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**ANALYSIS OF THE PROFITABILITY OF PICS BAGS  
FOR THE STORAGE OF BAMBARA GROUNDNUT SEEDS  
(*Vigna subterranea*) IN THREE REGIONS OF NIGER**

by

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# **ANALYSIS OF THE PROFITABILITY OF PICS BAGS FOR THE STORAGE OF BAMBARA GROUNDNUT SEEDS (*Vigna subterranea*) IN THREE REGIONS OF NIGER**

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## **Abstract**

Analysis of the Profitability of PICS Bags for Storage of Bambara Groundnuts (*Vigna subterranea*) in Three Regions of Niger, Seyni Boureima, Bokar Moussa and J. Lowenberg-DeBoer.

This study documents Bambara groundnut storage practices and estimates the economic returns from alternative storage and marketing strategies in Niger. A random sample of Bambara groundnut growers in the main Bambara groundnut growing areas of Niger were interviewed. A total of 164 respondents participated. Slightly over half of the Bambara groundnut stored is in potentially hermetic containers including double and triple layer bags, plastic jugs and metal drums. Use of storage insecticide varied by region. Over 12% of the quantity stored was treated with insecticide in the Maradi Region, but only about 2% in the other regions. Use of the Purdue Improved Crop Storage bag also varied by region. In the Dosso region in 2012, 47% of the Bambara groundnut was stored in PICS bags, but only 8% in Maradi and 4% in Zinder. Bambara groundnut prices vary seasonally, and they vary widely from market to market. Consequently, marketing flexibility is key to profitable commercialization. In most cases storing into the next rainy season (i.e. 8 to 9 months) is the most profitable strategy. Estimates indicate that producers using traditional storage technologies should market their Bambara groundnuts quickly because the storage damage can be severe. In contrast, PICS bags are quite profitable for Bambara groundnut producers in the study areas, especially when longer-term storage conditions are required. Even when the PICS bag is only used one season, the simple rate of return is over 100%.

Keywords: Niger, Bambara groundnut, storage, hermetic, profitability

JEL Codes: Q01, Q16, Q12

## **Introduction**

The Bambara groundnut (*Vigna subterranea*) is an African underutilized legume cultivated in sub-Saharan Africa. It is mainly grown as a subsistence crop, mostly by women and generally on abandoned or fallow land. In sub-Saharan Africa, the Bambara groundnut ranks third in cultivated legumes after peanuts (*Arachis hypogaea*) and cowpea (*Vigna unguiculata*) (Hampson et al., 2001). Bambara groundnut cultivation has several advantages in that it can give acceptable yields on poor soils and with a low rainfall. Nutritionally, it is superior to other legumes and is a preferred food source by many individuals. Indeed, the seeds are a good source of protein in the range of 20 to 25% (McFarlane, 1983) of methionine, an essential amino acid. The red seeds are very important in areas where iron deficiency is a major problem among populations because they contain twice as much iron as cream seeds. In addition, the plant has the ability to capture and fix atmospheric nitrogen contributing thus to increased crop yields.

Previous research has reported that the Bambara groundnut has enormous potential for industrial processes and an increased use for derived products. However, dry seeds are very difficult to cook, requiring more time (45 minutes for fresh seeds; 1-3 hours for dry seeds) and energy (Berchie et al, 2010.), which is one of the major constraints of the intensive cultivation of the Bambara groundnut in sub-Saharan Africa. Grain yields are estimated between 650-850 Kg ha<sup>-1</sup> with significant variations between the different countries in sub-Saharan Africa (Ayayi and Lale, 2001).

In Niger, the Bambara groundnut is usually grown as a monocrop in small areas or in combination with cereals in family fields. It is in most cases harvested before the grains ripen and consumed fresh by the producers after being boiled or sold directly at the weekly markets while the remainder is dried and stored for later use (seeds, sale of dry seeds boiled during the long dry season). There is a renewed interest of producers for the culture that is on a net increase. In 2012, the production was estimated at 32,228 tonnes compared with 22,447 tonnes, an average for the five previous years, that to say an increase of 46% (DS/MA, 2012).

Despite its importance as a source of food security, the Bambara groundnut has not been the subject of attention by scientific research, and the majority of information and know-how is owned by the producers themselves or in unpublished reports (Hampson et al., 2001). An exchange platform (BAMNET) was established through which individual researchers share their experiences of the plant.

The price seasonality of Bambara groundnut seeds is very pronounced across the country. Effective storage systems to await for the peak pricing period for this culture with growing interest would undoubtedly provide significant economic benefits to small producers. While traditional storage methods with loss rates up to 100% in some cases are ineffective, improved storage techniques including hermetic methods that allow a significant reduction in stock losses. Purdue University's project for improved cowpea storage (PICS) has led to the wide dissemination of the triple bagging method since 2008. This technique proved to be very effective for the conservation of cowpea and economically profitable for small producers. These producers were ahead of researchers testing hermetic methods with products other than cowpea, particularly in this case with Bambara groundnut.

The overall objective of this study was to determine whether the use of PICS bags is a competitive technology for the conservation of Bambara groundnut seeds. The specific objectives were to: (i) identify seasonal price fluctuations of Bambara groundnut seeds, and whether these changes are significant enough to justify the conservation of seeds; (ii) describe how these seeds are currently being stored and sold; (iii) assess the added value of the use of PICS bags compared to the traditional storage method.

## Litterature Review

### Taxonomy and geographical distribution of the Bambara groundnut

The Bambara groundnut (*Vigna subterranea* (L.) Verdc.) is believed to have originated in the African continent, and more specifically, in the central Mali, in West Africa. It belongs to the family of Leguminosae and the subfamily of Papilionoideae. It is an underutilized species widely cultivated in sub-Saharan Africa. The plant is now widely distributed and cultivated in Asia, in the northern part of Australia and in Central and Southern America.

Compared to peanuts or cowpeas, the Bambara groundnut has a lower status and is often perceived as a snack or a dietary supplement. In addition, the Bambara groundnut is traditionally grown by women implying that it is given a lesser value and priority in the allocation of land and labor. Typically less than half of the crop is sold, the remainder being consumed by the family itself.

Supply of seed sources are traditional, and in most cases, it is the older women who are the holders of varieties. These varieties are given to their unmarried or married daughters or to the daughters-in-law.

The production of the Bambara groundnut and the planted areas by region in Niger are given in Table 1. This Table 1 shows that among the regions selected for the purposes of the present study, Dosso and Maradi are among the main areas for the Bambara groundnut in Niger.

