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Grain storage and insect pests of stored grain in rural Niger

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ABSTRACT

We surveyed 1293 farmers and traders in southern Niger to learn about their grain storage practices and their views on the storage pest problem. We identified the insect species found in samples obtained from 40 localities in three regions of the country. We stored 371 grain samples collected from respondents in the laboratory for seven months to allow populations of the insects present to develop and emerge and the resultant grain weight loss to be determined. The commodities most commonly stored in Niger were millet and sorghum, kept in storage on average for about 6 months by 53% and 80% of respondents respectively. When millet samples from respondents were kept in the laboratory for seven months, two pests were found, the rice moth Corcyra cephalonica Stainton, and Tribolium spp. This millet experienced a weight loss of 17.1% during seven months storage. *Tribolium castaneum* Herbst, *Sitophilus granarius* L., Cryptolestes spp, *Sitotroga cerealella* Oliver, *Trogoderma granarium* Everts, *Rhyzopertha dominica* F. and *C. cephalonica* were found in stored sorghum, which lost 10.1% weight after seven months. Eleven other grains or foods were stored by 2.9–24.4% of respondents. Recorded weight losses were 15.9% for groundnuts, 12.6% for paddy rice, 7.6% for sesame and 7.4% for maize. Seeds of *Hibiscus sabdariffa* L. and Bambara groundnut were essentially destroyed by bruchids during storage, mean weight losses being 83.9% and of 61.8% respectively. Most respondents took no measures to control insect pests in their stored grains. Food security and quality in Niger would be greatly improved if Africa-manufactured technology that is safe, low-cost, insecticide free, and widely available could be implemented for post-harvest storage of food grains.

1. Introduction

The West African nation of Niger, located in the Sahel, has more than 80% of its population living on farms and relying on agriculture for livelihoods (Fig. 1). Average national grain production over the past 5 years is estimated to be about 5.9 million tons (MAG, 2012). Millet (*Pennisetum glaucum* (L.) R. Br.) and sorghum (*Sorghum bicolor* (L.) Moench) account for 70% of agricultural production. Cowpea *Vigna unguiculata* Walp is next in importance with 1.33 million tons, accounting for 22.5% of annual total production. Groundnut, *Arachis hypogea* L., with an average annual production of about 300,000 tons, contributes about 5.1% of available food. While rice and maize are important foods in urban areas of Niger, they account for less than 0.5% of total annual agricultural production. More than 270,000 tons of these two grains are imported annually (MAG, 2009; SIMA-Niger, 2011). Several crops are cultivated primarily by women, including sesame, *Sesamum indicum* L., Tiger nut *Cyperus esculentus* L., Bambara groundnut, *Vigna subterranea* (L.) Verdc, sorrel *Hibiscus sabdariffa* (L.) and fonio, *Digitaria exilis* (Kippist) Stapf. These contribute an average of roughly 2% of national food production.

Most food produced in Niger is harvested at the end the rainy season that starts in June and lasts into October. Stores kept by the producers themselves, by cooperatives and community grain banks, and by retailers and charities, provide food for the people over the course of the year. Depending on the product, storage may last only a month or so or as long as twelve months or more. During storage it is exposed to pests and is subject to losses they cause.

As a result of the country-wide diffusion of a simple, low-cost hermetic technology (Baributsa et al., 2010), in the form of PICS (Purdue Improved Crop Storage) triple-layer bags, losses of cowpea grain to bruchids in Niger have been substantially reduced. PICS bags are now available in many rural markets not only in Niger but

