EFFICACY OF COMMONLY USED BOTANICALS FOR THE MANAGEMENT OF ANGOUMOIS GRAIN MOTH, *SITOTROGA CEREALELLA* (OLIVIER) IN DIFFERENT STORED GRAINS

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This is to certify that thesis entitled, "EFFICACY OF COMMONLY USED BOTANICALS FOR THE MANAGEMENT OF ANGOUMOIS GRAIN MOTH, SITOTROGA CEREALELLA (Olivier) IN DIFFERENT STORED GRAINS" submitted to the DEPARTMENT OF ENTOMOLOGY, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of ***MASTER OF SCIENCE (M.S.) in ENTOMOLOGY*** *embodies the result of a piece of bona fide research work carried out by* ***MOSA. TASLIMA AMIN, Registration No. 08-2722*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: December, 2013

Place: Dhaka, Bangladesh

…………………………………….

Associate Professor

Dr. Tahmina Akter

Supervisor

Dedicated to

My

Beloved Parents

LIST OF ABBREVIATIONS

Full word	Abbreviation
and others	*et al.*
Bangladesh Agricultural Research Institute	BARI
Bangladesh Bureau of Statistics	BBS
Centimeter	cm
Co-efficient of Variation	CV
Degree Celsius (Centigrade)	^{0}C
Degrees of freedom	df
Et cetera	etc
Gram	gm
Inch	inch
Journal	*j.*
Kilogram	Kg
Least significant difference	LSD
Mean sum square	MS
Milliliter	ml
Millimeter	mm
Percent	%
Relative Humidity	R.H
Serial number	SL. No.

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Dated: December' 2013 ***The Author***

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ABSTRACT

The study was conducted on the efficacy of commonly used botanicals for the management of angoumois grain moth, S*itotroga cerealella* (Olivier) on stored wheat and maize grains in the laboratory of the department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207 during January to May, 2014. The treatments of the studies were: T_1 = Black pepper dust @ 5g/Kg on the upper layer of the grains,T_2 = Neem seed kernel dust @ 10g/Kg on the upper layer of the grains, T_3 = Tobacco leaves dust @ 7 g/Kg on the upper layer of the grains, T_4 = Neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of the grains, T_5 = Lantana Leaves dust @ 10 g/Kg on the upper layer of the grains, T_6 = Nishinda Leaves dust @ 10 g/Kg on the upper layer of the grains and T_7 = Untreated Control. The study was laid out in a Completely Randomized Design (CRD) with three replications. It was observed that more damages occurred in stored wheat grains than maize grains. T_3 treatment (using tobacco leaves dust) and T_4 treatment (using neem oil) were more effective than all other treatments against insect mortality, adult emergence and repellency effect on *S. cerealella.* In 1st generation, there were no infested grains (both wheat and maize) by weight and number basis were observed from T_3 and T_4 treatments treated grains respectively. The highest infested grains by weight (22.71% and 48.25%) and by number (25.85% and 57.82%) were recorded from T_7 untreated control grains of these two types of grains. But in 2nd generation, 100% infested grains by weight and number basis were recorded from T_7 untreated control grains in case of stored wheat grains, whereas 54.77% and 63.77% infested grains by weight and number basis were recorded from T_7 untreated control grains respectively in case of stored maize grains and on the other hand the lowest percentage of infestation of maize grains (0.00 %) were obtained T_3 and T_4 treatments respectively. Similar trend of infestation was also observed in case of stored maize grains in 3rd generation and after 2nd generation wheat grains were completely damaged by this insect.

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CHAPTER I

INTRODUCTION

Among the cereals, Wheat (*Triticum aestivum* L.*)* is the second most important staple food crop in Bangladesh after rice (BBS, 2008). After rice and wheat, maize (*Zea mays* L.) is an important cereal crop in Bangladesh serving as source of food, feed and industrial raw material. Over 85% of maize produced in the country is consumed as human food (Meseret, 2011). With the increase of population more food grain production is needed in the country. In storage, insect pests became important for seed and food purposes. Wheat, maize and other cereals are stored in the government and public godown.

Insect infestation on stored grains and their products is a serious problem throughout the world. There are approximately 200 species of insects and mite attacking stored grains and stored products (Maniruzzaman, 1981). According to Alam (1971), 5-8% of the food grains and different stored products are lost annually due to storage pests including the losses incurred in farm as 10%. Among these species Angoumois grain moth, *Sitotroga cerealella* Olivier is common and most destructive pest. It belongs to the family Gelechiidae under the order Lepidoptera.

Angoumois grain moth shows its activity only in storage in Bangladesh. It is an extremely efficient seed penetrator (Cogburn, 1974). In Bangladesh it is known as 'surui' and is one of the most serious pest of stored wheat and maize at post harvest. A Substantial amount of grain stored at farmer houses is badly damaged by Angoumois grain moth. In addition the pest is found to infest other stored products, such as joar, bran, sudan grass, etc. The insect is small size and concealed itself in grain facilities and their exportation by commerce to all parts of the world and the pest has become cosmopolitan in distribution. The insect is more or less active throughout the year but less active during the period from mid December to first part of March.

The adult is a small, buff to yellowish brown or straw colored moth about one- third inch long with a wing span of one- half inch. Both wings end in a thumb like projection and have fringed margins. The eggs are white when first deposited, but soon turn red. Adults do not feed on commodity. Only larvae cause serious damage to grains. Larval feeding inside the grain caused an appreciable amount of damage which has been stated about 8.1% (Shajahan, 1974).

Angoumois grain moth larvae feed on a number of whole kernel grains. Larval feeding produces large cavities within infested grain and causes a reduction in grain weight and quality. Pupation takes place inside the seed coat. Heavily infested grains spread bad smells and become less attractive for consumption. Infestations produce abundant heat and moisture that may encourage mould growth and attract secondary pests (Cogburn, 1974). This insect alone can account for over 40% of the total losses in stored grains in some areas (Boshra, 2007).

The Angoumois grain moth, *S. cerealella* caused a substantial damage of stored wheat and maize resulting in the reduction of viability of grains rendering them unsuitable for seeding and human consumption (Cotton, 1963). There are large numbers of dead adult moths, larvae excreta, exuviae and pupal shells present in the infested grains. These cause lower market price and degrade food value. So, it is necessary to control their populations in storage.

At present different kinds of preventive and curative control measures are practice to protect insect pests. Among them chemical control has been used for a long time, but has serious drawbacks (Sharaby, 1988). The indiscriminate use of chemical pesticides in storage has given rise to many well-known serious problems including genetic resistance of pest species and toxic residues in stored products increasing cost of application, environmental pollution, hazards from handling, etc (Ahmed *et al.,* 1981; Sharaby, 1988 and Khanam *et al*., 1990). It is an urgent need to find out a safe and some alternative to chemical insecticides to protect the stored products in storage. Recently, much attention has been paid to develop resistant varieties against the attack of the pest. In many areas of the world locally available materials are widely used to protect stored product against damage infestation (Golob and Webely, 1989 and Talukder *et a*l., 1990). Botanical plant products are less expensive, readily available, environmentally safe and less hazardous in comparison to chemical insecticides (Sexana *et al.,* 1980). The main advantages of botanicals are that they are easily produced and used by farmers in small scale industries.

There are about 2000 plant species reported to possess pest control properties (Ahmed *et al.,* 1984). The application of simple plant materials like black pepper, tobacco, neem, nishinda and lantana in several cases proved to be highly effective against stored product insects. The plant products included leaf powder, seed and oils.

As Angoumois grain moth *S. cerealella* (Olivier) is one of the serious damaging pest of stored grains. The present work was undertaken with a view to studying the extent of damage of this pest on stored wheat and maize in the laboratory and to test the efficacy of some botanicals for its control.

The objectives of this research work were:

- ❖ To study the extent of damage caused by Angoumois grain moth, *Sitotroga cerealella* (Olivier)
- ❖ To study the efficacy of some botanicals against Angoumois grain moth, *S. cerealella* (Olivier) for their control
- ❖ To find out the effective botanical (s) for controlling *S. cerealella* (Olivier)

CHAPTER II

REVIEW OF LITERATURE

Wheat (*Triticum aestivum* L.) and maize (Zea mays) is the second and third most important cereal crop in Bangladesh (Anon.2008). Nutritional values as well as diversified uses of wheat and maize proves its importance for cultivation and expansion. Insect pests cause heavy food grain losses in storage, particularly at the farm levels in tropical countries. The efficient control and removal of stored grain pests from food commodities have long been the goals of entomologists throughout the worlds because insect infestation is the most serious problem of stored grain and stored products. Losses due to insect infestation is the most serious problem of cereal grains, pulses, oil seeds in storage, particularly, in villages and towns of developing countries like Bangladesh.

David *et al*. (2005) revealed that losses of grain in storage due to insects were the final components of the struggle to limit insect losses in agricultural production. Losses caused by insects include not only the direct consumption of kernel, but also include accumulation of frass, exuviae, webbing, and insect cadavers. High levels of this insect detritus may result in grain that is unfit for human consumption. Insect induced changes in the storage environment may cause warm, moist ‘hotspots’ that are suitable for the development of storage fungi that cause further losses. Worldwide losses in stored products caused by insects, have been estimated to be between 5-10%. Heavy insect pest infestation caused about 30% damage in tropics.

On the other hand, Labadan (1968) observed that at least 5% of the stand this could increase 17% for the next 6 months. Caswell (1964) observed 30-50 % damage of wheat grains after 6 months of storage**.**

2.1: Origin and distribution of Angoumois grain moth, *S. cerealella*

Sitotroga cerealella is worldwide in distribution but found in abundance in mountainous and coastal areas where the climate is rather humid. This pest derives its common name from the colossal depredations caused by it in the province of Angoumois, France in about 1736.

2.2: Host of Angoumois grain moth

Angoumois grain moth is a serious pest of all cereals both in the field as well as in storage. It is a major pest of stored unhusked rice, though it commonly attacks wheat, maize, sorghum, barley and oat (Fletchwer and Ghosh, 1919). Burkholder (1970) considered the attack of this moth as an index for judging the quality of stored grains.

2.3: Systematic Position:

Phylum: Arthropoda
- Class: Insecta
  - Sub-class: Pterygota
    - Division: Endopterygota
      - Order: Lepidoptera
        - Family: Gelechiidae
          - Genus: *Sitotroga*
            - Species: *Sitotroga cerealella* (Oliver)

2.4: Biology of Angoumois grain moth

Mating: Adults mate 24 hrs after their emergence. Longevity of females is more than males.

Oviposition: On stored grains it lays 30-70 eggs with an average of 40 eggs throughout its life whereas it lays 120-350 eggs on paddy grains and other cereals and also on depressions, cracks, crevices and holes of storage structures and godowns (Fletcher and Ghosh, 1919). Dhotmal and Dumbre (1982) reported 40.88 to 57.88 eggs laid by a female on different rice varieties in a laboratory test and found that fine grain varieties were preferred for its egg laying. Fecundity was found to vary in the wild and domesticated strains of this moth. Oviposition period was reported as being from 3.3 to 5.0 days. Eggs are laid singly or in groups of 4-7 eggs depending upon the season and ovipositional site. Newly hatched egg is white in color but gradually changes to redish brown. It measures about 0.5 mm in diameter. The egg is oval shaped and hatches within a week. An average incubation period is 6 days. Hatching was reported to take 11 days at 17.3^{0}C temperature and 68.3% R.H. (Germanov, 1982). Unmated females have also been reported to lay eggs within a day of emergence (Ayertey, 1975). Prakash *et al*. (1981) reported that the female prefers a rough surface for egg lying than a smooth one in stored rice.

Larval period: Larva is yellowish white with a dark head and attains a length of 6-10 mm depending upon grain length. The larva lives inside a grain. The tiny larva crawls around for sometimes and soon finds a comparatively weaker spot or a crack or split in the husk through which it enters the grain. Larval migration is reported as being up to 10 cm horizontally and 5 cm vertically (Germanvo, 1982). After entering the grain, the larva often turns and practically closes the entry hole with a silken web. The larval life then begins in an environment of plenty of food and safety and continues in that state till it is fully grown to about 5 mm within two or three weeks. At this time the grain is practically hollow filed with faces and other refuge. The larva then cuts out a circular exit hole leaving over it just a sort of cap (Anonymous, 1981). Germanov (1982) described 4 larval stages during his studies under conditions of mass rearing and reported that larval stages I, II, III and IV were observed on the 9th, 12th, 18th and 20th days after grain infestation, respectively, at 65.8% R.H. and 22.3^{0}C temperature. Duration of larva was found to be 13.66 to 19.33 days in different rice varieties and development was found faster in fine-grained varieties (Dhotmal and Dumber, 1982). Full-grown larvae spin silken cocoons around them in hollows in the grain and become inactive 2 days before pupation (Crombiwe 1943).

Pupal period: Pupa is brown colored, develops inside silken cocoon and 4-5 mm in length. Pupal period is 4-7days (Crombiwe, 1943). The moth on emergence pushes off the cap on the circular exit hole. Germanov (1982) reported pupation on the 15th day after infestation at 22.3^{o}C temperature and 68.8% R.H.

