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Efficacy of plant powders as seed protectant against *Corcyra cephalonica* (Stainton) in stored pearl millet

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Abstract
An experiment was conducted at B. A. Collage of Agriculture, Anand Agricultural University, Anand during 2022-23 to investigate different nine plant powders *viz.*, orange peel powder, guava leaf powder, tulsi leaf powder, mint leaf powder, neem leaf powder, neem seed kernel powder, custard apple leaf powder, curry leaf powder and moringa leaf powder were evaluated as seed protectant against this pest. The result showed that the mixing of neem seed kernel powder and neem leaf powder @ 2.5 g/100 g pearl millet seeds was found the most effective against *C. cephalonica* as it achieved 93.88, 93.41 percent oviposition deterrence, 6.41, 6.59 days males longevity, 6.43, 6.64 days females longevity, 51.05, 51.61 eggs per female and 57.33, 60.00 percent viable eggs, respectively after seed treatment. The best treatment with (71.25%) reduction of adult emergence was achieved by neem seed kernel powder @ 2.5 g/100 g seeds. The sex ratio of males and females ranged from 1:1.00 to 1:1.02 in all the evaluated treatments. None of these plant powders tested at different doses, hampered the germination of pearl millet during storage periods of up to 65 days.

Keywords: Rice moth, bajra, storage pest management, botanicals, plant powders

Introduction

Pearl millet, *Pennisetum glaucum* (Linn.) R. Br. belonging to the Gramineae family, is the most widely cultivated millet variety due to its ability to thrive in challenging environmental conditions like drought, poor soil quality, and high temperatures. It is predominantly grown across approximately 30 million hectares in arid and semi-arid tropical regions in Asia and Africa, constituting about half of the world's millet production. This nutritious grain serves as a primary food source for 90 million underprivileged individuals, with India and Africa collectively accounting for 90% of the global production of pearl millet (Yadav *et al.*, 2012) [20].

From a nutritional standpoint, it is a rich source of energy and contains elevated levels of minerals, vitamins, lipids, crude fibers, and high-quality protein ranging from 9 to 13 percent (Uppal *et al.*, 2015) [19]. In terms of specific nutritional content, pearl millet grains typically consist of 4.31 to 5.30 percent crude fiber, 10 to 80 mg of calcium, 7 to 18.0 mg of iron, 5.3 to 7.0 mg of zinc, and 1.0 to 1.8 mg of copper. (Abdalla *et al.*, 2009) [1]. Rajasthan, Maharashtra, Uttar Pradesh, Gujarat and Haryana are the principal pearl millet-growing states, which produce 90% of national produce (Anonymous, 2021) [4].

The insect known as *Corcyra cephalonica* (Stainton), commonly referred to as the "Rice meal moth" or the "Flour moth," is a member of the Pyralidae family and falls under the Lepidoptera order (Stainton, 1866) [17]. It is a significant storage pest of pearl millet that is distributed across multiple regions, including Asia, Africa, North America, and Europe. Adult rice meal moths exhibit a grey coloration. Following mating, female moths typically deposit a range of 100 to 200 eggs in proximity to their food source. These eggs typically hatch within a span of 4 to 10 days. The larval stage involves the construction of a feeding tube gallery, composed of a silken structure and food particles, to facilitate nourishment and growth. Upon reaching full maturity, the larvae encase themselves in compact white cocoons for pupation. These pupae may be observed within storage pallets, sacks, or even within the food itself. The adult moths emerge from the pupae within a time frame of four to eight weeks, thereby perpetuating their life cycle (Pandey, 2011) [11]. The rice moth is a significant pest that poses a serious threat to various stored food commodities, including cereals, pulses, oilseeds, millets and other food products. Its presence not only leads to issues related to sanitation within storage facilities but also has adverse effects on the quality and quantity of the stored goods

Materials and Methods
A laboratory experiment was conducted to work out the efficacy of plant materials as seed protectants for the safe storage of pearl millet seeds against *C. cephalonica*. For the study on efficacy of plant powders, five pairs of newly emerged adults were released in jars containing 300 g pearl millet seeds treated with dose (2.5 g/100 g seeds) of test compounds *viz*., orange peel powder, guava leaves powder, tulsi leaves powder, mint leaves powder, neem leaves powder, neem kernel powder, custard apple leaves powder, curry leaves powder and moringa leaves powder (Fig 1). Each treatment was replicated three times (Fig 2).

