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Changes in Blackgram Seed Quality during Storage as Influenced by Various Packaging Materials and Storage Conditions

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Abstract: A storage experiment was conducted to know the influence of various packaging materials and storage conditions on blackgram seed quality. During the course of the investigation, various packaging materials such as cloth, gunny, high density polythene (HDPE) and vacuum packed bags were used and these bags were kept under ambient and cold storage for 18 months. As the storage period progressed, seed infestation with bruchids (*Callosobruchus* sps.) was observed in cloth, gunny and HDPE bags under ambient condition only after 8 months of storage. At the end of the storage period, there was no such bruchids infestation was seen in a vacuum packed bag of ambient condition and in all the packaging materials of the cold condition. Further, at the end of the storage period, seeds of vacuum packed bag under both ambient and cold conditions only have maintained minimum germination percent as described by the Central Seed Certification Board, Government of India. So, this technology can be effectively used to extend the storage period of blackgram without any storage chemicals i.e., in a chemical-free environment. Hence, along with maintaining seed health for a longer time, a threat to the environment can be completely averted.

Keywords: Ambient and cold conditions, Bruchids infestation, Blackgram, Conventional packaging, Vacuum packaging

The significant agricultural production could be impacted due to the variations in periodicity and intensity of climatic events like floods and droughts, temperature and rainfall patterns (Arun et al 2017). Moreover, a substantial amount of food grains is being damaged after harvest due to a lack of adequate storage and processing facilities. FAO estimated worldwide annual losses of about 10 per cent in stored grains (Parfitt et al 2010). Ensuring global food security requires a range of strategies including the diversification and improvement of staple food crops and the reduction of post-harvest loss. In India, due to insufficient and poor storage facilities, lack of knowledge in post-harvest pulse management and storage, the risk of damage due to post harvest storage (25-30 %) is a major concern in pulses (Anonymous 2017). Controlling these major losses along with other post harvest losses *viz.*, threshing, drying and milling losses can meet the demand for pulses and can reduce the import from various countries. Pulses can remain in edible condition for a long time if, properly stored. However, pulses are more difficult to store compared to cereals (Deshpande and Singh 2001) and suffer much greater damage due to insects and microorganisms resulting in deterioration of quality. Since, pulses have high protein content and are prone to very high insect infestation and thus, undergo heavy losses during storage (Lal and Verma 2007). Among the insects of grain legumes, bruchids (*Callosobruchus* spp.) are very serious pests both in the field and as well as in storage, that can cause considerable economic losses in various pulses such as chickpea, mung, peas, cowpea, lentil and arhar (Srinivasan et al 2008). This insect infestation either originates in the field or in storage and due to their internal feeding behaviour of larvae causes serious loss to the seeds in terms of both quantity and quality (Messina and Jones 2009).

Bruchids are controlled by treating the seeds with carbon disulfide, phosphine or methyl bromide or by dusting with several other insecticides. However, their use by the farmers is criticized worldwide (Williamson et al 2008) as these chemicals are highly toxic and environmentally undesirable and pose a threat to food safety and bio diversity. In addition to chemical control of bruchids, some plant derived extracts *viz.,* plant juice of banana, oil from soybean, maize and neem, hot pepper powder has proven beneficial (Swella and Mushobozy 2007), these plant derived extracts, despite many advantages, have certain limitations such as slow in action, easy degradability (Rozman, 2015), frequent application and importantly affecting non-target organisms to some extent (Trivedi et al 2018). With these limitations of using both synthetic and plant derived chemicals to control bruchids, research on chemical free storage has been conducted with the use of different packaging materials and their storage under different conditions to assess the storability of blackgram seeds.

