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Laboratory evaluation of some indigenous plant extracts as grain protectant against red flour beetle, *Tribolium castaneum* Herbst

Kota Sathish and Pulin Patgiri

Abstract
The present experiments were carried out in the laboratory of All India Co-ordinated Research Project on Post-Harvest Engineering &Technology (AICRP on PHE&T), Department of Agricultural Engineering, Assam Agricultural University, Jorhat-13, during the year 2014 – 2015 to evaluate the efficacy of *Jatropha curcas* and *Ocimum sanctum* leaves extracts as grain protectants against *Tribolium castaneum*. The effects of these plant extracts on percent mortality was recorded at 1, 3, 6, 12, 24, 48 and 72 hours after treatments and percent weight loss, *in vitro* adulticidal activity, percent weight gain over control and percent deterrent effect at 3, 6, 9 and 12 months after release of insects were observed. The highest mortality (70.00%) was recorded in Tulsi acetone extract which was followed by treatments with Jatropha petroleum ether (56.67%) after seventy two hours after treatment. In terms of weight loss Tulsi acetone extract (7.39%) was the most effective as far as weight loss was concerned and it was followed by treatment of Jatropha petroleum ether extract (7.94%) after the completion of twelve months of storage. Highest adulticidal activity was observed in wheat treated with Tulsi acetone extract (44.08%) and it was the most effective one after twelve months of storage. Tulsi acetone extract (43.05%) was again found to show the highest feeding deterrent effect after twelve months of storage of wheat. And it was followed once again by Jatropha petroleum ether (40.12%).

Keywords: Mortality, *Ocimum sanctum*, Plant Extracts, *Tribolium castaneum*.

1. Introduction
The Rust - red flour beetle (Bran bug) is a common and most destructive pest of stored products and is cosmopolitan in distribution. Both the adults and grubs cause serious damage to some kinds of grains including broken grains, flour and dried fruits. This pest generally found in granaries, mills, warehouse, and stored grains, feeding on rice (both husked and non-husked). Neither larvae nor adults could generally damage sound grains but they could feed on those grains only which had already been damaged by other pests. Currently different kinds of preventive and curative control measures are practiced to get protection against this insect pest. Among those, chemical pesticides have been used for a long time, but have serious drawbacks (Sharaby, 1988) [23], such as direct toxicity to beneficial insects, fishes and human (Munakata, 1977; Pimental, 1981; Goodland *et al*., 1985) [16, 21, 8], pesticide induced resistance (Brown, 1968; Waiss *et al.*, 1981) [3, 31], health hazard (Bhaduri *et al.*, 1989) [2] and increased environmental and social costs (Pimental *et al.*, 1980) [20]. In many countries, efforts are being made to minimize the use of harmful insecticides through the use of indigenous plant products, implementation of IPM approaches, use of bio-degradable products (Khattach and Hameed, 1986) [15] and applying insect growth regulators (Metcalf, 1975) [13] to protect stored grains. In many areas of the world locally available plant materials are widely used to protect stored product against damage by insect infestation (Goloband Webley, 1980; Talukder *et al*., 1990) [7, 25]. Botanical products are environmentally safe, less hazardous, economic and easily available. Botanicals like Bonkalmi, Bazna, Bishkatali, Datura, Durba, Eucalyptus, Ghora-neem, Hijal, Karanja, Mahogoni, Marigold, Neem, Nishinda, Pithraj, and many others may be grown by farmers with minimum expense and extracted by indigenous methods. These botanical materials can be used as an alternative to chemical pesticides. This will be very helpful in minimizing the undesirable side effects of synthetic pesticides. The present experiment was, undertaken to study the toxic effect of leaf extracts of Jatropha (*Jatropha curcas*) and Tulsi (*Ocimum sanctum*) in the management of red flour beetle.

2. Materials and Methods

The present study was conducted in the laboratory of the Post-Harvest Engineering & Technology, Department of Entomology, Assam Agricultural University (AAU), Jorhat, during the period from 2014 to 2016. The insect culture was maintained in jars placed in the incubator at 30±2°C and 60% ± 5 R.H to get the homogenous population. The culture medium was the wheat flour sterilized at 60°C for 60-90 minutes. Thirty beetles from the heterogeneous population (20F+10M) were liberated in 250gm of wheat flour placed in different jars. The mouths of jars were covered with muslin cloth, tied with rubber bands to avoid the escape of beetles. Beetles were allowed to remain in the culture medium for 3 days for egg laying and then removed from jars with the help of sieves and fine camel hair brushes for continuation of culture. The flour containing eggs was placed again in the same jars. The population received from these jars after a month that was considered as a uniform age for experimentation.