Oviposition deterrent activity
For each concentration, 300 g seeds of pearl millet were taken in a conical flask and mixed with each concentration of plant powder and seeds without treatment used as untreated seeds. After thoroughly mixing the seeds they were separated into three lots each having 100 g seeds, stored in jars (8 × 6.5 cm) and 5 pairs of newly emerged adults rice moth were introduced in each container. After 4 days, number of eggs laid in hundred treated seeds (Ts) and hundred untreated seeds (Cs) were recorded. The percentage of oviposition deterrence (POD) was calculated by following formula given by Singh and Jakhamola (2011) [15]. The weight of 1000 seeds were 7.0 g (Anon., 2007) [3].

$$\mathrm{POD} = \frac{\mathrm{Cs-Ts}}{\mathrm{Cs}} \times 100$$

Where,
Ts = number of eggs laid in treated seeds
Cs = number of eggs laid in untreated seeds

Adult emergence activity
After the eggs were counted, the experimental setup was kept undisturbed till the emergence of next generation of adults from the treated and untreated seeds. The number of adults which emerged from the untreated seeds (Ac) and treated seeds (At) were recorded. The percentage reduction in adult (PRA) emergence was calculated by following formula given by Singh and Jakahmola (2011) [15].

$$\mathrm{PRA} = \frac{\mathrm{Ac-At}}{\mathrm{Ac}} \times 100$$

Where,
Ac = number of adults emerged from the untreated seeds
At = number of adults emerged from the treated seeds