MATERIAL AND METHODS

A storage experiment was conducted under ambient and cold storage conditions at the University of Agricultural Sciences, Dharwad, Karnataka, India for 18 months (15 November 2019 to 15 May 2021). Average data related to temperature °c and relative humidity (%) that prevailed in the storehouse of ambient condition during the first 15 days of every alternate month were recorded with the help of Anemometer (Table 1), whereas, in the storehouse of cold condition, 5-7°C temperature with 60 ± 2 % relative humidity was maintained throughout the storage period. Freshly harvested healthy seeds of blackgram (DU-1) were collected from farmers' fields and then sun-dried. After sun drying, crops seeds were packed in different packaging *viz.,* cloth bag, gunny bag, HDPE bag and also vacuum packed (wherein the product to be packed is placed in a pouch of suitable material and the air is drawn out from the pack and hermetically sealing it) (Fig. 1). The seeds (3 kgs) were packed in the cloth, gunny and high density polythene (HDPE) bag and replicated 5 times in two storage conditions. However, in the case of vacuum packaging, 1 kg of seeds was packed and 9 bags were packed and replicated 5 times in two storage conditions. Further, stacking of bags was not done, to expose all the bags to prevailing environmental conditions. The characteristics of the polythene bag used for vacuum packaging are presented in Table 2. The machine used for vacuum packaging of different seeds was OLPACK 501/V manufactured by Interprise–Brussels S.A., Bruxtainer Division, Belgium. Seed health parameters such as germination (%), total seedling length (cm), moisture content (%) and **α**amylase activity were recorded. For the germination test, a number of normal seedlings were counted on the final day (on 7th day) (ISTA, 2013) and the average value was expressed in percent. Total seedling length is the summation of shoot length and root length of seedlings on the final day and the average value is expressed in centimeters. Moisture content was measured as per the procedure described by ISTA (2013) and α amylase activity was also measured (Sadasivam and Manickam 1996). Seeds with initial germination (98.00 %), total seedling length (49.8 cm), moisture content (8.10 %) and α amylase activity (54.77 µg maltose released/min/ml) were used for packaging. Again, on the 15th of every alternate month, representative samples were drawn from all treatments and all the above-mentioned seed health parameters were recorded for up to 18 months.

Table 1. Average temperature and relative humidity of storehouse of ambient condition

Months	Temperature (°C)	Relative humidity (%)
January-2020	21.3	68.6
March-2020	24.3	54.6
May-2020	28.5	67.2
July-2020	22.8	86.9
September-2020	22.7	85.4
November -2020	22.1	63.1
January-2021	20.9	74.1
March-2021	24.8	51.7
May-2021	26.6	67.8

Fig. 1. Different packages used for storage of blackgram seeds under ambient and cold conditions

RESULTS AND DISCUSSION

Germination: After 2 months of the storage period, there was no significant difference was observed in germination between the treatments (Table 3). As the storage period progressed, there was an infestation of seeds with bruchids under ambient condition in all packaging's except vacuum packed bags. The infestation of seeds with bruchids under ambient conditions was due to the pervious nature of packaging material that allowed the bruchids to penetrate the packaging and multiply. Similar results of seeds infestation

Table 2. Specifications of the LDPE bag used for vacuum packaging

Characters	Unit	Results	Tested as per (Guidelines of)
Thickness (Microns)	Microns	149.40	IS: 2508
Water vapor transmission rate	g/m^2/24 hrs at 38°C and 90.0 % Relative humidity	0.95	ASTM F 1249
Oxygen transmission rate	cc/(m^2 × day × atm)	0.91	ASTM D 1434-15

with insects in pervious packaging was reported by Patel et al (2018). The infestation of seeds with bruchids resulted in significant decrease in germination due to the internal feeding behaviour of larvae hence, those packaging's were discarded and observations were discontinued in which bruchids infestation were seen. Similar results of a decrease in germination due to infestation of bruchids were reported by Miah et al (2013) and Meenatchi et al (2018).