Table 1: Area planted and production of Bambara groundnut in different regions of Niger for the crop year of 2012

<b>Region</b>	<b>Area (ha)</b>	<b>Production (kg)</b>	<b>Yield (kg ha<sup>-1</sup>)</b>
Agadez	0	0	0
Diffa	N/A	N/A	N/A
<b>Dosso</b>	<b>46 243</b>	<b>20 195</b>	<b>437</b>
<b>Maradi</b>	<b>7 091</b>	<b>5 060</b>	<b>714</b>
Tahoua	5 023	1 207	240
Tillabéri	8 766	3 950	451
Niamey	N/A	N/A	N/A
<b>Zinder</b>	<b>3 219</b>	<b>1 795</b>	<b>558</b>
<b>Total</b>	<b>70 342</b>	<b>32 202</b>	

Source : Source : DSA/MDA, 2013

N/A : Not available

### Storage and marketing of Bambara groundnut seeds

In general, price fluctuations between periods of harvesting allows producers and buyers to collect gains from investments in storage (Jones et al., 2011a). However, it is still not economically feasible for small producers to take advantage of seasonality in prices of

agricultural products because according to Stephens and Barrett (2009), most sell some or their entire crop immediately after harvest because of financial constraints or to repay debt or simply because they do not have adequate storage systems to protect their harvest to a more favorable sale period. In this situation, delaying the sale of agricultural products to the lean period when prices are rising, forces producers to cover current expenses of the post-harvest period using alternative means (Jones et al. 2011a). This represents a cost especially as these funds are paid from revenue from other income generating activities.

Bambara groundnut seeds are generally self-consumed fresh. However, a substantial quantity remains stored for later consumption during the year, as the seed prices are relatively high because in most cases the supply remains below the demand after the harvest period (October/November). However, the major constraint to an increased and sustainable production of Bambara groundnut remains high losses due to pest infestations during storage (Ayamdoo et al., 2013). According to Golob et al. (1996), the destruction of the seed by insects starts in the fields, but takes place mostly during storage.

Weevils (Coleoptera: Bruchidae) are the most important destructive insects for stored grain legumes in the tropics (FAO, 2009); although Bambara groundnut seeds store well and are less prone to parasites or disease than some other legumes, probably because they are, in most cases, conserved in their shells. These insects infest seeds in the field and continue to multiply during storage (White, 2001). Losses caused to stored goods by these insects are very important and can reach 100% in the case of a *Callosobruchus maculatus* F. infestation, the most common weevil in hot regions (FAO, 2009). Baoua et al. (2014) reported losses of  $61.8 \pm 2.3\%$  due to *C. maculatus* and *C. subinnotatus* in Niger after 7 months of storage without treatment.

During the storage period, Bambara groundnut seeds are sometimes subject to pest attacks especially *Callosobruchus subinnotatus* (Golob et al., 1998). Experimental studies under controlled conditions showed that female weevils can lay more than 100 eggs, and a generation of only one month causes infestations to increase exponentially until the complete destruction of the stock in a few months (Dick and Credland, 1984). Unfortunately, the level of losses due to weevils in Africa are not well documented even if losses ranging from 14 to 100% have been reported in some places in the north of Ghana (Golob, unpublished). Damage by bruchids in the field before harvest have been rarely reported. Amuti and Larbi (1981) recorded an average loss of 3.7% after 5 months of storage in Ghanaian local conditions while Golob et al. (1998) reported Bambara groundnut seed losses exceeding 20%.

In an experimental study, Maina et al. (2011) reported that the severity of damage caused by *C. subinnotatus* is higher starting from the third month of Bambara groundnut seeds storage and reports that the longer the storage term is, the more important the damage is because of the increase spawning and adult emergence of *C. subinnotatus*.

In Niger, farmers and traders use indigenous knowledge for the storage of Bambara groundnut seeds, traditionally storing in pod form. Compared to large producers and traders who use woven bags and granaries, small farmers use drums and jars for their stocks (Chougourou and Alavo, 2011).

During the harvest period, the supply of Bambara groundnut grain is particularly high compared to the demand, which leads to lower prices, but after the season grain is hard to come by increasing the price speculation. Storage remains a problem with Bambara groundnuts because the grains are very susceptible to weevils. Traditionally, the grains are stored in drums or jars mixed with ash. Research on the Bambara groundnut value chain is rare because it is an underutilized culture. Marketing is difficult because of the lack of

information about the Bambara groundnut in local, sub-regional and international markets. Producers are not familiar with export markets because of lack of connections.

## **Methodology**

### **Study Areas**

To achieve the objectives of this study, a survey was conducted in three regions namely Niger Dosso, Maradi and Zinder, during the month of July 2013. To make the most of scarce resources questions were asked about both Bambara Groundnut and Rozelle since many farmers in this area produce both crops. In the region of Dosso, 6 villages belonging to three different rural communities (Arewa, Dogondoutchi and Dosso) were targeted while in Maradi, 5 villages belonging to three rural communities (Gazaoua, Aguié and Tessaoua) were covered by the survey. In Zinder, 5 villages spread in two rural communities (Mirriah and Magaria) were selected. A total of 164 respondents were interviewed: Dosso, 65; Maradi, 50; and Zinder 49.

### **Sampling and data collection**

To gather statistically valid information in the field, a 5 part questionnaire was developed. The first part concerns general information (region, town, site, etc.), the second is related to socio-economic characteristics of producers (name, sex, age, status, experience, etc.), the third part deals with planted areas and production, the fourth part is concerned with the varieties used and the fifth part focuses on new storage methods. In each region, villages were randomly drawn based on the list of villages producing Bamabara groundnut and Roselle. The sample of producers was randomly selected. An exhaustive list of all Bambara groundnut producers was established, and the survey sample was drawn randomly on the basis of this list. The data collection method is personal interviews conducted with the respondents. The interview was conducted by following, step by step, the various questions in the survey.

### **Processing and data analysis**

The collected data was used to calculate the percentage of producers using each storage method, storage duration and amount of Bambara groundnut grains stored using each method. An Excel spreadsheet was used for the calculation of the basic statistics. For the estimation of storage losses the calculations used Baoua et al. data (2014), who estimated Bambara groundnut grains losses at 61.8% after 7 months of storage using the traditional method that is to say without technology. For the sensitivity analysis, gains on storage were calculated by considering  $\pm 5\%$  of the storage loss rate. For PICS bags, we considered losses at 0.6% as used by Jones et al. (2011b). To calculate the gain on investment, we estimated the price of the PICS bag at 1000 f CFA and a negligible cost in terms of storage structure used by the producers.

## Results

### Socio-economic characteristics of producers

#### **Dosso region**

In the Dosso region, Figure 1 shows that it is mainly women who engage in the culture of Bambara groundnut. Women represent 77% of participants compared with 23% for men.

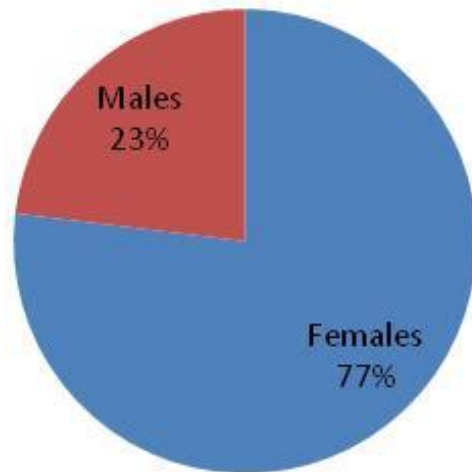


Figure 1: Sex distribution of the respondents at Dosso

It was observed that 12% of producers were aged between 20 and 29 years, 15% between 30 and 39 years, 26% between 40 and 49 years, 19% between 50 and 59 years, 23% between 60 and 69 years, 3% between 70 and 79 years and 2% have an age above 80 years (Table 2).

