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Amit Raj
Narendra Deva University of Agriculture and Technology Kumarganj, Faizabad, Uttar Pradesh, India

RB Singh
Narendra Deva University of Agriculture and Technology Kumarganj, Faizabad, Uttar Pradesh, India

Ramveer
Narendra Deva University of Agriculture and Technology Kumarganj, Faizabad, Uttar Pradesh, India

Sanjeev Kumar
Narendra Deva University of Agriculture and Technology Kumarganj, Faizabad, Uttar Pradesh, India

Anuj Shakya
Narendra Deva University of Agriculture and Technology Kumarganj, Faizabad, Uttar Pradesh, India

Correspondence
Amit Raj
Narendra Deva University of Agriculture and Technology Kumarganj, Faizabad, Uttar Pradesh, India

Studies on evaluation of different botanicals against Angoumois grain moth, *Sitotroga cerealella* Olivier in stored paddy

Amit Raj, RB Singh, Ramveer, Sanjeev Kumar and Anuj Shakya

Abstract
The effectiveness of eight seed protectants namely: deltamethrin @ 1 ppm (0.04 ml/kg seed), Spinosad @ 2 ppm (4.40 mg/kg seed), Emamectin benzoate @ 2 ppm (40.0 mg/kg seed), Lantana leaf powder @ 10.0 g/kg seed, Nirgundi leaf powder @ 10.0 g/kg seed, Neem seed kernel powder @ 5.0 g/kg seed and Citronella leaf powder @ 10.0 g/kg seed were evaluated against *S. cerealella* in paddy with 3 replications under CRD.
The emamectin benzoate @ 2 ppm (40.0 mg/ kg seed) was found best among tested seed protectants followed by nirgundi leaf powder 10.0 g and spinosad@ 2 ppm (4.40 mg/kg) to manage the seed damage by *S. cerealella* and also maintain the seed quality. However, neem seed kernel powder, and lantana leaf powder were also found effective and were at par with spinosad @ 2 ppm (4.40 mg/kg seed).

Keywords: Botanicals, angoumois grain moth, *Sitotroga cerealella* Olivier, stored paddy

Introduction
Rice (*Oryza sativa* L.) is a very important cereal crop belongs to the family Poaceae. India is one of the leading rice producing countries in the world. It produces more than 20.0% rice at global level which plays an important role in the world economy. Rice is the staple food crop which contributes about 52.0% of total food grains and 55.0% of total cereal production in India. The rice production reached to 106.10 million tonnes in present time conditions. Among the rice producing states in India, Andhra Pradesh is known as "Rice Bowl of India". Uttar Pradesh is an important rice growing state which covered 5.63 million hectare area with 11.94 million tonnes production and 2358 kg productivity (Anonymous, 2014-15) [3].
Rice is damaged by number of agents such as insects, rodents, fungi, mites, birds and various environmental factors; specially the temperature and moisture content. Insect infestation on stored grains and their products is a serious problem throughout the world. There are approximately 200 species of insects and mites attacking rice grains and stored products. Prakash *et al.* (1984) [4] reported seventeen species of insect-pests infesting rice in storage of which Angoumois grain moth (*Sitotroga cerealella),* rice weevil (*Sitophilus oryzae*) and red rust flour beetle (*Tribolium castaneum*) predominate in parboiled rice. On the other hand, moths and beetles predominate in raw rice and weevils predominate in milled rice. Angoumois grain moth, *Sitotroga cerealella* is the common and most destructive pest species on rice in storage. According to Alam (1971) [2] 5 to 8 per cent of rice grain seed and different stored products are lost annually due to storage pests and, if the losses incurred on farm was included then it would amount to be more than 10.0 per cent.
During the phase just prior to harvest and especially after harvest during storage, this product is attacked by insects stocks including Angoumois grain moth, *Sitotroga cerealella* Olivier (Gelechiidae: Lepidoptera). It is considered a dangerous pest for stored grains and difficult to combat. Today, the infestation of rice stocks by Angoumois grain moth emerges as a serious problem in the rice growing areas in Benin (Togola *et al.*, 2010) [6]. Under conditions of heavy infestation, the stored products can suffer even 100% loss. *S. cerealella* caused reduction in weight, germination of seed and the loss of nutritional value and market value of rice.
Single larva of Angoumois grain moth caused 13.0-24.0% economic losses in grain weight and reduction in nutritional value. Female moth laid eggs on the grains that hatched out as small white larvae which start feeding on its content after boring. Infested grains by the larvae of *S. cerealella* emit foul smelling, decrease in grain weight and quality and became unsuitable