2. a. Preparation of plant extracts

Fresh leaves of Jatropha and Tulsi were collected from the surroundings of AAU campus. Afterwards they were washed in running water. The plant materials were kept in shade for air-drying to gain constant weight. Powdered samples were prepared by pulverizing the dried leaves with the help of a grinder. The ground samples were passed through a 25-mesh sieve to obtain fine and uniform dust. The dust was preserved in airtight condition in polythene bags till their use in extract preparation. Ten gram of sample of each category was taken into what-man cellulose thimble, placed in a soxhlet which was siphoned to the flow back of bottom flask of mantle and mixed these system was heated with regarding boiling point of solvents over a period of time later collected crude extracts were taken in a round bottom flask and condensed to 10 ml by evaporation of solvent in a water bath maintained at 45°C, 55°C and 100 °C temperature for acetone, methanol and water extracts, respectively. After the evaporation of solvent, the condensed extracts were preserved in tightly corked labeled bottles and stored in a refrigerator until their use for insect bioassay.

2. b. Insect Bioassays

A laboratory test for direct toxicity by topical application method was conducted according to the method of (Talukder and Howse, 1993) [26] with slight modification. The concentration (0.2%) of each plant extracts were prepared with respective solvents. One milliliter of prepared solution was applied to the dorsal surface of the thorax of each insect using a micropipette. Ten insects (five males & five females) per replication were treated and each treatment was replicated thrice. The same number of insects was treated with water as check. After treatment, the insects were transferred into 9 cm diameter petri dishes (10 insects/petri dish) containing wheat grains. Insect mortalities were recorded at 3, 6, 9, 12, 24, 48 and 72 hours after treatment (HAT). The experimental data were statistically analyzed by Completely Randomized Design (CRD) using MSTAT statistical software in a microcomputer. The mean values adjusted by Duncan's Multiple Range Test (DMRT) (Duncan, 1951) [4].

Direct toxicity test technique was used for determination of mortality percent following (Talukdar and Howse, 1993) [26] with some modifications.

$$\text{Mortality percent} = \frac{\text{Total number of dead insects}}{\text{Total number of released insects}} \times 100$$

2. c. Weight loss percent

Samples were collected randomly and 1000 grains from each replication and control were counted, weighed and the percent weight loss of wheat grains in storage was computed. Weight loss percent of wheat grains was recorded by using the following formula (Harris, 1978) [10].

$$\text{Percent weight loss} = \frac{\text{O.W. F.W.}}{\text{O.W.}} \times 100$$

Where, O.W. = Original weight of grains on dry weight basis
F.W. = Final weight of grains on dry weight basis.

2. d. Feeding deterrence percent

Feeding Deterrence was calculated using the Feeding Inhibition (F.I.) percent following (Pande and Srivastava, 2003) [19].

$$\text{Feeding Inhibition (F.I.)} = \frac{C - T}{C + T} \times 100$$

Where, C = Thousand grain weight of grains in control
T = Thousand grain weight of grains in treated

2. e. Statistical analysis

The experimental data were statistically analysed by the method of analysis of variance developed by Fisher. The percentage value of the data was converted into angular transform values. The significance or non-significance of the given variance was determined by calculating the respective values of 'F' and by comparing the calculated 'F' value at 5 percent probability level. The standard error of the mean difference (SEd.) was calculated as follows:

$$\text{S.Ed.}(\pm) = \sqrt{\frac{2 \times \text{Error Mean Square}}{\text{Total No. of Replications}}}$$

The CD values at 5 percent was determined by using the following expression-

C.D. at 5 percent = S.E. of difference x $t_{0.05}$ for error degree of freedom.

3. Results and Discussion

The effects of different leaf extract of Jatropha and Tulsi against red flour beetle, *T. castaneum* are presented in Tables 1–5. The mortality Percentage of *Tribolium castaneum* through direct toxicity test was evaluated at 1, 3, 6, 12, 24, 48 and 72 hours after treatments.

