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Effect of packing material and seed treatment chemicals on seed storability in greengram

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Abstract
Storage studies were undertaken in greengram after pre storage treatments and results was performed better in seeds stored in super grain bag in all quality parameter compared to cloth bag during ten months *viz*., seed moisture content (9.32%), seed germination (80.8%), mean seedling length (24.47 cm), mean seedling dry weight (218 mg), seedling vigour index-I (1984) and seedling vigour index-II (1681), electrical conductivity (0.694 dSm^{-1}), total dehydrogenase activity (1.433 A_{480nm}), seed infection (17.57%) and seed infestation (7.52%). Among treatments studied deltamethrin @ 0.04 ml/kg seed recorded seed moisture content (8.15%), root length (9.41 cm), mean seedling length (26.97 cm) mean seedling dry weight (237 mg), seedling vigour index-II (1929), electrical conductivity (0.611 dSm^{-1}), total dehydrogenase activity (1.600 A_{480nm}), seed infection (8.50%), seed infestation (1.67%). Whereas, spinetoram @ 0.40 ml/kg also recorded better in seed germination (84.3%), shoot length (17.58) seedling vigour index-I (2244) at tenth month of storage. Interaction between packing material and chemical seed treatments on quality parameters were observed as seed germination in P_1T_3 (87.0%), mean seeding length in P_2T_2 (28.13 cm), mean seeding dry weight in P_1T_2 (257 mg), seedling vigour index-I in P_1T_3 (2356), seedling vigour index-II in P_1T_2 (2079), total dehydrogenase activity (1.686) (A_{480nm}) and lowest seed moisture content in P_1T_3 (8.12%), electrical conductivity in P_1T_2 (0.581 dSm^{-1}), seed infection in P_1T_3 (8.00%) and seed infestation in P_1T_2 (1.67%) at tenth month of storage.

Keywords: Green gram, seed storage, seed treatment, packing material

1. Introduction
Pulses are poor storer and infested by bruchids (*Callosobruchus* sps.) starts in the field continues till storage (Adebayo and Anjorin, 2018) [2]. The pulse beetle *Callosobruchus maculatus* is a major pest of economically important legumes, such as cow pea, lentil, green gram, and black gram and in storage; it is damaged to a major extent. The pest is being an internal feeder, it laid eggs on seed surface in field and during threshing. To manage this storage pest, use of synthetic insecticides is currently the most effective way to prevent the infestation. Moreover, most of these farmers cannot buy pesticides during storage to control pest and disease. However, the problems of many synthetic insecticides which include high persistence, poor knowledge of application by resource-poor farmers, high cost, genetic resistance and hazards to environment and human health have necessitated the search for relatively cheap, environmentally safe and sustainable control measures.
The use of botanical insecticides increased attention due to their safety and effectiveness. Botanicals can be used to keep free from pulse beetle attack and for long term storability and maintain seed quality. Locally available plant products have been tried with good success against a number of stored insect pests. Therefore, the objective of finding alternative to pesticide, research efforts are currently being focused on eco-friendly packaging materials play a major role in prolonging the shelf life of seed during storage.

2. Materials and Methods
Method of seed treatment was carried out with various seed protectants. The seeds were smeared with specified quantity of solutions and stirred for several times for uniform adherence of chemical and kept in open air to dry. Seeds after reached to minimum level of moisture content, seeds were kept in containers *viz*., cloth bag and super grain bag, then stored under ambient conditions in the STR laboratory from December, 2020 to September, 2021.

Factor-I: Packing materials
P_1: Super grain bag
P_2: Cloth bag

Factor-II: Treatments
T_1: Deltamethrin @ 0.04 ml/kg seed
T_2: Spinetoram @ 0.40 ml/kg seed
T_3: Chlorantraniliprole @ 0.10 ml/kg seed
T_4: Emamectin benzoate @ 40 mg/kg seed
T_5: Neem oil @ 7.5 ml/kg seed
T_6: Turmeric powder 10 g/kg seed
T_7: Control
Variety: BGS-9
Design: Factorial CRD
Replications: 3

The greengram variety BGS-9 seeds were procured from Karnataka State Seeds Corporation for storage experiment.
The experiment was conducted in Factorial Completely Randomized Design (FCRD) with three replications and stored up to the duration of which seeds maintain minimum seed standards.

