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On-farm storage losses of cowpea and bambara groundnut in Northern Ghana.

Golob, P.[1], Andan, H.F.[2], Atarigiya, J.[2] and Tran, B.M.D.[1]

Abstract

It is well known that grain legumes are subject to heavy damage by bruchid beetles during storage. Many laboratory studies have demonstrated that *Callosobruchus maculatus* can develop rapidly in cowpea. There are, however, few studies demonstrating what actually happens to cowpea on farms during storage. Even less is known about the damage to bambara groundnuts.

This paper presents the results of a survey conducted in northern Ghana during 1997 to identify the problems concerned with storing pulses. *C. maculatus* was the most important pest, although on bambara the infestation was dominated by *Callosobruchus subinnotatus*, a larger species.

Bambara, unlike cowpea, is not attacked before harvest as the pods are subterranean and it does not sustain such heavy damage during storage. Cowpea was readily attacked although the weight loss resulting from infestation was rarely in excess of 9% even after six months storage. Farmers rarely used conventional insecticide to protect the grain but they did use a variety of alternative methods including admixture of ash and dipping the grain in a solution in which a local weed, *Synedrella nodiflora*, had been boiled. These methods appeared to provide some protection.

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[1] Natural Resources Institute, Central Avenue, Chatham Maritime, Kent, ME4 4TB, United Kingdom. Fax: +44 (0)1634 880066/77

[2] Ministry of Food and Agriculture, Accra, Ghana.

Introduction

Grain legumes are commonly used as dry seed for cooking in much of tropical Africa. They have a protein content of approximately 20 to 25% (McFarlane, 1983), and their nitrogen fixing ability helps to increase agricultural yields. Cowpea (*Vigna unguiculata* (L.) Walp.) is the most important grain legume in Ghana. Bambara groundnut (*Vigna subterranea* (L.) Verdc) is also produced and sold at market as well as consumed on the farm. The mean area planted with each of these commodities in Ghana was estimated in 1987-1989 to be in the region of 147,000 hectares, and the mean annual production about 210,000 tonnes for cowpea, and 90,000 for bambara groundnut (Ghanaian Ministry of Food and Agriculture and Crops Research Institute, Kumasi, unpublished data). Legumes are grown throughout Ghana, but production is largely confined to the north of the country, in the Northern, Upper East and Upper West regions. Most farmers cultivate between 0.4 and 2 hectares of cowpea, which is often inter-cropped with cereals. In northern Ghana, cowpea forms a major part of the diet, and the majority of farmers cultivate it for subsistence, but some will also sell part of the harvest.

Stored legumes are attacked by bruchids (Coleoptera: Bruchidae). The larval stages develop inside the beans; damage and weight loss are caused by larvae consuming the seed. *Callosobruchus maculatus* (Fab.) is the most important pest developing on cowpea, and *Callosobruchus subinnotatus* (Pic) on bambara groundnut. Experimental studies have shown that in the laboratory, female bruchids can lay in excess of 100 eggs, and with a generation time of about a month (Dick and Credland, 1984), infestations grow exponentially until the complete stock is destroyed, in a few months.

The levels of losses due to bruchids in Africa are not well documented, due partly to the lack of suitable verified methodologies for assessment. Gudrups (unpublished data) found cowpea and bambara groundnut with damage levels of 22-23% on average, in markets in Accra and Tamale in February and May 1995. In markets in northern Ghana, levels of damage varied from 15 to 94% for cowpea and 14 to 100% for bambara (Golob, unpublished data). On-farm damage has rarely been studied, losses even less. Caswell (1974) described on-farm losses for cowpea in northern Nigeria increasing from 4% after harvest to 60 to 70% at the end of the storage season. For bambara groundnut, Amuti and Larbi (1981) recorded a mean weight loss of 3.7% after five months of storage under local Ghanaian conditions.

Material and Methods

SURVEY

This survey of stored cowpea and bambara groundnut covered two regions of Ghana, Northern Region and Upper East Region. Thirty-five farmers in one or two villages in each region were selected before harvest to participate in the study. Only farmers who intended to store for at least five months wer chosen. Post-Harvest Officers from the Ministry of Food and Agriculture made a monthly visit to the farmers during the whole storage period (from December 1996 to September 1997), and recorded the treatments applied to protect the crop against the bruchids infestation. They followed, both qualitatively and quantitatively, the removals of grain from stores, and measured

the damage caused by bruchids on two replicates of samples of 200 grain. The damage data allowed calculation of weight losses, using a rapid method of assessment.

