# Desiccant beads: A novel tool for managing pulse beetle in stored chickpea


## Abstract

Chickpea is the most dominant pulse having a major share under area shown 65 per cent and production 72 per cent followed by lentil and field pea. Pulse beetle, *Callosobruchus chinensis* L. is a primary pest of stored chickpea which causes 50-60 per cent loss in seed weight and 45.5-66.3 per cent loss in protein content of the seeds (Rustamani*et al.*, 1985) and injudicious and indiscriminate use of hazardous synthetic chemicals for preventing storage losses in chickpea may lead to human and animal health issues due to residual hazards. Therefore, the biorational management of the pulse beetle in stored chickpea has been undertaken keeping biology in mind will prevent the loss as well as protect human health hazard.The experiments on non-chemical biorational approaches like effect of desiccant beadswhich control the pulse beetle efficiently but have lesser toxicity hazards to non-target organisms and the environment was studied in the Department of Entomology, College of Agriculture, OUAT, BBSR, Odisha during 2018-2021.The results showed that desiccant beads *viz.*, zeolite and sodium aluminium silicate impregnated with chickpea seeds in the ratio of 1:1 proved effective in suppression of the pulse beetle in chickpeaduring six months of storage.



**Key words:**Desiccant beads, zeolite, sodium aluminium silicate,*Callosobruchus chinensis* L.


## Introduction

Pulse crops occupy a unique position in Indian agricultural economy.Pulses account for around 20 percent of the area under foodgrains and contribute around 7-10 percent of the total foodgrains production in the country.Poor storability and lack of improved storage facility is one of the important service constraints leading to post harvest losses in case of pulses to the extent of 25-50 percent (Jeswani and Baldev, 1990). Pulse beetle, *Callosobruchus chinensis* L. (Coleoptera: Bruchidae) is widely distributed and known as a major destructive insect of stored chickpea (Park *et al*., 2003; Aslam, 2004). It is a field-to-store pest as its infestation on pulses often begins in the field itself as adults lay eggs on mature pods (Huignard*et al*., 1985) and when such seed is harvested and stored, the pest population increases rapidly and results in total destruction within a short period of 3-4 months (Rahman and Talukder, 2006). The growth and development, ovipositional preference, suitability index and fecundity of *C. chinensis* is comparatively faster in chickpea as compared to other pulses (Wijenayake and Karunaratne, 1999).At present, the control methods of these insects are mostly based on using synthetic insecticides and fumigants (Environmental Protection Agency, 2001).Both the grubs and adults cause damage and the endosperm were eaten by the grubs leaving only the thin outer covering or thin film of seed coatmaking them completely unfit for human consumption (Atwal and Dhaliwal, 2005).

In India, the abundant use of pesticides and the mis-use of synthetic pesticides on the storagehave serious deficiencies led to development of resistance, secondary pest outbreak, loss of bio-diversity, environmental pollution and residual toxicity and occurrence of human health hazards.Therefore, now-a-days, eco-friendly, non-chemical and bio-rational approaches in insect pest management during storage are being considered as effective alternative and have assumed greater significance. Botanicals, plant oils, nano emulsions, carbon dioxide treatments and desiccant beads etc. are quite effective in keeping the pest damage under control which possesses no harmful effect on the stored chickpea kept for consumption and seed purposes.

## Materials and Methods:

### Management of pulse beetle in chickpea by using desiccant beads

The present study on the management of chickpea pulse beetle 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 beads were obtained from the local dealers of Gujarat. Specifically, the desiccant beads were 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 percent 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 in the seed to the drying beads through the air and there was no need for heating. These beads could be mixed with the seed or could 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 could subsequently be removed and re-used after regeneration. Regeneration could be done separately by heating for 2 hours at $2000^{0}$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 were cooled.