Table 2: Age distribution of Bambara groundnut producers at Dosso

Age	Number	% of respondents
20-29	8	12
30-39	10	15
40-49	17	26
50-59	12	19
60-69	15	23
70-79	2	3
80 and above	1	2



These results show that few producers are young while the majority is older. This shows that the Bambara groundnut cultivation in the region of Dosso is not only a feminine, but also an activity for older people.

The results in Figure 2 show that 86% of these producers are illiterate, 8% started primary school, 3% have a secondary level and only 3% have started a university education.

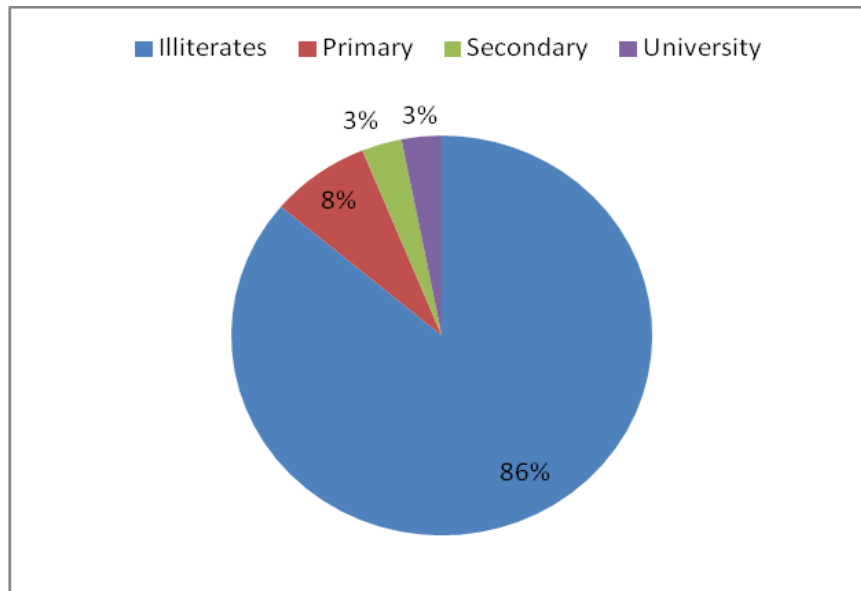


Figure 2: Level of formal education of producers at Dosso

These results show that the majority of producers have not received any formal education. This high rate of illiteracy among producers and among others, has certainly impacted the producers ability to master the techniques of Bambara groundnut production, and hence the observed low yields and the precariousness of storage systems.

Regarding the marital status, 77% of producers are married and 23% are divorced (Figure 3). The striking observation from Figure 3 is the absence of single producers. This can be attributed to a problem of land access or reinforces the idea that the culture of Bambara groundnut is devoted to the elderly.

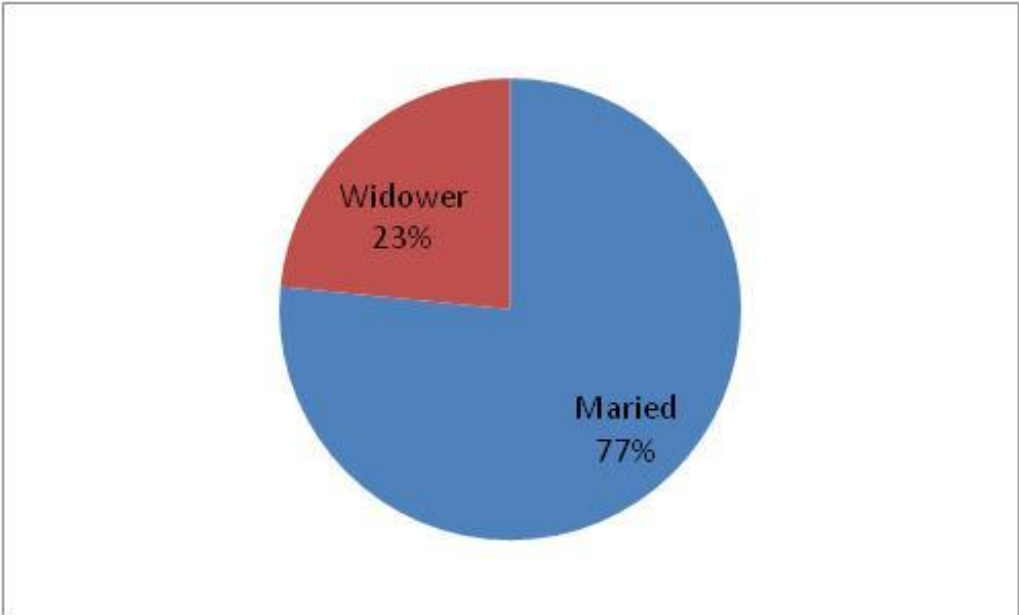


Figure 3: Marital status of the respondents at Dosso

Concerning producer’s household size, it is observed that 18% of the producers have a household size ranging between 1 and 5 people, 35% between 6 and 10 people, 23% between 11 and 15 people, 15% between 16 and 20 people, 6% between 21 and 25 people and 1% have a household size greater than or equal to 26 people (Figure 4).

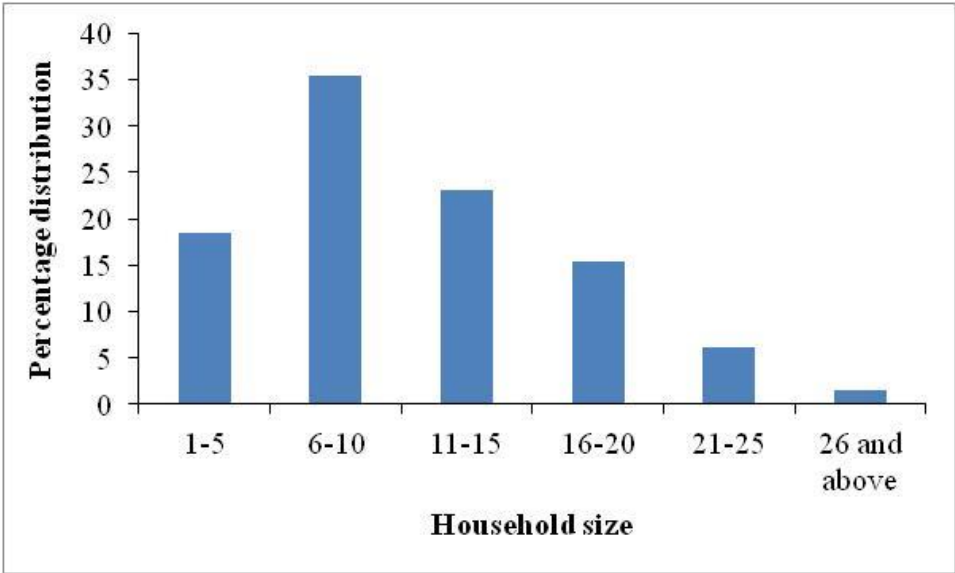


Figure 4: Household size of producers at Dosso

Table 3 shows that most producers engage in other income generating activities secondary to the culture of Bambara groundnut mainly livestock product, which engages 28% of producers.

