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Comparative bio-efficacy of botanical seed powders against the rice weevil, *Sitophilus oryzae* (Linnaeus) (Coleoptera: Curculionidae)

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Abstract
The present study was carried out to evaluate the comparative bio-efficacy of selected botanical seed powders against the major stored-product pest, *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae). Botanicals tested included *Entada rheedii* (African dream herb), *Abrus precatorius* (rosary pea), *Piper nigrum* (pepper), *Myristica fragrans* (nutmeg), *Zingiber officinale* (ginger), *Allium sativum* (garlic), *Capsicum annuum* (chilli), *Syzygium aromaticum* (clove), and *Azadirachta indica* (neem). Two independent laboratory bioassays (Experiment I and II) were conducted during 2022–2023 under controlled conditions at the Department of Agricultural Entomology, Pandit Jawaharlal Nehru College of Agriculture and Research Institute (PAJANCOA & RI), Karaikal, U.T. of Puducherry, India. Significant differences in insecticidal efficacy were observed among the treatments in both the experiments. Among the botanicals, black pepper seed powder consistently exhibited superior bio-efficacy, as evidenced by the highest adult mortality (87.08% and 83.33%), highest oviposition deterrence (92.16 % and 83.53 %), lowest adult emergence (2.08 and 4.08), highest inhibition rate (98.94 % and 97.96 %) lowest seed damage (0.67 % and 1.83 %), lowest weight loss (1.41 % and 2.04 %) and high feeding deterrent value (97.78 and 96.72), followed by clove ranked second in efficacy across most parameters. The findings highlight the potential of botanical seed powders, particularly *P. nigrum*, as effective, eco-friendly alternatives to synthetic insecticides for the management of *S. oryzae* in stored grains.

Keywords: Comparative bio-efficacy, botanical seed powders, sitophilus oryzae, piper nigrum, stored grain protection

Introduction

Rice, *Oryzae sativa* (Linnaeus) is an economically important staple food crop for a large part of the world's human population, especially in East and South Asia, the Middle East, Latin America and West Indies. Rice plays a major nutritional role in diet and strategic food security planning policies of most government in many developing nations. The economically important insect pests of stored rice are the rice weevils, *Sitophilus oryzae* (Linnaeus) and *Sitophilus granarius* (Linnaeus), the angoumois grain moth, *Sitotroga cerealella* (Olivier), and the lesser grain borer, *Rhizopertha dominica* (Fabricius) (Akinneye and Oyeniyi, 2016; Ashamo and Akinnawonu, 2012) [2, 4]. The most common insects that attack stored products belong to the order Coleoptera and Lepidoptera (Sachin, 2018) [20]. As many as 34 species of insects have been reported as pests of stored paddy and clean rice from different countries (Rashid *et al.,* 2009) [19].

The rice weevil, *S. oryzae,* originated from India and is now cosmopolitan in distribution, occurring throughout the tropical and subtropical regions of the world (Hong *et al.,* 2018; Jayakumar *et al.,* 2017) [7, 8]. The rice weevil causes a huge loss upto 100 per cent in stored maize and rice in India and other countries (Padmasri *et al.,* 2017) [14]. Loss of grains after 100 days of storage was estimated as 25 to 40 per cent (Bhargude *et al.,* 2021) [5]. It is one of the most devastating stored pest that causes about 30 to 40 per cent weight loss and upto 90 per cent damage potential within 5 to 6 months after infection (Pandi *et al.,* 2018) [16]. For control of stored grain pests, synthetic insecticides are used in several countries, however, indiscriminate use of insecticides has resulted in development of resistance and toxic residues in food grains (Mehta and Kumar, 2020) [10]. Botanical products have been successfully exploited as botanical insecticides, repellants and antifeedant. Many plant extracts are known to possess insecticidal activity against several stored product insects. The botanicals have advantage of being easily produced, locally available, broad spectrum and used by farmers in small as well as in large scale (Qadeem *et al.,* 2015) [18]. Thus, the following study was carried out to evaluate the efficacy of native botanicals for management against rice weevil, *S. oryzae.*

Materials And Methods

Mass culturing of the rice weevil, *S. oryzae*

The parental culture of adults of the rice weevil, *S. oryzae* was collected from wheat bran stored in house hold in Sathya sai nagar, TVS nagar, Madurai, Madurai district, Tamil Nadu. The male and female weevils were identified based on the rostrum width and length. Omar (2012) [13] described that the rostrum is a little longer and thinner and more curved in the female than in the male. Twenty pairs of *S. oryzae* were released into each plastic containers containing 0.5 kg of disinfested rice grains and the mouth of the containers were covered with kada cloth and tightly secured with a rubber band. The containers were kept undisturbed at the room temperature of 27 ± 2 ºC and a relative humidity of 75 ± 5 per cent under laboratory conditions until emergence of adults. The newly emerged adults from the culture after forty two days of release were utilized for maintaining subcultures that were used for the experiments (Plate 1).

