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Management of the red flour beetle *Tribolium castaneum* (Herbst.) (Coleoptera: Tenebrinionidae) in stored wheat using dry dust of Neem (*Azadirachta indica*) and Jarul (*Lagerstroemia speciosa*) as repellants

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Abstract
The responses of adult Red Flour Beetle, *Tribolium castaneum* (Herbst.) to the dry leaf dust of Neem *(Azadirachta indica)* and Jarul *(Lagerstroemia speciosa)* in wheat as repellants were observed. The research was carried out from January to October 2013, in the laboratory condition at the Entomology Laboratory, Department of Zoology, Jagannath University, Dhaka, Bangladesh. Three different doses *viz.* 0.1gm, 0.2gm and 0.3gm of dry leaf dust of two plants- *A. indica* and *L. speciosa* and a mixed dust of the two at 1:4 (w/w) ratio were used against 10 adult pests living in 20gm of wheat, and the number of repelled insects were checked after 48 to 72 hours. For the whole study, 105 such experiments were performed and a group of 5 experiments were taken into count as a single replication. Dust of Jarul leaves (0.3gm) was the most effective repellant against the red flour beetles, followed by Neem (0.3gm), Jarul (0.2gm) and mixed application (0.3gm). The highest of 34.5% repellency was recorded; significant variations were found in the percentage of repelled insects between almost all possible doses, and different doses with controls. Though higher doses showed better repellency, huge research is needed to know whether a higher dose could make harm to the food value of the corns or not; before prescribing them against red flour beetles for storage management of wheat.

Keywords: Red flour beetle, jarul, neem, repellant

Introduction
Human beings are entirely dependent on many field crops, and stored foods; including wheat and its products; which, most of the time, are infested by a large number of pests and cause considerable economic losses [1, 2]. The red flour beetle, *Tribolium castaneum* is one of the most severe pests to the stored wheat and flour. The worldwide annual losses to stored food grains and field crops caused by insects were estimated to be about 10% of the world production in the middle of the last century [3]. Substantial losses occur every year in the subcontinental developing countries. Post-harvest losses of stored products are expressed in terms of different weight and nutrient loss [4, 5, 6]. The chemically synthesized pesticides have been widely used in the grain storage and crop fields which achieved good results; but these agricultural chemicals polluted the grain and decrease their quality in colour, smell and taste. Climate and storage conditions, especially in the tropics, are often highly favourable for insect growth and development; control of these insects by chemical insecticides has serious drawbacks [7]. The indiscriminate use of chemical pesticides are useful against the pests for saving food kinds of stuff now a days, yet has given rise to many obvious serious problems, including genetic resistance by pest species, toxic residues, increasing costs of the application, environmental pollution, hazards from handling, etc. [8, 9, 10, 11, 12, 13, 14, 15]. This increasing problem of pest resistance to pesticides and contamination of the biosphere due to large scale use of broad-spectrum synthetic pesticides are created a worldwide interest in revolution and use of age-old traditional botanical pest control agents [16, 17]. Insecticides of plant origin are considered as alternatives to synthetic chemicals for being pest-specific and biodegradable [18]. So, derivatives of some plants have had temporary to restricted use in pest control or have been considered items of regional interest [19].

Tribolium castaneum causes damage directly to wheat kernels (germ and endosperm). Their presence in stored foods directly affects both the quantity and quality of the commodity [10, 20, 21, 22, 23]. It contaminates flour medium more than they consume. In severe infestation, they change the colour of the flour into pinkish with a disagreeable odour making it unfit for human consumption [24]. Such flour has an exceedingly low viscosity and its elasticity is adversely affected, which may cause gastric disturbance when used as food [25, 26] and the flour is said to be conditioned [27]. Management of this pest is required to keep the stored wheat consumable, as it is one of the major store grain pests to this corn.

Neem insecticides are derived from the tropical and subtropical tree *Azadirachta indica*, systematically classified in the family Meliaceae. It is commonly known as neem or Indian lilac [28]. The plant is native to Southern and Southeastern Asia and today it is grown in tropical and subtropical areas of Africa, North and South America and Australia [29]. The principal active ingredient in neem is azadirachtin, a tetranor triterpenoid limonoid [30]. Azadirachtin is present in minor quantities in all parts of the tree including leaves; but the highest concentration (0.2-0.6%) is found in the seeds [31]. The other limonoids, such as meliantriol, salannin, nimbin and nimbidin have been found in traces [32] and contribute to overall bioactivity [33, 34, 35]. Azadirachtinhas a wide spectrum of actions on insects such as repellent, antifeedant, insect growth regulator (IGR), anti-ovipositional, fecundity, and fitness reducing properties [36]. Jarul *(Lagerstroemia speciosa)* is a small to medium-sized tree growing to 20 metres (66 ft) tall, with smooth, flaky bark. The leaves are deciduous, oval to elliptic, 8-15 cm (3.1-5.9 inch) long and 3-7 cm (1.2-2.8 inch) broad, with an acute apex. The flowers are produced in erect panicles 20-40 cm (7.9-15.7 inch) long, each flower with six white to purple petals 2-3.5 cm (0.79-1.38 inch) long. The phytochemical investigation of leaf and fruit revealed that it contained steroids, terpenoids, glycosides, phenolic compounds, α-amino acids, saponins, starch, alkaloids, tannins and many other active metabolites. *L. speciosa* possessed many pharmacological effects including antimicrobial and antioxidant effects [37]. The plant has been chosen as it was reported free from termite attack in a study carried out in the Jahangirnagar University Campus, Bangladesh [38].

