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Impact of plant based neutral silica on seed quality of greengram (*Vigna radiata* L.) during seed storage

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Abstract
Bruchid, a pest is infested from the field, is a severe problem with stored greengram seeds. Although there are various approaches to addressing this issue, utilising plant based neutral is one of the most practical, cost-effective, and ecofriendly choice. Laboratory study was conducted in a completely randomised manner to investigate the effect of plant based neutral silica on the storability of greengram seeds. Greengram seeds were treated with plant based neutral and with chemical check deltamethrin @ 1 ml/l. The seeds were then stored in HDPE bags for nine months. The parameters of insect population and seed quality were recorded in order to assess the efficacy of different concentrations of silica. Neutral silica @ 2.0 g/l (T_3) recorded the highest seed quality parameters *viz.,* seed germination (80.4%), mean seedling length (33.53 cm), mean seedling dry weight (18.90 mg), seedling vigour index-I and II (2683 and 1514 respectively), lowest seed moisture content (9.98%), the electrical conductivity of seed leachate (1.40 $mScm^{-1}$), seed damage (1.55%) and compared to control the treatment neutral silica @ 2.0 g/l (T_3) has recorded the maximum C: B ratio of 1: 14.89 after nine months of storage. A successful seed storage management strategy that kept seed quality above MSCS level for up to nine months of storage was the neutral silica @ 2.0 g/l (T_3) seed treatment.

Keywords: Greengram, seed storage, neutral silica, inert dust, Callosobruchus chinensis, biological control, HDPE bag

Introduction
Greengram (*Vigna radiata* L.), commonly referred as mung bean or moong, is a crop with its primary origin in India and widespread cultivation in East Asia, Southeast Asia, and the Indian subcontinent. This versatile legume holds a significant position in Indian agriculture and dietary habits. Its importance lies in being a crucial pulse crop grown extensively across the country. Furthermore, it is utilized as nutritional food also acts as a cover crop and its deep root system protects the soil from erosion (Anon., 2018) [4]. Greengram is nutrient-dense food with a low energy density. It contains 23-32 percent protein, 63 percent carbohydrate, dietary fibre (16 g), fat (1.2%) on dry basis, also rich in magnesium and iron. It occupies approximately 4.21 lakh ha of land in Karnataka, producing 1.42 lakh tonnes and yielding 340 kg/ha. (Anon., 2021) [5].

Seed damage during storage by insect pests is very severe. Losses of up to 30-70 percent have been recorded on stored greengram in the absence of insect pest control measures (Yakubu *et al.*, 2012) [21]. The most important storage pest of greengram is the weevil (Bruchid) called *Callosobruchus chinensis*. Severe infestation can lead to total grain loss in storage. It is a field-to-store pest; adult beetles lay eggs on pods (in the field) or seeds (in storage). In India, various pulses have been infested by 17 species of bruchids from 11 genera (Arora, 1997) [6].

Chemical pesticides like phosphine and pyrethroids are mostly used to control these insect pests. However, concerns regarding insect resistance, food contamination from pesticide residues, human health risks, and environmental pollution have grown due to these chemical insecticides (Daglish, 2008) [9]. Inert dust, such as diatomaceous earth and kaolin were traditionally used as grain protectants. This is because, their formulations are non-toxic substances that can be mixed with seeds to control storage insect pests. Because inert dust does not decay, it offers long-term control of storage insect pests and is safe for humans and other mammals to consume.

Raw diatomaceous earth and plant powders are a promising alternative to synthetic insecticides for the control of stored product insect pests. Their advantages include the absence of hazardous residues in products, as well as being safe for people and harmless to non-target creatures (Ibrahim *et al.*, 2012) [12].

Seed treatments with biological control agents provide an environmental friendly alternative to the use of chemical inputs (Taylor and Harman, 1990) [19]. Seed treatments with the objective of establishing plant based neutral silica, on the other hand, are just beginning to be explored with interesting experimental results for the management of insect pests.

Therefore, to manage the storage insect pests, neutral silica and inert dust that can meet environmental and food safety criteria are needed. Due to the high susceptibility of greengram seeds to seed deterioration brought on by insect pest infestations, novel inert dust like diatomaceous earth and neutral silica has the potential to control storage insect pests and also to maintain seed quality throughout the storage period. Taking into consideration the need for the management of storage insect pests' infestation and increase the storage life of greengram seeds, present investigations were made to study.