for consumption. An infested corn also contains ears with minor holes on individual grain. The newly hatched caterpillar bores directly into the grain and remains inside the grain for both larval and pupal development. The larvae of this pest tunnel inside the kernels are causing substantial damage and are rendering the grain more susceptible to secondary insect-pests (Weston and Rattlingourd, 2000) [7].

In many areas of the world, locally available plant materials are widely used to protect stored products against insect infestations. Botanical plant products are less expensive, readily available, environmentally safe and less hazardous in comparison to chemical insecticides. The main advantage of botanicals is that they are easily produced, locally available, broad spectrum and used by the farmers in small scale. There are about 2000 plant species reported to possess pest control properties. Application of simple plant materials like neem, karanja, mahogany, nishinda, pithraj and datura in several cases proved to be very simple and highly effective against the cereals and other produces in storages. The plant products included oils, extracts, leaf powder, seed etc.

The insecticidal property of botanicals is not very quick (except natural pyrethrins) as compared to that of synthetic insecticides and fumigants. The plant products certainly possess certain advantages over synthetic chemicals.

Chemical constituents of essential oils of *Dennettia tripetala* and *Uvariodendron angustifolium* were found effective against the adult stages of *Sitotroga cerealella* on stored products and germination of rice grains. Dried neem leaf powder at 1.0% gave effective control against the Angoumois grain moth in paddy for at least 3 months (Abraham *et al*., 1972) [1]. Multiplication of the Angoumois grain moth was completely checked in paddy treated with 0.025% neem oil (Prakash *et al.*, 1981) [5].

Materials and Methods

The experiment was carried out in the laboratory of Seed Entomology under seed Technology Section and Department of Entomology of Narendra Deva University of Agriculture and Technology, Narendra Nagar, (Kumarganj), Faizabad (U.P.) during 2015.

The experiment laid out with ten treatments including control and each treatment replicated thricely.

Collection of paddy seed

Fresh and healthy harvested seed of rice variety, Pusa Basmati 1 was purchased from the local market of Faizabad for evaluation of effectiveness of protectants (Botanicals and Insecticides) against the Angoumois grain moth. Collected seed was disinfested by Aluminium phosphate @ 3 Tablet/tonne in airtight container before experiment. The disinfested 0.5 kg paddy seed was packed in jute bags of 1.0 kg capacity after mixing the protectants for each replication of each treatment under complete randomized design.

Rearing of test insect

Adults of Angoumois grain moth was collected from godown of seed processing plant of N.D.U.A.T., Kumarganj, Faizabad and released in a plastic container having 500 g healthy seed of Pusa Basmati 1. The mouth of container was covered with muslin cloth and tied by a rubber band. Thereafter, the jar was kept in B.O.D. incubator at 28 ± 1^0 C temperatures and 75 ± 5 per cent relative humidity. After rearing, all the newly emerged adults were taken out as parental population for further experimental studies.

Release of test insect (Angoumois grain moth)

The freshly emerged Angoumois grain moths were released @5 pairs/bag. The mouth of each bag was tied with the help of thread and kept on racks at ambient condition in seed Entomology laboratory.

Leaves of lantana, nirgundi and citronella plants (botanicals) and neem seed kernel were collected from area of NDUAT, Kumarganj. Leaves of these plants were grinded separately after drying. The grinded powder was sieved with muslin cloth.