Treatment combination

P_1T_1:	Super grain bag + Deltamethrin @ 0.040 ml/kg seed
P_1T_2:	Super grain bag + Spinetoram @ 0.40 ml/kg seed
P_1T_3:	Super grain bag + Chlorantraniliprole @ 0.10 ml/kg seed
P_1T_4:	Super grain bag + Emamectin benzoate @ 40 mg/kg seed
P_1T_5:	Super grain bag + Neem oil @ 7.50 ml/kg seed
P_1T_6:	Super grain bag + Turmeric powder 10 g/kg seed
P_1T_7:	Super grain bag + Control
P_2T_1:	Cloth bag + Deltamethrin @ 0.040 ml/kg seed
P_2T_2:	Cloth bag + Spinetoram @ 0.40 ml/kg seed
P_2T_3:	Cloth bag + Chlorantraniliprole @ 0.10 ml/kg seed
P_2T_4:	Cloth bag + Emamectin benzoate @ 40 mg/kg seed
P_2T_5:	Cloth bag + Neem oil @ 7.50 ml/kg seed
P_2T_6:	Cloth bag + Turmeric powder 10 g/kg seed
P_2T_7:	Cloth bag + Control

2.1 Observations recorded
The required quantities of seeds were drawn randomly at bi-monthly of storage period as per treatment schedule for recording observations on various seed quality parameters as Seed moisture content (%), Seed germination (%), Root length (cm), Shoot length (cm), Mean seedling length (cm), Mean seedling dry weight (mg), Seedling vigour index I and II , Electrical conductivity of seed leachates (dSm^{-1}), Total dehydrogenase activity, Seed insect infestation (%) and Seed health infection (%).

3. Results and Discussion
Seeds are hygroscopic in nature, viability and vigour of seeds are known to be regulated by variations during storage period, initial seed quality, packaging conditions, physiochemical factors, etc (Doijoide, 1988) [15]. Among these, different packaging materials are considered as one of the most important factor influencing longevity of seeds in storage.
Good storage is basic requirement in seed production programme for maintenance of seed viability and vigour from harvesting to till next planting. Proper packaging materials or storage containers are essential for retaining the seed quality and viability. Before or during marketing the seeds have to be stored in suitable containers.

One of eco-friendly and economic approaches to keep stored seed free from insect attack, is the use of protectants. Inability of the insect pest to develop resistance against them is an added advantage. There are encouraging reports on the use of certain products as seed protectants and impregnation of packaging materials with different products. These conventional practices needed scientific evaluation. This situation dictates the need for safe, locally available and less expensive materials for pest control in storage. There are encouraging reports on the use of certain indigenous plant products as grain protectants (Pawara *et al.* 2019) [28], but definite information on mortality doses, efficacy of oils and extracts by treatment of packaging materials and direct feeding with the seed and their residual life is meagre, hence needs detailed investigations.

3.1 Seed moisture content (%)
The results on seed moisture content as influenced by packing material, seed treatments and their interactions are presented in table 1.

3.1.1 Effect of packing material (P)
Significant difference with respect to moisture content in seeds during storage was observed irrespective of packing material compared to initial seed quality (8.00%). The packing material, super grain bag recorded significantly low moisture content (9.32%) and highest moisture content was observed in cloth bag (9.76%) during ten months of storage.
Higher moisture content in seeds it reduced the seed storability by increasing seed deterioration, which ultimately reduces the planting value of seeds in the field. The initial moisture content of different packing material seeds was similar but it was increased during storage period. The increasing rate was varied from packaging material where we store. As seed is highly hygroscopic living material; it absorbs moisture from air if it is stored in an environment where relative humidity is higher than seed moisture content (Copeland, 1976) [13]. The relative humidity was near 70 per cent or above through the storage period. The rate of absorbance was higher in cloth bags because of it is not air tight container but super grain bag is moisture proof so, increasing rate was lower. However the seed moisture fluctuation was more in cloth bag compared to super grain bag due to less exchange of moisture and gases. The results are also conformity with Gangaraju and Balakrishna (2016) [17] in blackgram and Ananthi *et al.* (2017) [7] in greengram.

3.1.2 Effect of seed treatment (T)
The significant differences among the seed treatments on seed moisture were noticed in ten months of storage period. Seeds treated with spinetoram in combination (T_2) recorded lowest moister content (8.17%), followed by deltamethrin (T_1) (8.15%), and highest moisture content was observed in control (T_7) (11.14%) during the storage of ten months.
The lower moisture present in seeds treated with chemicals may be due to the covering of the seed coat and prevent entry of water and fungal mycelia and provide protection from physical damage and entry of water/gases to seed. Similar results of present study also recorded by Shivagouda *et al.* (2014) [35] in pigeon pea and Gangaraju and Balakrishna (2016) [17] in blackgram.

3.1.3 Interaction of packing material and seed treatment (P×T)
Seed moisture content differed significantly due to interaction of packing material and seed treatments up to ten months of storage. The interaction P_1T_2 (8.12%) recorded lowest moisture while highest moisture content was observed in P_2T_7 (11.38%).

Variation might be due to extent of moisture transmission to seed from outside. Hence, seeds stored in cloth bag have been exposed to more frequency of moisture equilibrium with atmosphere which results in increased rate of absorption which accelerate rate of seed deterioration. These results are agreed with findings of Raikar *et al.* (2011) [30] in rice and Chitra *et al.* (2021) [12] in blackgram.

3.2 Germination (%)
The data on the germination percentage during the storage as influenced by the different packing material, seed treatment s and their interaction effects are presented in table 1.

