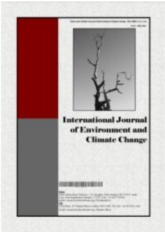

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Effect of Desiccant Beads on Groundnut Bruchid, *Caryedon serratus* (Olivier) Infestation in Stored Groundnut

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The purpose of this study was to evaluate the effect of desiccant beads on the stored groundnut against groundnut bruchid, *Caryedon serratus* Olivier. The experiment was carried out in the storage laboratory of Department of Entomology, OUAT, Bhubaneswar during 2019-20 in Completely Randomised Design. Groundnut pods(100 grams) in each treatment were mixed with 2 types of beads *viz*., zeolite beads and sodium aluminium silicate in four different ratios (1:1, 1:0.9, 1:0.8, 1:0.7) along with an untreated control and the observations on the fecundity, adult emergence, weight loss(%), moisture content, germination(%) were recorded during 6 months of storage at an interval of 60 days. Among the different treatments, the pods mixed with zeolite beads in 1:1 ratio was found to be the most superior treatment after 2, 4 and 6 months with the lowest fecundity (14.67, 25.67 and 34.33 eggs, respectively) and adult emergence (10.00, 17.33 and 25.00 adults, respectively). However, all the treatment dosages were found significantly superior over control which recorded maximum weight loss due to bruchid infestation. It was also noted that there was reduction in moisture content of the groundnut kernels with the increase of storage period with desiccant beads as these beads absorbed the moisture from the groundnut and created unsuitable environment for insect development and infestation. These beads did not show any adverse effects on the germination of groundnut.

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1. INTRODUCTION

Groundnut (*Arachis hypogaea* L.), is an important leguminous oilseed crop rich in nutrients. It is a rich source of edible oil and protein. The kernel consists of 48 to 50% oil and 26 to 28% protein [1]. It is rich in oleic and linoleic acid which is about 75 to 80% of the total fatty acid content and carbohydrate content in groundnut ranges from 10 to 20% (Sakhare et al., 2018). Groundnut being an important source of nutrition in human diet is stored as both pods and kernels and these are attacked by groundnut bruchid, *C. serratus* Olivier (Bruchidae: Coleoptera), which is considered as a major stored grain pest of groundnut. It causes damage both quantitatively and qualitatively. Kernels are found to be more susceptible to damage than pods during storage [2]. Storage of the pods after harvesting for a period of 5 to 6 months is very difficult due to the hidden infestation of bruchid in many groundnut producing states of India. The most important factors affecting the seed longevity in storage are seed moisture content and temperature [3].

The larvae of groundnut bruchid bore into the seed and feed upon the embryo and the endosperm. Final instar larvae come outside of the seed through the exit holes for pupation. Bruchid infestation causes considerable quantitative as well as qualitative losses to groundnut. This insect damage declines the quality of seed and oil, reduces its weight and nutritive value. Extent of damage (weight loss) caused by bruchid in shelled and unshelled groundnut is 70 and 80%, respectively and the extent of damage in tamarind is up to 79% [4].

The effect of infestation of *C. serratus* on the biochemical components of groundnut was studied by Sreedhar et al. [4]. The determination of quality loss of grains during storage is mandatory to determine the rate of physical and biochemical degradation in these grains. However, the post-harvest insect infestation severely affects quality and shelf-life of products [5]. The infestation due to stored grain insect pests also stimulates the growth of fungus as the moisture content of the seeds increases which in turn reduces the quality and viability of the seeds [6]. Desiccant-based drying can be more effective under these conditions and desiccants such as zeolite beads [7] and sodium aluminum silicate have been used for seed drying [8]. Very limited work has been done to study their role in management of stored grain insect pests. Hence, the present study was carried out to evaluate the efficacy of desiccant beads *against* groundnut bruchid, *C. serratus* during storage condition.

2. MATERIALS AND METHODS

The present study on the management of groundnut bruchid by using zeolite and sodium aluminium silicate beads was carried out at the storage laboratory, Department of Entomology, College of Agriculture, OUAT, Bhubaneswar. Zeolite beads and sodium aluminium silicate were obtained from the dealers of Gujarat. Specifically the desiccant beads are modified ceramic sieve materials that absorb and hold water molecules very tightly in their microscopic pores. These beads continue to absorb moisture until all of their pores are filled, up to 20 to 25% of their initial weight. When placed in an enclosed plastic, glass or metal container, the desiccant beads remove water from the air, creating and maintaining a very low humid environment. Seeds placed into a container with the beads lose moisture due to low humidity in the air, and continue to do so until they come to equilibrium with the ambient air inside the container. Hence, drying using desiccant beads simply transfers the water from the seed to the drying beads through the air and there is no need for heating. These beads can be mixed with the seed or can be closed in a porous bag or cloth and kept in the hermetic container along with the seeds for the convenience of separation. The same beads can subsequently be removed and re-used after regeneration. Regeneration can be done separately by heating for 2 hours at 200^{o}C to release the absorbed water. After heating, the beads should be immediately transferred to a moisture proof metal container with a lid (to reduce re-absorption of water) and kept until they are cooled.