The repellent activity of both the plants are reported, but no study has been reported to determine the repellency activity of Neem and Jarul leaves in a powdery or dust form, against the wheat or any other grains in the storage condition in Bangladesh. Thus, the present research experiments were carried out to determine the rate at which the used dust could repel the test insect pest, from stored wheat; to find out the percentage of organisms repelled for each of the doses of the different dust; to determine most effective dust and the doses; and, to determine the repellent efficiency among them.

Materials and Methods

The whole grains of wheat, containing the adult red flour beetle, *T. castaneum* were collected from the flour mills at Savar Bazar, Dhaka. Approximately, 10 kg of infected wheat were collected were a huge number of adult *T. castaneum* were living and multiplying. The total collected infected wheat, as well as the insects, were kept in a plastic container, and proper humidity was provided during the experiments. Not much aid was required to keep the rearing environment sound, and naturally, it was seen that the insects were growing in number over time.

Fresh and mature leaves of Jarul *(L. speciosa)* and Neem *(A. indica)* were collected. The collected leaves were meshed by using a grinder to its possible finest condition. Then the meshed leaves were dried in the sunlight to get a powdery appearance of the leaves; thus, dust was stored in a dry container. A mixture of Jarul (*L. speciosa)* and Neem (*A. indica*) dust was also prepared at 1: 4 w/w ratios for the experiment (Fig. 1).

The samples of fresh wheat were collected from the farmers during the time of harvest. No demarcation of wheat variety was maintained. The seeds were dried and made free from any unwanted organism or particles such as hays, etc. Then this collected wheat was made more susceptible to the insect (*T. castaneum)* by threshing lightly under thresher, in such a way that at least 20-25% of the total grains were broken into segments and inner carbohydrate-containing parts were exposed.

During each experiment**,** 20 gm of wheat was taken either on open petri dishes or plastic cups for treatment. For maintaining a comfortable humidity to the insect pests, a small piece of wet cotton was kept under the wheat. Four cups were taken and were treated either by the dust of neem, jarul or the mixture (Neem: Jarul:: 1: 4 w/w) of them. At each set of experiment, three cups were used for leaf dust application and a single cup of wheat was left untreated (control). In every cup/petri dish, 10 adult *T. castaneum* were released. An iron cage covered by finest cotton-net was used in which the experiments were carried out so that no insect can escape from the cage, after being repelled from cups. Three different doses (0.3gm, 0.2gm, 0.1gm) of particular dust was applied to different cups and mixed gently with the wheat. Every cup/ petri dish was checked after 48 hours, for the existing and dead insect.

Data was recorded on available insects within the cups or plates. Some insects were found repelled from dust-treated cups. And significantly, at the end of each experiment, some insects were almost always found in the control cups, where no potential repellant was added. Nevertheless, they were repelled from other cups treated by leaf dust. Five repeatation of an experiment were considered yielding a single result.

Data was summarized, compared and their mean, standard deviations were noted. Effects of different doses were checked using ANOVA and t-tests, using MS-Excel software.

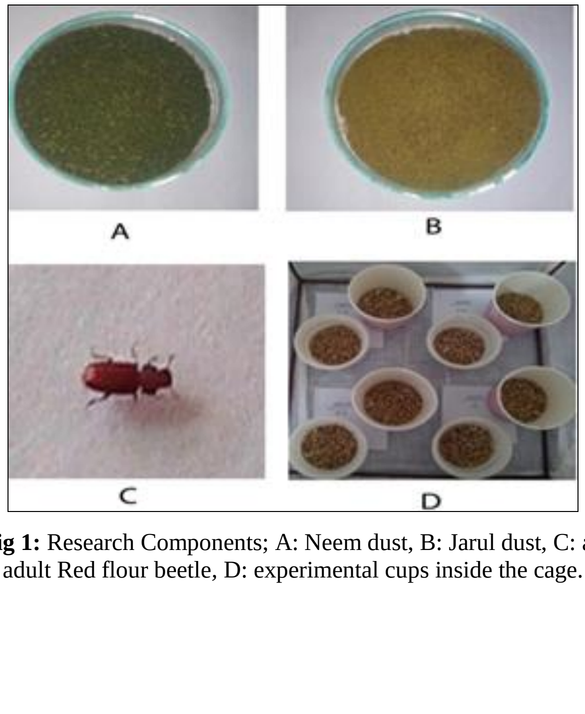

Fig 1: Research Components; A: Neem dust, B: Jarul dust, C: an adult Red flour beetle, D: experimental cups inside the cage.

Results

Determination of the most effective repellant doses

Jarul leaf dust was the most effective dust against the red flour beetles, as a repellant. And, its highest dose (0.3gm) showed the best result. It was followed by Neem 0.3gm, Jarul 0.2gm and mixed application of Neem and Jarul at1:4 w/w ratios. In a particular group of replications, the highest, lowest and mean several repelled organisms were recorded. It was observed that the increase in dust doses showed higher repellant activity. The detailed results are given in the Table 1, Table 2, Table 3; and the findings are illustrated in Fig. 2, Fig. 3 and Fig. 4.