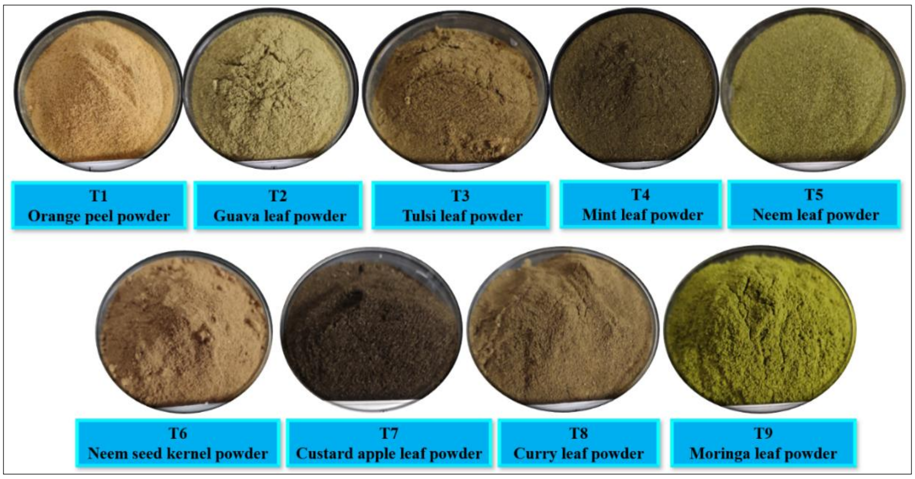

Fig 1: Different types of plant powders used against *C. cephalonica*

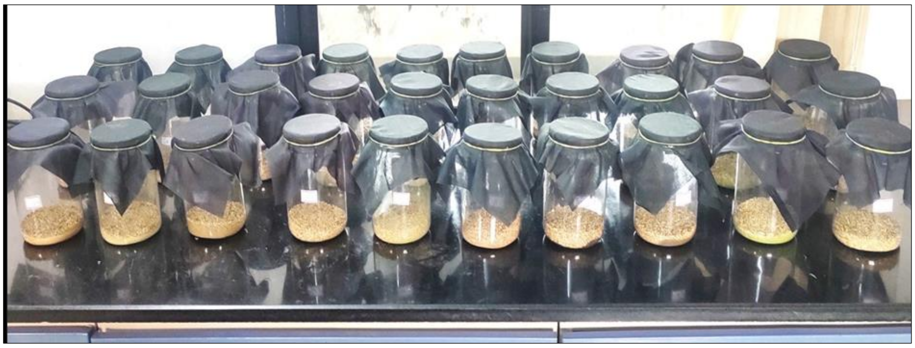

Fig 2: Evaluation of the effectiveness of different plant powders against C. cephalonica

Longevity of male and female emerged
The longevity of males and females were recorded from treated and untreated seeds.

Fecundity
For recording the fecundity, freshly emerged adults from the larvae reared on treated food were kept in separate jars for egg-laying. The total number of eggs laid by five pair of adults were counted daily till the death of the females in each treatment.

Egg viability
For egg viability, a random sample of 50 eggs were taken from each repetition and placed in a petri dish. The

observation of hatched or unhatched eggs were counted with the help of a microscope.

Germination test

The laboratory test was conducted as per the ISTA procedure by adopting the paper method (ISTA, 2015) [6], To determine the effect of plant powders on the germination percentage of pearl millet seeds, a second lot of 100 treated and untreated seeds (without the release of adult moths) were stored for 65 days in three separate repetitions for each treatment. The germination test was carried out with germination paper. After the seeds were placed on the germination paper the between paper roll was kept in the germinator at 20±0.50 ºC temperature and 95±1% relative humidity. The final count's normal seedlings were carried out on seven days of the germination test and germination was expressed in percentage

Results and Discussion

Percent oviposition deterrence

In the present investigation, it was found that all the plant powders showed a significant reduction in oviposition, which indicated the higher protectant potential of these powders against rice moth damage. The reduction in eggs over control due to different plant powders varied significantly (Table 1). Regarding different plant powders, the oviposition deterrent property ranged from 76.97 to 93.88 percent.

Neem seed kernel powder @ 2.5 g/100 g seeds exhibited the highest oviposition deterrent property (93.88%), which was at par with neem leaves powder at the same concentration (93.41%). The moderately effective treatments were orange peel powder (88.55%), tulsi leaves powder (86.62%), curry leaves powder (85.11%) and custard apple leaves powder (84.98%) at the same concentration. Guava leaves powder, mint leaves powder and moringa leaves powder @ 2.5 g/100 g seeds were confirmed the lowest oviposition deterrent properties (76.97, 78.11 and 83.58% respectively).

Overall, it was observed that all the plant powders treatments, neem seed kernel powder @ 2.5 g/100 g seeds showed maximum oviposition deterrence activity against *C. cephalonica* as it recorded a maximum reduction in oviposition and the treatment of neem leaves powder @ 2.5 g/100 g seeds was at par with neem seed kernel powder. These powders might possess oviposition deterrence that could change the physiology and behaviour of the adult *C. cephalonica* as reflected in their egg fecundity.

In the present study, the use of neem seed kernel and neem leaves powder resulted in a significant reduction in *C. cephalonica* oviposition. Similar findings were reported by Pandey *et al.* (1985) [10], who observed a considerable decrease in egg laying of *C. cephalonica* due to the use of neem compounds. However, due to limited research on *C. cephalonica*, this aspect remained unaddressed in the current investigation. Another study by Dulera *et al.* (2015) [5] assessed the effectiveness of various plant products against rice moth and found that karanj kernel powder and neem leaves powder @ 2.5 and 5.0 g/ 100 g seeds of groundnut significantly reduced (98.58, 98.68, 98.47 and 98.53%) oviposition, respectively.