Collection of rice

To evaluate the efficacy of botanical seed powders against rice weevil, *S. oryzae,* the variety, BPT 5204 unhusked rice were collected from Seed Technology Unit, Department of Genetics and Plant Breeding, PAJANCOA and RI, Karaikal,

U. T. of Puducherry and the variety BPT 5204 rice grains were collected from Sun Rice Enterprises, Kumbakonam, Tanjore district, Tamil Nadu.

Sterilization of rice

The husked and unhusked rice grains, which were used to conduct the study on the efficacy of botanical seed powders against rice weevil were thoroughly sterilized under UV light before starting the experiments. Both the unhusked and husked rice were placed in enamel trays and kept under UV light in the laminar air flow chamber for 7 h. After 3 h of exposure, the paddy was thoroughly mixed for uniform exposure. After seven hours, the paddy was taken out 15 minutes after switch off of UV light in the laminar air flow chamber.

Preparation of botanical seed powders

The botanical seeds, bulbs and rhizome were collected from Alagar kovil hills (Western ghats) and Kannadiyar Herbals, Madurai district, Tamil Nadu (Table 1) (Plate 2). The collected seeds were washed in tap water and ground into paste like consistency with a mixer by adding a little amount of water. The prepared paste were spread on the enamel coated trays and left for shade drying. After complete drying, the powder was scraped out from the tray and pulverized in an electric blender to convert into fine powders. Then the powders were sieved and stored in air tight plastic containers to use for experiments (Plate 3.). The list of the botanical seed parts used in the experiment is mentioned in the following table.

Table 1: Treatments of botanical seed powders

S.No	Common name	Botanical name	Family	Part used
1.	African dream herb	*Entada rheedii* (Sprengel)	Fabaceae	Seeds
2.	Rosary pea	*Abrus precatorius* (Linnaeus)	Fabaceae	Seeds
3.	Pepper	*Piper nigrum* (Linnaeus)	Piperaceae	Seeds
4.	Nutmeg	*Myristica fragrans* (Houttuyn)	Myristicaceae	Seeds
5.	Chilli + Garlic + Ginger	*Capsicum annum* (Linnaeus) + *Allium sativum* (Linnaeus) + *Zingiber officinale* (Willdenow) Roscoe	Solanaceae + Amaryllidaceae + Zingiberaceae	Fruit + Bulb + Rhizome
6.	Clove	*Syzygium aromaticum* (Linnaeus) Merrill and Perry	Myrtaceae	Flower bud
7.	Neem	*A. indica*	Meliaceae	Seeds
8.	Untreated check	-	-	-

Management of the rice weevil, *S. oryzae* on husked and unhusked rice grains with botanicals

Experiment I

About 100 g of UV sterilized grains of BPT 5204 rice and unhusked grains were weighed and transferred to separate plastic containers, in which 1 g of botanical powder was added and mixed thoroughly. The containers were closed with lid and allowed for 15 minutes until the botanical powders settled over the grains as a thin layer. Five pairs of newly emerged adult insects were released in each container. The experiment was laid out with eight treatments replicated thrice for botanical seed powders. The experiment I was carried out from May to August, 2022.

For *S. oryzae*, husked rice was used as host. The post treatment counts on adult mortality were taken on 2, 5, 7, 10, 12, 14, 21 and 30 days after inoculation (Vijayashanthi, 2014; Metha and Kumar, 2020) [12, 27]. Per cent ovideterrence was worked out 25 days after inoculation and then monthly (Swamy *et al.,* 2014) [24]. Per cent inhibition rate and per cent

grain damage were assessed monthly and per cent weight loss and feeding deterrent index were assessed at the end of the experiment (Vijayashanthi, 2014; Mehdi, 2012; Bhargude *et al.*, 2021) [5, 10, 27].

Experiment II

For experiment II, also known as the confirmation experiment. Experimental procedures as mentioned in 3.5.1 were repeated and carried out to confirm the results of experiment I. The experiment II was conducted from September to December, 2022.