Table 3: Secondary activities performed by the respondents

Secondary activity	% of respondents
Craft	4
Trade	50
Shoes repairing	2
Pounding millet	2
Livestock breeding	28
Koranic treatment	4
Agricultural processing	7
Small business	2

### Maradi region

In the region of Maradi, unlike Dosso, the cultivation of Bambara groundnut is mainly the work of men. Indeed, Figure 5 shows that 82% of Bambara groundnut producers in the sample are men.

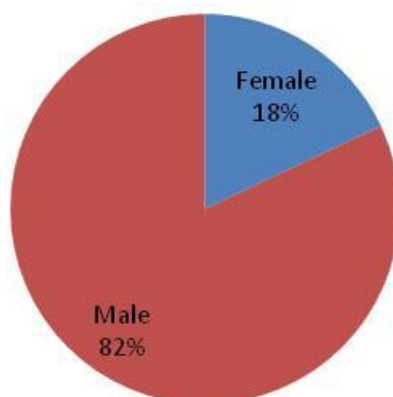


Figure 5: Sex distribution of respondents at Maradi

The age of farmers is given in Table 4, which shows that only 4% of producers can be qualified young with an age between 20 and 29 years. The age group 30-39 years represents 30% of the producers, and 8% of the producers are in the fourth age group (70 and older). These results reinforce the idea that the culture of Bambara groundnut is an activity of older people of both sexes.

Table 4: Age distribution of Bambara groundnut producers at Maradi

Age	Number of producers	% of producers
20-29	2	4
30-39	15	30
40-49	9	18
50-59	10	20
60-69	10	20
70 and above	4	8

Among the surveyed participants 74% are illiterate, 15% underwent a primary education and 11% a high school education (Figure 6). Unlike Dosso, no producer has any university level training. In addition, Figure 7 shows that 96% of the producers are married and 4% are divorced. There are no single persons who cultivate Bambara groundnut areas among the respondents.

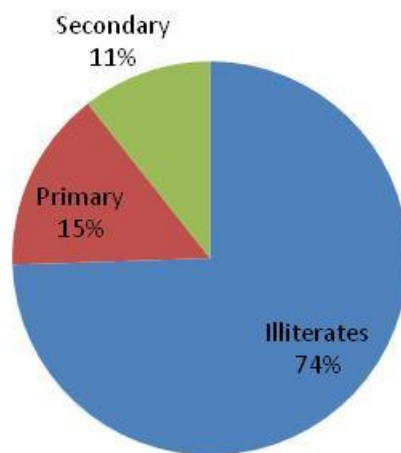


Figure 6: Level of formal education of producers at Maradi

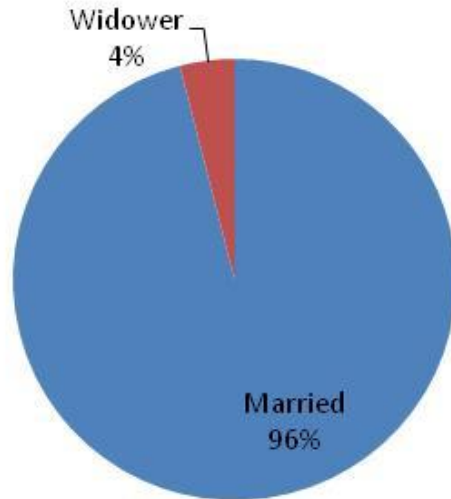


Figure 7: Marital status of the respondents at Maradi

Concerning producers' household size, Figure 8 shows that 42% of the producers have a household size between 6 and 10 people, 28% between 11 and 15 people, 22% between 16 and 20 people, 6% between 21 and 25 people, and 2% greater than or equal to 26 people. It is found that in Maradi, the household size is relatively high which potentially has a negative influence on production of Bambara groundnut. The results show that especially midsize households engage more in the production of Bambara groundnut (Fig. 8).

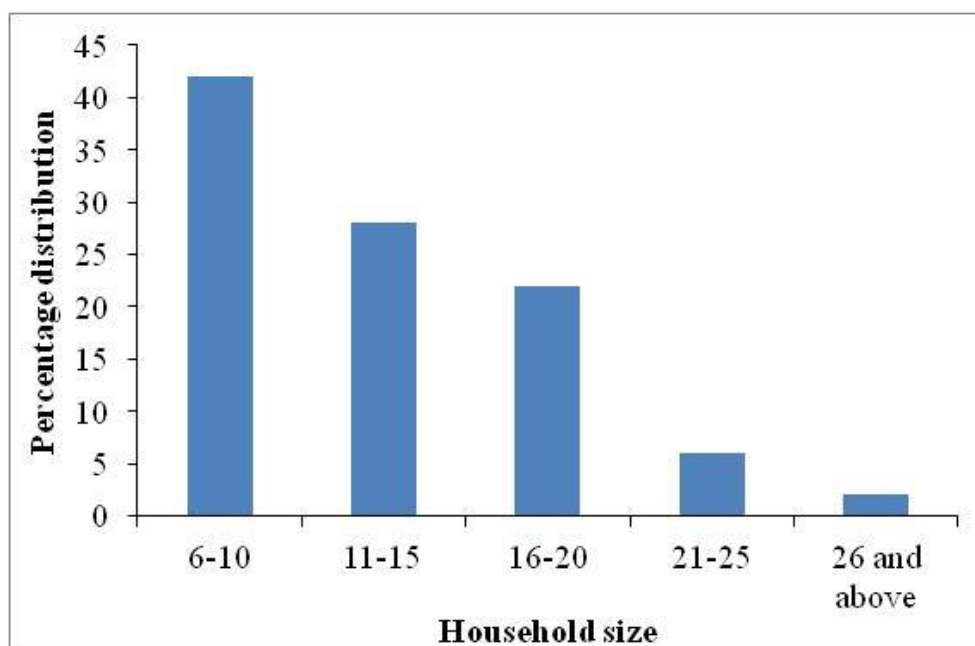


Figure 8: Household size of producers at Maradi

Producers also engage in other income generating secondary activities such as livestock breeding which engages 50% of producers, trade (28%) and others (Table 5).

Table 5: Secondary activities performed by the respondents

Secondary activity	% of producers
Agriculture	3
Agriculture and livestock breeding	3
Trade	28
Livestock breeding	50
Exodus	3
Fight	3
Small Business	3
Agricultural Processing	3
Timber Sale	3

### Zinder region

In Zinder, and similarly to Maradi, the cultivation of the Bambara groundnut remains largely the work of men who represent 80% of the participants in the sample (Fig. 9).