Percent reduction of adult emergence

The data presented in Table 1 and indicated that the mean percent reduction of adult emergence (PRA) from different plant powders treated seeds of pearl millet ranged from 32.06 to 71.25 percent. The highest (71.25%) PRA was observed in neem seed kernel powder @ 2.5 g/100 g seeds. The treatment of neem leaves powder @ 2.5 g/100 g seeds was the next best treatment with a 64.33 percent reduction of adult emergence. Apart from these treatments, orange peel powder (48.14%), tulsi leaves powder (47.46%), curry leaves powder (43.98%) and custard apple leaves powder (42.37%) with the same concentration were found effective in percent reduction of the adults. The treatments of guava leaves powder, mint leaves powder and moringa leaves powder @ 2.5 g/100 g seeds were found least effective as it recorded 32.06, 37.56 and 41.38 percent reduction of adult emergence, respectively (Fig 4).

In the present study, neem seed kernel powder at a concentration of 2.5 g/100 g of seeds was noted as the highest efficacy, comparable to neem leaves powder at the same concentration. These findings align with the results reported by Senguttuvan *et al.* (1995) [14], who conducted a comparative evaluation of various plant products against rice moth and identified neem leaves powder as the most toxic substance, followed by neem seed kernel powder. Therefore, these findings are confirmed by the outcomes reported by past authors. However, in the study conducted by Patnaik *et al*. (2012) [12], focused on the effectiveness of karanj powder and observed 27.50 pwe cent adult emergence. Additionally, Ramanaji (2020) [13] reported that the application of neem seed kernel powder @ 2.5 g/100 g of groundnut significantly reduced 95.89% percent adult emergence.

The reduction in adult emergence could either be due to egg mortality or larval mortality or even reduction in the hatching of the eggs. The egg mortality has been attributed to the toxic compounds present in the plant material by Su (1977) [18] while Singh *et al.* (1978) [16] considered the physical properties caused changes in the surface tension and oxygen tension in the egg. Disruption of the water balance of eggs and developing embryos may also result in death as suggested by Messina and Renwick (1983) [9].

Sex ratio

The sex ratio (Male: Female) of *C. cephalonica* was calculated from the adults emerged under laboratory conditions (Table 2). The sex ratios (♂:♀) of *C. cephalonica* ranged from 1:1.00 on mint leaves powder and curry leaves powder @ 2.5 g/100 g seeds to 1:1.02 on tulsi leaves powder, orange peel powder @ 2.5 g/100 g seeds. So, it can be said that the female had a slight preponderance over the male. A more or less similar result was also reported by Allotey and Azalekor (2000) [2], who showed the sex ratios (♂:♀) of 1:1 on *C. cephalonica.* Whereas Dulera *et al*. (2015) [5], reported sex ratios (♂:♀) ranging from 1:1.00 to 1:1.10 on *C. cephalonica*

Among the different plant powders tested, neem seed kernel powder and neem leaves powder treated seeds @ 2.5 g/100 g seeds were found superior over other treatments and registered 117 and 145 emergences of adults. Out of 117 adults, 58 were found to be males and 59 were females. Thus, the sex ratio (Male: Female) was 1:1.01 in the seeds treated with neem seed kernel powder @ 2.5 g/100 g seeds. Out of 145 adults, 72 were found to be males and 73 were females. Thus, the sex ratio (Male: Female) was 1:1.01 in the seeds treated with neem leaves powder @ 2.5 g/100 g seeds.

Longevity of male and female

The reduction of lifespan over control due to different plant powders varied significantly (Table 3). In the present investigation, it was found that live males differed significantly with the duration of 6.41 to 9.49 days and live females differed significantly with the duration of 6.43 to 11.05 days when reared on different treatments of plant powders.

