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Effect of Hermetic Storage on Seed Quality Maintenance of Dolichos Bean [*Lablab purpureus* (L.) var *Typicus* Prain]

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ABSTRACT

Background: Dolichos bean is one of the important vegetable legume crops. During storage, protection of seed from bruchid attack is a major problem worldwide. Once the bruchid attacks, the extent of damage could be up to 100%, leading to both quantitative and qualitative loss by making it unfit for consumption. Existing traditional methods are less effective or impractical and the use of chemical methods can be harmful to the farmers and consumers. So, there is urgent need of hermetic storage method for seed quality maintenance. Keeping in view, the present study was carried out to investigate on hermetic storage practices for seed quality maintenance.

Methods: Triple-layer PICS technology, a chemical-free hermetic storage was evaluated for storage of dolichos bean to moisture content, germination and quality. Four different types of storage bags *viz.,* jute bags, polythene bags, triple layer PICS bags and jute bags treated with chlorpyrifos were used for evaluating their efficacy in managing dolichos bean seed attributes. The data on various parameters pertaining to seed characteristics and changes in biochemical composition of dolichos bean seeds stored in different bags was recorded at every two month intervals for 3 times (2,4 and 6 months) by using standard protocols. Complete Randomized Design (CRD) (Snedecor and Cochran, 1967) was used for the data analysis. The data was subjected to statistical analysis as per the methods suggested by Panse and Sukhatme (1985).

Result: Results on moisture content showed that, in case of storage in PICS bags, there was no decrease in seed moisture content at 2, 4 and 6 months respectively and germination percent in triple-layer PICS bag at 2, 4 and 6 months storage was highest among all bag types. Test weight (g), protein content (%) and carbohydrate content (%) at 2, 4 and 6 months storage respectively were higher in triple layer PICS bag. The mean fat content recorded was highest in jute bag (1.25%) and lowest in triple layer PICS bag (0.63%). Our study concludes that the triple layer PICS bags hermetic technology is efficient in managing maintaining same level of moisture content percent, germination percent and test weight compared to other bags over 3 different periods of storage. The triple layer PICS bags are also highly useful for retaining carbohydrate percent and protein percent at almost the same levels compared to initial values.

Key words: Dolichos bean, Hermetic storage, Triple-layer purdue storage bag, Seed quality.

INTRODUCTION

Dolichos bean [*Lablab purpureus* (L.) var *typicus* Prain], also known as Indian bean or Hyacinth bean, is an important vegetable legume belonging to the family Fabaceae. India is considered to be the centre of origin of Dolichos bean. It is cultivated as an inter-crop with cereals. and is one of the most popular perennial vegetable crops in India. In South India, this crop is best grown as a vegetable for fresh green pods, dry seeds for various food preparations and remaining plant parts as a fodder for livestock. The leguminous vegetables are the major and cheap sources of protein with ability to address malnutrition (Pidigam *et al*., 2019). The nutritive quality of Dolichos bean is considered superior than that of the French bean (Aykroyd, 1963, Singh *et al*., 2021). The mature seed is highly proteinaceous (22.4 to 31.3%) (Deka and Sarkar, 1990).

The crop suffers losses in the field as well as in the storage. In general, post-harvest losses due to bruchid damage are high in dolichos bean and can account up to 100% in severe infestation. The bruchids render infested pulses unfit for consumption because of the presence of excreta and metabolic waste products like uric acid which leads to fungal infection of the grains (Gowda and Kaul, 1982). Existing traditional methods are ineffective or impractical and the use of chemical methods can be harmful to the farmers (fumigants) and consumers (residues). Mixing

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of beans with ash, which is used for storage of beans in smaller quantities and other indigenous methods like solarisation, mixing fine dust, botanicals insecticides, oviposition deterrants, fumigation, contact insecticides, illuminated bags (Manpreet *et al*., 2016) are less effective and provide variable results as there is no standard dosage and guidelines for their usage (Songa and Rono, 1998). There is a need for non-chemical methods of stored product protection, because chemical control is often not acceptable for sustainable farming. Once the bruchids attacks, the germination, test weight, quality decreases and makes the beans unfit for use as seed to raise a new crop.

