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Triple bag hermetic technology for post-harvest preservation of Bambara groundnut (*Vigna subterranea* (L.) Verdc.)

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ABSTRACT

Experiments were conducted to evaluate the performance of hermetic triple bagging using Purdue Improved Crop Storage (PICS) bags for storage of Bambara groundnut (*Vigna subterranea* (L.) Verdc.). One set of experiments used grain heavily infested by *Callosobruchus maculatus* (F.) while a second set began with a low level infestation. Each experiment consisted of *V. subterranea* grain kept in four replicate 50 kg PICS bags or two replicate woven bags as controls. Two to five days after the beginning of the experiments, oxygen level inside the bags averaged about 21% (v/v) in the controls but decreased significantly in PICS bags, reaching 10% (v/v) with the heavily infested grain but falling only slightly in the lightly infested grain. After 7 months of storage, (i) the number of *C. maculatus* adults found between and within the grains, (ii) the 100 seed weight, (iii) the number of seed with holes, and (iv) the percentage germination of grain stored in PICS bags did not differ from what had been measured on the day that the experiment was set up. In woven bags, by contrast, there was a massive increase in *C. maculatus* numbers with means of 309 and 251 adults per 500 g in heavily and lightly infested grain, respectively. Grain weight losses in the woven bag controls ranged from 8 to 19% and the percentage of *C. maculatus* emergence holes per 100 seed increased from 51 to 135%.

1. Introduction

Bambara groundnut, *Vigna subterranea*, is a legume rich in carbohydrates, proteins and lipids (Owusu-Domfeh et al., 1970; Linnemann, 1987) and is used in sub-Saharan Africa for food. In the Sahelian zone, Bambara groundnut is cultivated generally in small areas, mainly by women (Drabo et al., 1997; Hamidou, 2005). Niger is the second largest producer in West Africa after Burkina Faso (FAOSTAT, 2010). In 2011, Bambara groundnut production in Niger was estimated at 22,470 tons, 64% of it concentrated in the Dogondoutchi area in the central and southern part of the country (Anonymous, 2011). The crop is consumed and sold in markets in the region and is stored in the same way as cowpea; it commands a relatively high price in the dry season long after harvest. According to recent data, the average cost per kilogram increased from 265 CFA at harvest time in September 2011 to 439 FCFA in April 2012, an increase of 66% after 7 months of storage (SIM Niger, 2011, 2012). Bambara groundnut can contribute to food security and poverty alleviation in the Sahel, but long term storage is a constraint because of the bruchids *Callobruchus maculatus* and *Callosobruchus subinotatus* (Pic) (Begemann, 1986; Lale and Vidal, 2001). *C. maculatus* is the species of greater concern because it reproduces faster than *C. subinotatus* (Keals et al., 1998; Lale and Kolo, 1998; Rees, 2004; Swanevelder, 1998; Lale and Vidal, 2001). Bruchids penetrate and consume the seeds causing both weight loss and low germination rates (Munthali and Sondashi, 2004; Maina et al., 2006).

Several methods have been recommended for long term storage of Bambara grain without using insecticide : i) solar disinfestation (Lale, 1998; Lale and Vidal, 2000, 2003; Lale and Ajayi, 2001); ii) mixing with ash or sand (Kitch and Ntoukam, 1991; Wolfson et al., 1991; Baoua et al., 2012a); iii) treating the grain with extracts of cashew *Anacardium occidentale* (L.) (Oparaeke and Bunmi, 2006), chili pepper *Capsicum frutescens*, splinter and onion leaves (Ofuya, 1986), and storage with essential oils of *Sysgium armaticum*, chili *Piper guinensis* and ginger *Zingiber offinale* (Ajayi and Lale, 2001). Most of these methods are useful only for small amount of grains. Bambara is a major cash crop for women in Niger. To improve storage and marketing of Bambara grain, there is a need for technology applicable to larger amounts. In the western part of Niger,

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hermetic bags have been tested for Bambara groundnut storage with a reported profit margin of 528% (GrainPro, 2011). The use of hermetic Purdue Improved Cowpea Storage (PICS) has recently become widespread in Sub-Saharan Africa (Baributsa et al., 2010; Baoua et al., 2012b). Extension and supply chain activities have been implemented in ten countries across West and Central Africa to call attention to the technology and make it available to farmers. The present study was designed to assess the performance of PICS bags for the preservation of Bambara groundnut grain. The results should contribute to the development of Bambara groundnut value chain sector in the Sahel.

2. Materials and methods

Experiments were carried out with naturally infested Bambara groundnut at the INRAN entomology laboratory in Maradi, Niger. All studies were done at ambient room temperature, which ranged from 28 to 39 °C, and ambient relative humidity (5–30% rh). Grain moisture content was 6–8%. The PICS 50 kg triple-bags used were manufactured by Lela Agro (Kano, Nigeria). PICS bags consist of two separate high-density polyethylene (HDPE) inner bags with 80 μm wall thickness, one fitted inside the other, and both of which are enclosed in a woven polypropylene bag to enable handling.

Grain was purchased locally and thoroughly mixed to create a uniform infestation. Two categories of grain were purchased: (1) heavily infested Bambara groundnut with more than 30% of the seed already having holes and harboring a high population of bruchids, and; (2) lightly infested seed with little evidence of bruchid infestation. Grain was purchased from farmers who had not used chemicals on the grain. For each experiment, all units of each treatment were set up on the same day. Replicate treatments were held on pallets in the laboratory for the duration of the experiment.