To record removals from the store, each farmer was given coloured pots or cups where they put stones to record removals. One stone indicating the removal of one bowl, colours corresponding to the type of removal (for sale, seeds, food or gift). The bowl, having a capacity of approximately 4.5 kg, is the local unit used for measuring these commodities. These records were checked against monthly interviews with each farmer. When removals were made for sale the price obtained was also recorded.

A rapid method for estimating losses in stored cowpea and bambara groundnut was developed prior to this survey (Wright and Golob, in press) to allow fast and reliable assessment of the weight losses caused by the bruchids in the stores, from the percentage of beans damaged. The relationship between the two variables was investigated on samples collected from local markets, and covering a wide range of damage. The relationship was determined to be well represented by a second degree polynomial equation, which can be used in calculations, and a graph was produced, together with a simple protocol, for use in the field.

Due to the participatory nature of the survey, some data were incomplete. Such cases were not included in the analysis.

DATA ANALYSIS

Damage and loss

The average percentage damage given here for the whole storage period are calculated by weighting the observed damage by the amount of beans removed at the time of measurement (i.e. monthly):

$$\text{Average \% damage} = \frac{\sum_{\text{over the whole storage}}^{\text{for each month}} (\text{removal} \times \%\text{damage})}{\sum_{\text{over the whole storage}}^{\text{for each month}} (\text{removals})} \qquad \text{(equation 1)}$$

$$\text{Average \% weight loss} = \frac{\sum_{\text{over the whole storage}}^{\text{for each month}} (\text{removal} \times \%\text{loss})}{\sum_{\text{over the whole storage}}^{\text{for each month}} (\text{removals})} \qquad \text{(equation 2)}$$

These figures are therefore representative of the actual damage on beans removed, at the time of removal, taking into account the variation of the damage during the storage period and the removals of beans by the farmers. The percentage weight losses, calculated in the same way, are expressed in a manner which is relevant to the farmer.

Statistics

Where needed, percentages were normalised using an arcsine square root transformation. Mean and standard error to the mean were calculated, and are given as 'mean ± SEM'. Comparison of the mean values were made between pairs with t-tests. For transformed data, reverse transformed percentages were then calculated for the means, and are also presented as they are easier to read.

Results

The bambara groundnuts found during the survey were varieties which were mottled or stripprd red in colour. Cowpeas were all local white varieties, those from Upper East had larger grains than those from Northern Region.

QUANTITIES STORED

The quantities of cowpea stored differed markedly between the two regions. In Northern Region, farmers stored on average 135 ± 22 bowls, when in Upper East Region the average was only 21 ± 2 bowls. About the same quantities of bambara were stored in Northern Region, 36 ± 1 bowls, and Upper East Region, 32 ± 3 bowls.

WEIGHT LOSS

Calculation of weight loss, which is derived from the assessment of grain damage, could not be completed for those farmers whose grain exhibited very low levels of damage.

Percentage of farmers affected

In Northern Region, stored cowpea of 89% of the farmers suffered measurable weight losses, but in Upper East Region, it was only the case for 29% of the farmers. For bambara groundnut, it was 37% of the farmers in Northern Region and 20% in Upper East Region.

Percentage weight loss

For farmers who suffered measurable weight losses, table 1 presents the average percentage weight losses for cowpea and bambara in the two regions over the entire storage period. Losses were significantly greater for farmers storing cowpea in Northern Region.

PERCENTAGE DAMAGE

Data from all farmers were used to calculate these values, as they were directly measured. Table 2 presents the average percentage damage over the storage period, for each commodity, in the two regions studied. Again, the two regions differed only for damage to cowpea.

Figure 1 shows the evolution of the damage measured on cowpea in Northern Region over the whole period of storage. These are the averages, over the region, of the data collected monthly during the survey. They only show the evolution of the damage inside the stores, without taking into account the removals from the stores (cf table 2).

REMOVALS FROM THE STORES

Variation in time and use

Figure 2 shows the monthly removals over the storage period. Where possible, removals were classified in two categories: sales, or a combination of all removals for food, gifts or to use as seeds for the next crop. This information was not available after May, in Upper East Region. From the stores of cowpea, in Northern Region, there was a slow increase at first, then a peak in May and June, followed by a steep decrease. Almost the entire stock is sold, over the storage period. In contrast, in Upper East Region, sales are less prevalent. Quantities removed decrease during the storage period, with the exception of a peak in May,when prices peak. Before May, sales represent only a small proportion of the removals.

Removals from stores of bambara groundnut follow a similar pattern in both regions. They first increase, then fall in May, with a second increase, followed by a final decrease. Generally, slightly less beans were used for sales than for other purposes.