3. a. Mortality percent (%)

One hour after treatment: There was no mortality when the insects were exposed to two different plant leaf extracts after one hour.

Three hour after treatment: It was found that the Tulsi acetone extract revealed the highest percentage of mortality of 23.33 percent and followed by Jatropha petroleum ether extract (1.67%). No mortality was observed from the remaining treatments along with control.

Six hours after treatment: Mortality of *Tribolium castaneum* after six hours exposure with different treatments showed that the mortality varied from zero to 36.67 percent when the insects were exposed for six hours. Among the treatments, the highest mortality of 36.67 percent was recorded in Tulsi acetone extract. It was followed by Jatropha petroleum ether (20.00%), Jatropha methanol (1.67%) and in the remaining treatments of Jatropha acetone, Tulsi hexane, Tulsi petroleum ether, Jatropha hexane, Tulsi methanol extract and control did not resulted in any mortality six hours after treatment.

Twelve hours after treatment: The mortality percentage ranged from zero to 40.00 percent among the treatments. Highest mortality was recorded in Tulsi acetone extract (40.00%). It was followed by treatments with Jatropha petroleum ether (30.00%), Jatropha methanol (16.67%), Jatropha acetone (15.00%), Tulsi hexane (10.00%) and Tulsi petroleum ether extract (8.33). Jatropha hexane, Tulsi methanol extract and control also did not affect any mortality 12 hours after treatment.

Twenty four hours after treatment: It is evident from the table 1 all the treatments showed significant variation. The mortality percentage in the treatments with extracts varied from 6.67 to 60.00 percent against no mortality in control. The highest mortality (60.00%) was recorded in treatment with Tulsi acetone extract which was statistically superior to other treatments. It was followed by treatments with Jatropha petroleum ether (45.00%), Jatropha methanol (26.67%), Jatropha acetone (23.33%), Tulsi hexane (21.67%), Tulsi petroleum ether (18.33%) and Jatropha hexane extract (16.67%). The lowest mortality among the treatments was recorded from Tulsi methanol extract (6.67%).

Forty eight hours after treatment: The data revealed that the treatments differ significantly and were superior over control. Mortality percentage varied from 6.67 to 65.00 percent whereas no mortality was recorded in control. The highest mortality (65.00%) was recorded in Tulsi acetone extract which was followed by treatments with Jatropha petroleum ether (55.00%), Jatropha methanol (41.67%), Jatropha acetone (30.00%), Tulsi hexane (23.33%) and Tulsi petroleum ether (20.00%) and Jatropha hexane extract (13.33%). The lowest mortality was recorded from Tulsi methanol extract (6.67%).

Seventy two hours after treatment: The treatments differ significantly and were superior over control. Mortality percentage varied from 11.67 to 70.00 percent whereas no mortality was recorded in control. The highest mortality (70.00%) was recorded in Tulsi acetone extract which was followed by treatments with Jatropha petroleum ether (56.67%), Jatropha methanol (41.67%), Jatropha acetone (36.67%),Tulsi hexane (35.00%), Tulsi petroleum ether (26.67%) and Jatropha hexane extract (25.00%). The lowest mortality was recorded from Tulsi methanol extract (11.67%).

3. b. Weight loss percent (%)

Three months after storage: It was observed from the data of three months after storage that all treatments were effective in checking the percent weight loss due to *Tribolium castaneum* in various degrees. The treated wheat grains had significantly less weight losses than untreated check. It was found that Tulsi acetone extract @ 2 ml per 1 kg of wheat recorded lowest percent weight loss (2.81%) followed by weight loss in Jatropha petroleum ether extract (3.24%). Jatropha methanol extract showed 3.78 percent weight loss. Jatropha acetone extract which showed a weight loss of 4.36 percent was the next in effectiveness. In Tulsi hexane, Tulsi petroleum ether extracts the weight loss were 4.60 percent, 5.63% respectively. These were followed by Jatropha hexane extract (7.51%). In Tulsi methanol extract highest weight loss (9.68%) was found among the treatments. It was observed that all the treatments were statistically superior over untreated control (12.80%).