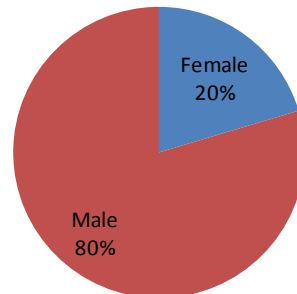


Figure 9: Sex distribution of the respondents at Zinder

Table 6 shows the age distribution of the producers. It is clear from Table 6 that similar to Dosso and Maradi, it is mainly older people who engage in the culture of Bambara groundnut. There is a strong dominance of the 40 to 49 and 50 to 59 years age groups, representing respectively 35% and 22%. The 20 to 29 age group qualifying as young represents only 6%.

Age	Number of respondents	Frequency
20-29	3	6.12
30-39	7	14.29
40-49	17	34.69
50-59	11	22.45
60-69	6	12.24
70-79	4	8.16
80 and over	1	2.04

Table 6: Age, number of respondents interviewed and frequency in Zinder for July 2013 survey on Bambara groundnut storage

In regards to the level of formal education of respondents, it is observed that 87% of the farmers are illiterate, only 11% have a primary education and 2% started secondary school (Fig. 10).

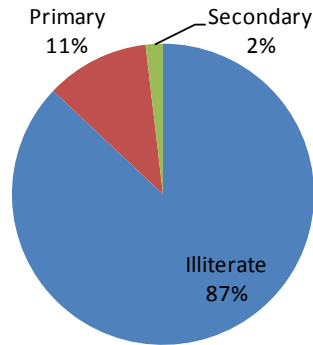


Figure 10: Level of formal education of producers at Zinder

The marital status of producers is given in Figure 11. It was found that 96% of the producers are married. No single was recorded among the participants.

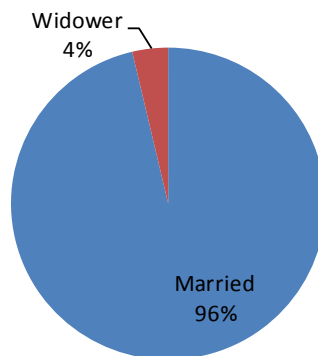


Figure 11: Marital status of the producers at Zinder

For the producers' household size in Zinder, Figure 12 shows that it is mostly medium-sized households who engage more in the production of Bambara groundnut. Thus, households ranging in size from 6-10 people and 11-15 people account respectively for 41% and 31% compared with 7% for small-sized households (1-5 people) and 2% for a household size of more than 26 people. This could be explained by the fact that small households do not have enough family labor to produce both major and minor crops; whereas for large households, the availability of land could be a limiting factor for the production of secondary crops.



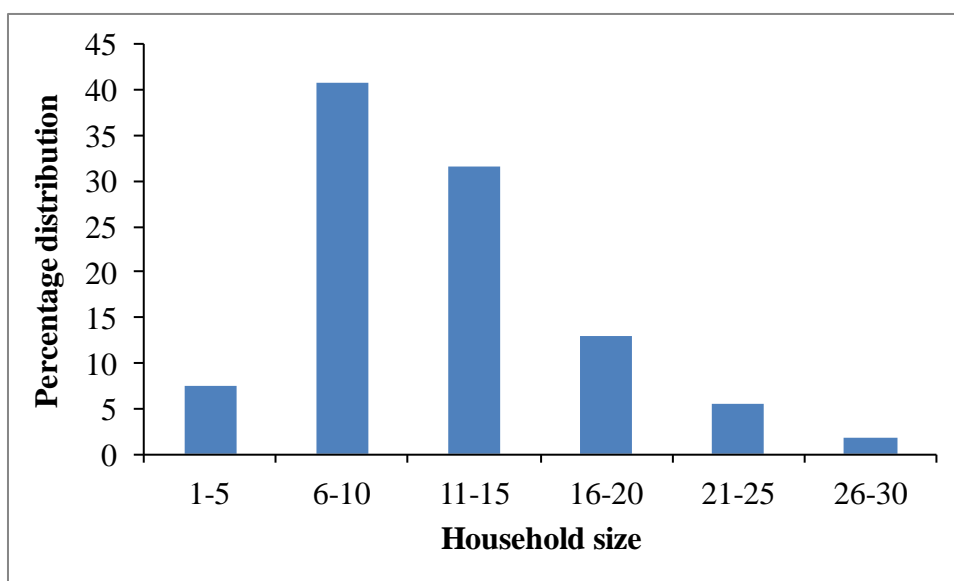


Figure 12: Household size of producers at Zinder

The participants in the study area have other income-generating activities including livestock breeding which engages 35% of the respondents, trade with 22% among others (Table 7).

Table 7: Secondary activities performed by the respondents at Zinder

Secondary activities	% of producers
Agriculture	10
Other	4
Hairdressing	2
Trade	22
Sales intermediary	2
Livestock breeding	35
Koranic teaching	2
Exodus	2
Forging	4
Masonry	2
Maraboutage	2
Radio repairing	2
Motorcycle tax	2
Agricultural processing	8
Water sale at the fountain	2

## **Bambara groundnut seed storage method by region**

### **Dosso region**

All respondents store Bambara groundnut grains in containers at home such as plastic jugs, simple bags, double bags, triple bags, barrels, granaries and jars (Table 8 and 9). Whether in 2012 or 2011, granaries and triple bagging remain the most used methods in the surveyed area: 26% and 29% of the respondents use granaries; 17% and 19% use triple bags, respectively for 2012 and 2011. The use of plastic jugs as a Bambara groundnut storage mean comes third. Of the 54 surveyed people in 2012, only one person used a barrel as the storage container for the Bambara groundnut grains, it is the same for 2011 (Table 9). It should also be noted that some respondents use more than one method of Bambara groundnut storage bringing the sum of the use frequencies to more than 100% in 2011.

Table 8: Storage method and percentage of participants using these conservation techniques in 2012 in the region of Dosso

Storage method	Number of participants	Percentage (%)
Plastic jugs	7	13
Plastic jugs + insecticide	2	4
Double bagging	4	7
Barrel	1	2
Metallic barrel + insecticide	1	2
Granary	14	26
Banco Granary + insecticide	3	6
Jar	1	2
Simple bag	6	11
Simple bag + insecticide	5	11
Triple bagging	9	17
<b>Total</b>	<b>54</b>	<b>100</b>

Table 9: Storage method and percentage of participants using these conservation techniques in 2011 in the region of Dosso

Méthode de stockage	Nombre d'acteurs	Pourcentage (%)
Plastic jugs	7	13
Plastic jugs + insecticide	1	2
Double bagging	4	8
Barrel	1	2
Granary	15	29
Granary + insecticide	4	8
Jar	1	2
Simple bag	4	8
Simple bag + insecticide	6	12
Triple bagging	10	19
<b>Total</b>	<b>52</b>	<b>101</b>

Small storage containers such as jars or barrels are used on average by 2% of respondents. Conservation techniques range from use of the container only to addition of insecticides or fine sand to fight infestations and prolong the shelf life. Thus, 12% of the respondents combine the use of simple woven bags with insecticide, 8% add insecticide to the granary, compared to 2% who use insecticide in plastic jugs.

According to Chougourou and Alavo (2011), the use of fine sand is linked to the fact that it coats the thin layer of waterproof wax that covers the cuticle of weevils and constitutes a barrier to the females trying to lay their eggs. Fine sand also has an abrasive effect on insects and causes death by dehydration.