Before seed infestation with bruchids, the rate of seed deterioration was higher in cloth, gunny and HDPE bags which are kept under ambient storage as compared to cold storage and it might be due to the differential rate of seed respiration as they were kept in different environmental conditions. Similar results of a higher rate of seed deterioration in ambient condition as compared to cold storage condition were reported by Vange et al (2015) and Gupta et al (2017). The rate of seed deterioration was much lower in both ambient and cold conditions in vacuum packed seeds as they were kept in modified atmospheric condition, which enables them to maintain more stable relative humidity inside the package and they were packed in a polythene bag having higher thickness, lower water vapor and oxygen transmission rate. In vacuum packed bag, the seeds were placed under low oxygen concentration and due to the low oxygen concentration in the package, there was very little oxidation of the product and thereby, seeds were less deteriorated as compared to other packaging materials. However, vacuum packed seeds stored in cold condition have performed better as compared to ambient condition and this is because of temperature difference in both conditions as the temperature is also one of the factors which determine the rate of deterioration. Similar results of maintaining the seed viability and vigour for a longer period by vacuum packaging have been reported by Tripathi and Lawande (2014), Khanna et al (2017) and Meena et al (2017). In cold storage condition, as the storage period progressed, there was a decline in viability and vigour of all the seeds in all the pervious packaging due to ageing. As the ageing of seeds is a function of temperature, oxygen and moisture. In cold storage, temperature and moisture are well managed but oxygen has played a major role in seed deterioration. It is well known that, oxygen is an important factor to regulate a series of physiological processes caused by respiration, which was associated with seed deterioration. The results of the investigation are in accordance with the findings of Basavegowda and Arunkumar (2013) and Bhadru et al (2018). Apart from temperature, the main factors of seed deterioration are oxygen and moisture content and maintenance of these constraints will have a greater impact on seed longevity and it can be achieved by vacuum packaging. The beneficial effect of vacuum storage on extending seed longevity has also been reported in sweet corn seeds (Chiu et al 2003). Yeh et al (2005) reported that, the longevity of primed bitter gourd seeds was markedly

Table 3. Influence of packaging and storage conditions on germination (%) at different time intervals of storage in blackgram seeds

Treatments		Storage period (Months)								
		2	4	6	8	10	12	14	16	18
Ambient storage	T_1-Cloth bag	96.8 (79.7)	93.0 (74.7)	90.5 (72.0)	*	*	*	*	*	*
	T_2-Gunny bag	96.5 (79.2)	92.5 (74.1)	90.3 (71.9)	*	*	*	*	*	*
	T_3-HDPE bag	97.0 (80.0)	93.5 (75.2)	90.8 (72.3)	*	*	*	*	*	*
	T_4-Vacuum packed bag	98.0 (81.9)	98.0 (81.9)	97.5 (80.9)	97.5 (80.9)	97.0 (80.0)	96.8 (79.7)	96.5 (79.2)	96.0 (78.5)	96.0 (78.5)
Cold storage	T_5-Cloth bag	97.5 (80.9)	95.5 (77.8)	93.0 (74.7)	90.3 (71.9)	85.8 (67.9)	82.0 (64.9)	78.8 (62.6)	76.0 (60.7)	72.5 (58.4)
	T_6-Gunny bag	97.0 (80.0)	94.8 (76.8)	93.5 (75.2)	90.0 (71.6)	86.3 (68.3)	81.5 (64.5)	78.5 (62.4)	76.3 (60.9)	73.0 (58.7)
	T_7-HDPE bag	96.8 (79.7)	95.3 (77.5)	93.3 (75.0)	89.5 (71.1)	86.0 (68.0)	81.8 (64.7)	79.3 (62.9)	76.5 (61.0)	72.2 (58.2)
	T_8-Vacuum packed bag	98.0 (81.9)	98.0 (81.9)	97.8 (81.5)	97.5 (80.9)	97.3 (80.5)	97.0 (80.0)	96.8 (79.7)	96.5 (79.2)	96.3 (78.9)
	C. D (p=0.01)	1.7	1.0	1.7	1.9	2.2	1.9	1.8	2.0	1.9

Figures in parenthesis are arcsine values

*Observations in cloth, gunny and HDPE bag treatments have been stopped due to bruchids infestation after 8 months of storage period

As per central Seed Certification Board, Department of Agriculture & Co-operation, Ministry of Agriculture, Government of India, the minimum seed germination for black gram is 75 %

decreased after 12 months of storage under ambient oxygen conditions, but seed viability was maintained under partial vacuum storage conditions. Similar results of maintaining seed viability for a longer period by vacuum packaging were reported by Meena et al (2017) and Wang et al (2018). Bruchids last for 29-30 days at 30ºC and 70 per cent relative humidity (Raina 1970) and they have higher fecundity (War et al 2017). Many researchers have investigated the origin of the infestation of bruchids and reported that it either starts in the field or in storage. However, in the present study, it originated in the store because no bruchids were detected after two months of storage; if infested in the field, heavy bruchids were seen due to their short life cycle and high fecundity.