To study the effect of desiccant beads on *C. serratus*, thoroughly dried 100 g of groundnut pods kept in sealed container were infested with five pairs of *C. serratus* 1 week prior to mixing with the zeolite/sodium aluminium silicate beads and replicated three times. The beads were tested at different concentrations comprising pod bead ratios of 1:1, 1:0.9, 1:0.8 and 1:0.7. An untreated control was also maintained and the infestation of the pest was observed after 2, 4 and 6 months of storage and the data on fecundity, adult emergence, weight loss, moisture content due to infestation and germination per cent were recorded and analyzed statistically.

3. RESULTS AND DISCUSSION

3.1 Efficacy of Desiccant Beads on Fecundity of *C. serratus*

Efficacy of the zeolite beads and sodium aluminium silicate beads was evaluated by mixing the beads with groundnut pods of local variety cv. *Devi* at different concentrations (pod bead ratios) of 1:1, 1:0.9, 1:0.8 and 1:0.7. Those were kept in air tight containers at room temperature and the observation recorded on effect of desiccant beads on fecundity of *C. serratus* released in to the beads treated groundnut pods were presented in the Table 1.

The observation of fecundity of the bruchid on the groundnut pods treated with zeolite and sodium aluminium silicate beads after two months of storage marked superior performance of beads over the control. Among the different doses, pod bead ratio of 1:1 and 1:0.9 were found significantly superior and recorded 18.00 and 22.50 eggs, respectively over other doses whereas the lower doses of 1:0.8 and 1:0.7 recorded 27.67 and 33.16 eggs, respectively. Between these two types of beads zeolite beads were more effective in reducing the fecundity of the bruchid (56.13 eggs) than sodium aluminium silicate beads (62.27 eggs). The interaction effect between beads and dosages revealed that among the different treatments, zeolite beads at 1:1 ratio exhibited most significant effect and recorded lesser number of eggs (14.67 eggs), whereas significantly high number of eggs (36.00 eggs) was recorded with sodium aluminium silicate beads at 1:0.7 ratio.

After four months of treatment the same trend continued and among the different doses used in the study on groundnut pods mixed with desiccant beads in the ratio of 1:1 and 1:0.9 reduced the fecundity to 28.67 and 37.50, respectively whereas 1:0.7 dosage was least effective and recorded 58.16 eggs. Out of these two beads used in the study zeolite beads restricted the fecundity to 99.00 whereas sodium aluminium silicate beads treatment resulted in 108.20 eggs. The interaction studies showed the superior performance of zeolite beads at 1:1 ratio where significantly the lowest number of eggs (25.67) were observed followed by sodium aluminium silicate beads at 1:1 ratio (31.67) eggs whereas significantly high fecundity (67.33 eggs) was observed in pods treated with sodium aluminium silicate beads at 1:0.7 ratio. All the treatments were found significantly superior over control which recorded 346.33 eggs.

After six months of treatment also pod bead ratio at 1:1 showed superior performance by recording lesser number of eggs (38.33) whereas at 1:0.7 ratio was least effective and recorded 78.33 eggs. Zeolite beads continued to be the most effective treatment and recorded 156.27 eggs whereas sodium aluminium silicate beads treatment recorded 161.93 eggs. The interaction effect between beads and dosages revealed that the zeolite beads mixed with the groundnut pods in 1:1 ratio proved to be the most effective in restricting the eggs to 34.33, whereas, significantly high fecundity (80.00 eggs) was observed in the treatment mixed with sodium aluminium silicate beads in 1:0.7 ratio.

The overall outcome obtained from the fecundity studies revealed that though neither of the beads could completely prevent the egg laying by the groundnut bruchid, the zeolite beads mixed with the pods in 1:1 ratio was found to be the most superior treatment during six months of storage and the other combinations were comparatively less effective in reducing the fecundity of the bruchid.

Similar type of results were reported by Sultana et al. [8] who observed that green gram seeds mixed with drying beads recorded the lowest oviposition (10 to13 eggs per10 g of seeds) by *Callosobruchus chinensis* after six months of storage. The seed moisture content was the primary factor limiting oviposition, rather than whether the storage container was hermetic. These observations are in line with Jyothsna [9], who reported that zeolite beads mixed with the groundnut pods in 1:1 ratio was found to be the most effective treatment in reducing the fecundity of *C. serratus*. Also Bidyarani [10] reported that greengram seeds when mixed with the zeolite beads in the ratios of 1:0.7, 1:0.8 and 1:0.9 resulted in 90.00% reduction in egg laying by the beetle after one month of treatment, but after 2 and 3 months of treatment, the pod bead ratio of 1:1 was found to be superior as compared to other treatments and reduced the egg laying by 90.00%.

Reduced fecundity of insects in the stored groundnut pods mixed with desiccant beads might be due to maintenance of lower seed moisture levels inside the container. These beads remove water from the air inside the container and create a very low humid environment. Thus, the pods placed in the container with desiccant beads will lose water due to the low air humidity. This adverse situation makes the bruchid uncomfortable for its activity and survival. Seed moisture content below 7% affects the normal activity and development of stored grain insect-pests and at levels below 9.5% certain insect-pests are unable to lay eggs. These observations are in line with findings of Lakshmi Prasad [11].