The shortest male longevity observed on the treatment of neem seed kernel powder @ 2.5 g/100 g seeds (6.41 days) and neem leaves powder @ 2.5 g/100 g seeds (6.59 days) were significantly superior over other powder treatments, whereas orange peel powder (7.76 days), tulsi leaves powder (7.89 days), curry leaves powder (8.03 days), custard apple leaves powder (8.11 days) and moringa leaves powder (8.21 days) with the same concentration were found next in order which were at par with each other. The longest longevity of males was observed on the treatment of guava leaves powder @ 2.5 g/100 g seeds (9.04 days) which was at par with mint leaves powder @ 2.5 g/100 g seeds (8.64 days). It was revealed from the data that the longest male longevity was observed due to neem seed kernel powder @ 2.5 g/100 g seeds while lowest due to guava leaves powder @ 2.5 g/100 g seeds.

The shortest female longevity observed on the treatment of neem seed kernel powder @ 2.5 g/100 g seeds (6.43 days) and neem leaves powder (6.64 days) were significantly superior over other powder treatments and it was at par with each other. whereas orange peel powder (7.69 days), tulsi leaves powder (7.92 days), curry leaves powder (8.07 days) and custard apple leaves powder (8.23 days) with the same concentration were found next in order which were at par with each other. The shortest longevity of females was observed on treatments of guava leaves powder @ 2.5 g/100 g seeds (9.68 days) which were at par with mint leaves powder (9.13 days). The results also indicated that females lived longer than males.

Thus, it was found that using neem seed kernel powder @ 2.5 g/100 g seed resulted in the shortest longevity for both male and female moths. This effect was comparable to using neem leaves powder at the same concentration. In contrast, Meena and Bhargava (2010) [7] reported that treatment given to adults with tulsi leaves powder @ 1.0, 2.5 and 5.0 g/100 g seeds led to the longest longevity, indicating that tulsi leaves powder was the least effective in reducing lifespan. However, they found that neem, karanj, dhatura, and mint powders were highly effective and resulted in the shortest lifespan. The present findings align with these previous studies, although minor differences can be attributed to variations in storage conditions, dosage concentrations and storage materials. In addition, Dulera *et al.* (2015) [5] also reported significant effectiveness of karanj kernel powder and neem leaves powder, at concentrations of 2.5 and 5.0 g/100 g of groundnut seeds, against *C. cephalonica.* This treatment considerably reduced the lifespan of male and female moths, indicating a significant impact on their longevity.

Fecundity

All the doses of different test compounds were found to be significantly effective in reducing the fecundity over control (Table 3). The percent reduction in fecundity of test insects on treated pearl millet seeds increased with the increase in dose level of each treatment. The per female fecundity ranged from 51.05 to 91.54 in all the treatments. The treatment of neem seed kernel powder @ 2.5 g/100 g seeds was excellent for reducing per female fecundity and reported 51.05 eggs. It was significantly at par with neem leaves powder @ 2.5 g/100 g seeds and recorded 51.61 eggs per female. The next most effective treatment for reducing female fecundity was orange peel powder @ 2.5 g/100 g seeds which recorded 61.04 eggs per female. The treatment of tulsi leaves powder (72.24 eggs per female), curry leaves powder (74.58 eggs per female) and custard apple leaves powder (75.97 eggs per female) with the same concentration were moderately effective treatments and significantly at par with each other. The treatment of guava leaves powder @ 2.5 g/100 g seeds and mint leaves powder @ 2.5 g/100 g seeds were the least effective treatment and significantly at par with each other recorded 90.05 and 87.97 eggs per female, respectively. These results are in accordance with those of Meena *et al.* (2016) [8], who found that neem leaves powder @ 0.1, 2.5 and 5.0 g/100 g of seeds reduce the fecundity of *C. cephalonica.*