Price variation in time

Figure 3 presents the average price obtained by the farmer, per bowl of commodity sold, each month. The number of sales is also shown. In Upper East Region, data were not available after May.

Sales of cowpea in Northern Region were made at low prices, around 1500 Cedis per bowl, and they remained rather constant until June. Prices fell to 1000 Cedis in July and August, then rose up again. In Upper East Region, prices were much higher, starting at 2000 Cedis, and growing quickly to about 2700 from February to May.

The price variation of a bowl of bambara groundnut was very similar in the two regions. Prices started around 1500 Cedis, then rose to a maximum of 2000 in February for Upper East Region, and in April for Northern Region. No sales of bambara groundnut were recorded in Northern Region after July.

PROTECTION METHODS USED

During the survey, the methods of protection used on the stored commodities were recorded. Globally, they differed according to the commodity, and to the region. Table 3 presents the methods of treatment used on cowpea, ranked according to the percentage damage suffered on the treated stock. In table 4, the protection methods used on bambara were classified according to the type of treatment as the damage recorded on bambara groundnut were low or very low.

Discussion

QUANTITIES STORED

The quantities stored reflect the use of the crop. In Northern Region, cowpea is grown primarily as a cash crop, and only secondarily as a food crop. The quantities stored are therefore substantially greater than in Upper East Region, where cowpea is mostly

used as a food crop and farmers do not produce sufficient surplus for sale. Bambara groundnuts are used primarily as food crop in both regions.

REMOVALS AND PRICES

Some farmers save a lot of grain for planting as seeds, especially for bambara groundnut, but also for cowpea. There are no improved bambara groundnut seeds on the market, and very little improved cowpea.

In Northern Region, cowpea is mostly sold in the first half of the storage season, when the prices remain low as a result of continuous supply coming on to the market. The sales are made in the months after harvest to raise cash to meet debts (e.g. loans for production activities and fertiliser, hire of tractor and to pay school fees). The opposite situation is observed in Upper East Region, where prices increase with the increase in demand when nobody wants to sell. In Northern Region, prices remain low in May and June because farmers are selling for cash to finance the new planting season. Prices obtained by farmers included in the survey even fall in July and August because cowpeas produced in southern Ghana appear in markets in the north and also because of the arrival of early maturing varieties. Prices only rise in September and October, during the period immediately prior to the harvest of the main crop.

The prices recorded in this survey are prices attained by the cowpea which was sold, not the maximum prices that good quality cowpea could fetch. Figures from the Ghanaian government show that between December and September, the increase in price for cowpea can be as much as 51% (I. Gudrups, unpublished data). Bambara groundnut is not primarily a marketable crop, therefore it is always relatively scarce on markets, and so commands a good price, even just after harvest, when prices would be expected to fall.

WEIGHT LOSSES AND DAMAGE

The weight losses recorded were lower than might be expected. This is partly due to the method of assessment, which takes into account the declining amount of food in the store as the storage season progresses, and calculates the losses on the beans removed from the stores by the farmers, i.e. the *actual* loss incurred. Few other estimates have done this, and therefore over-estimated the actual losses.
This is illustrated by a representative example: farmer Adamu Bukari, from Northern Region, stored 80 bowls of cowpea. During the storage period, damage peaked at 42.5% and weight loss at 7.2%. Using the method of assessment described here, the cumulated figures are: 21.3% for damage, and 3.1% for weight loss.

The weight losses measured in this study appear to be of negligible importance, but the damage is certainly not, because damaged beans will command a much reduced price at market. Prices for cowpea and bambara are reduced if they are insect damaged. This explains why prices recorded for selling cowpea in Northern Region did not increase with time, because the beans were damaged, and did not reach the premium prices offered for undamaged grain. At Tamale market, the main market in northern Ghana, good quality cowpea is bought at a premium price by traders from the south (up to 2600 cedis per bowl). Poor quality cowpea stays in Tamale and is retailed locally by women traders.

In May 1997, it was noted that the damage levels found in Northern Region were consistent with only two generations of bruchids during six months storage. Also, in many cases, all adult bruchids found in the samples were dead, some inside the grain. Figure 1 shows that the damage to cowpea increases only until March or April. Although this could be related to the decreasing number of farmers who keep cowpea in store (it is likely that only farmers whose stock is not too badly damaged keep their beans), the typical increase of damage observed in experimental conditions is not apparent in the field. It appears that populations of bruchids do not develop as quickly and dramatically as they do under experimental conditions.

