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Maintaining dryness during storage contributes to higher maize seed quality

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A B S T R A C T

Smallholder farmers in Pakistan store their seeds and grains in porous polypropylene (woven) and jute bags or in bulk. Seed stored in these containers is susceptible to fluctuating seasonal relative humidity and temperature, which promote mold and insect growth. The present study assessed the performance of Purdue Improved Crop Storage (PICS) bags for maize seed storage during a two-month period. Seed moisture content increased in polypropylene bags while it remained constant in PICS bags. No change in germination was observed in maize seeds stored in PICS bags while in polypropylene bags it was reduced in half when compared to the initial germination. Seed stored in polypropylene bags had higher insect damage with a weight loss of 35% while in PICS bags the infestation was minimal with a weight loss of about 3%. Higher aflatoxin contamination levels were observed in seeds stored in polypropylene than PICS bags. PICS bags are effective at preserving the dryness of maize seed in storage during high relative humidity conditions, which leads to maintenance of seed quality.

1. Introduction

Maize is a high-yielding cereal crop with global production of 2525.7 million tons in 2015 (FAO, 2016). Pakistan is one of the eight major maize-producing countries in Asia with 5.2 million metric tons per year (FAO, 2017). Millions of smallholder farmers in Sub-Saharan Africa and Asia are involved in maize production and depend on it for their livelihoods. Although maize consumption as animal feed is rapidly increasing in Asia, it is still an important staple food in the hill and tribal regions of Pakistan, especially Azad Jammu and Kashmir (AJK). In the AJK, more than 82% of maize production is used for human consumption and is planted on almost 41% of farmed area in the kharif (summer) season (Qureshi et al., 2002). Rosegrant et al. (2009) predicted a double increase in the demand for maize in the developing world by 2025. Increasing maize production could help address this challenge. But preserving what is produced, especially in developing countries, is equally important and would help alleviate the growing demand for maize.

Postharvest losses along the value chain from harvest to consumption results in increased prices and lost income for resource-poor farmers. Thus, sustainable agriculture not only involves producing more grains for a growing population but also to preserve what is already produced to ensure food and nutrition security. Global annual food losses amount to 1.3 billion metric tons or enough food to feed 2 billion people (FAO, 2013). In Kenya, losses of more than 30% have been reported due to insect pest infestation during the storage season (Wongo, 1996; Tefera et al., 2011). Similar situations prevail in many developing countries in Africa and Asia including Pakistan. Several insect pests e.g. *Sitophilus zeamais*, *Prostephanus truncates*, *Tribolium castaneum* and *Rhyzopertha dominica* are known to cause damage to stored grains including maize (Adams and Schulter, 1978; Tefera et al., 2011; Ng'ang'a et al., 2016; DeGroote et al., 2017). First instar larvae of grain-boring insects such as Angoumois grain moth (*Sitotroga cerealella*) and lesser grain borer (*Rhyzopertha dominica*) are known to cause invisible damage on the germ of the seed leading to loss of viability (Prakash and Rao, 1995). The infestation of grain and seed by insect pests is exacerbated by high temperature and relative humidity, which are prevalent in many developing countries. Seeds are hygroscopic as their moisture contents change in response to the relative humidity

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in which they are exposed to and thus affect the seed longevity during storage (Ellis and Roberts, 1980). Higher moisture content in dried seeds promotes the growth of insects and microorganisms that affect seed viability in storage (Murdock et al., 2012; Bradford et al., 2016). Likewise, aflatoxin-producing molds (*Aspergillus flavus*) develop at higher relative humidity and temperature, and are prevalent in stored grains in Pakistan (Abdel-Hadi et al., 2012; Ahsan et al., 2010). In warm and humid environments, aflatoxin concentrations increase rapidly if grains are not properly dried and stored (Bankole et al., 2006). Aflatoxins cause liver cancer, renal diseases, and gastroenteritis, and have also been associated with child growth impairment esophageal cancer and neural tube defects (Wu et al., 2014).

Preventing postharvest losses is a major challenge for smallholder farmers in developing countries. Hermetically sealed containers such as the Purdue Improved Crop Storage (PICS) bags have been reported to maintain quality of stored seeds and grains of more than 15 crops including cowpeas, maize, common beans, mungbeans, pigeon peas, sorghum, and several other crops (Baoua et al., 2012, 2014; Murdock et al., 2012; Mutungi et al., 2014, 2015; Vales et al., 2014; Murdock and Baributsa, 2015) against insect pests. Storage in PICS bags has helped to reduce aflatoxin contamination in maize (Williams et al., 2014; Ng'ang'a et al., 2016; Tubbs et al., 2016). Most of these studies have shown that PICS bags are able to maintain a constant relative humidity inside bags regardless of the outside environment. Therefore, the present study was conducted to evaluate the performance of PICS bags for safe maize seed storage under high summer relative humidity in farming communities of Pakistan.