3.2 Efficacy of desiccant beads on adult emergence of *C. serratus*

The results obtained on the effect of desiccant beads on the adult emergence of *C. serratus* were presented in the Table 2.

The observation on adult emergence of *C. serratus* obtained from groundnut pods treated with desiccant beads found to be significantly superior over the untreated control (Table 2). None of the treatments could prevent complete adult emergence of groundnut bruchid after two months of treatment. Significantly low adult emergence (12.33) was recorded from the pods treated with desiccant beads used at 1:1 ratio followed by treatment at 1:0.9 (16.50 adults) whereas the highest adult emergence (26.33) was noticed in pods treated with beads in 1:0.7 ratio. Among the two beads used in the experiment zeolite beads were comparatively most effective and recorded 38.06 adults as against 43.93 adults obtained from sodium aluminium silicate beads. The interaction effect of doses and beads revealed that zeolite beads mixed with pods of groundnut in the ratio of 1:1 proved to be the best treatment which recorded significantly fewer adults (10.00) as against 30.33 adults observed from sodium aluminium silicate beads (1:0.7) treatment. The untreated control recorded 128.67 adults.

The observations recorded after four months of treatment also showed the similar trend where among the different doses, pod and bead ratio of 1:1 was more effective and reported lesser number of adults (20.33) as against 45.50 adults emerged from 1:0.7 dose. The zeolite beads continued their superiority (77.40) over sodium aluminium silicate beads (84.00) in reducing the adult emergence. Among the different treatment combinations zeolite beads at 1:1 (17.33) and 1:0.9 (21.67) ratios were effective over other treatments. Treatments with sodium aluminium silicate beads (1:0.7) recorded 50.67 numbers of adults. All the treatments were found significantly superior over the control (275.67).

The observations taken after six months of treatment revealed the superiority of treatment T_1 at 1:1 ratio by recording low adult emergence (29.83) in contrast to high adult emergence (64.83) from treatment T_4 (1:0.7 ratio) next to the untreated control (404.67). Zeolite beads treated pods recorded 114.06 adults as against 122.00 adults emerged from sodium aluminium silicate beads. The adult emergence was significantly lower in pods treated with zeolite beads in 1:1 ratio (25.00) whereas the pods treated with sodium aluminium silicate beads in 1:0.7 ratio resulted in high adult emergence (69.33).

The present findings are in agreement with El-Bakry et al. [12] who observed that Ag-loaded 4A-zeolite beads were highly effective with less adult emergence and high adult mortality of rice weevil (*Sitophilus oryzae*) and lesser grain borer (*Rhyzopertha dominica*) due to high moisture absorbing capacity. Similar findings were also reported with Jyothsna [9] where significantly less weight loss with pod bead ratio of 1:1 was found while 1:0.7 pod bead ratio resulted in significantly high weight loss. The present results are in conformity with the findings of Bidyarani [10]. They also observed minimum number of *C. chinensis* adults in greengram seeds treated with zeolite beads at 1:1 ratio and the adult emergence increased with decrease in the bead ratio to 1:0.7. The results also support the experiments of Lakshmi Prasad [11]. He found less *C. chinensis* adult emergence in zeolite beads mixed with green gram seeds in comparision to sodium aluminium silicate beads. The high efficacy of zeolite beads over sodium aluminium silicate beads could be attributed to the high moisture absorbing capacity of zeolite beads which in turn reduced the moisture content of the pods and made them less suitable for fecundity, survival and development.

3.3 Effect of Desiccant Beads on Pod Damage (%) due to *C. serratus* Infestation

The observations on the effect of desiccant beads on the pod damage percentage due to the infestation of groundnut bruchid are presented in Table 3.