PROTECTION METHODS

This survey lists several methods of protection of cowpea and bambara groundnut in the north of Ghana. To show possible effects, the data were presented with the damage measured on the commodities, but a causal effect cannot be inferred with certainty from this study, as there may be several other sources of variation of the damage (e.g. the initial level of infestation and the type of storage structure used).

Traditional methods

Admixture of ash appeared to be a widespread method of protection in Upper East Region, where all farmers included in the survey used ash on cowpea, at least as part of a treatment. Ashes were also used on bambara, although not so commonly. It was noted during the survey that samples of bambara groundnuts treated with ash did not bear any bruchid eggs, when some samples from stocks which were not treated had many eggs.

Treatments of the bambara groundnuts did not differ widely between the two regions. Bambara were either not treated, or if protected, it was in most cases by immersing the beans in water in which Kim-kim, a Labiatae (*Synidrella nodiflora*), had been boiled, or in water with shea-nut butter (*Vitellaria paradoxa*).

Pesticides

In Northern Region, cowpea stores at farm level are mainly treated with pesticides. There was no use of chemicals in Upper East Region on cowpea, where ash was generally added to the commodity. Chemicals are not generally used on bambara groundnut either; only two farmers (in Northern Region) reported using Actellic (pirimiphos- methyl). The availability of pesticides is a restricting factor for rural areas, as is the price of these chemicals. This would explain their widespread use only on cowpea in Northern Region, on commodities mainly destined to be sold on the market.

Untreated cowpea stocks suffered an average damage of 36% in Northern Region(table 3). The application of synthetic contact insecticides such as cypermethrin or Sumicombi (fenitrothion + fenvalerate) did not provide any measure of protection. This was probably because of poor application methods leading to underdosing and the use of poor quality formulations. Clearly, farmers and extension workers require much more training if they are to make best use of these chemicals.

During this survey, and previous studies in these areas, it was noted that aluminium phosphide tablets, from phosphine gas evolves, were used improperly. It does not only limit the efficacy of the fumigation, but is dangerous for farmers and their families, and could lead to development of resistance in the local strains of bruchids exposed to sub-lethal concentrations. Although it will be impossible to effectively prohibit the use of phosphine by farmers in this part of Africa because they are readily available and cheap, and their use is not centrally controlled (see paper by Brice, J and Golob, P, presented at this conference), the availability of the gas re-emphasises the need for training of extension workers and farmers.

Conclusion

The bambara groundnut is not considered to be a cash crop, but this survey revealed that good prices could be obtained for this commodity. Damage found in these farm samples was much lower than was found previously in samples collected from markets. This may be due to differences in varietal susceptibility as those found on markets were from different localities in Northern Region and were uniformly white in colour rather than the mainly red colour collected during this survey. The effects of varietal differences on susceptibility to bruchid damage needs to be examined further.

Weight losses at farm level were not known before this survey. By using the rapid method of estimation, it was possible to calculate and analyse these losses over the period of storage. One of the most important observations reported here, is that weight losses are not as high as was previously supposed. The bruchid infestations appear to be much slower and weaker than experimental work infers. More experimental work is needed to understand this reduction of the potential population growth of the bruchids.

However, damage levels are high and economically significant. In a previous technical and socio-economic survey on post-harvest constraints and opportunities in cereal and legume production systems in northern Ghana (John Brice, unpublished data), it was reported that "farmers viewed pest control as an important area in the storage of grains throughout northern Ghana". Damage, mainly caused by the emergence holes of the adult bruchids, probably reduces seed germination and affects the appearance of the beans.

Because the beans sold by farmers are damaged, they command lower prices. Because of the risk of low prices, farmers cannot safely store their harvest until the prices are high for good quality commodities, and cowpea cannot be used as cash crop as much as it could. This is the case in Northern Region. In Upper East Region, farmers do not store large quantities of cowpea. The lack of certainty about the prices that they could obtain at the end of the storage period adds to production constraints.
Previous studies have shown that cowpea sold on markets is usually of poor quality, with high levels of damage from bruchids. As this study has shown that only a small proportion of this damage takes place at the farm level, it is reasonable to postulate that damage might occur at the traders and wholesalers level, when large quantities of the commodity are stored. The next phase of this study will concentrate on this level.

This survey also reported the use of some traditional methods of protection, some of which are widespread. Their effectiveness needs to be ascertained. Alternative methods of protection have been developed, as part of this project, and should reinforce the protection offered to farmers, leading to even lower losses, and acceptable levels of damage.

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Table 1: Weight losses for Cowpea and bambara groundnut in the 2 regions studied.