Total seedling length: Deterioration in seed quality is associated with a decrease in seedling length with time. In the present investigation, the seedling length was considerably decreased in cloth, gunny and HDPE bags but not in vacuum packed bags irrespective of storage conditions and seeds (Table 4). Ageing has a damaging effect on enzymes that are necessary for the conversion of food reserve in the embryo to a usable form and ultimately reduced seedling-associated parameters. With the advancement in the storage period, decrease in seedling length was more in cloth, gunny and HDPE bags in cold condition and these treatments were non-significant with each other throughout the storage period. In contrast, a minimal decrease was recorded in vacuum packed bags stored in cold condition as compared to ambient condition and was due to the differential rate of seed deterioration in which seeds are stored. This decreasing trend in seedling length might be attributed to oxidative stress which induced the production of reactive oxygen species that caused lipid peroxidation in terms of malondialdehyde (MDA) as a final product which in turn hinders the cellular metabolism resulting in lower ATP production required for growth and development of the seedling (Blokhina et al 2003). After 18 months of storage, a significant difference was observed

Table 4. Influence of packaging and storage conditions on total seedling length (cm) at different time intervals of storage in blackgram seeds

Treatments		Storage period (Months)								
		2	4	6	8	10	12	14	16	18
Ambient storage	T_1-Cloth bag	49.6	49.0	47.7	*	*	*	*	*	*
	T_2-Gunny bag	49.4	49.2	48.0	*	*	*	*	*	*
	T_3-HDPE bag	49.6	49.1	47.7	*	*	*	*	*	*
	T_4-Vacuum packed bag	49.8	49.8	49.8	49.7	49.5	49.3	49.3	48.9	48.7
Cold storage	T_5-Cloth bag	49.6	49.2	48.9	47.9	47.1	46.7	46.5	45.7	44.2
	T_6-Gunny bag	49.6	49.6	48.9	47.8	47.2	47.2	46.2	46.1	44.7
	T_7-HDPE bag	49.7	49.5	48.9	47.9	47.6	46.8	46.5	45.9	44.6
	T_8-Vacuum packed bag	49.8	49.8	49.8	49.8	49.6	49.4	49.2	49.2	49.0
	C. D (p=0.01)	0.4	0.8	0.5	0.7	0.7	0.5	0.8	0.9	0.7

Table 5. Influence of packaging and storage conditions on moisture content (%) at different time intervals of storage in blackgram seeds

Treatments		Storage period (Months)								
		2	4	6	8	10	12	14	16	18
Ambient storage	T_1-Cloth bag	9.03	8.40	9.13	*	*	*	*	*	*
	T_2-Gunny bag	9.08	8.38	9.00	*	*	*	*	*	*
	T_3-HDPE bag	9.03	8.43	9.05	*	*	*	*	*	*
	T_4-Vacuum packed bag	8.15	8.13	8.18	8.08	8.15	8.20	8.13	8.10	8.13
Cold storage	T_5-Cloth bag	8.73	8.78	8.75	8.73	8.70	8.60	8.68	8.83	8.78
	T_6-Gunny bag	8.70	8.68	8.63	8.68	8.78	8.70	8.70	8.75	8.75
	T_7-HDPE bag	8.60	8.70	8.73	8.80	8.83	8.73	8.65	8.70	8.80
	T_8-Vacuum packed bag	8.13	8.12	8.15	8.13	8.13	8.10	8.10	8.15	8.13
	C. D (p=0.01)	0.17	0.16	0.20	0.17	0.24	0.20	0.24	0.30	0.26

Table 6. Influence of packaging and storage conditions on α amylase activity (µg maltose released/min/ml) at different time intervals of storage in blackgram seeds