### Maradi region

In Maradi the most used containers are simple bags (woven polypropylene) and plastic jugs, 23% and 15% of survey participants, respectively. Double and triple bagging are used by only 10% and 8% of the respondents in 2012, respectively. Traditional storage systems combine these facilities with the use of ash, sand or insecticide for an effective conservation of Bambara groundnut stocks. Tables 10 and 11 list the different storage systems used by sample participants in 2012 and 2011.

Table 10: Storage method and percentage of participants using these conservation techniques in 2012 in the region of Maradi

Storage method	Number of participants	Percentage
Plastic jugs	6	15
Plastic jugs + ash	1	3
Plastic jugs + insecticide	1	3
Jar + sand	2	5
Double bagging	4	10
Double bagging + insecticide	4	10
Double bagging + ash	1	3
Plastic bag	2	5
Plastic bag + insecticide	1	3
Simple bag	9	23
Simple bag + insecticide	4	10
Triple bagging	3	8
Hole + firm ash	1	3
<b>Total</b>	<b>39</b>	<b>100</b>

Table 11: Storage method and percentage of participants using these conservation techniques in 2011 in the region of Maradi

Storage method	Number of participants	Percentage
Plastic jugs	5	15
Plastic jugs + ash	1	3
Jar + sand	1	3
Double bagging	2	6
Double bagging + insecticide	4	12
Double bagging + ash	1	3
Granary + plastic	1	3
Black plastic	3	9
Simple bag	9	26
Simple bag + insecticide	3	9
Plastic bag + insecticide	1	3
Triple bagging	2	6
Hole + firm ash	1	3
<b>Total</b>	<b>34</b>	<b>100</b>

### Zinder region

Also at Zinder, in the surveyed area, plastic jugs and simple bags are storage containers used by most respondents for storing Bambara groundnut grains whether in 2012 or 2011. Various containers used to store Bambara groundnut are reported in Table 12. In 2012, over 44% of respondents used plastic jugs compared with 40% in 2011. Simple polypropylene bags are used by 29% in 2012 and 2011. Double and triple bagging techniques are less used in the region of Zinder. One respondent used double bags in 2011 and none in 2012, two used triple bags in 2012 compared with one in 2011. Pottery jars, commonly called canaries, are used for Bambara groundnut storage by 18% of respondents in 2011 and 13% in 2012. Conservation techniques consist of the use of these containers with the addition of neem leaves (*Azadirachta indica*), sand or insecticide.

Table 12: Storage system and percentage of participants using these conservation techniques in 2012 and 2011 in the region of Zinder

Storage method	2012		2011	
	Number of participants	Percentage	Number of participants	Percentage
Plastic jugs	19	44	18	40
Plastic jugs+neem leaves	1	2	1	2
Barrel+insecticide	1	2	0	0
Jar	6	13	8	18
Simple bag	13	29	13	29
Simple bag+insecticide	1	2	2	4
Crater + sand	2	4	1	2
Double bagging	0	0	1	2
Triple bagging	2	4	1	2
<b>Total</b>	<b>45</b>	<b>100</b>	<b>45</b>	<b>100</b>

### Quantity of stored grains by system and by region

#### **Dosso region**

More than 15,000 tons and almost 11,000 tons of Bambara groundnut grains were stored in 2012 and 2011, respectively, by the respondents in the sample in the Dosso region (Table 13). The storage system used by most participants is the triple bagging with 7,272.50 kg of stored Bambara groundnut using this method or 47% of the total tonnage stored in 2012 and 4,532.5 kg or 42% for 2011. Granaries come second in terms of the quantity of stored grains by container type with 2,757.50 kg of stored Bambara groundnut representing 18% of the total stock of those surveyed in 2012 (Table 13) and 2,762.5 kg or 25% in 2011. Simple bags rank third with a total of 1,657.50 kg in 2012 or 11% of the total stock and 1,475 kg in 2011, representing 14% of the total amount of stored Bamabara groundnut in 2011 by the respondents in the Dosso sample.

Overall about 61% of the Bambara groundnut was stored in potentially hermetic containers in 2012. Those potentially hermetic containers include: plastic jugs, one layer plastic bags, double bags, triple bags and drums. In 2012 2% of the quantity of Bambara groundnut stored by respondents was treated with insecticide.

Table 13: Amount of Bambara groundnut grains stored in 2012 and 2011 by storage system in the region of Dosso

Storage Container	2012		2011	
	Stored quantity (Kg)	Percentage (%)	Stored quantity (Kg)	Percentage (%)
Plastic jugs	775.00	5.06	602.50	5.52
Plastic jugs + insecticide	132.50	0.86	12.50	0.11
Double bagging	692.50	4.52	347.50	3.18
Barrel	100.00	0.65	67.50	0.62
Metallic barrel + powder	300.00	1.96	0	0
Granary	2757.50	17.99	2762.50	25.30
Granary + insecticide	378.750	2.47	0	0
Jar	100.00	0.65	200.00	1.83
Bag + plastic	25.00	0.16	100.00	0.92
Simple bag	1657.50	10.81	1475.00	13.51
Simple bag + insecticide	1137.50	7.42	817.50	7.49
Triple bagging	7272.50	47.44	4532.50	41.52
<b>Total</b>	<b>15328.75</b>	<b>100</b>	<b>10917.50</b>	<b>100</b>

Table 14 shows the stored quantity by container and producer. It is clear from Table 14 that granaries and plastic jugs are used to store small quantities of grains, while metal barrels and bags (simple, double and triple) are used to store larger amounts of Bambara groundnut.

Table 14: Total quantity of Bambara groundnut by storage technique and producer in Dosso

Container	Average quantity* (Kg)	Quantity per participant (kg)
Plastic jugs	688.75	98.39
Plastic jugs+insecticide	72.5	48.33
Double bagging	520	130.00
Barrel	83.75	83.75
Metallic barrel +powder	150	150.00
Granary	2760	190.34
Granary +insecticide	189.375	54.11
Jar	150	150.00
Bag+plastic	62.5	-
Simple bag	1566.25	313.25
Simple bag+insecticide	977.5	177.73
Triple bagging	5902.5	621.32

Average of 2011 and 2012

### Maradi region

In 2012, the total amount of stored Bambara groundnut grain by respondents was 2355.75 kg compared to 2410 kg in 2011 (Table 14). Almost 38% of the Bambara groundnut stock was in double bags in 2012 compared to 45% in 2011. In terms of stored quantity by container, woven sacks (simple bags) are in second place with 676.25 kg or 29% in 2012 compared with 858.75 kg representing 36% of the total amount of stored Bambara groundnut by the respondents in 2011 (Table 14).

The use of the triple bagging method is relatively low compared to the Dosso region, only 100 kg (4% of total) of Bambara groundnut were stored using the triple bagging method in 2012 and 62.5 kg in 2011 or about 3%. The conclusion that emerges from Table 15 is that insecticides or repellents are applied only on small stockpiles in jars, plastic bags and simple bags. In 2012 56% of Bambara groundnut reported stored was in potentially hermetic containers. Overall in 2012, 12% of the groundnut was treated with storage insecticides.