2. Material and methods

2.1. Experimental details

This study was conducted for about two months (from June 8 to August 4, 2015) in farmers' storehouses in the Kotli district of Azad Kashmir, Pakistan. Storehouses are used by farmers to keep their produce for domestic consumption and seed for planting. Relative humidity and temperature data were hourly recorded during the experiment using a data logger (Rhino Research Thailand) placed in a corner of the storehouse. Locally produced maize seeds of cultivar “Sarhad White” were used during this study. Completely Randomized Design (CRD) was used for this experiment and each experimental unit was replicated thrice. PICS bags of 50-kg capacity were provided by the Purdue's Afghanistan Agricultural Extension Project (AAEP II) from Herat, Afghanistan. The bags were cut into smaller size due to small quantity (10-kg) of seed used in this experiment.

2.2. Seed storage and sampling

Maize seed (10-kg each bag) was stored in PICS and polypropylene (woven) bags at ambient storage conditions of the storehouse. Data Loggers (Centor Thai, Rhino Research Group, Thailand) were used to collect data on Relative Humidity (RH) and temperature of the storehouse for the duration of the experiment. At the end of the experiment, 1-kg seed samples were taken to assess storage losses and aflatoxin contamination.

2.3. Determination of seed moisture contents and germination

Seed moisture content was determined using the protocol developed by International Seed Testing Association (ISTA, 2015). Low constant temperature method was applied by drying grinded sample of 5 g maize seed in an oven at 103 °C for 17 h. Seed germination was tested by placing four replicates of 100 seeds, from randomly drawn seed samples, in sterilized and moistened blotting paper in a germinator (SANYO Japan, MIR-254) at 25 °C (ISTA, 2015). Seeds were scored germinated when radicle protrusion was visible.

Germination index (GI) was calculated as described by the Association of Official Seed Analysts (1983) using formula

$$GI = \frac{\text{No. of germinated seeds}}{\text{Days of first count}} + \frac{\text{No. of germinated seeds}}{\text{Days of final count}}$$

Root and shoot lengths were measured 15 days after sowing. Germination energy (%) was recorded by counting the number of seedlings germinated the fourth day after the start of germination.

2.4. Assessment of losses due to insects

At the beginning of the experiment, maize seed was clean and appeared not infested. No assessment of insect infestation was done. At the end of the experiment, randomly drawn 2-kg samples of stored maize seed were sieved to separate grain and insects. Live insects were sorted by species and then counted manually for assessment of live insect populations. Damaged grains and grains with damaged embryos were counted. Percent weight losses were estimated using the equation of Adams and Schulter (1978).

$$\text{Percent weight loss} = \frac{Und - DNu}{U(Nd + Nu)} \times 100$$

where “U” represents weight of undamaged grain, “D” is the weight of damaged grain, “Nd” is the number of damaged grain and “Nu” is the number of undamaged grain.

Grains with damaged embryo (%) were estimated by separating the damaged grains from those having intact embryo using the following equation:

$$\text{Grains with damaged embryo (\%)} \frac{\text{Grains with damaged embryo}}{\text{Total number of grains}} \times 100$$

2.5. Determination of aflatoxin contamination

Fifty (50) grams of thoroughly milled grains were used for aflatoxins B_1 and G_2 analysis. Aflatoxins B_1 and G_2 were purified with Vicam Afla B_1 and G_2 HPLC columns following standard procedures developed by the manufacturer and mobile phase was analyzed on Shimadzu HPLC (Shimadzu Scientific Instruments, Inc. Kyoto, Japan). Aflatoxin levels were quantified by comparing the B_1 and G_2 peaks with the standards (range 1–50 ppb) prepared by Sigma Chemical Corporation St. Louis, MO.

Data collected on different parameters were analyzed using analysis of variance technique by statistical package Statistix-10 (Tallahassee, FL, USA). Least significance difference (LSD) test at 0.05 probability level was used to compare the treatment means.

3. Results

3.1. Environmental conditions during the experiment

Hourly relative humidity as well as temperature data were averaged for each day (Fig. 1). The average RH varied significantly with a minimum of 43% on June 12, 2015 and a maximum of 87% on August 2, 2015 (Fig. 1). There was an increasing trend of RH from