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# Effective and economic storage of pigeonpea seed in triple layer plastic bags

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ABSTRACT

Pigeonpea [*Cajanus cajan* (L.) Millsp.] seed stored in triple layer Purdue Improved Cowpea Storage (PICS) bags for eight months retained germination and seed integrity significantly better than seed stored in traditional gunny bags. PICS bags prevented major damage caused by bruchids (*Callosobruchus maculatus* F.), while grain stored in gunny bags suffered severe losses. The aflatoxin levels in stored seed were low and not significantly different between the two storage systems. The levels of $O_2$ in PICS bags artificially infested with *C. maculatus* dropped rapidly during the first month of storage while the levels of $CO_2$ increased. Even in absence of bruchids (noninfested seed) PICS bags preserved seed germination for extended periods of time better than gunny bags; possibly due to the higher and more stable relative humidity inside the PICS bags. Higher seed germination would result in improved plant stands in the field and subsequent higher yields and increased productivity. Thus, PICS bags have shown potential to positively impact the economy of pigeonpea farmers in the semi-arid tropics.



## 1. Introduction

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is a short lived (3–5 years) perennial bush legume planted often as an annual crop on 4.4 million ha in sole and intercropping systems in the semi-arid tropics of Asia, Africa and Latin America (FAOSTAT, 2011). The average yield is low (755 kg/ha, FAOSTAT, 2011), but the yield potential of the new cytoplasmic-male sterile (CMS) based hybrids could reach 4 t/ha (Saxena and Nadarajan, 2010). Pigeonpea is sensitive to photoperiod and has a wide range of maturities (from super-early to long duration) (Vales et al., 2012). Pigeonpea has high protein content (21–25%, Saxena et al., 2010) and is mainly used for human consumption as dry split peas (dal), or as immature green peas (fresh or canned). Pigeonpea has a number of additional roles in subsistence agriculture: (1) after harvesting, the plants are used as fuel and construction materials; (2) most leaves drop to the ground during the crop growth period and add organic matter to the soil; (3) the roots have rhizobia that fix nitrogen (up to 40 kg/ha) and (4) help to release bound phosphorus in the soil; (5) grain and leaves are used as feed and fodder; and (6) leaves and roots have medicinal properties (Mula and Saxena, 2010).

If pigeonpea grain is to be processed as dal, farmers typically sell it to trade dealers as soon as possible after harvest, and the trade dealers then sell it to processors. Storing the grain and selling it at a time when the prices have risen due to scarcity of dal in the market or other factors could provide an economic incentive for the farmers to store; however, their need for cash at harvest time, the lack of low-cost, effective storage systems and the potential loss to storage pests deter famers from following this alternative strategy. Healthy and undamaged pigeonpea seed is needed to plant the next crop and must be properly stored by the farmers or purchased from specialist seed growers or private companies. Because of the wide range of maturities, pigeonpea seed needs to be stored for variable periods of time (up to nine months). Bruchids (*Callosobruchus* spp.) are major storage pests of pigeonpea and other legumes and cause substantial losses (Ramzan et al., 1990; Srivastava and Pant, 1989). The level of bruchid damage is affected by the original infestation level and the storage conditions. In control treatments with an initial infestation of six pairs of adult bruchids per kg of pigeonpea seed Chauhan and Ghaffar (2002) observed 91% seed damage by 41 weeks of storage, whereas with five pairs of adult bruchids in 3 kg of pigeonpea seed Gunewardena (2002) obtained 59% bruchid damage by six months. Bruchid damaged seed (1) has no seed value (2) sells at drastically reduced prices in the markets of any developing country and (3) is totally unfit for dal making and export.

Post-harvest losses of food grain due to insects and molds have been conservatively estimated to be 10–15% (Grolleaud, 2002) and

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total grain losses due to insect pests is not uncommon. The main concerns about long term storage include (1) physical damage to the seed caused by storage pests that results in weight losses and reduction of germination together with (2) additional deterioration of seed germination and quality that result from the extended storage period. Reduction of seed germination rates will result in lower plant stands and subsequent yield reduction unless the seeding rate is increased and/or reseeding practiced. These options would increase seed and/or labor cost. Storage concerns apply not only to farmers but also to breeders and seed producers who need to preserve breeder, foundation and certified seed.

Another important concern related to storage is the accumulation of secondary metabolites like aflatoxins that are toxic to humans and animals (Bryden, 2012). Bio-deterioration of pigeonpea seed in storage due to growth of fungi, especially under high humidity and warm storage conditions (i.e., Northeast Uttar Pradesh, India) causes important losses (e.g., decrease of shelf life of stored pigeonpea seed) (Pandey et al., 2012) and health concerns. Twenty diverse fungal species from eight genera were isolated from pigeonpea seed samples from North-east Uttar Pradesh including *Aspergillus flavus*, *A. niger* and *A. terreus* (Pandey et al., 2012). A study of aflatoxin contamination in pigeonpea samples from three agro-climatic regions of Andhra Pradesh showed no aflatoxin presence in freshly harvested samples (Rajyalakshmi, 1978). After three months of storage, 20.8 per cent of the pigeonpea samples contained toxins; four per cent of these were at a level considered unsafe (above 20 μg/kg). After six months the frequency of aflatoxin contamination had further increased (Rajyalakshmi, 1978). Bankole et al. (1996) detected 32.0 μg/kg of aflatoxins in pigeonpea seed stored in jute bags for six months.