Commodity	Region	Transformed data		Significance	Reverse transformed
		Average	SEM		Average
Cowpea	Northern	0.219	± 0.013		4.7%
	Upper East	0.103	± 0.017	$p < 0.001$	1.1%
Bambara	Northern	0.117	± 0.012		1.4%
	Upper East	0.128	± 0.028	NS	1.6%

Table 2: Damage for Cowpea and bambara groundnut in the 2 regions studied.

Commodity	Region	Transformed data		Significance	Reverse transformed
		Average	SEM		Average
Cowpea	Northern	0.608	± 0.035		32.6%
	Upper East	0.249	± 0.019	$p < 0.001$	6.1%
Bambara	Northern	0.207	± 0.024		4.2%
	Upper East	0.162	± 0.025	NS	2.6%

Table 3: Methods of treatment used on stored cowpea, ranked according to the percentage damage suffered:

Treatment	Region	Mean % damage	Transformed mean ± SEM	Number of farmers
Cypermethrin / sun dried	NR	66.2	0.851	1
Phosphine / Cypermethrin	NR	60.1	0.803	1
Cypermethrin	NR	45.3	0.685 ± 0.059	8
Sumicombi (Fenitrothion + Fenvalerate)	NR	44.5	0.679 ± 0.126	4
sun dried	NR	40.5	0.646	1
not treated	NR	36.2	0.608 ± 0.087	9
Cypermethrin / Sumicombi	NR	36.0	0.607 ± 0.003	2
Napthalene	NR	23.4	0.486 ± 0.053	2
Phosphine	NR	17.4	0.419 ± 0.032	5
Mix with ash, no heat: heated over fire later	UER	7.8	0.280	1
Mix with ash	UER	7.4	0.272 ± 0.200	2
Heat over fire and mix ash	UER	6.2	0.248 ± 0.019	31
Heat over fire and mix ash and orange peel	UER	3.5	0.187	1

Table 4: Methods of treatment used on stored bambara groundnut, classified according to the type of treatment:

Type of treatment	Treatment	Region	Mean % damage	Transformed mean ± SEM	Number of farmers
Not treated	-	NR	6.0	0.244 ± 0.181	12
	-	UER	4.5	0.213	1
Actellic (Pirimiphos methyl)	2% dust	NR	16.7	0.409	1
	25% emulsifiable concentrate	NR	9.1	0.301	1
Dry materials mixed	Mixed with wood ash	UER	3.4	0.185 ± 0.168	2
	Mixed with ash and kul-enka	UER	2.1	0.146	1
	Kimkim mixed with seed	UER	0.9	0.095 ± 0.018	2
Water based ash	Immerse in warm water	UER	5.7	0.239	1
	Immerse in ash in warm water	UER	1.4	0.119	1
	Steamed ash in water, pored over bambara, dried	UER	1.3	0.116 ± 0.070	3
	Immerse in warm water, dry, mix in ash	UER	0.6	0.077 ± 0.045	3
dawadawa	Dawadawa seed boiled in water, poured over grain	UER	10.7	0.328 ± 0.212	3
	Dawadawa seed boiled in water, poured over grain, coat with ash	UER	0.1	0.022	1
	Dawadawa seed and kimkim boiled in water, poured over grain	UER	3.2	0.179	1
kimkim	Dipped in boiled kimkim water	NR	2.5	0.158 ± 0.066	12
	Immerse in kimkim boiled water	UER	6.4	0.253 ± 0.224	5
	Immerse in kimkim and neem leaves boiled water	UER	26.5	0.518	1
	Immerse in kimkim boiled water, dry, mix with ash	UER	1.2	0.110 ± 0.003	2
	Immerse in kimkim boiled water, dry,	UER	0.6	0.078 ± 0.051	5
shea butter	Soak in shea butter waste water	NR	2.0	0.141 ± 0.138	6
	Immerse in water in which shea butter dissolved	UER	1.6	0.125 ± 0.003	2
neem & orange peel	Added orange peel to water with neem	UER	0.0	0.000	1

Kul-enka: Graminae sp. (not yet fully identified)
Kimkim: *Synidrella nodiflora*
Dawadawa: *Parkia clappertonia*
Shea: *Vitellaria paradoxa*
Neem: *Azadirachta indica.*

Figure 1: Average damage on stored cowpea in Northern Region (transformed data, mean and SEM, with reverse transformed mean percentages and number of farmers who had cowpea left in store).

Figure 2: Monthly removals over the storage period for cowpea and bambara groundnut, in the Northern and Upper East regions. All figures are in bowls (approximately 4.5 kg).

Figure 3: Variation of the average price per bowl during the storage period for cowpea and bambara, in the Northern and Upper East regions. (figures not available for Upper East Region after May)