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Hermetic sealed storage IRRI super bag: Reduces post-harvest losses in seed grains

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Abstract
Post-harvest losses occur due to poor storage system, which deteriorates seed quality. All traditional storage systems like jute bags, PVC/woven bags, clay pots, drums etc. are not really hermetic and can’t store seed or grain safely for longer time. It would be difficult to measure the loss due to physiological changes in seed at the farm level. An attempt was, therefore, made to control the insect-damage, maintain germination and proper moisture level in IRRI Super bags at farmer’s level. Visualising this, the on-farm study at BAU, KVK Sabour, Bhagalpur and ICAR, KVK Buxar was conducted during 2015-16. Lentil seeds used for research in KVKs were initially dried to moisture content ranging from 12.1 to 13.9% and cooled in shade before storage. There was merely 0-1% increase in moisture-content after storage in Super bags, whereas it increased by 1.6-2.0% in jute bags which attracted more insect-pest infestation and reduced germination. There was no or negligible count of dead or alive insect-pests infesting Super-bag stored seed, while noticeable count of dead and live insects was recorded into grains. Seed germination ability remained unaffected in Super bags, but it drastically deteriorated (8.5-10.9%) in jute-bag stored seed at different locations. Discolouration of seed stored in Super bag was also lesser as compared to that stored in jute bag. It implies that IRRI Super bags are suitable for lentil seed storage in room condition. Though the cost of Super bag is a bit higher than jute bag, but its benefits well-nigh compensate the cost.

Keywords: Super bag, hermetic, seed storage, germination, moisture content

Introduction
The crop spectrum of India includes mainly cereals, pulses, spices and other cash crops. The farmers generally store the grains for their own consumption, and as seed for sowing in the next season. According to FAO, about 70 percent of the farm produce is stored by farmers for their home consumption for the purpose of seed, feed and other use in India, either in a container or in bulks. The major storage structures in rural areas at the farmer level are earthen pots smeared outside, plastic or jute bags, metallic drum sealed at the upper cover/lid, bamboo and plant materials. For bulk storage, farmers prefer go-downs, ware-houses or silos. But, generally, they are neither rodent-proof nor secure from fungal and insect attack. Food and Agriculture Organization of U.N. predicts that about 1.3 billion tons of food are globally wasted or lost per year (Gustavasson, *et al.* 2011) [5]. On an average, of the total 6% loss of food grains occurs in such storage structures, about half is due to rodents, and rest is due to insects and fungi (Kannan, 2014) [7]. Factors that contribute to food loss range from mechanization of practices such as harvesting to handling, processing and others, to weather conditions, production practices, management decisions, transportation facilities, grading issues, infrastructure, consumer preferences/attitudes, and availability of financial markets. According to a World Bank study (1999), post-harvest losses of food grains in India are 7-10 percent of the total production from farm to market level, and 4-5 percent at market and distribution level. However, annual post production losses are 10%, which means that about 15 million tons of food grains are lost during harvesting, threshing, and storage (Ali *et al*., 2015) [6]. In ancient times, underground storage pits were dug into the soil or rock and had supporting walls of brick or cement to make the storage system airtight, and this might be considered as hermetic storage. As a result, insects and other aerobic organisms die or can’t grow. The factors affecting the growth of these organisms are ambient temperature, relative humidity and