Repellency activity of Neem dust on *Tribolium castaneum*

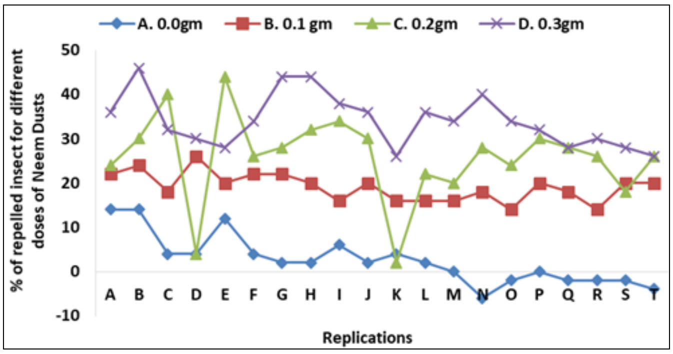

Fig 2: Replicated percentage of repelled insects at different doses of neem dust

For the use of neem dust against *T. castaneum*, the efficiency of the dust as a repellant was noted according to the percentages of total test insects treated by different doses of the dust within the wheat (Table1, Table 2 and Table 3). In controlled condition, where no treatment was used to repel them, the average repellency was 0.26±0.81 (out of 10), with the maximum number of the repelled organisms were 3 out of 10 organisms; where the lowest was -2 (negative), what meant the addition of 2 new individuals in it, which had been repelled from the surrounding experiments. The mean highest and lowest repellency among all doses of Neem leaf dust was (1.4±1.14) and (-0.6±0.89), respectively**.** The repelled organisms' ratio of the test organisms was 2.6% an average, with 14% maximum and -6% minimum

When 0.1gm neem dust was used against 10 pests within 20gm of wheat to repel them, the average repellency was 1.91±0.82 (out of 10), with the maximum number of the repelled organism was 4 out of 10 organisms; where the lowest was 0. The mean highest and lowest repellency was (2.6±1.14) and (1.4±0.55), respectively**.** The repelled organisms' ratio of the test organisms was 19.1% on average, with 26% maximum and 14% minimum.

When 0.2gm neem dust was used against 10 pests within 20gm of wheat to repel them, the average repellency was 2.5454±0.76 (out of 10), with the maximum number of the repelled organism was 6 out of 10 organisms; where the lowest was -2, what meant the addition of 2 new individuals from surrounding experiments. The mean highest and lowest repellency was (4.4±1.14) and (0.2±0.45), respectively**.** The repelled organisms' ratio of the test organisms was 25.454% on average, with 44% maximum and 2% minimum.

When 0.3gm neem dust was used against 10 pests within 20gm of wheat to repel them, the average repellency was 3.41±0.66 (out of 10), with the maximum number of the repelled organism was 6 out of 10 organisms; where the lowest was 2. The mean highest and lowest repellency was (4.6±0.89) and (2.6±0.55), respectively**.** The repelled organisms' ratio of the test organisms was 34.1% on average, with 46% maximum and 26% minimum.

Repellency activity of Jarul dust on *T. castaneum*

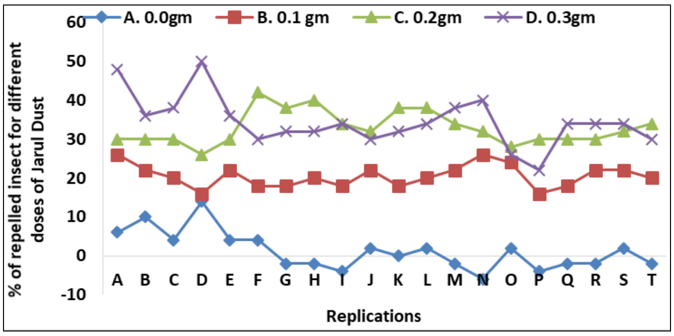

Fig 3: Replicated percentage of repelled insects at different doses of jarul dust

For the use of jarul dust against *T. castaneum*, the following results were remarkable. In controlled condition, where no treatmentwas used to repel them, the average repellency was 0.12±0.80(out of 10), with the maximum number of the repelled organism was 7 out of 10 organisms; where the lowest was -2, what meant the addition of 2 new individuals from surrounding experiments. The mean highest and lowest repellency was (1.4±3.21) and (-0.6±0.55), respectively**.** The repelled organisms' ratio of the test organisms was 1.2% on average, with 14% maximum and -6% minimum (Fig. 3). The efficacy of different doses of Jarul dust treatment to the test insects, the results are shown in the Table 1 and Table 2.

When 0.1gm jarul dust was used against 10 pests within 20gm of wheat to repel them the average repellency was 2.05±0.81 (out of 10), with the maximum number of the repelled organism was 3 out of 10 organisms; where the lowest was 0, The mean highest and lowest repellency was (2.6±0.55) and (1.6±1.34), respectively**.** The repelled organisms' ratio of the test organisms was 20.5% on average, with 26% maximum and 16% minimum.

When 0.2gm jarul dust was used against 10 pests within 20gm of wheat to repel them the average repellency was 3.29±0.79(out of 10), with the maximum number of the repelled organism was 6 out of 10 organisms; where the lowest was 2, The mean highest and lowest repellency was (4.2±0.84) and (2.6±0.55), respectively**.** The repelled organisms' ratio of the test organisms was 32.9% on average, with 42% maximum and 26% minimum.

When 0.3gm jarul dust was used against 10 pests within 20gm of wheat to repel them the average repellency was 3.45±0.64(out of 10), with the maximum number of the repelled organism was 6 out of 10 organisms; where the lowest was 1, The mean highest and lowest repellency was (5±1) and (2.2±0.83), respectively**.** The repelled organisms' ratio of the test organisms was 34.5% on average, with 50% maximum and 22% minimum.

