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Hermetic storage with plastic sealing to reduce insect infestation and secure paddy seed quality: A powerful strategy for rice farmers in Mozambique

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ABSTRACT

Rice is the world's most important staple food and the basis of the diet of the majority of the population. In small farm agriculture, the yields obtained in cereal production are usually low and losses, both in the field and during storage, are dramatically high, particularly in developing countries. In Mozambique, these aspects, together with an increased frequency of floods, are hindering advances in rice production. Aimed at contributing to the reduction of losses in stored rice, trials were carried out to compare the effectiveness of traditional raffia bags and of hermetic storage using single and double plastic bags concerning quantitative losses and seed quality, including germination potential, after three and six months of storage. Pest identification, insect populations estimates, percentage of weight loss, germination power and seedling vigor were evaluated. The results showed that, in descending order of density, Angoumois grain moth (*Sitotroga cerealella* Olivier), lesser grain borer (*Rhyzopertha dominica* F.), rice/maize weevil (*Sitophilus zeamais* Mostch. and *Sitophilus oryzae* L.) and red flour beetle [*Tribolium castaneum* (Herbst)] were the main insects infesting the rice. When compared to hermetic storage with both single and duplicate airtight bags, traditional storage presented statistically significant higher mean infestation density (30.63–53.94 individuals/kg in traditional and 0.71–3.50 individuals/kg in hermetic storage) and percentage of weight loss (3.03–3.44% in traditional contrasting with 0.27–0.47% in hermetic conditions). In traditional storage a significant 38.25% drop in the germination potential was also observed, attaining values below the established minimum tolerated in Mozambique (80%), while under hermetic storage, that reduction remained within the acceptable values of 13.9–17.5%. The distinct storage methods did not produce significant differences on the moisture content of the grain. These results demonstrate that the use of hermetic storage has resulted in a safe, pesticide-free, and sustainable storage method, suitable for rice seeds, with advantages over traditional bagging. The results presented here lead to propose hermetic storage to be adopted by paddy small farmers, in order to lever food security and income generation in the country.

1. Introduction

The fact that the quality of rice in tropical regions, both for seed and grain, can only be maintained for a short period of time in traditional open storage systems stands as a food security problem and, in some countries, hampers the popularity of this crop among small farmers. Poor drying techniques and storage infrastructure conditions, together with very high relative humidity (r.h.) and temperature regimes during the storage period are the most important factors that contribute to the development of molds, increased insect activity and higher respiration of the grain, leading to losses that can reach 10–15% of the total production (Rickman and Aquino, 2007; FAO, 2010). However, drying to proper moisture levels is not sustainable from the economic point of view for farmers in developing countries and, even when the grain is kept under acceptable moisture levels, important production losses still occur due to the attack of insects, rodents and birds (Rickman and Aquino, 2007). Most small farmers in Africa store their grains in

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traditional granaries which are flawed by structural and functional inadequacies, calling for an improvement of these structures in a process that must take into consideration the availability and access of the technologies by the farmers. Methods of preservation of grains at intermediate moisture levels under hermetic storage conditions emerge as a feasible and cost-efficient strategy to be adopted in warm and moist climates (Ellis and Hong, 2007). Farmers who use improved granaries experience less pest damage in storage and are encouraged to convince other members of their community to do the same (Nukenine, 2010).

In Mozambique, the total area with potential for producing rice is estimated to be about 900,000 ha, of which only about 200,000 ha are currently being cultivated (MINAG, 2008). About 90% of the cultivated area is located in the provinces of Zambezia and Sofala, in the lowlands of the center of the country. In the north, the provinces of Nampula and Cabo Delgado share 7% of the total rice production in suitable areas, and the remaining 3% is grown in the south of Mozambique, mainly in the Gaza province (MINAG, 2008). Rice production has increased steadily over the last 16 years: in 1994/1995 the national production reached 113 thousand tons while in the 2010/2011 campaign, the registered production was 192 thousand tons and during 2012, the total output reached a record 343 000 tonnes (229 000 tonnes, milled basis) (FAO, 2012a, 2013). According to Muendane et al. (2000) and Zandamela (2004), this increase was due to an expansion of areas of production and only a slight increase in the culture yield achieved with cultural practices, which is currently ca. 1 ton/ha. The current amount of production cannot satisfy the estimated national annual need of ca. 450,000–550,000 tons. This national deficit results in the country spending a large amount of income on imports from abroad, to satisfy the nutritional need of the population.