Table 1. Effect of desiccant beads on fecundity of *C. serratus*

Treatment	Dosage	Fecundity of *C. serratus* (100 g of pods)								
		2MAT		Mean	4MAT		Mean	6MAT		Mean
		Zeolite beads	Sodium aluminium silicate		Zeolite beads	Sodium aluminium silicate		Zeolite beads	Sodium aluminium silicate	
T_1 (Pods : Beads)	1:1	14.67 (3.96)	21.33 (4.72)	18.00 (4.34)	25.67 (5.16)	31.67 (5.71)	28.67 (5.43)	34.33 (5.94)	42.33 (6.58)	38.33 (6.22)
T_2 (Pods : Beads)	1:0.9	17.33 (4.28)	27.67 (5.35)	22.50 (4.81)	33.67 (5.89)	41.33 (6.51)	37.50 (6.20)	48.67 (7.05)	53.33 (7.37)	51.00 (7.21)
T_3 (Pods : beads)	1:0.8	23.67 (4.97)	31.67 (5.71)	27.67 (5.34)	40.33 (6.43)	54.33 (7.44)	47.33 (6.93)	56.33 (7.57)	68.67 (8.35)	62.5 (7.96)
T_4 (Pods : Beads)	1:0.7	30.33 (5.60)	36.00 (6.08)	33.16 (5.84)	49.00 (7.07)	67.33 (8.27)	58.16 (7.67)	76.67 (8.81)	80.00 (9.00)	78.33 (8.90)
T_5 – Control		194.67 (13.99)		194.67 (13.99)	346.33 (18.64)		346.33 (18.64)	565.33 (23.80)		565.33 (23.80)
Mean		56.13 (6.56)	62.27 (7.17)		99.00 (8.64)	108.20 (9.31)		156.27 (10.63)	161.93 (11.02)	
		SE(m)±	**CD (P=0.05)**		**SE(m)±**	**CD (P=0.05)**		**SE(m)±**	**CD (P=0.05)**	
Type of Beads (F_1)		0.041	0.12		0.044	0.13		0.035	0.10	
Dosage (F_2)		0.065	0.19		0.069	0.21		0.055	0.16	
Interaction (F_1XF_2)		0.091	0.27		0.098	0.29		0.078	0.23	

Figure in parentheses are square root transformed values MAT- Months after treatment

Table 2. Effect of desiccant beads on adult emergence of *C. serratus*

Treatment	Dosage	Number of *C. serratus* adults emerged(100 g of pods)								
		2MAT		Mean	4MAT		Mean	6MAT		Mean
		Zeolite beads	Sodium aluminium silicate		Zeolite beads	Sodium aluminium silicate		Zeolite beads	Sodium aluminium silicate	
T_1 (Pods :Beads)	1:1	10.00 (3.31)	14.67 (4.72)	12.33 (4.01)	17.33 (4.28)	23.33 (4.93)	20.33 (4.60)	25.00 (5.09)	34.67 (5.97)	29.83 (5.53)
T_2 (Pods : Beads)	1:0.9	12.33 (3.64)	20.67 (5.35)	16.50 (4.49)	21.67 (4.75)	28.00 (5.38)	24.83 (5.06)	34.33 (5.94)	45.33 (6.80)	39.83 (6.37)
T_3 (Pods : Beads)	1:0.8	17.00 (4.23)	25.33 (5.71)	21.16 (4.97)	32.00 (5.74)	42.33 (6.58)	37.16 (6.16)	46.00 (6.85)	56.00 (7.55)	51.00 (7.20)
T_4 (Pods : Beads)	1:0.7	22.33 (4.83)	30.33 (6.08)	26.33 (5.45)	40.33 (6.43)	50.67 (7.19)	45.50 (6.81)	60.33 (7.83)	69.33 (8.38)	64.83 (8.10)
T_5 – Control		128.67 (11.38)		128.67 (11.38)	275.67 (16.63)		275.67 (16.63)	404.67 (20.14)		404.67 (20.14)
Mean		38.06 (5.48)	43.93 (6.65)		77.40 (7.56)	84.00 (8.14)		114.06 (9.17)	122.00 (9.77)	
		SE(m)±	**CD (P=0.05)**		**SE(m)±**	**CD (P=0.05)**		**SE(m)±**	**CD (P=0.05)**	
Type of Beads (F_1)		0.071	0.21		0.062	0.18		0.061	0.18	
Dosage (F_2)		0.112	0.33		0.098	0.29		0.096	0.29	
Interaction (F_1XF_2)		0.158	0.47		0.138	0.41		0.136	0.40	

Figure in the parentheses are square root transformed values MAT- Months After Treatment

After 2 months of treatment the lowest pod damage percentage was noticed in pods treated with the beads in 1:1 ratio (8.51%) whereas at 1: 0.7 ratio the damage was 16.02%. The untreated control recorded the maximum pod damage (51.44%). The pod damage recorded with zeolite beads were 19.97% whereas it was 20.07% with sodium aluminium silicate beads. The interaction effect between pods and beads were found non-significant.

The observations recorded after 4 months of treatment revealed that pods beads ratio of 1:1 resulted in 11.92% pod damage followed by 1:0.9, 1:0.8 and 1:0.7(14.07%, 16.46% and 18.00%, respectively). The lowest damage was noticed with zeolite beads (10.69%) at 1:1 ratio whereas the maximum damage was noted with pods treated with sodium aluminium silicate at 1:0.7 ratio (19.31%). The interaction between the pods and the beads were found non-significant.

After 6 months of treatment, the lowest pod damage was found with pod bead ratios of 1:1 (14.39%) which is significantly superior to 1:0.9 which recorded 16.55% damage. The highest percentage of damage was noticed with 1:0.7(22.58%). The untreated control recorded 100% damage and all the treatments were found significantly superior over control. Among the different pods and beads interaction combinations studied, the zeolite beads mixed at 1:1 and 1:0.9 ratios resulted in the minimum pod damage of 13.00% and 15.78% whereas sodium aluminium silicate at 1:0.7 ratio resulted in the maximum damage (23.89%).