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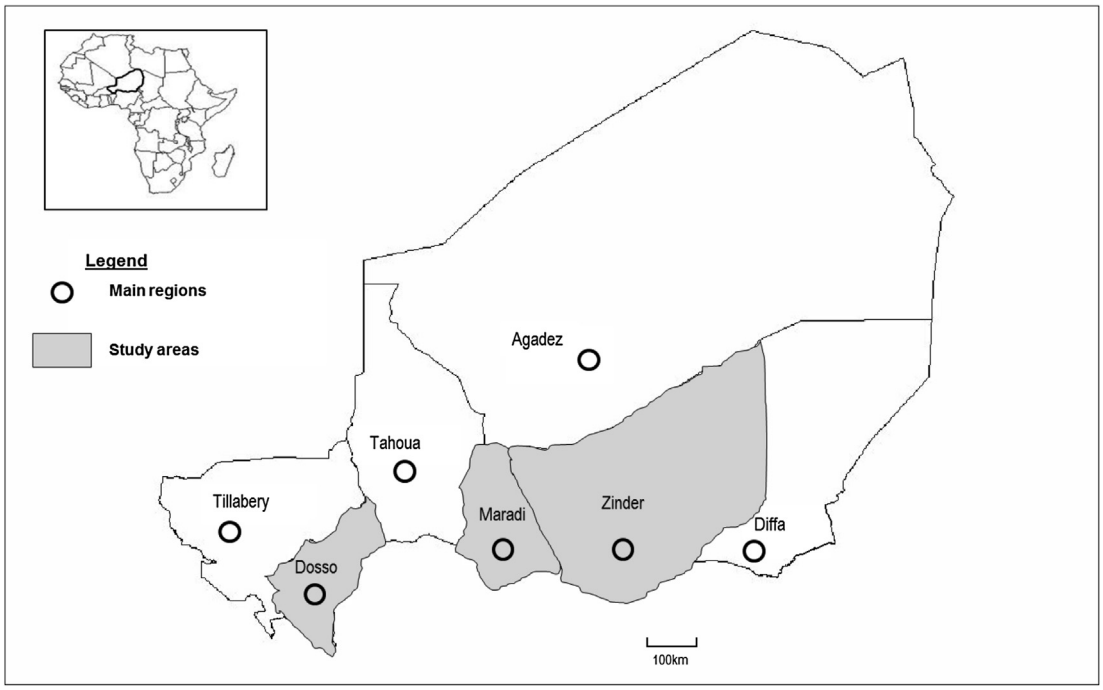

Fig. 1. Location of the West African nation of Niger, with positions of the three study regions of Dosso, Maradi and Zinder.

throughout West Africa. This technology arrests bruchid population growth and allows safe storage of cowpea for up to several years (Murdock et al., 2012; Baoua et al., 2012).

The research described here was undertaken to: (i) assess how food commodities other than cowpea are stored in Niger; (ii) determine the extent to which farmers are aware of storage insect pests in a variety of crops, and; (iii) ascertain their main control methods, if any. In addition, we sought (iv) to determine the insect species attacking stored grain and (v) to estimate the degree of associated mass loss. This assessment was carried out to learn if there was reason to promote the extension of PICS storage bags for use with other food commodities in the Sahel.

1.1. Methodology

We conducted the survey and sample collection components of our study during the early part of the annual storage season, specifically, from the 2nd to the 8th of December 2012. The work was carried out in the regions of Dosso (13° 2′49.49″N; 3°12′14.08″E), Maradi (13°28′60.00″N; 7° 5′60.00″E) and Zinder (13°48′19.00″N; 8°59′18.00″E). All three regions are located in the southern agricultural belt of Niger (Fig. 1). We focused primarily on people storing agricultural products in 40 localities selected randomly; these encompassed eleven rural and urban markets. We used a questionnaire to document the quantity of food stored and the duration of storage. We solicited respondents' opinions of the degree to which the different commodities are subject to insect pest attacks using a 4-point scale: 0 – no response, 1 – minor problem, 2 – moderate damage and 3 – major damage. We asked each interviewee to describe any control methods he or she used to protect each stored product. Data were entered into an Excel template, noting the average quantities stored and the length of the storage period.