Adult emergence: The adult is a good filter, short-lived (5-7) days, gray or buff colored moth, usually nocturnal in habit. The wingspan is 10-15 mm, body length 5-10 mm with grayish / yellowish, darker spots on forewings. The apex of hind wings is fringed with hairs, which is sharply pointed towards the tips and widely separated so that abdomen is partially visible. Adults mate 24 hrs after emergence. Longevity of females is more than males. The shape of their abdomen can distinguish male and female. In male, the abdomen is thinner, pointed and blackish when viewed from the ventral side where as in females; abdomen is bulky and long without any blackish coloration.

2.5: Nature and extent of damage

Only larvae feed on grain kernels. Ramesh *et al.* (2000) studied storage losses in unhusked rice in farmer’s stores of district Kangra, Himachal Pradesh, India, during August 1998. A total of 180 samples collected from six blocks of the district were found to be infested with six species of insects, viz., Angoumois grain moth, *S. cerealella*, rice weevil, *Sitophilus oryzae*, lesser grain borer, *Rhizopertha dominica*, rust red flour beetle, *Tribolium castaneum*, saw-toothed grain beetle, *Oryzaephilus surinamensis* and rice moth, *Corcyra cephalonica.* The maximum infestation was 66.14 percent by *S. oryzae* followed by 23.53 percent by *T. castaneum*, 4.59 percent by *O. surinamensis*, 3.80 percent by *C. cephalonica*, 1.14 percent by *S. cerealella* and 0.79 percent by *R. dominica*. On an average 18.09 percent grains were found to be damaged and there were 3.96 percent weight losses due to insect feeding in unhusked rice.

Aviles and Guibert (1986) reported that the pyralid, *S. cerealella* and the bostrichid *R. dominica* were the most important pests of stored grain and seed rice, respectively and they were able to survive and reproduce under the adverse condition of storage.

Podoler and Applebaum (1968) stated that the thicker seed coat reduced the damage to various genotypes.

Mookherjee *et al.* (1970) observed the extent of damage due to insect pest in stored seeds. They collected the seeds of rice, corn, wheat, barley, jowar and bajra and stored at different levels. These seeds were examined in the laboratory for insect infestation. The study revealed the damage to vary between 0 to 70%, 0 to 100%, 0 to 75%, 0 to 22.7%, 0 to 11% and 0.9% in the above mentioned 6 seeds respectively.

Shahjahan (1974) stated that an average damage of 8% stored grains were observed due to the attack of only Angoumois grain moth.

Aviles and Guibert (1986) reported that the pyralid, *Sitotroga cerealella* and the bostrichid *Rhizopertha dominica* were the most important pests of grain and seed rice, respectively and they were able to survive and reproduce under the adverse condition of storage.

2.6: Effect of Environment on Pest Survival

Warren (1956) reported that *Sitotroga cerealella* (Oliver) exhibited variable responses when reared on several strains of corn at two moisture levels.

Maity *et al.* (1999) stated that storing grain at high temperature but low humidity curbed the infestation by the pest.

Grewal and Atwal (1967) concluded that 25 – 30^{0}C and 80% RH are most favourable for development, survival and reproduction of the Indian strain of *S. cerealella*.

Hansen *et al. (*2004) stated that the highest population increase of *S. cerealella* occurred at 30^{0}C. High relative humidity and temperatures higher than 30^{0}C are not suitable for development of this pest.

2.7: Factors regulating loss of grain in storage

2.7.1: Biotic factors

Both biotic and abiotic factors are responsible for the loss of stored grain in storage. Baloch *et al.* (1994) revealed that the major biotic factors influencing grain loss during storage are insects, moulds, birds and rats.

Gentile and Trematerra (2004) reported that twenty insect pests infested stored grain, with *Sitotroga cerealella, Troqium pulsatorium, Ephestia elutella, Plodia interpunctella, Cryptolestes ferrugineus, Oryzaephilus surinamensis, Rhyzopertha dominica, Sitophilus granaries, Sitophilus oryzae* and *Tribolium castaneum* being the most dominant pests. *Sititroga cerealella* occurred during pre harvest and post harvest storage.

Chudhary and Mahla (2001) reported that insect pests of stored cereal food grains were varied depending upon the prevailing climatic conditions. About 10 (ten) insect species were infested in stored grains.

Samuels and Modigli (1999) observed that wheat and maize was infested by Angoumois grain moth, rice weevil and rust red flour beetle when it stored in jute bags, perus, metal bins and polyethylene bags for 6(six) months. Insect infested grains should not be consumed as it may pose a serious health hazard in man.

2.7.2: Abiotic factors

Abiotic factors including temperature, humidity and type of storage, all affect environmental conditions in storage. High temperature causes deterioration, while low temperature is good for storage. High temperature accelerates the respiration of grain, which produces carbon dioxide, heat and water, conditions favorable for spoilage. Humidity equally impacts grain storage. Increasing humidity increases spoilage, while decreasing humidity is good for storage (Baloch *et al*., 1994).

The type of storage plays a fundamental role in storage efficiency. If a concrete or mud storage structure can absorb water or allow the water vapors to pass through, in case of a jute bag, the bio- chemical changes and mould attack are minimal, but the risk of insect infestation increases. Sun drying or turning of food grain has many advantages as it provides an opportunity for inspection and precautionary measures to avoid spoilage. Aeration greatly minimizes mould growth, insect activity and respiration of the seed. Further aeration provides a cooling action and equalizes the temperature throughout the mass of the grain stored (Baloch *et al*., 1994).

Climate conditions, grain conditions at storage, grain and pest control practices all contribute to the rate of loss caused by insects and mould growth. As these factors interact, it is difficult to isolate them or identify one factor, which has a direct influence on loss. Average statistics for loss, whether for store types, areas, or quantities of grain stored are inconclusive. An average figure for loss for a region or a country holds no significance unless a decision regarding a new system of storage, or new pest control techniques is required. Nevertheless average loss figures are always sought (Baloch *et al*., 1994).

2.8: Storage structure for protection of stored grains

Local storage structures which are commonly used in rural India and Bangladesh fail to provide complete grain protection from insects. In general, these structures are not moisture proof. The moisture content is high in stored grain which facilitates insect multiplication. The longer the storage period, higher is the insect infestation (Prakas, 1982).

Singh (2001) made a survey on the storage structures used by the farming community in North Bihar, India. He reported that they owned at least 13 different types of storage structures for storing of their agricultural products. Among all gunny bags were maximum (25.78%), however, the farmers use different types of structures at a time.

Mandal *et al*. (1984) reported that average losses and deterioration of grains in silo/godown storage were estimated to be 1.5% and for warehouse storage to be 2.8%. Among the existing structures used by the private sector, bamboo made “dole” was suitable for short term storage.

2.9: Toxicity Test

Dakshinamurthy (1988) carried out an experiment to study the effectiveness of some plant products on the development and cross infestation by the stored pests, *Sitotroga cerealella* and *Rhizopertha dominica* in the laboratory. They found that eucalyptus powder mixed with rice at the rate of 1% by weight was effective in reducing the number of adults *S. cerealella*.

David *et al*. (1998) showed that it had repellent, insecticidal and juvenile hormone activity against several species of insect pests including stored product pest larvae of Lepidoptera and *Culex quinquefasciatus*.

Dayrit *et al.* (1995) tested volatile oils from the leaves of nishinda (*Vitex negundo*) using *plutella xylostella* and confirmed that *V. negundo* and neem seeds oils act as a promising botanical insecticide showing lower egg hatching in ovicidal tests and in topical toxicity tests.

Facknath and Sunita (2006) reported that neem (*Azadirachta indica A. juss*.) has been demonstrated to reduce insect population in stored products through its toxic and growth-disrupting and other effects on the pests. Grain movement and percussion also help to kill pests in grain. The combination of neem and grain movement on population growth and development of four insect pests is reported in this study. Dried whole neem leaves, neem leaf powder and neem seed kernel oil were combined individually with dried beans and rice in separate experiments and subjected to varying degrees of gentle grain tumbling. The results showed that the combined treatments were more effective in reducing populations and disturbing growth and development of insect pests.

Jilani and (1987) reported that several indigenous plant materials have traditionally been used as stored grain protectant against insect pests in various parts of the world.

Sharma (1999) reported that neem seed (*A. indica*) kernel powder at 4% and neem leaf powder at 5% protected maize for 5 months against *Sitotroga cerealella, S. oryzae, R. domonica* and *T. granarium*. Neem oil (nimbicidine, 1%) was toxic to the adults of *S. cerealella, S. oryzae, R. dominica, T. granarium and T. castaneum.* Neem oil (nimbicidine, 2%) effective reduced the emergence of F_1 and F_2 progeny of the pests and completely protected maize up to a months and suggested that neem products can be mixed with stored maize to protect the grains up to 9 months from the attack of these major pests.

Miah *et al.* (1993) showed that nishinda (*V. negundo*) leaf powder was most effective in reducing egg number and adult emergence among several local plant materials in Bangladesh.

A paper presented by Prakash *et al*. (1993) at a national symposium held on January 1990 in India showed that only 7 products of 20 plants reduced adult populations significantly. These were neem seed oil followed by *Piper nigrum* seed powder, leaves of *V. negundo* leaves of *Andrographis paniculata*, dried mandarin fruit peel rhizome powder of turmeric and seed powder of *Cassia fistula* respectively.

Padmanaban *et al.* (1997) evaluated fresh leaves, dried leaves, dried leaf powder of N. negundo against second instar larvae of *C. chinensis* and reported that *Vitex* dried leaf powder were comparatively more effective than the other plant products after 30 days of application.

Ramesh *et al*. (2000) studied storage losses in unhusked rice in farmer's stores of district Kangra, Himachal Pradesh, India, during August 1998.A total of 180 samples collected from six blocks of the district were found to be infested with six species of insects, viz., angoumois grain moth, *Sitotroga cerealella,* rice weevil, *Sitophilus oryzae*, lesser grain borer, *Rhizopertha dominica,* rust red flour beetle, *Tribolium castaneum*, saw-toothed grain beetle, *Oryzaephilus surinamensis,* and rice moth, *Corcyra cephalonica*.The maximum infestation was 66.14 percent by *S. Oryzae* followed 23.53 percent by *T. castaneum*, 4.59 percent by *O. surinamensis*, 3.80 percent by *C. cephalonica*, !.14 percent by *S. cerealella* and 0.79 percent by *R. dominica*. On an average 18.09 percent weight losses due to insect feeding in stored grain.

Senguttuvan *et al.* (1995) evaluated a range of plant products against angoumois grain moth, *Sitotroga cerealella and Corcyra cephalonica* on the basis of % dry matter loss %

damaged kernels and pods. They observed that *V. negundo* leaf powder, neem leaf powder and neen oil were most effective than neem kernel powder in adult emerging.

Singh *et al.* (1988) evaluated six plant extracts against *R. dominica* in the laboratory, extracts of neem, *Azadirachta indica*, *Bassia longifolia* and *Pongamia glabra* were highly toxic. The crude extract of water hyacinth (*Eichorrnia rassipes*) was evaluated for its biological activity against the *S. cerealella, T. castanium, S. oryzae, Callosobruchus maculates* and *C. cephalonica*

2.10: Botanicals as Repellent

Several indigenous plant materials have traditionally been used as stored grain protectant against insect pest in various parts of the world.

Rahman *et al.* (2001) conducted a bio assay to evaluate the seed oils of neem (*A. indica*), castor (*Ricinus communis*), pithraj (*Aphanamixis polystachya*), safflower and sesame against *Alphitobius diaperinus* (Panzer). Adult insects were fed on wheat grains with the oils at concentrations of 1, 2, 4 and 5%. Insect mortality was recorded at 24, 48, 72 and 96 hours after treatment (HAT). All seed oils exhibited significant repellent property against *A. diaperinus* with repellency increasing with rate and exposure time. The highest mean repellency was recorded in 5% pithraj oil (86.69%).

Rahman *et al.* (1999) reported that the extracts of neem (*A. indica, A. juss*), urmoi (*Sapium sebiferum* L.) and turmeric (*Curcuma longa*. L.) were evaluated for their repellency against the Angoumois grain moth, *S. cerealella*, rice weevil, *S. oryzae* L. and the granary weevil, *Sitophilus granaries* L. in the laboratory. The results showed that 100, 75, 50 and 25mg/ml extracts of all the three plants had a repellent effect. Ethanol and acetone were found to be better solvents for extracting greater amounts of toxic component from seeds and rhizomes. Significant positive correlation was found between extracts concentration and insect response. Urmoi and neem were almost similar in their effectiveness. However, the potency of turmeric decreased more rapidly than that of neem and urmoi due to higher volatilization of the active components in turmeric.

Rahman (1998) evaluated the extracts and dust of Neem, Urmoi and Turmeric for their repellency, feeding deterrence, direct toxicity and residual effects against the weevil, *S. oryzae* and graion weevil *S. granaries*. The results showed that 100, 75, 50 and 25 mg/ml extracts of all the three plants had a repellent effect. Ethanol and acetone extracts were more effective than water extracts. The emergence of F_1 progeny, seed damage rate, percent weight loss and inhibition rate of two weevil species reduced significantly in almost all treatments compared to control.

Igantowicz and Wesolowska (1996) confirmed and compared the repellency of several plant powders against three species of stored product pest (*S. cerealella, C. chinensis, S*, *oryzae* and *S. granarius*) and reported that the powdered seed kernels of neem, *A. indica* were more effective as repellents than the powders of dry leaves and seed shells; they further reported that the repellency of neem products increased with the increase of the concentration of the product.