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

## Results and Discussion:

### Effect of desiccant beads on fecundity of *C. chinensis* L.

Among the different doses, seed bead ratio of 1:1 and 1:0.9 were found significantly superior to other doses and recorded 19.83 and 24.34 eggs respectively, whereas the lower doses of 1:0.8 and 1:0.7 observed29.67 and 35.50eggs respectively. Between these two types of beads, zeolite beads were more effective in reducing the egg laying capacity of the e pulse beetle (39.33 eggs) than sodium aluminium silicate beads (45.87 eggs) at 2 MAT. The interaction effectbetween beads and dosages revealed that among the different treatments, zeolite beads at 1:1 ratio exhibited most significant effect and recorded the least number of egglaying(16.00 eggs), whereas significantly maximum number of eggs (38.67 eggs) was registered with sodium aluminium silicate beads at 1:0.7 ratio. The same trend continued after four months of treatment. The different doses used in the effect on chickpea seeds mixed with desiccant beads in the ratio of 1:1 and 1:0.9 reduced the fecundity to 30.17 and 39.83respectively, whereas 1:0.7 dosage was the least effective and registered 60.75 eggs. Out of these two beads used in the study, zeolite beads restricted the fecundity to 71.13, whereas sodium aluminium silicate beads treatment resulted in 80.43 eggs. The interaction studies highlighted the superior performance of zeolite beads at 1:1 ratio where significantly the lowest number of eggs (27.33) were observed followed by sodium aluminium silicate beads at 1:1 ratio (33.00) eggs, whereas significantly the highest fecundity (70.00 eggs) was observed in seeds treated with sodium aluminium silicate beads at 1:0.7 ratio. All the treatments were found significantly superior to control which recorded 198.33 eggs. After six months of treatment also seed bead ratio of 1:1 exhibited superior performance by observing lesser number of eggs (40.25) whereas at 1:0.7 ratio was the least effective and recorded 81.00 eggs. Zeolite beads continued to be the most effective treatment and registered 114.47 eggs whereas sodium aluminium silicate beads treatment recorded 120.23 eggs. The interaction effect between beads and dosages concluded that the zeolite beads mixed with the chickpea seeds in 1:1 ratio proved to be the most effective in restricting the eggs to 36.33, whereas, significantly the highest fecundity (82.67 eggs) was observed in the treatment mixed with sodium aluminium silicate beads in 1:0.7 ratio. Similar type of results was reported by Sultana *et al.* (2021) who observed that green gram seeds mixed with drying beads recorded the lowest oviposition (10 to13 eggs per 10 g of seeds) by *Callosobruchus chinensis* after six months of storage.

**Effect of desiccant beads on adult emergence of *C. chinensis* L.**

The observations on adult emergence of *C. chinensis* obtained from chickpea seeds treated with desiccant beads found to be significantly superior to the untreated control. None of the treatments could prevent complete adult emergence of chickpea pulse beetle after two months of treatment. Significantly the lowest adult emergence (13.50) was recorded from the seeds treated with desiccant beads used at 1:1 ratio followed by treatment at 1:0.9 (18.17 adults), whereas the highest adult emergence (27.75) was noticed in seeds treated with beads in 1:0.7 ratio. Among the two beads used in the experiment, zeolite beads were comparatively most effective and registered 29.27 adults as against 34.77 adults obtained from sodium aluminium silicate beads. The interaction effect of doses and beads revealed that zeolite beads mixed with seeds of chickpea in the ratio of 1:1 proved to be the best treatment which recorded significantly fewer adults (11.33) as against 31.50 adults observed from sodium aluminium silicate beads (1:0.7) treatment. The untreated control registered 77.33 adults.The observations recorded after four months of treatment also indicated the similar trend where, seed and bead ratio of 1:1 was the most effective and reported lesser number of adults (21.42) as against 46.75 adults emerged from 1:0.7 dose. The zeolite beads continued their superiority (58.74) over sodium aluminium silicate beads (64.40) in reducing the adult emergence. Among the different treatment combinations, zeolite beads at 1:1 (18.67) and 1:0.9 (23.33) ratios were effective over other treatments. Treatments with sodium aluminium silicate beads (1:0.7) recorded 51.50 numbers of adults. All the treatments were found to be significantly superior to the control (175.00). The observations recorded after six months of treatment revealed the superiority of treatment T1 at 1:1 ratio by recording low adult emergence (32.17) in contrast to high adult emergence (66.42) from treatment T4 (1:0.7 ratio) next to the untreated control (270.67). Zeolite beads treated seeds recorded 88.93 adults as against 96.30 adults emerged from sodium aluminium silicate beads. The adult emergence was significantly lower in seeds treated with zeolite beads in 1:1 ratio (28.00) whereas the seeds treated with sodium aluminium silicate beads in 1:0.7 ratio resulted in higher adult emergence (71.16)