Statistical analysis

The per cent data recorded for grain damage, adult mortality, weight loss, feeding deterrent index and oviposition deterrence were converted into angular transformation and the number of eggs and adults were transformed into square root transformation ($\sqrt{X+0.5}$).

Completely Randomized Design (CRD) analysis was carried out using wasp 2.0 software to analyse the data collected from the laboratory experiments. Critical difference values were calculated at 5 per cent probability level and the treatment mean values of the experiments were compared using DMRT (Vijayashanthi, 2014) [27].

Adult mortality

The number of live insects were recorded on 2, 5, 7, 10, 12, 14, 21, 30 days after inoculation for rice weevil and daily for angoumois moth.

Per cent mortality = $\frac{No.of\ dead\ insects}{Total\ no.of\ insects} \times 100$ Parugrug and Roxas (2008) [17]

Abbott's correction was done to get corrected mortality, since mortality was also recorded in control for angoumois grain moth.

Corrected mortality = $\frac{X-Y}{X} \times 100$

Where, X –per cent living in check

Y – per cent living in treatment Abbott (1925) [2]

Oviposition

About 10 seeds were randomly selected from each treatment on 25 days after inoculation for rice weevil and then taken monthly. The number of eggs laid on each seed was recorded.

Ovideterrence

Per cent ovideterrence

$$= \frac{No.of\ eggs\ laid\ on\ untreated\ check\ - No.of\ eggs\ laid\ on\ treated\ seeds}{No.of\ eggs\ laid\ on\ untreated\ check} \times 100$$

Singh (2011)

Adult emergence

Number of newly emerged adults was recorded every month.

Inhibition rate

Per cent inhibition rate of adult emergence was calculated using the following formula.

Per cent inhibition rate

$$= \frac{No.of\ newly\ emerged\ adults\ on\ untreated\ check - No.of\ newly\ emerged\ adults\ on\ treated\ seeds}{No.of\ newly\ emerged\ adults\ on\ untreated\ check} \times 100$$

Akinneye and Oyeniyi (2016)

Per cent grain damage

About 100 seeds were randomly selected from each treatment for every month and numbers of damaged seeds were counted.

Per cent grain damage $= \frac{Number\ of\ damaged\ grains}{Total\ number\ of\ grains\ used} \times 100$ Metha and Kumar (2020) [12]

Weight loss

Initial weight of 100 g of seeds was recorded and used for the experiment. The rest of the observations on weight were taken monthly.

Per cent weight loss

$$= \frac{Initial\ weight\ of\ sound\ grains - Final\ weight\ of\ damaged\ grains}{Initial\ weight\ of\ sound\ grains} \times 100$$

Bhargude *et al.* (2021)

Feeding Deterrent Index (FDI)

The initial and final weights of grains in treatment and untreated check were recorded to calculate the feeding deterrent index by using the following formula.

$$FDI = \frac{Weight\ loss\ in\ untreated\ check - Weight\ loss\ in\ treated}{Weight\ loss\ in\ untreated\ check} \times 100$$

Mehdi (2012)

Experimental Results and Discussion

Effect of botanical seed powders against the rice weevil, *S. oryzae*

Seven number of botanical seed powders were evaluated against the rice weevil. Pepper seed powder was the best among the treatments showing the highest adult mortality (87.08 % and 83.33 %), lowest oviposition (0.03 and 0.14), lowest adult emergence (2.08 and 4.08), highest ovideterrence (92.16 % and 83.53 %), highest inhibition rate (98.94 % and 97.96 %), lowest seed damage (0.67 % and 1.83 %), lowest weight loss (1.41 % and 2.04 %) and better FDI value (97.78 and 96.72) in experiment I and II (Table 2 and 3).

Pepper seed powder recorded the highest adult mortality with the mean of 87.08 per cent in experiment I and 83.33 per cent in experiment II (Fig. 1). This is supported by Devi and Devi (2013) [6] who expressed that the powders of pepper at 1 per cent was highly effective resulting in total mortality of *S. oryzae* by one week and inhibition rate was also high in pepper recording 100 per cent at 1 per cent concentration.

Kumar *et al.* (2016) [9] reported that pepper seed powder (10g/kg) resulted in 84.76 per cent adult mortality by a week and the number of adults emerged was 27.50 in 60 days after release of 50 adults.

