

NRI Report 2417

**Improvements In The Storage And
Marketing Quality Of Grain
Legumes: Final Technical Report**

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**Improvements In The Storage And
Marketing Quality Of Grain Legumes:**

Final Technical Report

Project R 6503

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Executive Summary

The objective of this three-year project based in northern Ghana was to identify qualitative and quantitative losses in the storage of grain legumes by small-scale farmers and develop means of reducing the losses. The project used participatory surveys to monitor the loss in value during storage, both on-farm and in the markets. These surveys showed that heavy losses occurred during storage in markets.

Participatory surveys provided data on the current post-harvest situation and identified the main constraints to the storage and marketing of pulses in northern Ghana. This included:

- the quantity of cowpea and bambara typically stored by farmers and traders;
- the duration of storage;
- the reasons why this storage is not prolonged;
- the extent of the damage due to insect pests; and
- the price fluctuations both in time and due to insect damage.

The surveys also identified methods which farmers and traders were using to control losses. Storage losses and insect damage were monitored using a rapid assessment method designed by the project. Cowpeas may suffer heavy insect damage, more than 30%, whilst stored on the farm; losses can exceed 10% by weight. Insect damage is clearly substantial during storage both on-farm and at market ranging from 2.6% to 70%. Although some on-farm traditional methods of grain protection are effective, the use of protective measures by traders is inadequate.

In Northern Region, more than 90% of the cowpea production is sold (Golob *et al.*, in press) and these sales represent a significant source of income for small-scale farmers. Although some cowpeas are sold immediately after harvest to raise cash to meet debts, it is desirable that farmers retain the bulk of their harvest until later in the year when prices have risen; in 1997 prices increased from 1400 to 1700 cedis in four months. Early sales, because of fears of storage losses, can therefore result in a significant loss of farm income.

Poor quality grain will also affect prices obtained at market, especially at periods of peak demand. Grain of high quality fetches a premium both for the local trader and for the farmer, particularly as insect-undamaged grain is difficult to find. However, whilst remaining in the trader's store insect damage increases significantly; it is not unusual to see grain with more than 50% damage. Farmers need to offer good quality grain and it is essential that traders are able to maintain this quality whilst they hold stocks in store.

Loss of quality has resulted in loss of income, which is passed back to the farmer. For example, in Tamale market in 1997, when prices were at a peak in April, large clean cowpeas sold for 120,000 cedis per sack whereas cowpeas which had 25% damage were 106,000 cedis, a 12% loss in value, and when prices dropped to their lowest level in August this loss of quality resulted in an 18% loss in value.

The control methods developed by the project are divided into short to medium term and long term approaches.

Short to medium term approaches

- *On-farm control.* Low cost methods, either improvements to traditional methods or new methods, were developed and their effectiveness tested in on-station trials. The most promising methods (below) were then tested on-farm, allowing farmers to make a choice based on availability of material, wealth, tradition, and personal preferences:
 - Solar disinfestation using grass matting, jute sacks and clear polythene sheeting;
 - Hermetic containers using small, locally-available plastic bins;
 - Application of *Vitellaria paradoxa* (shea) nut butter;
 - Application of powdered chilli pepper, wood ash from the kitchen fire or powdered *Securidaca longipedunculata* (palaga);
 - Dipping grain in water-based solutions containing *Synidrella nodiflora* (kimkim);
- *Support for market traders.* Methods developed for traders included phosphine fumigation, the use of inert dusts and physical barriers, and good storage hygiene. Proper fumigation techniques have been demonstrated and a pilot fumigation centre, sponsored by UK and local government, has been opened at Tamale market.

Long term approaches

- *Screening for resistance.* Local cowpea and bambara varieties were screened for resistance to bruchids. This preliminary work showed that there are resistance traits in some of the local varieties that could be selected by breeding programmes.
- *Qualities of the varieties.* Attention was given to the characteristics that make local varieties of cowpea and bambara more acceptable to the consumer including organoleptic and cooking qualities.

Project outputs will be recorded on a video, providing an account of the storage of grain legumes, and highlighting the control methods developed by the project.

Content

	Page
Acknowledgements	i
Executive Summary	iii
Content	v
INTRODUCTION.....	1
SURVEYS	3
Rapid method of loss assessment	5
On-farm losses surveys	8
Marketing & socio-economic survey	17
EXPERIMENTAL WORK.....	20
Methods for on-farm control	20
<i>Sun drying</i>	20
<i>Additives</i>	24
<i>Hermetic storage</i>	26
<i>On-farm trials</i>	28
Methods for traders	29
<i>Traders' stores</i>	29
<i>Lined bag test</i>	31
<i>Fumigation site</i>	32
RESISTANCE TO BRUCHIDS AND QUALITY OF LEGUMES VARIETIES	33
Varietal resistance in cowpea	34
Varietal resistance in bambara.....	34
Qualities of varieties of legumes	38
Conclusion.....	41
SUMMARY AND FUTURE WORK.....	41
References:.....	43
Project outputs	43
Other references:	43
APPENDIX I	
RAPID LOSS ASSESSMENT TECHNIQUE.....	45
APPENDIX II	
METHODS OF TREATMENT USED ON COWPEA AND ON BAMBARA	47
APPENDIX III	
RESISTANCE SCREENING OF BAMBARA VARIETIES.	49

INTRODUCTION

1. The DFID-funded project "Improvements in the storage and marketing quality of grain legumes" in northern Ghana started in March 1996, and finished in February 1999. In order to improve food security, and alleviate poverty of underprivileged groups of small-scale farmers, the project aimed at reducing the losses incurred between harvesting and consumption of legumes, which are a major alternative source of protein. Cowpea (*Vigna unguiculata* (L.) Walp.) and bambara groundnut (*Vigna subterranea* (L.) Verdc.) play an important role in the diet and economy of many small-scale farmers in Northern Ghana. The grains of both legume species suffer substantial damage and loss of quality as a result of infestation by members of the Bruchidae family, *Callosobruchus maculatus* (F.) and *C. subinnotatus* (Pic).

2. Grain legumes are commonly used as dry seed for cooking in much of tropical Africa. They are of particular importance as a subsistence crop in tropical and semi-tropical countries where there is a shortage of animal protein (Kay, 1979) as they have a protein content of approximately 20 to 25% (McFarlane, 1983). In addition to their value as a food stuff, their nitrogen-fixing ability helps increase soil fertility without the use of expensive nitrogenous fertilisers.

3. Cowpea is the most important grain legume in Ghana. Bambara groundnut 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). Whilst legumes are grown throughout Ghana, the bulk of production takes place in the three northern regions (Northern, Upper West and Upper East 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 home consumption, but some also sell part of the harvest to raise cash to meet costs of medical expenses, school fees, etc.

4. Grain legumes are mostly stored on the farm though traders and wholesalers do store considerable quantities of the marketed surplus (Gudrups *et al.*, 1996). Traders purchase produce immediately after harvest when prices are low and store for six to seven months until the lean period in May/June (Golob *et al.*, 1996)

5. Stored legumes are attacked by bruchids (Coleoptera: Bruchidae), which also attack the mature pods in the field before harvest. The feeding of adult bruchids is of no economic importance. Damage and weight loss are caused by larvae, which develop inside the grain consuming the seed. Cowpeas are attacked by *C. maculatus* and bambara groundnut by *C. subinnotatus* and *C. maculatus*, the former being of more importance. 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.

6. Storage losses as a result of insect damage have been identified in cowpea and bambara groundnut during previous visits to northern Ghana (Gudrups *et al.*, 1996; Golob *et al.*, 1996).

7. The levels of losses due to bruchids in Africa are not well documented, due partly to the lack of suitable verified methodologies for assessment. A survey undertaken by the Post Harvest Loss Prevention Project in Uganda in 1992 identified losses to cowpeas of 1.7 and 5.9% of harvested crop after three and six months storage on-farm respectively (cited in Gudrups *et al.*, 1996). In West Africa, where ambient conditions are more conducive to insect development, damage can be even greater particularly when stored by traders. For example, 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. Insect damage can be particularly severe if protective measures are not undertaken and if storage facilities are in poor condition (Gudrups *et al.*, 1996). In markets in northern Ghana, damage in traders' stores varied from 15 to 94% for cowpea and 14 to 100% for bambara (Golob, unpublished data).

8. 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. On bambara groundnut, Amuti and Larbi (1981) recorded a mean weight loss of 3.7% after five months of storage under local Ghanaian conditions. Golob *et al.* (1996) determined average storage losses in traders stores to be between 50% and 100% by weight of cowpeas after six months storage. Storage losses in bambara were also found to exceed 50% but the seeds were not usually damaged as quickly or to the same extent as cowpea.

9. In northern Ghana, grain legumes are harvested at the beginning of the dry season, in October and November. The dried grain is stored on the farm and can be used for household food, traditional gifts (weddings and funerals), sowing of the next crop, or for sales. Market traders may buy direct from farmers or through agents (Golob *et al.*, 1996). At certain time of the year, especially between November and May, these traders will store grain and then sell it on to local retailers or to larger wholesalers who transport the grain to markets in Accra and other large southern towns. Consumers in the south, therefore, are likely to be urban dwellers who demand relatively good quality produce and are prepared to pay a premium for it.