The present results are in conformity with the findings of Bidyarani (2013) who 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 (2013) who observed less number of *C. chinensis* adult emergence in zeolite beads mixed with green gram seeds in comparisons to sodium aluminium silicate beads.

**Effect of desiccant beads on seed damage (per cent) due to *C. chinensis* L infestation**

It was observed that after 2 months of treatment, the lowest seed damage percentage was noticed in the seeds treated with the beads in 1:1 ratio (6.29 per cent), whereas at 1: 0.7 ratio the damage was 13.51 per cent. The untreated control recorded the maximum seed damage (31.25 per cent). The seed damage recorded with zeolite beads was 13.93, per cent whereas it was 14.51 per cent with sodium aluminium silicate beads. The interaction effect between seeds and beads was found non-significant. The observations recorded after 4 months of treatment revealed that seeds beads ratio of 1:1 resulted in 9.84 per cent seed damage followed by 1:0.9, 1:0.8 and 1:0.7(12.38 per cent, 14.39 per cent and 16.61 per cent, respectively). The lowest damage was noticed with zeolite beads (8.20 per cent) at 1:1 ratio whereas the maximum damage was noted with seeds treated with sodium aluminium silicate at 1:0.7 ratio (17.95 per cent). The interaction between the seeds and the beads was found non-significant.

After 6 months of treatment, the lowest seed damage was found with seed beads ratio of 1:1 (12.37 per cent) which was significantly superior to 1:0.9 which recorded 15.08 per cent damage. The highest percentage of damage was observed with 1:0.7(21.54 per cent). The untreated control exhibited88.00 per cent damage and all the treatments were found significantly superior to control. Among the different seeds and beads interaction combinations studied, the zeolite beads mixed at 1:1 and 1:0.9 ratios resulted in the minimum seed damage of 11.46 per cent and 12.55 per cent, respectively whereas sodium aluminium silicate at 1:0.7 ratio resulted in the maximum damage (22.55 per cent).Similar type of resultswere found with Jyothsna (2014), who observed that the seeds mixed with beads in 1:1 ratio was highly effective in reducing the damage caused by *C. chinensis*after 3, 6 and 9 months of storage.

**Effect of desiccant beads on weight loss (%) due to damage by *C. chinensis* L.**

The observations recorded from the experiment after two months of treatment indicated that chickpea seeds mixed with desiccant beads in 1:1 ratio resulted in 4.81 per cent weight loss followed by dosage 1:0.9 (5.98 per cent), 1:0.8 (7.08 per cent) and 1:0.7 (8.32 per cent) weight loss. The Zeolite beads registered 10.63 per cent weight loss, whereas sodium aluminium silicate beads caused 11.71 per cent weight loss. The interaction effect between beads and dosages was found non-significant. The control recorded the highest weight loss (29.67 per cent). The observations taken after four months of treatment followed similar trends. The chickpea seeds mixed with beads in 1:1 ratio was highly effective and resulted in low weight loss (9.41per cent) in compared to 13.53per cent weight loss observed with 1:0.7 dosage. The weight loss recorded in zeolite beads treatment was significantly less (18.77per cent) as compared to sodium aluminium silicate beads (21.04per cent). Among the various seeds and beads interaction combinations studied, zeolite beads mixed with seeds in 1:1 and 1:0.9 ratios resulted in the minimum weight loss of 7.64per cent and 8.83per cent whereas, sodium aluminium silicate beads mixed with seeds in 1:0.7 ratio resulted in the maximum weight loss (14.99per cent). Storage of the chickpea seeds mixed with desiccant beads up to six months of storage indicated that among the different dosages used in the study, the first three doses (1:1, 1:0.9 and 1:0.8) registered significantly less weight loss (11.87, 13.34 and 16.11per cent) and were found statistically at par with each other. The seedsmixed with zeolite beads resulted in 27.34per cent weight loss, whereas with sodium aluminium silicate beads it was 28.48 per cent. The interaction effect of dosages and beads was found non-significant. The control recorded 78.11 per cent weight loss during six months of storage.Sultana *et al.*, (2021) 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 (2014), who revealed that the chickpea seeds mixed with beads in 1:1 ratio was highly effective and resulted in low weight loss (7.82per cent) as compared to 12.38per cent weight loss observed with 1:0.7 dose after 6 months of storage.