The observations recorded on per cent seed moisture content, per cent germination and per cent damaged seed at 90 and 180 days after insect release were recorded as per earlier describe methods.

Results and Discussion

Effectiveness of seed protectants against *S. cerealella*

All the tested seed protectants against *S. cerealella* were found significantly superior over untreated control at 3 and 6 month of storage. The details have been described as below:

1. Effect of seed protectants on the moisture content

The result (Table 1) showed that in all the treatments, the seed moisture content was significantly less over control at different intervals of storage.

After 3 month of storage, the maximum 10.26% seed moisture content was recorded in seed treated with neem seed kernel powder @ 5.0 g kg^{-1} seed followed by 10.23% lantana leaf powder @ 10.0 g kg^{-1} seed, 10.16% nirgundi leaf powder @ 10.0 g kg^{-1} seed, 10.0% untreated, 9.66% citronella leaf powder @ 10.0 g kg^{-1} seed, 9.63% spinosad @ 2 ppm (4.40 ml kg^{-1} seed), 9.50% emamectin benzoate @ 2 ppm (40.0 mg kg^{-1} seed) and 8.96% deltamethrin @ 1 ppm (0.04 ml kg^{-1} seed).

After 6 month of storage the maximum seed moisture content 9.53% was recorded in seed treated with neem seed kernel powder @ 5.0 g kg^{-1} seed followed by 8.80% deltamethrin @ 1 ppm (0.04 ml kg^{-1} seed), 8.76% untreated control, 8.73% nirgundi leaf powder @ 10.0 g kg^{-1} seed, 8.7% emamectin benzoate @ 2 ppm (40.0 mg kg^{-1} seed), 8.56% citronella leaf powder @ 10.0 g kg^{-1} seed, 8.40% spinosad @ 2 ppm (4.40 mg kg^{-1} seed) and 8.40% lantana leaf powder @ 10.0 g kg^{-1} seed.

2. Effect of seed protectants on germination

The least germination was recorded in control at different days of storage within the treatments which have significantly lower germination than other tested protectants (Table 2).

After 3 month of storage the germination per cent ranged from 88.66 to 77.66% within the treatments. The maximum germination 88.66% was observed in emamectin benzoate @ 2 ppm (40.0 mg kg^{-1} seed) followed by 86.00% nirgundi leaf powder @ 10.0 g kg^{-1} seed, 85.33% spinosad @ 2 ppm (4.40 mg kg^{-1} seed), 85.0% deltamethrin @ 1 ppm (0.04 ml kg^{-1} seed), 84.33% lantana leaf powder @ 10.0 g kg^{-1} seed, 83.66% neem seed kernel powder @ 5.0 g kg^{-1} seed. However, least germination 81.33% was found in citronella leaf powder @ 10.0 g kg^{-1} seed was least effective than other. Among tested protectants nirgundi leaf powder, spinosad, deltamethrin, neem seed kernel powder were at par with each other.

After 6 month of storage the germination per cent ranged from 86.66 to 72.66%. The maximum germination 86.66% was observed in emamectin benzoate @ 2 ppm (40.0 mg kg^{-1}

seed) followed by 83.66% spinosad @ 2 ppm (4.40 mg kg^{-1} seed), 83.00% nirgundi leaf powder @ 10.0 g kg^{-1} seed, 81.66% Deltamethrin @ 1 ppm (0.04 ml kg^{-1}seed), 80.66% neem seed kernel powder @ 5.0 g kg^{-1} seed, 80.33% lantana leaf powder @ 10.0 g kg^{-1} seed and 78.66% citronella leaf powder @ 10.0 g kg^{-1} seed. However at 6 month of storage spinosad, deltamethrin, neem seed kernel powder and nirgundi leaf powder were at par with each other.

3. Effect of seed protectants on seed damage

The results (Table 3) showed that all the treatments were effective and significant superior over control at different intervals of storage under studies.

