Quality evaluation of paddy seed used at Chókwè and Macia, Mozambique, and the use of hermetic storage as a convincing approach for rice farmers

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Abstract

The low quality of rice in Mozambique is often related to seed origin, certification, selection and storage. The plants often suffer from low seedling vigor, poor growth, non-uniform height and maturity, are prone to insects and disease pests, and show inability to withstand adverse weather conditions at early stages of growth. Experiments were conducted from October to December 2012 to assess the physical, physiological and phytosanitary conditions of rice seeds used during the 2012/13 season by farmers from the districts of Chokwe and Macia, in the Gaza province of Mozambique. To compare the quality of the seed of rice varieties with its location, certification and type of storage, 80 samples were collected between certified and non-certified seed for five varieties (ITA 312, IRGA 417, MAKASSANE, LIMPOPO, OM2514) and seeds of unknown origin, stored using raffia bags of 50 kg. Physical purity, moisture content, germination, vigor and identification and incidence of fungi were evaluated. In addition, trials were conducted to compare the effectiveness of traditional storage (using raffia bags) and of hermetic storage concerning quantitative losses and seed quality, after three and six months of storage. The results showed that the Limpopo variety displayed the highest percentage of germination (95.75%) and ITA 312 the lowest germination (73.85%). The value observed in this later variety is below the minimum (80%) required by Regulation on Production, Sales, Quality Control and Certification Seed Mozambique, and was rejected as seed and used as grain for consumption. No significant differences were observed between the germination of the certified (81.64%) and uncertified seed (80.38). Under traditional storage, a significant 38.25% drop in the germination potential was observed, attaining values below the established minimum tolerated in Mozambique, while under hermetic storage, it dropped 13.9-17.5%, remaining within the acceptable values. The purity of the seed was above the minimum required (98%) in all treatments while the moisture content of the grain was not significantly different when paddy origin, varieties, certification or storage method were analyzed. The contaminating fungi were in the genera *Alternaria*, *Bipolaris*, *Curvularia*, *Exserohilum*, *Fusarium*, and *Phoma* are associated with the rice field and *Aspergillus*, mainly *A. flavus* associated with storage. The incidence of field fungi decreased significantly during storage in all methods while *A. flavus* increased significantly under either traditional or hermetic conditions. Angoumois grain moth (*Sitotroga cerealella* Olivier), lesser grain borer (*Rhyzopertha dominica* F.), rice/maize weevil (*Sitophilus zeamais* Mostch. and *S. oryzae* L.) and red flour beetle [*Tribolium castaneum* (Herbst)] were the main insects infesting the rice. When compared to hermetic storage, in traditional storage, a statistically significant higher mean density (30.63-53.94 individuals/kg in traditional and 1.08-3.50 individuals/kg in hermetic storage) and percentage of weight loss (3.03-3.44% in traditional contrasting with 0.29-0.31% in hermetic conditions) was observed.

Keywords: seed quality, fungi, insect, hermetic storage, food security

1. Introduction

Rice is the worlds' most important staple food and the basis of the diet of the majority of the population. In Mozambique, from a potential area of 900,000 ha to produce rice, only about 200,000 ha of rice are produced (MINAG, 2008). About 90% of that area is located in the center, in the provinces of Zambezia and Sofala, where rice is cultured in valleys. About 7% of the appropriate area of rice production is located in the north, in Nampula and Cabo Delgado provinces, and the remaining 3% is in the south of Mozambique, mainly in the Gaza province (MINAG, 2008). Rice consumption in Mozambique has been increasing rapidly from 86,000 tons in 1990 to 519,000 tons in 2010 at an annual growth rate of 8.6% (USDA, 2011). About 90% of the rice area is classified as rain-fed lowland ecology, while irrigation accounts for only 3% (Seck et al., 2010). Paddy yield has stagnated at around 1 ton/ha for the last three decades. Food loss has many negative economic and environmental impacts, including reduced farmer income and increased consumer expenses (Lipinski et al., 2013). This results in large expenditures to import rice to satisfy demand.