Materials and Methods

Seeds of greengram cv.BGS-9 with initial germination of 92 percent and 8.50 percent moisture were used for this study. Experiments were carried out at AICRP on Seed (Crops), UAS, GKVK, Bangalore during July 2022 to April 2023. One kg of freshly harvested certified seed with zero percent insect pest infested seeds were taken for each treatment. The seeds were treated with the appropriate dose of plant based neutral silica and inert dust. Seeds were mixed manually for approximately two minutes to achieve uniform distribution of the silica powder with the seed mass. Treated seeds were packed in HDPE bags and kept in a room under ambient temperature. The temperature and relative humidity of the room were recorded on a standard weekly basis.

Treatment details

The effect of plant based neutral silica and inert dust with different treatments against storage insect pests of greengram and their effect on seed quality parameters of greengram was evaluated in this experiment. The experiment was carried out in Completely Randomized Design (CRD) with six treatments and four replications. Details of treatments are described below.

Treatments

T_1: Neutral silica @ 1.0 g/l
T_2: Neutral silica @ 1.5 g/l
T_3: Neutral silica @ 2.0 g/l
T_4: Diatomaceous earth @ 5 g/kg seed
T_5: Deltamethrin @ 1.0 ml/l
T_6: Untreated control

* Seeds were treated with 5 ml kg^{-1} of seed for the seeds treated with neutral silica at different concentrations.

Collection of experimental data

The seed samples were drawn at bimonthly intervals up to six months of storage and evaluated for the moisture content of the seed and seed germination were calculated and expressed as percentage. Mean seedling length and mean seedling dry weight were also measured at the end of 8 days. Vigour index was calculated using the formula of Abdul-Baki and Anderson (1973) [1]. The observations of quality parameters and seed health were recorded bimonthly for up to six months and then monthly observations up to nine months of seed storage (July 2022 to April 2023) were recorded.

Results and Discussions

In the present study the seed moisture content (Table 1) varied from 8.50 to 12.53 percent. Seeds treated with neutral silica @ 2.0 g/l (T_3) had the lowest seed moisture content of 9.98 percent, while the other neutral silica and inert dust treatments had higher seed moisture content in proportion to insect population after nine months of storage. Whereas, untreated seeds recorded the lowest hundred seed weight (3.73 g) and highest seed moisture content (12.53%). The decrease in the seed weight and increase in seed moisture content is mainly due to an increase in the insect population and might be due to insect biological activity. The results obtained in the current study are similar to Hasan *et al.* (2020) [11] in gram seeds, and Lamani and Deshpande (2017) [16] where they observed that the minimal increase of seed moisture content of greengram seeds was in the neutral silica treatment at higher concentrations compared to other treatments.

During the storage period, seeds treated with neutral silica @ 2.0 g/l (T_3) (80.4%) and diatomaceous earth at 5 g/kg seeds (T_4) treated seeds (78.4%) both exhibited satisfactory germination (Table 2). According to this, it can be stated that higher dosages of neutral silica and diatomaceous earth treated seeds maintains higher germination rates above Indian minimum seed certification standard value of 75 percent compared to lower levels. The direct feeding of storage insect pests on storage materials and the natural aging of greengram seeds caused the germination rates to vary from 92.0 to 63.7 percent. After eight months of storage, seed germination decreased drastically. The primary cause of this was due to development of seed pathogens (*Aspergillus flavus*, *Aspergillus Niger*) and seed mortality caused by seed damage due to insect infestation on greengram seeds (Yerragopu *et al.*, 2019 [22] in soybean). The results obtained in the experiment are in concurrence with Haghighi *et al.* (2012) [10] in tomato. The maintenance of rate of germination suggested that exogeneous silicon seed treatment improved seed germination by enhancing antioxidant defence and also suggested that the active involvement of silicon in biochemical processes of seed. Compared with non-silicon treatment, silicon addition increased the activities of superoxide dismutase (SOD) and catalase (CAT) and decreased the production of superoxide anion (O_2^-) and hydrogen peroxide (H_2O_2) in radicles of seedling (Torabi *et al.*, 2012 in *Borago officinalis* L.). The results obtained in the experiment are concurrent with Shi *et al.* (2014) [18].

The seeds treated with neutral silica @ 2.0 g/l (T_3) recorded highest (Table 3 and Plate 1) mean seedling length (42.02 and 33.53 cm), (Table 4) mean seedling dry weight (23.14 and 18.90 mg), (Fig. 1) vigour index-I (3856 and 2683) and (Fig. 2) vigour index II (2133 and 1514) from initial to end of nine months of storage period. Overall, the neutral silica and inert dust treatments at higher concentrations (2.0 g/l) showed a beneficial effect on seed germination, seedling vigour indices when compared to untreated seeds. With the passage of time, a decrease in vigour index was observed due to insect infestation (%) which has led to reduction in germination, mean seedling length and mean seedling dry weight, which in turn resulted in reduced seed vigour. Current findings are contemporaneous with Jiang *et al.*, 2022 [14] in rice and Alsaeedi *et al.* (2019) [2] in cucumber.