At 3 month of storage, the seed damage per cent by *S. cerealella* was ranged from 0.33 to 3.33 per cent within the seed protectants. The minimum damage 0.33% was recorded in seed treated with emamectin benzoate @ 2 ppm (40.0 mg kg^{-1} seed) with followed by deltamethrin @ 1 ppm (0.04 ml kg^{-1} seed) and nirgundi leaf powder @ 10.0 g kg^{-1} seed with 0.66% seed damage spinosad @ 2 ppm (4.40 mg kg^{-1} seed) with 1.00%, lantana leaf powder @ 10.0 g kg^{-1} seed with 1.33%, neem seed kernel powder @ 5.0 g kg^{-1} seed 1.66%. The maximum damage found in citronella leaf powder @10.0 g kg^{-1} seed with 2.00%.

After 6 month of storage most effective treatment within the seed protectants was emamectin benzoate @ 2 ppm (40.0 mg kg^{-1} seed) with 1.00% seed damage followed by spinosad @ 2 ppm (4.40 mg kg^{-1} seed) with 1.33%, nirgundi leaf powder @ 10.0 g/kg seed with 1.66%, deltamethrin @ 1 ppm (0.04 ml kg^{-1} seed) with 2.00%, neem seed kernel powder @ 5.0 g kg^{-1} seed with 2.33%, lantana leaf powder @ 10.0 g kg^{-1} seed with 3.00% and citronella leaf powder @ 10.0 g kg^{-1} seed with 3.66%. All treatments were significantly superior then the untreated control that have maximum insect damage 5.33% at six months of storage period.

Table 1: Effect of protectants on seed moisture content against Angoumois grain moth on paddy seed at different interval of storage

Treatments	Dose/kg seed	Per cent seed moisture content at	
		3 month	6 month
T_1 Deltamethrin	1 ppm 0.04 ml	8.96 (17.40)	8.80 (17.25)
T_2 Spinosad 45SC	2 ppm 4.40 mg	9.63 (18.08)	8.40 (16.84)
T_3 Emamectin benzoate	2 ppm 40.00 mg	9.50 (17.94)	8.70 (17.15)
T_4 Lantana leaf powder	10.00 g	10.23 (18.65)	8.40 (16.84)
T_5 Nirgundi leaf powder	10.00 g	10.16 (18.59)	8.73 (17.16)
T_6 Neem seed kernel powder	5.00 g	10.26 (18.69)	9.53 (17.98)
T_7 Citronella leaf powder	10.00 g	9.66 (18.11)	8.56 (17.01)
T_8 Control (Untreated)	Untreated	10.00 (18.43)	8.76 (17.22)
SEm±	-	0.20	0.24
CD at 5%	-	0.68	NS

Figures in parenthesis are angular transformed value

Table 2: Effect of protectants on seed germination against Angoumois grain moth on paddy seed at different interval of storage

Treatments	Dose/kg seed	Per cent seed germination at	
		3 month	6 month
T_1 Deltamethrin	1 ppm 0.04 ml	85.00 (67.24)	81.66 (64.67)
T_2 Spinosad 45SC	2 ppm 4.40 mg	85.33 (67.50)	83.33 (66.16)
T_3 Emamectin benzoate	2 ppm 40.00 mg	88.66 (70.35)	86.66 (68.62)
T_4 Lantana leaf powder	10.00 g	84.33 (66.71)	80.33 (63.68)
T_5 Nirgundi leaf powder	10.00 g	86.00 (68.06)	83.00 (65.67)
T_6 Neem seed kernel powder	5.00 g	83.66 (66.20)	80.66 (63.92)
T_7 Citronella leaf powder	10.00 g	81.33 (64.41)	78.66 (62.50)
T_8 Control (Untreated)	Untreated	77.66 (61.80)	72.66 (57.21)
SEm±	-	0.78	0.67
CD at 5%	-	2.56	2.17

Figures in parenthesis are angular transformed value

Table 3: Effect of protectants on seed damage against Angoumois grain moth on paddy seed at different interval of storage