SURVEYS

10. A technical and socio-economic survey was carried out using Rapid Rural Appraisal (RRA) techniques, throughout the three northern regions of Ghana (Northern, Upper East and Upper West Regions) in July and August, 1996 (Brice *et al.*, 1996). The survey investigated post-harvest constraints in relation to other agricultural issues, and concentrated particularly on gaining information concerning local storage structures, traditional methods of grain protection and the storage and marketing of grain legumes.
11. Two teams were established, each with at least one scientist and one socio-economist (familiar with the technical content of the projects and RRA techniques respectively). Having developed and tested the general methodology during visits to a number of villages around the Tamale area, the teams separated: the first team covered the eastern side of the Northern Region and then the Upper East Region, whilst the second team covered the western side of the Northern Region and Upper West Region. The two teams met to compare findings before and after visiting the upper regions. Each team visited approximately 11 villages, spending one day in each. Both groups and individuals were interviewed in each village: where possible separate groups of men and women were selected since responsibilities and perception were often found to vary with gender.
12. An initial discussion was held with the village elders/chief (with the rest of the village present) to collect information on general practices and problems. During these discussions, data was collected on the length of storage practised by individual farmers; this data was then used to select groups of farmers for further in-depth discussions. Where possible, individuals not included in these discussions were interviewed to provide case studies.
13. The objectives of the legume component of this survey were to identify the methods of on-farm storage (to complement the information obtained on trader storage by gathered Golob *et al.* 1996); to confirm which varieties of legumes are grown and stored by farmers, together with their growing and storage characteristics; and to determine the typical storage life of legumes, together with the reasons for early sale.
14. Severe constraints exist to the quantity of produce that can be grown. The main problem is the falling levels of soil fertility (hampered by the high cost and poor availability of fertilisers). Other reasons are the general scarcity of affordable cultivation equipment (animal and tractor drawn equipment), and the high cost of labour. Quantities of commodities placed in storage are, therefore, generally lower than would be desired by farmers.
15. A wide variety of protection methods against insect attack was encountered throughout the three regions. A total of 32 methods were identified: eight using inert materials (such as sand, ash, etc.); 19 using plant materials; and five using synthetic materials. Farmers' perceptions of the effectiveness of different methods were found to vary considerably, making it difficult to assess which methods are the most effective. The particular method deployed was strongly influenced by tribal customs (as was the case with storage structures and the types of legumes grown), often resulting in neighbouring tribal groups using totally different methods, usually with

mixed results. A very real need was demonstrated for the testing of the effectiveness of specific methodologies, and recommendations were made to this effect (types of materials to be examined) for the forthcoming project activities.

16. Legumes were found to be widely grown throughout the three regions. Whilst improved, higher yielding varieties are available in most of the areas, poor resistance to disease and insect attack, both pre- and post-harvest, means that their usage is limited. Whilst insect damage in storage is undoubtedly a problem, other constraints, mainly financial, were identified as restricting long-term storage. This had the effect of reducing the apparent pest control problems in some areas. However, if production and/or financial constraints can be reduced in the future, the quantities in, and the duration of, storage will be dramatically increased. Storage insect problems will then become severe.

17. Traditional varieties of cowpea and bambara were cultivated by men and women in all of the villages visited during the survey. Harvested produce was utilised for seed, family consumption and sale if yields and finance permitted. Due to the small quantities stored, the most common storage structure used for threshed legumes was the fired clay pot. Legumes were also stored in jute sacks (where the farmer could afford to purchase the sacks) and small mud silos (commonly called the Buo). Unthreshed legumes are usually stored in larger structures made from zana matting such as the Kambong or Linga stores.

18. Resistance, crop yield, and organoleptic characteristics (such as taste, appearance and cooking time) varied among the local varieties of cowpea and bambara. Farmers took advantage of these variations by growing two or more complementary varieties to maximise their production for consumption and sale. Local varieties of both legumes were always stored to provide seed for next year's planting. However, storage for consumption and sale at a later date was not always possible.

19. Improved, higher yielding varieties of cowpea were only grown in a small number of villages even though they commanded good prices; no improved varieties of bambara appeared to have been developed. When compared to improved varieties, traditional varieties were considered to be more resistant to disease and insect pests in the field and in storage. They were also more tolerant of local soils and growing conditions. Improved cowpea varieties were usually sold immediately after harvest, as they are very susceptible to damage in stores.

20. The marketing of cowpea and bambara was almost exclusively the responsibility of the female members of the household. Women also dominated trading activities at local markets and were as well represented as men at regional markets (Golob *et al.*, 1996). Market prices indicated that by extending storage until later in the growing season, farmers could profit from significant increases in market prices of both commodities. Cowpea prices could increase by more than 200% between harvest and the following planting periods, with a corresponding increase of 180% for bambara nuts.

Rapid method of loss assessment

21. Loss surveys were devised to provide a precise record of the losses actually incurred by farmers during the storage season.
22. In order to facilitate the loss survey, a rapid assessment technique was designed for predicting weight loss in cowpea and bambara groundnut due to insect infestation (Wright and Golob, in press).
23. Most estimates of damage or weight loss caused by bruchid infestation of cowpeas have been obtained from observing damage caused by insect attack under controlled laboratory conditions. Very few estimates have been made of losses that occur on farms during storage, and those that have been produced have been derived from just one or two samples collected at the start and end of storage. Loss estimation usually requires collection of samples from the farm and transportation to a laboratory for examination. This is time-consuming and tedious.
24. A method was therefore developed to enable a much more rapid determination of loss, which could be used *in situ* on the farm. It depends on relating grain damage, represented by the number of grains exhibiting insect emergence holes, to weight loss. Standard curves have been produced for bambara groundnuts and cowpea varieties grown in northern Ghana. The number of holes per grain does not significantly alter the equation of the curves. A simple method for examining grain at the farm, using small compartmentalised titre dishes, was developed.
25. Bruchid damage in cowpeas and bambara groundnuts is typified by very clear exit holes produced as the new adults emerge from the grains. In addition, since females preferentially oviposit on grains that are free of eggs, grains tend to show similar levels of infestation to one another with similar numbers of exit holes. Since weight loss is essentially a result of the presence of emergence holes it seemed likely that damage (the proportion of grains showing holes) could be used as a direct correlate of weight loss.
26. For some of the pulses it has previously been shown that visual damage can be related to weight loss (Caswell, 1981). For samples (of 100 grains) with less than 50% damage the relationship was linear:

$$Y = 1.8077X$$

Y = number of holes
X = % damage

27. In Brazil, Santos *et al.* (1978) also showed a linear relationship between the number of holes and weight loss in *Vigna sinensis* (L.) attacked by *C. maculatus*.

$$Y = 0.2298X \quad (r^2=0.722)$$

Y = % weight loss
X = no of holes in 100 grains

28. Oliveira *et al.* (1984), continuing the Brazilian work, used five different cowpea varieties, attacked by *C. maculatus*, and showed that percentage weight loss and number of holes in 100 grains could be related in the following way:

$$Y = 0.2222 + 0.5042X$$

$$(r^2=0.680)$$

$$Y = \% \text{ weight loss}$$

$$X = \text{no of holes in 100 grains}$$

This was valid if the number of holes fell within the range 6.08 to 28.10 per 100 grains.

Method

29. The work was carried out in collaboration with the Savannah Agricultural Research Institute (SARI) in Tamale, Ghana. Samples of each crop had been collected from the local markets.

30. The cowpeas were of the local white-seeded type. They were small, having a mean weight of 0.12g (± 0.023 g SD). Bambara, also local types, were more variable. They were usually light brown and had a mean weight of 0.6g (± 0.14 g SD). These two crops were sold by the bowl (approx. 2.5 kg) in the market. Both the cowpea and the bambara were representative of the grains available throughout Northern Region in Ghana.

31. Each market sample was broken down by coning and quartering. From this reduced sample all extraneous matter, as well as all broken grains, were discarded to give a working sample of approximately 500 grains. Weight loss was determined using the working sample via the count and weigh method (Boxall, 1986), which has the advantage of not requiring a base-line sample nor any measurements of moisture content. It should be stressed that the working sample only contained whole grains. The count and weigh procedure necessitates dividing the working sample into damaged and undamaged fractions. For the purposes of this study 'damaged' was defined as grains showing an insect-formed exit hole or tunnel. 'Undamaged' included all perfect grains as well as those whole grains showing signs of shrivelling, torn testa, disease or water marking and also those that obviously had insects internally but from which the adults were still to emerge.

32. Damage in cowpeas was due to *C. maculatus*. In bambara groundnuts both *C. maculatus* and *C. subinnotatus* were present. This meant that the exit holes tended to be readily observable. *C. subinnotatus* is larger than *C. maculatus* and generally causes larger exit holes. Since all the laboratory-produced samples had only *C. maculatus* damage and, for the market samples, it was not possible to allocate proportion of damage to each species, all exit holes were treated as being identical for the sake of this experiment. Future work will need to establish what differences there are, if any, in terms of calibration of loss scales as a result of infestation by these two bruchids.