Purdue Improved Crop Storage (PICS) bag is a simple, effective technology for reducing grain losses to insects during post-harvest storage. PICS bags consist of two layers of high-density polyethylene (HDPE, 80µ thick) inner bags and one polypropylene (PP) woven outer bag (Baributsa *et al.*, 2012). They were proven to provide excellent protection for cowpea grain against bruchid seed beetles in West Africa (Murdock *et al.,* 2012: Baoua *et al*., 2012, 2013). The triple layer PICS technology owes its effectiveness to the airtight storage creating an atmosphere inside the bag that is not suitable for insect growth and replication. Hermetic storage is a method of using sealed, airtight containers to control moisture and insects in stored dry agricultural commodities. The bags were tried for hermetic storage of maize, cow pea, redgram, chick pea, green gram, black gram, wheat and paddy to safe gourd the produce from various stored grain pests and to retain quality of produce for longer time. Keeping the above in view, an experiment was designed to evaluate the efficacy of different bags for hermetic storage of dolichos bean seed aiming for maintaining seed quality parameters.

MATERIALS AND METHODS

Experiment was carried out at the Post Graduate Research Laboratory, College of Horticulture, Sri Konda Laxman Telangana State Horticultural University, Rajendranagar, Hyderabad, Telangana state, India during 2018. Approximately 180 kg of dried dolichos bean seeds of variety RND-1 with initial seed moisture of 10% were obtained from National Seeds Corporation and used for the experiment by storing them in different types of storage bag.

Four different types of storage bags *viz.,* (i) Jute bags (ii) Polythene bags (iii) Triple layer PICS bags (Two layers of high-density polyethylene (HDPE, 80µ thick) inner bags and one polypropylene (PP) woven outer bag) and (iv) Jute bags treated with Chlorpyrifos were used for evaluating their efficacy in managing dolichos bean seed quality attributes. Jute bags and polythene bags were purchased from local market. The untreated jute bags and polythene bags were used as such for storing the dried dolichos bean seeds, while the jute bags treated with chemical were turned inside out before spraying with insecticide (20 EC chlorpyrifos diluted with water (1 : 19) was sprayed) on the inner side. Later, the jute bags were shade dried and used for the experiment. The triple layer PICS bags were sourced locally. Five kilograms of dried Dolichos bean seeds with 10 per cent moisture were weighed separately and placed in each of four types of bags. Each of these storage bags was infested with 10% of dolichos bean seed in which the bruchids *Callosobruchus theobromae* were mulltiplied. The bags were then moved gently upside and down for uniform mixing of bruchid infested seed with uninfested seed before closing the bags. The storage bags (one layer at a time starting with the inner most in the triple layer PICS bags) were sealed with heat sealer and the outer polypropylene bag was tied with a thread tightly which gives mechanical protection to the inner two layers. Each of the four bag treatments used for the experiment were replicated thrice with identical conditions (10% moisture). Hence, a total of 36 such storage bags were part of the experiment.

Methodology and equipments

Initial data on test weight (g), germination per cent, moisture content (%) and proximate composition *viz.,* carbohydrate content (%), fat content (%) and protein content (%) were recorded for the dolichos bean seeds with 10% moisture content just a day before the setting up of the experiment. After the experiment was set up, all the bags were closed and the data on various parameters pertaining to seed characteristics and changes in biochemical composition of dolichos bean seeds stored in different bags was recorded at every two month intervals for 3 time points (2,4 and 6 months) by using standard protocols.

Statistical analysis

Complete randomized design (CRD) (Snedecor and Cochran, 1967) was followed for setting up the experiment, wherein four different treatments and three storage periods were considered as two factors influencing insect growth in the seeds. The data was subjected to statistical analysis as per the methods outlined by Panse and Sukhatme (1985) using the mean values of random samples in each replication from all the treatments to find out the significance of treatment effect.

RESULTS AND DISCUSSION

Initial details of test weight (23.6 g), germination per cent (100), moisture content (10%), protein content (40%), fat content (1%) and carbohydrate content (20.04%) of RND-1 variety of dolichos bean seeds were calculated from three replicates before experiment initiated.

Analysis of variance of CRD

Analysis of variance with respect to bag types, storage periods and their interactions for test weight, moisture content, germination percentage, protein content, carbohydrate content and fat content was high and significant indicating sufficient variations (Table 1).

Effect of storage bag on per cent change in moisture content (%) of dolichos bean seeds at different storage periods.