Six months after storage: Tulsi acetone extract recorded the lowest weight loss (4.26%) in wheat after six months of storage and it was followed by Jatropha petroleum ether extract where a weight loss of 4.75 percent was observed. The next in line was Jatropha methanol extract showing 5.06 percent weight loss followed by Jatropha acetone extract treatment where weight loss of wheat was observed to be 6.75 percent. Weight loss observed in the treatments of Tulsi hexane (7.00%), Tulsi petroleum ether (7.24%) and Jatropha hexane extract (9.37%) were next in their effectiveness. Wheat treated with Tulsi methanol extract showed a weight loss of 11.55 percent. Untreated control showed weight loss of 15.05 percent which was significantly different from all the other treatments.

Nine months after storage: Lowest percent of weight loss was observed in Tulsi acetone extract treatment (6.57%), it was followed by weight loss of wheat in Jatropha petroleum ether extract (7.01%). In Jatropha methanol extract the weight loss was 7.10 percent. Jatropha acetone extract showed weight loss of 7.62 percent. The weight loss of wheat in treatments with Tulsi hexane 8.83 percent, Tulsi petroleum ether extract 9.23 percent and Jatropha hexane extract showed weight loss of 11.84 percent. Among the treatments Tulsi methanol extract was least effective (13.95%). Maximum weight loss was recorded in untreated control (18.16%) which was significantly inferior over all the treatments.

Twelve months after storage: After the completion of twelve months of storage, the weight loss of wheat was observed to be very near to nine months of storage. Results showed that Tulsi acetone extract (7.39%) was the most effective as far as weight loss was concerned and it was followed by treatment of Jatropha petroleum ether extract (7.94%). The weight loss observed from Jatropha methanol (8.56%), Jatropha acetone ether (8.91%), Tulsi hexane (9.42%) and Tulsi petroleum ether extract (10.22%). Out of the remaining treatments, the weight loss in Jatropha hexane extract (12.46%) and the highest weight loss of 14.52 percent from Tulsi methanol extract were observed but these two were still significantly superior to untreated control (18.94%).

3. c. *In vitro* adulticidal activity

Three months after storage: Data taken after three months of storage of wheat showed that all the treatments were effective in various degrees in checking the population buildup of *Tribolium castaneum* as these had significantly less population than untreated check. The results revealed that Tulsi acetone extract @ 2 ml per kg was found to be the most effective against *Tribolium castaneum* after three months of storage. The mortality of *Tribolium castaneum* was found to be 37.50 percent in Tulsi acetone extract after three months of storage. Jatropha petroleum ether extract also showed

substantial effectiveness with 29.91 percent mortality and it was found to be statistically superior to all the other treatments. It was followed by Jatropha methanol (25.95%), Jatropha acetone (24.32%) and Tulsi hexane extract (24.46%). Tulsi petroleum ether, Jatropha hexane and Tulsi methanol extracts mortality of *Tribolium castaneum* were found to be 22.45, 20.72 and 19.38 percent, respectively. All the treatments were significantly different from the untreated control (13.27%).

Six months after storage: At six months of storage, adulticidal activity showed that Tulsi acetone extract (46.88%) was most effective against *Tribolium castaneum* and it was statistically superior to all the other treatments. Jatropha petroleum extract (38.68%) was also found to be quite effective. The lowest adulticidal activity was seen in untreated check with (14.15%). It was followed by Jatropha methanol extract (31.19%). The adulticidal activity of Jatropha acetone (27.07%), Tulsi hexane (25.79%) and Tulsi petroleum ether extract (24.17%). The percent mortality of *Tribolium castaneum* from Jatropha hexane and Tulsi methanol extracts were 21.89 percent and 20.42 percent, respectively.

Nine months after storage: The adulticidal activity showed that Tulsi acetone extract (44.87%) was found to be most effective after nine months storage against *Tribolium castaenum.* It was statistically superior to all other treatments. Jatropha petroleum ether extract also found to be effective (29.44%). The next treatments were Jatropha methanol (25.89%); Jatropha acetone (23.58%), Tulsi hexane (21.74%), Tulsi petroleum ether (19.57%), Jatropha hexane (18.15%) and Tulsi methanol extract (17.42%) were found to be superior over untreated control (12.36%).

Twelve months after storage: At twelve months of storage, highest adulticidal activity was observed in wheat treated with Tulsi acetone extract (44.08%) and it was the most effective one. Jatropha petroleum ether (27.63%), Jatropha methanol (23.72%), Jatrophaacetone extract (22.51%) were found to be statically at par. The other treatments in order were Tulsi hexane (22.12%), Tulsi petroleum ether (18.57%), Jatropha hexane (16.17%), Tulsi methanol extract (15.73%) and control (13.95%).