moisture as well as condition of the material used for construction of storage structure. Insect-damage to the stored grains is considered as 36-43% (Bala *et al*. 1990) [2]. Storage losses include different parameters such as: weight loss and viability loss of planting materials affecting germination. A considerable amount of stored seed of lentil is spoiled, as moisture creeps into the jute gunny bags used for storing the grains and seeds. In spite of keeping these bags at supposedly drier places like husk stacks etc., the seeds get moistened and insect-pest population increases tremendously damaging the seed grains. This also increases the chances of fungal and microbial infection in seeds resulting in discoloration and affecting germination ability. Hermetic storage system means storage of seeds or grains in controlled atmospheric conditions. These rely on the atmosphere within the grain being modified through respiration by the grain, insects, or fungi. The system is so prepared that oxygen level in the inter-granular atmosphere is continuously reduced, often to less than 3%, inducing rise in carbon dioxide level to arrest aerobic respiration. Modern commercial hermetic systems used nowadays, are high-density plastics to restrict oxygen movement between inner and outer atmospheres. The similar effect can be attained using smaller sealed plastic or metal containers. The IRRI Super bag is made of flexible polyvinyl chloride (PVC) material and has zip for closing and opening or can be sealed by simple jute rope. IRRI has developed hermetic bags that are made of special plastic that keep the moisture level minimum during storage and limit gaseous exchange controlling the infestation of insect-pests. The IRRI Super bag is prepared for storage capacity of 25 and 50 kg. In this investigation, we compared the 50kg IRRI Super bags with current farmers' practices to determine their effect on grain and seed quality. On-farm trials were conducted at Sabour and to evaluate performance of IRRI super bags with the objectives (i) to test benefits of Super bags in terms of quality of stored seed as compared to current storage practices through participatory trials for seed storage and (ii) to calculate additional profit (or savings) from use of Super bags for the individual end-user trailing Super bags, thus enabling a "go-go or no-go" decision regarding continued use (and future purchase) of Super bags.

Materials and Methods

For estimating post-harvest losses, there is a need to establish the extent of losses during storage under different agro-climatic conditions. Causes of losses due to storage include sprouting, transpiration, respiration, rot due to mould and bacteria, and attack by insect-pests. Sprouting, transpiration and respiration are physiological activities that vary with the storage environment, mainly depending upon temperature and relative humidity. These physiological changes affect the internal composition of the grains and result in destruction of edible material, thereby bringing changes in nutritional quality. But it would be difficult to measure the losses due to physiological changes at the farm level. Nevertheless, an attempt was made to control the insect damage, germination rate and moisture content in IRRI Super bag at farmer's field. The study was conducted on-farm at KVKs as well as at farmers' field in collaboration with IRRI India. At KVK Sabour and Buxar, lentil seed was used for study. The seed used for research was initially dried and cooled in the shade before storage. On these locations, there were two treatments in all, including (i) IRRI Super bag (ii) traditional jute bag. At BAU, five replications were laid out at the KVK Sabour farm, and five replications were laid out with farmers in their respective houses in different villages through KVK, Sabour. At ICAR KVK, Buxar, five replications were laid out at the KVK farm and two replications at farmers' house in two different villages. To validate the results of on-farm trials, field trials were conducted at farmers' place through Bihar Water Development Society (BWDS) for lentil and chickpea at eight locations each, and wheat at three locations for 150 days (March 15, 2015 to August 16, 2015) in Aurangabad district of drought-prone South Bihar. IRRI Super bags, traditional jute bags, moisture meter, magnifying glass, plastic box and tissue papers were used for experiment. IRRI Super bag was placed inside the jute bag and crop seed was loaded into each of the bags. The super bags were locked with jute rope and then the gunny bags were tied with a rope. All bags were loaded following the same procedure for different crops at different locations. As a principle, as much air as possible was removed from Super bag before closing it. It was ensured that all bags are labelled well (date, variety, and remain accessible for trial period) and placed on pallet. Bags were closed properly, and the stack was covered with a net or some suitable protective cover to protect from birds and rodents. Before placing seed in the IRRI Super bag, a sample weighing 500gm was collected to measure moisture content, germination and counting of insect population affecting seed. The storage system was regularly observed in order to check any possible default. After completion of storage period, same amount (500gm) of sample was taken out from each bag for measuring the same parameters as moisture content, viability and insect population. Samples were analysed, and data were recorded. Moisture content was measured with digital moisture meter and germination test was done for seed quality or seed viability.