Mixed application (Neem: Jarul::1:4 ratio) against red flour beetle

For the use of Neem and jarul mixed dust against *T. castaneum*, the following results were noted. In controlled condition, where no dust was used to repel them, the average repellency was 0.07±0.63 (out of 10), with the maximum number of the repelled organism was 2 out of 10 organisms; where the lowest was -2, what meant the addition of 2 new individuals from surrounding experiments. The mean highest and lowest repellency was (1±0.71) and (-0.6±0.89), respectively**.** The repelled organisms' ratio of the test organisms was 0.7% on average, with 10% maximum and -6% minimum (Fig. 4).

When 0.1gm mixed dust was used against 10 pests within 20gm of wheat to repel them the average repellency was 1.92±0.71 (out of 10), with the maximum number of the repelled organism was 4 out of 10 organisms; where the lowest was 1, The mean highest and lowest repellency was (2.6±0.55) and (1.2±0.45), respectively**.** The repelled organisms' ratio of the test organisms was 19.2% on average, with 26% maximum and 12% minimum.

When 0.2gm mixed dust was used against 10 pests within 20gm of wheat to repel them the average repellency was 2.61±0.65 (out of 10), with the maximum number of the repelled organism was 6 out of 10 organisms; where the lowest was 1, The mean highest and lowest repellency was (3.2±1.64) and (2±0.71), respectively**.** The repelled organisms' ratio of the test organisms was 26.1% on average, with 32% maximum and 20% minimum.

When 0.3gm mixed dust was used against 10 pests within 20gm of wheat to repel them the average repellency was 3.09±0.72 (out of 10), with the maximum number of the repelled organism was 5 out of 10 organisms; where the lowest was 2, The mean highest and lowest repellency was (3.6±1.40) and (2.6±0.55), respectively**.** The repelled organisms' ratio of the test organisms was 30.9% on average, with 36% maximum and 26% minimum.

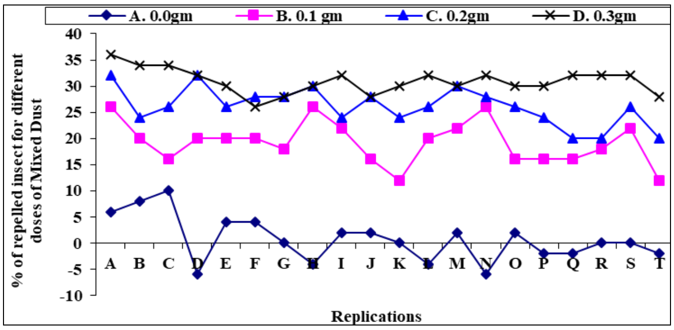

Fig 4: Replicated percentage of repelled insects at different doses of mixed dust

Different doses as repellants among all types of leaf dusts

The data revealed that, in the 20gm of wheat, 0.3gm of Neemdust caused best repellency (34.1%), followed by 0.2gm (25.8%) and 0.1gm of dust (19.1%). it means by increasing the dose, it effects more. The same interpretation was remarked both for jarul dust and mixed dust. For the jarul dust, 0.3gm dose showed the best repellency; followed by 0.2gm, and 0.1gm. Here, the percentages of repellency were 34.5%, 32.9% and 20.5%, respectively. For the Mixed dust, the best repellency was found in 0.3gm (30.9%), and then 0.2gm (26.1%) and 0.1gm (19.2%). Detailed result is given in Fig. 4. So, for every type of dust, by increasing the dose, comparatively, the higher percentage of repellency of insect pest was acquired.

For the case of same doses of Neem, Jarul and mixed dust; jarul showed the best repellency. When the lowest dose (0.1gm/20gm wheat) was used, jarul dust could repel 20.5% pest, where the mixed dust repelled 19.2% and neem dust repelled 19.1% of the test insect pest. And in case of other doses, the highest repellency was noted for Jarul Dusts. For 0.2 gm dust, jarulrepelled 32.9% insect, followed by the mixed dust (26.1%),and neem dust (25.8%). When 0.3gm dust was used, jarul repelled 34.5% insect followed by neem (34.1%) and mixed (30.9%) dusts. Detailed results are shown in Fig. 5.

So, for different doses of dust, comparatively, Jarul dust caused a higher percentage of repellency of insect pests.

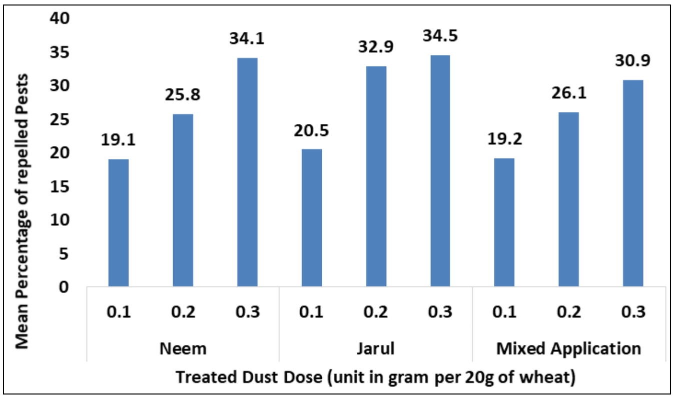

Fig 5: Percentage of repelled insects at different doses of all types of powdery leaves

Summary of Data analysis results

In ANOVA analyses, significant variations were found within all groups except for "Dose 1 of different dust without control". T-tests were performed wherever variations have been found. As the ANOVA showed no variation in different dustDose 1, t-tests were not performed for Neemdose1 with Jaruldose 1, Neemdose 1 with Mixeddose 1, and Jaruldose 1 with Mixeddose 1. Significant variations were found in dust doses, same doses of different dust in most of the cases except only three: jarul dose 2 with jarul dose 3, neem dose 3 with jarul dose 3, and neem dose 2 with mixed dose 2 (Table 1).