3. d. Percent weight gain over control

Three months after storage: Three months after treatment highest percent weight gain over control was recorded from Tulsi acetone extract (10.28%) treatment @ 2 ml per kg of wheat followed by Jatropha petroleum ether (9.84%), Jatropha methanol (9.36%), Jatropha acetone extract (8.81%). The next treatments were Tulsi hexane (8.59%), Tulsi petroleum ether extract (7.59%) and these were followed by Jatropha hexane (5.71%) and Tulsi methanol extract (3.54%).

Six months after storage: Maximum percent weight gain over control was observed in treatment of Tulsi acetone extract (11.26%) and it was followed by Jatropha petroleum ether extract (10.78%) after six months of storage. The next effective treatments were Jatropha methanol (10.50%), Jatropha acetone (8.89%), Tulsi hexane (8.64%), Tulsi petroleum ether extract (8.41%). These treatments were followed by Jatropha hexane (6.24%) and Tulsi methanol extracts (3.92%).

Nine months after storage: Highest percent of weight gain over control was noticed in treatment by Tulsi acetone extract (12.39%) which was followed by Jatropha petroleum ether (11.99%), Jatropha methanol (11.89%), Jatropha acetone (11.33%), Tulsi hexane (10.18%), Tulsi petroleum ether extract (9.83%), Jatropha hexane (7.15%) and Tulsi methanol extracts (4.89%) were the treatments next in the order.

Twelve months after storage: Weight gain over control after twelve months of storage was found to be very near to nine months after storage data of wheat. Here Tulsi acetone extract (12.05%) was again found to gain the maximum over control and it was followed once again by Jatropha petroleum ether extract (11.54%). Of the rest, the weight gain over control was for the extracts of Jatropha methanol (10.91%), Jatropha acetone extract (10.55%), Tulsi hexane (10.10%), Tulsi petroleum ether extract (9.23%). Jatropha hexane extract and Tulsi methanol extract recorded 6.94 percent and 4.98 percent weight gain over control, respectively.

3. e. Feeding inhibition percent (F.I.) [%]

Three months after storage: Three months after treatment highest percentage of feeding deterrent effect was recorded from Tulsi acetone extract (63.98%) treatment @ 2 ml per kg of wheat, which was statistically superior to other treatments. And it was followed by Jatropha petroleum ether (59.57%), Jatropha methanol (54.41%), Jatropha acetone extract (49.17%). The next treatments were Tulsi hexane (47.16%), Tulsi petroleum ether (38.90%) and Jatropha hexane extract (26.03%). The lowest feeding deterrent effect was observed in Tulsi methanol extract (13.87%). No deterrent effect was observed in control.

Six months after storage: Maximum percentage of feeding deterrent effect was observed in treatment of Tulsi acetone extract (55.91%), which was statistically superior to other treatments. And it was followed by Jatropha petroleum ether extract (52.04%) after six months of storage. The next effective treatments were Jatropha methanol (49.70%), Jatropha acetone (38.07%), Tulsi hexane (36.51%), Tulsi petroleum ether extract (35.03%). These treatments were followed by Jatropha hexane (23.25%) and Tulsi methanol extracts (13.16%). From control no deterrent effect was recorded.

Nine months after storage: Highest percentage of feeding deterrent effect was noticed in treatment by Tulsi acetone extract (46.88%) which was followed by Jatropha petroleum ether (44.32%) and Jatropha methanol extract (43.80%). Jatropha acetone (40.89%), Tulsi hexane (34.58%), Tulsi petroleum ether (32.61%), Jatropha hexane (21.05%) and Tulsi methanol extract (13.10%) were the treatments next in the order. There was no deterrent effect in the control treatment.

Twelve months after storage: Tulsi acetone extract (43.05%) was again found to show the highest feeding deterrent effect after twelve months of storage of wheat. And it was followed once again by Jatropha petroleum ether (40.12%), Jatropha methanol extract (36.88%). Of the rest, the feeding deterrent effects for the extracts of Jatropha acetone (35.15%), Tulsi hexane (32.70%) and Tulsi petroleum ether extract (29.01%). Jatropha hexane and Tulsi methanol extract recorded 19.67 and 13.12 percent, respectively. Control exhibited no deterrent effect.