The low quality of rice production in Mozambique is related to growing conditions, selection, and storage. The plants often suffer from low seedling vigor, poor growth, non-uniform height and maturity, are prone to weeds, insects and disease pests, and show inability to withstand adverse weather conditions at early stages of growth. Particularly in rural areas, a large part of the rice produced by small farmers is traditionally stored in raffia bags or/and in barns. The permeable characteristics of raffia bags allow establishment of pests and thus impacting grain quantity and quality (Hayma, 2003). In addition to the low productivity, Mozambique also experiences quality and quantity loos during storage (Fujisaka et al., 1996). Our approaches to reduce loss are: correlating the quality of the seed of rice varieties with its location, certification and type of storage. During storage we identified the noxious agents that can reduce seed quality/quantity (fungi and insects) and we compared traditional and hermetic storage in order to maintain the seed quality/quantity.

2. Materials and Methods

2.1. Identification the quality of the seed of rice varieties with its location and certification

Trial were carried out from October to December 2012, and 80 seed samples of 1 kg from different varieties and origins were taken from Farmers in the districts of Chókwè and Macia in Gaza Province (Table 1).

2.2. Identification the quality of the seed of rice varieties and type of storage

Experiment was carried from January 4th to July 4th, 2013. This six months period corresponds to the average storage time of rice in the country. The assay was conducted in a 35 m^2 previously cleaned room (Guenha et al., 2014). To evaluate the efficacy of hermetic storage, super bags (GrainProPhils, Philippines) where compared with the traditional on-farm storage, raffia bags, both with a capacity of 50 kg. Super bags were also protected with raffia bags. For each treatments for replications of (i) Control (C): traditional raffia bag); ii) hermetic storage (H): super bags and 20kg paddy ITA 312 variety were prepared per treatment and maintained for six months. At the end of the sixth month, 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 and fungi, seed vigor and losses extend. 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).

Table 1 Number of seed samples collected by provenience, type of seed and seed variety.

			Number of samples	**%**
Region				
	Chókwè		53	66.25
		Chilembene	8	
		Massavasse	20	
		Conhane	13	
		Sede (PZ,D6,D4 & ZV)	12	
	Macia		27	33.75
		Mangol	18	
		Xithango	7	
		Chissano	2	
Total			80	100
Seed origin				
	Produced by farmer		63	78.75
	certified		16	20
	Without information		1	1.25
Total			80	100
Seed Variety				
	ITA 312		35	43.75
	IRGA 417		26	32.5
	MAKASSANE		2	2.5
	LIMPOPO		4	5
	OM2514		1	1.25
	Unknown		11	15
Total			80	100

2.3. Grain moisture and temperature monitoring

Temperature and relative humidity were recorded using a hygrometer (HOBO©) with a precision of ± 1°C for temperature, and ± 5% for relative humidity. Moisture content was determined according to the ISO-712:2009 Cereals and cereal products - Determination of moisture content - Reference method.

2.4. Identification and incidence of fungi, insects, and damage estimates

After we identified the fungi species, we counted the % of infected seeds and quantified that

Percentage using the formula $Im = \frac{\Sigma I}{n}$, where: *Im*-average Incidence of species of fungi; $\Sigma\ I$ – sum of the incidence of species of fungus; and *n*-samples evaluated. Insects were collected from each 1 kg composite sample, identified using standard approaches and counted to determine the mean number of insects and species per kg *Weight Loss* due to insect activity was assessed using the variant *count and weigh method* proposed by Adams and Schulten (1978). Each test was done employing four replicates of 100 seeds per replicate, taken at random from the sample of work. The weight loss and damaged grains percentages were calculated using the following equations:

$$\%\ weight\ loss = \frac{(a \times d) - (c \times b)}{a \times (d + b)} \times 100$$

$\%\ damaged\ grains = \frac{d}{e} \times 100$,

Where *a* is the weight of undamaged grains; *b* the number of undamaged grains; *c* the weight of damaged grains; *d* the number of damaged grains; and *e* the total number of grains.