Table 1: Percentage of *T. castaneum* repelled in different doses of different leaf dust

Experiments	Percentage of insect repelled								
	Neem			Jarul			Mixed Application		
1	Dose 1	Dose 2	Dose 3	Dose 1	Dose 2	Dose 3	Dose 1	Dose 2	Dose 3
2	22±14.83	24±16.73	36±11.40	26±5.48	30±7.07	48±8.37	26±5.48	32±4.47	36±11.40
3	24±8.94	30±10.00	46±8.94	22±8.37	30±7.07	36±5.48	20±7.07	24±8.94	34±8.94
4	18±8.37	40±7.07	32±4.47	20±10.00	30±7.07	38±10.95	16±5.48	26±5.48	34±5.48
5	26±11.40	04±15.17	30±7.07	16±13.42	26±5.48	50±10.00	20±10.00	32±16.43	32±8.37
6	20±7.07	44±11.40	28±8.37	22±4.47	30±7.07	36±5.48	20±7.07	26±8.94	30±14.14
7	22±4.47	26±5.48	34±5.48	18±8.37	42±8.37	30±7.07	20±7.07	28±4.47	26±5.48
8	22±8.37	28±4.47	44±8.94	18±8.37	38±8.37	32±4.47	18±8.37	28±4.47	28±8.37
9	20±7.07	32±4.47	44±5.48	20±7.07	40±10.00	32±8.37	26±5.48	30±7.07	30±10.00
10	16±8.94	34±5.48	38±8.37	18±8.37	34±11.40	34±5.48	22±8.37	24±5.48	32±4.47

11	20±10.00	30±7.07	36±5.48	22±8.37	32±8.37	30±7.07	16±5.48	28±4.47	28±8.37
12	16±8.94	2±4.47	26±5.48	18±8.37	38±8.37	32±4.47	12±4.47	24±5.48	30±7.07
13	16±5.48	22±8.37	36±5.48	20±7.07	38±16.43	34±5.48	20±10.00	26±5.48	32±4.47
14	16±5.48	20±7.07	34±5.48	22±8.37	34±5.48	38±8.37	22±8.37	30±7.07	30±7.07
15	18±8.37	28±4.47	40±10.00	26±5.48	32±8.37	40±7.07	26±11.40	28±4.47	32±8.37
16	14±5.48	24±5.48	34±5.48	24±5.48	28±4.47	26±5.48	16±5.48	26±5.48	30±7.07
17	20±10.00	30±7.07	32±8.37	16±8.94	30±7.07	22±8.37	16±5.48	24±5.48	30±7.07
18	18±8.37	28±8.37	28±4.47	18±8.37	30±7.07	34±5.48	16±8.94	20±7.07	32±4.47
19	14±5.48	26±5.48	30±0.00	22±8.37	30±7.07	34±5.48	18±4.47	20±7.07	32±4.47
20	20±10.00	18±8.37	28±8.37	22±8.37	32±8.37	34±5.48	22±8.37	26±5.48	32±4.47
21	20±7.07	26±5.48	26±5.48	20±10.00	34±5.48	30±0.00	12±4.47	20±7.07	28±4.47
Note: Dose-1. 1:200 w/w; Dose-2. 2:200 w/w; Dose-3. 3:200 w/w									

Results were analyzed on the percentage of test insects after application of different dust at different doses in the experiments. The comparison was made among the summarized mean percentages of insect pest numbers for a particular dose of dust. Three Dusts-Neem, Jarul and Mixed (Neem and Jarul at 1:4w/w ratios) dust were used in 3 subsequent doses. When 0.1 gm of dust was used, it was termed as *Dose 1; Dose 2* for 0.2gm and *Dose 3* for 0.3gm of dust inside 20gm of broken wheat-containing 10 adult individuals of *T. castanium.*

Discussion

The utilization of plant materials to protect field crops and stored commodities against insect attack has a long history. Many of the plant species concerned have also been used in traditional medicine by local communities and have been collected from the field or specifically cultivated plants for these purposes. Leaves, roots and flowers have been admixed as protectors with various commodities in different parts of the world, particularly in India, China and Africa. During the last few years, new interest has arisen in natural botanical insecticides. Until now only a small part of the plant kingdom (estimated at 250000- 500000 species around the globe) has been investigated phytochemically and the fraction subjected to biological and pharmacological is even lower. Amongst the most promising of the natural products investigated to date are metabolites. Although only about 10000 secondary plant metabolites have been chemically identified, the total number of plant chemicals may exceed 400000. They are a vast commutation of defence chemicals, comprising repellents, feeding and oviposition deterrents, growth inhibitors, sterilant, toxicant, etc. [39].

According to a very old report [40], losses of 25% or more may occur in tropical countries through insect attack after harvest. Despite our best efforts, world crop loss due to pests is approximately 35% of the total production each year [41, 42]. This reduction is further increased by the post-harvest losses caused by insects and another pest [43].