The electrical conductivity (Table 5) of seed leachate gradually increased over time. It differed from 0.48 to 2.05 mS cm^{-1}. Least electrical conductivity of seed leachate among the treatments was observed in neutral silica @ 2.0 g/l (T_3) treated seeds about 1.40 mS cm^{-1} which was on par with diatomaceous earth @ 5 g/kg seeds (T_4) (1.49 mS cm^{-1}) and a chemical check *i.e*., deltamethrin @ 1.0 ml/l (T_5) treated seeds (1.78 mS cm^{-1}) after nine months of storage. The conductivity of seed leachate, which increased as storage time increased, is inversely proportional to seed quality. The enhanced electrical conductivity of seed leachate is owing to the increased permeability of the cell membrane and decreased compactness of the seed coat, which allow sugars, organic acids, and amino acids to escape in the presence of water (Basra, 2000) [8]. The current study's seed leachate conductivity results agreed with those of Jagadeesh *et al.* (2017) [13] in pigeon pea and Babu *et al.* (2008) [7] in soybean.

Impact of plant based neutral silica and inert dust on storage insect pests of greengram during storage

The percentage of insect (Fig. 3) ranged from 0.00 to 23.00. *Callosobruchus chinensis* infestation rose as storage time increased. After nine months of storage, seeds treated with neutral silica @ 2.0 g/l (T_3) (Plate 2) were least infested (1.55%), while the maximum insect infestation (23.00%) was recorded in untreated seeds (T_6).

As time advances, the percentage of damaged seeds increased. This increased seed damage, or exit holes, is caused by an increase in insect population levels of *C. chinensis* that soar with favourable temperature conditions, which may further be caused by decrease in insecticide effectiveness as they are exposed to storage conditions. When compared to untreated seeds, the majority of neutral silica and inert dust treatments demonstrated potent lethal activity on *C. chinensis*. These observations are similar to that of Khinchi *et al.* (2017) [15] in chickpea and Yerragopu *et al.* (2019) [22] in soybean. The neurotoxic mechanism of action, the repellent property of neutral silica, and the dehydrating property of inert dust, these factors contribute to the reduced quantity of bruchids in treated seeds.

Cost-Benefit ratio

The least amount of insect infestation was 1.55 percent in seeds treated with neutral silica @ 2.0 g/l (T_3), resulting in a loss of ₹ 249 owing to damage. This was mainly because of increased dosage of neutral silica being more efficient in managing the storage insect pests and maintaining the seed quality at the end of the storage period.

The treatment neutral silica @ 2.0 g/l (T_3) recorded the highest C: B ratio of 1: 14.9, followed by diatomaceous earth @ 5 g/kg seeds (T_5) of 1: 8.5. Whereas, the untreated seeds (T_6) incurred a huge economic loss when compared to other treatments.

Table 1: Effect of plant based neutral silica on seed moisture content (%) of greengram cv. BGS-9 seeds stored under ambient condition

Treatments	Seed moisture (%)					
	Storage period (July 2022 - April 2023)					
	2 MAS	4 MAS	6 MAS	7 MAS	8 MAS	9 MAS
T_1	8.87	9.32	9.82	10.52	10.75	11.42
T_2	8.69	8.80	9.22	9.65	10.23	10.87
T_3	8.53	8.56	8.83	9.46	9.56	9.98
T_4	8.57	8.68	8.93	9.47	9.69	10.31
T_5	8.77	9.26	9.61	9.90	10.44	11.24
T_6	8.87	9.70	9.97	10.71	11.05	12.53
Mean	8.88	9.06	9.40	9.95	10.29	11.06
S. Em±	0.21	0.23	0.22	0.26	0.27	0.29
CD (P=0.05)	NS	0.68	0.65	0.77	0.81	0.87
CV (%)	4.80	5.02	4.65	5.18	5.28	5.30

MAS: Months After Storage, NS: Non-Significant, Initial seed moisture (%): 8.50

Treatments:

T_1: Neutral silica @ 1.0 g/l

T_2: Neutral silica @ 1.5 g/l

T_3: Neutral silica @ 2.0 g/l

T_4: Diatomaceous earth @ 5 g/kg seed

T_5: Deltamethrin @ 1.0 ml/l

T_6: Control (Untreated)

Table 2: Effect of plant based neutral silica on seed germination (%) of greengram cv. BGS-9 seeds stored under ambient condition