Pepper seed powder recorded the lowest adult emergence from 0.33 to 4.00 and 0.67 to 6.67 in experiment I and II, respectively. The highest per cent inhibition of 98.94 and 97.96 was registered in pepper seed powder in experiment I and II, respectively (Fig. 2). It was found that pepper seed powder was the best treatment against *S. oryzae.* Asawalam *et al.* (2012) [3] reported that use of pepper seed powder treated rice increased the adult mortality and suppressed the adult emergence of rice weevils, recording the highest mean mortality of 18.8 at 35 DAT and the number of adults that emerged (3.25) was significantly lower in the pepper treatment which had low weight loss.

The reports from study conducted by Sousa *et al.* (2005) [23] expressed that *P. nigrum* reduced the number of eggs (0.00 %), the oviposition (100.00 %) and the adult emergence in 100.00 per cent and expressed that the efficiency was related to the repellent effect of their volatile compounds which might cause sterility in males as well as in females which supported the results of the present study.

The maximum ovideterrence of 92.16 and 83.53 per cent was recorded by pepper seed powder over the four months of experiment I and II, respectively (Fig. 3). The present findings are in accordance with the findings of Singh (2011) [22] who reported that black pepper powder at dose of 1.0 mg/100 g of chick pea seeds against *C. maculatus* registered 39.90 per cent oviposition deterrence.

In experiment I, first month, clove, nutmeg and neem seed powders also recorded the highest oviposition deterrence of 83.33, 83.33 and 83.33 per cent (Fig. 3). The present findings are in accordance with the reports of Sahoo *et al.* (2018) [21] and Ugwuona *et al.* (2021) [26] expressed that the toxic volatile compounds which are available in clove, nutmeg and neem acted as repellents and deterred the adult rice weevil from egg laying on the rice grains. This might be the reason in recording the highest oviposition deterrence in the present study.

Ashamo *et al.* (2011) stated that *P. guineense* had the highest insecticidal activity by totally preventing the adult emergence at 2 per cent oil concentration. Swella and Mushobozy (2007) [25] evaluated the efficacy of black pepper against *C. maculatus* and reported lower damage per cent (7.90 %) and mean number of dead adults (13.25) in black pepper treatment with 14 days of storage. These findings are in accordance with the results of the present study

Pal *et al.* (2021) [15] reported that pepper reduced the grain damage per cent on number basis (1.20 %) and on weight basis (1.30 %), weight loss per cent (0.91 %) and weevil population count (2.71) that supported the results of the present experiment recording the least seed damage in pepper seed powder with the mean value of 0.67 per cent in experiment I and 1.83 per cent in experiment II in four months and the weight loss of 1.41 per cent and 2.04 per cent in experiment I and II, respectively (Fig. 4). The FDI value of 97.78 and 96.72 was recorded in experiment I and II, respectively (Fig. 4), which proved that pepper seed powder was found to be more effective. This statement is in conformity with the findings of Mehdi (2012) [10] who recorded the FDI value of 78.80 in *P. nigrum* against the rice weevil.

Table 2: Evaluation of botanical seed powders as seed protectants on the adult mortaliy, oviposition, adult emergence and ovideterence of the rice weevil, *S. oryzae* in Experiment I and II

SI. No.	Seed powders	Adult mortality		Oviposition		Adult emergence		Ovideterence	
		Expt I	Expt II	Expt I	Expt II	Expt I	Expt II	Expt I	Expt II
1.	African dream herb	7.50	6.67	0.87	1.01	145.41	158.00	14.70	8.67
2.	Rosary pea	13.75	10.00	0.40	0.45	64.75	72.83	54.06	50.61
3.	Pepper	87.08	83.33	0.03	0.14	2.08	4.08	92.16	83.53
4.	Nutmeg	23.75	27.50	0.46	0.56	105.50	109.50	59.95	37.21
5.	Chilli+Garlic+Ginger	16.25	18.33	0.62	0.73	128.75	130.16	37.43	25.46
6.	Clove	58.75	55.83	0.12	0.24	4.50	6.50	84.37	71.61
7.	Neem	29.58	25.83	0.35	0.32	36.50	40.16	67.13	62.07
8.	Untreated check	0.00	0.00	0.98	1.10	212.67	220.16	-	-