3.2.1 Effect of packing material (P)
The germination percentage was found to differ significantly in the storage in two different packaging materials. At the end of storage period the seeds stored in super grain (P_1) have recorded highest germination percentage (80.8%) at ten months of storage period. Whereas, lowest germination (74.9%) was found in case of seeds stored in cloth bag (P_2) (Plate 23 and 24).

Cloth bag absorb more moisture leads to faster deterioration during storage leads to reduction in seed germination. Similar results found in Kathivaran *et al.* (2008) in lablab, Shivagouda *et al.* (2014) [35] in pigeon pea and Umesha *et al.* (2017) [42] in cluster bean.

3.2.2 Effect of seed treatment (T)
The germination percentage was differed significantly in seeds treated with different seed treatments from six months of storage compared to initial seed quality (96.00%). Among chemical seed treatments seeds treated with spinetoram @ 0.4 ml/kg seeds (T_2) have recorded highest germination potential (84.33%) while lowest (68.33%) noticed in control (T_7).

Chemicals not only provide protection from insects and diseases but they also protect seed from physical damage by acting as thin layer around seed which helps in reducing seed deterioration which may helps seed germination. Similar results with chemicals to help seed germination were also found in Khinchi *et al.* (2017) [22] and Nishad *et al.* (2020) [25].

3.2.3 Interaction of packing material and seed treatments (P×T)
Germination percentage differed significantly due to interaction of packing material and seed treatments up to ten months of storage. The interaction P_1T_2 (81.0%) recorded highest germination (%) and it is followed by P_1T_1 (85.0%), while lowest was observed in P_2T_7 (67.3%).

The decline in germination percentage could be attributed to irreversible ageing during storage which causes deteriorative changes in physiological and biological characteristics of seed. These results by using various chemicals and packing material are agreed with findings of Gangaraju and Balakrishna (2016) [17] and Chitra *et al.* (2021) [12] in blackgram.

3.3 Root length (cm)
The results on root length as influenced by packing material, seed treatments and interactions between both are presented in table 1.

3.3.1 Effect of packing material (P)
In the present research programme, there was significant difference with respect to root length in seeds during storage was observed in ten months of the storage irrespective of packing material compared to initial seed quality (15.50 cm). The packing material, super grain bag recorded significantly high root length (cm) (8.44 cm) and lowest root length (cm) was observed in cloth bag (8.16 cm) during ten months of storage.

Seeds stored in super grain bag significantly higher root growth than cloth bag. Moisture content had the influential effect on seed storage and high moisture content in cloth bags obviously deteriorated seedling growth. These findings are in accordance with Monira *et al.* (2012) [24] in soybean.

3.3.2 Effect of seed treatment (T)
The significant differences among the seed treatments on root length were noticed during ten months of storage period. Seeds treated with deltamethrin (T_1) recorded highest root length (9.41 cm), followed by deltamethrin (T_2) (9.02 cm), and lowest root length was observed in (T_7) (6.87 cm) during the storage of ten months.

In present study chemicals protect and will also helps in reduce infection in early stages of germination leads to better root growth. These are concordance with findings of Amruta *et al.* (2015) [6], Priyanka *et al.* (2015) [29].

3.3.3 Interaction of packing material and seed treatments (P×T)
Root length differed significantly due to interaction of packing material and seed treatments chemical up to ten months of storage. The interaction P_1T_2 (10.33 cm) recorded highest root length and it is followed by P_2T_2 (10.10 cm), while lowest root length was observed in P_2T_7 (5.77 cm).

During storage period vigor of seeds declined due to catabolic activity in seed and thus seed though viable, reduction in length of root due to ageing. Similar were observed by Salimath *et al.* (2014) [32].

3.4 Shoot length (cm)
The data on the shoot length during the storage as influenced by the different packing material, seed treatments and their interaction effects are presented in table 1.

3.4.1 Effect of packing material (P)
The shoot length was differed significantly for packaging materials. At the end of storage period the seeds stored in super grain bag (P_1) have recorded highest shoot length (16.03 cm). Whereas, lowest shoot length (15.43 cm) was found in case of seeds stored in cloth bag (P_2).

According to Salimath *et al.* (2014) [32] seed quality in cloth bag was reduced due to high rate of seed deterioration by biotic and abiotic factors to which cloth bags are more susceptible. These findings were conformity with Singh *et al.* (2007) [37] in lentil, Paul *et al.* (1996) [27] in mungbean.

3.4.2 Effect of seed treatment (T)
The shoot length was differed significantly in seeds treated with different seed treatments during whole storage period compared to initial seed quality (29.00 cm). Among chemical seed treatments seeds treated with spinetoram (T_1) have recorded highest shoot length (cm) (17.56 cm) while lowest (11.99 cm) noticed in control (T_7).

In present study chemicals protect and will also helps in reduce infection in early stages of germination leads to better shoot growth. These are concordance with findings of Priyanka *et al.* (2015) [29], Umesha *et al.* (2017) [42] in cluster bean

3.4.3 Interaction of packing material and seed treatments (P×T)
Shoot length differed significantly due to interaction of packing material and seed treatments during storage up to ten months. The interaction P_1T_2 (17.80 cm) recorded highest shoot length (cm) and it is followed by P_1T_3 (17.70 cm), while lowest shoot length was observed in P_2T_7 (9.91 cm).