Table 16 shows the quantities of Bambara groundnut grains stored by container and year. It is found that the plastic jugs, jars and plastic bags are used mainly for storing small quantities unlike woven sacks.



Table 15: Quantity of stored Bambara groundnut in 2012 and 2011 by storage system in the region of Maradi

Container	2012		2011	
	Quantity (kg)	Percentage	Quantity (kg)	Percentage
Plastic jugs	102.50	4.35	53.75	2.23
Plastic jugs + insecticide	45.00	1.91	30.00	1.24
Plastic jugs + ash	0	0	10.00	0.41
Jar	62.50	2.65	37.50	1.56
Double bagging	895.00	37.99	1075.00	44.61
Woven sack	676.25	28.71	858.75	35.63
Plastic bag	144.50	6.13	10.00	0.41
Plastic bag + insecticide	35.00	1.49	60.00	2.49
Simple bag + insecticide	210.00	8.91	212.50	8.82
Simple bag + ash	85.00	3.61	0	0
Triple bagging	100.00	4.24	62.50	2.59
Total	2355.75	100	2410	100

Table 16: Total quantity of Bambara groundnut by storage technique and producer at Maradi

Container	Total quantity* (Kg)	Quantity per producer (kg)
Plastic jugs	78.13	14.20
Plastic jugs+insecticide	37.50	37.50
Plastic jugs+ash	10.00	10.00
Jar	50.00	33.33
Double bagging	985.00	328.33
Jute sack	767.50	767.50
Plastic bag	77.25	51.50
Plastic bag+insecticide	47.50	47.50
Simple bag+insecticide	211.25	105.63
Simple bag+ash	85.00	85.00
Triple bagging	81.25	32.50

Average of the two years

### Zinder region

Table 17 shows the quantities of stored Bambara groundnut grains by storage method in 2012 and 2011. In the region of Zinder, participants mostly use plastic jugs and simple bags to store their Bambara groundnut crops. In 2012, the total amount of the stock was 1806.25 kg, 557.5 kg of which in simple bags or 31% and 438.75 kg in plastic jugs representing 24% of the total stored quantity. Double and triple bags are used for 95 kg (5%) of the stock and 137.5 kg (7% of total stock), respectively. It is thus observed as in the region of Maradi the low use of triple bagging for storing Bambara groundnut. The relatively high adoption of this method in the Dosso region can be explained by the existence of a relatively efficient distribution network. In that sense this result is consistent with those of the 2009 cowpea storage study (Moussa *et al.*, 2010)

Quantities of stored grains per respondent and storage technique are given in Table 18. It was noted as in the other two regions that plastic jugs are mainly used to store small amounts while barrels, polypropylene bags and jars are reserved for large stock quantities. In 2012, 57% of Bambara groundnut was stored in potentially hermetic containers. That same year only 1% was treated with storage insecticides.

Table 17: Quantity of stored Bambara groundnut by container in 2012 and 2011 at Zinder

Storage system	2012		2011	
	Quantity (kg)	Percentage	Quantity (kg)	Percentage
Plastic jugs	438.75	24.29	758.75	40.09
Plastic jugs + neem leaves	25	1.38	17.5	0.92
Plastic jugs + sand	36.25	2.01	32.5	1.72
Double bagging	95	5.26	17.5	0.92
Barrel + insecticide	305	16.89	25	1.32
Jar	117.5	6.51	250	13.21
Jar + ash	37.5	2.08	26.25	1.39
Jar + sand	20	1.11	267.5	14.13
Simple bag	557.5	30.87	345	18.23
Simple bag+ leaves	7.5	0.42	32.5	1.72
Simple bag + insecticide	25	1.38	50	2.64
Crater	3.75	0.21	0	0
Triple bagging	137.5	7.61	62.5	3.30
Pot	0	0	7.5	0.40
Total	1806.25	100.00	1892.5	100.00

Table 18: Quantity of Bambara groundnut grains by storage technique and average quantity by participant in the region of Zinder

Container	Average quantity (kg)	Quantity per participant (kg)
Plastic jugs	598.75	32.36
Plastic jugs + neem leaves	21.25	21.25
Plastic jugs + sand	34.38	17.19
Double bagging	56.25	56.25
Barrel + insecticide	165	165
Jar	183.75	26.25
Jar + ash	31.875	31.88
Jar + sand	143.75	143.75
Simple bag	451.25	34.71
Simple bag+ leaves	20	20
Simple bag + insecticide	37.5	25
Bowl	1.88	1.25
Triple bagging	100	66.66
Pot	3.75	3.75

### **Traditional uses of Bambara groundnut by the respondents**

Bambara groundnut grains are eaten fresh or dried. In the dry state, they are boiled and eaten either alone or accompanied with onions, tomatoes, oil and other ingredients. Dry grains can be consumed as roasted or crushed into a powder and made into biscuits or mixed with cereal to form a porridge.

### **Seasonal price fluctuations**

Price fluctuations for 2011 and 2012 depending on the season and regional markets are illustrated in Figure 14. These results show that prices are low early in the season (September-December) in all three study areas. In the Dosso region, the first price increase is in January-February to reach a peak in May when the price of a kilogram of Bambara groundnut was 394 FCFA/kg compared to 155 FCFA/kg at harvest or a ratio of 2.30. In the contrary, Maradi and Zinder prices start to rise from the month of February and reach their peak in July in Maradi (500 FCFA / kg) and in June in Zinder (454 FCFA / kg). The lowest prices are recorded around harvesting with 70 FCFA on average in Maradi (September) or a ratio of 7.14 between the peak month and the harvest month when prices are at their lowest.

In Zinder, prices are at their lowest in August with an average of 150 FCFA for one kilogram of Bambara groundnut compared with 454 FCFA during the peak price time or a ratio of 3.

Price fluctuations are very important not only within the same region but further more between regions. The most significant fluctuations were recorded in Maradi.

At the regional level, the price fluctuation does not only depend on the season, but also from one market to another. For the same month, the price of a kilogram of Bambara groundnut sometimes quadruples from one market to another within the same region.