During the baseline survey we collected grain samples from respondents. Initial weights were determined by weighing three samples of 100 seeds separately. Beginning January 15, 2012, all individual samples were stored in the laboratory in open 1000 ml bottles, their mouths covered with Muslin cloth to allow air exchange but to keep insects from entering or escaping. The bottles were kept in a concrete cabinet into which was also placed on a lower shelf a metal bucket filled with water to keep the relative humidity inside the cupboard elevated. The cabinet also contained a data logger (Model EL-USB-2. Lascar, Wiltshire, Great Britain) to record the temperature and humidity. Monthly inspections of each sample documented the insect pest species emerging and its numbers. Analyses were terminated on July 15 after 7 months of storage. The 100 seed weights were again determined, as described above. Weight loss for each sample was calculated using the formula:

$$\text{percentage weight loss} = \left(\frac{\text{initial weight} - \text{weight after 7 months}}{\text{initial weight}}\right)*100$$

2. Results and discussion

The field survey interviewed 1293 individuals, of whom 66.3% were farmers and 33.7% were traders; 11.8% of respondents were women. We collected 371 grain samples; these were taken to the

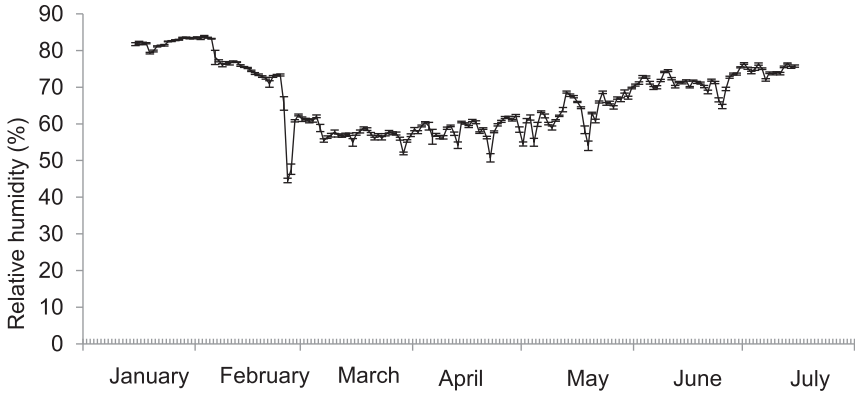

Fig. 2. Daily variation of relative humidity in the rearing room. Bars at each point represent daily ranges.

Table 1
Percentage of survey respondents who stored postharvest crops in three regions of Niger.

Crops	Regions			
	Dosso	Maradi	Zinder	All localities
Millet	92.8	76.7	87.9	79.7
Sorghum	57.7	48.9	72.9	52.8
Groundnut, shelled	45	19	41.5	24.4
Groundnut, unshelled	0	20.4	9.2	16.6
Maize	30.6	23.8	21.3	24.1
Bambara groundnut	27	0.4	0	2.6
Hibiscus seeds	38.6	14.1	1.9	14.4
Rice	7.2	5.7	0.5	6.4
Tiger nut	1.8	9.8	2.4	7.8
Dried tomato	0	6.7	0	5.2
Sesame	3.6	12.2	1	9.7
Cassava flour (Gari)	1.8	3.7	2.9	2.9
Okra	5.4	2.8	0.5	2.6

laboratory and subsequently held at ambient temperatures ranging between 25 and 35 °C. Relative humidity (R.H.) in the holding cabinet tended to fall from the initial 81% R.H. into the 50 percent range and then rise again to about 76% during the seven months of storage (Fig. 2).

Twelve different agricultural products were stored by the people we surveyed. In all three regions, millet and sorghum were the commodities most often put into storage. They were stored by 52.8% and 79.7% of respondents, respectively (Table 1). Quantities ranged from as little as 3 kg per respondent to as high as 500 tons (Table 2). The large volume stores were held by traders. Farmers and traders stored on average 5.3 tons of millet and 3.9 tons of sorghum. Storage duration was as long as 60 months for traders, and as short as less than a month for some producers; it averaged 5–6 months for all respondents.