Treatments	Seed germination (%)					
	Storage period (July 2022 - April 2023)					
	2 MAS	4 MAS	6 MAS	7 MAS	8 MAS	9 MAS
T_1	89.2	85.3	80.4	79.4	75.5	70.6
T_2	90.8	89.2	83.3	82.3	78.4	72.5
T_3	91.5	91.0	88.3	86.2	83.3	80.4
T_4	91.0	90.0	87.2	85.3	82.3	78.4
T_5	90.2	85.3	83.3	80.4	76.4	71.5
T_6	88.2	80.4	79.4	76.4	70.6	63.7
Mean	90.15	86.87	83.65	81.67	77.75	72.85
S. Em±	1.71	1.78	2.01	2.09	2.12	2.15
CD (P=0.05)	NS	5.28	5.98	6.20	6.31	6.39
CV (%)	3.78	4.10	4.80	5.13	5.48	5.89

MAS: Months After Storage, NS: Non-Significant, Initial seed germination: 92 percent

Treatments:

T_1: Neutral silica @ 1.0 g/l

T_2: Neutral silica @ 1.5 g/l

T_3: Neutral silica @ 2.0 g/l

T_4: Diatomaceous earth @ 5 g/kg seed

T_5: Deltamethrin @ 1.0 ml/l

T_6: Control (Untreated)

Table 3: Effect of plant based neutral silica on mean seedling length (cm) of greengram cv. BGS-9 seeds stored under ambient condition

Treatments	Mean seedling length (cm) Storage period (July 2022 - April 2023)					
	2 MAS	4 MAS	6 MAS	7 MAS	8 MAS	9 MAS
T_1	37.80	37.05	35.08	33.28	30.52	29.95
T_2	38.79	37.95	36.53	35.60	33.02	31.12
T_3	42.02	40.26	38.31	36.76	35.17	33.53
T_4	40.38	39.48	38.13	36.26	34.17	32.47
T_5	38.58	37.63	35.76	34.70	31.47	30.42
T_6	36.60	36.15	33.84	31.97	30.43	28.24
Mean	39.03	38.09	36.28	34.76	32.46	30.96
S. Em±	1.01	0.92	0.83	0.88	0.74	0.88
CD (P=0.05)	3.00	2.74	2.46	2.61	2.21	2.62
CV (%)	5.18	4.85	4.56	5.06	4.58	5.69

MAS: Months After Storage, Initial mean seedling length: 42.90 cm
Treatments:
T_1: Neutral silica @ 1.0 g/l
T_2: Neutral silica @ 1.5 g/l
T_3: Neutral silica @ 2.0 g/l
T_4: Diatomaceous earth @ 5 g/kg seed
T_5: Deltamethrin @ 1.0 ml/l
T_6: Control (Untreated)

Table 4: Effect of neutral silica and inert dust on mean seedling dry weight (mg) of greengram cv. BGS-9 seeds stored under ambient condition

Treatments	Mean seedling dry weight (mg) Storage period (July 2022 - April 2023)					
	2 MAS	4 MAS	6 MAS	7 MAS	8 MAS	9 MAS
T_1	21.29	19.27	17.56	16.93	16.56	15.28
T_2	22.73	19.90	18.23	18.28	17.64	17.26
T_3	23.14	22.54	21.71	21.02	20.05	18.90
T_4	23.09	22.45	21.29	20.83	19.86	18.62
T_5	22.31	19.56	17.74	17.16	17.02	16.19
T_6	19.91	18.66	16.87	16.19	15.71	14.25
Mean	22.09	20.41	18.91	18.41	17.81	16.76
S. Em±	0.57	0.51	0.55	0.48	0.43	0.47
CD (P=0.05)	1.68	1.51	1.65	1.43	1.28	1.40
CV (%)	5.12	4.98	5.86	5.23	4.85	5.64

MAS: Months After Storage, Initial mean seedling dry weight: 23.43 mg
Treatments:
T_1: Neutral silica @ 1.0 g/l
T_2: Neutral silica @ 1.5 g/l
T_3: Neutral silica @ 2.0 g/l
T_4: Diatomaceous earth @ 5 g/kg seed
T_5: Deltamethrin @ 1.0 ml/l
T_6: Control (Untreated)

Table 5: Effect of neutral silica and inert dust on electrical conductivity ($mScm^{-1}$) of greengram cv. BGS-9 seeds stored under ambient condition

Treatments	Electrical conductivity ($mScm^{-1}$) Storage period (July 2022 - April 2023)					
	2 MAS	4 MAS	6 MAS	7 MAS	8 MAS	9 MAS
T_1	0.68	1.03	1.37	1.54	1.63	1.87
T_2	0.62	0.98	1.25	1.41	1.56	1.67
T_3	0.54	0.75	1.01	1.14	1.29	1.40
T_4	0.56	0.80	1.14	1.22	1.36	1.49
T_5	0.68	1.00	1.32	1.50	1.67	1.78
T_6	0.75	1.12	1.46	1.63	1.72	2.05
Mean	0.64	0.95	1.09	1.41	1.54	1.71
S. Em±	0.02	0.02	1.04	0.05	0.05	0.05
CD (P=0.05)	0.06	0.07	0.13	0.14	0.16	0.16
CV (%)	4.57	4.02	5.31	5.05	5.39	4.72