33. Weight loss was calculated using:

$$\% \text{ wt loss} = \frac{(UNd)-(DNu)}{U(Nd+Nu)} \times 100$$

where: U = Wt of undamaged fraction
 Nu = Number of undamaged grains
 D = Wt of damaged fraction
 Nd = Number of damaged grains

34. The percentage damage was determined at the same time:

$$\% \text{ damage} = \frac{Nd}{(Nu+Nd)} \times 100$$

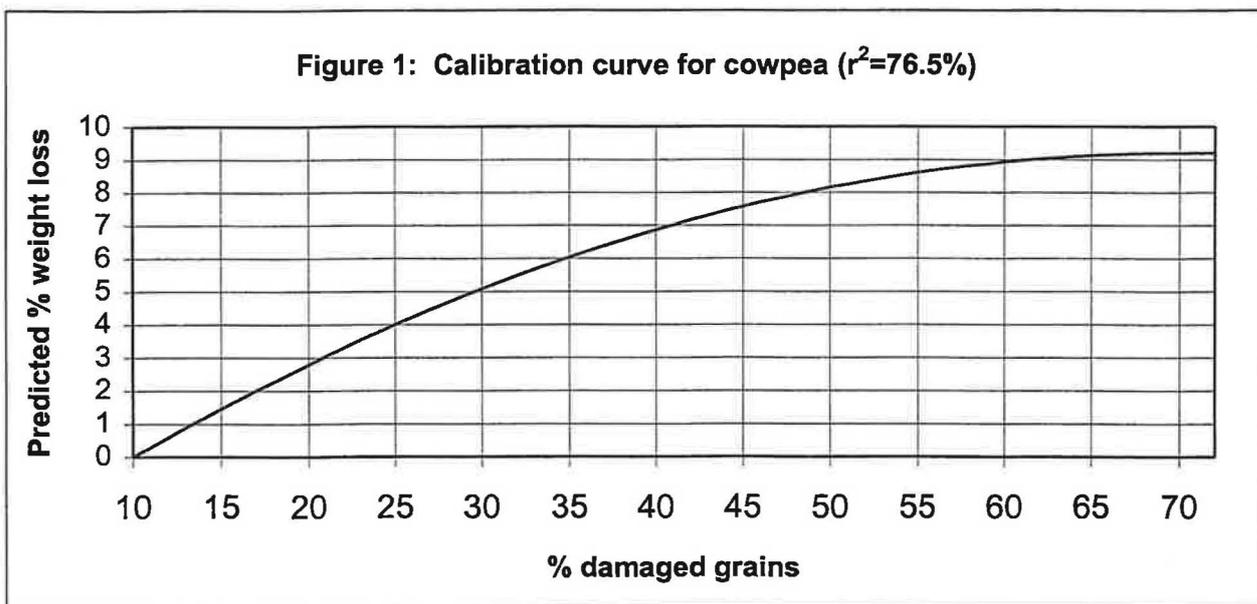
35. At the outset of the work it was unclear which parameter in the field would act as the best indicator for weight loss. The total number and distribution of holes in each sample was therefore also determined.

Results

36. The mean weight loss per hole, irrespective of the number of holes present, was determined (Appendix 1). By sorting grains into groups comprising those with the same number of holes it was possible to determine how percentage loss varied dependent on the number of holes present.

37. Results for the cowpea samples are plotted in Figure 1. The best fit line for the graph is given by:

$$y = -3.31 + 0.3551x - 0.00252x^2 \quad \text{where: } y = \% \text{ loss; } x = \% \text{ damage}$$



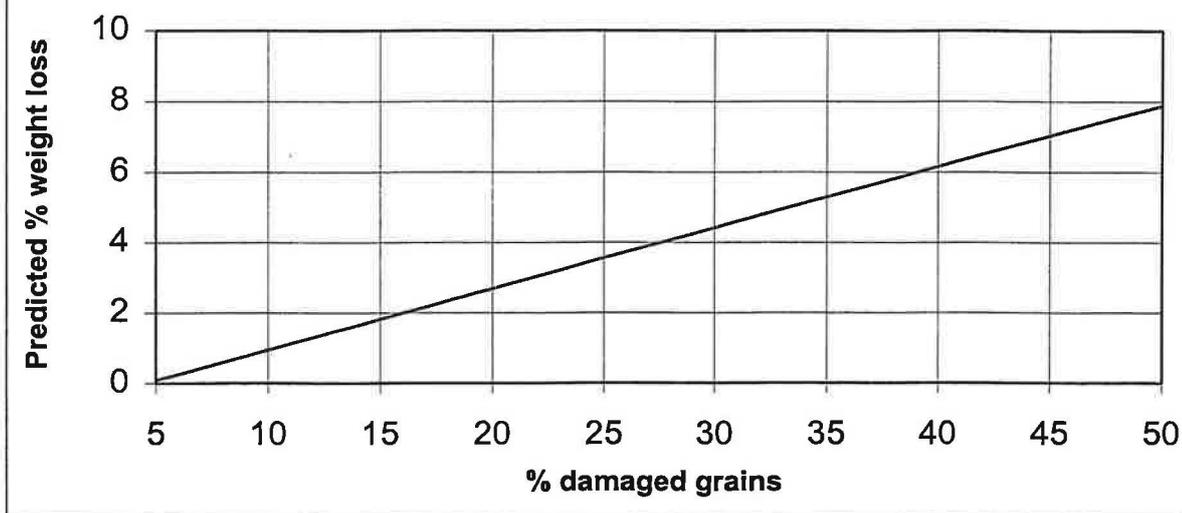
The relationship between the two variables is strong ($r^2 = 76.5\%$; $s^2 = 3.129$) for the range of damage levels between 9-72%.

38. Results for the bambara samples are plotted in Figure 2. The best fit line is described by:

$$y = -0.788 + 0.1735x \quad \text{where: } y = \% \text{ loss; } x = \% \text{ damage}$$

The fitted model shows a good relationship ($r^2 = 75.1\%$; $s^2 = 2.152$) between the two variables for the range of damage values of 4-48%.

Figure 2: Calibration line for bambara groundnut ($r^2=75.1\%$)



39. Field workers are supplied with the two graphs and a results record sheet for work in the field. A sample of approximately 200 grains is taken at random from the store, placed into a perspex titre block, and each grain quickly examined to determine the proportion of grains that are damaged.

40. By using the relevant graph the corresponding loss figure can be determined. For example, in cowpeas a sample with 25% damage has a predicted weight loss of 4%. Using 200 grains gives an accuracy of $\pm 7\%$ which means our example has a loss in the range of 3.7-4.3%. Whilst this is not as precise as other methods, the ability to take large numbers of individual samples in a short period of time allows a good working estimate of *average* losses to be determined.

41. This method was subsequently used in Upper East and Northern Regions to evaluate damage and weight loss of cowpea and bambara stored by more than 150 farmers.

On-farm losses surveys

42. Two surveys were undertaken, over two consecutive storage seasons. The first one included a survey of the storage situation more generally and covered quantities stored, removals from the stores, damage and loss, as well as protection methods used. The second survey, restricted to villages in Northern Region, focused on damage and losses alone.

43. The results of the first survey have been presented at the VII International Stored Products Working Conference in Beijing (Golob *et al.*, in press)

44. This survey of stored cowpea and bambara groundnut covered both Northern and Upper East Regions. Thirty five farmers in one or two villages in each region were selected before harvest. Post-Harvest Officers from the Ministry of Food and Agriculture made a monthly visit to the farmers throughout the storage season (from December 1996 to September 1997), and recorded the treatments applied to control bruchids. They checked the quantities of grain removed from the stores between each

visit and the use made of this grain, and measured the damage caused by bruchids on two replicates of samples of 200 grain.

45. The average percentage weight losses given here for the whole storage period are calculated by weighting the calculated weight loss by the amount of grain removed at the time of measurement (i.e. monthly), and the loss over the entire season is obtained by cumulating these losses. Thus the final weight loss expressed takes account of both the increasing damage caused by insects and the reducing quantity of grain remaining in the store.

$$\text{Average \% weight loss} = \frac{\sum_{\text{for each month over the whole storage}} (\text{removal} \times \% \text{ weight loss})}{\sum_{\text{for each month over the whole storage}} (\text{removals})} \times 100$$

where removal = weight of removed grain.

The cumulated grain damage was similarly calculated.

46. During the storage season 1997-98, a second survey covered 131 farmers, in 20 villages in four districts of the Northern Region for cowpea, and 111 farmers in 16 villages in two districts of the Northern Region for bambara groundnuts. Percentage damage was measured, but grain removals were not. Therefore the figures illustrating weight loss are simply sample estimates, and are not related to actual losses as were calculated for the previous year study.

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

48. The quantities stored reflect the use of the crop. In the Northern Region, cowpea is grown primarily to sell, and only secondarily as a food crop. There is therefore substantially more cowpea stored than in the Upper East Region, where cowpea is mostly used to supply the family with food. Bambara groundnuts are used primarily for food for home consumption in both regions.

49. The variation in time and use of the removals from the stores were recorded. Figure 3 shows the monthly removals over the storage period. From the stores of cowpea, in the 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.

50. In contrast, in the Upper East Region, sales are less prevalent. Quantities removed decrease during the storage period, with the exception of a peak in May, due

to more important sales. Before May, sales represent only a small proportion of the removals.

51. Removals from stores of bambara groundnut follow a similar pattern in both regions. There are two peaks of removals, one from February to April, and the second in June or July. Sales represent up to half of the total removals.