Treatments		Storage period (Months)								
		2	4	6	8	10	12	14	16	18
Ambient storage	T_1-Cloth bag	54.34	51.96	50.57	*	*	*	*	*	*
	T_2-Gunny bag	54.30	51.68	50.41	*	*	*	*	*	*
	T_3-HDPE bag	54.16	51.94	51.43	*	*	*	*	*	*
	T_4-Vacuum packed bag	54.77	54.77	54.20	54.47	54.17	54.17	53.96	53.23	53.19
Cold storage	T_5-Cloth bag	54.54	53.30	51.85	50.44	47.92	46.83	43.28	42.91	42.07
	T_6-Gunny bag	54.21	53.17	52.30	50.73	48.47	46.90	44.04	42.80	43.69
	T_7-HDPE bag	54.20	53.31	52.05	50.14	46.89	47.40	44.69	41.70	41.01
	T_8-Vacuum packed bag	54.77	54.77	54.63	54.48	54.24	54.27	53.93	53.64	53.45
	C. D (p=0.01)	0.72	0.90	1.19	1.64	2.04	2.65	3.35	3.81	4.04

between the cloth, gunny, HDPE bags and vacuum packed bags whereas, no significant difference was observed between vacuum packed bags stored in ambient and cold storage conditions. Similar results of higher reduction in seedling length due to ageing were revealed by Meena et al (2017) and Autade and Ghuge (2018).

Moisture content: There was a lot of fluctuation in the seed moisture content (Table 5) stored in cloth, gunny and HDPE bags in ambient condition as compared to cold condition. Seeds are hygroscopic in nature hence, they have absorbed moisture when relative humidity was high and they have lost the moisture when humidity was low under ambient condition (Table 2). Similar results of variation in moisture content under ambient condition in pervious packaging materials were reported by Kumar et al (2017) and Shankar et al (2018). Similarly, when seeds were stored in pervious packaging materials (cloth, gunny and HDPE bags) and kept in cold condition, seeds absorbed the moisture initially but thereafter there was no change in moisture content due to the prevalence of similar storage condition throughout the storage period. Similar results of the initial increase in moisture content when stored in pervious packaging materials and kept in relative humidity same as that of cold storage have been reported by Bakhtavar et al (2019).Hygroscopic nature of seeds holds good only when seeds are packed in pervious packaging materials but not in impervious packaging materials like vacuum packed bags as they have very less water vapour and air transmission rate and higher thickness (Table 2). Due to these special characters of polythene bag used for vacuum packaging, there was no variation in moisture content of the seeds throughout the storage period in cold and ambient conditions. Similar results of no variation in moisture content of seeds when vacuum packed have been reported by Deepa et al(2013) and Meena et al (2017).

α Amylase activity: In seeds, amylase is the major amylolytic enzyme found during germination and is involved in the degradation of endosperm starch. Degradation of starch into soluble sugars is important to support seedling growth and it can be degraded with the help of amylase activity. There was a decrease in α amylase activity as the storage period progressed and this reduction indicates the deterioration of seeds (Table 6). Except at the initial storage period, there was a significant difference in α amylase activity and reduced more in conventional packaging's *viz.,* cloth, gunny and HDPE bags and less in vacuum packed bags under both cold and ambient conditions. After 18 months of storage, a non-significant difference was observed within cloth, gunny and HDPE bags in cold condition and these treatments were significantly differing with vacuum packed bags of both the conditions. No variation in α- amylase activity of vacuum packed seeds is because vacuum treatment enabled seeds to keep low moisture content as oxygen and water were isolated from the storage condition and hence, ageing factor of seeds were controlled in vacuum condition (Wang et al 2018). In general, decreased α amylase activity with an increase in storage period might be due to a reduction in free sugars and amino acids. Further, a direct correlation exists between loss of viability and decline in enzyme activity. Similar results of a decrease in α amylase activity due to ageing have been reported by Bhanuprakash et al (2006). Further, Norastehnia et al (2007) observed the accumulation of aldehyde compounds with the advancement of deterioration especially methyl jasmonate (MeJA) which is a potent inhibitor of alpha-amylase. Higher concentrations of MeJA reduced the concentration of the enzyme protein and consequently inhibition of gibberellin biosynthesis since gibberellin stimulates the alpha-amylase synthesis and its secretion from the embryonic axis into cotyledons.