MAS: Months After Storage, Initial electrical conductivity: 0.48 $mScm^{-1}$
Treatments:
T_1: Neutral silica @ 1.0 g/l
T_2: Neutral silica @ 1.5 g/l
T_3: Neutral silica @ 2.0 g/l
T_4: Diatomaceous earth @ 5 g/kg seed
T_5: Deltamethrin @ 1.0 ml/l
T_6: Control (Untreated)

Table 6: Effect of neutral silica and inert dust on insect infestation (%) of greengram cv. BGS-9 seeds stored under ambient condition

Treatments	Insect infestation (%) Storage period (July 2022 - April 2023)					
	2 MAS	4 MAS	6 MAS	7 MAS	8 MAS	9 MAS
T_1	0.00	0.46	1.09	1.99	2.45	4.91
T_2	0.00	0.22	0.90	1.72	2.18	3.27
T_3	0.00	0.00	0.27	1.09	1.45	1.55
T_4	0.00	0.00	0.28	1.18	1.91	2.07
T_5	0.00	0.36	1.09	1.82	2.35	3.82
T_6	0.00	1.55	3.62	6.27	10.38	23.00
Mean	NA	0.43	1.21	2.35	3.45	6.44
S. Em±	NA	0.02	0.06	0.11	0.17	0.34
CD (P=0.05)	NA	0.07	0.18	0.32	0.50	1.01
CV (%)	NA	10.98	10.08	9.08	9.73	10.61

MAS: Months After Storage NA: Not Analysed Initial insect infestation (%): Nil
Treatments:
T_1: Neutral silica @ 1.0 g/l
T_2: Neutral silica @ 1.5 g/l
T_3: Neutral silica @ 2.0 g/l
T_4: Diatomaceous earth @ 5 g/kg seed
T_5: Deltamethrin @ 1.0 ml/l
T_6: Control (Untreated)

Table 7: Cost-Benefit ratio

Treatments	Plant based neutral silica dosages/kg seeds (ml or mg/kg)	Plant based neutral silica dosages/100 kg seeds	Insect infestation (%) 9 MAS	Total loss per quintal (₹)	C: B
T_1	50 mg	5 g	4.91	667	1: 4.3
T_2	75 mg	7.5 g	3.27	463	1: 6.2
T_3	100 mg	10 g	1.55	249	1: 14.9
T_4	5 g	500 g	2.07	339	1: 8.5
T_5	0.05 ml	5 ml	3.82	534	1: 5.4
T_6	-	-	23.00	2881	

MAS: Months after Storage
Treatments:
T_1: Neutral silica @ 1.0 g/l
T_2: Neutral silica @ 1.5 g/l
T_3: Neutral silica @ 2.0 g/l
T_4: Diatomaceous earth @ 5 g/kg seed
T_5: Deltamethrin @ 1.0 ml/l
T_6: Control (Untreated)