Our data document that postharvest storage is a common practice of rural farmers as well as traders in Niger. The major grains millet and sorghum are grown only in the rainy season and harvested at the end of it; storage ensures that food is available throughout the year. At least 24% of respondents considered insect pests on stored millet and sorghum to be very important while another 46–52% considered them to have moderate significance. About one in three respondents used pesticides on their stored millet and one of nine on their sorghum.

Samples collected during the survey were stored for seven months and subsequently evaluated for the presence of insects and for weight losses. The results confirmed the importance of insect pests on these two major crops. After seven months of storage of millet, we found that *Corcyra cephalonica* Stainton and *Tribolium castaneum* (Herbst) had emerged, and that there had been a grain weight loss of 17.1% (Table 3). Seven different insect pests emerged from the stored sorghum samples. Associated with this was a weight loss of 10.9%. These losses are substantially higher than the 1% loss rate for millet and 2.4% for sorghum reported from rural areas of India after 9 months of storage (Pushpamma et al., 1985). The losses we observed also exceed those documented by FAO, where storage losses in West Africa have been estimated to fall between 2 and 10.1% for millet and between 4 and 9.5% for sorghum (http://www.fao.org/docrep/W1544E/W1544E05.htm).

As noted, we observed only two insect species emerging from stored millet, even though at least eight different post-harvest pest species have been described on this crop in the Sahel (Sharma et al., 2007; Moustapha, 2010). The discrepancy is presumably due to geographical and annual variation in abundance as well the natural

Table 2
Quantities of crops stored, storage duration and opinions about insect damage by urban traders and rural stores in Niger.

	Quantities of products stored by respondents (kg)			Duration of storage for each crop (months)			Opinion of insect pest damage (% respondents)			
Crops	Mean ± SE	Min	Max	Mean ± SE	Min	Max	No answer	Low	Medium	High
Millet	5311.0 ± 1275.0	5	400,000	5.2 ± 5.1	0.3	36	13.5	10.3	51.7	24.5
Sorghum	3991.6 ± 1535.0	3	500,000	5.9 ± 6.1	0.23	60	22.3	7.9	45.5	24.1
Groundnut, unshelled	2046.4 ± 1386.8	12	200,000	5.4 ± 5.4	0.3	48	19.4	12.7	44.5	22.9
Groundnut, shelled	6171.0 ± 1882.0	50	100,000	2.1 ± 3.9	0.3	24	19.5	12.7	44.5	22.9
Maize	12,200.0 ± 3198.0	2	400,000	4.4 ± 7.4	0.2	60	23.1	13.0	51.2	12.7
Bambara groundnut	120.0 ± 26.3	60	200	3.5 ± 3.5	1	10	23.3	0	17.6	58.8
Hibiscus seed	959.6 ± 294.2	3	10,000	5.8 ± 5.0	1	24	4.8	4.8	52.7	37.6
Rice	667.6 ± 129.0	15	6000	2.4 ± 3.5	1	24	31.3	28.9	30.1	9.6

Table 3
Observed insect pests and mean weight loss per crop after 7 months of collected crop storage in the laboratory.

Crops	Number of samples	Insect pest observed	Weight losses after 7 months of storage
Millet	78	*C. cephalonica*, *T. castaneum*	17.1 ± 1.8
Sorghum	112	*Tribolium* castaneum; *S. granarius* Linnaeus, 1875; *Cryptolestes* spp, *Sitotroga cerealella* Oliver; *Trogoderma granarium* Everts, *C. cephalonica*, *R. dominica*	10.9 ± 1.42
Maize	56	*Tribolium* spp; *S. zeamais*; *Cryptolestes* spp; *R. dominica*, *T. castaneum*	7.4 ± 1.0
Groundnut	23	*C. cephalonica*, *T. castaneum*	15.9 ± 2.5
Bambara groundnut	28	*C. maculatus*, *C. subinnotatus* (Pic.)	61.8 ± 2.3
Hibiscus seed	32	*A. obtectus*	83.9 ± 52.8
Paddy rice	23	*R. dominica*, *T. castaneum*	12.6 ± 2.0
Sesame	19	*T. castaneum*, *C. cephalonica*	7.6 ± 4.1

relative scarcity of some of the species described by the above authors.