CONCLUSION

The vacuum packaging technology can be effectively used for the safe storage of blackgram seeds for a longer period without any aid of chemicals.

REFERENCES

Anonymous. 2017. *Pulses in India: Retrospect and Prospects*. Government of India, Ministry of Agriculture & Farmers Welfare

Arun KC, Aggarwal PK, Joshi PK and Vyas S 2017. Farmers' prioritization of climate smart agriculture (CSA) technologies. *Agricultural Systems* **151**: 184-191.

Autade AD and Ghuge SB 2018. Effect of packaging materials on seed quality of soybean seed during storage. *International Journal of Agricultural Sciences* **10**(11): 6223-6225.

Bakhtavar MA, Afzal I and Basra SMA 2019. Moisture adsorption isotherms and quality of seeds stored in conventional packaging materials and hermetic Super Bag. *PLoS one* **14**(2): 1-11.

Basavegowda GS and Arunkumar H 2013. Effect of commercial cold storage conditions and packaging materials on seed quality of chickpea (*Cicer arietinum* L). *Global Journal of Science Frontier Research: D Agriculture and Veterinary* **13**(2): 22-26.

Bhadru D, Lakshmi SN, Pradeep T and Rani KJ 2018. Assessment of quality of maize seed after cold storage. *Journal of Pharmacognosy and Phytochemi*stry **7**(3): 2756-2759.

Bhanuprakash K, Yogeesha HS, Nail LB and Arun MN 2006. Studies on physiological and biochemical changes in relation to seed viability in aged onion seeds. *Journal of Horticultural Sciences* **1**(1): 15-18.

Blokhina O, Virolainen E and Fagerstedt KV 2003. Antioxidants, oxidative damage and oxygen deprivation stress: a review. *Annals of Botany* **91**(2): 179-194.

Chiu KY, Chen CL and Sung JM 2003. Partial vacuum storage improves the longevity of primed sh-2 sweet corn seeds. *Scientia Horticulturae* **98**: 99-111.

Deepa GT, Chetti MB, Khetagoudar MC and Adavirao GM 2013. Influence of vacuum packaging on seed quality and mineral contents in chilli (*Capsicum annuum* L.). *Journal of Food Science and Technology* **50**: 153-158.

Deshpande SD and Singh G 2001. Long Term Storage Structures in Pulses, *National Symposium on Pulses for Sustainable Agriculture and Nutritional Security* Indian Institute of Pulses Research, New Delhi, pp.17-19.

Gupta A, Punia RC and Dhaiya RC 2017. Seed ageing and deterioration during storage of pearlmillet hybrid along with their parental line. *Research in Environment and Life Science* **10**(6): 554-556.

ISTA 2013. International rules of seed testing. *Seed Science and Technology* **27**: 25-30.

Khanna N, Jain P and Teckchandani CK 2017. Comparative study of quality and nutritive parameters of insect infested bengal gram under vacuum and modified atmosphere storage in laminated ldpe bags. *International Journal of Current Microbiology and Applied Sciences* **6**(12): 4303-4308.

Kumar PA, Channakeshava BC and Siddaraju R 2017. Influence of seed treatments and packaging materials on seed longevity of alfalfa (*Medicago sativa* L.) CV. RL-88. *Plant Archives* **17**(2): 1221-1227.

Lal R and Verma P 2007. Technical Bulletin – Post Harvest Management of Pulses IIPR, Kanpur.

Meena MK, Chetti MB and Nawalagatti CM 2017. Seed quality behavior of Soybean (*Glycine max*) as influenced by different packaging materials and storage conditions. *Legume Research* **40**(6): 1113-1118.

Meenatchi, Alice JRPS, Patricia PP, Moses JA and Ramakrishnan CA 2018. Hermetic storage - an ecofriendly safe storage method for long term storage of black gram. *12th International working conference on stored product protection* (IWCSPP) in Berlin, Germany, October 7-11, 2018.

Messina FJ and Jones JC 2009. Does rapid adaptation to a poor-quality host by *Callosobruchus maculatus* (F.) cause cross-adaptation to other legume hosts?. *Journal of Stored Product Research* **45**: 215-219.