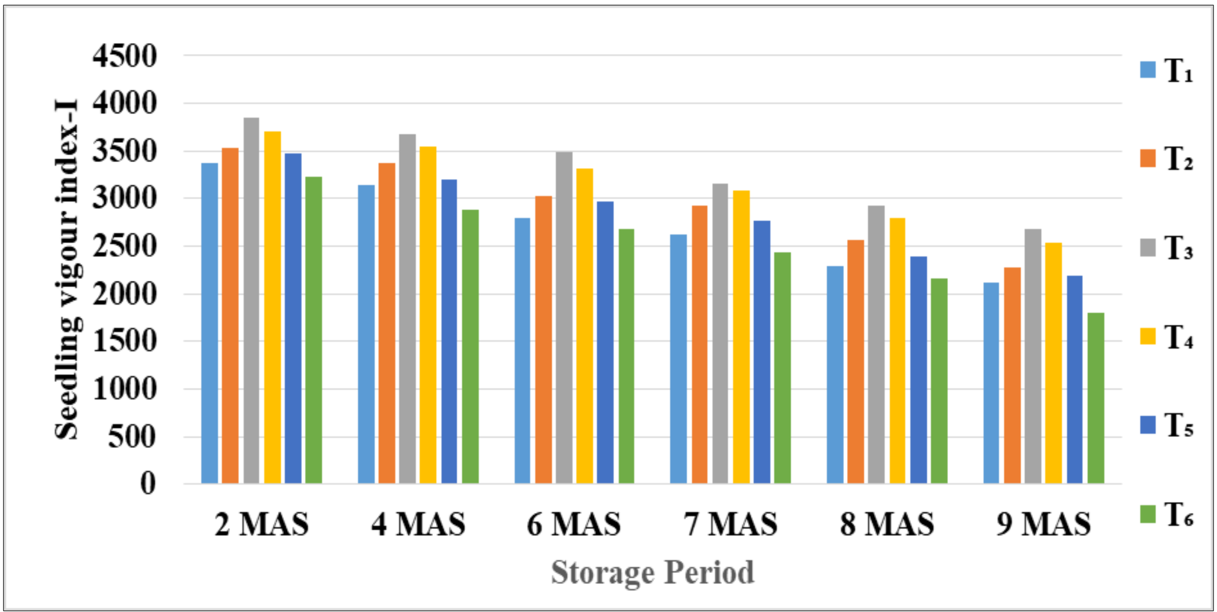
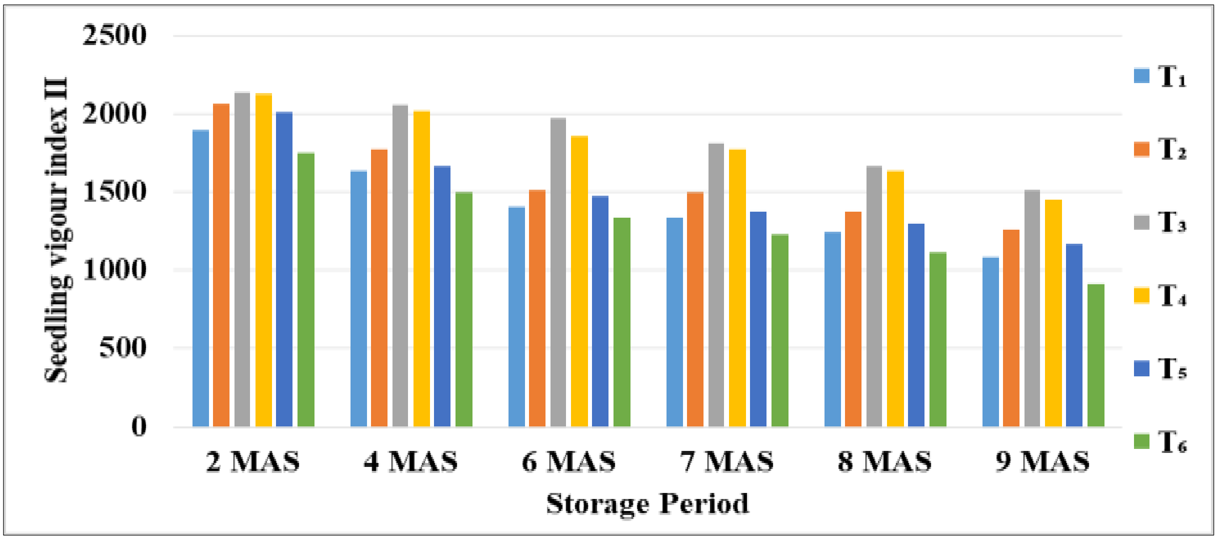
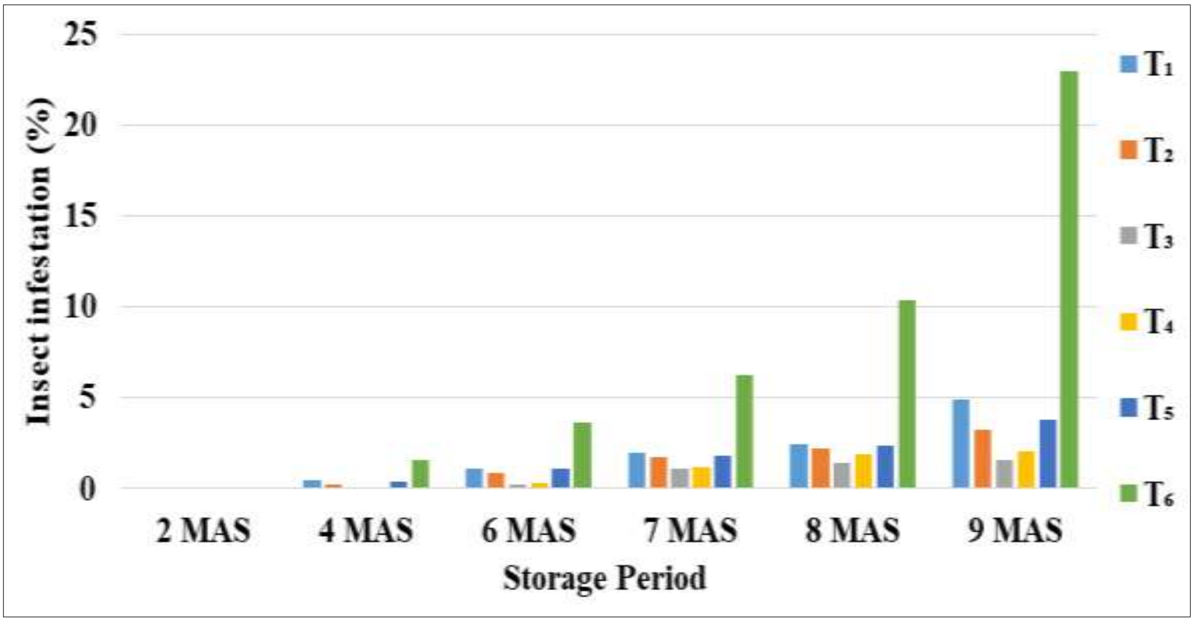