Initial moisture content of dolichos bean seed was 10%. Among the different types of storage bags, highest moisture content (%) was observed in the PICS bag (10.37) followed by jute insecticide treated bag (9.05), polythene bag (8.91) and jute bag (8.52). Hence, all bags were significantly different (P<0.001) with each other. The minimum moisture content was recorded in jute bag (8.52). Among different sets storage periods, maximum moisture content was recorded after 2 months storage period (9.32). Least was observed in 6 months storage period (9.09). The two groups of periods were significantly different (P<0.001) with each other. Among the interactions, of different types of storage bags and different storage periods, maximum moisture content (%) was recorded in triple layer PICS bag stored for 6 months (10.46) followed by Triple layer PICS bag stored for 4 months (10.41), which was at par (Table 2).

The minimum moisture content was reported from jute bag stored for 2 months (8.60), jute bag stored for 4 months (8.52), jute bag stored for 6 months (8.45), polythene bag stored for 6 months (8.59), which were at par. The PICS bags in interaction with different storage periods showed increase in moisture content compared to all other types of storage bags at different storage periods (Table 2). Comparing among different types of storage bags, triple layer PICS bag showed highest moisture content followed by jute bags treated with insecticide, polythene bag and jute bags. The decreased moisture content in bags other than triple layer PICS bag could be due to decreased ambient relative humidity levels of the air during the drier winter months. The results of the present investigation are similar with earlier investigations of Martin *et al.,* 2015 in wheat grain storage, Yakubu *et al*., 2010 in post harvest maize storage, Edoh Ohnakossan *et al.,*2013 in maize storage, Anankware *et al.,* 2013 maize storage and Bbosa *et al*., 2014 evaluated in maize storage. Bhandari *et al.* (2017) evaluated for maize quality, Abass *et al.,* 2018 maize post harvest storage technologies. Among all the bags, triple layer PICS bags were performed well and these bags retained the moisture content of the dried dolichos bean seeds stored in them (Table 2).

Effect of storage bags on change in germination (%) of dolichos bean seeds at different storage periods.

The initial germination percentage of seeds recorded was 95%. Among the different types of storage bags, highest germination per cent was recorded in triple layer PICS bag (93.3) followed by jute bag treated with insecticide (88.7), polythene bag (86.4) and least in jute bag (84.0), which were significantly different (P<0.001) with each other (Table 3).

In comparison of different sets of storage periods, maximum germination percentage was recorded after 2 months storage (89.50) followed by 4 months storage (88.17) and 6 months storage (86.67). In polythene bag, jute bag treated with insecticide and jute bags germination percent differed compared to initial among the periods of storage.

Table 1: CRD Analysis of Variance (ANOVA) of seed parameters in RND-1 variety of dolichos bean.

Source of variation	Degrees of freedom	Test weight (g)	Moisture content (%)	Germination per cent (%)	Protein content (%)	Carbohydrate content (%)	Fat content (%)
A (Bag types)	3	29.559**	5.780**	141.778**	21.921**	1.126**	0.734**
B (Storage periods)	2	2.906**	0.156**	24.111**	7.309**	0.413**	0.365**
A×B (Interaction)	6	0.723**	0.104**	2.444*	0.569**	0.038**	0.100**
Error (B)	24	0.154	0.008	0.722	0.110	0.003	0.000
Total	35	2.929	0.528	14.444	2.470	0.129	0.101
General mean		21.514	9.213	88.111	36.376	18.844	1.005
C. V.		1.823	0.999	0.965	0.913	0.303	1.317

Significance Levels * = <0.05, ** = <0.01, *** = <0.001

Table 2: Effect of storage bags on per cent change in moisture content (%) of dolichos bean seeds at different storage periods.

Factor (A): Different storage bags	Before storage (g) (%)	Factor (B): Different storage periods			
		2 months (B_1)	4 months (B_2)	6 months (B_3)	Mean A
Jute bag (A_1)	10.00	8.60^{c}	8.52^{e}	8.45^{c}	8.52^{b}
Polythene bag (A_2)		9.23^{c}	8.90^{d}	8.59^{e}	8.91^{b}
Triple layer PICS bags (A_3)		10.23^{b}	10.41^{a}	10.46^{a}	10.37^{a}
Jute bags treated with chloropyriphos (A_4)		9.18^{c}	9.13^{c}	8.85^{d}	9.05^{b}
Mean B		9.32^{a}	9.24^{a}	9.09^{b}	
Factors	S.E(m)		C.D at 5%		C.V (%)
Factor A	0.03067		0.08952		0.99
Factor B	0.02656		0.07753		
Factor (A×B)	0.05312		0.15506		

Values followed by the different letters (a,b,c,d) are significantly different.