Miah MA, Ali MR, Husna A and Mollah M 2013. Efficacy of some botanicals against pulse beetle, *Callosobruchus Maculatus* (FAB.) on stored green gram (*Vigna Radiata). Bangladesh Journal of Entomology* **23**(1): 11-20.

Mills JT and Woods SM 1994. Factors affecting storage life of farm-stored field peas (*Pisum sativum* L.) and white beans (*Phaseolus vulgaris* L.). *Journal of Stored Product Research* **30**(3): 215-226.

Norastehnia RH, Sajedi M and Nojavan A 2007. Inhibitory effects of methyl jasmonate on seed germination in maize (*Zea mays* L.): Effect on α-amylase activity and ethylene production. *General and Applied Plant Physiology* **33**(1-2): 13-23.

Parfitt J, Barthel M and Macnaughton S 2010. Food waste within food supply chains: Quantification and potential for change to 2050. *Philosophical Transactions of Royal Society B: Biological Sciences* **365**: 3065-3081.

Patel JV, Antala DK and Dalsaniya AN 2018. Influence of different packaging materials on the seed quality parameters of chickpea. *International Journal of Current Microbiology and Applied Sciences* **7**(12): 2458-2467.

Raina AK 1970. *Callosobruchus* spp. infesting stored pulses (Grain legumes) in India and a comparative study of their biology. *Indian Journal of Entomology* **32**: 303-310.

Rozman V 2015. Control of stored products pests by natural products. *Integrated Protection of Stored Products IOBC-WPRS Bulletin* **111**: 295-299.

Sadasivam S and Manickam A 1996. *Biochemical Methods for Agricultural Sciences*, New Age International (P) Ltd., New Delhi, pp. 1-97.

Shankar SV, Pandiarajanb T and Ganapathy S 2018. Biochemical changes of black gram grains during hermetic storage. *Research Journal of Chemical and Environmental Sciences* **6**(6): 15-21.

Srinivasan T, Durairaj C and Vinothkumar B 2008. Damage potential of bruchids in different edible legumes and interspecific competition between two species of *Callosobruchu*s spp. (Bruchidae: Coleoptera). *Madras Agricultural Journal* **95**(7-12): 400-406.

Swella GB and Mushobozy DMK 2007. Evaluation of the efficacy of protectants against cowpea bruchids (*Callosobruchus maculatus* (F.) on cowpea seeds (*Vigna unguiculata* (L.) Walp.). *Plant Protection Science* **43**: 68-72.

Tripathi PC and Lawande KE 2014. Effect of seed moisture and packaging material on viability and vigour of onion seed. *Journal of Engineering and Applied Science* **3**:1-5.

Trivedi A, Nayak N and Kumar J 2018. Recent advances and review on use of botanicals from medicinal and aromatic plants in stored grain pest management. *Journal Entomology and Zoology Studies* **6**(3): 295-300.

Vange T, Ikyeleve F and Okoh JO 2015. Effect of packaging materials and storage condition on soybean germination and seedling vigour in makurdi. *Research Journal of Seed Science* **9**:1-4

Wang W, He A, Peng S, Huang J, Cui K and Nie L 2018. The Effect of Storage Condition and Duration on the Deterioration of Primed Rice Seeds. *Frontiers Plant Science* **19**: 1-17.

War AR, Murugesan S, Boddepalli VN, Srinivasan R and Nair RM 2017. Mechanism of Resistance in Mungbean [*Vigna radiata* (L.) R. Wilczek var. radiata] to Bruchids, *Callosobruchus* spp. (Coleoptera: Bruchidae). *Frontiers in Plant Science* **8**: 1031

Williamson S, Ball A and Pretty J 2008. Trends in pesticide use and drivers for safer pest management in four African countries. *Crop Protection* **27**: 1327-1334.

Yeh YM, Chiu KY, Chen CL and Sung JM 2005. Partial vacuum extends the longevity of primed bitter gourd seeds by enhancing their anti-oxidative activities during storage. *Scientia Horticulturae* **104**: 101-112.

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