Treatments	Dose/kg seed	Per cent seed damage at	
		3 month	6 month
T_1 Deltamethrin	1 ppm 0.04 ml	0.66 (0.66)	2.00 (8.13)
T_2 Spinosad 45SC	2 ppm 4.40 mg	1.00 (1.00)	1.33 (6.53)
T_3 Emamectin benzoate	2 ppm 40.00 mg	0.33 (0.33)	1.00 (5.73)
T_4 Lantana leaf powder	10.00 g	1.33 (1.33)	3.00 (9.88)
T_5 Nirgundi leaf powder	10.00 g	0.66 (0.66)	1.66 (7.33)
T_6 Neem seed kernel powder	5.00 g	1.66 (1.66)	2.33 (8.74)
T_7 Citronella leaf powder	10.00 g	2.00 (2.00)	3.66 (11.01)
T_8 Control (Untreated)	Untreated	3.33 (3.33)	5.33 (13.34)
SEm±	-	0.31	0.56
CD at 5%	-	1.06	1.85

Figures in parenthesis are angular transformed value

Effectiveness of seed protectants against *S. cerealella*

Per cent seed moisture content

Seed moisture content of seed is mainly depending on the condition of storage environments and nature of seed protectants.

At 3 month of storage the maximum seed moisture per cent was recorded in neem seed kernel powder @ 5.0 g/kg seed with 10.26% and minimum seed moisture content in deltamethrin @ 1 ppm (0.04 ml/kg seed) with 8.96% seed moisture. At 6 month of storage the maximum seed moisture was recorded in neem seed kernel powder @ 5.0 g/kg seed with 9.53% and minimum in spinosad @ 2 ppm (4.40 mg/kg seed) and lantana leaf powder @ 10.0 g/kg seed with 8.40% seed moisture content is non-significantly at 6 month.

Per cent seed germination

The germination per cent was recorded significantly better in all treatments over control. All seed protectants were able to reduced germination losses and able to maintain the germination above IMSCS level. At 3 month of storage the maximum germination was recorded in emamectin benzoate @ 2 ppm (40.0 mg/kg seed) with 88.66% and minimum germination citronella leaf powder @ 10.0 g/kg seed with 81.33%. At 6 month of storage the germination percentage was again observed highest in emamectin benzoate @ 2 ppm (40.0 mg/kg seed) with 86.66% and minimum germination was observed in citronella leaf powder @ 10.0 g/kg seed with 78.66%.

Per cent seed damage

All the tested seed protectants showed least seed damage by Angoumois grain moth at significant level over control. At 3 months of storage the minimum insect damage with 0.33% was observed in seed treated with emamectin benzoate @ 2 ppm (40.0 mg/kg seed) and maximum with 3.33% damaged seed treated with citronella leaf powder @ 10.0 g kg/seed. At 6 months of storage the minimum insect damage with 1.00% was recorded in emamectin benzoate @ 2 ppm (40.0 mg/kg seed) and maximum with 5.33% citronella leaf powder @ 10.0 g kg/seed.

Conclusion

- Among tested seed protectants the emamectin benzoate @ 2 ppm (40.0 mg) followed by nirgundi leaf powder @ 10.0 g and spinosad @ 2 ppm (4.40 mg/kg seed) were found more effective due to minimum insect infestation and higher germination percent, even up to 180 days.
- All the chemicals were proved better than botanicals.
- However, nirgundi leaf powder @ 10.0 g/kg seed, neem seed kernel powder @ 5.0 g/kg seed and lantana leaf powder @ 10.0 g/kg seed as botanicals seed protectants were also proved effective against *S. cerealella* and also able to maintained germination above IMSCS level. These botanicals were at par with spinosad 45SC @ 2 ppm 4.40 mg) even after 180 days of seed storage
- Citronella leaf powder @ 10.0 g/kg seed was least effective than other but better than control.

Due to effective results of nirgundi leaf powder, neem seed kernel powder and lantana leaf powder during the evaluation of protectants it may be concluded that there is need to test more locally and easily available eco-friendly seed protectants at farmers/village level to protect the paddy seed against *S. cerealella* and maintain the seed quality.

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