During storage period vigor of seeds declined due to catabolic activity in seed and thus seed though viable, reduction in length of shoot (Salimath *et al.*, 2014) [32] and during ageing deteriorative changes leads to lower availability of energy during germination. Similar were observed by Arunandly and Senanayake (1991) [8] in soybean.

3.5 Mean seedling length (cm)
The results on mean seedling length are influenced by packing material, seed treatments and interactions between both are presented in table 1.

3.5.1 Effect of packing material (P)
In the present research programme, there was significant difference with respect to mean seedling length in seeds during storage was observed in ten months of the storage irrespective of packing material, seed treatments compared to initial seed quality (44.50 cm). The packing material, super grain bag recorded significantly high mean seedling length (24.47 cm) and lowest seedling length (cm) was observed in cloth bag (23.58 cm) during ten months of storage (Plate 25 and 26).

The present study revealed that mean seedling length decreased in all the three containers with the advancement of storage period. The lowest mean seedling length (cm) in cloth bag might be attributed to ageing effect leading to depletion of food reserve and decline in synthetic activity of embryo. These are concordance with findings of Salimath *et al.* (2014) [32] in greengram, Gangaraju and Balakrishna (2016) [17].

3.5.2 Effect of seed treatment (T)
The significant differences among the seed treatment on seedling length were noticed during ten months of storage period. Seeds treated with deltamethrin (T_1) recorded highest mean seedling length (26.97 cm) followed by neem oil (T_5) (26.64 cm), and lowest seedling length was observed in (T_7) (18.85 cm) during the storage of ten months.

In present study chemicals protect and will also helps in reduce infection in early satges of germination leads to better seedling growth. These are concordance with findings of Umesha *et al.* (2017) [42] in cluster bean.

3.5.3 Interaction of packing material and seed treatments (P×T)
Mean seedling length differed significantly due to interaction of packing material and seed treatments up to ten months of storage. The interaction P_2T_2 (28.23 cm) followed by P_1T_2 (28.13 cm), while lowest seedling length was observed in P_2T_7 (15.68 cm).

During storage period vigor of seeds declined due to catabolic activity in seed and thus seed though viable, reduction in length of shoot and during ageing deteriorative changes leads to lower availability of energy during germination. These are concordance with findings of Priyanka *et al.* (2015) [29].

3.6 Mean seedling dry weight (mg)
The data on the mean seedling dry weight during the storage as influenced by the different packing material, seed treatments and their interaction effects are presented in table 1.

3.6.1 Effect of packing material (P)
The mean seedling dry weight was found to differ significantly in the storage storing seeds in two different packaging materials till ten months compared to initial seed quality (320 mg). At the end of storage period the seeds stored in super grain (P_1) have recorded highest mean seedling dry weight (218 mg) at ten months of storage period. Whereas, lowest mean seedling dry weight (213 mg) was found in case of seeds stored in cloth bag (P_2).

Low deteriorative changes in super grain bag helps in seedlings to produce more bio mass, because initial availability of food material is more. These results are in lineage with the findings of Shivagouda *et al.* (2014) [35] in red gram.

3.6.2 Effect of seed treatments (T)
The mean seedling dry weight was differed significantly in seeds treated with different seed treatments during whole storage period. Among chemical seed treatments seeds treated with deltamethrin (T_1) have recorded highest mean seedling dry weight (237 mg) while lowest (190 mg) noticed in control (T_7).

Infection was less during early stages leads to grow healthy seedlings leads to produce more dry weight. These results are in lineage with the findings of Amruta *et al.* (2015) [6].

3.6.3 Interaction of packing material and seed treatments (P×T)
Mean seedling dry weight differed significantly due to interaction of packing material and seed treatments up to ten months of storage. The interaction P_1T_2 (257 mg) recorded highest mean seedling dry weight and it is followed by P_1T_3 (227 mg), while lowest mean seedling dry weight was observed in P_2T_7 (185 mg).

Infection was less during early stages leads to grow healthy seedlings leads to produce more dry weight. These are concordance with findings of Amin *et al.* (2008) [5] in grass pea.

3.7 Seedling vigour index-I
The results on seedling vigour index-I are influenced by packing material, seed treatments and interactions between both are presented in table 2.

3.7.1 Effect of packing material (P)
In the present research programme, there was significant difference with respect to seedling vigour index-I in seeds during ten months of storage was observed irrespective of packing material, seed treatments chemical. The packing material, super grain bag recorded significantly high seedling vigour index-I (1984) and lowest seedling vigour index-I was observed in cloth bag (1784) during ten months of storage.

Pervious nature of cloth bag absorbs moisture from outside which is favourable for pest and pathogen incidence. It might be due to faster rate of moisture increase in seeds and high respiratory activity leading to faster deterioration of stored food materials which leads to shortage of stored food materials for seedling development. This indirectly affected seedling vigour and finally leads to lowest vigour index. Similar results were observed by Raikar *et al.* (2011) [30] in rice, Azad Ahmad Wani (2014) [9] in maize.