Viability

All doses of various plant powders showed significant improvements in reducing egg viability compared to the control (Table 3). The highest percent reduction in egg viability was observed when treating pearl millet seeds with neem seed kernel powder and neem leaves powder @ 2.5 g/100 g seeds (57.33 and 60.00% reduction, respectively). These two treatments were significantly similar in their effectiveness. The second most effective treatment for reducing egg viability was orange peel powder (74.00%), which was significantly at par with tulsi leaves powder (74.00%), curry leaves powder (76.00%), custard apple leaves powder (78.67%) and moringa leaves powder (78.67%). The least effective treatments in reducing egg viability were guava leaves powder and mint leaves powder @ 2.5 g/100 g seeds. Both treatments were significantly at par with each other, resulting in 92.00% and 89.33% egg viability, respectively. These findings are similar to those reported by Meena and Bhargava (2010) [7]. They found maximum reduction in egg viability when treating seeds with different plant powders such as neem, karanj, citrus and mint, using three different dose levels (1.0, 2.5 and 5.0 g/100 g of sorghum seeds).

Germination (%)

Pearl millet is highly susceptible to *C. cephalonica* and other storage pest infestations, requiring the use of protective treatments. It is crucial to ensure that the protective materials used do not hamper the germination of pearl millet. To assess this, a laboratory germination test was conducted to evaluate the effects of different powders used as seed protectants on the germination of treated pearl millet seeds. The data presented in Table 3 revealed that all the treatments non significantly influenced the germination percentage compared to the control. The highest germination percentage (75.33%) was observed in pearl millet seeds treated with neem seed kernel powder @ 2.5 g/100 g seeds and neem leaves powder (74.67%) at the same dose level. All the treatments exhibited similar levels of effectiveness. These are more or less similar to Dulera *et al.* (2015) [5] as they also observed that groundnut seeds treated with karanj kernel powder at a dose of 5.0 g/100 g seeds exhibited the highest germination percentage and seeds treated with neem leaves, neem seed kernel and tulsi leaves powder resulted in promising germination. It is worth noting that all treatments showed 100 percent germination after a storage period of 65 days. Therefore, it can be concluded that none of the plant powders tested had an adverse effect on the germination of pearl millet seeds.

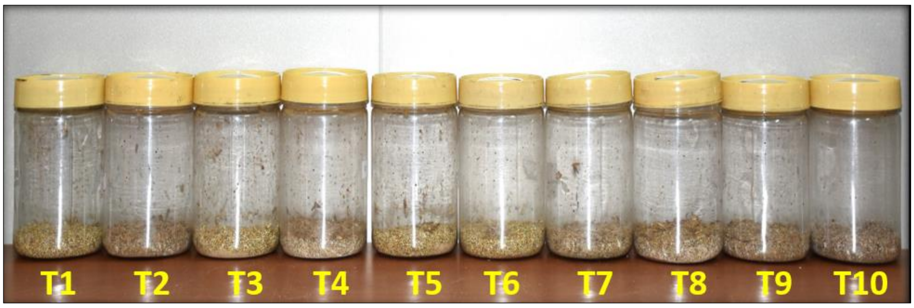

Fig 3: Effectiveness of different plant powders against C. cephalonica in stored pearl millet

Table 1: Impact of different plant powders on ovipositional deterrence and reduction of adult emergence of *C. cephalonica* in stored pearl millet

Treat. No.	Plant powders	Dose g/100 g seeds	Total laid Eggs	Oviposition deterrence (%)	Total adults emerged	Reduction of adult emergence (%)
1	Orange peel	2.5	257	70.25 (88.55)	212	43.93 (48.14)
2	Guava leaves	2.5	510	61.39 (76.97)	277	34.48 (32.06)
3	Tulsi leaves	2.5	298	68.58 (86.62)	214	43.54 (47.46)
4	Mint leaves	2.5	489	62.16 (78.11)	254	37.77 (37.56)
5	Neem leaves	2.5	148	75.16 (93.41)	145	53.34 (64.33)
6	Neem seed kernel	2.5	136	75.71 (93.88)	117	57.59 (71.25)
7	Custard apple leaves	2.5	331	67.30 (84.98)	235	40.61 (42.37)
8	Curry leaves	2.5	326	67.45 (85.11)	228	41.54 (43.98)
9	Moringa leaves	2.5	363	66.18 (83.58)	239	40.02 (41.38)
10	Control	-	2265	-	408	-
S.Em.±				1.36	-	1.12
C.D. at 5%				4.01	-	3.31
C.V. (%)				3.83	-	4.94