El-Lakwah *et al.* (1996) carried out a laboratory studies to investigate the effects of acetone and petroleum ether extracts of *Lantana camara* and *Nerium oleander* alone and in mixture with pirimiphos-methyl (7.5 – 20.0 mg/kg) and/or fenvalerate (0.3 -10 mg/kg) on the adult mortality (after 2, 3, 7, 14 and 21 days) progeny (after 60 days) of adults of *Rhyzopertha dominica*. Insect mortality increased with higher concentrations and longer exposure periods.

The repellency and toxicity of Azadirachtin and 3 neem extracts of stored product insects, *S. cerealella, Cryptolests ferrugineous, S oryzae* and *T. castaneum* were investigated by Xie *et al.* (1995), where *T. castaneum* was more sensitive to the repellent action of neem than the other 2 species.

Palaniswamy and Wise (1994) conducted an experiment in laboratory and field in the USA. Three neem–based formulations were tested to determine their repellent and feeding deterrent effects against *Phyllotreata cruciferae* on rape. At concentrations ranging from 0.05 to 12.00% a.i., Safer,s Neem insecticide (SNI)was more effective than RD-9 Repelin (a mixture of extracts of *P. pinnata, M. longifolia, Sesamum indicum* and *Ricimus communis*) for Margosan-O (azadirachtin) in decreasing plant damage through a higher mortality and repellency. RD-9 Repelin showed repellency for 1-2 days at 12% and for 6 hours at 1.2% concentration.

Mohiuddin *et al.* (1987) tested some plant extract for their repellency to the *Tribolium castaneum.* Seed extracts of neem, *Ocimum basilicum*, *Tagetes erecta*, *Momordica charantia*, celery and garlic were less repellent than *I. bijuga* oil but more repellent than oils from *Cuminum cyminum*, bottle gourd.

CHAPTER III

MATERIALS AND METHODS

The different sets of experiments on Angoumois grain moth, *Sitotroga cerealella* (Olivier) were conducted in the laboratory of the Department of Entomology of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from January to May, 2014.

3.1 Test insect and its collection

The study was conducted on the efficacy of commonly used botanicals for the management of Angoumois grain moth in different stored grains. The Angoumois grain moth is the most serious pest injurious to cereals like wheat and maize.

Angoumois grain moth can be a pest in the field to storage. It is sensitive to cold temperatures. The wingspan is 1/2 inch. The forewings are clay-yellow and without markings; the hind wings are gray. The rear edges of the forewings and hind wings are fringed. Adults do not need to feed. The female moths laid eggs anywhere such as bags, walls, grains etc. A single female can lay up to 200 eggs. The number of eggs is dependent on food, season, or temperature. Two or three larvae may develop on kernel of corn. The incubation period is about 5 days and the newly hatched larvae bore into the kernel. The larva remains inside the kernel until adult emergence. The larval period is about 3-5 weeks, the pupal periods about 10 days. Adults emerge through a small round hole in the kernel. Upon adult emergence, females move to a surface above the food to release the sex pheromone. Males are attracted to this pheromone for mating. Adults are generally short lived (about 7 days) are non feeding.

3.1.1 Test insect collection

Adults of Angoumois grain moths were collected along with the infested rice from farm’s store house of Sher-e-Bangla Agricultural University, Dhaka.

3.2 Stock culture of *S. cerealella* (Olivier)

The collected insects were maintained in the laboratory of Entomology Department, Sher-e-Bangla Agricultural University, Dhaka. Different stages of *S. cerealella* were reared in mass rearing chamber with wheat grain in the laboratory. Adult moths were separated from infested seeds and then transferred to another plastic container and released in fresh wheat and maize grains with the help of aspirator for multiplication.

Plate 1. Special mass rearing chamber for Angoumois grain moth

Plate 2. Aspirator for collection of *S. cerealella* from infested grain

3.3 Identification of Male and Female Moths

The male moth is smaller in size than the female moth. The females were on an average 5.5 mm long and 1.4 mm broad and the male was 5.0 mm long and 1.1 mm broad (Alam, 1971). The female had wider wing span than that of the male but fringed wings in both sexes. There was no distinct color differences of male and female moth. Both the male and female were straw colored.

3.4 Collection and preparation of Test Materials

Seeds of wheat and maize were collected from Agronomy field laboratory of Sher-e-Bangla Agricultural University, Dhaka in January’ 2014 to carry out the study. The seeds were cleaned, dried and salted out from damage unhealthy seeds and stored in large size poly bag with airtight condition to keep free from the insects and microorganisms.

3.5 Experiments and treatments

Petri dishes (1.0 cm height X 6 cm diameter) were used to set the experiment (Plate 3&5).In each Petridis 50 g wheat and maize seeds were taken and leaf dust of Lantana, Nishinda ,Tobacco, dust of Neem seed kernel and dust of Black pepper were mixed with Wheat and Maize grains respectively and Neem oil wettable cloth was placed on the Petri dishes.

Treatments

T_1 = Black pepper dust @ 5g/Kg on the upper layer of the grains

T_2 = Neem seed kernel dust @ 10g/Kg on the upper layer of the grains

T_3 = Tobacco leaves dust @ 7 g/Kg on the upper layer of the grains

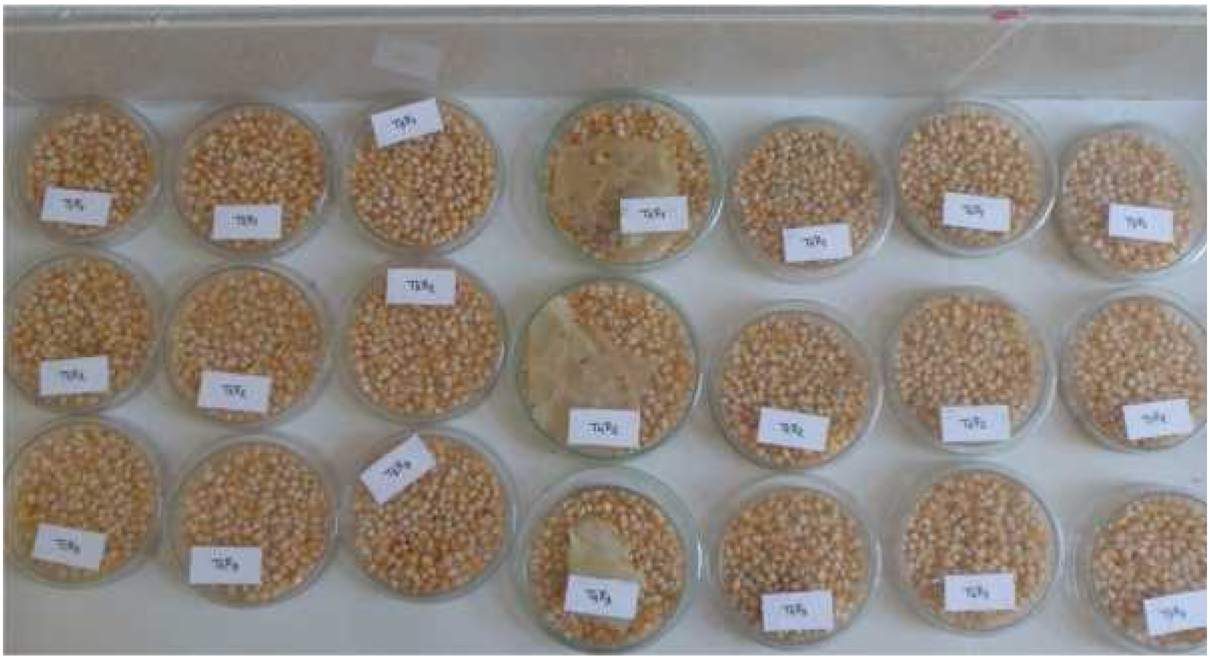
T_4 = Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of the grains

T_5 = Lantana Leaves dust @ 10 g/Kg on the upper layer of the grains

T_6 = Nishinda Leaves dust @ 10 g/Kg on the upper layer of the grains

T_7 = Untreated Control

A



B

Plate 3. A-Experimental set up of Wheat grains with botanicals and B-Experimental set up of Maize grains with botanicals

3.6 Plant materials

Lantana, Nishinda, Neem, Tobacco and Black pepper were used as the test plants.

3.6.1 Nishinda

Vitex negundo L. is an erect shrub in the Family Verbanaceae. Nishinda plant commonly name as five-leaved chaste tree, because its leaves are arranged in cluster as palm of human hand with five fingers. Locally it is known as Indrani, Nilpushpi, Samalu and its English name is Indian privali.

Morphology

Its leaves are digitate, with five lanceolate leaflets, sometimes three. Flower is white or blue in color, crowded in short cyme, forming erect and tapering panicles. The fruit is a succulent, drupe rounded to egg-shaped. It is black or purple when ripe.

Distribution

Plant grows in everywhere in Bangladesh and west Bengal especially in the Sundarban areas. It also thrives in Philippines, China, Korea, Indonesia, Japan and other Asian tropical and subtropical countries.

Uses

Nishinda is widely known for pharmaceutical use against a number of diseases. Every part of this plant is valuable. Leaf juice is used in asthma and cough. They can be burnt as fumigant against mosquitoes and other insects. Roots are well known to be tonic, febrifuge and expectorant. They are also used in dyspepsia, worms, leprosy, rheumatism and many other ailments. Flowers are used against diarrhea, cholera, liver diseases and cardiac difficulties. Fruits are crushed into pulps to use in relief of paralyses, limb-pain and weakness. Dried fruits are used for treatment of angina, cold, cough and rheumatic problems. However, the branches and leaves act as insect repellent so, being used for preserving stored grains against insect attack.

3.6.2 Black pepper

Piper nigrum is a perrenial flowering vine in the family Piperaceae.

Morphology

The leaves of pepper are petiolate, simple, alternate, oval and leathery. The leaves are dark green in upper and whitish green on the underside. Two or three pairs of opposite, lateral veins spring. The inflorescence is a flower spike that comes from the main stem node as opposed to the leaves. Flowers are greenish yellow, arranged in a spiral along the spine. The fruit is an oval drupe. They are green but they become yellow to red and finally black. Inside each fruit there is a seed, which occupies the largest volume of the fruit and cream in color.

Distribution

Black pepper is a tropical plant native to India and pepper production increased in Sri Lanka. In Bangladesh Chittagong hill tracts and Sylhet are pepper producing countries.

Uses

Black pepper is most widely used as condiments. Pepper is stated to be more toxic to housefly and also used as an insect repellant and moth killer.

Plate 4. Twigs of Nishinda

Plate 5. Dust of Nishinda leaves

Plate 6. Seeds dust of Black pepper **Plate 7. Seeds of Black pepper**

3.6.3 Neem

Azadirachta indica (Neem) is a tree in the family Meliaceae**.**

Morphology

Neem is a fast-growing, evergreen tree. The branches are wide and spreading. The opposite, pinnate long leaves with 20 to 31 medium to dark green leaflets .The terminal leaflet is often missing. The petioles are short. The flowers are white in color and fragrant. Protandrous, bisexual flowers and male flowers exist on the same individual tree. The fruit is a smooth (glabrous) olive-like drupe which varies in shape from elongate oval to nearly roundish and greenish yellow when ripe. Inside each fruit there is an elongated seeds (kernels) having a brown seed coat.

Distribution

Azadirachta is native to India, Pakistan and Bangladesh growing in tropical and sub-tropical regions.

Uses

All parts of neem are used for preparing many different medicines, especially for skin disease. Neem seed kernels are used to prevent insects in storage condition. Neem does not directly kill insects on the crop. It acts as an anti-feedant, repellent, and egg-laying deterrent, protecting the crop from damage.

Plate 8. Neem seed kernel

Plate 9. Dust of Neem seed kernel

Plate 10. Neem oil in jar

Plate 11. Neem oil wettable tissue

3.6.4 Tobacco

Nicotiana tabacum (Tobacco) is a shrub or small tree in the family Solanaceae. The tobacco plant is often called by its genus name, *Nicotiana.*

Morphology

The leaf shape can be ovate (egg-shaped), obcordate (heart-shaped) or elliptic (oval, but with a small point at one end). The leaves grow toward the base of the plant, and can be lobed or unlobed but are not separated into leaflets. On the stem, the leaves appear alternately, with one leaf per node along the stem. The leaves possess a distinct petiole. The underside of the leaf is fuzzy or hairy. The five flower petals are contained within a corolla and can be colored white, yellow, pink or red. The tobacco fruit consists of a capsule containing two seeds.

Distribution

World leading tobacco growing countries are China, USA, India, Brazil, Russia, Turkey, Itali, Greece, Japan, Canada etc. In Bangladesh tobacco growing countries are Rangpur, Kustia, Sylhet, Mymensingh, Dhaka, Faridpur etc.

Uses

Tobacco are used in producing Cigarettes , Hookah etc. Tobacco water is a traditional organic insecticide used in domestic gardening. Tobacco dust can be used for preserving stored grains against insect attacks.

3.6.5 Lantana

Lantana camara (Lantana) is an Evergreen shrub in the family Verbenaceae. It is also known as Red sage, Wild sage, Shrub Verbena,Yellow sage etc.