Results and Discussion

The results revealed that condition of Super bags, after 186-203 days of storage was good, while jute bags were partially damaged. Cost of jute bag is Rs 35 which stores 30 kg seed and its life is only one year. However, jute bags are readily available in local market, but at present there is no ready access of Super bags to a local seller. Super bags are excellent for storing lentil seed, as lesser infestation of seed with pulse beetles was observed, and moisture level was maintained within permissible limits. There was comparatively higher level of moisture in seed stored in jute bags indicating poor health and resulted in fast deterioration of quality once opened.

At KVK, Sabour, average of 10 replications (5 at KVK Farm and 5 at farmers' field) indicated that moisture content was maintained up to termination of trial (around six months), infestation of insects was less, discoloration of grains was less, and germination percentage was higher in lentil grains stored in IRRI Super bags compared to Jute bags (Table 1). There was a less reduction in germination of seed stored in IRRI Super bags (from 94.7 to 94%) than conventional jute bags (from 93.8 to 85.3%) (Table1). Likewise, there was no loss in weight of seed stored in IRRI Super bag, but there was 10.6% reduction in weight of seed stored by conventional practice in jute bags. It implies that considering a 30 kg/ha seed rate of lentil, there is saving of 3.2 kg seed, which at the market price of Rs 80/kg costs Rs. 256. This gain may compensate the additional cost incurred in purchasing Super bag @ 120 per bag. However, the Super bags can also be used for next season without incurring any extra cost and thus adding to the profit of next cropping season. It was observed that there was no change in percent moisture status of seed stored in Super bag but it increased from 11.6 to 13.2% in traditional system of jute bag storage. The seed sample weighing 500g after completion of experiment contained 21.2 live and 11.6 dead insect counts in jute bag stored seed as compared to merely 1 live and 3.5 dead insects in Super bag stored seed. Similarly, the discoloured seed count accrued by only 1.2 per 1000 in Super bag as compared to 9.1 in jute bag storage system.

At KVK, Buxar (Table 2), average of 7 replications (5 at KVK Farm and 2 at farmers' field) indicated that there was a small reduction (1.9%) in germination of seed stored in IRRI Super bags than conventional jute bags (10.9%). There was no loss in weight of seed stored in IRRI Super bag, while it reduced by 3.8% when stored using conventional practice of jute bag. Thus at 30 kg/ ha seed rate of lentil, it saved of 1.14 kg seed, which at the market price of Rs 80/kg costs Rs. 91. It was observed that moisture content of seed stored in Super bags increased by 1% (from 12.1 to 13.1%), whereas it increased by 2% in traditional system of jute bag storage (from 12.1 to 14.1%). The seed sample, initially free of any dead or live insect contained 8.70 live and 3.86 dead insects in jute bag stored seed after the completion of experiment, whereas no insect was noticed in Super bag stored seed. The discoloured seed count increased by 4.8 per 1000 in Super bag as compared to 8.0 in jute bag storing method.

The results of field trials in Aurangabad district (Table 3) showed that the moisture content of lentil, chickpea or wheat seed remained unchanged when stored in Super bag. However, when stored in jute bag it increased by 1.07, 1.25 and 1.00% in lentil, chickpea and wheat, respectively. The reduction in % germination of seed of lentil (1.00%) and chickpea (0.25%) stored in Super bag was comparatively lesser than in case of jute bag (4.25% in lentil and 3.50% in chickpea). The reduction in % germination of wheat seed was almost equal, when stored in Jute bag (1.67%) or Super bag (1.66%). The live insects in all crop seeds were absent before and after storage in both, Jute bag as well as Super bag. Narrower differences between two bags in this district could be due to prevailing dry atmospheric conditions compared to other sites (Fig 1).