The results obtained on the effect of desiccant beads on the per cent damage due to infestation of *C. serratus* in the pods of groundnut proves that though these beads could not provide cent percent control of the pest, the subsequent damage caused by it was significantly reduced. The zeolite beads proved to be superior over sodium aluminium silicate in reducing the percentage pod damage. The pod bead ratio of 1:1 was found more effective than other doses. The outcome of this study is also in line with the findings of Sultana et al. [8] who reported that the green gram seeds stored in hermetic container with zeolite beads resulted in 9.00% pod damage whereas it was 9.33% in sodium aluminium silicate after 6 months of treatment.

Similar type of result were found with Jyothsna [9], who revealed that the pods mixed with beads in 1:1 ratio was highly effective in reducing the damage caused by *C. serratus* after 3, 6 and 9 months of storage. She also revealed that zeolite beads were comparatively more effective in reducing the damage than sodium aluminium silicate beads. When the desiccant beads used in amounts potentially capable of absorbing sufficient water to reduce the seed moisture content to the desired level as well as absorbing water from the air inside the container, respiration will not occur inside the bags. Thus, the insect cannot cause more damage to the stored groundnut.

3.4 Effect of Desiccant Beads on Weight Loss Percentage due to Damage by *C. serratus*

Effect of desiccant beads on weight loss expressed as per cent weight loss observed at 2 months interval were presented in Table 4.

The observations recorded from the experiment after two months of treatment indicated that groundnut pods mixed with desiccant beads in 1:1 ratio resulted in 4.00 % weight loss followed by dosage 1:0.9(4.99%), 1:0.8(6.05%) and 1:0.7(7.22%) weight loss and these treatments were found at par with each other. Zeolite beads caused 9.46% weight loss whereas sodium aluminium silicate beads recorded 10.56% weight loss. The interaction effect between beads and dosages was found non-significant. The control recorded the highest weight loss (27.78%).

The observations taken after four months of treatment followed similar trends. The groundnut pods mixed with beads in 1:1 ratio was highly effective and resulted in low weight loss (8.15%) in compared to 13.11% weight loss observed with 1:0.7 dosage. The weight loss recorded in zeolite beads treatment was significantly less (18.69%) when compared to sodium aluminium silicate beads (21.78%). Among the various pods and beads interaction combinations studied, zeolite beads mixed with pods in 1:1 and 1:0.9 ratios resulted in the minimum weight loss of 6.74% and 7.92% whereas sodium aluminium silicate beads mixed with pods in 1:0.7 ratio resulted in the maximum weight loss (15.06%).

Storage of the groundnut pods mixed with desiccant beads up to six months of storage revealed that among the different dosages used in the study the first three doses (1:1, 1:0.9 and 1:0.8) recorded significantly less weight loss

(13.05%, 15.15% and 17.01%) and were found statistically at par with each other. The pods stored with zeolite beads resulted in 27.94% weight loss whereas with sodium aluminium silicate beads it was 28.86%. The interaction effect of dosages and beads was found non-significant. The control recorded 76.43% weight loss during six months of storage.

The results obtained on the effect of desiccant beads on the developmental biology and infestation by *C. serratus* in the pods of groundnut proves that though the beads could not provide complete control of pest, the development of pest and subsequent damage caused by it was significantly reduced when the pods were mixed with beads in 1:1 ratio. Among the beads, zeolite beads proved more effective over sodium aluminium silicate beads. These beads absorbed the moisture from the pods and created unsuitable environment for insect development and infestation. Sultana et al. [8] supported the present findings where the greengram seeds mixed with sodium aluminium silicate beads and zeolite beads resulted in significantly less weight loss after 6 months of storage. The present findings are also in accordance with Jyothsna [9], who revealed that the groundnut pods mixed with beads in 1:1 ratio was highly effective and resulted in low weight loss (7.82%) as compared to 12.38% weight loss observed with 1:0.7 dose after 6 months of storage.

3.5 Effect of Desiccant Beads on Moisture Content of Groundnut

The observations recorded after two months of storage revealed that among the different dosages used in the experiment, the first three doses in the ratio 1:1, 1:0.9 and 1:0.8 recorded significantly low moisture content (5.46%, 5.52% and 5.60%, respectively) and they were at par with each other while the lowest dosage of 1:0.7 noted 5.68% moisture content which was found at par with 1:0.8 treatment (Table 5). Out of these two beads used in the study significantly high moisture content was observed in groundnut pods treated with sodium aluminium silicate beads (7.45%) than zeolite beads (7.20%). The interaction effect of dosages and beads was found non-significant. The pods treated with zeolite beads in the ratio 1:1 recorded the minimum 5.31% moisture while sodium aluminium silicate beads mixed with pods at 1:0.7 recorded the maximum moisture content (5.85%). The moisture recorded in control was 14.35%.

After four months of treatment also the same trend continued where among the different treatments pod and bead ratio of 1:0.7 recorded significantly high moisture content (4.65%) in contrast to 1:1 ratio where significantly low moisture content was found (4.36%). The untreated control recorded 13.65% moisture. Sodium aluminium silicate beads which recorded 6.47% moisture content were found significantly superior to zeolite beads (6.21%). The pods mixed with sodium aluminium silicate beads in ratio 1:0.8 and 1:0.7 recorded significantly high moisture content of 4.77% and 4.85%, respectively.