Morphology

Lantana is a fast growing tropical shrub. Leaves are Medium green, toothed, hairy and rough. Borne in opposite pairs or whorls of 3. Flowers are small, 5-lobed, salverform, grouped tightly into rounded, flattened or domed, terminal heads. Color choices range from white to yellow, pink, salmon-pink, red, purple or combinations of the colors above. Fruits are fleshy 2 seeded drupes turning from green to metallic blue when ripe;

Plate 12. Dry leaf of Tobacco

Plate 13. Dust of dry tobacco leaves

Plate 14. Twig of Lantana

Plate 15. Dust of Lantana leaves

green fruit is poisonous for animals and humans, ripe fruit is consumed by birds which spread the seeds.

Distribution

They are native to tropical regions of the Americas and Africa but exist as an introduced species in numerous areas, especially in the Australian-Pacific region.Lantana species are widely cultivated for their flowers in tropical and subtropical environments and in temperate climates.

Uses

Lantana leaves can display antimicrobial, fungicidal and insecticidal properties. Lantana has been grown specifically for use as an ornamental plant. Lantana dust can be used for preserving stored grains against insect attacks.

3.7 Preparation of Plant Dust

Fresh leaves of Nishinda and Lantana and neem seed kernel were collected from the campus of Sher-e-Bangla Agricultural University, Dhaka. The tobacco leaves, black pepper and neem oil used were purchased from the local market.

After collection, all fresh leaves of the plants were washed with water and kept in the shade up to 15 days for air-drying. The dried plant materials (leaf and seed/fruit) were then ground separately with electrical grinder and sieving through 0.66 mm diameter sieve to obtain fine powder. (plate- 5, 7, 9, 13 and 15). The powder was being preserved into plastic pot at low temperature till their uses.

Leaf dusts of tobacco, lantana, nishinda, dust of neem seed kernel and dust of black pepper were mixed with wheat and maize grains on the upper layer of seeds in each Petri dish at the rate of 7 g/kg, 10 g/kg, 10g/kg, 1ogm/kg and 5gm/kg respectively. Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) was placed on the upper layer of seeds in each Petri dish. . Afterwards 5 pairs of adult moth (male & female) were released in each Petri dish. There were 4 replications considering each petridish as a replication. Thus this study was made in three generation of these insects in separately. So in this experiment two more sets with 4 replications were taken for this study purpose. 1st set for 1st generation, 2nd set for 2nd generation and 3rd set for 3rd generation were observed respectively.

3.8 Adult Mortality and New Emergence

50 gm of insect free wheat and maize grains were taken into Petri dish separately. Each treatment was added in each Petri dish excluding control and mixed thoroughly. Then 5 pairs of newly emerged adult moths were released carefully into each Petri dish. Insect mortality was recorded at 24 hours intervals up to 3 days.

The Petri dish were observed from outside daily to examine death of released moths. The mortality of the adult was recorded against wheat and maize grains. After 24 – 28 days, new adults started emerging from those grains. The number of emerged Angoumois grain moth at different days from each treated Petri dish including control was recorded. The counting of emergent adult moths was made by opening the lid. After beginning, few moths came out from the Petri dish at first and the rest of them came out after gently shakings the Petri dish.

3.9 Observation on damage and weight loss of wheat and maize grains

When the emergence of the moths was completed the seeds were cleaned and the numbers of damaged and normal seeds were counted. Grains with hole were considered as damaged or infested seeds. To determine the percentage of damaged seeds, number of seeds having hole and normal seeds were counted per Petri dish or replicate and percentage of damaged seeds were calculated by using the following formula-

$$\% \text{ Infestation (by Number)} = \frac{\text{Number of infested seeds}}{\text{Total Number of seeds}} \times 100$$

The final weight of seeds was taken to obtain weight loss. Sieving and winnowing was done to clean the wheat and maize seeds. The clean seeds except those having holes in each Petri dish were weighted separately. The weight losses of wheat and maize seeds were found out by subtracting the final weight from the initial weight (50 gm). The weight losses were converted into percentage of weight loss of wheat and maize seeds respectively. From the above mentioned data, percentage of weight loss, percentage (%) of infested seeds (by weight), percentage reduction in infestation and percent protection of weight loss over control were calculated as follows:

$$\% \text{ Infestation (by weight)} = \frac{\text{Weight of infested seeds}}{\text{Total weight of seeds}} \times 100$$

$$\% \text{ Infestation reduction} = \frac{(\% \text{ Infestation in control} - \% \text{ Infestation in the concerned treatment})}{\% \text{ Infestation in control}} \times 100$$

$$\% \text{ Protection of loss due to treatment} = \frac{(\text{Loss in control} - \text{Loss in the concerned Treatment})}{\text{Loss in control}} \times 100$$

3.10 Observation of Repellency test

Repellency test were conducted according to the method of Talukder and Howse (1994) with slight modifications. A petri dish (9 cm) was divided into 3 parts, treated, untreated portion (3.5 cm each) and neutral centre portion (without grain) 2 cm (Plate 16).

Plate 16: Repellency test of botanicals of *S. cerealella* adult using treated wheat grains. The upper part of each Petri dish containing treated grains and lower part containing control (without treatment) & middle portion is neutral.

Ten grams of grains were taken in treated and untreated portion of Petri dishes. With the help of a pipette 1 ml solution of each treatment was applied on treated grain side portion and other untreated grain side portion. The treated portion was than air dried. Ten insects were released at the center portion of each Petri dish and a cover was placed on the Petri dish. For each treatment, four replications were used. Then the insect present on each portion (treated and untreated) were counted at hourly intervals up to fifth hour (Plate 16). The data were expressed as percentage repulsion (PR %) by the following formula as described by Talukder and Howse (1994).

PR (%) = (NC – 50) × 2

Where,

NC = The percentage of insect present in the control half. Position (+) values expressed repellency and negative values express attractions. Data (PR %) was analyzed using analysis of variance (ANOVA) after transforming them into percentage. The average values were then categorized according to the following classes (McDonald *et al.* 1970).

Class	Repellency rate (%)
0	>0.01 to 0.1
I	0.1 to 20.0
II	20.1 to 40.0
III	40.1 to 60.0
IV	60.1 to 80.0
V	80.1 to 100.0

3.11 Statistical Analysis

The observed data were statistically analyzed by Completely Randomized Design (CRD). Mean values were adjusted by Duncan's Multiple Range Test (DMRT) (Duncan, 1951). All statistical analysis were done through a package program namely Microsoft Statistical (MSTAT) Program in a computer.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the efficacy of commonly used botanicals for the management of Angoumois grain moth, *Sitotroga cerealella* (Olivier) in different stored grains. The results have been presented and discussed below under the following headings:

4.1 Efficacy of botanicals on Angoumois grain moth on wheat grains

4.1.1 Number of dead insects

Cumulative number of dead insects after 24, 48 and 72 hours showed statistically significant variation for commonly used botanicals for the management of Angoumois grain moth in stored wheat grains (Table 1).

After 24 hours of application the highest number of dead insects (9.75) were recorded in T_4 treatment (Neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of wheat grains) which was close to T_3 (7.00) treatment (Tobacco leaves dust @ 7g/Kg on the upper layer of wheat grains) whereas the lowest number of dead insects (3.00) were recorded from T_5 (Lantana Leaves dust @ 10 g/Kg on the upper layer of wheat grains) treatment which was higher than T_1 (Black pepper dust @ 5gmKg on the upper layer of wheat grains), T_2 (Neem seed kernel dust @ 10g/Kg on the upper layer of wheat grains) and T_6 (Nishinda Leaves dust @ 10 g/Kg on the upper layer of wheat grains) treatments (4.75, 5.00 and 4.75) respectively. On the other hand, no dead insects were found in T_7 (untreated control) treatment. After 48 hours the cumulative highest numbers of dead insects were observed in T_4 (10.00) treatment which was closely followed by T_3 (8.75) treatment whereas no dead insects were found in T_7 treatment. T_1 (6.50), T_2 (6.50), T_5 (5.25) and T_6 (6.00) treatments were statistically similar in respect of number of dead insects (Table 1). After 72 hours of treatment the cumulative highest number of dead insects were found in T_4 (10.00) treatment which was statistically identical to T_3 (9.50) treatment and close to T_1 (7.75), T_2 (7.50), T_5 (7.00) and T_6 (7.50) treatments respectively, whereas there were no dead insects were recorded in T_7 treatment.

4.1.2 Insect Mortality

Insect mortality showed statistically significant variation for commonly used botanicals to the management of Angoumois grain moth in stored wheat grains (Figure 1). The highest mortality (100.00%) was observed in T_4 treatment which was statistically identical (95.00%) with T_3 treatment and closely followed by T_1 (77.50%) treatment which was statistically identical with T_2 (75.00%), T_5 (70.00%) and T_6 (75.00%) treatments respectively, while there was no mortality recorded in T_7 treatment which was (0.00%).

Table 1. Number of dead Angoumois grain moth after different times treatment of botanicals in stored grains of wheat

*Treatment(s)	No. of dead insects after		
	24 hours	48 Hours	72 Hours
T_1	4.75 c	6.50 c	7.75 b
T_2	5.00 c	6.50 c	7.50 b
T_3	7.00 b	8.75 b	9.50 a
T_4	9.75 a	10.00 a	10.00 a
T_5	3.00 d	5.25 c	7.00 b
T_6	4.75 c	6.00 c	7.50 b
T_7	0.00 e	0.00 d	0.00 c
$LSD_{(0.01)}$	1.255	1.196	1.048
Level of Significance	0.01	0.01	0.01
CV(%)	12.81	9.73	7.44

In a column means having similar letter are statistically identical and those having dissimilar letter differ significantly as per 0.01 level of probability and numeric data represents the mean value of 4 replications.

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains, T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains, T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains, T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper (20×20 cm^2) on the upper layer of the grains, T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains, T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains and T_7: Untreated control

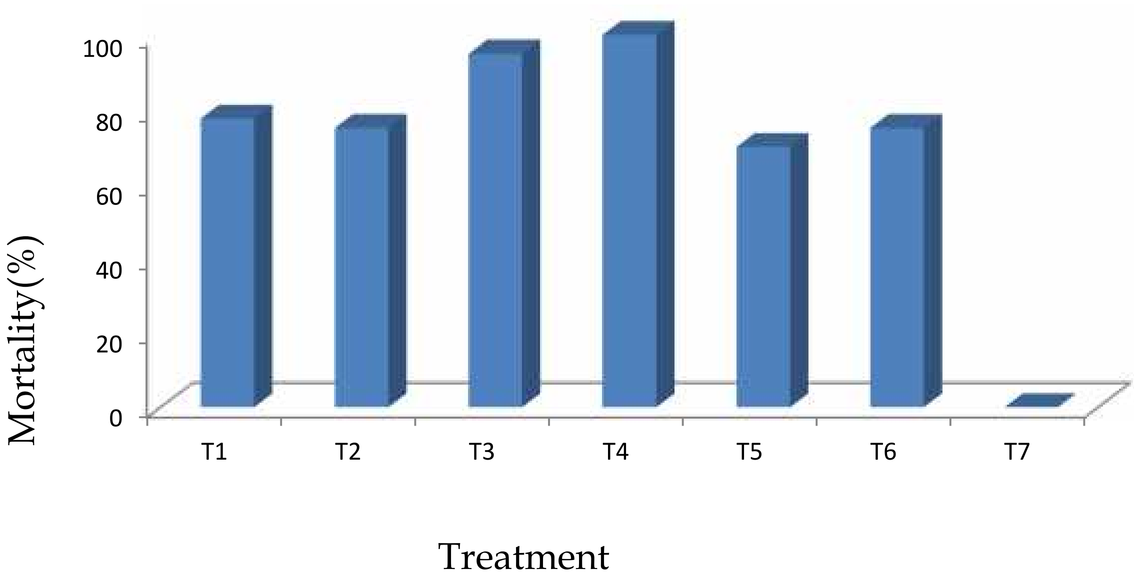


Figure 1. Effects of commonly used botanicals for percentage of mortality of Angoumois grain moth in wheat grains

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains

T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains

T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains

T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper (20×20 cm^2) on the upper layer of the grains

T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains

T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains

T_7: Untreated control

4.1.3 Adult emergence

Adults emerged in 1st and 2nd generation varied significantly for the application of commonly used botanicals to the management of Angoumois grain moth in stored grains of wheat (Table 2).

In 1st generation no adults emerged in T_3 and T_4 treatments respectively, while the highest number of adults were recorded in T_7 (43.75) treatment which was close to T_6 (39.75) treatment. At 2nd generation there were no emerged adults were recorded in T_3 and T_4 treatments respectively, while the highest adult was recorded in T_7 (89.25) treatment which was close to T_5 (88.00) and T_6 (84.00) treatments respectively. In case of total adult emergence for 1st and 2nd generation together no adults emerged in T_3 and T_4 treatments respectively, while the highest adult was recorded in T_7 (133.00) treatment which was close to T_5 (122.50) and T_6 (123.75) treatments respectively.

4.1.4 Status of seeds in 1st and 2nd generation by weight and number

Status of seeds in terms of healthy and infested by weight and number showed statistically significant variation (Table 3 to Table 6) under the present trial for commonly used botanicals to the management of Angoumois grain moth in stored grains of wheat.