3.7.2 Effect of seed treatment (T)
The significant differences among the seed treatments on seedling vigour index-I was noticed from six months of storage period compared to initial seed quality (4272). Seeds treated with spinetoram (T_2) recorded highest seedling vigour index-I (2244), (T_2) and lowest seedling vigour index-I was observed in control (T_7) (1291) during the storage of ten months.

This decrease in seed quality parameters during storage may be attributed to ageing effects, leading to depletion of stored food reserves and decline in synthetic activity of the embryo apart from death due to fungal invasions. Similarly the decline in seedling vigour results were obtained by Freits *et al.* (2002) [16] in cotton, Sreeramaiah and Bommegowda (1992) [38].

3.7.3 Interaction of packing material and seed treatments (P×T)
Seedling vigour index-I differed significantly due to interaction of packing material and seed treatments up to ten months of storage. The interaction P_1T_3 (2356) recorded highest seedling vigour index-I and it is followed by P_1T_2 (2279), while lowest seedling vigour index-I was observed in P_2T_7 (1055).

Depletion of stored food reserves and decline in synthetic activity of the embryo apart from death due to fungal invasions. These results are agreed with the findings of Babu and Ravi (2008) [10] in soybean, Adebisi Moruf Ayodele (2013) [3].

3.8 Seedling vigour index-II
The data on the seedling vigour index-II during storage as influenced by the different packing material, seed treatments and their interaction effects are presented in table 2.

3.8.1 Effect of packing material (P)
The seedling vigour index-II was found to differ significantly in the storage two different packaging materials till ten months compared to initial seed quality (3072). At the end of storage period the seeds stored in super grain (P_1) have recorded highest seedling vigour index-II (1681) at ten months of storage period. Whereas, lowest seedling vigour index-II (1605) was found in case of seeds stored in cloth bag (P_2).

In cloth bag, seeds deteriorate faster due to active participation of pathogens during germination and lead to low dry matter production and low vigour of seedlings. Results are in conformity with findings of Shivagouda *et al.* (2014) [35] in redgram, Azad Ahmad Wani *et al.* (2014) [9].

3.8.2 Effect of seed treatment (T)
The seedling vigour index-II was differed significantly in seeds treated with different seed treatments during whole storage period. Among chemical seed treatments seeds treated with deltamethrin (T_1) has recorded highest seedling vigour index-II (1929) while lowest (1310) noticed in control (T_7).

During storage, effect of chemical is reduced leading to active participation of pathogens during germination and lead to low dry matter production and low vigour of seedlings. Present results are in conformity with findings of Priyanka *et al.* (2015) [29].

3.8.3 Interaction of packing material and seed treatments (P×T)
Seedling vigour index-II differed significantly due to interaction of packing material and seed treatments up to ten months of storage. The interaction P_1T_2 (2079) recorded highest seedling vigour index-II, while lowest seedling vigour index-II was observed in P_2T_7 (1268).

Seedling vigour index declined during storage might be due to changes in free radical scavenging enzymes, increase in free radical production, degradation of protein and increase in amino acid pool for reduction in vigor and viability during ageing. These results are agreed with the findings of Babu and Ravi (2008) [10] in soybean and Adebisi Moruf Ayodele (2013) [3].

3.9 Electrical conductivity (dSm^{-1})
The results on electrical conductivity are influenced by packing material, seed treatments and interactions between both are presented in table 2.

After harvesting, seed loses their viability and vigour in storage due to improper place of storage, high moisture and storage pest. Integrity of plasma membrane gives an indirect indication for ageing of seed, vigour and seed health. In low vigour seeds, deterioration of plasma membrane results in outflow of components of cell from seed when saturated with water which is also characterized as seed leachates. In contrast, high vigour seeds have firm membrane and create less efflux of cell constituents. The analysis of EC of seed leachates gives an accurate estimation of membrane permeability. EC of the seed leachates was measured to find the cell membrane stability of treated as well as untreated seeds.

3.9.1 Effect of packing material (P)
In the present research programme, there was significant difference with respect to electrical conductivity in seeds during storage was observed up to ten of the storage irrespective of packing material. The packing material, super grain bag recorded significantly low electrical conductivity (0.694 dSm^{-1}) and highest electrical conductivity was observed in cloth bag (0.709 dSm^{-1}) during ten months of storage.

Electrical conductivity of leachates rapidly increases in seeds stored in cloth bags because faster deterioration whereas the seeds stored in super grain bags were slowly increased. Thus loss of integrity on membrane was faster in seeds stored in cloth bags (Umesha *et al.*, 2017) [42].