A typical practice in the semi-arid tropics to protect seed from bruchid attack involves drying the freshly harvested pigeonpea seed in the sun, usually for about four days. While this may help, there is a continuing risk of post-treatment re-infestation. Dried seed is subsequently stored in metal bins, polyethylene or gunny bags and earthen structures, with turning and the application of inert dusts (mainly ash of fire wood) and neem or castor oils (Yadav, 1997). Chemical insecticides can be used to control the storage pests, but may be hazardous, especially if the farmers do not take proper precautions in choosing them and handling them. Another concern about insecticides is that they may degrade rapidly in tropical climates because of the high temperatures and humidity. Genetic resistance to bruchids could be used as a complementary way to reduce damage caused by the pest (Jadhav et al., 2012) but it takes time to develop new cultivars with high standards of yield and quality and multiple disease resistances. Solar heating combined with the use of transparent polyethylene bags prevents losses to storage pests in cowpea (Murdock and Shade, 1991; Ntoukam et al., 1997) and beans (Chinwada and Giga, 1996). Solar disinfestation was also found to be effective in controlling bruchids in pigeonpea (Chauhan and Ghaffar, 2002; Gunewardena, 2002) without negatively affecting germination.

The storage procedures described above have been adopted by only a small proportion of farmers. There is a need for economically feasible, low labor intensive, safe (no use of chemicals) and convenient (easy to transport) storage technology that would benefit farmers and reduce losses due to damage caused by pests or reduction in germination and quality associated with long term storage. The triple-layer plastic bag called the Purdue Improved Cowpea Storage (PICS) system is an economic, simple, and effective technology used for cowpea and other grains; it greatly reduces losses to storage insects (Moussa et al., 2009). An intense outreach program to implement the use of PICS technology in Africa was initiated in 2007 (Baributsa et al., 2010). The PICS system might also serve as an alternative for storage of pigeonpea grain and seed. However, it is first necessary to establish that PICS hermetic bags are an effective, safe, and convenient alternative for pigeonpea storage. The objective of the present study is to evaluate the performance of the PICS storage bags versus the traditionally used gunny bags on pigeonpea (1) seed germination, (2) seed moisture, (3) seed coat color, (4) aflatoxin contamination, and (5) insect (bruchid) damage control over storage periods ranging from two to eight months.

## 2. Materials and methods

### 2.1. Seed

Around 650 kg of seed from the medium duration pigeonpea cultivar (pure line) Asha were obtained from a local farmer from Tandur, Rangareddy district, Andhra Pradesh, India. The seed was harvested on February 3rd, 2012 and naturally sun dried for four days with no chemicals applied. The following traits were evaluated at ICRISAT (Patancheru, Andhra Pradesh, India) where the storage experiment was conducted: (i) seed germination, (ii) seed moisture, (iii) weight of 100 seed, (iv) seed coat color, (v) aflatoxin levels, (vi) seed damage, (vii) numbers of adult bruchids, and (viii) numbers of eggs; the initial values found were used as the baseline reference.

### 2.2. Bruchids

Bruchids (*Callosobruchus maculatus* F.) were obtained from naturally field infested pigeonpea seed at ICRISAT, Patancheru, India. The population was multiplied under laboratory conditions (30 ± 2 °C) using seed from the medium duration pigeonpea variety Asha, the same variety as used in this study. These cultures were maintained in several plastic jars (15 cm × 10 cm diameter) covered with fine mesh lids to provide good ventilation. Based on the morphological characters of the freshly emerged adult bruchids, mating pairs were separated and shifted to the respective treatments using fine camel hair brushes. Sixty pairs of adult bruchids supplied the initial infestation in each storage bag (each bag containing 10 kg of seed) after which the bags were transferred to the seed storage area (ICRISAT, Patancheru, Andhra Pradesh, India).

### 2.3. Storage bags

For storage of pigeonpea we used gunny bags and PICS (Purdue Improved Cowpea Storage, http://www.ag.purdue.edu/ipia/pics/Pages/Home.aspx) bags. The gunny sacks, made from natural jute fibers, typically hold around 50–100 kg of seed and have high breathability, allowing air to pass through them. In order to prevent escape of adult bruchids we covered all the gunny bags with two 60 × 100 cm muslin cloth pollination bags. The PICS bags obtained from Lela Agro (Kano, Nigeria) consist of three non-connected bags (layers), the inner and middle layers composed of 80 μm high density polyethylene plastic (HDPE) while the outermost layer is woven polypropylene for strength. The storage bags used (gunny bags and PICS bags) were carefully inspected for stitching defects and sealing imperfections in order to ensure that good quality bags were used.

### 2.4. Experimental design

The experiment was conducted at ICRISAT, Patancheru (Andhra Pradesh, India) (17° N, 78° E) in a storage room at ambient temperature. The treatments combinations were: (1) gunny bags containing noninfested grain, (2) PICS bags noninfested, (3) gunny sacks infested as described above and (4) PICS bags infested with adult bruchids. Asha seed (10 kg) was placed in each bag. In the infested treatments, 60 pairs of adult bruchids were placed in the bags at the beginning of the experiment. The bruchids were gently