The doses varied significantly (including and excluding control) for Neem, Jarul and Mixed dust against the pests. Where variations within the doses of all dust were found, t-tests for all possible pairs of doses and dust were done. The tested doses and the results were as given in the Table 2.

Table 2: Results of ANOVA analysis of dust impacts on *T. castanium* repellency

Sl	ANOVA	F stat	F crit	P-value	df	Variations
1	All dusts all doses with control	461.34	2.66	2.14×10^{-83}	3	++
2	All dust all doses without control	106.54	3.07	3.68×10^{-27}	2	++
3	Neem all doses with control	99.32	2.76	1.29×10^{-22}	3	++
4	Neem doses without control	27.32	3.24	4.44×10^{-08}	2	++
5	Jarul doses with control	207.43	2.76	1.25×10^{-30}	3	++
6	Jarul doses without control	46.60	3.24	5.98×10^{-11}	2	++
7	Mixed dust with control	314.70	2.76	2.01×10^{-35}	3	++
8	Mixed dust without control	93.75	3.24	2.02×10^{-15}	2	++
9	Dose 1 different dust without control	1.23	3.24	0.30493	2	--
10	Dose 2 different dust without control	7.09	3.24	0.00242	2	++
11	Dose 3 different dust without control	3.29	3.24	0.04824	2	++

Interpretations of Variations on repellency effects
++ = Significant variations found at 95% level of Confidence
-- = Significant variations not found

ANOVA (Analysis of Variance) was observed for effects of overall all dust, all doses with control to find out if there were any significant variations at all; all dust all doses, without control to find out variations within the doses only (3*3= 9 doses); effects of Neem all doses with control for variations (if any); Neem all doses without control to find variations within the doses of the same dust (Neem); Jaruldoses with control; Jaruldoses without control for variations within doses; Mixed dust with control and Mixed dust without control, to find out the significant variations (if any) of the doses. Thus, ANOVA tests were performed for all doses of all dust, different doses of the same dust, and within same doses of different dusts. T tests were performed where ANOVA showed significant variations. The summarize t-test results are given in Table 3.

Table 3: t-test results on the effects of different dust doses as repellants

Sl	T-tests between	t-Test Results and interpretations				
		t stat	t crit one tail	P-value	df	Variation
1	Neem dose 1 with control	11.51	1.68595	2.96×1^{-14}	38	++
2	Neem dose 2 with control	9.14	1.68595	1.95×10^{-11}	38	++
3	Neem dose 3 with control	17.24	1.68595	7.37×10^{-20}	38	++
4	Neem dose 1 with Neem dose 2	2.87	1.68595	0.00326	38	++
5	Neem dose 2 with Neem dose 3	3.20	1.68595	0.00136	38	++
6	Neem dose 3 with Neem dose 1	9.85	1.68595	2.53×10^{-12}	38	++
7	Jarul dose 1 with control	15.13	1.68595	5.66×10^{-18}	38	++
8	Jarul dose 2 with control	21.75	1.68595	2.38×10^{-23}	38	++
9	Jaruldose 3 with control	18.35	1.68595	8.68×10^{-21}	38	++
10	Jarul dose 1 with Jarul dose 2	10.73	1.68595	2.28×10^{-13}	38	++
11	Jarul dose 2 with Jarul dose 3	0.92	1.68595	0.1806	38	--
12	Jarul dose 3 with Jarul dose 1	8.85	1.68595	4.48×10^{-11}	38	++
13	Mixed dose 1 with control	13.85	1.68595	9.74×10^{-17}	38	++
14	Mixed dose 2 with control	20.24	1.68595	2.94×10^{-22}	38	++
15	Mixed dose 3 with control	27.38	1.68595	6.29×10^{-27}	38	++
16	Mixed dose 1 with Mixed dose 2	5.64	1.68595	8.63×10^{-07}	38	++
17	Mixed dose 2 with Mixed dose 3	4.99	1.68595	6.85×10^{-06}	38	++
18	Mixed dose 3 with Mixed dose 1	10.9	1.68595	1.17×10^{-13}	38	++
19	Neem dose1 with Jarul dose 1					**
20	Neem dose 2 with Jarul dose 2	2.94	1.68595	0.00275	38	++
21	Neem dose 3 with Jarul dose 3	0.203	1.68595	0.42009	38	--
22	Neem dose 1 with Mixed dose 1					**
23	Neem dose 2 with Mixed dose 2	0.12	1.68595	0.44965	38	--
24	Neem dose 3 with Mixed dose 3	2.21	1.68595	0.01634	38	++
25	Jarul dose 1 with Mixed dose 1					**
26	Jarul dose 2 with Mixed dose 2	5.44	1.68595	1.62×10^{-06}	38	++
27	Jarul dose 3 with Mixed dose 3	2.34	1.68595	0.0123	38	++

** Was not performed After ANOVA of doses showed no variation
Interpretations of Variations on repellency effects:
++ = Significant variations found at 95% level of Confidence
-- = Significant variations not found

Comparison of the results was made with a number of previous studies [7, 8, 9, 10, 11, 12, 13, 14, 17, 18, 44, 45, 46, 47]. The results given by the mentioned research projects were to see the effects of neem and other botanicals like *Rhyania* and *Sabadilla*. But, none of the above-mentioned researchers used the prepared dry leaf dust as a repellant. The results of the current research supported the interpretations of the mentioned researchers and adding hereby in the sense that both Neem and Jarul dust can be used commercially as repellants against red flour beetle.