Table 2. Adult emergence of Angoumois grain moth in 1st and 2nd generation in stored grains of wheat after botanical application

*Treatment(s)	Adult emerged (No.) in	
	1st generation	2nd generation
T_1	19.50 d	78.50 c
T_2	27.75 c	82.25 bc
T_3	0.00 e	0.00 d
T_4	0.00 e	0.00 d
T_5	34.50 b	88.00 ab
T_6	39.75 ab	84.00 abc
T_7	43.75 a	89.25 a
$LSD_{(0.01)}$	5.633	5.771
Level of Significance	0.01	0.01
CV(%)	11.92	4.78

In a column means having similar letter are statistically identical and those having dissimilar letter differ significantly as per 0.01 level of probability and numeric data represents the mean value of 4 replications.

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains

T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains

T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains

T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper (20×20 cm^2) on the upper layer of the grains

T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains

T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains

T_7: Untreated control

4.1.4.1 Study of 1^{st} generation of *S. cerealella*

In 1^{st} generation on weight basis, the highest weight of healthy seeds were recorded in T_3 (50.00 gm) and T_4 (50.00 gm) treatments respectively, which were close to T_2 (45.05 gm) and T_6 (44.78 gm) treatments respectively, whereas lowest was observed in T_7 (36.52 gm) treatment which was closely followed by T_1 (41.74 gm) treatment. In case of infested seeds, there were no infested seeds were recorded from T_3 and T_4 treatments respectively, which were statistically different from all other treatments. The highest weight of infested seeds were observed in T_7 (10.73 gm) treatment which was close to T_1 (5.52 gm) treatment. In case of % infestation, the highest infestation was recorded from T_7 (22.71%) treatment which was statistically different from all other treatments while no infestation was recorded in T_3 and T_4 treatments respectively. The highest infestation reduction over control was recorded in T_3 (100.00%) and T_4 (100.00%) treatments respectively and lowest was found from T_1 (48.57%) treatment (Table 3).

In 1^{st} generation by number, the highest number of healthy seeds were recorded in T_3 (1379.50) and T_4 (1379.00) treatments respectively, which were close to T_2 (1262.25) treatment, whereas lowest was recorded in T_7 (1022.00) untreated control treatment which was close to T_1 (1128.25) treatment. In case of infested seeds, there were no infested seeds obtained from T_3 and T_4 treatments respectively, which were statistically different from all other treatments. The highest number of infested seeds were recorded in T_7 (356.25) treatment which was statistically different from all other treatments. In case of % infestation, the highest infestation was found from T_7 (25.85%) treatment which was statistically different from all other treatments while no infestation was recorded in T_3 and T_4 treatments respectively. The highest infestation reduction over control was recorded in T_3 (100.00%) and T_4 (100.00%) treatments respectively and lowest was observed from T_1 (29.67%) treatment (Table 4).

Table 3. Percentage of stored wheat seed infestation on weight basis by Angoumois grain moth after application of botanicals in 1st generation

*Treatment(s)	Total weight of seeds		Infestation (%)	Infestation reduction over control (%)
	Healthy (g)	Infested (g)		
T_1	41.74 d	5.52 b	11.68 b	48.57
T_2	45.05 b	2.74 d	5.73 d	74.77
T_3	50.00 a	0.00 e	0.00 e	100.00
T_4	50.00 a	0.00 e	0.00 e	100.00
T_5	44.27 c	2.92 c	6.18 c	72.79
T_6	44.78 b	2.88 c	6.03 c	73.45
T_7	36.52 e	10.73 a	22.71 a	--
$LSD_{(0.01)}$	0.448	0.090	0.190	--
Significance level	0.01	0.01	0.01	--
CV (%)	3.50	5.36	3.25	--

In a column means having similar letter are statistically identical and those having dissimilar letter differ significantly as per 0.01 level of probability and numeric data represents the mean value of 4 replications.

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains

T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains

T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains

T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper (20×20 cm^2) on the upper layer of the grains

T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains

T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains

T_7: Untreated control

Table 4. Percentage of stored wheat seed infestation on number basis by Angoumois grain moth after application of botanicals in 1st generation

*Treatment(s)	Total number of seeds		Infestation (%)	Infestation reduction over control (%)
	Healthy (No.)	Infested (No.)		
T_1	1128.25 d	250.75 b	18.18 b	29.67
T_2	1262.25 b	115.50 d	8.38 d	67.58
T_3	1379.50 a	0.00 e	0.00 e	100.00
T_4	1379.00 a	0.00 e	0.00 e	100.00
T_5	1254.75 c	124.00 c	8.99 c	65.22
T_6	1256.75 c	122.50 c	8.88 c	65.65
T_7	1022.00 e	356.25 a	25.85 a	--
$LSD_{(0.01)}$	4.325	3.746	0.253	--
Significance level	0.01	0.01	0.01	--
CV (%)	4.17	3.35	4.25	--

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.01 level of probability and numeric data represents the mean value of 4 replications.

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains

T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains

T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains

T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper (20×20 cm^2) on the upper layer of the grains

T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains

T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains

T_7: Untreated

4.1.4.2 Study of 2nd generation of *S. cerealella*

In 2nd generation by weight basis, the highest weight of healthy seeds were recorded in T_3 (50.00 gm) and T_4 (50.00 gm) treatments respectively, whereas no healthy seeds were recorded from T_7 (0.00 gm) treatment which was statistically identical with T_1 (0.00 gm), T_2 (0.00 gm), T_5 (0.00 gm) and T_6 (0.00 gm) treatments respectively. In case of infested seeds, there were no infested seeds were recorded from T_3 and T_4 treatments respectively, whereas highest (37.35 gm) was recorded in T_5 treatment which was statistically identical with T_2 (37.25g) treatment and close to T_1 (34.28 gm), T_6 (34.22 gm) and T_7 (32.08 gm) treatments respectively. In case of % infestation, no infestation was attained in T_3 and T_4 treatments respectively, whereas the highest (100%) infestation was found from T_7 treatment which was statistically identical with T_1, T_2, T_5 and T_6 treatments respectively. The highest infestation reduction over control was recorded in T_3 (100.00%) and T_4 (100.00%) treatments respectively and no infestation reduction over control was recorded from T_1 (0.00%), T_2 (0.00%), T_5 (0.00%) and T_6 (0.00%) treatments respectively (Table 5).

In 2nd generation in number, the highest number of healthy seeds were recorded in T_3 (1379.50) and T_4 (1379.25) treatments respectively, whereas no healthy seeds were recorded from T_7 (0.00) treatment which was statistically similar at T_1 (0.00), T_2 (0.00), T_5 (0.00) and T_6 (0.00) treatments respectively. In case of infested seeds, there were no infested seeds were recorded from T_3 and T_4 treatments respectively, whereas the highest number of infested seeds (1379.25) were recorded in T_2 treatment which was statistically identical with T_1, T_5, T_6 and T_7 treatments respectively. In case of % infestation, the highest (100%) infestation was found from T_7 treatment which was statistically identical with T_1, T_2, T_5 and T_6 treatments respectively, whereas no infestation was attained in T_3 and T_4 treatments respectively. The highest infestation reduction over control was recorded in T_3 (100.00%) and T_4 (100.00%) treatments respectively and no infestation reduction over control was recorded from T_1 (0.00%), T_2 (0.00%), T_5 (0.00%) and T_6 (0.00%) treatments respectively (Table 6).

Table 5. Percentage of stored wheat seed infestation on weight basis by Angoumois grain moth after application of botanicals in 2nd generation

*Treatment(s)	Total weight of seeds		Infestation (%)	Infestation reduction over control (%)
	Healthy (g)	Infested (g)		
T_1	0.00 b	34.28 b	100.00 a	0.00
T_2	0.00 b	37.25 a	100.00 a	0.00
T_3	50.00 a	0.00 d	0.00 b	100.00
T_4	50.00 a	0.00 d	0.00 b	100.00
T_5	0.00 b	37.35 a	100.00 a	0.00
T_6	0.00 b	34.22 b	100.00 a	0.00
T_7	0.00 b	32.08 c	100.00 a	--
$LSD_{(0.01)}$	0.020	0.385	0.020	--
Significance level	0.01	0.01	0.01	--
CV (%)	5.00	3.77	3.00	--

In a column means having similar letter are statistically identical and those having dissimilar letter differ significantly as per 0.01 level of probability and numeric data represents the mean value of 4 replications.

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains

T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains

T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains

T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper (20×20 cm^2) on the upper layer of the grains

T_5: Lantana leaves dust @ 10 g/kg on the upper layer of grain

T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of grain

T_7: Untreated control

Table 6. Percentage of stored wheat seed infestation on number basis by Angoumois grain moth after application of botanicals in 2nd generation

*Treatment(s)	Total number of seeds		Infestation (%)	Infestation reduction over control (%)
	Healthy (No.)	Infested (No.)		
T_1	0.00 b	1378.25 a	100.00 a	0.00
T_2	0.00 b	1379.25 a	100.00 a	0.00
T_3	1379.50 a	0.00 b	0.00 b	100.00
T_4	1379.25 a	0.00 b	0.00 b	100.00
T_5	0.0 b	1377.75 a	100.00 a	0.00
T_6	0.0 b	1377.75 a	100.00 a	0.00
T_7	0.0 b	1378.00 a	100.00 a	--
$LSD_{(0.01)}$	2.538	4.845	0.020	--
Significance level	0.01	0.01	0.01	--
CV (%)	2.32	4.25	3.00	--

In a column means having similar letter are statistically identical and those having dissimilar letter differ significantly as per 0.01 level of probability and numeric data represents the mean value of 4 replications.

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains

T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains

T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains

T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper (20×20 cm^2) on the upper layer of the grains

T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains

T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains

T_7: Untreated control

Plate 17. Healthy Wheat grains after 2nd generation

Plate 18. Infested Wheat grains after 2nd generation

Plate 19. Infested Wheat grains with hole

Plate 20. Infested Wheat grains with larva

4.1.5 Weight loss

In 1st generation in case of weight loss, no weight loss was observed in T_3 (0.00%) and T_4 (0.00%) treatments respectively, whereas the highest weight loss was recorded in T_5 (5.63%) treatment which was statistically identical to T_1 (5.47%), T_6 (4.70%) and T_7 (5.51%) treatments followed by T_6 (4.70%) and less in T_2 (4.43%) treatment. In 2nd generation in case of weight loss, the highest weight loss was found in T_7 (35.85%) treatment which was statistically different from all other treatments (Table 7).

Table 7. Effect of commonly used botanicals on weight loss of stored grains of wheat at different generations of Angoumois grain moth

*Treatment(s)	Weight loss (%)	
	1st generation	2nd generation
T_1	5.47 a	31.45 b
T_2	4.43 b	25.50 c
T_3	0.00 c	0.00 d
T_4	0.00 c	0.00 d
T_5	5.63 a	25.30 c
T_6	4.70 ab	31.55 b
T_7	5.51 a	35.85 a
$LSD_{(0.05)}$	0.948	0.773
Level of Significance	0.01	0.01
CV(%)	12.88	4.81

In a column means having similar letter are statistically identical and those having dissimilar letter differ significantly as per 0.01 level of probability and numeric data represents the mean value of 4 replications.

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains, T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains,T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains, T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper (20×20 cm^2) on the upper layer of the grains,T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains, T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains, and T_7: Untreated control

4.1.6 Repellency effect

Repellency effect showed statistically significant variation for commonly used botanicals to the management of Angoumois grain moth in stored grains of wheat (Figure 2).

In case of repellency effect after 1 hour of treatment application the highest repellency rate was found from T_3 (90.00%) and T_4 (90.00%) treatments respectively, which was close to T_2 (50.00%) treatment whereas the lowest repellency rate was recorded in T_1 (20.00%) treatment which was closely followed by T_5 (30.00%). After 2 hours of treatment application the highest repellency rate was observed from T_3 (90.00%) and T_4 (90.00%) treatments respectively, which were statistically different from all other treatments. After 3 hours of treatment application the highest repellency rate was observed from T_3 (100.00%) treatment which was statistically identical with T_4 (100.00%) and T_6 (100.00%) treatments respectively and similar trends of results were observed after 4 and 5 hours of treatment application.