But in case of triple layer PICS bag, there is minor change in the germination percentage even after 2, 4 and 6 months of storage, though storage periods were significantly different (P<0.001) with each other. Among all interactions, triple layer PICS bag stored for 2 months (93.67) showed higher germination per cent followed by for 4 months (93.33). These storage periods have given better germination per cent compared with other interactions. The minimum was recorded in jute bag stored for 6 months (82.67).

With different storage periods, 2 months storage period performed better compared to 4 months and 6 months.. With increase in storage period due to the increased levels of infestation and multiplication of bruchid the damage to the dolichos bean seeds happened, resulted in the reduction of the germination per cent of the dolichos bean seed. Among different storage bags, triple layer PICS bag performed better compared with jute bag insecticide treated, polythene bag and jute bag. Maximum reduction in percent germination was observed in jute bag treated with insecticide, polythene bag and jute bag with 10% moisture content. This might be due to circulation of air, growth and multiplication of insects in traditional storage bags like jute bags, polythene bags and jute bag treated with insecticide. These results are similar with earlier investigation done on crop storage by Anankware *et al*., 2013 in maize, Njoroge *et al*., 2014 in maize and Sarr *et al.,* 2014 in groundnut, Baributsa *et al*. (2017) in groundnut and Amadou *et al.* (2016) in *Hibiscus sabdariffa* grain. Among all bag types triple layer PICS bags performed best compared with other bags irrespective of storage periods (Table 3).

Effect of storage bags on change in test weight (g) of dolichos bean seeds at different storage periods.

Initial 100 seed weight of dolichos bean was recorded as 23.60g. After storage maximum test weight was recorded in triple layer PICS bag (23.44 g) followed by jute bag treated with insecticide (22.24 g), polythene bag (21.22 g) and least was observed in jute bag (19.16 g), which were significantly different (P<0.001) with each other.

In case of 2, 4 and 6 month storage in comparison to initial storage period, all significantly differed (P<0.001) with each other. The lowest test weight was in 2 months storage period (22.06 g) followed by 4 months storage period (21.38 g) and 6 months storage period (21.10 g) but three were at par (Table 4).

Among interactions, seed stored in triple layer PICS bag stored for 2 months (23.48 g), 4 months (23.42 g) and 6 months (23.41g) recorded highest test weight followed by other interactions. They were the best among all other interactions. The least test weight was observed in jute bag

Table 3: Effect of storage bag on change in germination (%) of dolichos bean seeds at different storage periods.

Factor (A): Different storage bags	Before storage	Factor (B): Different storage periods			
	(%)	2 months (B_1)	4 months (B_2)	6 months (B_3)	Mean A
Jute bag ($A_{1)}$		85.33^{d}	84.00^{e}	82.67^{f}	84.0^{d}
Polythene bag (A_2)	95	88.00^{e}	86.33^{d}	85.00^{e}	86.4^{c}
Triple layer PICS bags (A_3)		93.67^{a}	93.33^{a}	93.00^{a}	93.3^{a}
Jute bags treated with chloropyriphos (A_4)		91.00^{b}	89.00^{c}	86.00^{d}	88.7^{b}
Mean B		89.50^{a}	88.17^{b}	86.67^{c}	
Factors	S.E(m)		C.D at 5%		C.V (%)
Factor A	0.28328		0.82684		0.965
Factor B	0.24533		0.71606		
Factor (A×B)	0.49065		1.43213		

Values followed by the different letters are significantly different.

Table 4: Effect of storage bags on change in test weight (g) of dolichos bean seeds at different storage periods.

Factor (A): Different storage bags	Before storage	Factor (B): Different storage periods			
	(g) (%)	2 months (B_1)	4 months (B_2)	6 months (B_3)	Mean A
Jute bag (A_1)		20.23^{h}	18.33^{i}	18.41^{j}	19.16^{d}
Polythene bag (A_2)		22.19^{d}	21.00^{f}	20.48^{g}	21.22^{c}
Triple layer PICS bags (A_3)		23.48^{a}	23.42^{a}	23.41^{a}	23.44^{a}
Jute bags treated with chloropyriphos (A_4)	23.60	22.33^{b}	22.27^{c}	22.11^{c}	22.24^{b}
Mean B		22.06^{a}	21.38^{b}	21.10^{b}	
Factors	S.E(m)		C.D at 5%		C.V (%)
Factor A	0.13072		0.38154		1.82
Factor B	0.11321		0.33043		
Factor (A×B)	0.22641		0.66085		

Values followed by the different letters are significantly different.

stored for 4 months (18.33). In comparison of different sets of storage periods, maximum test weight loss was recorded after 6 months of storage followed by 4 months and 2 months storages. This may be due to increase in storage duration, the infestation levels were increased and damage by bruchids lead to loss of weight of seed.

