controlling adult mortality, grain weight loss and adult emergence owing to *T. castaneum*. As a result, 1.5 g/100 g of grains of neem leaf powder can be recommended as a safe control method against *T. castaneum* in stored wheat. When it came to treating *T. castaneum* with some inert materials, boric acid treatment was the most effective, followed by cow dung ash and coal ash. Besides the chemical insecticide, fenvalerate used as a check showed a greater result than botanical powders. Even though chemical insecticides have an excellent track record of protecting seeds against storage pests, their negative impact on the environment and human health necessitates the development of a new technique for their safe use. In addition, several storage pests have acquired resistance to pesticides made from synthetic chemicals. These issues can be solved using botanicals such as plant powders and inert materials at a 1.5 g/100 g grain. They are extremely beneficial for safeguarding seeds from stored product insects in an environmentally friendly manner.

Declaration of interests

The authors have no conflict of interest to declare.

Data sharing

All relevant data are within the manuscript.

Acknowledgement

The authors are highly grateful to the Dean, College of Agriculture, Iroisemba, Central Agricultural University, Imphal for providing the necessary facilities to conduct the experiment

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