4. Conclusion

This present study concluded that different solvents extracts of *Jatropha curcas* and *Ocimum sanctum* possess toxic principles with insecticidal effect and could be potential grain protectants against *T. castaneum.* Among the tested plants Tulsi acetone leaf extracts showed the highest toxic effect against *Tribolium castaneum.* Therefore, leaves extracts of Tulsi and Jatropha may be recommended as cheap, easily available at farm level, eco-friendly with low mammalian toxicity and a good alternative to synthetic insecticides.

Table 1: Effect of solvent extracts of different plant leaves on mortality of *Tribolium castaneum* at different time intervals

Treatments	Dose (ml)	Mortality percent (%)						
		1 HAT	3 HAT	6 HAT	12 HAT	24 HAT	48 HAT	72 HAT
Jatropha acetone	0.2	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	15.00 (22.78)	23.33 (28.87)	30.00 (33.20)	36.67 (37.25)
Tulsi acetone	0.2	0.00 (0.01)	23.33 (28.87)	36.67 (37.25)	40.00 (39.22)	60.00 (50.75)	65.00 (53.71)	70.00 (56.77)
Jatropha hexane	0.2	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	16.67 (24.09)	13.33 (21.41)	25.00 (29.99)
Tulsi hexane	0.2	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	10.00 (18.43)	21.67 (27.73)	23.33 (28.87)	35.00 (36.26)
Jatropha methanol	0.2	0.00 (0.01)	0.00 (0.01)	1.67 (7.42)	16.67 (24.09)	26.67 (31.08)	41.67 (40.19)	41.67 (40.19)
Tulsi methanol	0.2	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	6.67 (14.96)	6.67 (14.96)	11.67 (19.97)
Jatropha petroleum ether	0.2	0.00 (0.01)	1.67 (7.42)	20.00 (26.55)	30.00 (33.20)	45.00 (42.11)	55.00 (47.85)	56.67 (48.81)
Tulsi petroleum ether	0.2	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	8.33 (16.77)	18.33 (25.34)	20.00 (26.55)	26.67 (31.08)
Control	-	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)
SEd±			0.44	0.52	0.70	0.72	0.83	1.03
C.D.@ (P=0.05%)		NS	0.93	1.09	1.48	1.51	1.75	2.16

HAT = Hours after treatment
Data are mean of 3 replications each having 20 insects and 5g grains
Data within the parentheses are angular transformed values
NS = Non significant

Table 2: Effect of solvent extracts of different plant leaves on percent weight loss of wheat grains due to *Tribolium castaneum* infestation at different months after storage.

Treatments	Weight loss %			
	3 MAS	6 MAS	9 MAS	12 MAS
Jatropha acetone	4.36 (12.05)	6.75 (15.05)	7.62 (16.02)	8.91 (17.36)
Tulsi acetone	2.81 (9.65)	4.26 (11.91)	6.57 (14.85)	7.39 (15.77)
Jatropha hexane	7.51 (15.90)	9.37 (17.82)	11.84 (20.12)	12.46 (20.66)
Tulsi hexane	4.60 (12.38)	7.00 (15.34)	8.83 (17.28)	9.42 (17.87)
Jatropha methanol	3.78 (11.21)	5.06 (12.99)	7.10 (15.45)	8.56 (17.01)
Tulsi methanol	9.68 (18.12)	11.55 (19.86)	13.95 (21.92)	14.26 (22.18)
Jatropha petroleum ether	3.24 (10.37)	4.75 (12.58)	7.01 (15.35)	7.94 (16.36)
Tulsi petroleum ether	5.63 (13.72)	7.24 (15.60)	9.23 (17.68)	10.22 (18.64)
Control	12.80 (20.95)	15.05 (22.82)	18.16 (25.21)	18.57 (25.52)
SEd ±	1.08	1.26	1.60	1.80
C.D @ (P=0.05%)	2.27	2.64	3.36	3.78

HAT = Hours after treatment
Data are mean of 3 replications each having 20 insects and 5g grains
Data within the parentheses are angular transformed values
NS = Non significant

Table 3: Effect of solvent extracts of different plant leaves on *in-vitro* adulticidal activity of *Tribolium castaneum* at different months after storage