Figures in parentheses are percent oviposition deterrence values and values of percent reduction of adult emergence, whereas figures outside the parentheses indicate angular transformed values

Table 2: Sex ratios of emerged *C. cephalonica* on stored pearl millet treated with different plant powders

Treat. No.	Plant powders	Dose g/100 g seeds	Sex		Total adult emergence	Sex-ratio
			Male	Female		
1	Orange peel	2.5	105	107	212	1:1.02
2	Guava leaves	2.5	138	139	277	1:1.01
3	Tulsi leaves	2.5	106	108	214	1:1.02
4	Mint leaves	2.5	127	127	254	1:1.00
5	Neem leaves	2.5	72	73	145	1:1.01
6	Neem seed kernel	2.5	58	59	117	1:1.01
7	Custard apple leaves	2.5	117	118	235	1:1.01
8	Curry leaves	2.5	114	114	228	1:1.00
9	Moringa leaves	2.5	119	120	239	1:1.01
10	Control	-	204	204	408	1:1.00

Figures indicate total number adults per treated seeds

Table 3: Impact of different plant powders on longevity, fecundity, egg viability and germination of stored pearl millet seeds

Treat. No.	Plant powders	Dose g/100 g seeds	Longevity (Days)		Per female fecundity	Egg viability (%) (n=50 eggs)	Germination (%) (n=100 seeds)
			Male	Female			
1	Orange peel	2.5	2.78*(7.76)	2.77*(7.69)	7.81*(61.04)	59.35**(74.00)	74.00
2	Guava leaves	2.5	3.01(9.04)	3.11(9.68)	9.49(90.05)	73.65(92.00)	72.33
3	Tulsi leaves	2.5	2.81(7.89)	2.81(7.92)	8.50(72.24)	59.35(74.00)	73.67
4	Mint leaves	2.5	2.94(8.64)	3.02(9.13)	9.38(87.97)	71.01(89.33)	73.00
5	Neem leaves	2.5	2.57(6.59)	2.58(6.64)	7.18(51.61)	50.77(60.00)	74.67
6	Neem seed kernel	2.5	2.53(6.41)	2.54(6.43)	7.14(51.05)	49.22(57.33)	75.33
7	Custard apple leaves	2.5	2.85(8.11)	2.87(8.23)	8.72(75.97)	62.58(78.67)	73.00
8	Curry leaves	2.5	2.83(8.03)	2.84(8.07)	8.64(74.58)	60.68(76.00)	73.33
9	Moringa leaves	2.5	2.86(8.21)	2.88(8.28)	8.92(79.53)	62.53(78.67)	73.00
10	Control	-	3.08(9.49)	3.32(11.05)	9.57(91.54)	78.72(96.00)	75.67
S.Em.±			0.03	0.03	0.10	1.19	1.29
C.D. at 5%			0.11	0.10	0.30	3.52	NS
C.V. (%)			2.37	2.08	2.08	3.29	3.03

Figures in parentheses are mean longevity, fecundity and percent egg viability values, whereas figures outside the parentheses indicate transformed values: 1. *square root transformed values
2. **angular transformed values

Conclusions

In conclusion, research findings demonstrate the remarkable efficacy of neem seed kernel and neem leaf powder treatments, particularly at a concentration of 2.5 g/100 g pearl millet seeds, in effectively managing C. cephalonica infestation. These treatments employ a multifaceted approach, deterring oviposition, reducing the longevity of adult insects, limiting egg production and viability, all while preserving the germination potential of pearl millet seeds during storage periods of up to 65 days. This comprehensive pest management strategy not only safeguards the quality of pearl millet but also offers a sustainable and environmentally friendly solution.

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