The EC values recorded for treated seeds were significantly lower than those of the untreated seeds. The higher EC values obtained with leachates from untreated seeds from cloth bag were associated with low viability and reduced seedling vigour. The weaker the membrane system, the larger would be the quantity of electrolytes leached from the seeds and greater the conductivity of steep water. This was presumably due to lack of membrane integrity in those seeds resulting in the enhanced leaching of electrolytes (Umesha *et al.*, 2017) [42]. Similar results were also found by Halim *et al.* (2012) [20] in onion, Akter *et al.* (2014) [4] in soybean and Gangaraju and Balakrishna (2016) [17] in blackgram.

3.9.2 Effect of seed treatment (T)

The significant differences among seed treatments on electrical conductivity were noticed from four months of storage period compared to initial seed quality (0.280). Seeds treated with deltamethrin in combination (T_1) recorded lowest electrical conductivity (0.611 dSm^{-1}) and highest electrical conductivity was observed in (T_7) (0.858 dSm^{-1}) during the storage of ten months.

The higher EC values obtained with leachates from untreated seeds from cloth bag were associated with low viability and reduced seedling vigour. Increase EC may be attributed to permeability of seed membrane as seed ages, many substances such as sugars, amino acids, fatty acids and free radical production by lipid peroxidation leads to leakage of electrolytes during storage (Umesha *et al.*, 2017) [42]. Loss of membrane integrity during storage would be the main reason for increased electrical conductivity and also evidenced by structural change and changes in membrane composition (Delouche and Baskin, 1973) [14]. These results are in conformity with findings of Shobha *et al.* (2006) [36] and Tejashwi *et al.* (2014) [41].

3.9.3 Interaction of packing material and seed treatments (P×T)

Electrical conductivity differed significantly due to interaction of packing material and seed treatments up to ten months of storage. The interaction P_1T_2 (0.581 dSm^{-1}) recorded lowest electrical conductivity and it is followed by P_1T_3 (0.594 dSm^{-1}), while highest electrical conductivity was observed in P_2T_7 (0.887 dSm^{-1}).

In cloth bags ageing is faster leads to membrane damage faster leads to vigour of seed is reduced by which solute leakage is increased. There is a significant correlation between conductivity of leachates and viability of seeds. Also it concluded that close association between the enhanced solute leakage and disintegration of membrane integrity leads to reduce seed vigor/viability which can relate to the mode of packaging material to store seed.

Many workers reported negative correlation between EC and seed quality Kathiravan *et al.* (2008) [21] in lablab, Tejashwi *et al.* (2014) [41].

3.10 Total dehydrogenase activity (A_{480} nm)

The data on the total dehydrogenase activity during the storage as influenced by the different packing material, seed treatments and their interaction effects are presented in table 2.

3.10.1 Effect of packing material (P)

The total dehydrogenase activity was found to differ significantly in the storage till ten months by storing seeds in two different packaging materials compared to initial seed quality (2.410). At the end of storage period the seeds stored in super grain bag (P_1) have recorded highest total dehydrogenase activity (1.433) at ten months of storage period. Whereas, lowest total dehydrogenase activity (1.220) was found in case of seeds stored in cloth bag (P_2).

The similar beneficial effect of containers in retention of higher seed quality were also documented by Patil (2000) [26] in chickpea in greengram and Sushma (2003) [40] in garden pea.

3.10.2 Effect of seed treatment (T)

The dehydrogenase activity was differed significantly in seeds treated with different seed treatments during whole storage period. Among chemical seed treatments seed treated with deltamethrin (T1) has recorded highest dehydrogenase activity (1.600) while lowest (1.422) noticed in control (T_7).

Seed quality parameters with advancing storage period were also reported by Ramesh (2002) [31] in soybean, Gayithri *et al.* (2008) [18] in soybean and Shakuntala (2012) [34] in rice.

3.10.3 Interaction of packing material and seed treatments (PXT)

Dehydrogenase activity differed significantly due to interaction of packing material and seed treatments from seven months of storage up to ten months of storage.

Highest dehydrogenase activity noticed in P_1T_2 (1.686) followed by P_1T_3 (1.618), while lowest was observed in P_2T_7 (1.135). The total dehydrogenase activity was high in initial month of storage, however during storage period there was a decline in total dehydrogenase activity. A sharpfall in dehydrogenase activity with ageing and found that direct correlation exists between germinability and dehydrogenase activity. Similarly, decline in dehydrogenase activity with storage period was observed by Ramesh (2002) [31] in soybean, Umesha *et al.* (2017) [42] in cluster bean and Gayithri *et al.* (2008) [18] in soybean.

3.11 Seed infection (%)

The results on seed infection are influenced by packing material, seed treatments and interactions between both are presented in table 2.

3.11.1 Effect of packing material (P)

In the present research programme, there was significant difference with respect to seed infection in seeds during storage was observed from eight months to ten of the storage irrespective of packing material. The packing material, super grain bag recorded significantly low seed infection (17.57%) and highest seed infection was observed in cloth bag (22.10%) during ten months of storage (Plate 27).

Increased moisture content in cloth bag caused increased disease incidence. Similar increase in fungal infection during storage with the fluctuations in seed moisture has also been reported by Maurya *et al.* (2002) [23] in soybean.