52. Prices obtained at sale were also recorded. Sales of cowpea in the Northern Region in the period following harvest were made at around 1500 Cedis per bowl (about 2.5 kg), and they remained rather constant until June. Prices fell to a minimum 1000 Cedis in July and August, then rose thereafter, reaching 1500 Cedis in September.

53. In the 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 both regions. Prices started around 1500 Cedis, then rose to a maximum of 2000 in February for the Upper East Region, and in April for the Northern Region. No sales of bambara groundnut were recorded in the Northern Region after July.

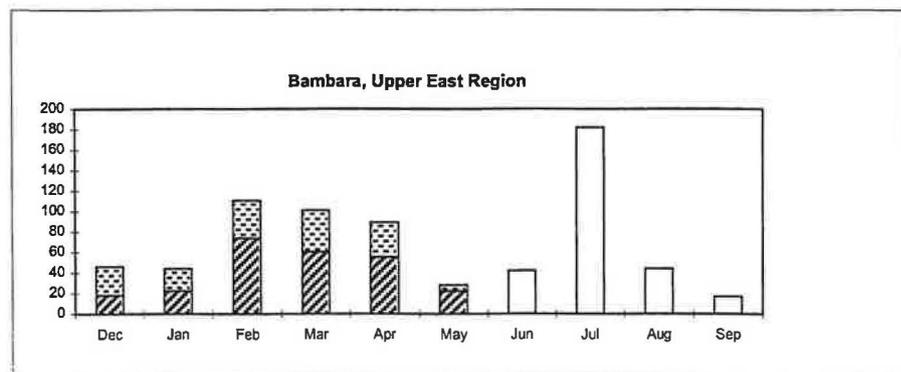
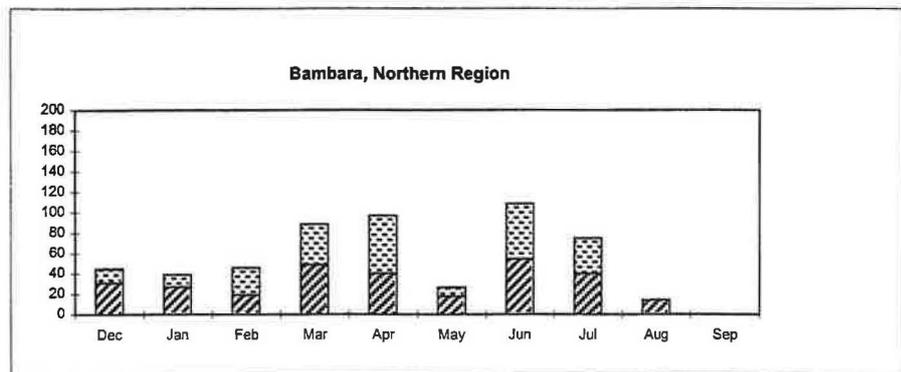
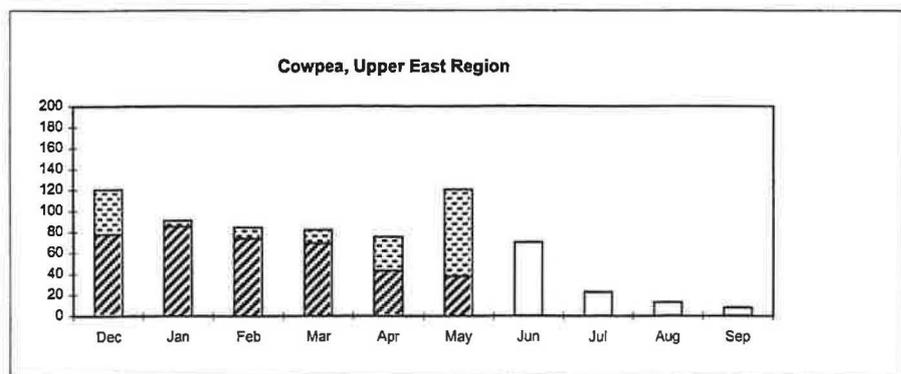
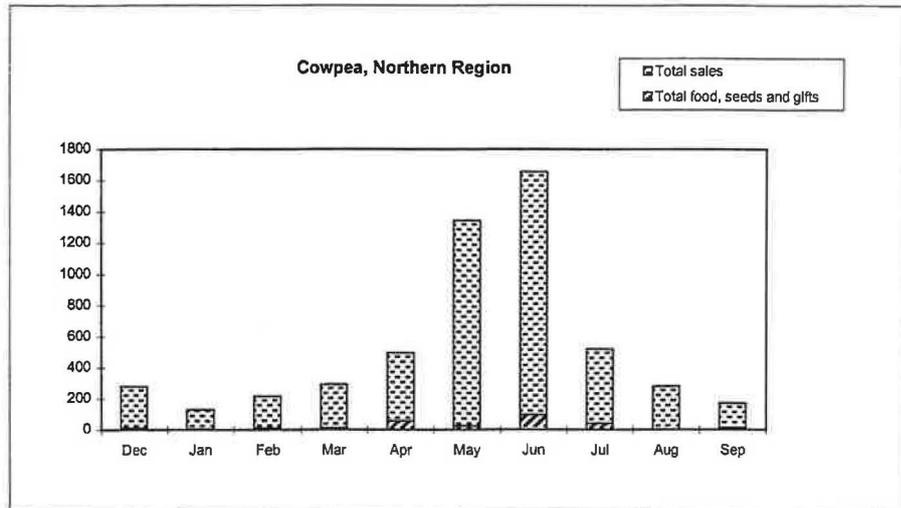
54. Some farmers save a lot of grain for planting, especially bambara, but also cowpea. No improved bambara groundnut seeds were seen either on-farm or on the market, and very little improved cowpea.

55. In the 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. The opposite situation is observed in the Upper East Region, where prices increase with the increase in demand when nobody wants to sell.

56. In the 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 cowpea from southern Ghana begins to be marketed in the north. Prices only rise in September and October just before harvest is due.

57. The prices recorded in this survey are prices attained by the cowpea which was sold, not the maximum prices that good quality cowpea could reach. 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 a crop which is wholesaled, therefore it is always relatively scarce in markets, and so commands a good price, even just after harvest, when prices would normally be expected to be low.

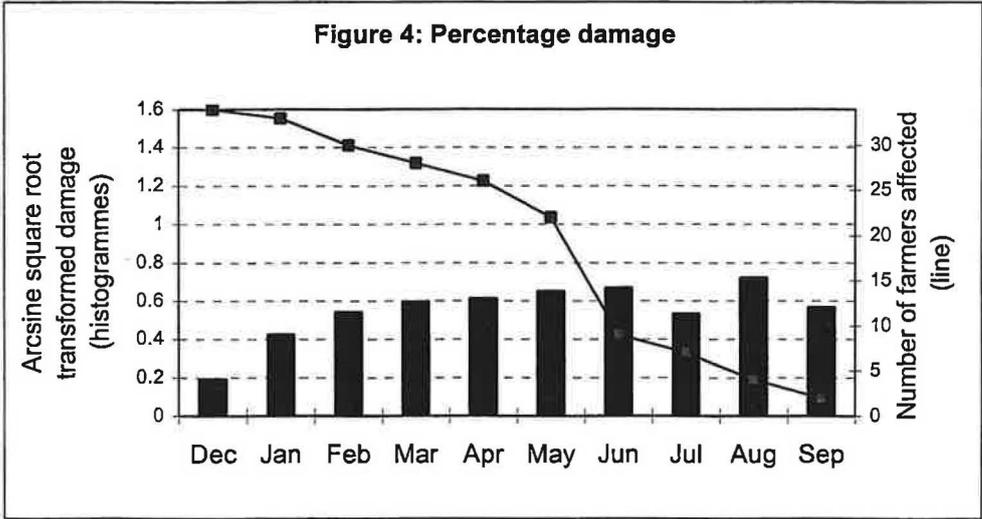
Figure 3: Removals from the stores



58. Data from all farmers were used to calculate the percentage damage, as it was directly measured. Table 1 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 in cowpea. Figure 4 shows the evolution of the damage measured in cowpea in the Northern Region over the whole period of storage. These are the averages, over the region, of the data collected monthly during the survey.