**Effect of desiccant beads on moisture content of chickpea seeds**

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 registered significantly low moisture content (5.28per cent, 5.37 per cent and 5.47 per cent, respectively) which were at par, while the lowest dosage of 1:0.7 noted 5.58 per cent moisture content which was at par with 1:0.8 treatment (5.47 per cent) .Out of the two beads used in the research study, the highest moisture content was observed significantly in chickpea seeds treated with sodium aluminium silicate beads (7.27 per cent) than zeolite beads (7.04 per cent). The interaction effect of dosages and beads was found non-significant. The seeds treated with zeolite beads in the ratio 1:1 exhibited the minimum 5.12 per cent moisture while sodium aluminium silicate beads mixed with seeds at 1:0.7 registered the maximum moisture content (5.73 per cent). The moisture displayed in control was 14.10 per cent. After four months of treatment also the same trend resumed where the seed and bead ratio of 1:0.7 indicated significantly the highest moisture content (4.50 per cent) in contrast to 1:1 ratio where significantly low moisture content was found (4.15 per cent). The untreated control exhibited 11.23 per cent moisture. Sodium aluminium silicate beads which reported 4.70 per cent moisture content were found significantly superior to zeolite beads (4.29 per cent). The seeds mixed with sodium aluminium silicate beads in ratio 1:0.8 and 1:0.7 registered significantly high moisture content of 4.61 and 4.70 per cent, respectively. The moisture content observed six months after treatment revealed that the moisture content had reduced drastically below 4 per cent in all the treatments and it varied in between 3.37 to 3.69 per cent. Zeolite beads recorded significantly low moisture content (4.65per cent) than sodium aluminium silicate beads (4.96 per cent). Zeolite beads at the ratio 1:1 registered the lowest moisture content (3.14 per cent), whereas sodium aluminium silicate beads at 1:0.7 noted the highest moisture content (3.83 per cent). There was no significant interaction effect indicated between the seeds and the beads. The initial moisture content of the chickpea seeds reduced from 14.10 to 5.12 per cent, 4.03 per cent and 3.14 per cent after 2, 4 and 6 months of storage, respectively when zeolite beads were mixed with the seeds in 1:1 ratio. On the other hand, sodium aluminum silicate beads mixed with the seeds at 1:1 ratio resulted in reduction of the moisture content to 3.59 per cent after 6 months of storage. Keshavulu*et al.* (2012) 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 3.7per cent. The present results are in agreement with Hay *et al.* (2012) 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 per cent after long term storage.

**Effect of desiccant beads on germination of chickpea seeds**

The observations taken after two months of treatment revealed that the highest germination was observed in $T_1$ and $T_2$ treatments with seed and bead ratio of 1:1 (82.84 per cent) and 1:0.9 (81.34 per cent) which were at par. The dosages used at 1:0.8 and 1:0.7 ratios registered comparatively less germination percentage (79.67 and 78.17 per cent) than the higher doses. The per cent germination of chickpea seeds was the highest in zeolite beads treated seeds (79.00 per cent) than sodium aluminum silicate beads (77.80 per cent).The interaction effect between seeds and dosages did not show any significant effect on germination of chickpea seed. After four months of treatment also the same dosages of seed and bead ratios of 1:1 and 1:0.9 continued to show superior performance where the germination percentage was observed to be 74.67 per cent and 72.50 per cent respectively, whereas a lower germination percentage of 71.67 and 69.17 per cent were noticed at the dosages of 1:0.8 and 1:0.7, respectively. Significantly the lowest germination was recorded in control (49.67 per cent). The interaction effects between the doses and the beads did not exhibit any significant outcome on seed germination of chickpea. The germination per cent observed after six months of treatment exhibited similar trend in which seed and bead ratios of 1:1 and 1:0.9 were superior and recorded 68.50 and 66.84 per cent germination respectively in contrast to 65.33 per cent and 63.50 per cent germination registered in the lower doses of 1:0.8 and 1:0.7. The present findings are in line with Nivethitha *et al.* (2020), where germination test revealed no reduction in germination percentage and no hard seed formation even in 1:3 ratio of seeds with zeolite beads. The results are in close proximity with the findings of Laksmi Prasad (2013) where germination percentage of greengram seed was declined after 6 months of storage as compared to initial germination to an extent of 7.1 per cent, 8.1 per cent and 9.1 per cent when treated with zeolite beads, silica gel and sodium aluminium silicate beads, respectively.