Overall bag type, test weight and storage periods and their interactions at 10% moisture content, revealed that the triple layer PICS bag with artificial infestation of bruchid, *Callosobruchus theobromae* (10%) has very less reduction in test weight compared to the initial weight due to death of pest inside the bag with hypercarbia (increased levels of CO_2) and hypoxia (reduced levels of O_2), which are not congenial to the pest for its survival and do not cause further damage to the seed. The results are similar to the investigations of Affognon *et al.,* 2014 in storage of common bean, Bbosa *et al.,* 2014 and Cugala *et al.,* 2014 in maize storage, Sudini *et al.,* 2015 in groundnut storage and Murdock and Baributsa 2014 in cowpea storage.

Effect of storage bags on per cent change in protein content (%) of dolichos bean seeds at different storage periods.

Initial protein content of dolichos bean seed recorded was 40%. In case of different storage bags, all bags were significantly different (P<0.001) with each other. The protein content (%) of dolichos bean seed was highest in triple layer PICS bag (38.4) followed by jute bag treated with insecticide (36.8), polythene bag (35.4) and jute bag (34.9). In comparison of different sets of storage periods, maximum protein content (%) was recorded after 2 months storage period (37.15) followed by 4 months storage period (36.38) and 6 months storage period (35.59) and which were significantly differ (P<0.001) with each other (Table 5).

Among the interactions, two interactions *i.e.,* triple layer bag stored for 2 months (38.92) and 4 months (38.51), which were at par and recorded highest protein content (%) followed by triple layer PICS bag (37.76) stored for 6 months. The triple layer bag with different storage period was better than all interactions.

Among all the bags, triple layer PICS bags were performed well followed by jute bags treated with insecticide, polythene bag and jute bags. As the bruchid infestation levels and seed damage were less in the triple layer PICS bag, which caused less loss in protein content in seed stored in triple layer PICS bag compared to the other types of bags used for storing the produce (Table 5). Sudini *et al*., 2014 reported that the PICS bag reduced the deterioration of protein quality in groundnut during storage.

Effect of storage bags on per cent change in carbohydrate content (%) of dolichos bean seeds at different storage periods.

Initial carbohydrate content (%) of dolichos bean seed recorded was 20.04%. After storage, maximum carbohydrates content (%) was recorded in triple layer PICS bag (19.29) followed by jute bag treated with insecticide (18.91), polythene bag (18.73) and jute bag (18.45), which were significantly different (P<0.001) with each other. Among all types of bags used for storage, triple layer PICS bag performed best. In comparison of different sets of storage periods, maximum carbohydrate content (%) was recorded after 2 months storage period (19.03) followed by 4 months storage period (18.84) and 6 months storage period (18.66), which were significantly different (P<0.001) with each other (Table 6). Two months storage period performed better than the 4 and 6 months storage periods as the infestation of bruchid increases as storage period increases by multiplication in number of bruchids, which caused loss to the seed stored. Among interactions, three combinations, *viz.,* triple layer PICS bag stored for 2 months (19.37), triple layer PICS bag stored for 4 months (19.26) and triple layer bag stored for 6 months (19.24) were at par and showed highest carbohydrate content (%) followed others. The triple layer PICS bag with 2 months storage period, 4 months storage period and 6 months storage period were best among all interactions. The minimum carbohydrate content (%) was recorded in jute bag stored for 6 months (18.12). Among all the bags, triple layer PICS bags were performed well followed by jute bags treated with insecticide, polythene bag and jute bags. As the bruchid infestation levels in the triple layer PICS bag was less which lead to less loss in carbohydrate content in seed stored in triple layer PICS bag treatment compared to the other type of storage bags. All other bags have heavy infestation of pest and caused loss in stored produce and quality (Table 6).

Table 5: Effect of storage bags on change in protein content (%) of dolichos bean seeds at different storage periods.