Two treatments were used for each type of grain: 1) PICS bags filled with 40 kg of Bambara grain in four replicates, and; 2) a control of woven polypropylene bags filled with 40 kg in two replicates. Descriptions of how the PICS technology is used is available in several languages on the PICS website (http://www.ag.purdue.edu/ipia/pics).

The experiment with heavily infested grain was initiated on 15th January and terminated on 15th August 2012. The experiment with the lightly infested grain was conducted from 3 March to 3 October 2012,

The initial infestation level in the Bambara groundnut lot was determined by randomly collecting three separate samples of 500 g of grain per bag. Each sample was sieved to separate and count dead and living adults. Pupae were counted as adults. One hundred seeds were picked randomly from each sample and soaked in water for 24 h to soften them. The water-imbibed seeds were cracked and opened to count the living as well as the dead and desiccated larvae. After seven months, the bags were opened to evaluate the degree of bruchid infestation, damage level and any effects of storage on germination. Oxygen and CO_2 concentrations in each bag were determined using a Mocon PAC Check® Model 325 Headspace analyzer (Mocon, Minneapolis, MN). Measurements were made daily at 12:00 M local time (GMT + 1) over the first 20 days. One hundred seeds from each treatment were selected randomly for the germination tests, which were conducted in the field. For each treatment 4 rows of 25 seeds were sown. The plot was watered daily and the number of germinating seeds recorded 7 days after sowing. At the end of the experiments, the two inner HDPE liners were examined to determine the number of holes made by bruchids and inspected for other physical changes.

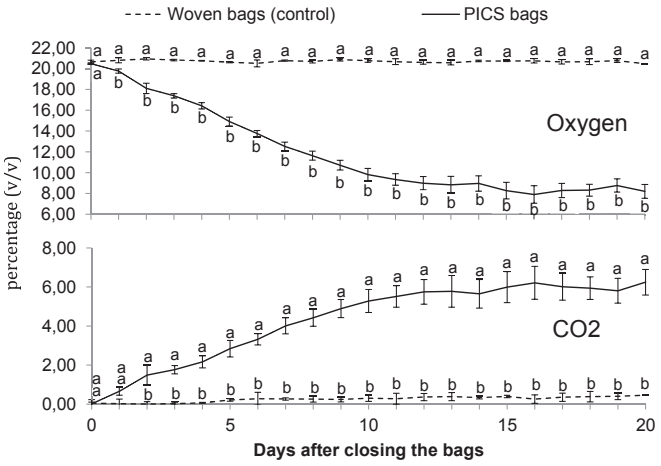

Fig. 1. Daily variation of oxygen and carbon dioxide levels in triple bags and woven bags filled with highly-infested Bambara groundnut *Vigna subterranea*. Points represent mean values ± S.E.M.

Means of different treatments were compared using Analysis of Variance (ANOVA) followed by LSD tests. Statistical analysis was done with Statistical Package for the Social Sciences (SPSS) version 17.0, IBM Inc. (Chicago, Illinois).

3. Results

Oxygen levels associated with the heavily infested grain already differed significantly between treatments one day after closing the bags, showing means of 19.8 ± 0.2% by volume (v/v) for PICS bags and 20.8 ± 0.2% (v/v) for the control ($t = 3.16$; $df = 4$; $P < 0.05$). At the 20th day (Fig. 1) it reached 8.2 ± 0.7% (v/v) for PICS bags versus 20.5 ± 0.0% (v/v) for the control ($t = 12.43$; $df = 4$; $P < 0.001$). CO_2 levels differed between treatments on the second day after closing the bags with an average of 1.5 ± 0.2% (v/v) for PICS bags and 0.0 ± 0.0% (v/v) in the control treatments ($t = 3.78$; $df = 4$; $P < 0.05$). On the 20th day CO_2 levels were 6.2 ± 0.2% (v/v) in PICS bags and 0.5 ± 0.1% (v/v) in the controls ($t = 24.21$; $df = 4$; $P < 0.001$). In the lightly infested grain, the oxygen levels differed between the two treatments four days after the beginning of the experiment with a mean of 20.6 ± 0.0% (v/v) for the PICS bags and 21.1 ± 0.0% (v/v) for the controls ($t = 9.14$; $df = 4$; $P < 0.01$). On the 20th day oxygen levels averaged 19.8 ± 0.2% (v/v) in PICS bags and 21.1 ± 0.0 (v/v) in

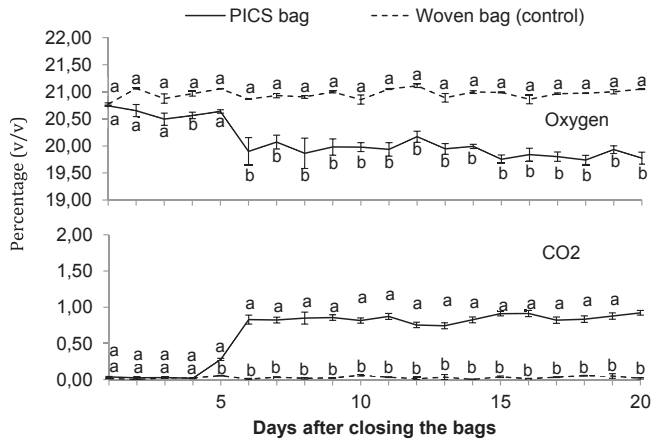

Fig. 2. Daily variation of oxygen and carbon dioxide levels in triple-layer PICS bags and woven bags filled with lightly infested Bambara Groundnut *Vigna subterranea* grain. Values represent means ± S.E.M.