2.5. Seed germination capacity and vigor

Standard germination tests for control and treated seeds were carried out according to the International Seed Testing Association (2002) procedures to evaluate the effect of each treatment on seed germination capacity. The working samples were counted in a factorial Completely Randomized Design of 100 seeds in each replication, in a total of 400 pure seeds for each treatment. Seedling vigor was determined based on two counts: the first one was undertaken at 5th day and the second count at 14th day. In each date, the number of normal, abnormal and non-germinated seeds was recorded. Germination was calculated according to the formula: $P(\%) = \frac{Y}{Z} \times 100$, where *P* (%) is the percentage of germination; *Y* the number of normal seedlings; and *Z* the total number of seeds analyzed. Seed viability was further estimated according to the electrical conductivity (EC) test (Rodo, 2002). Fifty previously weighed seeds, in each replication, were immersed in 75 ml of distilled water, remaining in the incubator for 24 hours at room temperature and covered with aluminum foil (Rodo, 2002). After this period the reading of EC with a conductimeter (CrisonMainceri-Tech, Cidade, País) was performed and the results expressed as µS.cm-1g-1.

2.6. Data analysis

For quality of the seed of rice varieties with its location, and certification two Non-Parametric ANOVA several methods were used: (a) KRUSKAL-WALLIS: to compare several means and evaluate more than two treatments (groups); and (b) MANN-WHITNEY to compare several means and evaluate two treatments (groups).For Quality of the seed of rice and type of storage, Two-way Factorial ANOVA and TUKEY'S HSD mean separation test CORRELATION Pearson Product-Moment Correlation Coefficient (Pearson's r).All tests were worked under 0.95% confidence limits.

3. Results and Discussion

3.1. Quality of the seed of rice varieties with its location and certification

Tables 2 and 3 present the list offungi identified and compared the incidence of seeds produced by region and seed type, and by farmer and certified seed. The most frequent were *Alternaria padwickii* (Ganguly) M.B. Ellis, *Aspergillus flavus* Link and *Fusarium moniliforme* J. Sheld. The District of Chókwè had better fewer incidence of fungi than Macia district (Table 2). The certified seeds were in better sanitary conditions than those produced by farmers (Table 3).

Table 2 Fungi identification and incidence by region.

Fungi	Gaza region	
	Chókwè	**Macia**
Alternaria padwickii (Ganguly) M.B. Ellis	**2.89 b**	**3.04 a**
Aspergillus flavus Link	3.83 a	2.86 a
Bipolaris oryzae (Breda de Haan) Shoemaker	2.07 a	1.77 a
Curvularia lunata (Wakker) Boedijn	**1.03 b**	**5.14 a**
Curvularia oryzae Bugnic.	**0.87 b**	**1.32 a**
Exserohilum rostratum (Drechsler) Leonard & Suggs	0.19 a	0.34 a
Fusarium moniliforme J. Sheld.	**13 a**	**9.1 a**
Nigrospora oryzae (Berk. & Broome) Petch	0.35 a	0.58 a
Phoma sorghina (Sacc.) Boerema, Dorenb. & Kesteren	4.67 a	5.64 a
Pyricularia oryzae Cavara	1.48 a	3.38 a

For each parameter - means followed by different letters are significantly different ($p \leq 0.05$) (Mann-Whitney).

Table 3 Fungi identification and incidence: seeds produced by farmer vs certified.

Fungi	Seed origin	
	Farmer production	**Certified**
Fusarium moniliforme J. Sheld.	**13.22 a**	**6.78 b**
Alternaria padwickii (Ganguly) M.B. Ellis	**3.32 a**	**1.44 b**
Bipolaris oryzae (Breda de Haan) Shoemaker	1.55 a	2.31 a
Aspergillus flavus Link	3.27 a	4.53 a
Phoma sorghina (Sacc.) Boerema, Dorenb. & Kesteren	4.89 a	5.63 a
Exserohilum rostratum (Drechsler) Leonard & Suggs	0.22 a	0.31 a
Pyricularia oryzae Cavara	2.45 a	0.63 a
Curvularia lunata (Wakker) Boedijn	2.65 a	1.16 a
Curvularia oryzae Bugnic.	0.43 a	0.69 a
Nigrospora oryzae (Berk. & Broome) Petch	0.54 a	0.38 a

For each parameter - means followed by different letters are significantly different ($p \leq 0.05$) (Mann-Whitney).