Groundnut is another crop stored by many respondents. Storage in the unshelled form is the more common practice among those surveyed but the larger mass stored was in the shelled form. Individuals who kept groundnuts in storage stored an average of 1.1 tons of unshelled grain, while shelled groundnuts averaged 0.4 tons in storage per respondent. Storage in shelled form seems to be more common in the Dosso and Zinder regions, where it was practiced by 41 and 45% of respondents, respectively. As with other commodities, the largest groundnut stocks were held by traders, who averaged 3.0 tons of unshelled grain and 1.0 ton of shelled grain per respondent. Across the three regions, women constitute 18.4% of the respondents who stored unshelled groundnut. The average duration of storage for unshelled groundnuts was 5–6 months. Shelled groundnuts, by contrast, were stored for an average of only two months because the shelled grain is primarily used for processing for oil extraction or other by-products.

The incidence of insect pests on stored groundnut was viewed as high by 23% of respondents and as moderate or high by two-thirds of the participants. Most people (85.4%) take no measures to protect their stored crop while 14.3% use chemical pesticides. Inspection of samples held in the laboratory for seven months revealed the presence of *C. cephalonica* and a mean 15.9% weight loss during storage. The bruchid *Caryedon serratus* (Olivier) was not found in our samples even though this species is reputed to be the most damaging groundnut storage pest in the Sahel (Prevett, 1967; Sembène et al., 2012). In Senegal, *Corcyra cerratus* can cause losses of up to 80% of groundnut stocks (Ndiaye, 1991). In India, storage losses of groundnuts range between 10 and 15% (Ranga Rao et al., 2010).

Maize was stored by 21.3–30.6% of respondents in the different regions. Maize is mostly imported by traders to be sold as food in urban centers. Surveyed traders stored an average of 3.2 tons per respondent for a period averaging 4–5 months. Some 12.7% of respondents considered insects very important while more than half (51.2%) considered them to be a moderate problem. No control measures were undertaken by respondents. The only steps taken during processing involved winnowing and cleaning the grain before selling it. Sitophilus. zeamais Motschulsky, 1855 and *Rhizopertha dominica* (L.) emerged from the collected grain stored in the laboratory; mean weight loss after seven months was 7.5%. The larger grain borer, *Prostephanus truncatus* (Horn) was not found in the stored maize, even though it is known to be present in Niger. Absence of *P. truncatus* was surprising, since most of the maize stored was imported from neighboring countries where that species is present and has a significant economic impact. *P. truncatus* has been reported in areas of Niamey, Dosso and Gaya (Adda et al., 1996). According to Shires (1979) a temperature of 25 °C and a relative humidity of 80% is required for development of *P. truncatus*.

Table 4
Percentages of rural Niger respondents who use pest control methods for stored crop.

Products	PICS bags	Pesticides	None	Other
Millet	0.2	32.1	64.0	3.7
Sorghum	0.2	10.6	88.4	0.8
Groundnut	0.1	14.3	85.4	0.2
Bambara groundnut	0.3	0.8	98.5	0.4
Hibiscus grain	0	6.02	89.8	4.0
Maize	0.2	32.4	64.0	3.4
Rice	0.0	0.2	99.8	0.0
Sesame	0.0	1.7	98.0	0.3

It may be that the typically low relative humidity in the Sahel region is so low that the insect cannot thrive on dry grain.