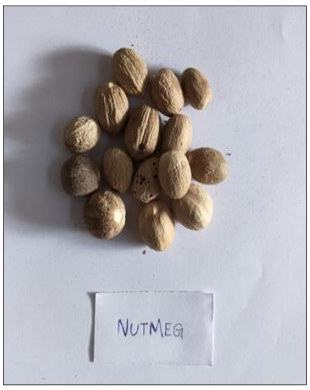
Table 3: Evaluation of botanical seed powders as seed protectants on the inhibition rate, seed damage, weight loss and feeding deterrent index of the rice weevil, *S. oryzae* in Experiment I and II

SI. No.	Seed powders	Inhibition rate		Seed damage		Weight loss		Feeding deterrent index	
		Expt I	Expt II	Expt I	Expt II	Expt I	Expt II	Expt I	Expt II
1.	African dream herb	42.40	39.68	55.75	53.25	45.80	46.25	28.59	26.18
2.	Rosary pea	74.39	74.03	33.16	45.08	28.85	26.55	55.01	57.60
3.	Pepper	98.94	97.96	0.67	1.83	1.41	2.04	97.78	96.72
4.	Nutmeg	62.17	59.10	17.67	19.83	12.22	10.88	8093	82.64
5.	Chilli+Garlic+Ginger	53.69	53.29	48.75	35.67	37.09	33.76	42.16	46.10
6.	Clove	97.95	96.72	3.41	6.25	4.10	3.74	93.60	94.02
7.	Neem	86.90	84.96	37.67	43.67	18.60	16.92	70.99	72.98
8.	Untreated check	-	-	72.16	74.41	64.15	62.67	-	-

Egg Grubs

Pupa Male Female Adult

Plate 1: Life stages of the rice weevil, *S. oryzae* on husked rice



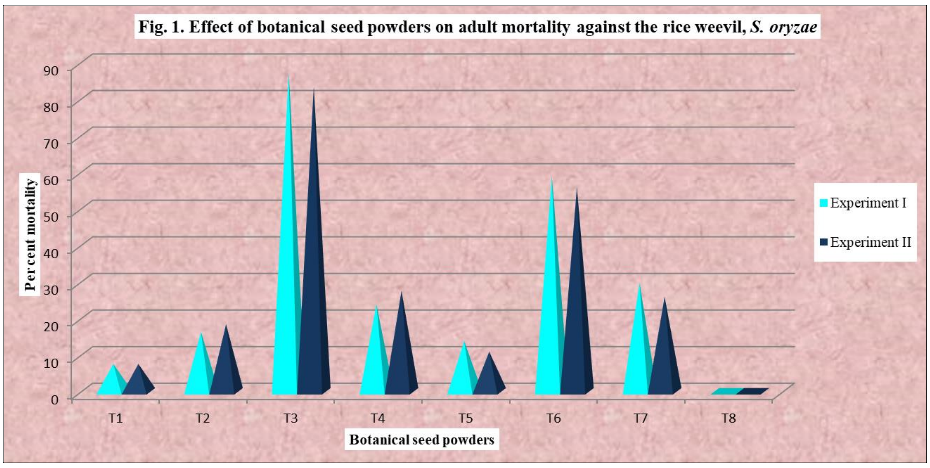
AFRICAN DREAM HERB ROSARY PEA PEPPER NUTMEG

CHILLI + GARLIC + GINGER CLOVE NEEM

Plate 2: Different plant seeds used as seed protectants against the rice weevil, *S. oryzae*