Figure 1 shows the percentage of seed germination and vigor (measured by electrical conductivity) comparing the results between the two regions, by certified /not certified seed and by variety. In Chókwé the seeds showed less vigor as well the seeds produced by the farmer. Limpopo variety presented the bests results although very few samples were taken.

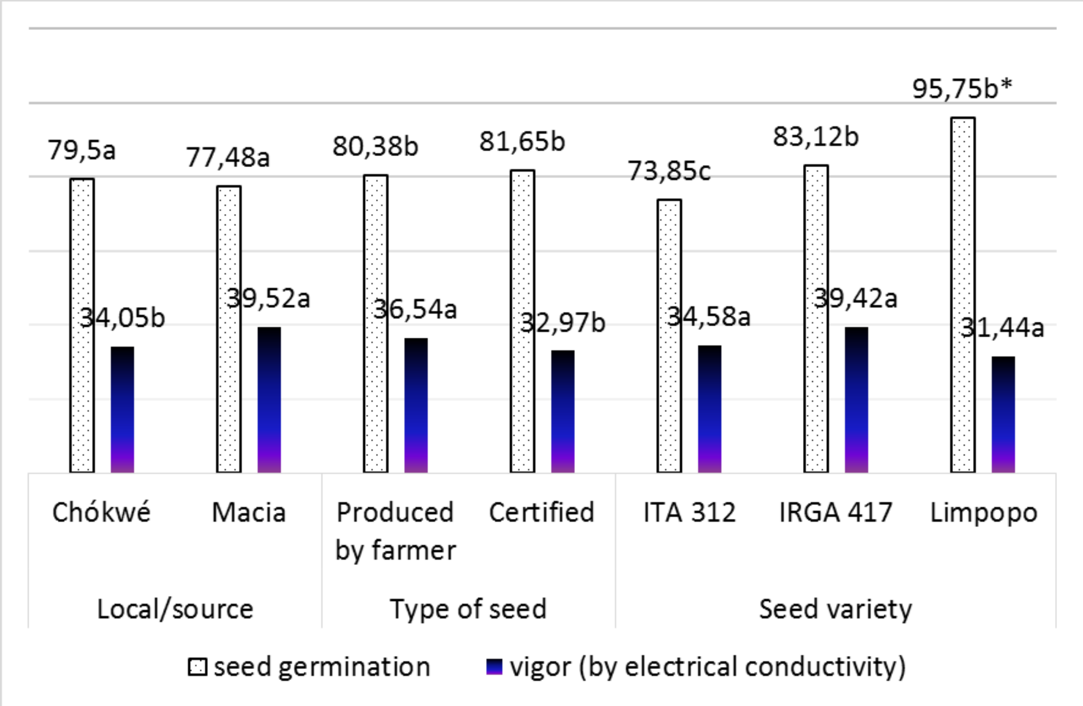

Figure 1 Percentage of seed germination and vigor (measured by electrical conductivity) comparing source, certified /not certified and by variety.

3.2. Identification the quality of the seed of rice and type of storage

The mean moisture increase slightly but didn't differ meaningfully before and after six months storage and type of storage (Table 4) (Guenha et al., 2014).

Table 4 Mean moisture content before after storage using traditional and hermetic bags.

Type of storage	**Storage (months)**	
	0	**6**
Traditional	11.96±0.04 Aa	12.68±0.22 Aa
Hermetic single	11.96±0.04 Aa	12.18±0.23 Aa

* For each parameter - means followed by different letters (upper in column and lower in line) are significantly different (p≤0.05) (capital letter ↓) (lowercase letter →)

Table 5 presents the all fungi identified and compared the incidence before and after six months storage and between traditional and hermetic storage. Only fungi associated to storage as *Alternaria padwickii* and *Aspergillus flavus* increased with storage either traditional or hermetic.