Factor (A): Different storage bags	Before storage	Factor (B): Different storage periods			
	(%)	2 months (B_1)	4 months (B_2)	6 months (B_3)	Mean A
Jute bag (A_1)		35.94^{d}	34.85^{e}	33.88^{g}	34.90^{d}
Polythene bag (A_2)		36.69^{c}	35.44^{d}	34.22^{f}	35.40^{c}
Triple layer PICS bags (A_3)	40	38.92^{a}	38.51^{a}	37.76^{b}	38.40^{a}
Jute bags treated with chloropyriphos (A_4)		37.07^{c}	36.73^{c}	36.51^{c}	36.80^{b}
Mean B		37.15^{a}	36.38^{b}	35.59^{c}	
Factors	S.E(m)		C.D at 5%		C.V (%)
Factor A	0.11074		0.32323		0.91
Factor B	0.09590		0.27992		
Factor (A×B)	0.19181		0.559852		

Effect of storage bags on per cent change in fat content (%) of dolichos bean seeds at different storage periods.

Before storage the initial fat content (%) recorded was 1%. In case of different storage bags, all bags were significantly different (P<0.001) with each other. The fat content (%) of dolichos bean seed is reported was highest in jute bag (1.25) followed by jute bag treated with insecticide (1.21), polythene bag (0.93) and triple layer PICS bag (0.63). Among all, triple layer PICS bag has showed less fat content (%) (0.61) compared to all other traditional storage bags used for storing dolichos bean seeds (Table 7).

In comparison of different sets of storage periods, maximum fat content (%) was recorded after 2 months storage period (1.12) followed by 4 months storage period (1.09) and 6 months storage period (0.80). As the storage duration increased, the fat content of the seeds showed the reduced results which were significantly different (P<0.001) with each other at different storage periods such as 2, 4 and 6 months. Among all interactions, significantly maximum fat content of 1.48% was recorded in jute bag stored for 2 months (1.48) followed by jute bag stored for 4 months (1.41) and jute bag treated with insecticide stored for 2 months (1.41) and however, these interactions were at par and followed by others. Triple layer PICS bag stored for 2 months (0.61) and for 4 months (0.61) recorded least fat content (%), which were at par followed by triple layer PICS bag stored for 6 months (0.67). The triple layer bag with 6, 4 and 2 months storage period respectively showed less fat content among all interactions. The exact reason for the enhancement of fat content in jute bag and jute bag treated with insecticide compared to the triple layer PICS bag needs further studies.

Seed quality parameters in storage

The data on the moisture content showed that the triple layer PICS bag has highest moisture content among the bag types and irrespective of storage periods, triple layer PICS bag retained the moisture content within the bag, while the other bags which caused reduction in moisture content with environmental changes. The triple layer PICS bags is not influenced by the surrounding environmental conditions and maintain the moisture content of the produce stored in the bag and no further loss of moisture to the seed (Ibrahim *et al*., 2018). The best germination per cent was recorded in triple layer PICS bag (93.3%) compared to all other types of storage bags. As the infestation levels in the triple layer PICS bag was less. There is no damage to the vital parts of the seed that stored in the PICS bags so that aided in the germination capacity of the seed, its quality seed, hence, showed good germination percentage. The results are in line with the results of Yakubu *et al*. 2010, who recorded

Table 6: Effect of storage bags on per cent change in carbohydrate content (%) of dolichos bean seeds at different storage periods.

Factor (A): Different storage bags	Before storage	Factor (B): Different storage periods			
	(%)	2 months (B_1)	4 months (B_2)	6 months (B_3)	Mean A
Jute bag (A_1)		18.72^{d}	18.50^{c}	18.12^{f}	18.45^{d}
Polythene bag (A_2)		18.86^{c}	18.74^{d}	18.58^{e}	18.73^{c}
Triple layer PICS bags (A_3)	20.04	19.37^{a}	19.26^{b}	19.24^{b}	19.29^{a}
Jute bags treated with chloropyriphos (A_4)		19.18^{b}	18.87^{c}	18.69^{d}	18.91^{b}
Mean B		19.03^{a}	18.84^{b}		18.66^{c}
Factors	S.E(m)		C.D at 5%		C.V (%)
Factor A	0.01901		0.05549		0.30
Factor B	0.01646		0.04806		
Factor (A×B)	0.03293		0.09611		

Values followed by the different letters are significantly different.