**Conclusion:**

The desiccant beads were modified ceramic sieve materials that absorb and hold water molecules very tightly in their microscopic pores.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 was the major reason for moisture adsorption from theseeds.The chickpea seeds mixed with zeolite desiccant beads in 1:1 ratio significantly lowered the moisture content and recorded less fecundity and seed damage than sodium aluminum silicate beads and showed no adverse effect on germinationduring six months of storage. The use of drying beads or desiccant beads can be used as drying substances in storage receptacles for a long-term storage.

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**Table 1. Effect of desiccant beads on fecundity of *C. chinensis* L.**

| Treatment | Dosage | No. of eggs laid by *C. chinensis*/female | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2MAT | | Mean | 4MAT | | Mean | 6MAT | | Mean |
| | | Zeolite beads | Sodium Aluminium silicate | | Zeolite beads | Sodium Aluminium silicate | | Zeolite beads | Sodium Aluminium silicate | |
| $T_1$ (Seeds: Beads) | 1:1 | 16.00 (4.00) | 23.67 (4.87) | 19.83 (4.45) | 27.33 (5.23) | 33.00 (5.75) | 30.17 (5.49) | 36.33 (6.03) | 44.16 (6.65) | 40.25 (6.34) |
| $T_2$ (Seeds: Beads) | 1:0.9 | 19.67 (4.44) | 29.00 (5.39) | 24.34 (4.93) | 35.50 (5.96) | 44.16 (6.65) | 39.83 (6.31) | 51.67 (7.19) | 56.00 (7.48) | 53.84 (7.38) |
| $T_3$ (Seeds: Beads) | 1:0.8 | 25.00 (5.00) | 34.33 (5.86) | 29.67 (5.45) | 43.00 (6.58) | 56.67 (7.53) | 49.84 (7.06) | 58.00 (7.62) | 71.33 (8.45) | 64.67 (8.04) |
| $T_4$ (Seeds: Beads) | 1:0.7 | 32.33 (5.69) | 38.67 (6.22) | 35.50 (5.96) | 51.50 (7.18) | 70.00 (8.37) | 60.75 (7.79) | 79.33 (8.90) | 82.67 (9.09) | 81.00 (9.00) |
| $T_5$ – Control | | 103.67 (10.18) | | 103.67 (10.18) | 198.33 (14.08) | | 198.33 (14.08) | 347.00 (18.62) | | 347.00 (18.62) |
| Mean | | 39.33 (6.27) | 45.87 (6.77) | | 71.13 (8.43) | 80.43 (8.97) | | 114.47 (10.70) | 120.23 (10.96) | |
| | | **SE(m)±** | **CD (p=0.05)** | | **SE(m)±** | **CD (p=0.05)** | | **SE(m)±** | **CD (p=0.05)** | |
| Type of Beads (F1) | | 1.074 | 3.19 | | 1.863 | 5.54 | | 3.022 | 8.98 | |
| Dosage (F2) | | 0.760 | 2.26 | | 1.318 | 3.91 | | 2.137 | 6.35 | |
| Interaction (F1XF2) | | 1.861 | 5.53 | | 3.227 | 9.59 | | 5.235 | 15.55 | |