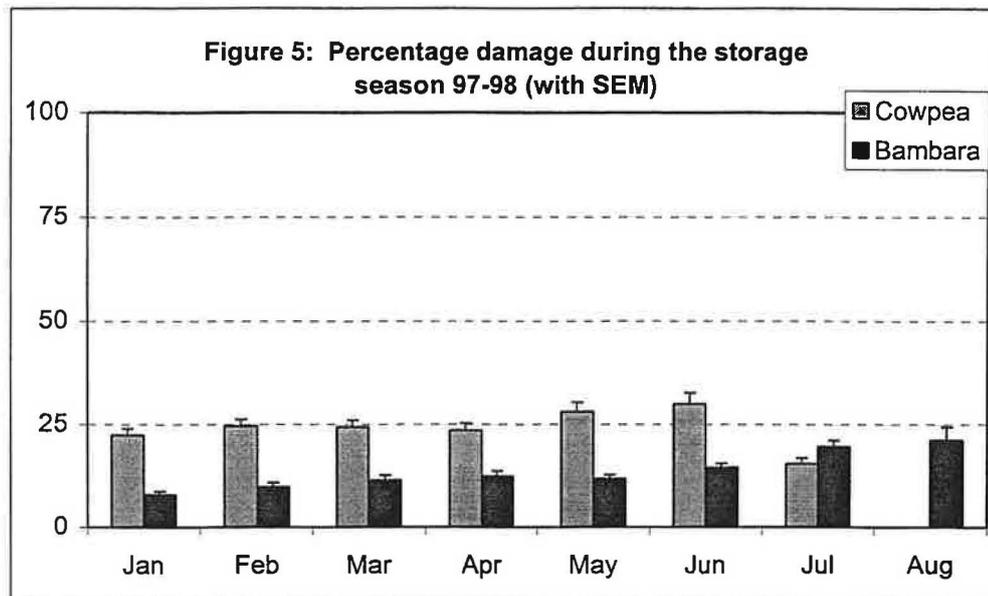
Table 1: Damage during farm storage of cowpea and bambara groundnut

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



59. The percentage damage recorded on cowpea during the storage season (figure 5) ranged from 2 to 100%, with a mean of 25%. The apparent decrease at the end of the season was only recorded in one district, on seven farmers. If the July figure is not taken into account, the increase in percentage damage over the storage period is clear. Figure 6 shows that the binomial regression is better than the linear at modelling this increase.

60. Of the 131 farmers, some stored only until January, others up to July. Figure 5b shows the average percentage damage recorded, according to the duration of storage. It appears that farmers store longer if the percentage damage remains low, and that when it increases, they sell. The hypothesis that farmers store for longer if the damage remains low will need to be tested in the second phase of the project, particularly with PRA studies to identify the reasons and motivations for selling.



61. Percentage damage recorded in bambara samples ranged from 0.5 to 81%, with monthly means increasing from 8 to 21% between January and August (figure 5).

62. As for cowpea, the increase in damage during the storage season is statistically significant, as shown by the regressions on figure 6. The linear regression shows that the increase in damage is greater for bambara (the slope is steeper).

63. The percentage damage recorded in cowpea samples during this second survey is similar to the figures from the previous year, from the Northern Region, despite the different mode of calculation. The values are slightly lower, but the pattern of increase over the months is the same.

64. Figures recorded on bambara are quite different. The maximum percentage damage recorded during the first survey was four percent. In the second, it was 21%, a figure more similar to the damage recorded on cowpea. Even the pattern of increase is similar, with a steeper increase during the first months of storage, followed by a plateau.

65. The variation of the damage experienced on bambara by farmers, from one year to the next illustrates well the necessity for this type of survey to be undertaken over several seasons. Among the many factors at the source of this variation, are the level of attack the following year, which will influence the number of beetles infesting the grain at the onset of the current storage season, the climatic variations during the growing season, and the exact timing of harvest and of any subsequent control attempt.

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

Figure 5bis: Percentage damage in cowpea during storage season 97-98 (with SEM).
 Data for all districts, by duration of storage.

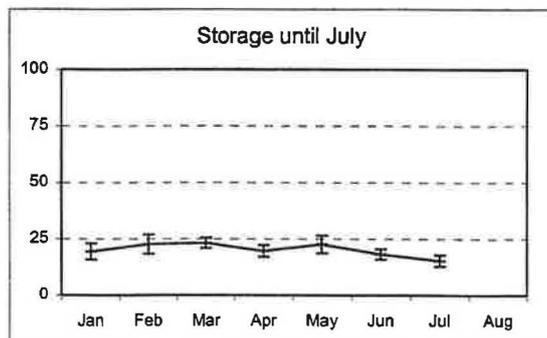
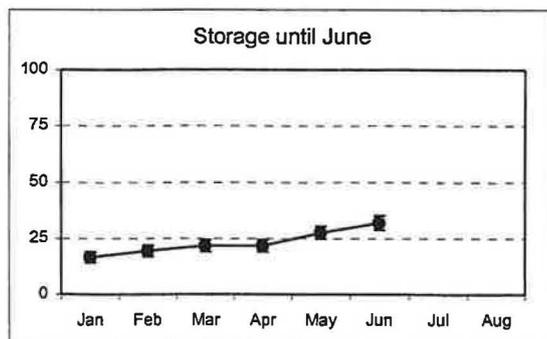
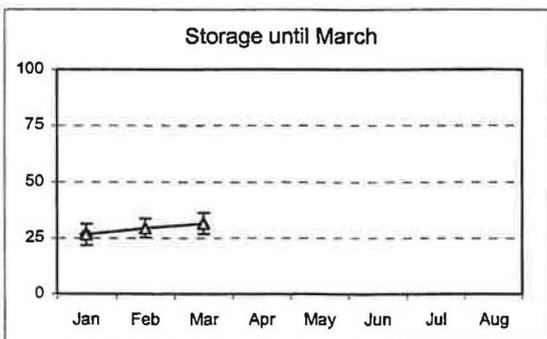
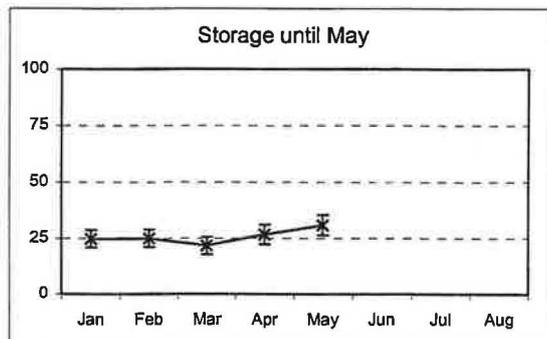
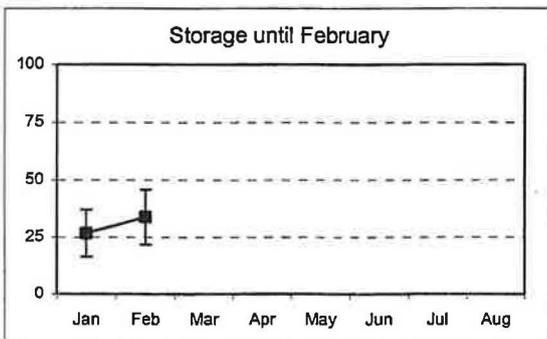
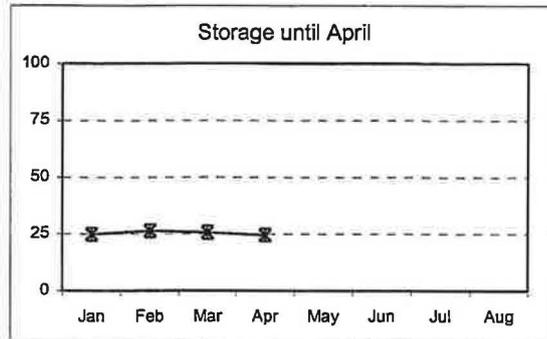
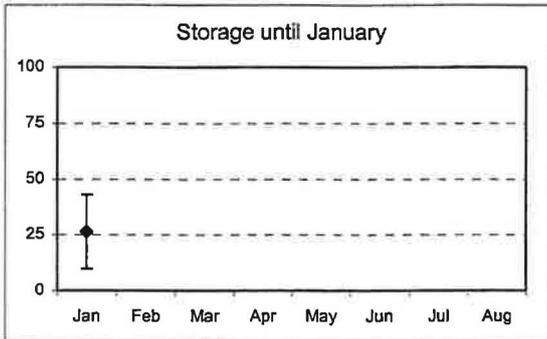
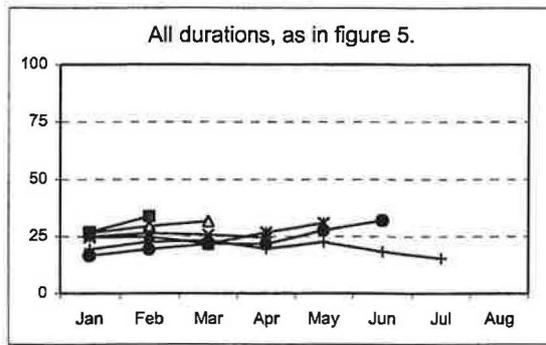
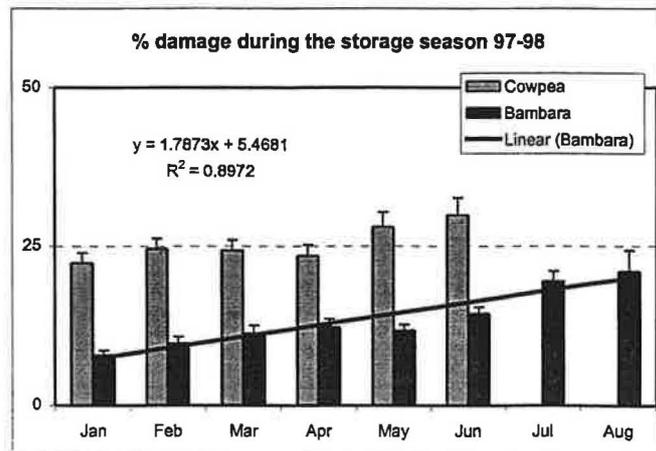
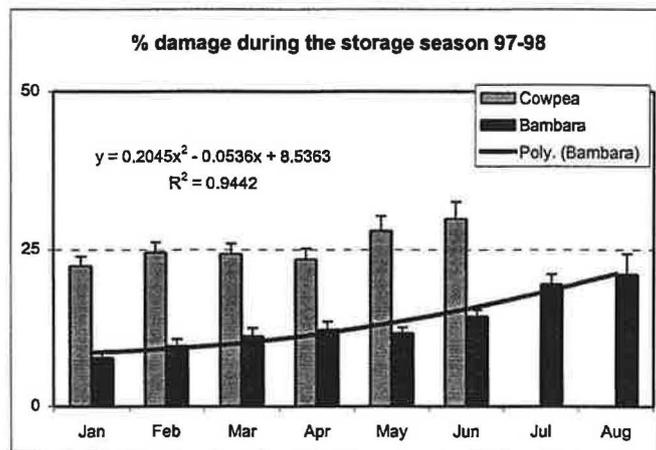
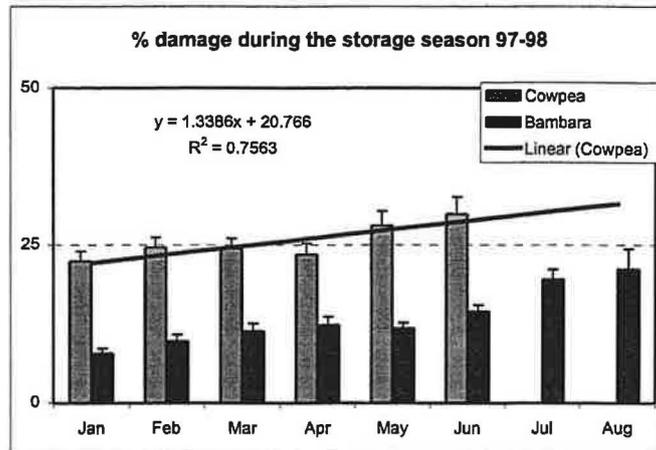
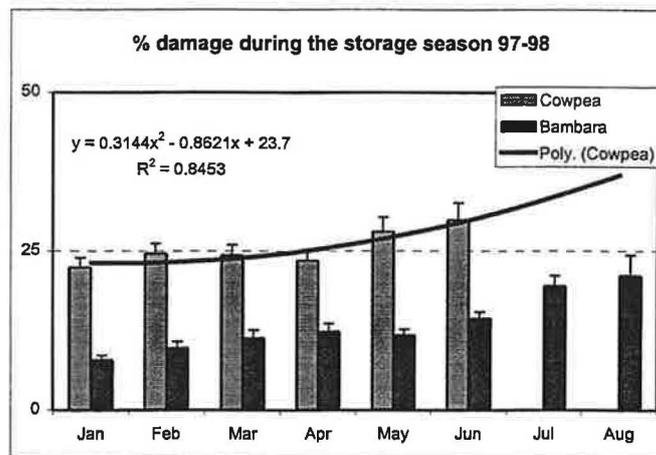