Table 7: Effect of storage bags on per cent change in fat content (%) of dolichos bean seeds at different storage period.

Factor (A): Different storage bags	Before storage	Factor (B): Different storage periods			
	(%)	2 months (B_1)	4 months (B_2)	6 months (B_3)	Mean A
Jute bag (A_1)		1.48^{a}	1.41^{b}	0.86^{e}	1.25^{a}
Polythene bag (A_2)		0.98^{d}	0.97^{d}	0.84^{e}	0.93^{c}
Triple layer PICS bags (A_3)	1.00	0.61^{g}	0.61^{g}	0.67^{f}	0.63^{d}
Jute bags treated with chloropyriphos (A_4)		1.41^{b}	1.37^{c}	0.84^{e}	1.21^{b}
Mean B		1.12^{a}	1.09^{a}	0.80^{b}	
Factors	S.E(m)		C.D at 5%		C.V (%)
Factor A	0.00441		0.01287		1.31
Factor B	0.00382		0.01115		
Factor (A×B)	0.00764		0.02229		

Values followed by the different letters are significantly different.

that there is higher mortality of maize weevil, *S. zeamais*, in triple layer PICS bags at low temperature and low seed moisture level as they created hypoxia (depleted oxygen levels) conditions sooner compared to the seeds stored at high temperatures and moisture level. Baoua *et al*. 2014 compared the germination percentage after storing Bambara groundnut (*Vigna subterranean*) slightly infested with *C. maculatus* and *C. subinotatus* for a period of seven months in triple layer bags and woven polypropylene bags and observed the germination percentage was found to be 34.8% in polypropylene bag and 89.3% in triple layer bags. The test weight of 100 randomly selected dolichos bean seed was recorded maximum in triple layer PICS bag. The seed with less damage per cent and good quality in triple layer PICS bag contributed for highest test weight. Similar results are reported by Anankware *et al.* 2013. They compared the effectiveness of triple layer bags with that of jute and polythene bags against maize weevil, *S. zeamais* and observed highest percent mortality of *S. zeamais*, seed germination recorded in triple layer bags and increased level of seed damage, weight loss in jute bags followed by polythene bags. Mortality 95-100% of storages pests of maize P*. truncatus, S. zeamais* with no significant loss weight and a germination of 90.5% when stored in triple layer plastic bags but higher weight loss, poor mortality of storage insects and reduction in germination percentage of maize stored for a period of 6.5 months in woven polypropylene bags was recorded by Baoua *et al.* 2014.

Nutritional aspects in storage

The maximum carbohydrate content (%) was reported in triple layer PICS bag (19.29%), as the damage was less on seed due to less bruchid infestation. The carbohydrate content was retained as in initial samples before experimentation in the triple layer PICS bag treatment compared to all other treatments. The protein content (%) was recorded maximum in the triple layer PICS bag (38.40%) compared to all other storage bags, as the damage due to bruchid infestation on seed was less. Therefore, these is no loss of both the protein and carbohydrates from the dolichos bean seeds stored in triple layer PICS bags due to no pest in these bags and they have not eaten away the contents of seed that contained protein and carbohydrates. Sudini *et al*., 2014 reported that the PICS bag reduced the deterioration of quality in groundnut. The study revealed that the increased fat content in the jute bag (1.25%) was increased followed by jute bag treated with insecticide (1.21%). The least fat was observed in triple layer PICS bag. The inconsistency of fat content over periods of storage was reported. The reason for increase of fat content in non- hermetic storage bags would be attributed for the fat reported from heavily infested bruchids that were building up in these bags. The triple layer PICS bag created the hypercarbia and hypoxia conditions within the bag and lead to mortality of pest, which further reduced the damage to seed. This helped in maintaining the good germination per cent, test weight, protein content and carbohydrate content with in the seeds stored in the bag.

CONCLUSION

The present investigation concludes that the triple layer PICS bags hermetic technology is efficient in dolichos beans in managing moisture content (%), germination per cent and test weights compared to other storage methods. Storage in PICS bags also ensures the nutritional quality in terms of carbohydrates and proteins. The use of triple layer PICS bags for grain storage as an improved storage practice, works on the principle of creating hypercarbia and hypoxia, is highly efficient in retaining seed quality parameters over six months of storage period. The chemical-free triple layer PICS bag technology, hence can be recommended for long term storage of dry produce of 'dolichos beans'.

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