Figures in the parentheses are square root transformed values                    Months after treatment

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

| Treatment | Dosage | Number of *C. chinensis* adults emerged | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2MAT | | Mean | 4MAT | | Mean | 6MAT | | Mean |
| | | **Zeolite beads** | **Sodium Aluminium silicate** | | **Zeolite beads** | **Sodium Aluminium silicate** | | **Zeolite beads** | **Sodium Aluminium silicate** | |
| $T_1$ (Seeds: Beads) | 1:1 | 11.33 (3.37) | 15.67 (3.96) | 13.50 (3.67) | 18.67 (4.32) | 24.16 (4.92) | 21.42 (4.63) | 28.00 (5.29) | 36.33 (6.03) | 32.17 (5.67) |
| $T_2$ (Seeds: Beads) | 1:0.9 | 14.00 (3.74) | 22.33 (4.73) | 18.17 (4.26) | 23.33 (4.83) | 30.00 (5.48) | 26.67 (5.16) | 36.16 (6.01) | 46.00 (6.78) | 39.83 (6.31) |
| $T_3$ (Seeds: Beads) | 1:0.8 | 19.67 (4.44) | 27.00 (5.20) | 23.34 (4.83) | 34.67 (5.89) | 41.33 (6.43) | 38.00 (6.16) | 48.16 (6.94) | 57.33 (7.57) | 52.75 (7.26) |
| $T_4$ (Seeds: Beads) | 1:0.7 | 24.00 (4.90) | 31.50 (5.61) | 27.75 (5.27) | 42.00 (6.48) | 51.50 (7.18) | 46.75 (6.84) | 61.67 (7.85) | 71.16 (8.44) | 66.42 (8.15) |
| $T_5$ – Control | | 77.33 (8.74) | | 77.33 (8.74) | 175.00 (13.23) | | 175.00 (13.23) | 270.67 (16.45) | | 270.67 (16.45) |
| Mean | | 29.27 (5.41) | 34.77 (5.90) | | 58.74 (7.66) | 64.40 (8.02) | | 88.93 (9.43) | 96.30 (9.81) | |
| | | **SE(m)±** | **CD (p=0.05)** | | **SE(m)±** | **CD (p=0.05)** | | **SE(m)±** | **CD (p=0.05)** | |
| Type of Beads (F1) | | 0.845 | 2.51 | | 1.613 | 4.79 | | 2.396 | 7.12 | |
| Dosage (F2) | | 0.597 | 1.77 | | 1.140 | 3.39 | | 1.694 | 5.03 | |
| Interaction (F1XF2) | | 1.463 | 4.35 | | 2.793 | 8.30 | | 4.151 | 12.33 | |

Figures in the parentheses are square root transformed values Months after treatment

**Table 3. Effect of desiccant beads on seed damage (%) due to *C. chinensis*L. infestation**

| Treatment | Dosage | Seed damage(%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2MAT | | Mean | 4MAT | | Mean | 6MAT | | Mean |
| | | Zeolite beads | Sodium Aluminium silicate | | Zeolite beads | Sodium Aluminium silicate | | Zeolite beads | Sodium Aluminium silicate | |
| $T_1$ (Seeds: Beads) | 1:1 | 6.45 (14.77) | 6.12 (14.30) | 6.29 (14.54) | 8.20 (16.62) | 11.47 (19.82) | 9.84 (18.24) | 11.46 (19.82) | 13.27 (21.41) | 12.37 (20.61) |
| $T_2$ (Seeds: Beads) | 1:0.9 | 8.08 (16.56) | 9.54 (17.94) | 8.81 (17.28) | 10.22 (18.60) | 14.54 (22.40) | 12.38 (20.61) | 12.55 (20.79) | 17.61 (24.84) | 15.08 (22.89) |
| $T_3$ (Seeds: Beads) | 1:0.8 | 10.89 (19.27) | 11.63 (19.94) | 11.26 (19.63) | 13.47 (21.53) | 15.31 (23.02) | 14.39 (22.27) | 14.51 (22.40) | 20.70 (27.06) | 17.61 (24.84) |
| $T_4$ (Seeds: Beads) | 1:0.7 | 13.00 (21.16) | 14.02 (21.96) | 13.51 (21.53) | 15.27 (23.01) | 17.95 (25.09) | 16.61 (24.02) | 20.52 (26.94) | 22.55 (28.36) | 21.54 (28.35) |
| $T_5$ – Control | | 31.25 (36.80) | | 31.25 (36.80) | 64.32 (53.32) | | 64.32 (53.32) | 88.00 (69.72) | | 88.00 (69.72) |
| Mean | | 13.93 (21.90) | 14.51 (22.40) | | 22.30 (28.14) | 24.71 (29.80) | | 29.41 (32.82) | 32.43 (34.68) | |
| | | **SE(m)±** | **CD (p=0.05)** | | **SE(m)±** | **CD (p=0.05)** | | **SE(m)±** | **CD (p=0.05)** | |
| Type of Beads (F1) | | 0.453 | 1.35 | | 0.691 | 2.05 | | 0.879 | 2.61 | |
| Dosage (F2) | | 0.320 | 0.95 | | 0.488 | 1.45 | | 0.621 | 1.85 | |
| Interaction (F1XF2) | | 0.785 | NS | | 1.196 | NS | | 1.522 | 4.52 | |