The moisture content noted six months after treatment revealed that the moisture content had reduced drastically below 4% in all the treatments and it varied in between 3.59% to 3.85%. Zeolite beads recorded significantly low moisture content (5.74%) than sodium aluminium silicate beads (6.01%). Zeolite beads at the ratio 1:1 recorded the lowest moisture content (3.37%) whereas sodium aluminium silicate beads at 1:0.7 noted the highest moisture content (3.97%). There is no significant interaction effect found between the pods and the beads. All the treatments were found significantly superior over the control which recorded 12.84% moisture.

From the findings it was observed that there was decrease in moisture content of the groundnut kernels with the increase of storage period with desiccant beads. The initial moisture content of the groundnut kernels reduced from 11.37% to 5.31%, 4.24%, and 3.37% after 2, 4 and 6 months of storage, respectively when zeolite beads were mixed with the pods in 1:1 ratio. On the other side, sodium aluminum silicate beads mixed with the pods at 1:1 ratio resulted in reduction of the moisture content to 3.59% after 6 months of storage. The maximum reduction in moisture content was obtained by the zeolite beads which might be due to their highly polar surface within the pores which is the major reason for moisture adsorption from the seeds.

A zeolite-based desiccant, called drying beads, has also been employed for use in drying seeds and agricultural commodities [7]. As the desiccant absorbs water from the air inside the container, the relative humidity (RH) decreases and water evaporates from the seeds until the desiccant capacity is saturated or the system comes to equilibrium. A benefit of drying beads is that water is held very tightly in its pores, rapidly

Table 3. Effect of desiccant beads on pod damage (%) due to C. serratus infestation

Treatment	**Dosage**	**Pod damage (%)**								
		2MAT		**Mean**	**4MAT**		**Mean**	**6MAT**		**Mean**
		Zeolite beads	**Sodium aluminium silicate**		**Zeolite beads**	**Sodium aluminium silicate**		**Zeolite beads**	**Sodium aluminium silicate**	
T_1 (Pods :Beads)	1:1	8.71 (17.14)	8.30 (16.73)	8.51 (16.93)	10.69 (19.07)	13.15 (21.25)	11.92 (20.16)	13.00 (21.12)	15.78 (23.40)	14.39 (22.26)
T_2 (Pods : Beads)	1:0.9	10.34 (18.73)	11.37 (19.69)	10.85 (19.21)	12.20 (20.42)	15.95 (23.52)	14.07 (21.97)	14.46 (22.34)	18.64 (25.56)	16.55 (23.95)
T_3 (Pods : Beads)	1:0.8	13.61 (21.63)	13.46 (21.51)	13.54 (21.57)	15.45 (23.13)	17.47 (24.69)	16.46 (23.91)	16.22 (23.74)	21.46 (27.58)	18.84 (25.66)
T_4 (Pods : Beads)	1:0.7	15.75 (23.37)	16.29 (23.79)	16.02 (23.58)	16.70 (24.10)	19.31 (26.06)	18.00 (25.08)	21.27 (27.45)	23.89 (29.24)	22.58 (28.35)
T_5 – Control		51.44 (45.81)			77.84 (61.95)			100.00 (90.00)		
Mean		19.97 (25.34)	20.07 (25.51)		26.57 (29.73)	27.66 (31.49)		32.99 (36.93)	34.47 (39.16)	
		SE(m)±	**CD (P=0.05)**		**SE(m)±**	**CD (P=0.05)**		**SE(m)±**	**CD (P=0.05)**	
Type of Beads (F_1)		0.433	N.S.		0.363	1.08		0.236	0.70	
Dosage (F_2)		0.685	2.034		0.575	1.71		0.373	1.11	
Interaction (F_1XF_2)		0.968	N.S.		0.813	N.S.		0.527	1.57	

N.S.- Not significant MAT- Months after treatment

Table 4. Effect of desiccant beads on moisture on weight loss (%) of groundnut kernels

Treatment	**Dosage**	**Weight loss (%)**								
		2MAT		**Mean**	**4MAT**		**Mean**	**6MAT**		**Mean**
		Zeolite beads	**Sodium aluminium silicate**		**Zeolite beads**	**Sodium aluminium silicate**		**Zeolite beads**	**Sodium aluminium silicate**	
T_1 (Pods :Beads)	1:1	3.52	4.48	4.00	6.74	9.57	8.15	12.56	13.54	13.05
T_2 (Pods : Beads)	1:0.9	4.23	5.75	4.99	7.92	11.92	9.92	14.63	15.68	15.15
T_3 (Pods : Beads)	1:0.8	5.16	6.94	6.05	9.04	13.74	11.39	16.61	17.42	17.01
T_4 (Pods : Beads)	1:0.7	6.62	7.83	7.22	11.15	15.06	13.11	19.47	21.24	20.35
T_5 – Control		27.78			58.63			76.43		
Mean		9.46	10.56		18.69	21.78		27.94	28.86	
		SE(m)±	**CD (P=0.05)**		**SE(m)±**	**CD (P=0.05)**		**SE(m)±**	**CD (P=0.05)**	
Type of Beads (F_1)		0.288	0.86		0.304	0.90		0.324	N.S.	
Dosage (F_2)		0.455	1.35		0.480	1.43		0.513	1.52	
Interaction (F_1XF_2)		0.644	N.S.		0.679	2.02		0.725	N.S.	