Figure 6: Percentage damage and regressions (with SEM)



67. For the farmers who suffered measurable weight losses, table 2 presents the average percentage weight losses for cowpea and bambara groundnut in the two regions studied, over the entire storage period. For each commodity, the weight losses were compared between regions. They differed significantly only for cowpea.

Table 2: Weight losses during farm storage of cowpea and bambara groundnut.

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

68. 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 grain 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 the Northern Region, stored 80 bowls of cowpea. During the storage period, sample damage peaked at 42.5% and weight loss at 7.2%. Using the method of assessment described here, the real or actual estimates are: 21.3% for damage, and 3.1% for weight loss.

69. Results from the second year survey show that losses in samples of cowpea varied from 0 to 9%, with monthly averages remaining under 5%. For bambara, even in August, the monthly average weight loss remained just below 3%.

70. The weight losses measured in this study appear to be of limited importance, but the damage is certainly not, because damaged beans command a much reduced price, at the market. Prices for cowpea and bambara are reduced if they are insect damaged. Thus selling prices of cowpea in the Northern Region did not increase in time, because the beans were damaged, and did not reach the premium prices offered for undamaged grain. At Tamale market, in the Northern Region, 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 sold by women retailers.

71. During the survey, the methods used by farmers to protect stored pulses against insect pests were recorded. They differed according to the commodity, and to the region (for details, see appendix 2).

72. In the Northern Region, cowpea stores at farm level if treated, are mainly treated with pesticides.

73. There was no use of chemicals in the Upper East Region on cowpea, where admixture of ash from the kitchen fire appeared to be a widespread method of protection and all farmers interviewed practised this method, at least as part of a treatment.

74. Chemicals are not generally used on bambara, and methods used were similar in both regions. Bambara were either not treated, or if protected, it was mostly by immersing the grain in water in which "kim-kim" (*Synidrella nodiflora*), a Labiatae, had been boiled, or in water with shea butter (extracted from the nuts of *Vitellaria paradoxa*).

75. In the Upper East Region, ashes were also used on bambara, although not as commonly as on cowpea. It was noted that samples of bambara treated with ash did not bear any bruchid eggs, though samples from stocks which were not treated had many eggs.

76. The availability of pesticides is a restricting factor for rural areas, as is the price of these chemicals. This would explain their more common use on cowpea in the Northern Region, on commodities mainly destined to be sold on the market.

Conclusion

77. *C. maculatus* was the most important pest, although on bambara the infestation was dominated by *C. subinnotatus*, a larger species.

78. 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.

79. These two surveys have shown that weight loss is not very high at farmers' level. However, the percentage damage is of significance, as the levels observed have a negative impact on the value of the commodity on markets. There is therefore a need for improved control of the bruchid pests during storage on the farm.

Marketing & socio-economic survey

80. By studying the operations of the legume market in northern Ghana, this survey aimed at identifying the effects of insect pest damage on the price of grain legumes and on the revenue of traders (Bediako, 1998).

81. The work started by a detailed study of the market structures, the types of traders and retailers and the storage facilities used. Storage trade operations were characterised, including annual purchasing and selling trends, price levels, handling of

purchases and profit/loss analysis. Insect pest damage on the grain was assessed and its effect on revenue calculated.

82. The results presented here are concerned with the assessment of damage during storage, and the relationship between damage and price of the grain legume.

83. During a complete storage season, monthly visits were made to eight traders in Tamale market. Samples from their cowpea stocks were collected, and the percentage damage assessed. Three of the traders said they treated their sacks of cowpea against insect pests, although the treatment appeared effective in only one case.

84. The percentage damage on untreated grain goes up to an average value of 70% in June, which corresponds to a calculated weight loss of above 9%.

Table 3: Percentage damage recorded from traders' stocks.

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
<i>Percentage damage in traders' stocks with no treatment</i>									
Imoro Mahama	4	21	44	54	58	61	sold		
Abdul Azzis	4	6	10	49	58	59	62	65	sold
Abdulai Alhassan	-	10	20	20	35	37	72	75	sold
Alhadji Moro Shaibu	-	-	18	21	-	28	30	sold	
Issaka Nichema	12	-	20	35	46	sold			
Average	6.67	12.25	22.35	35.70	49.19	46.35	54.67	70.00	
SEM	2.667	4.404	5.659	6.985	5.498	8.215	12.667	5.000	
<i>Percentage damage in traders' stocks with treatment</i>									
Tahiri & Amadu	9	19	42	59	63	sold			
Fuseini Nabila	3	3	3	4	3	4	5	6	sold
Mahamadu Iddrissu	2	2	3	4	-	32	33	37	sold
Average	4.58	8.13	15.90	22.17	32.75	17.75	19.00	21.50	
SEM	2.103	5.641	13.151	18.167	29.750	14.250	14.000	15.500	

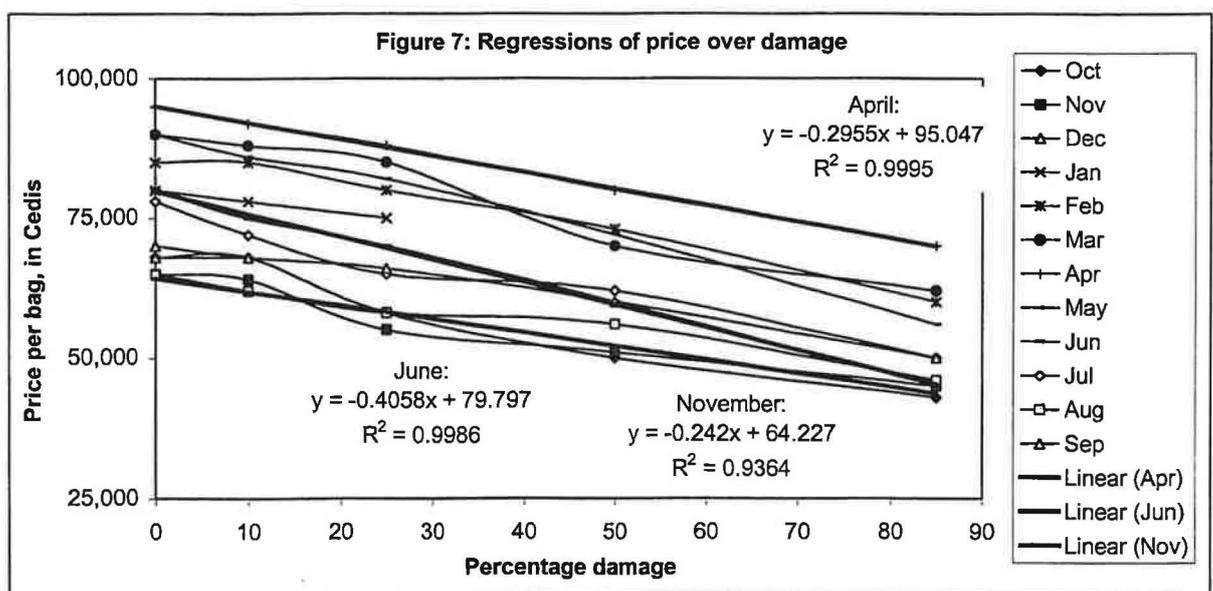
85. At the beginning of the storage season, most of the cowpea on sale on the market has little to no insect damage. Conversely, after several months of storage, all the cowpea is damaged, and it is almost impossible to find good quality grain, without holes. To test a possible link between damage and price, it was therefore necessary to create an artificial situation where cowpea of all qualities could be compared, at the same time throughout the storage season.