Figure 2 shows the total of insects by species per kg under different types of storage after 6 months of storage. The species identified in dominance order were: angoumois grain moth [*Sitotroga cerealella* (Olivier) (Lepidoptera, Gelechiidae) (811 adults), lesser grain borer [*Rhyzopertha dominica* F. (Coleoptera, Bostrychidae)] (521 adults), rice/maize weevil [*Sitophilus* spp. (Coleoptera, Curculionidae) (109 adults) and red flour beetle [*Tribolium castaneum* (Herbst) (Coleoptera, Tenebrionidae)] (35 adults). The overall results show a marked decrease of infestation in rice under hermetic storage in comparison with traditional raffia bags. In fact, under traditional storage, 811 angoumois grain moth were caught, while after six months under hermetic storage none (Guenha et al., 2014).

Table 5 Incidence of fungi associated to stored rice before and after 6 months of storage.

Fungi	**Type of Storage**	**Time of storage (months)**	
		0	**6**
Alternaria padwickii	Traditional	10.1 A	15.3 Ca
	Hermetic	10.1 A	14.3 Aa
Aspergillus flavus	Traditional	2.3 A	29.4 Ca
	Hermetic	2.3 A	26.1 Ca
Bipolaris oryzae	Traditional	2.3 A	0.25 Aa
	Hermetic	2.3 A	0.9 Aa
Curvularia eragrostidis	Traditional	0.0 A	0.25 Aa
	Hermetic	0.0A	0.6 Aa
Curvularia lunata	Traditional	0.7 A	0.1 Aa
	Hermetic	0.7 A	0.6 Aa
Fusarium moniliforme	Traditional	13.3 A	4.5 Ba
	Hermetic	13.3 A	2.5 Ba
Nigrospora oryzae	Traditional	0.0 A	0.0 Aa
	Hermetic	0.0 A	0.0 Aa
Phoma sorghina	Traditional	2.0 A	4.4 Aa
	Hermetic	2.0 A	4.5 Aa
Pyricularia oryzae	Traditional	0.9 A	0.0 Aa
	Hermetic	0.9 A	0.0 Aa

* For each parameter - means followed by different letters (upper in column and lower in line) are significantly different ($p \leq 0.05$) (capital letter ↓) (lowercase letter →)

The percentage values of grains damaged by insects are presented in Table 6. The results show significant differences ($p<0.05$) between traditional and hermetic storage. These losses can be translated as 30.3-34.4 kg/ton when the traditional method is used and 3.1-2.9 kg/ton when hermetic storage was adopted.

Germination capacity was tested before and after six months of storage. The initial germination capacity was determined to be 88.1%. After storage, our results show that traditional storage resulted in a significant reduction of germinating power of seed rice ($p<0.05$), attaining mean values of 61.75% after the storage period, while under hermetic conditions, seed germination didn't vary ($p<0.05$) with storage (Table 6). Table 6 provides the mean values of electrical conductivity measured in the grain before and after storage. No statistically differences were observed during storage under hermetic conditions at $p<0.05$, while under traditional storage it increased meaningfully after six months corresponding decrease of seed vigor associated with raffia bags (Guenha et al., 2014).