N.S.- Not significant; MAT- Months after treatment

Table 5. Effect of desiccant beads on moisture content (%) of groundnut kernels

Treatment	Dosage	Moisture content (%)								
		2MAT		Mean	4MAT		Mean	6MAT		Mean
		Zeolite beads	Sodium aluminium silicate		Zeolite beads	Sodium aluminium silicate		Zeolite beads	Sodium aluminium silicate	
T_1 (Pods :Beads)	1:1	5.31	5.61	5.46	4.24	4.48	4.36	3.37	3.81	3.59
T_2 (Pods : Beads)	1:0.9	5.38	5.67	5.52	4.31	4.61	4.46	3.43	3.88	3.65
T_3 (Pods : Beads)	1:0.8	5.44	5.76	5.60	4.39	4.77	4.58	3.67	3.93	3.80
T_4 (Pods : Beads)	1:0.7	5.51	5.85	5.68	4.46	4.85	4.65	3.74	3.97	3.85
T_5 – Control		14.35		14.35	13.65		13.65	12.84		12.84
Mean		7.20	7.45		6.21	6.47		5.41	5.69	
		SE(m)±	**CD (P=0.05)**		**SE(m)±**	**CD (P=0.05)**		**SE(m)±**	**CD (P=0.05)**	
Type of Beads (F_1)		0.040	0.12		0.046	0.14		0.061	0.18	
Dosage (F_2)		0.023	0.07		0.026	0.08		0.013	0.04	
Interaction (F_1XF_2)		0.049	N.S.		0.053	0.16		0.071	N.S.	

MAT- Months after treatment; N.S.- Not significant lowering the RH to very low levels. In addition to it, its water holding capacity is essentially the same regardless of the RH. This present findings are in partial accordance with Sultana et al.,[8] where the zeolite beads were capable of drying the greengram seeds from 10% to near 6% moisture content within 6 months of treatment, but sodium aluminum silicate and activated alumina were slower to equilibrate.

Similar results were obtained with the findings of Nivethitha et al., [13] where the okra seeds and zeolite beads were taken in the ratio of 1:0.5, 1:1, 1:2 and 1:3 and after 120 hour the highest moisture elimination was noticed in seeds dried with zeolite beads (4.59%) in 1:3 ratio. Jyothsna [9] also observed that with increase of storage period with desiccant beads there was decrease in kernel moisture content and among the different treatments groundnut pods mixed with sodium aluminium silicate beads in 1:0.8 and 1:0.7 ratio recorded significantly high moisture content after 6 months of storage and. The results of this study are also in line with the findings of Lakshmi Prasad [11], who reported that the greengram seeds mixed with zeolite beads at 1:1 ratio reduced the initial moisture content of 10.20% to 6.22 %, 6.19 %, 6.15 %, 6.13 %, 6.10 % and 6.07 % after 1, 2, 3, 4, 5 and 6 months of storage respectively. Similarly, Bidyarani [10] also reported that the initial moisture content of greengram seeds mixed with zeolite beads (1:1 ratio) was reduced to 9.26% at 1 MAT, 7.69% at 2 MAT and 5.76% at 3 MAT in air tight container. Keshavulu et al., [14] also noticed that zeolite bead technology was able to reduce the *C. chinensis* damage in greengram during storage by bringing down the moisture content to 3.7%. The present results are in agreement with Hay et al., [15] who emphasized that moisture content of the seeds depends on the ratio of the beads to seeds and reported that zeolite beads had reduced the moisture content of rice seeds to 4.2% after long term storage.

3.6 Effect of Desiccant Beads on Germination of Groundnut Kernels

The observations on the effect of desiccant beads on germination per cent of groundnut kernels after 2, 4 and 6 months of storage are presented in the Table 6.

The observations taken after two months of treatment revealed that the highest germination was observed in T_1 and T_2 treatments with pod and bead ratio of 1:1 (87.00%) and 1:0.9 (85.33%) were found at par with each other. The dosages used at 1:0.8 and 1:0.7 ratio recorded comparatively less germination percentage (83.66% and 81.67%) than the higher doses. The per cent germination of groundnut kernels was highest in zeolite beads treated pods (82.60%) than sodium aluminum silicate beads (81.40%). The interaction effects between the doses and the beads did not show any significant effect on seed germination.

After four months of treatment also the same dosages of pod and bead ratios of 1:1 and 1:0.9 as continued to show superior performance where the germination percentage was recorded as 78.83% and 76.83% respectively, whereas a lower germination percentage of 74.00% and 71.67% were found at the dosages of 1:0.8 and 1:0.7, respectively. Significantly the lowest germination was recorded in control (53.33%). The interaction effect between pods and dosages did not show any significant effect on germination of groundnut.