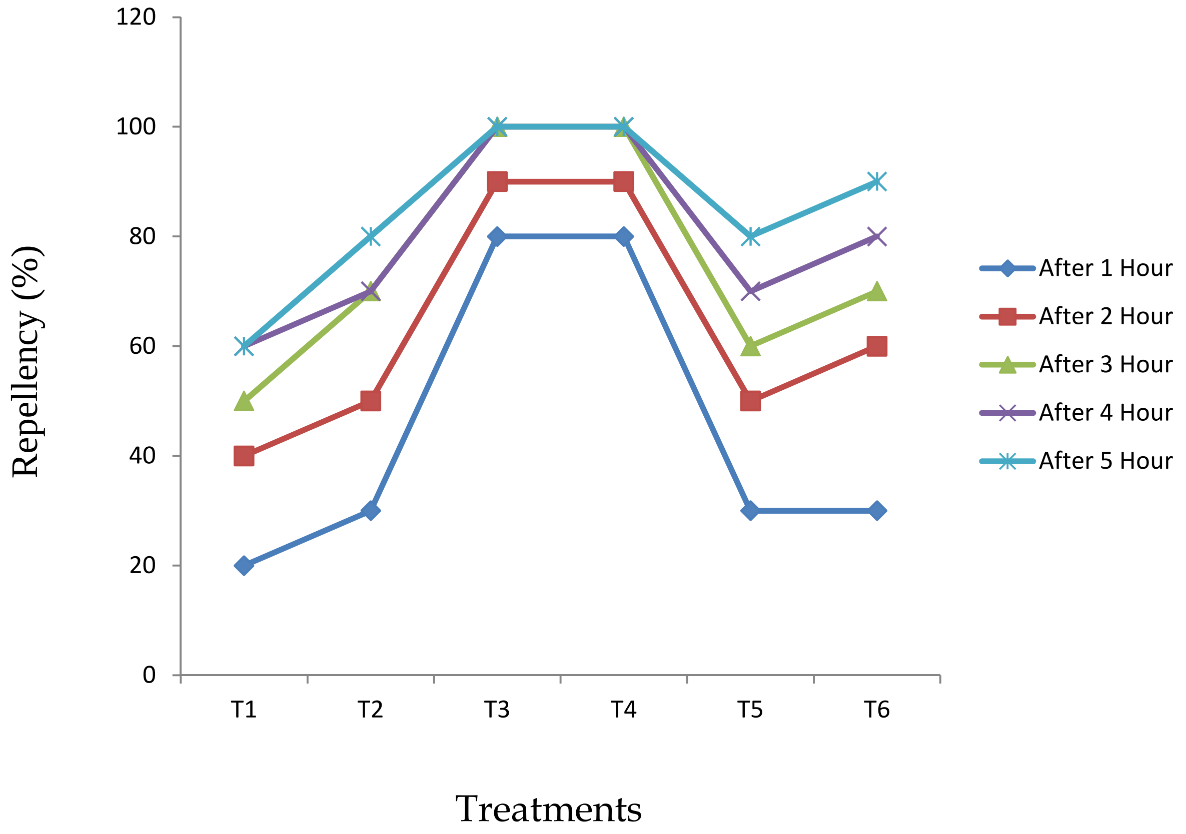


Figure 2. Repellency effect of commonly used botanicals on stored grains of wheat at different hours after treatment

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains

T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains

T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains

T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper (20×20 cm^2) on the upper layer of the grains

T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains

T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains

T_7: Untreated control

4.2 Efficacy of botanicals on Angoumois grain moth on maize grains

4.2.1 Number of dead insects

Cumulative number of dead insects after 24, 48 and 72 hours showed statistically significant variation for commonly used botanicals to the management of Angoumois grain moth in stored grains of maize (Table 8).

After 24 hours of application the highest number of dead insects (8.00) were recorded in T_4 treatment (Neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of maize grains) which was statistically different from all other treatments. On the other hand, no dead insects were found in T_7 (untreated control) treatment. After 48 hours the cumulative the highest numbers of dead insects were observed in T_4 (9.75) treatment which was statistically identical with T_3 (8.25) and T_5 (7.75) treatments respectively and close to T_1 (7.00) treatment which was statistically identical with T_2 (7.25) and T_6 (7.00) treatments respectively, whereas there were no dead insects in T_7 treatment (Table 9). After 72 hours of treatment the cumulative highest number of dead insects were found in T_4 (10.00) treatment which was statistically identical with all other treatments and close to T_1 (8.00) treatment while there were no dead insects in T_7 treatment.

4.2.2 Insect Mortality

Insect mortality showed statistically significant variation for commonly used botanicals to the management of Angoumois grain moth in stored grains of maize (Figure 03). The highest mortality (100.00%) was observed in T_4 treatment which was statistically identical with T_2 (82.50%), T_3 (97.50%), T_5 (87.50%) and T_6 (82.50%) treatments respectively and closely followed by T_1 (80.00%) treatment while there was no mortality recorded in T_7 treatment which was (0.00%).

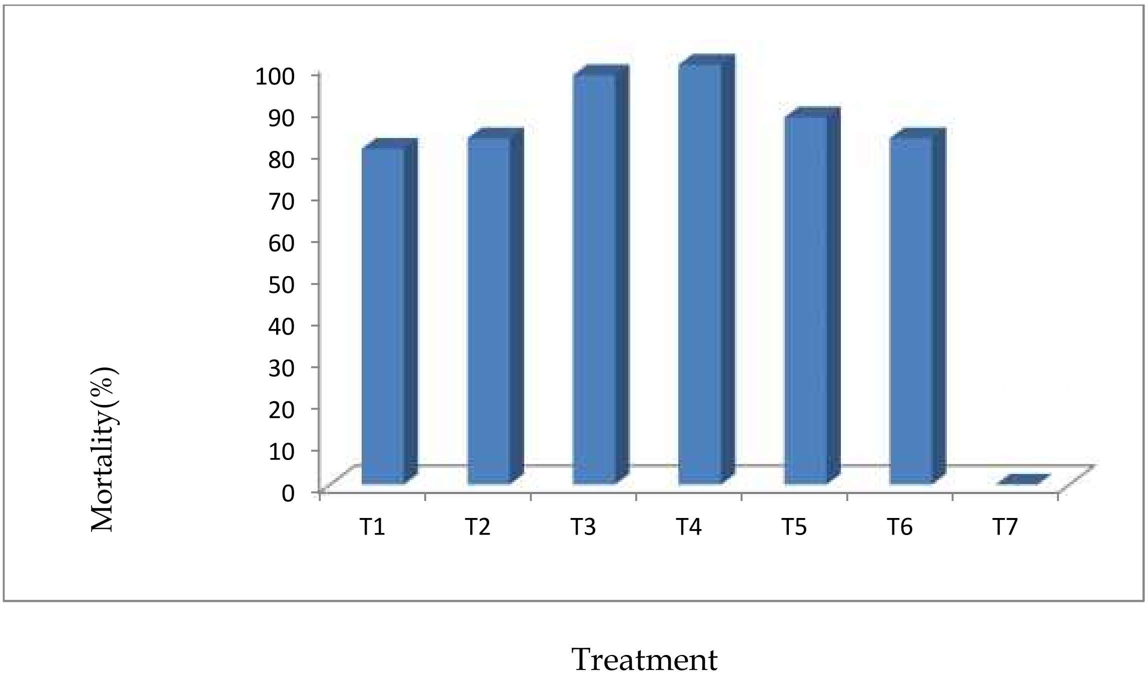


Figure 3 . Effect of commonly used Botanicals for percentage of mortality of Angoumois grain moth in maize grains

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains

T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains

T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains

T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper (20×20 cm^2) on the upper layer of the grains

T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains

T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains

T_7: Untreated control

Table 8. Number of dead Angoumois grain moth after different times treatment of botanicals in stored grains of maize

*Treatment(s)	No. of dead insects after		
	24 hours	48 Hours	72 Hours
T_1	4.25 b	7.00 b	8.00 b
T_2	5.50 b	7.25 b	8.25 ab
T_3	5.25 b	8.25 ab	9.75 ab
T_4	8.00 a	9.75 a	10.00 a
T_5	3.75 b	7.75 ab	8.75 ab
T_6	4.00 b	7.00 b	8.25 ab
T_7	0.00 c	0.00 c	0.00 c
$LSD_{(0.01)}$	2.106	2.184	1.802
Level of Significance	0.01	0.01	0.01
CV(%)	23.95	16.25	11.88

In a column means having similar letter are statistically identical and those having dissimilar letter differ significantly as per 0.01 level of probability and numeric data represents the mean value of 4 replications.

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains

T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains

T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains

T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper/cloth (20×20 cm^2) on the upper layer of the grains

T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains

T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains

T_7: Untreated control

4.2.3 Adult emergence

Adults emerged in 1st, 2nd and 3rd generation varied significantly for the application of commonly used botanicals to the management of Angoumois grain moth in stored grains of maize (Table 9).

In 1st generation no adults emerged in T_3 and T_4 treatments respectively, while the highest number of adults were recorded in T_7 (9.50) treatment which was close to T_1 (7.50) treatment which was statistically identical with T_5 (6.25) and T_6 (7.25) treatments respectively. In 2nd generation there were no emerged adults were recorded in T_3 and T_4 treatments respectively, while the highest adult was recorded in T_7 (14.00) treatment which was statistically identical with T_2 (11.50) and T_6 (12.75) treatments respectively. At 3rd generation there were no emerged adults were recorded in T_3 and T_4 treatments respectively, while the highest adult was recorded in T_7 (23.00) treatment which was statistically different from all other treatments and statistically identical with T_5 (19.00) treatments. In case of total adult emergence for 1st, 2nd and 3rd generation no adults emerged in T_3 and T_4 treatments respectively, while the highest adult was recorded in T_7 (46.50) treatment which was statistically different from all other treatments.

4.2.4 Status of seeds in 1st, 2nd and 3rd generation by weight and number

Status of seeds in terms of healthy and infested by weight and number showed statistically significant variation under the present trial for commonly used botanicals to the management of Angoumois grain moth in stored grains of maize.

Plate 21. Healthy Maize grains

Plate 22. Infested Maize grains

Plate 23. Infested Maize grains with hole

Table 9. Adult emergence of Angoumois grain moth in 1st, 2nd and 3rd generation in stored grains of maize after botanical application

*Treatment(s)	Adult emerged (No.) in		
	1st generation	2nd generation	3rd generation
T_1	7.50 b	9.00 c	18.25 b
T_2	4.50 c	11.50 abc	14.25 b
T_3	0.00 d	0.00 d	0.00 c
T_4	0.00 d	0.00 d	0.00 c
T_5	6.25 bc	11.00 bc	19.00 ab
T_6	7.25 b	12.75 ab	15.75 b
T_7	9.50 a	14.00 a	23.00 a
$LSD_{(0.01)}$	1.978	2.462	4.461
Level of Significance	0.01	0.01	0.01
CV(%)	19.76	14.78	17.28

In a column means having similar letter are statistically identical and those having dissimilar letter differ significantly as per 0.01 level of probability and numeric data represents the mean value of 4 replications.

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains ,T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains, T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains, T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper (20×20 cm^2) on the upper layer of the grains, T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains , T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains and T_7: Untreated control

4.2.4.1 Study of 1^{st} generation of *S. cerealella*

In 1^{st} generation in weight basis, the highest weight of healthy seeds were recorded in T_3 (50.00 gm) and T_4 (50.00 gm) treatments respectively, which were close to T_2 (38.94 gm) treatment whereas lowest was observed in T_7 (23.25 gm) treatment and close to T_6 (35.38gm) treatment which was statistically identical with T_5 (35.25gm) treatment. In case of infested seeds, there were no infested seeds were recorded from T_3 and T_4 treatments respectively and the highest was observed in T_7 (21.67 gm) treatment which was statistically different from all other treatments. In case of % infestation, no infestation was recorded in T_3 and T_4 treatments respectively, while the highest infestation was recorded from T_7 (48.25%) which was statistically different from all other treatments. The highest infestation reduction over control was recorded in T_3 (100.00%) and T_4 (100.00%) treatments respectively and lowest was found from T_5 (41.99%) treatment (Table 10).

In 1^{st} generation by number, the highest number of healthy seeds were recorded in T_3 (367.00) and T_4 (367.50) treatments respectively, which were close to T_2 (266.25), whereas lowest was recorded in T_7 (155.00) treatment which was statistically different from all other treatments. In case of infested seeds, there were no infested seeds were obtained from T_3 and T_4 treatments respectively and the highest number was recorded in T_7 (212.50) treatment which was statistically different from all other treatments. In case of % infestation, no infestation was recorded in T_3 and T_4 treatments respectively and the highest infestation was found from T_7 (57.82%) which was statistically different from all other treatments. The highest infestation reduction over control was recorded in T_3 (100.00%) and T_4 (100.00%) treatments respectively and lowest was observed from T_5 (37.43%) treatment (Table11).

Table 10. Percentage of stored maize seed infestation on weight basis by Angoumois grain moth after application of botanicals in 1st generation

*Treatment(s)	Total weight of seeds		Infestation (%)	Infestation reduction over control (%)
	Healthy (g)	Infested (g)		
T_1	36.75 c	12.65 c	25.61 c	46.92
T_2	38.94 b	9.82 d	20.14 d	58.26
T_3	50.00 a	0.00 e	0.00 e	100.00
T_4	50.00 a	0.00 e	0.00 e	100.00
T_5	35.25 d	13.70 b	27.99 b	41.99
T_6	35.38 d	13.52 b	27.66 b	42.67
T_7	23.25 e	21.67 a	48.25 a	--
$LSD_{(0.01)}$	0.317	0.514	0.859	--
Significance level	0.01	0.01	0.01	--
CV (%)	4.41	2.53	2.01	--

In a column means having similar letter are statistically identical and those having dissimilar letter differ significantly as per 0.01 level of probability and numeric data represents the mean value of 4 replications.