Figures in the parentheses are angular transformed values MAT- Months after treatment

**Table 4. Effect of desiccant beads on weight loss (%) of chickpea seeds due to *C. chinensis* L. infestation**

| **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** | |
| $T_1$ (Seeds: Beads) | 1:1 | 4.32 (11.95) | 5.29 (13.30) | 4.81 (12.65) | 7.64 (16.02) | 10.21 (18.60) | 9.41 (17.88) | 11.32 (19.63) | 12.41 (20.61) | 11.87 (20.18) |
| $T_2$ (Seeds: Beads) | 1:0.9 | 5.22 (13.18) | 6.73 (15.01) | 5.98 (14.06) | 8.83 (17.28) | 11.80 (20.12) | 10.32 (18.72) | 12.13 (20.07) | 14.55 (22.46) | 13.34 (21.41) |
| $T_3$ (Seeds: Beads) | 1:0.8 | 6.19 (14.41) | 7.97 (16.32) | 7.08 (15.43) | 9.95 (18.36) | 13.62 (21.65) | 11.79 (20.12) | 15.89 (23.52) | 16.33 (23.83) | 16.11 (23.64) |
| $T_4$ (Seeds: Beads) | 1:0.7 | 7.75 (16.02) | 8.88 (17.34) | 8.32 (16.74) | 12.06 (20.37) | 14.99 (22.71) | 13.53 (21.53) | 19.24 (25.98) | 21.02 (27.26) | 20.13 (26.62) |
| $T_5$ – Control | | 29.67 (33.02) | | 29.67 (33.02) | 55.38 (48.07) | | 55.38 (48.07) | 78.11 (62.13) | | 78.11 (62.13) |
| Mean | | 10.63 (19.03) | 11.71 (19.99) | | 18.77 (25.72) | 21.04 (27.26) | | 27.34 (31.47) | 28.48 (32.28) | |
| | | **SE(m)±** | **CD (p=0.05)** | | **SE(m)±** | **CD (p=0.05)** | | **SE(m)±** | **CD (p=0.05)** | |
| Type of Beads (F1) | | 0.407 | 1.21 | | 0.613 | 1.82 | | 0.800 | 2.38 | |
| Dosage (F2) | | 0.287 | 0.85 | | 0.433 | 1.29 | | 0.566 | 1.68 | |
| Interaction (F1XF2) | | 0.704 | NS | | 1.061 | 3.15 | | 1.386 | NS | |

Figures in the parentheses are angular transformed values MAT- Months after treatment