Bambara groundnut was stored by 2.6% of respondents across the three regions (Table 1); nearly half (41.2%) of stores were women. This legume is particularly important in the Dosso region, where 47% of respondents store it. Bambara grain is stored on an average of 100 kg per respondent for a mean duration of 3–4 months. The problem caused by insect pests was rated as high by 58.8% of respondents and as moderate by an additional 17.6% (Table 2). Most respondents did not apply any control method during storage (Table 4); they sold their grain before losses to bruchids became serious. A few people (0.4%) stored their crops by mixing with sand and only 0.3% used PICS bags despite the effectiveness of that technology for controlling *C. maculatus* F. on cowpea (Murdock et al., 2012; Baoua et al., 2012). Samples of Bambara groundnut kept for seven months in the laboratory confirmed the susceptibility of the seeds of this pulse to insect attack. Bruchids *C. maculatus* and *C. subinnotatus* Pic emerged from the grain; weight loss was 61.8% after 7 months of storage. Both pests have been reported in the literature by several authors (Begemann, 1986; Golob et al., 1998).

Seeds of sorrel, Hibiscus sabdariffa Linn, are known for their rich nutrient content while the plant itself is valued for its therapeutic properties (Mahadevan et al., 2009). The grain contains an average of 26% protein, 20% fat and 40% total sugars (Cissé et al., 2009). In the Sahel, women process the seeds by cooking and fermentation to produce “soumbala”, a fortifier used in many sauces in West Africa. Our survey revealed that hibiscus seeds are stored by 14.4% of respondents, most of them being women. Larger-scale storage was done by traders, who stored for 5–6 months. Hibiscus seed was viewed as highly susceptible to pests by 37.6% of respondents and moderately affected by 52.7%. For post-harvest preservation, only 6.0% of respondents used pesticides while 89.8% did nothing. Most prefer to sell their seed at or soon after harvest before the first signs of insect infestation appear. Observations of collected grain stored in the laboratory revealed the presence of the bruchid *Acanthoscelides obtectus* Say. Weight loss after 7 months of storage was severe: 83.9%.

Nigerien paddy rice is produced along the Niger River, especially in the regions of Tillabery and Dosso. As with maize, rice imports are important; at least 6.4% of respondents hold small stores of the grain for two or three months. Urban centers are regularly resupplied by the wholesalers' importers. The vulnerability of the crop to insect pests was considered low by 28.9% of respondents and moderate by 30.1%. *R. dominica* and *T. castaneum* were found in the samples of paddy rice after 7 months of storage; weight loss was 12.6%, significantly higher than the 1.67% weight loss reported in northern Benin by Togola et al. (2013).

Other products such as sesame, dried vegetables, flour and Tiger nut were stored by 3–10% of respondents; some 20.3% of those who stored sesame were women. Laboratory analysis recorded an average weight loss of 7.6% after seven months, with *C. cephalonica* and *T. castaneum* emerging from the sesame samples.

Our data shed new light on the postharvest practices and storage conditions for agricultural commodities in Niger. In terms of volume, millet and sorghum are the commodities stored in the greatest quantities. Estimated losses after 7 months of storage can be substantial, ranging between 11 and 17% by weight under the conditions of our experiments. Pests likewise cause significant losses of stored maize, rice, and sesame. Bambara groundnuts and *H. sabdariffa* seeds experience extreme losses, up to 60–80%. For most stored crops Nigerien respondents took few if any control actions (Table 4). Chemical control was practiced by a small proportion of traders, particularly those who stored large quantities of millet and sorghum (Table 4). Our results reveal the need for more research and development as well as extension activities to help Sahelian farmers and traders reduce storage losses and increase food availability. PICS bags, a hermetic technology now widely distributed in West Africa for cowpea storage, and which retards the development of most insects (Mitcham et al., 2006; Murdock, unpublished), offers a practical, inexpensive, non-chemical, Africa-manufactured technology to reduce food losses and increase incomes of growers and those who store at all levels. Improving food storage is equivalent to increasing yields, but better, for it requires no additional land or water.

As food shortages loom, especially in the least developed parts of the world where populations are growing most rapidly (Anonymous, 2013), the need for more food will only grow. In the face of limited available land and rainfall, the upside of increasing food production is limited. One excellent way to increase the food supply is to promote better storage. This is equivalent to increasing yields, yet better, because it does not require additional land and water.

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