86. From damaged cowpea, artificial lots of cowpea were created in the laboratory, with levels of damage of 0%, 10%, 25%, 50% and 80%. These lots were frozen, and then presented every month to traders who were asked to value them, in five markets in northern Ghana. Although the data collected during this study does not necessarily reflect actual market prices (as specific grades may have not been

traded every month), the price estimates provided by the traders can provide a useful insight into the relationship between price and quality.

87. In the towns of Bolgatanga, Bowku, Yendi and Gushegu, prices increase steadily during the storage season. The prices given by traders did not differentiate between low levels of damage (0% and 10%), but higher levels of damage imposed lower prices.

88. In Tamale, the situation was somewhat different. The effect of damage on the prices is more marked and prices reached a peak in May, then fell. The relationship is clear, as demonstrated by significant regressions between the price and the percentage damage for every month except January and February where 25, 50 and 80% damaged samples were not tested (figure 7).



Conclusions

89. The damage caused by insect infestation is very important and increases sharply during the 5 first months of storage. The relationship between damage and price is positive for high levels of damage, but less clear at low levels.

90. There is a large seasonal fluctuation in the price of cowpea, which suggests that returns from storage are high. However, these returns decrease when the cowpea becomes heavily damaged.

91. Many other factors can affect the price of cowpea, including location, exogenous factors (for example new market entrants, such as donor relief agencies), the nature of the transaction (for example bulk selling may attract different prices to small-scale transactions), and loss of quality not attributable to insect damage (discoloured, shrivelled or broken grains).

EXPERIMENTAL WORK

92. The second part of the project examined methods for controlling bruchid beetles, to reduce the damage during storage.

93. Pre-harvest infestation of cowpea and bambara by *C. maculatus* and *C. subinnotatus* occurs at a low level. However, once in store, the insect populations rapidly multiply. During storage, grain can also be infested by immigration from outside the store. There are, therefore, two ways of limiting or avoiding damage during storage: disinfestation of grain before storage, and control of the infestation or re-infestation during storage. A combination of methods for both approaches will provide the best results.

94. Control methods must not only be biologically effective, but they must also be economically sustainable. Some of the methods tested were new, and required testing for efficacy under local conditions as well as for farmer acceptability. Others were traditional methods, identified by the surveys, and needed testing for efficacy and possible optimisation.

Methods for on-farm control

Sun drying

95. Fumigation is regarded as the most appropriate method for disinfesting grain. However, for small scale farmers its use is inappropriate because of the inherent dangers involved. An alternative method for disinfestation is to subject the grain to solar energy.

96. Murdock and Shade (1991) investigated solar disinfestation as a low-cost insect control technique for cowpeas in tropical countries. They found that exposure for one hour to temperatures $\geq 57.3^{\circ}\text{C}$ killed all stages of the bruchid beetle *C. maculatus* and that this was achievable in a simple solar heater in which cowpeas are placed between layers of black and clear plastic. This was developed into a larger-scale device in northern Cameroon with a capacity of 50kg (Kitch *et al.*, 1992). On-farm tests resulted in almost complete avoidance of bruchid damage, in contrast to the complete destruction of untreated control samples. Unfortunately, when Murdock *et al.* (1995) reviewed the development and extension of the solar disinfestation technique described above they found the cost of the solar heater to be too high for low resource farmers, the originally intended target recipients. The authors suggested that very small-scale producers are unlikely to use anything more than the simplest and least expensive technologies.

97. Experiments were undertaken to develop a very low cost method of solarisation using locally-available materials. These on-station experiments were undertaken at the Savannah Agricultural Research Institute (SARI) near Tamale, Ghana. A number of solar disinfestation methods were compared for cowpeas and bambara groundnuts.

98. Approximately 2kg of the commodity was spread as a layer approximately one kernel thick onto a range of surfaces as follows:

- i. concrete only;
- ii. dried shea nut residue (SNR) coating on concrete;
- iii. black plastic sheet resting on zana matting;
- iv. an empty jute bag resting on zana matting.

99. All these materials were locally available and can be found commonly on farms in northern Ghana. SNR is a by-product of shea nut processing, dark brown in colour. Thin polythene bags were cut open to provide a single layer of black plastic of 1.4 x 1.2m. The intact jute bags were second-hand cocoa sacks obtained from the local market, where they are widely used for storage and trading of durable commodities. Zana matting is woven from local grasses and used commonly for covering floor surfaces, fencing and protecting stores. It is approximately 0.025m thick and was used in the trial to insulate the solar heaters from the concrete. Full sized zana mats are approximately 3 x 1.4m. For the purpose of the experiment, they were cut into six pieces of approximately 1 x 0.7m.

100. The factors tested were as follows:

- i. clear plastic covering: each heater design was tested with and without a thin clear plastic layer over the top;
- ii. exposure time: these were two hours (approximately 11.00 to 13.00 hours) and five hours (approximately 10.00 to 15.00 hours);
- iii. commodity: cowpeas and bambara groundnuts were used.

101. The clear plastic was taken from bags similar in thickness, size and price to the black plastic bags and were similarly cut open to form a sheet.

102. Cowpeas and bambara groundnuts were bought from Tamale market. The cowpeas were infested by many adult bruchids but the bambara groundnuts showed no obvious evidence of infestation.

103. Temperatures were monitored at 10 minute intervals using thermistors connected to a data logger, and moisture content changes were calculated from relative humidity data collected using Reethorpe sensors.

104. A second, medium scale, experiment was undertaken, to test a situation comparable to those experienced by farmers: larger quantities of grain to treat, and limited area on which to spread them. The experimental variables were:

- i. with or without a transparent plastic cover;
- ii. thin layer of grain (1 to 2 cm) or thick layer (5 cm);
- iii. cowpea or bambara;
- iv. turning the grain at regular intervals (every hour) or not.

105. All these treatments were placed on jute sacks, on top of zana mats. Ambient and grain temperatures were measured.

106. ANOVA was applied to the mean time above 57.3°C for those treatments which reached this limit. There was a significant interaction between cover type and exposure time for both cowpeas and bambara ($F_{1,22}=13.98$, $P=0.001$ and $F_{1,22}=11.67$, $P=0.002$ respectively) but no significant difference between the black plastic and jute designs. Table 4 shows the mean times above this temperature.

Table 4: Time in minutes that black plastic and jute designs spent above 57.3°C. LSD between any two means = 24.6 and 36.7 minutes for cowpea and bambara respectively.

Cover type	Exposure time/ hours	Mean time above 57.3°C/ minutes	
		Cowpea	Bambara
None	2	0.0	31.3
	5	10.0	67.5
Clear plastic	2	111.3	110.0
	5	186.3	235.0

107. Table 4 shows that for cowpeas the uncovered designs did not exceed the temperature limit of 57.3°C for long enough to achieve the limit of 60 minutes given by Murdock and Shade (1991), while those with the plastic cover greatly exceeded this limit. Bambara designs with no cover did exceed 60 minutes above 57.3°C during five hours exposure though the time was not significantly different from that at two hours exposure. Exposure for five hours achieved a significantly longer period above 57.3°C than exposure for two hours for both cowpeas and bambara when using a clear plastic cover. Similar results were obtained if the data were analysed for the time above 60°C.

108. ANOVA was performed on a square root transformation of the emerged insect counts from each replicate of cowpeas. Significant factors were the design ($P = 0.002$) and cover ($P = 0.006$). Table 5 shows the transformed and untransformed mean insect emergence numbers according to design, and Table 6 shows the same data by cover.

Table 5: Mean numbers of emerged adults from each design of heater for cowpeas. LSD between jute and other transformed means = 7.5, between all other transformed means = 7.2.