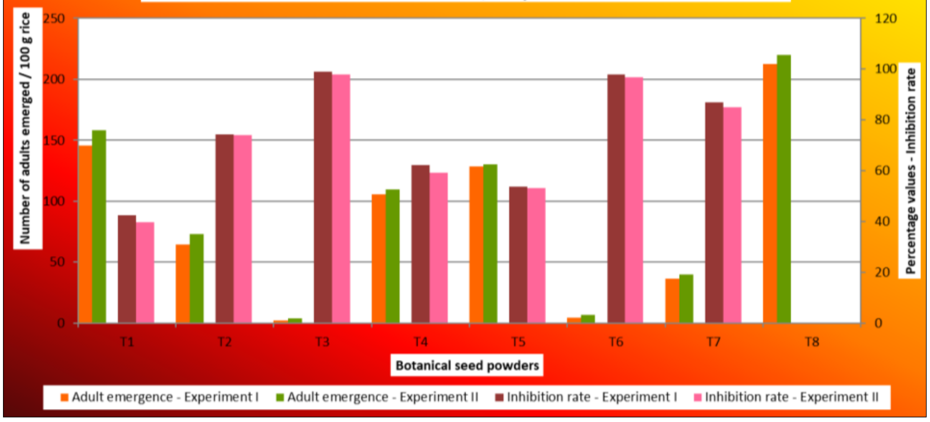
Botanical seed powders

Plate 3: Different seed protectants used against the rice weevil, *S. oryzae*



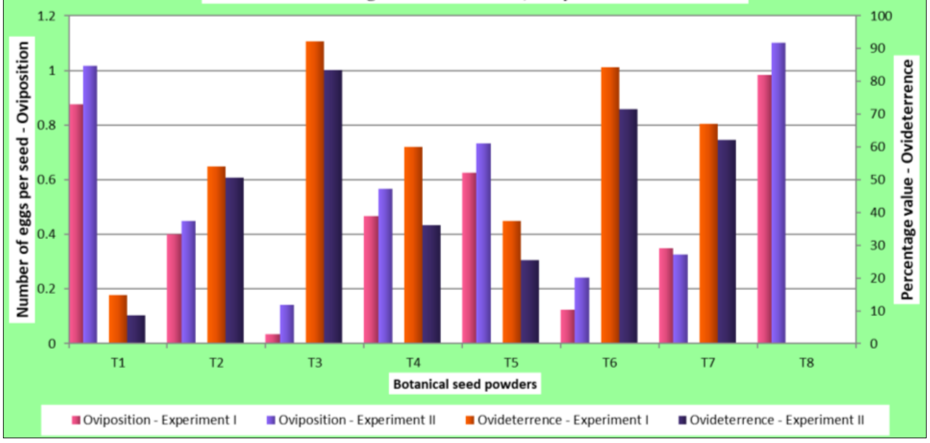
T1-African dream herb seed powder	T4- Nutmeg seed powder	T7-Neem seed powder
T2- Rosary pea seed powder	T5- Chilli + garlic + ginger powder	T8- Untreated check
T3- Pepper seed powder	T6-Clove seed powder	

Fig. 2. Effect of botanical seed powders on adult emergence and inhibition rate against the rice weevil, *S. oryzae*



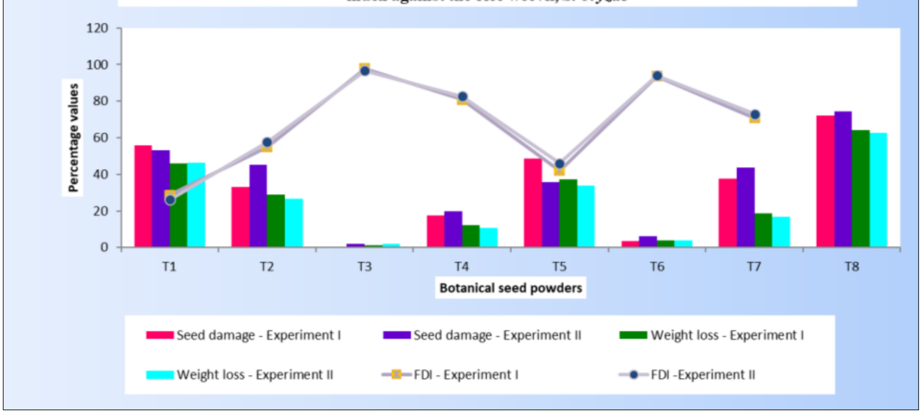
T1-African dream herb seed powder	T4- Nutmeg seed powder	T7-Neem seed powder
T2- Rosary pea seed powder	T5- Chilli + garlic + ginger powder	T8- Untreated check
T3- Pepper seed powder	T6-Clove seed powder	

Fig. 3. Effect of botanical seed powders on oviposition and ovideterrence against the rice weevil, *S. oryzae*



T1-African dream herb seed powder	T4- Nutmeg seed powder	T7-Neem seed powder
T2- Rosary pea seed powder	T5- Chilli + garlic + ginger powder	T8- Untreated check
T3- Pepper seed powder	T6-Clove seed powder	

Fig. 4. Effect of botanical seed powders on per cent seed damage, weight loss and feeding deterrent index against the rice weevil, *S. oryzae*



T1-African dream herb seed powder	T4- Nutmeg seed powder	T7-Neem seed powder
T2- Rosary pea seed powder	T5- Chilli + garlic + ginger powder	T8- Untreated check
T3- Pepper seed powder	T6-Clove seed powder	

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