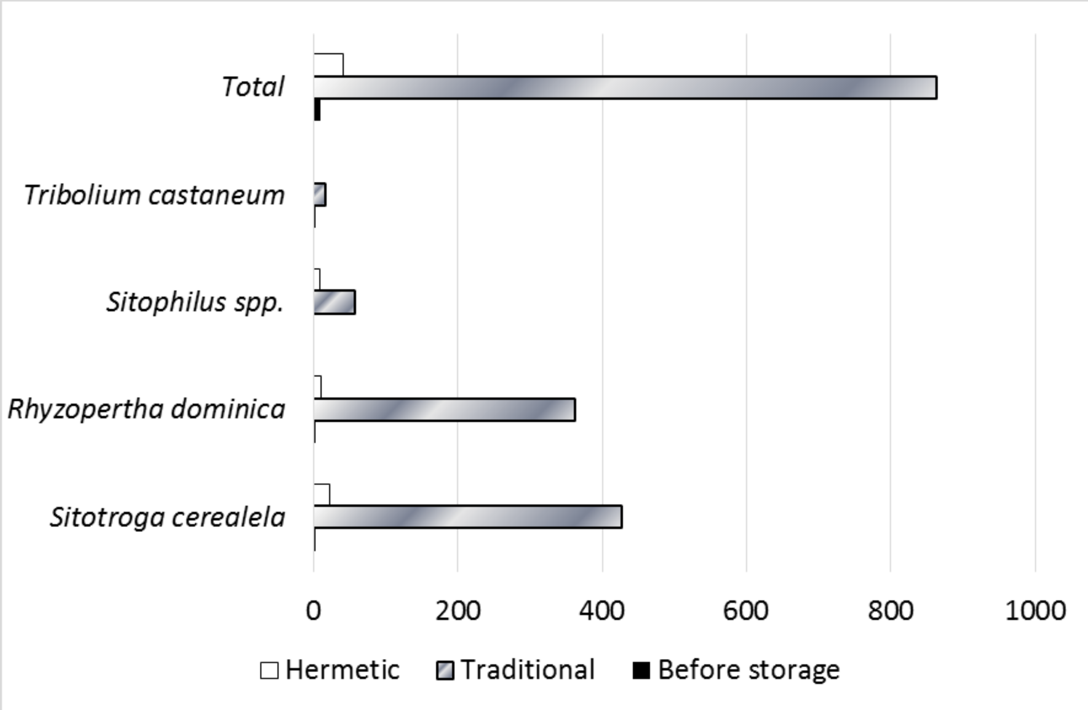

Figure 2 Total of insects by species caught per kg under different type of storage after 6 months of storage.

Table 6 Percentage of weight losses and of seed germination, Electrical conductivity (µS/cm.gr) of the seeds before and after storage under the two types of storage: traditional and hermetic.

Type of storage	*Percentage of weight losses - Storage (months)	**Percentage of seed germination - Storage (months)		***Electrical conductivity - Storage (months)	
	6	0	6	0	6
Traditional	3.03±0.43Aa	88.10±0.53 Aa	61.75±2.19 Ac	42.77±1.28 Aa	57.82±1.20Ab
Hermetic single	0.29±0.11Ba	88.10±0.53 Aa	84.50±1.54 Ba	42.77±1.28 Aa	46.19±1.49 Ba

* Error: Between MS = 1.4759, df = 90; ** Error: Between MS = 56.778, df = 135; ***Error: Between MS = 39.377, df = 135; For each parameter - means followed by different letters (upper in column and lower in line) are significantly different ($p \leq 0.05$) (capital letter ↓) (lowercase letter →).

Pearson correlations were pair-wised calculated between each measured parameter are shown at Table 7 ($p<0.05$). The results show that all factors are correlated. Storage type was positively correlated with germination capacity and negatively correlated with infestation, weight losses and seed vigor parameters. Weight losses were negatively correlated with seed germination and positively correlated with seed vigor and seed germination was negatively correlated with electrical conductivity/seed vigor (Guenha et al., 2014).

Storage type was positively correlated with germination capacity and negatively correlated with infestation, weight losses and seed vigor parameters. Weight losses were negatively correlated with seed germination and positively correlated with seed vigor and seed germination was negatively correlated with electrical conductivity/seed vigor (Guenha et al., 2014).

Table 7 Pearson's correlation between mean density of insects, percentage of weight losses, percentage of seed germination and electrical conductivity of the seeds after storage (three and six months).