Conventional packaging materials are porous in nature and even dried seeds can regain moisture in these packaging materials under high ambient relative humidity. Super Bags are made up of high strength polyethylene (PE) with barrier layers and mostly comes in green color. Hermetic Super Bag has very low oxygen (≤ 4 cc/m2 /day) and water vapor transmission rate (≤ 5 $gm^{-2}day^{-1}$) and can be used to store seeds safely (GrainPro, 2018) [4]. Super Bag resists any significant change in seed moisture due to gas coated barrier layers. Rice seed stored in Super Bag retained high germination and grain milling quality (Ben *et al.*, 2006) [3]. Hermetic Super Bags reduced the storage losses of cowpea grain in Niger as compared to woven plastic bags. Hermetic Super Bags reduced the storage losses of cowpea grain in Niger as compared to woven plastic bags (Mbofung *et al.*, 2013) [8]. For all crop seeds, germination was severely affected in all packaging materials both at 8 and 14% initial seed moisture content except storage in Super Bag at 8% SMC. Wheat seed stored in Super Bag at 8% seed moisture content almost maintained initial germination while germination of cotton, maize and quinoa seeds declined 7%, 14% and 30% respectively in Super Bag at 8% seed moisture content. Seed storage in Super Bag can help to prevent the significant increase in seed moisture at higher RH (Bakhtavar *et al.*, 2019) [1]

Table 1: Comparative storage performance of IRRI Super bag vis-à-vis traditional jute bag for lentil at KVK, Sabour

Treatment	Weight of seed (kg)		Moisture content (%)		Germination (%)		Discoloration /1000 grains		Insect count / 500g grain				Grains damaged by insects (%)	
									Live		Dead			
	Bf	Af	Bf	Af	Bf	Af	Bf	Af	Bf	Af	Bf	Af	Bf	Af
Jute bag	33.1	29.6	11.6	13.2	93.8	85.3	9.4	18.5	0.0	21.2	0.0	11.6	--	--
Super bag	34.1	34.1	11.7	11.7	94.7	94.1	9.2	10.4	0.0	01.0	0.0	03.5	--	--

Bf, Before start of experiment; Af, After completion of experiment

Table 2: Comparative storage performance IRRI Super bag vis-à-vis traditional jute bag for lentil at KVK, Buxar

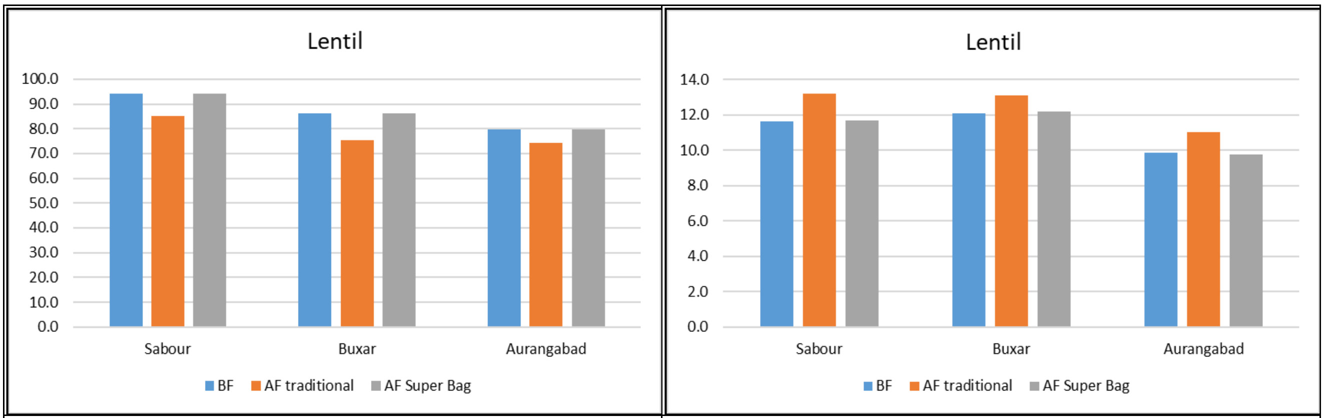
Treatment	Weight of seed (kg)		Moisture content (%)		Germination (%)		Discoloration /1000 grains		Insect count / 500g grain				Grains damaged by insects (%)	
									Live		Dead			
	Bf	Af	Bf	Af	Bf	Af	Bf	Af	Bf	Af	Bf	Af	Bf	Af
Jute bag	50.0	48.9	12.1	13.1	86.3	75.4	21.0	29.1	0.0	8.7	0	3.86	0.0	7.80
Super bag	50.0	50.0	12.1	12.2	86.3	86.4	20.8	25.6	0.0	0.0	0	0.00	0.0	0.00