Fig 1: Effect of plant based neutral silica on seedling vigour index I of greengram cv. BGS-9



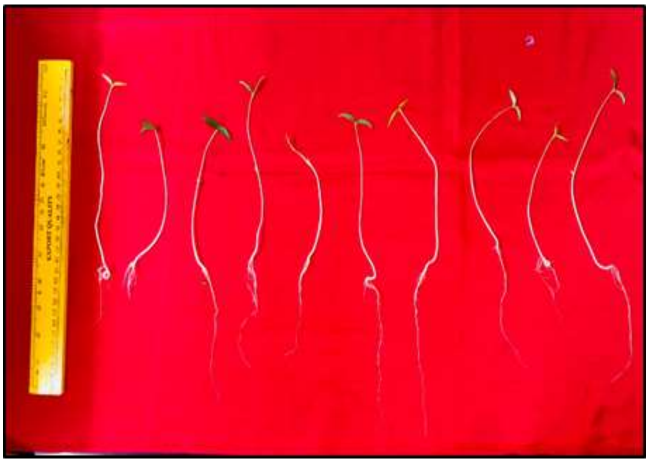
MAS: Months after Storage
Treatments
T_1: Neutral silica @ 1.0 g/l
T_2: Neutral silica @ 1.5 g/l
T_3: Neutral silica @ 2.0 g/l
T_4: Diatomaceous earth @ 5 g/kg seed
T_5: Deltamethrin @ 1.0 ml/l
T_6: Control (Untreated)

Fig 2: Effect of plant based neutral silica on seedling vigour index II of greengram cv. BGS-9.



MAS: Months After Storage
Treatments
T_1: Neutral silica @ 1.0 g/l
T_2: Neutral silica @ 1.5 g/l
T_3: Neutral silica @ 2.0 g/l
T_4: Diatomaceous earth @ 5 g/kg seed
T_5: Deltamethrin @ 1.0 ml/l
T_6: Control (Untreated)

Fig 3: Effect of plant based neutral silica on seed infestation (%) of greengram cv. BGS-9.



Seeds treated with neutral silica @ 2 g/l (T_3) Untreated seeds (T_6)

Plate 1: Effect of plant based neutral silica on seedling length (cm) in greengram cv. BGS-9 after nine months of storage

Seeds treated with neutral silica @ 2 g/l (T_3) Untreated seeds (T_6)

Plate 2: Comparison of T_3 and T_6 on *Callosobruchus chinensis* infestation (%) in greengram cv. BGS-9 after nine months of storage

Conclusion

Plant based neutral silica and inert dust are a promising alternative to synthetic insecticides for the control of stored product insect pests and to maintain seed quality during storage of greengram seeds. The results from the present study revealed that greengram seeds treated with plant based neutral silica *i.e.*, neutral silica @ 2.0 g/l (T_3) was effective in maintaining seed moisture content (%), seed germination (%), mean seedling length (cm), mean seedling dry weight (mg), seedling vigour index I and II and also there was very minimal increase in the electrical conductivity of seed leachate attributing towards its effectiveness in maintaining seed quality throughout the storage period. Similarly, the same treatment concentration was effective in keeping *Callosobruchus chinensis* under control which in turn reduced the insect infestation (%) or seed damage (%) being recorded the highest C: B ratio of 1: 14.9.

Therefore, from the study it can be concluded that neutral silica @ 2.0 g/l (T_3) seeds can be used as a seed treatment technique during storage of greengram seeds.