Pearson's correlation								
Variable	**Mean**	**SD**	**Storage type**	**Insects population**	**Weight losses**	**Seed germination**	**Electrical conductivity**
Storage type	102.00	0.8208	1.0000	-0.5307	-0.6471	0.5020	-0.6242
Insects population	15.27	31.2974	-0.5307	1.0000	0.5385	-0.4071	0.4363
Weight losses	1.30	1.8178	-0.6471	0.5385	1.0000	-0.4654	0.6350
Seed germination	78.92	12.2635	0.5020	-0.4071	-0.4654	1.0000	-0.4615
Electrical conductivity	50.02	7.9386	-0.6242	0.4363	0.6350	-0.4615	1.0000

* Marked correlations significant ($p < 0.05$)

4. Conclusions

The certified seed showed lower incidence of fungi, associated with the stored rice and higher vigor when compared with the other samples. There were no significant differences between almost all the types of seed and germination percentage: IRGA 417 and Limpopo samples showed values above the minimum required to be accepted as seed in Mozambique and Limpopo the highest vigor. For peasants and small farmers, hermetic storage, using single plastic super bags can be assumed to be more efficient in protecting the rice seed, contributing to: reduce meaningfully the insect pest infestation; keep the germination power and seedling vigor above the recommended minimum values regulated in Mozambique; reduce post-harvest losses. For small rice farmers, hermetic storage, using a "single hermetic bag" might conciliate the "three pillars" of sustainability: economic demands, environmental resilience and social equity. Reducing postharvest losses increases the amount of food available to farmers for their own consumption or for sale to markets; reduces the need to convert more ecosystems into food production, fertilizers applications; and use energy for producing, processing, transporting, and storing food.

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References

Adams, J.M., Schulten, G.G.M., 1978. Losses caused by insects, mites and microorganisms. In: Harris, K.L., Lindblad, C.J. (Eds.), Post-harvest grain loss assessment methods. American Association of Cereal Chemists. St. Paul, USA, pp. 83-85.

Fujisaka, S., Zandamela, C.B., Denning, G.L., 1996. Rainfed Lowland Rice and research needs in Mozambique. Report document to IRRI. Mozambique.

Guenha,R., Salvador, B. V., Rickman, J., Goulao,L.F., Muocha,I. M., Carvalho,M. O., 2014. Hermetic storage with plastic sealing to reduce insect infestation and secure paddy seed quality: A powerful strategy for rice farmers in Mozambique. Journal of Stored Products Research 59, 275–281.

Hayma, J., 2003. The Storage of Tropical Agricultural Products 4th Ed. Wageningen, Netherlands. Agromisa Foundation.

International Seed Testing Association [ISTA], 2002. International rules for seed testing. Seed Science and Technology 37, 54-59.

Lipinski, B., Hanson, C., Waite, R., Searchinger, T., Lomax, J., Kitinoja, L., 2014. Reducing Food Loss and Waste. Creating a Sustainable Food Future, Installment Two –Working Paper | World Resources Institute.

Mathur, S.B., Kongsdal, O., 2003. Common Laboratory Seed Health Testing Method for Detecting Fungi. First edition. International Seed Testing Association, Bassersdorf, Switzerland, pp: 425.

Ministério de Agricultura e Desenvolvimento Rural da Republica de Moçambique, [MINAG], 2008. Plano de Acção para a Produção de Alimentos 2008-2011, Available on http://fsg.afre.msu.edu/Mozambique/caadp/MINAG_PAPA_FoodCommoditiesStrategicPlan2008.pdf(10thMay 2013).

Rodo, A.B., 2002. Avaliação de Potencial Fisiológico de Sementes de Cebola e sua.

Relação com o Desempenho das Plântulas em Campo. PhD dissertation, Instituto Superior de Agricultura/ Universidade de São Paulo, Brazil, pp. 123.

Seck, P.A., Tollens, E.,Wopereis, M.C.S., Diagne, A., Bamba, I., 2010. Rising trends and variability of rice prices: Threats and opportunities for Sub-Saharan Africa. Food Policy 35, 403-1.

USDA, 2011. PS&D Online. http://worldfood.apionet.or.jp/index-e.html.