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains

T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains

T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains

T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper (20×20 cm^2) on the upper layer of the grains

T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains

T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains

T_7: Untreated control

Table 11. Percentage of stored maize seed infestation on number basis by Angoumois grain moth after application of botanicals in 1st generation

*Treatment(s)	Total number of seeds		Infestation (%)	Infestation reduction over control (%)
	Healthy (No.)	Infested (No.)		
T_1	245.00 c	122.50 c	33.33 c	42.36
T_2	266.25 b	102.00 d	27.70 d	52.09
T_3	367.00 a	0.00 e	0.00 e	100.00
T_4	367.50 a	0.00 e	0.00 e	100.00
T_5	235.00 d	133.25 b	36.18 b	37.43
T_6	235.25 d	133.00 b	36.12 b	37.53
T_7	155.00 e	212.50 a	57.82 a	--
$LSD_{(0.01)}$	2.639	2.648	0.434	--
Significance level	0.01	0.01	0.01	--
CV (%)	4.49	3.32	5.80	--

In a column means having similar letter are statistically identical and those having dissimilar letter differ significantly as per 0.01 level of probability and numeric data represents the mean value of 4 replications.

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains

T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains

T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains

T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper (20×20 cm^2) on the upper layer of the grains

T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains

T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains

T_7: Untreated control

4.2.4.2 Study of 2^{nd} generation of *S. cerealella*

In 2^{nd} generation in weight basis, the highest weight of healthy seeds were recorded in T_3 (50.00 gm) and T_4 (50.00 gm) treatments respectively, which were close to T_5 (33.08 gm) and T_6 (33.04 gm) treatments respectively, whereas lowest was observed in T_7 (19.99 gm) treatment which was statistically different from all other treatments. In case of infested seeds, there were no infested seeds were recorded from T_3 and T_4 treatments respectively and the highest was observed in T_7 (24.20 gm) treatment which was statistically different from all other treatments. In case of % infestation, no infestation was recorded in T_3 and T_4 treatment while the highest infestation was recorded from T_7 (54.77%) which was statistically different from all other treatments. The highest infestation reduction over control was recorded in T_3 (100.00%) and T_4 (100.00%) treatments respectively and lowest was found from T_2 (32.23%) treatment (Table 12).

In 2^{nd} generation by number, the highest number of healthy seeds were recorded in T_3 (367.75) and T_4 (367.50) treatments respectively, which were close to T_5 (220.50) and T_6 (220.25) treatments respectively, whereas lowest was recorded in T_7 (133.25) treatment which was statistically different from all other treatments. In case of infested seeds, there were no infested seeds were obtained from T_3 and T_4 treatments respectively and the highest number was recorded in T_7 (234.50) treatment which was statistically different from all other treatments. In case of % infestation, no infestation was recorded in T_3 and T_4 treatments respectively, while the highest infestation was found from T_7 (63.77%) which was statistically different from all other treatments. The highest infestation reduction over control was recorded in T_3 (100.00%) and T_4 (100.00%) treatments respectively and lowest was observed from T_2 (27.83%) treatment (Table 13).

Table 12. Percentage of stored wheat seed infestation on weight basis by Angoumois grain moth after application of botanicals in 2nd generation

*Treatment(s)	Total weight of seeds		Infestation (%)	Infestation reduction over control (%)
	Healthy (g)	Infested (g)		
T_1	30.26 c	17.13 c	36.14 c	34.01
T_2	29.77 d	17.58 b	37.12 b	32.23
T_3	50.00 a	0.00 e	0.00 e	100.00
T_4	50.00 a	0.00 e	0.00 e	100.00
T_5	33.08 b	15.18 d	31.45 d	42.58
T_6	33.04 b	15.30 d	31.65 d	42.21
T_7	19.99 e	24.20 a	54.77 a	--
$LSD_{(0.01)}$	0.474	0.358	0.778	--
Significance level	0.01	0.01	0.01	--
CV (%)	3.67	5.39	6.42	--

In a column means having similar letter are statistically identical and those having dissimilar letter differ significantly as per 0.01 level of probability and numeric data represents the mean value of 4 replications.

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains
T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains
T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains
T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper (20×20 cm^2) on the upper layer of the grains
T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains

T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains

T_7: Untreated control

Table 13.Percentage of stored wheat seed infestation on number basis by Angoumois grain moth after application of botanicals in 2nd generation

*Treatment(s)	Total number of seeds		Infestation (%)	Infestation reduction over control (%)
	Healthy (No.)	Infested (No.)		
T_1	201.75 c	165.75 c	45.10 c	29.28
T_2	198.50 c	169.25 b	46.02 b	27.83
T_3	367.75 a	0.00 e	0.00 e	100.00
T_4	367.50 a	0.00 e	0.00 e	100.00
T_5	220.50 b	146.75 d	39.96 d	37.34
T_6	220.25 b	148.00 d	40.19 d	36.98
T_7	133.25 d	234.50 a	63.77 a	--
$LSD_{(0.01)}$	3.758	3.127	0.752	--
Significance level	0.01	0.01	0.01	--
CV (%)	3.77	4.27	4.12	--

In a column means having similar letter are statistically identical and those having dissimilar letter differ significantly as per 0.01 level of probability and numeric data represents the mean value of 4 replications.

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains

T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains

T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains

T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper (20×20 cm^2) on the upper layer of the grains

T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains

T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains

T_7: Untreated control

4.2.4.3 Study of 3rd generation of *S. cerealella*

In 3rd generation in weight basis, the highest weight of healthy seeds were recorded in T_3 (50.00 gm) and T_4 (50.00 gm) treatments respectively, whereas lowest was observed in T_7 (14.02 gm) treatment and close to T_2 (15.09 gm) and T_5 (14.85 gm) treatments respectively. In case of infested seeds, there were no infested seeds were recorded from T_3 and T_4 treatments respectively and the highest was observed in T_7 (28.38 gm) treatment which was followed by T_2 (27.50 gm) and T_5 (27.75 gm) treatments respectively. In case of % infestation, the highest infestation was recorded from T_7 (66.93%) which was close to T_2 (64.57%) and T_5 (65.14%) treatments respectively while no infestation was recorded in T_3 and T_4 treatments respectively. The highest infestation reduction over control was recorded in T_3 (100.00%) and T_4 (100.00%) treatments respectively and lowest was found from T_5 (2.67%) treatment (Table 14).

In 3rd generation by number, the highest number of healthy seeds were recorded in T_3 (367.50) and T_4 (367.00) treatments respectively, whereas lowest was recorded in T_7 (93.50) treatment which was close to T_2 (100.50) and T_5 (99.00) treatments respectively. In case of infested seeds, there were no infested seeds were obtained from T_3 and T_4 treatments respectively and the highest number was recorded in T_7 (274.75) treatment which was close to T_2 (266.00) and T_5 (268.50) treatments respectively. In case of % infestation, the highest infestation was found from T_7 (74.61%) which was close to T_2 (72.58%) and T_5 (73.06%) treatments respectively, while no infestation was recorded in T_3 and T_4 treatments respectively. The highest infestation reduction over control was recorded in T_3 (100.00%) and T_4 (100.00%) treatments respectively and lowest was observed from T_5 (2.08%) treatment (Table 15).

Table 14. Percentage of stored maize seed infestation on weight basis by Angoumois grain moth after application of botanicals in 3rd generation

*Treatment(s)	Total weight of seeds		Infestation (%)	Infestation reduction over control (%)
	Healthy (g)	Infested (g)		
T_1	17.85 b	25.73 d	59.04 d	11.79
T_2	15.09 d	27.50 b	64.57 b	3.53
T_3	50.00 a	0.00 e	0.00 e	100.00
T_4	50.00 a	0.00 e	0.00 e	100.00
T_5	14.85 d	27.75 b	65.14 b	2.67
T_6	16.83 c	26.79 c	61.42 c	8.23
T_7	14.02 e	28.38 a	66.93 a	--
$LSD_{(0.01)}$	0.556	0.601	0.997	--
Significance level	0.01	0.01	0.01	--
CV(%)	6.09	3.54	2.10	--

In a column means having similar letter are statistically identical and those having dissimilar letter differ significantly as per 0.01 level of probability and numeric data represents the mean value of 4 replications.

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains

T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains

T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains

T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper (20×20 cm^2) on the upper layer of the grains

T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains

T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains

T_7: Untreated control

Table 15. Percentage of stored maize seed infestation on number basis by Angoumois grain moth after application of botanicals in 3rd generation

*Treatment(s)	Total number of seeds		Infestation (%)	Infestation reduction over control (%)
	Healthy (No.)	Infested (No.)		
T_1	118.75 b	249.25 d	67.73 d	9.22
T_2	100.50 d	266.00 b	72.58 b	2.72
T_3	367.50 a	0.00 e	0.00 e	100.00
T_4	367.00 a	0.00 e	0.00 e	100.00
T_5	99.00 d	268.50 b	73.06 b	2.08
T_6	112.00 c	256.50 c	69.61 c	6.70
T_7	93.50 e	274.75 a	74.61 a	--
$LSD_{(0.01)}$	4.320	3.846	0.941	--
Significance level	0.01	0.01	0.01	--
CV(%)	4.20	3.02	4.92	--

In a column means having similar letter are statistically identical and those having dissimilar letter differ significantly as per 0.01 level of probability and numeric data represents the mean value of 4 replications.

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains

T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains

T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains

T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper (20×20 cm^2) on the upper layer of the grains

T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains

T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains

T_7: Untreated control

4.2.5 Weight loss

In 1st generation in case of weight loss, no weight loss was observed in T_3 (0.00%) and T_4 (0.00%) treatments respectively, whereas the highest weight loss was recorded in T_7 (10.15%) treatment which was statistically different from all other treatments (Table 17). In 2nd generation in case of weight loss, the highest weight loss was found in T_7 (11.63%) treatment which was close to T_1 (5.28%) and T_2 (5.30%) treatments respectively, whereas no weight loss was found in T_3 (0.00%) and T_4 (0.00%) treatments respectively. In 3rd generation in case of weight loss, no weight loss was observed in T_3 (0.00%) and T_4 (0.00%) treatments respectively, whereas the highest weight loss was recorded in T_7 (15.20%) treatment which was statistically different from all other treatments (Table 16).

4.2.6 Repellency effect

Repellency effect showed statistically significant variation for commonly used botanicals to the management of Angoumois grain moth in stored grains of maize (Table 17).

In case of repellency effect after 1 hour of treatment application the highest repellency rate was found from T_3 (80.00%) and T_4 (80.00%) treatments respectively, whereas the lowest repellency rate was recorded in T_1 (20.00) treatment which was statistically different from all other treatments. After 2 hours of treatment application the highest repellency rate was observed from T_3 (90.00%) and T_4 (90.00%) treatments respectively, which were closely followed by T_6 (60.00%) treatment whereas the lowest repellency rate was recorded in T_1 (40.00%) treatment which was closely followed by T_2 (50.00%) and T_5 (50.00%) treatments respectively. After 3 hours of treatment application the highest repellency rate was observed from T_3 (100.00%) and T_4 (100.00%) treatments respectively, which were closely followed by T_2 (70.00%) and T_6 (70.00%) treatments respectively, whereas the lowest repellency rate was recorded in T_1 (50.00) treatment which was closely followed by T_5 (60.00%) treatment. After 4 hours of treatment application the highest repellency rate was observed from T_3 (100.00%) and T_4 (100.00%) treatments respectively, which were closely followed by T_6 (80.00%) treatment whereas the lowest repellency rate was recorded in T_1 (60.00) treatment which was followed by T_2 (70.00%) and T_5 (70.00%)

treatments respectively. After 5 hours of treatment application the highest repellency rate was observed from T_3 (100.00%) and T_4 (100.00%) treatments respectively, which were followed by T_6 (90.00%) treatment whereas the lowest repellency rate was recorded in T_1 (60.00) treatment which was closely followed by T_2 (80.00%) and T_5 (80.00%) treatments respectively.

Table 16. Effect of commonly used botanicals on weight loss of stored grains of maize at different generations

*Treatment(s)	Weight loss (%)		
	1^{st} generation	2^{nd} generation	3^{rd} generation
T_1	1.21 bc	5.28 b	12.84 b
T_2	2.10 b	5.30 b	14.75 a
T_3	0.00 c	0.00 d	0.00 c
T_4	0.00 c	0.00 d	0.00 c
T_5	2.10 b	3.50 c	14.80 a
T_6	2.20 b	3.33 c	12.77 b
T_7	10.15 a	11.63 a	15.20 a
$LSD_{(0.05)}$	1.245	0.803	1.603
Level of Significance	0.01	0.01	0.01
CV(%)	24.54	9.68	7.96

In a column means having similar letter are statistically identical and those having dissimilar letter differ significantly as per 0.01 level of probability and numeric data represents the mean value of 4 replications.

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains

T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains

T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grains

T_4: Neem oil wettable cloth @ 1.0 ml/tissue paper (20×20 cm^2) on the upper layer of the grains

T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains

T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains

T_7: Untreated control

Table 17. Repellency effect of commonly used botanicals on stored grains of maize at different hours after treatment

*Treatment(s)	Percent of repelled after application of treatment				
	1 hour	2 hour	3 hour	4 hour	5 hour
T_1	20.00 c	40.00 d	50.00 d	60.00 d	60.00 d
T_2	30.00 b	50.00 c	70.00 b	70.00 c	80.00 c
T_3	80.00 a	90.00 a	100.00 a	100.00 a	100.00 a
T_4	80.00 a	90.00 a	100.00 a	100.00 a	100.00 a
T_5	30.00 b	50.00 c	60.00 c	70.00 c	80.00 c
T_6	30.00 b	60.00 b	70.00 b	80.00 b	90.00 b
$LSD_{(0.01)}$	6.123	6.091	5.365	8.125	8.358
Level of Significance	0.01	0.01	0.01	0.01	0.01
CV(%)	6.12	5.52	4.56	5.89	4.58

In a column means having similar letter are statistically identical and those having dissimilar letter differ significantly as per 0.01 level of probability and numeric data represents the mean value of 4 replications.