So far, in the insect management arena, we noticed that root, seed, barks, sap, juice, flower sap, fruit extract etc. has been used by the mentioned researchers to manage many grains and seeds that human consume. But, none has been so far reported to use dry leaf dust for store management prescription. Most probably this is the pioneering research using such leaf dust against *T. castaneum.*

The dust particles are, somehow, equal or smaller in size in comparison to an adult *T. castaneum* pest. Besides, the chemical composition of the dust with which the corns are treated, there might have some mechanical factors for what a sub-adult or adult *T. castaneum* does not feel comfortable to move within the grains. And, these uncomfortable feelings flew the pests away from the wheat. As much the density of dust increase, uncomfortable feelings increases and their movement are highly inhibited by such leaf dust; and they try to leave the place. But, this is not the only factor the pests face; there must have some chemical factors, too, for what the variations of repellency activities have been noticed.

Another important issue is mentionable; the present investigation never finds a dead pest in any experiment. It refers that it could not be interpreted in any of the used botanical dust have a lethal impact on the test organism or not. Most of the researchers reported the lethal potency of their tested botanicals against many insects [8, 9, 10, 18, 44, 45]. The present research also claims that, as a better management minimum harm to the target crop or grain and ensures maximum protection from a pest; using dry leaf dust as a repellant is quite better than using liquid or liquefied extracts of botanicals or solution. Because liquids facilitate microorganism and start degeneration of the food value of the stored grains. So, in storage management, use of dry dust of botanicals is suggested, if no harm occurs to the food value of the stored grain.

Jarul dust is, anyway, better than the neem dust. A small number of doses was used here in the experiment in the sense that, it is not possible commercially to collect a large volume of dust to protect, say, 500 tons of wheat. As minimum doses showing better results, integration of the dust with other mechanical, chemical and biological pest management systems, can be applied. And obviously, further research is necessary before using such integrations.

Conclusion

The battle between human and the stored grain pests is the epic of the evolutionary history, as every organism is possessive to keep his food particle from the competitors. Many a methods has been developed and so far, mankind is eligible enough to protect their food stuffs from different kinds of pests. Now, the challenge is, keeping the grains safe along with the feasibility, efficiency, competency in terms of cost and above all, executing it in the most green and nonchemical ways. Our findings can will help to think people in this directions, we hope. And, one day, of course some of the researchers will figure out the best possible and sustainable storage techniques for our food grains so that mankind can have some stored grains during the time of recession and famine.