3.11.2 Effect of seed treatment (T)

The significant differences among the seed treatments on seed moisture were noticed from eight months to ten months of storage period compared to initial seed quality (0.00). Seeds treated with deltamethrin @ 0.40 ml/kg seeds (T_1) recorded lowest seed infection (8.50%) and highest seed infection was observed in (T_7) (32.00%) during the storage of ten months.

During ageing chemical were reduced their activity on external infection by the infection is increased. Similar findings were also reported by Abdul-Baki and Anderson (1973) [1], Maurya *et.al.* (2002) [23].

3.11.3 Interaction of packing material and seed treatments (P×T)

Seed infection differed significantly due to interaction of packing material and seed treatments from eight months of storage up to ten months of storage. Lowest seed infection recorded in P_1T_3 (8.00%) followed by P_1T_2 (8.33%), while highest seed infection was observed in P_2T_7 (37.33%).

Higher seed moisture content leads to increase in microbial population easily which leads to increase in infection. Hence, seed cannot store for more period with high seed moisture The similar findings were also reported by in soybean and Biradar (2001) [11] in greengram.

3.12 Seed infestation (%)

The data on the infestation percentage during the storage as influenced by the different packing material, seed treatments and their interaction effects are presented in table 2.

3.12.1 Effect of packing material (P)

The infestation percentage was found to differ significantly in the storage form seventh months by storing seeds in two different packaging materials compared to initial seed quality (0.00). At the end of storage period the seeds stored in super grain bag (P_1) have recorded lowest infestation percentage (7.52%) at ten months of storage period. Whereas, highest infestation (12.24%) was found in case of seeds stored in cloth bag (P_2) (Plate 28).

In pulses, the pulse beetle is the major problem both in field and during storage. Bruchid enter the store along with harvested seeds and start multiplying in more congenial environment of the store. Super grain bag maintained low incidence of bruchid and other pest infestation might be due impervious nature of super grain bag prevents entry of pests into seeds and also these bags help in maintaining seed moisture and seed viability. The results were in conformity with Vinodkumar *et al.* (2014) [43] in red gram.

3.12.2 Effect of seed treatment (T)

The infestation percentage was differed significantly in seeds treated with different seed treatment during whole storage period. Among chemical seed treatments seeds treated with deltamethrin (T_1) have recorded lowest infestation (1.67%) while highest (20.00%) noticed in control (T_7).

Treatment with spinetoram significantly reduced larval and adult population or bruchids due to their ovicidal and inhibitory repellent properties. The similar results with chemical (insecticidal) treatment of seeds were reported by Srimathi *et al.* (2003) [39] in cowpea, Ghelani *et al.* (2009) [19] in pearl millet.

3.12.3 Interaction of packing material and seed treatments (P×T)

Infestation percentage differed significantly due to interaction of packing material and seed treatments from seventh months of storage up to ten months of storage. Lowest seed infestation in P_1T_2 (1.67%), whereas highest infestation was observed in P_2T_7 (23.00%). Chemical as thin layer of protection and packing material also helps to reduce infestation. The seed coat could also reduce insecticide penetration and protect the larvae, as mentioned by Sanon *et al.* (2010) [33] and Priyanka *et al.* (2015) [29] in field pea.

Table 1: Effect of packaging materials and seed treatments on Seed Moisture, Germination, Shoot length, Root length, Mean seedling length, Mean seedling dry weight in greengram var. BGS-9 during storage

Treatments	Period of storage (December-2020 to September-2021)					
	Seed Moisture	**Germination**	**Root Length**	**Shoot length**	**Mean Seedling Length**	**Mean Seedling Dry Weight**
Packing material (P)						
P_1- Super grain bag	9.32	80.8	8.44	16.03	24.47	218
P_2- Cloth bag	9.76	74.9	8.16	15.43	23.58	213
Mean	9.54	77.90	8.30	15.73	24.03	215.07
SEm±	0.02	0.28	0.10	0.19	0.22	1.74
CD (P=0.05)	0.06	0.81	0.28	0.55	0.63	5.05
Treatment (T)						
T_1-Deltamethrin @ 0.04 ml/kg	8.15	83.0	9.41	17.56	26.97	237
T_2-Spinetoram @ 0.40 ml/kg	8.17	84.3	9.02	17.58	26.60	233
T_3-Chlorantraniliprole @ 0.1 ml/kg	8.27	81.8	7.98	16.26	24.24	211
T_4-Emamectin benzoate @ 40 mg/kg	9.58	76.1	7.50	13.94	21.44	201
T_5-Neem oil @ 7.5 ml/kg	10.68	77.1	9.29	17.35	26.64	215
T_6-Turmeric powder 10 g/kg	10.80	74.5	8.03	15.43	23.45	220
T_7-Control	11.14	68.3	6.87	11.99	18.85	190
Mean	9.54	77.90	8.30	15.73	24.03	215.07
SEm±	0.04	0.52	0.18	0.36	0.41	3.26
CD (P=0.05)	0.12	1.52	0.52	1.04	1.18	9.45
Interaction (P×T)						
P_1T_1	8.19	85.0	8.50	17.32	25.82	209
P_1T_2	8.12	81.0	10.33	17.80	28.13	257
P_1T_3	8.16	87.0	9.38	17.70	27.08	227
P_1T_4	8.17	81.6	8.66	17.46	26.12	218
P_1T_5	8.26	84.6	8.04	16.54	24.59	203
P_1T_6	8.29	79.0	7.91	15.98	23.89	210
P_1T_7	8.36	82.0	6.70	11.94	18.64	200
P_2T_1	10.80	70.3	8.30	15.94	24.24	215