***Treatment(s)**

T_1: Black pepper dust @ 5 g/kg on the upper layer of the grains

T_2: Neem seed kernel dust @ 10 g/kg on the upper layer of the grains

T_3: Tobacco leaves dust @ 7 g/kg on the upper layer of the grainsT_4: Neem oil wettable cloth @ 1.0 ml/tissue paper/cloth (20×20 cm^2) on the upper layer of the grains

T_5: Lantana leaves dust @ 10 g/kg on the upper layer of the grains

T_6: Nishinda leaves dust @ 10 g/kg on the upper layer of the grains

T_7: Untreated control

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY

The study was conducted on the Efficacy of commonly used Botanicals for the management of Angoumois grain moth, *Sitotroga cerealella* (Olivier) in different stored grains in the laboratory of the Department of Entomology of Sher-e-Bangla Agricultural University, Dhaka during the period from January' 2014 to May' 2014.

The experiments consisted of 7 (seven) treatments as T_1 = Black pepper dust @ 5g/Kg on the upper layer of the grains, T_2 = Neem seed kernel dust @ 10g/Kg on the upper layer of the grains, T_3 = Tobacco leaves dust @ 7 g/Kg on the upper layer of the grains, T_4 = Neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of the grains, T_5 = Lantana Leaves dust @ 10g/Kg on the upper layer of the grains, T_6 = Nishinda Leaves dust @ 10g/Kg on the upper layer of the grains and T_7 = Untreated Control. Among the botanicals, T_3 (using tobacco leaves dust) and T_4 (using neem oil wettable paper) showed the best performance than other materials in protecting the wheat and maize grains from the attack of Angoumois grain moth in storage.

In case of wheat grains after 24 hours of application, the results from the experiment showed the highest number of dead adult moths (9.75) were recorded in neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of wheat grains whereas the lowest number of dead insects (3.00) were recorded from lantana leaves dust @ 10 g/Kg on the upper layer of wheat grains and similar trend of results were observed after 48 and 72 hours of treatment application. The highest mortality (100.00%) was observed in neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of wheat grains whereas no mortality was recorded in untreated control. In case of total adult emergence for 1st and 2nd generation together no adults emerged in tobacco leaves dust @ 7g/Kg and neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of wheat grains respectively, while the highest adult was recorded in untreated control. In 1st generation in weight basis, the highest weight (50 g) of healthy seeds were recorded in tobacco leaves dust @ 7 g/Kg and neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of wheat grains respectively, whereas lowest (36.52 g) was observed in untreated control. In 1st generation in number basis, the highest healthy seeds (1379.50 and 1379.00) were recorded in tobacco leaves dust @ 7g/Kg and neem oil wettable cloth @ 1.0ml/tissue paper (20x20 cm^2) on the upper layer of wheat grains respectively, whereas lowest (1022) was observed in untreated control. In 2nd generation in weight basis, the highest weight (50 g) of healthy seeds were recorded in tobacco leaves dust @ 7 g/Kg and neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of wheat grains respectively, whereas no healthy seeds were observed in untreated control and similar trend of results were observed from all other treatments. In 2nd generation in number basis, the highest (1379.50 and 1379.25) healthy seeds were recorded in tobacco leaves dust @ 7 gm/Kg and neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of wheat grains respectively, whereas no healthy seeds were observed in untreated control and similar trend of results were observed from all other treatments.

In case of weight loss, in 1st and 2nd generation no weight loss was observed in tobacco leaves dust @ 7 g/Kg and neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of wheat grains respectively, whereas the highest (5.51% and 35.85%)) weight loss was recorded in untreated control at 1st and 2nd generation respectively. In case of repellency effect after 1 hour of treatment application the highest (90%) repellency rate was found from tobacco leaves dust @ 7 g/Kg and neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) and similar trend of results were observed after 2, 3, 4 and 5 hours of treatment application.

In case of maize grains after 24 hours of treatment application, the results found from the experiment were the highest (8.00) number of dead insects were recorded in neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of maize grains whereas the lowest (3.75) number of dead insects were recorded from lantana leaves dust @ 10 g/Kg on the upper layer of maize grains and similar trend of results were observed after 48 and 72 hours of treatment application respectively. The highest mortality (100.00%) was observed in neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of maize grains whereas no mortality was recorded in untreated control. In case of total adult emergence for 1st, 2nd and 3rd generation no adults emerged in tobacco leaves dust @ 7 g/Kg and neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of maize grains while the highest adult was recorded in untreated control. In 1st generation in weight basis, the highest (50 g) healthy seeds were recorded in tobacco leaves dust @ 7g/Kg and neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of maize grains respectively, whereas lowest (23.25 g) was observed in untreated control. In 1st generation in number basis, the highest (367.00 and 367.50) healthy seeds were recorded in tobacco leaves dust @ 7 g/Kg and neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of maize grains respectively, whereas lowest (155.00) was observed in untreated control.

In 2nd generation in weight basis, the highest weight (50 g) of healthy seeds were recorded in tobacco leaves dust @ 7 g/Kg and neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of maize grains whereas lowest (19.99 g) was observed in untreated control. In 2nd generation in number basis, the highest (367.75 and 367.50) healthy seeds were recorded in tobacco leaves dust @ 7 g/kg and neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of maize grains respectively, whereas lowest (133.25) was observed in untreated control. At 3rd generation in weight basis, the highest (50 g) healthy seeds were recorded in tobacco leaves dust @ 7 g/Kg and neem oil wettable cloth @1.0 ml/tissue paper (20x20 cm^2) on the upper layer of maize grains respectively, whereas lowest (14.02 g) was observed in untreated control. In 3rd generation in number basis, the highest (367.50 and 367.00) healthy seeds were recorded in tobacco leaves dust @ 7 g/Kg and neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of maize grains respectively, whereas no healthy seed was observed in untreated control.

In case of weight loss, no weight loss was observed in tobacco leaves dust @ 7 g/Kg and neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) on the upper layer of maize grains at 1st, 2nd and 3rd generation respectively, whereas the highest (10.15%, 11.63% and 15.20%) weight loss was recorded in untreated control at 1st, 2nd and 3rd generation respectively.

In case of repellency effect after 1 hour of treatment application the highest (80.00%) repellency rate was found from tobacco leaves dust @ 7 g/Kg and neem oil wettable cloth @ 1.0 ml/tissue paper (20x20 cm^2) and similar trend of results were observed after 2, 3, 4 and 5 hours of treatment application.

Considering the results of different experiments, it could be suggested that in most cases, the angoumois grain moth, *S. cerealella* (Olivier) could be minimized by use of botanicals and also discourage the use of insecticides because of their toxicity to the users, consumers and the environment also.

CONCLUSION

The angoumois grain moth, *Sitotroga cerealella* (Olivier) is one of the most serious pests of stored grains at post harvest level. Considering the adult mortality, adult emergence, percent infested grains both by weight and number and percent infestation reduction over control the treatment with tobacco leaves dust @ 7 g/Kg and neem oil wettable cloth @ 1.0 ml/tissue paper on the upper layer of grains of wheat or maize were the most effective in comparison with all other treatments for the management of angoumois grain moth infesting stored wheat and maize grains. The use of tobacco leaves dust or neem oil wettable cloth might be the most economical and practical approach in the integrated management of this pest.

RECOMMENDATIONS

Based on the above results following recommendations may be made:

- Considering environmental safety and health hazards tobacco leaves dust or neem oil may be used to control Angoumois grain moth in different stored grains

- More number of botanicals and their derivatives may be included in further elaborative research for controlling Angoumois grain moth in different stored grains

CHAPTER VI

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APPENDICES

Appendix I: Analysis of variance of the data on number of dead insects after different times and percentage of mortality of *S. cerealella* in wheat grains influenced by commonly used botanicals

Source of variation	Degrees of freedom	Mean square			Insect mortality (%)
		No. of dead insects after different duration of treatments			
		24 hours	48 hours	72 hours	
Between	6	37.071**	40.321**	43.536**	4353.571**
Within	21	0.393	0.357	0.274	27.381

** Significant at 1% level of probability

Appendix II: Analysis of variance of the data on adult emerged of *S. cerealella* in wheat grains at 1st and 2nd generation and total as influenced by commonly used botanicals

Source of variation	Degrees of freedom	Mean square		
		Percent adult emerged at		
		1st generation	2nd generation	Total
Between	6	1289.071**	6834.869**	13631.488**
within	21	7.917	8.310	16.083

** Significant at 1% level of probability

Appendix III: Analysis of variance of the data on healthy, infested seeds, % infestation in weight and number basis at 1st generation of *S. cerealella* in wheat grains influenced by commonly used botanicals

Source of variation	Degrees of freedom	Mean square					
		1st generation in weight (gm)			1st generation in number		
		Healthy seeds (gm)	Infested seeds (gm)	% infestation	Healthy seeds	Infested seeds	% infestation
Between	6	88.102**	54.769**	245.558**	66523.738**	66249.893**	348.662**
within	21	0.050	0.002	0.009	4.667	3.500	0.016

** Significant at 1% level of probability

Appendix Iv: Analysis of variance of the data on healthy, infested seeds, % infestation in weight and number basis at 2nd generation of *S. cerealella* in wheat grains influenced by commonly used botanicals

Source of variation	Degrees of freedom	Mean square					
		1st generation in weight (gm)			1st generation in number		
Between	6	Healthy seeds (gm)	Infested seeds (gm)	% infestation	Healthy seeds	Infested seeds	% infestation
within	21	2380.952**	1182.508**	9523.810**	1812071.821**	1808986.976**	9523.810**
		0.000	0.037	0.000	1.607	5.857	0.000

** Significant at 1% level of probability

Appendix V: Analysis of variance of the data on weight loss in wheat grains on *S. cerealella* influenced by commonly used botanicals

Source of variation	Degrees of freedom	Mean square	
		Weight loss (%)	
		1st Generation	2nd Generation
Between	6	26.024**	907.176**
within	21	0.224	0.149

** Significant at 1% level of probability

Appendix VI: Analysis of variance of the data on number of dead insects after different times and percentage of mortality of *S. cerealella* in maize grains influenced by commonly used botanicals

Source of variation	Degrees of freedom	Mean square			Insect mortality (%)
		No of dead insects after different duration of treatments			
		24 hours	48 hours	72 hours	
Between	6	23.238**	38.786**	46.976**	4697.619**
Within	21	1.107	1.190	0.810	80.952

** Significant at 1% level of probability

Appendix VII: Analysis of variance of the data on adult emerged of *S. cerealella* in maize grains at 1st, 2nd and 3rd generation and total as influenced by commonly used botanicals

Source of variation	Degrees of freedom	Mean square			
		Percent adult emerged at			
		1st generation	2nd generation	3rd generation	Total
Between	6	55.583**	138.726**	340.405**	1377.786**
Within	21	0.976	1.512	4.964	7.524

** Significant at 1% level of probability

Appendix VIII: Analysis of variance of the data on healthy, infested seeds, % infestation in weight and number basis at 1st generation of *S. cerealella* in maize grains influenced by commonly used botanicals

Source of variation	Degrees of freedom	Mean square					
		1st generation in weight(gm)			1st generation in number		
		Healthy seeds(gm)	Infested seeds (gm)	% infestation	Healthy seeds	Infested seeds	% infestation
Between	6	347.102**	246.136**	1158.987**	23440.202**	23573.036**	1743.601**
within	21	0.025	0.066	0.184	1.738	1.750	0.047

** Significant at 1% level of probability

Appendix IX: Analysis of variance of the data on healthy, infested seeds, % infestation in weight and number basis at 2nd generation of *S. cerealella* in maize grains influenced by commonly used botanicals

Source of variation	Degrees of freedom	Mean square					
		2nd generation in weight(gm)			2nd generation in number		
		Healthy seeds (gm)	Infested seeds (gm)	% infestation	Healthy seeds	Infested seeds	% infestation
Between	6	488.328**	340.686**	1637.166**	31868.786**	31896.286**	2358.954**
within	21	0.056	0.032	0.151	3.524	2.440	0.141

** Significant at 1% level of probability

Appendix X: Analysis of variance of the data on healthy, infested seeds, % infestation in weight and number basis at 3rd generation of *S. cerealella* in maize grains influenced by commonly used botanicals

Source of variation	Degrees of freedom	Mean square					
		3rd generation in weight (gm)			3rd generation in number		
		Healthy seeds (gm)	Infested seeds (gm)	% infestation	Healthy seeds	Infested seeds	% infestation
Between	6	1125.196**	708.866**	3857.214**	65909.250**	66147.655**	4891.913**
within	21	0.077	0.090	0.248	4.655	3.690	0.221

** Significant at 1% level of probability

Appendix XI: Analysis of variance of the data on weight loss in maize grains on *S. cerealella* influenced by commonly used botanicals

Source of variation	Degrees of freedom	Mean square		
		Weight loss (%)		
		1st Generation	2nd Generation	3rd Generation
Between	6	48.733**	62.675**	192.223**
within	21	0.387	0.161	0.641

** Significant at 1% level of probability