In Mozambique, particularly in rural areas, a large part of the rice produced by small farmers is traditionally stored in raffia bags and in barns. The permeable characteristics of raffia bags do not prevent the establishment of pests under the environmental conditions of high temperature and humidity, and the damage caused to the grain impacts its amount and quality (Hayma, 2003). Thus, in addition to the low productivity, Mozambique also suffers post-harvest rice losses, reducing the interest of this crop to small scale family farmers (Fujisaka et al., 1996).

Manipulation of the atmospheric composition for the protection of dry stored products, such as grains, has been extensively and continuously researched for more than 50 years (Adler et al., 2000; Calderon and Barkai-Golan, 1990; Jay, 1984; Navarro et al., 1994; Navarro, 2006; Yakubu et al., 2010). The use of plastics in hermetic storage is a relative cheap method and hermetic storage itself reduces the need of insecticidal or fumigation treatments, with important economic and environmental advantages. Hermetic storage isolates the ecosystem, preserving the product from the external environment while O_2 reduction and CO_2 accumulation are promoted due to the continuing respiration of the product, leading to a reduced reproductive capacity of weevils and their eventual suffocation (Navarro et al., 1994). The CO_2-rich versus O_2–poor atmosphere also reduces the development of aerobic fungi, mycotoxins and grain metabolic activity resulting in a reduction of oxidation, favoring preservation (Faroni et al., 2009; Dos Santos et al., 2012). In developing countries, hermetic storage, a modified atmosphere-based technology, can be a cost-effective storage solution at farmer level, keeping the grain safe from insect infestation, while maintaining an acceptable germination potential (Mantovani et al., 1986; Rickman and Aquino, 2007; Villers et al., 2008; Navarro et al., 2012; IRRI, 2013), hence helping to protect farmers from seasonal fluctuations in grain prices and grain availability (Navarro et al., 1994). This technology has been implemented commercially in the form of grain bags outside Europe, or sealed bunker storage in Australia, United States of America and countries from the Middle East. Based on these previous successful cases, the present work aimed at evaluating the effectiveness of adopting airtight plastic bag storage of rice and comparing it with storing solely in traditional raffia bags, the usual method used by rice farmers in the Maputo province of Mozambique to preserve their seeds and to store the grain for up to six months. The results obtained will assist decision making regarding moving from traditional approaches to more effective and also cost-effective hermetic methods, thus making this alternative available for rice farmers and associated mills.

2. Material and methods

2.1. Paddy variety and origin

The experiments were conducted using the "ITA 312" variety, which is one of the most widely used by rice farmers in the Maputo province, Mozambique, under irrigation. The paddy was obtained from the rice mill 'Inácio de Sousa, Lda', located in Palmeira, also in the Maputo province. Grains were transported to the Umbelúzi Agricultural Station of the Institute for Agrarian Research of Mozambique (IIAM), where the experimental work was conducted.

2.2. Treatments and experimental design

The trial was carried from January 4th to July 4th, 2013. This six month period corresponds to the average storage time of rice in the country. The assay was carried out in a 35 m^2 previously cleaned room.

To evaluate the efficacy of hermetic storage, super bags (both single and double plastic from GrainPro Phils, Philippines) where compared with the traditional on-farm storage using only 50 Kg raffia bags. It should be noted that super bags were also protected with raffia bags (Fig. 1). For each of the three treatments i) Control (C): traditional raffia bag; ii) airtight Simple (S); and iii) airtight Double (D), eight lots of 20 kg paddy were prepared to stand for four replications per treatment/time. Hence, four lots were stored for three months and the remainder was maintained for six months.

2.3. Sampling

At the end of the third and sixth months, a composite 1 kg portion of rice from each treatment/replicate was sampled and used for determination of the degree and type of insect infestation, seed vigor and extent of losses. Samples were taken from the four cardinal points at the top and bottom position as well as in the periphery and center of the bags, using the methodology recommended by Mathur and Kongsdal (2003), thus obtaining subsamples, which were then mixed to obtain the composite sample of about 1 kg.

2.4. Grain moisture and temperature monitoring

Temperature and r.h. were recorded during the storage period using a hygrometer (HOBO©CIDADE; PAÍS) with a precision of $\pm 1^\circ$ C for temperature, and ±5% for r.h. Moisture content was determined according to the ISO-712:2009 Cereals and cereal products – Determination of moisture content – Reference method. Two subsamples of 5 g per replicate were assayed before and after hermetic experiments.