**Table 5. Effect of desiccant beads on moisture content (%) of chickpea seeds**

| 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 | |
| $T_1$ (Seeds: Beads) | 1:1 | 5.12 | 5.43 | 5.28 | 4.03 | 4.28 | 4.15 | 3.14 | 3.59 | 3.37 |
| $T_2$ (Seeds: Beads) | 1:0.9 | 5.23 | 5.50 | 5.37 | 4.12 | 4.43 | 4.27 | 3.25 | 3.71 | 3.48 |
| $T_3$ (Seeds: Beads) | 1:0.8 | 5.33 | 5.61 | 5.47 | 4.20 | 4.61 | 4.41 | 3.43 | 3.78 | 3.61 |
| $T_4$ (Seeds: Beads) | 1:0.7 | 5.42 | 5.73 | 5.58 | 4.29 | 4.70 | 4.50 | 3.55 | 3.83 | 3.69 |
| $T_5$ – Control | | 10.23 | | 10.23 | 9.66 | | 9.66 | 8.51 | | 8.51 |
| Mean | | 6.27 | 6.50 | | 5.26 | 5.54 | | 4.38 | 4.68 | |
| | | **SE(m)±** | **CD (p=0.05)** | | **SE(m)±** | **CD (p=0.05)** | | **SE(m)±** | **CD (p=0.05)** | |
| Type of Beads (F1) | | 0.308 | 0.91 | | 0.280 | 0.84 | | 0.264 | 0.78 | |
| Dosage (F2) | | 0.217 | 0.65 | | 0.198 | 0.59 | | 0.187 | 0.55 | |
| Interaction (F1XF2) | | 0.533 | NS | | 0.485 | 1.44 | | 0.457 | 1.36 | |

MAT- Months after treatment

**Table 6. Effect of desiccant beads on germination (%) of chickpea seeds**

| **Treatment** | **Dosage** | **Germination (%)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **2MAT** | | **Mean** | **4MAT** | | **Mean** | **6MAT** | | **Mean** |
| | | **Zeolite beads** | **Sodium Aluminium silicate** | | **Zeolite beads** | **Sodium Aluminium silicate** | | **Zeolite beads** | **Sodium Aluminium silicate** | |
| $T_1$ (Seeds: Beads) | 1:1 | 83.67 (9.20) | 82.00 (9.11) | 82.84 (9.16) | 76.33 (8.79) | 73.00 (8.60) | 74.67 (8.70) | 69.67 (8.41) | 67.33 (8.27) | 68.50 (8.34) |
| $T_2$ (Seeds: Beads) | 1:0.9 | 82.00 (9.11) | 80.67 (9.04) | 81.34 (9.07) | 73.67 (8.64) | 71.33 (8.50) | 72.50 (8.57) | 68.00 (8.30) | 65.67 (8.17) | 66.84 (8.24) |
| $T_3$ (Seeds: Beads) | 1:0.8 | 80.33 (9.02) | 79.00 (8.94) | 79.67 (8.98) | 74.67 (8.70) | 68.67 (8.35) | 71.67 (8.52) | 67.33 (8.27) | 63.33 (8.02) | 65.33 (8.14) |
| $T_4$ (Seeds: Beads) | 1:0.7 | 79.00 (8.94) | 77.33 (8.85) | 78.17 (8.90) | 72.00 (8.54) | 66.33 (8.21) | 69.17 (8.38) | 65.33 (8.14) | 61.67 (7.92) | 63.50 (8.03) |
| $T_5$ – Control | | 70.00 (8.43) | | 70.00 (8.43) | 49.67 (7.12) | | 49.67 (7.12) | 32.33 (5.77) | | 32.33 (5.77) |
| Mean | | 79.00 (8.89) | 77.80 (8.87) | | 69.29 (8.38) | 65.80 (8.17) | | 60.53 (7.84) | 58.07 (7.69) | |
| | | **SE(m)±** | **CD (p=0.05)** | | **SE(m)±** | **CD (p=0.05)** | | **SE(m)±** | **CD (p=0.05)** | |
| Type of Beads (F1) | | 1.555 | 4.62 | | 1.372 | 4.08 | | 1.241 | 3.69 | |
| Dosage (F2) | | 1.100 | 3.27 | | 0.970 | 2.88 | | 0.877 | 2.61 | |
| Interaction (F1XF2) | | 2.693 | NS | | 2.376 | NS | | 2.149 | NS | |

Figures in the parentheses are square root transformed values Months after treatment