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References
1. Alam MZ. Pest of stored grains and other stored products and their control Agricultural information service, Dhaka, Bangladesh, 1971.
2. Khan AR, Mannan A. Stored products entomology in the Tropics. Agricultural Zoology. Rev. 1991; 4:67-95.
3. Wolpert A. Rats in store in India. Farmer Esterm Economy. 1966; 53:439.
4. Howe RW. Losses caused by insects and mites in stored food and feeding staffs Nutrition Abstracts. 1965; 35:285-293.
5. Krishnamurthy K. Post-harvest loss in food grains. Bull. Grain techno. 1975; 13:33-49.
6. Watters FL, Shuyler HR. Control of post-harvest losses. FAO plant protection. Bull. 1977; 25:184-188.
7. Saraby A. Anti-insect properties of the essential oil of lemon grass, Cymbopogen citrates against the lesser cotton leaf worm Spodopteraexigua (Hbn).I nsect science. Application. 1988; 9(1):77-80.
8. Champ BR, Dyte CE. Report of FAO global survey of pesticide susceptibility of stored grain pests. FAO Plant Production and Protection, Series No.5. Rome, 1976.
9. Ahmed SM, Chandler H, Pereira J. Insecticidal potential and biological activity of Indian indigenous plants against Muscadomestica. International pest control. 1981; 23(6):170-175.
10. Sinha RN. Spolage of fram stored grain by molds. Insects and mitesinwestern Canada, Condition of Department Agricultural Publication, 1971, 1437-1438.
11. Wilbur DA, Mills RB. Stored Grain Insects. In: Fundamentals of applied Entomology Mac Millan Publishing Co. Inc, 1985, 89-90.
12. Khanam LAM, Khan AR, Talukder D. Insecticidal properties of royna, aphanamixispolys tachea Wall (Parker) (Meliaceae) against Tribolioumconfusum Duval. Journal of Asiatic Society Bangladesh, Science. 1990a; 16(2):71-74.
13. Pacheco IA, Sartori MR, Taylor RWD. Levantamento de resistenc iadeinsetos-pragas de graosarmazenados a fos. Na, no Estado de Sao Paulo. Coletanea do Instituto de Tecnologia de Alimentos. 1990; 20:144-154.
14. Rajendran S, Narasimhan KS. Phosphine resistance in the cigarette beetle Lasioderma Serricone (coleopteran: Anobiidae) and overcoming control failures during fumigation of stored tobacco. International Journal of Pest Management. 1994; 40:207-210.
15. White NDG, Leesch JG. Chemical control. In: Integrated pest management of Insects in Stored products. Marcel Dekker, Incecticide New York, 1995.
16. Jembere B, Obeng OD, Hassanali A, Nyamasyo GN. Products derived from the leaves of Ocimum Kilimanndscharicum (Labiatae) as post-harvest grain protectants against the infestation of three major stored product insect pests. Bull. Entomology. 1995; 85:361-367.
17. Okonkwo EW, Okoye WI. The efficacy of four seed powders and the essential oils as protectants of cow–pea and maize grain against infestation by Callosobruchesmaculatus (Fabricius) (coleopteran: Bruchidae) and Sitophiluszeamais (Motshulsky) (Coleoptera: Curculionidae) in Nigeria. International Jurnal of Pest Management.1996; 42:143-146.
18. Heyde JVD, Saxena RC, Schmutterer H. Neem oil and neem extracts as potential insecticides for control of Hemipterous insects. Proc.2nd International Neem Conference, Fanischholzhausen. 1983, 377-390.
19. Saxena RC. Naturally occurring pesticides and their potential. In: Chemistry and Food Supplies; The New Frontiers. Pergamon Press, Oxford, New York, 1983, 143-161.
20. Periera J, Wohlegemuth R. Neem (Azadirachta indica A. Juss.) of West African origin as a protectant of stored maize. Zoological agriculture of Entomology. 1982; 24(2):208-214.
21. Burkhholder WE, Faustini DL. Biological methods of survey and control in: Ecology and Management of food industry Pests JR Gorham Edition, 1991, 361-372.
22. Mondal KAMSH. Quinone secretions of the flour beetles, Tribolioum: Problems and Prospects. Tribolium Information Bull. 1992; 32:78-79.
23. Mondal KAMSH. Flour beetle, Tribolioum spp. (Coleoptera: Tenebrionidae) as pests and their control. Agricultural Zoological Review. 1994; 6:95-119.
24. Good. Ahmed SM, Grainge M. Potential of the neem tree (Azadirachta indica) for pest control and rural development. Economic Botany. 1936; 40(2):201-209.
25. Payne NM. Some effects of Tribolium on flour.Journal of Economical Entomology. 1925; 18:737- 743.
26. Mondal KAMSH. Response of Tribolioumcastneum larvae to the different components of conditioned medium. Tribolioum Information Bull. 1983; 23:104-111.
27. Park T. Observation on the general biology of the confused flour beetle, Triboliumconfusum Duv. Quaternary Review of Biology. 1934; 9:36-54.
28. Siddiqui BS, Rasheed M, Ilyas F, Gulzar T, Tariq RM, Naqvi DNH. Analysis of insecticidal Azahirachta indica. 2004; 59:104-112.
29. Schmutterer H. Properties and Potential of natural Pesticides from the neem tree, Azadirachta indica Annual Review of Entomology. 1990; 35:271-297.
30. Mordue AJ, Blackwell A. Azadirachtin: an update. Journal of Insect Physiology. 1993; 11 (39):903-924.
31. Govindchari TR. Chemistry and biological investigation on Azadirachta indica. Current. 1992; 63:117-122.
32. Akhter M. Nematicidal potential of the neem tree Azadiracta indica (A.Juss). Integrated Pest Management Reviews. 2000; 5(1):57-66.
33. Isman MB, Machial CM. Pesticides based on plant essential oils: from traditional practice to commercialization. Naturally Occurring Bioactive Compounds. 2006; 3:29-44.
34. Morgan ED. Azadirachtin, a scientific gold mine.

Bioorganic and Medicinal Chemistry. 2009; 17:4096-4105.
35. Salehzadeh A, Jabbar A, Jennens L, Ley SV, Annadurai RS, Adams R. The effects of phytochemical Pesticides on the growth of cultured invertebrate and vertebrate cells. Pest management science. 2002; 58:268-276.
36. Schmutterer H. Which insect pests can be controlled by application of neem seed kernel extracts under field conditions? Journal of Applied Entomology. 2009; 100(1-5):468-475.
37. Al-Snafi AE. Medicinal value of Lagerstroemia speciosa: An updated review. International Journal of Current Pharmaceutical Research. 2019; 11(5):18-26.
38. Mandal *et al*. Incidence of termite infestation to tree species in Jahangirnagar University campus, Bangladesh. Bangladesh Journal of Life Science. 2010; 22(2):7-15.
39. Champagne Ed, Isman BM, Towers NHG. Insecticide of plant origin eds, 1989.
40. Hill EG. Controlling insect's pests in flour mills. MAFF booklet, 1978, 137.
41. McEwen, Arnason JT, Philogene BJR, Morand P. Developed from a symposium sponsored by the division of Agrochemicals at the 3rd chemical congress of North America 19th National meeting of the American Chemical Society, Toronto Ontario, Canada, 1978, 95-109.
42. Pimental D. World food pest losses and the environment American Association for the advancement of science Selested Symposium no. 13.Westview, Boulder, Colorado, 1978.
43. Wright JW, Metacclf RL, Mekeivey JR, Wileley J, Sons JJ. Insecticides in human health.In the fuyire for Insecticides: needs and Prospects. New York, 1976, 17-34.
44. Thorsteinson A. Host Selection in phytophagous insect. A Review of Entomology. 1960; 5:193-218.
45. Hsiao T. Chemical basis of host selection and plant resistance in all oligophagousinsects. Entomological Experimental application. 1969; 12:423-440.
46. Munakata K, Wood DL, Silverstein PM, Nakazima M. Insect antifeedant in the plant.Control of insect behaviour by Natural Products, Academic Press, NY, 1970, 179-187.
47. Narasimhan KS. Phosphine resistance in the cigarette beetle Lasiodermaserricorne (Coleoptera: Anobiidae) and overcoming control failures during fumigation of stored tobacco. International journal of pest management. 1994; 40(2):207-210.