The germination per cent observed after six months of treatment showed similar trend in which pod and bead ratios of 1:1and 1:0.9 were superior and recorded 72.50% and 71.00% germination, respectively in contrast to 69.33% and 67.50% germination recorded in the lower doses of 1:0.8 and 1:0.7. Again the interaction effect between doses and beads were found non-significant. However, the untreated control recorded only 34.67% germination.

The results obtained from the present investigations on the effect of desiccant beads on germination of groundnut kernels indicated that the desiccant beads mixed with the kernels did not affect the germination per cent drastically during six months of storage. The present findings are in line with Nivethitha et al. [13], where germination test revealed no reduction in germination percentage and no hard seed formation even in 1:3 ratio of seeds with zeolite beads. Jyothsna [9] also supported the present results and reported that beads treated with groundnut did not affect the germination percent drastically even after 9 months of storage. However, pod and bead ratios of 1:1 and 1:0.9 were superior and recorded 72.50% and 71.33% germination, respectively in contrast to 69.50% and 67.67% germination observed in lower doses of 1:0.8 and 1:0.7. The results are in close proximity with the findings of Sultana et al. [8] where the seed germination percentages of green gram declined in association with the

Table 6. Effect of desiccant beads on germination (%) of groundnut kernels

Treatment	Dosage	Germination (%)								
		2MAT		Mean	4MAT		Mean	6MAT		Mean
		Zeolite beads	Sodium aluminium silicate		Zeolite beads	Sodium aluminium silicate		Zeolite beads	Sodium aluminium silicate	
T_1 (Pods :Beads)	1:1	87.67 (9.42)	86.33 (9.35)	87.00 (9.38)	80.33 (9.02)	77.33 (8.85)	78.83 (8.93)	73.67 (8.64)	71.33 (8.50)	72.50 (8.57)
T_2 (Pods : Beads)	1:0.9	86.00 (9.33)	84.67 (9.26)	85.33 (9.29)	78.00 (8.89)	75.67 (8.75)	76.83 (8.82)	72.00 (8.54)	70.00 (8.43)	71.00 (8.48)
T_3 (Pods : Beads)	1:0.8	84.33 (9.24)	83.00 (9.17)	83.66 (9.20)	76.33 (8.79)	74.00 (8.66)	75.16 (8.72)	71.33 (8.50)	67.33 (8.27)	69.33 (8.38)
T_4 (Pods : Beads)	1:0.7	82.67 (9.15)	80.67 (9.04)	81.67 (9.09)	73.67 (8.64)	71.67 (8.52)	72.67 (8.58)	69.33 (8.39)	65.67 (8.16)	67.50 (8.27)
T_5 – Control		72.33 (8.56)		72.33 (8.56)	53.33 (7.37)		53.33 (7.37)	34.67 (5.97)		34.67 (5.97)
Mean		82.60 (9.14)	81.40 (9.07)		72.33 (8.54)	70.40 (8.43)		64.20 (8.01)	61.80 (7.87)	
		SE(m)±	**CD (P=0.05)**		**SE(m)±**	**CD (P=0.05)**		**SE(m)±**	**CD (P=0.05)**	
Type of Beads (F_1)		0.025	N.S.		0.035	0.10		0.041	0.12	
Dosage (F_2)		0.040	0.12		0.055	0.16		0.065	0.19	
Interaction (F_1XF_2)		0.056	N.S.		0.078	N.S.		0.091	N.S.	

Figure in parentheses are angular transformed values; MAT- Months after treatment; N.S.- Not significant increase in damage to stored seeds inoculated with pulse beetle. Germination percentage of greengram seeds declined from 98% to 79% during 6 months of storage. The decrease in germination per cent of groundnut seeds in all the treatments with increase in storage period could be due to increase in pest infestation over the period and decreased vigour of the seed with increased storage period. Similar type of result was found with Laksmi Prasad [11] where germination percentage of greengram seed was declined after 6 months of storage as compared to initial germination to an extent of 7.1 %, 8.1 % and 9.1 % when treated with zeolite beads, silica gel and sodium aluminium silicate beads, respectively. Raja et al. [16] also reported that there was a significant reduction in germination (9.26%) of greengram seeds with an increase in level of bruchid infestation.

4. CONCLUSION

In the present study, two types of desiccant beads were used *viz*., zeolite beads and sodium aluminium silicate beads to test their efficacy against *C. serratus* in four different pod bead ratios (1:1, 1:0.9, 1:0.8 and 1:0.7). The findings indicated that though none of the treatments completely gave cent per cent protection to the groundnut pods from pest infestation, but reduced the moisture content of the kernels thus having adverse effect on the biology of the insect-pest and reduced the pod infestation and damage pods. Among the different dosages pods mixed with zeolite beads in 1:1 ratio was found significantly superior over other treatments. However, the beads did not show any adverse effects on the germination of groundnut.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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