Bf, before start of experiment; Af, After completion of experiment

Table 3: Comparative storage performance IRRI Super bag vis-à-vis traditional jute bag in district Aurangabad (Lentil, n=8; Chickpea, n=8; Wheat, n=3)

Treatment	Moisture content (%)		Germination (%)		Live insect count/ 500g grain	
	Before	After	Before	After	Before	After
Lentil						
Jute bag	9.93	11.00	78.63	74.38	0.00	0.00
Super bag	9.75	9.75	80.88	79.88	0.00	0.00
Chickpea						
Jute bag	9.88	11.13	83.50	80.00	0.00	0.00
Super bag	9.88	9.88	85.38	85.13	0.00	0.00
Wheat						
Jute bag	10.33	11.33	80.33	78.00	0.00	0.00
Super bag	10.00	10.00	83.33	81.67	0.00	0.00

Treatment	Moisture content (%)		Germination (%)		Live insect count/ 500g grain	
	Before	After	Before	After	Before	After
Lentil						
Jute bag	9.93	11.00	78.63	74.38	0.00	0.00
Super bag	9.75	9.75	80.88	79.88	0.00	0.00
Chickpea						
Jute bag	9.88	11.13	83.50	80.00	0.00	0.00
Super bag	9.88	9.88	85.38	85.13	0.00	0.00
Wheat						
Jute bag	10.33	11.33	80.33	78.00	0.00	0.00
Super bag	10.00	10.00	83.33	81.67	0.00	0.00



Germination rate | Moisture content

BF- Before Storage; AF traditional- After storage in traditional method; AF Super Bag- After storage in Super Bag

Fig 1: Comparison for germination rate and moisture content for three different districts

Conclusion

Based on the results of on-farm trials, it can be inferred that IRRI Super bag is superior to traditional jute bag storage practice. It was found that there was merely 0-1.0% increase in moisture content after storage in Super bags, whereas it increased by 1.6-2.0% in jute bags which attracted more insect-pest infestation and reduced germination. There was no or negligible count of dead or alive insect-pests infesting seed in Super bag stored seed, while noticeable count of dead and live insects was recorded in a grain sample of 500g in jute bag storage system. Another interesting observation was the germination rate in Super bags, which was nearly same for all trials across all locations ensuring superiority of Super bag storage over jute bags. Discolouration of seeds in Super bag was less as compared to that stored in jute bag. It implies that IRRI Super bags are suitable for lentil seed storage in room condition. The farmers who participated in the trial were convinced about the benefit of Super bags and expressed their feelings to buy those bags for seed storage. The benefitsof Super bagcompensate its comparative higher cost (Rs.120/unit) as compared to jute bag (Rs 35/unit).Moreover, to prevent rodent attack in the stacked bags, it is advised to keep clean space around the stack and maintain a space of at least 1.5 feet between the stacks and/or wall. Further field study on lentil, chickpea and wheat by the NGO, Bihar Water Development Society in district Aurangabad also confirmed and validated these results. According to the result, IRRI super bag can be considered as a suitable material for seed storage and will be adopted by farmers to store their local seed. For adoption and to create awareness of this technology proper training is required through out the state.

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