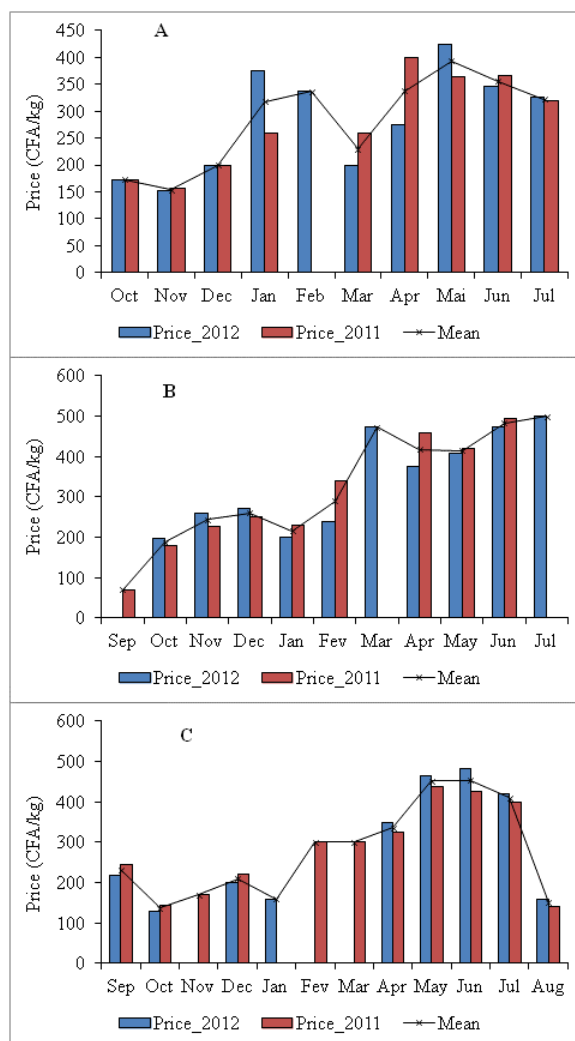


Figure 13: Seasonality of Bambara groundnut prices at Dosso (A), Maradi (B) and Zinder (C)

### Profitability of PICS bags

Socio-economic studies have shown that most farmers are illiterate in all three surveyed regions. Misuse of insecticides is a problem because farmers can not read the label instructions. The use of insecticides by these producers for the medium-term storage of their products is therefore a problem not only for the health of consumers, but also for the individual who applies it. It is therefore crucial to find an alternative to the traditional storage method (with or without insecticide) that is more profitable and healthy. Tables 19 and 20 give the process of calculating the gain on investment (*return on storage*) after 8-9 months of storage with opportunity costs of 25 and 35%. The net income and the gain on storage in Tables 19 and 20 are based on a harvest conducted in October and sold between June and July, when prices are at their highest, which corresponds to a storage period of 9 months.

Based on the literature review, we estimated at 1% on average storage losses after a phostoxin insecticide treatment (3 tablets per 100 kg of seed).

Because of the high price fluctuations between the harvest time and the lean season (June-July), and the duration (about 9 months), storage with PICS bags is very profitable for Bambara groundnut producers compared to the traditional storage method without insecticide.

Table 19: Calculation of the net income of producers with a sensitivity study of  $\pm 5\%$  of estimated losses ( $61.8 \pm 5\%$ ).

Selling period	Harvest	Traditional storage method				PICS storage bags	
	October	Without insecticide			With Phostoxin	1 year	2 years
		Sold in July					
Stock (kg)	100	100	100	100	100	100	100
Storage loss (%)	-	66.8	61.8	56.8	1	0.6	0.6
Commercial quantity (Kg)	100	33.2	38.2	43.2	99	99.4	99.4
Selling price (CFA/Kg)	165.5	449.33	449.33	449.33	449.33	449.33	449.33
Total income (CFA)	16550	14918	17164	19411	44484	44663	44663
<b>Costs</b>							
Bag	0	250	250	250	250	1000	500
Insecticide cost	-	-	-	-	450	-	-
Total cost of storage	0	250	250	250	700	1000	500
<b>Net income</b>	16550	14668	16914	19161	43784	43663	44163

Indeed, the net income with PICS bag has more than doubled relative to the income at harvest or the income generated after 9 months of storage with traditional storage containers (Table 19).

The net income generated after 9 months of storage with PICS bag is comparable to that obtained with a phostoxin treatment by means of 3 tablets per 100 kg of seed, renewed once during the 9 months of storage. When the PICS bag is reused for a second season, its profitability is higher than that of the chemical phostoxin treatment with 44,163 FCFA compared with 43,783 FCFA, respectively.

Even with an opportunity cost of 35%, a small Bambara groundnut producer who chooses to store his or her production with PICS bags in order to sell it during the lean period could double annual revenue with a 128% return on storage when the bag is used for a season

and 135% if the PICS bag is reused for a second season (Table 19). In both cases, the profitability using the PICS bag is comparable to that obtained with an insecticide treatment (Phostoxin).

On the other hand, even with a minimal opportunity cost of 25%, the traditional storage without insecticide is even with losses estimated at 56.8%, that is to say at a rate 5% lower than the losses estimated in the literature.

Table 20: Net profit and return on investment for producers (OCC 25% and 35%)

Selling Period	Sale at harvest	Traditional storage method				PICS storage bags	
		Without insecticide			With Phostoxin	1 year	2 years
	October	July					
<b>Net income</b>	16550	14668	16914	19161	43784	43663	44163
Storage losses (%)	-	66.8	61.8	56.8	1	0.6	0.6
<b>OCC 25%</b>	-	3150	3150	3150	3234	3291	3291
Net gain on storage	-	-5032	-2786	-539	23999	23823	24322
Return on storage (%)	-	-30%	-17%	-3%	139%	136%	143%
<b>OCC 35%</b>	-	4410	4410	4410	4528	4607	4476
Net gain on storage	-	- 6292	4046	-1799	22706	22507	23137
Return on storage (%)	-	-37%	- 24%	- 11%	135%	134%	138%

### Conclusion

Confronting the demographic and current climate issues, the storage of dry Bambara groundnut grains is seen as an important issue for food security in Niger. The results of the study show that in the Dosso region it is mostly older women (married or divorced) who predominantly practice the cultivation of Bambara groundnut while in Maradi and Zinder it is a male-dominated activity with a high proportion of older married or divorced elders producers of both sexes. In all three regions, singles do not grow Bambara groundnut and most farmers have no formal education.

The overwhelming majority of farmers store their harvest in various, for the most part, non-hermetic containers (simple bags, plastic jugs and granaries). Plastic jugs, granaries and

plastic bags are used mainly for storing small amounts of Bambara groundnut grains, while metal barrels and polypropylene bags are reserved for large quantities. The storage methods range from the standalone use of these containers to the addition of neem leaves (*Azadirachta indica*), sand or insecticide.

Slightly over half of the Bambara groundnut stored is in potentially hermetic containers including double and triple layer bags, plastic jugs and metal drums. Use of storage insecticide varied by region. Over 12% of the quantity stored was treated with insecticide in the Maradi Region, but only about 2% in the other regions. Use of the Purdue Improved Crop Storage (PICS) bag also varied by region. In the Dosso region in 2012, 47% of the Bambara groundnut was stored in PICS bags, but only 8% in Maradi and 4% in Zinder.

In order for the producers to take advantage of seasonal prices, 8 to 9 months of storage on average seems to be necessary. In addition, the price fluctuation is larger from one region to another and is even larger from a market to another within the same region. This fluctuation is much more pronounced in the Maradi region than in the other two regions namely Dosso and Zinder.

This survey showed that PICS bags are very profitable for Bambara groundnut producers in the study areas especially when longer-term storage conditions are required. Even when the PICS bag is only used one season, the simple rate of return is over 100% compared to selling at harvest or traditional storage. Returns to PICS bag use were comparable to storage with phostoxin when the bag is used one year. When the PICS bag is reused returns are better than storing with phostoxin. PICS technology is much more cost effective than the traditional storage method.

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