Treatments	% Adult mortality			
	3 MAS	6 MAS	9 MAS	12 MAS
Jatropha acetone	24.32 (29.54)	27.07 (31.34)	23.58 (29.04)	22.51 (28.31)
Tulsi acetone	37.50 (37.75)	46.88 (43.19)	44.87 (42.04)	44.08 (41.58)
Jatropha hexane	20.72 (27.07)	21.89 (27.88)	18.15 (25.21)	16.17 (23.70)
Tulsi hexane	24.46 (29.63)	25.79 (30.51)	21.74 (27.780	22.12 (28.04)
Jatropha methanol	25.95 (30.61)	31.19 (33.94)	25.89 (30.57)	23.72 (29.13)
Tulsi methanol	19.38 (26.11)	20.42 (26.85)	17.420 (24.66)	15.73 (23.36)
Jatropha petroleum ether	29.91 (33.14)	38.68 (38.44)	29.44 (32.85)	27.63 (31.70)
Tulsi petroleum ether	22.45 (28.27)	24.17 (29.44)	19.57 (26.25)	18.57 (25.52)
Control	13.27 (21.35)	14.15 (22.09)	12.36 (20.57)	13.95 (21.92)
SEd±	0.93	1.485	1.66	2.59
C.D. @ (P=0.05%)	1.96	3.04	3.49	5.44

HAT = Hours after treatment
Data are mean of 3 replications each having 20 insects and 5g grains
Data within the parentheses are angular transformed values
NS = Non significant

Table 4: Effect of solvent extracts of different plant leaves on percent weight gain over control due to treatments against *Tribolium castaneum* infestation at different months after storage

Treatments	% Weight gain over control			
	3 MAS	6 MAS	9 MAS	12 MAS
Jatropha acetone	8.81 (17.26)	8.89 (17.34)	11.33 (19.66)	10.55 (18.95)
Tulsi acetone	10.28 (18.69)	11.26 (19.60)	12.39 (20.60)	12.05 (20.30)
Jatropha hexane	5.71 (13.82)	6.24 (14.46)	7.15 (15.50)	6.94 (15.27)
Tulsi hexane	8.59 (17.04)	8.64 (17.09)	10.18 (18.60)	10.10 (18.52)
Jatropha methanol	9.36 (17.81)	10.50 (18.90)	11.89 (20.16)	10.91 (19.28)
Tulsi methanol	3.54 (10.84)	3.92 (11.41)	4.89 (12.77)	4.98 (12.89)
Jatropha petroleum ether	9.84 (18.27)	10.78 (19.16)	11.99 (20.25)	11.54 (19.85)
Tulsi petroleum ether	7.59 (15.99)	8.41 (16.85)	9.83 (18.26)	9.23 (17.68)
SEd±	1.86	1.78	1.57	1.55
C.D @ (P=0.05%)	3.90	3.75	3.29	3.26

HAT = Hours after treatment
Data are mean of 3 replications each having 20 insects and 5g grains
Data within the parentheses are angular transformed values

Table 5: Deterrent effect of plant extracts against *Tribolium castaneum*

Treatments	Feeding inhibition %			
	3 MAS	6 MAS	9 MAS	12 MAS
Jatropha acetone	49.17 (44.51)	38.07 (38.08)	40.89 (39.74)	35.15 (36.35)
Tulsi acetone	63.98 (53.10)	55.91 (48.37)	46.88 (43.19)	43.05 (40.99)
Jatropha hexane	26.03 (30.66)	23.25 (28.82)	21.05 (27.30)	19.67 (26.32)
Tulsihexene	47.16 (43.35)	36.51 (37.16)	34.58 (36.00)	32.70 (34.86)
Jatropha methanol	54.41 (47.51)	49.70 (44.81)	43.80 (41.42)	36.88 (37.38)
Tulsi methanol	13.87 (21.86)	13.16 (21.26)	13.10 (21.21)	13.12 (21.23)
Jatropha petroleum ether	59.57 (50.50)	52.04 (46.15)	44.32 (41.72	40.12 (39.29)
Tulsi petroleum ether	38.90 (38.57)	35.03 (36.27)	32.61 (34.81)	29.01 (32.58)
Control	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00(0.01)
SEd±	1.08	1.26	1.60	1.80
C.D. @ (P=0.05%)	2.27	2.64	3.36	3.78

HAT = Hours after treatment
Data are mean of 3 replications each having 20 insects and 5g grains
Data within the parentheses are angular transformed values

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