P_2T_2	10.68	79.0	10.10	18.13	28.23	227
P_2T_3	10.68	75.3	8.48	16.57	25.05	205
P_2T_4	10.72	79.0	8.41	16.51	24.92	212
P_2T_5	10.89	70.0	7.64	14.34	21.98	212
P_2T_6	10.90	69.3	7.96	14.06	22.02	205
P_2T_7	11.38	67.3	5.77	9.91	15.68	185
Mean	9.54	77.90	8.30	15.73	24.03	215.07
SEm±	0.06	0.74	0.25	0.51	0.58	4.61
CD (P=0.05)	0.17	2.14	0.73	1.47	1.67	13.36
CV (%)	1.07	1.65	5.25	5.57	4.16	3.80

Table 2: Effect of packaging materials and seed treatments on Seedling vigour index- I, Seedling vigour index- II, Electrical conductivity, Total dehydrogenase activity, Seed infection and Seed infestation in greengram var. BGS-9 during storage

Treatments	Period of storage (December-2020 to September-2021)					
	Seedling Vigour Index- I	Seedling Vigour Index- II	Electrical Conductivity	Total Dehydrogenase Activity	Seed Infection	Seed Infestation
Packing material (P)						
P_1- Super grain bag	1984	1681	0.694	1.433	17.57	7.52
P_2- Cloth bag	1784	1605	0.709	1.411	22.10	12.24
Mean	1883.6	1643.0	0.702	1.422	19.83	9.88
SEm±	18.61	15.20	0.004	0.007	0.39	0.34
CD (P=0.05)	53.92	44.03	0.011	0.019	1.12	1.32
Treatment (T)						
T_1-Deltamethrin @ 0.04 ml/kg	2237	1929	0.611	1.600	8.50	1.67
T_2-Spinetoram @ 0.40 ml/kg	2244	1878	0.628	1.598	10.00	3.33
T_3-Chlorantraniliprole @ 0.1 ml/kg	1984	1691	0.677	1.490	13.33	4.00
T_4-Emamectin benzoate@ 40 mg/kg	1616	1530	0.749	1.304	20.83	10.33
T_5-Neem oil @ 7.5 ml/kg	2059	1628	0.641	1.413	26.17	12.17
T_6-Turmeric powder 10 g/kg	1754	1537	0.747	1.331	28.00	17.67
T_7-Control	1291	1310	0.858	1.220	32.00	20.00
Mean	1883.6	1643.0	0.702	1.422	19.83	9.88
SEm±	34.82	28.43	0.007	0.012	0.73	0.63
CD (P=0.05)	100.87	82.37	0.021	0.036	2.10	2.46
Interaction (P×T)						
P_1T_1	2195	1779	0.640	1.513	8.67	1.67
P_1T_2	2279	2079	0.581	1.686	8.33	1.67
P_1T_3	2356	1972	0.594	1.618	8.00	2.67
P_1T_4	2133	1784	0.663	1.578	12.00	4.00
P_1T_5	2081	1723	0.674	1.498	12.67	3.33
P_1T_6	1887	1659	0.681	1.482	14.00	4.67
P_1T_7	1528	1641	0.822	1.300	15.67	4.33
P_2T_1	1705	1418	0.677	1.308	26.00	16.33
P_2T_2	2231	1712	0.632	1.456	25.33	10.67
P_2T_3	1888	1545	0.649	1.369	27.00	13.67
P_2T_4	1969	1593	0.670	1.344	26.00	13.00
P_2T_5	1539	1482	0.823	1.318	30.00	22.33
P_2T_6	1527	1351	0.829	1.304	26.67	17.00
P_2T_7	1055	1268	0.887	1.135	37.33	23.00
Mean	1883.6	1643.0	0.702	1.422	19.83	9.88
SEm±	49.24	40.21	0.010	0.017	1.03	0.89
CD (P=0.05)	142.65	116.49	0.029	0.050	2.98	2.58
CV (%)	4.53	4.24	2.475	2.12	5.97	5.62

4. Conclusion

Storage studies were maintained seed quality above IMSCS level in seeds stored in super grain bag and seeds treated with spinetoram @ 0.40 ml/kg seed and Deltamethrin @ 0.04 ml/kg as synthetic insecticides and biological insecticide as neem oil, in all seed quality parameters during ten months. Further, nano seed treatment to enhance seed longevity of green gram by reducing field infestation during storage can be studied.

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