References

1. Baki AAA, Anderson JD. Vigor determination in soybean seed by multiple criteria 1. Crop science. 1973;13(6):630-633.
2. Alsaeedi AH, Elgarawany MM, El-Ramady H, Alshaal T, Al-Otaibi AO. Application of silica nanoparticles induces seed germination and growth of cucumber (*Cucumis sativus*). Met. Environ. Arid. Land Agric. Sci. 2019;28:57-68.
3. Anonymous. International Rules of Seed Testing. Seed Sci. & Technol. 1997;27:27-32.
4. Anonymous. Agricultural Research Service, U. S. Dept. of Agriculture. Farmers.gov; c2018.
5. Anonymous. Greengram outlook report, ANGRAU; c2021.
6. Arora GL. Bruchidae of North-West India. Oriental Insects Supplement No. 7. The association for the study

of oriental insects, New Delhi; c1997. p. 132.
7. Babu HM, Hunje R, Biradarpatil N, Motagi B. Effect of seed treatment with botanicals on storability of soybean. Karnataka J Agril. Sci. 2008;21:357-360.
8. Basra SM, Rehman KU, Iqbal S. Cottonseed deterioration: assessment of some physiological and biochemical aspects. International Journal of Agriculture and Biology. 2000;2(3):195-198.
9. Daglish GJ. Impact of resistance on the efficacy of binary combinations of spinosad, chlorpyrifos-methyl and s-methoprene against five stored-grain beetles. Journal of Stored Products Research. 2008;44(1):71-76.
10. Haghighi M, Afifipour Z, Mozafarian M. The alleviation effect of silicon on seed germination and seedling growth of tomato under salinity stress. Journal of Fruit and Ornamental Plant Research. 2012;76(1):119-126.
11. Hasan MA, Sultana S, Akter K, Wara TU, Hasan M, Uddin MM. Biorational management of pulse beetle (*Callosobruchus chinensis* L.) in gram seed. Asian Plant Research Journal. 2020;6(2):14-22.
12. Ibrahim ND, Audu A, Dike MC, Lawal M. Effect of raw diatomaceous earth and plant powders on *Callosobruchus subinnotatus* (Pic.) infesting stored Bambara groundnut grains. Scientific Journal of Pure and Applied Sciences. 2012;1(1):9-16.
13. Jagadeesh V, Patta S, Triveni S, Keshavulu K, Rani KJ, Raghavendra K. Effect of biological seed coating on pigeon pea seedling vigour. International Journal of Current Microbiology and Applied Sciences. 2017;6(8):843-854.
14. Jiang Y, Yang J, Li M, Li Y, Zhou P, Wang Q, Sun Y, Zhu G, Wang Q, Zhang P, Rui Y. Effect of silica-based nanomaterials on seed germination and seedling growth of rice (*Oryza sativa* L.). Nanomaterials. 2022;12(23):4160.
15. Khinchi SK, Sharma MM, Khinchi MK, Bairwa DK, Acharya D. Naga BL, *et al.* Studies on efficacy of certain vegetable oils against pulse beetle, *Callosobruchus chinensis* Linn on chickpea, *Cicer arietinum* L. Int. J Chemi. Stud. 2017;5(3):255-259.
16. Lamani K, Deshpande VK. Effect of different seed processing methods on seed recovery and seed quality of onion cv. Arka Kalyan. Int. J Pure App. Biosci. 2017;5(5):644-648.
17. Lu MM, De Silva DM, Peralta E, Fajardo A, Peralta M. Effects of nanosilica powder from rice hull ash on seed germination of tomato (*Lycopersicon esculentum*). Philippine E-Journal for Applied Research and Development. 2015;5:11-22.
18. Shi Y, Zhang Y, Yao H, Wu J, Sun H, Gong H. Silicon improves seed germination and alleviates oxidative stress of bud seedlings in tomato under water deficit stress. Plant Physiology and Biochemistry. 2014;78:27-36.
19. Taylor AG, Harman GE. Concepts and technologies of selected seed treatments. Annual Review of Phytopathology. 1990;28(1):321-339.
20. Torabi F, Majd A, Enteshari S. Effect of exogenous silicon on germination and seedling establishment in *Borago officinalis* L. J Medicinal Plants Res. 2012;6(10):1896-1901.
21. Yakubu BL, Mbonu OA, Nda AJ Cowpea (*Vigna unguiculata*) pest control methods in storage and recommended practices for efficiency: A review. Journal of Biology, Agriculture and Healthcare. 2012;2(2):27-33.
22. Yerragopu PS, Hiregoudar S, Nidoni U, Ramappa KT, Sreenivas A, Doddagoudar SR. Effect of plant-mediated synthesized silver nanoparticles on pulse beetle, *Callosobruchus chinensis* (L.). Int. J Curr. Microbiol. Appl. Sci. 2019;8:1965-1972.