Design	Mean number of emerged adults	
	Untransformed	Transformed
Concrete	412.1	20.3
SNR	387.7	19.7
Black plastic	52.8	7.3
Jute	61.5	7.8

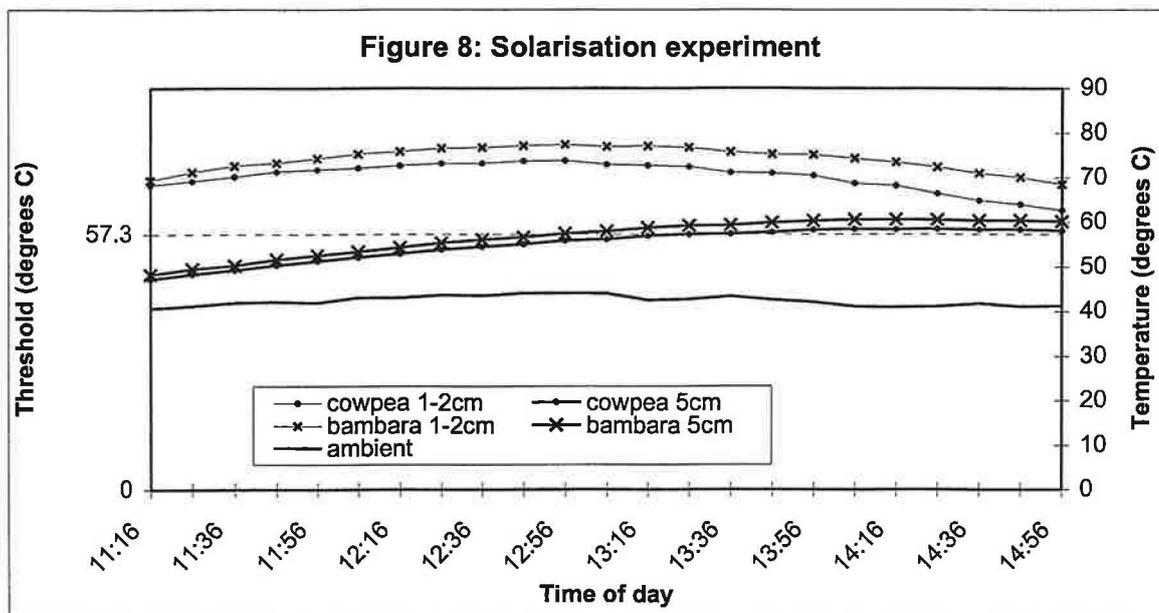
Table 6: Mean number of emerged adult from heaters with and without plastic covers. LSD between the transformed means = 5.2.

Cover	Mean number of emerged adults	
	Untransformed	Transformed
None	345.6	18.6
Plastic	92.7	9.6

109. The tables show that the black plastic and jute designs were not significantly different but both had significantly fewer emerged adults than the other two designs;

also that those designs with clear plastic covers had significantly fewer emerged adults than those without.

110. The results of the medium scale experiment were that a sufficiently high temperature could be attained even with a thicker layer (see figure 8), although the temperature at the bottom of a thick layer could be as much as 17°C cooler than at the bottom of a thin layer. By turning the grains every hour, the temperature at the bottom of a thick layer could be raised by 4°C. This experiment also showed that the threshold temperature could be more easily reached with a transparent sheet as a cover and that bambara reached higher temperatures than cowpea.



111. This experiment also demonstrated the importance of ambient temperature: during the time of exposure it was recorded at 40°C and above.

112. The results show clearly that the designs using black plastic or jute on top of zana matting with clear plastic covers achieved the highest temperatures for longest, and the best levels of disinfestation, and that exposure for five hours gave the longest period above the lethal temperature of 57.3°C.

113. Bambara groundnuts were consistently hotter than cowpeas but the experimental design did not allow this to be tested statistically. For this commodity the jute bag design with no clear plastic cover also achieved the target of 57.3°C for one hour, suggesting that this design may be successful. This would be important, as it does not use any plastic, making the design as cheap and appropriate as possible.

114. Jute sacks are particularly attractive because they are used for trading cowpeas and bambara anyway, and are therefore available where these commodities are grown, and they have residual value, making the cost of the heater lower than with black plastic sheets. They also facilitate grain handling. This was particularly true when collecting the grain after treatment: sweeping them up off the concrete floor allowed them to get dirty and was time consuming, which was also the case when picking them off black plastic sheets. The sacks could be picked up at each corner and the

grain poured into another sack quickly, cleanly and easily. They are also flexible: to make a large-scale heater, as many sacks as required can be laid side-by-side on top of full-size zana mats. This avoids the need to join materials and maintains the residual value of the sacks. The jute sack design, with or without a clear plastic cover, was therefore recommended as the best design for further development.

115. The recommendations for on-farm solar disinfestation of cowpea and bambara are therefore as follows:

- a layer of commodity should be spread on a jute sack, placed on a zana mat;
- and covered with a transparent plastic sheet, if one is available;
- this layer should be as thin as possible, but can be up to 5 cm thick if there is a transparent cover;
- grain should be mixed quickly every hour, especially if the layer is thick;
- exposure should last for at least 3 hours, in the middle of the day, on a sunny day.

Foreground: Layer of cowpea on jute bags, on a Zana mat

Middle ground: same technique, with a transparent plastic sheet as cover.



Additives

116. Solarisation allows the disinfestation of the commodity before the onset of storage. However, there is always a risk of re-infestation in the store, and the disinfestation may not have been totally effective, leaving a low population of bruchids that could re-establish itself. Traditional methods of protection of stored legumes were identified during the first survey. These methods are mainly based on

the use of additives. The effectiveness of some of these methods was tested experimentally at the SARI site.

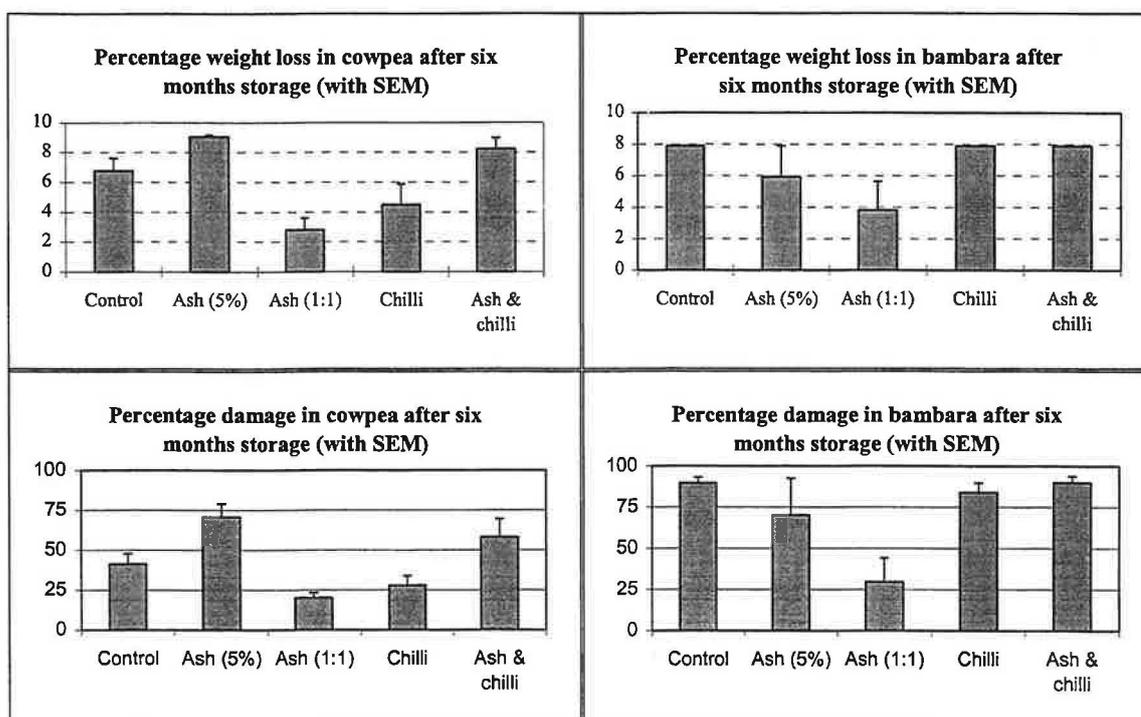
117. For shelled cowpea and bambara, in clay pots, the treatments tested were: wood ash (5% by weight), ash (1:1 by volume), chilli pepper (1% by weight) and ash (5%) plus chilli pepper (1%). Admixtures of shea nut butter, chilli pepper (1%), shea nut & chilli pepper (1%) and shea nut residue were also tested, on legume grains kept in jute sacks.

118. It is possible to store legume grains unshelled. Cowpea pods are thin and offer no resistance to pests, but the pods of bambara groundnut could offer good protection against bruchids. The survey revealed that wetting dried bambara pods and then re-drying is thought to increase this protection. The effect of pre-wetting & drying was therefore tested.

119. Percentage damage was measured on the treated grains after six months of storage. The percentage weight loss was then calculated using the rapid assessment method (see above). The emergence of adults of *C maculatus* were recorded monthly from samples of 200 grams of cowpea.

120. When grain was stored in earthenware pots, only the admixture of ash at 1:1 by volume proved to be effective at controlling damage and loss on cowpea and bambara (figure 9): weight loss on cowpea goes from almost 7% on the control, to below 3% with ash (1:1). Corresponding damage went from 40% to about 20%. With cowpea, chilli pepper at 1% also reduced the loss, but not to the same extent. It had no effect on bambara.

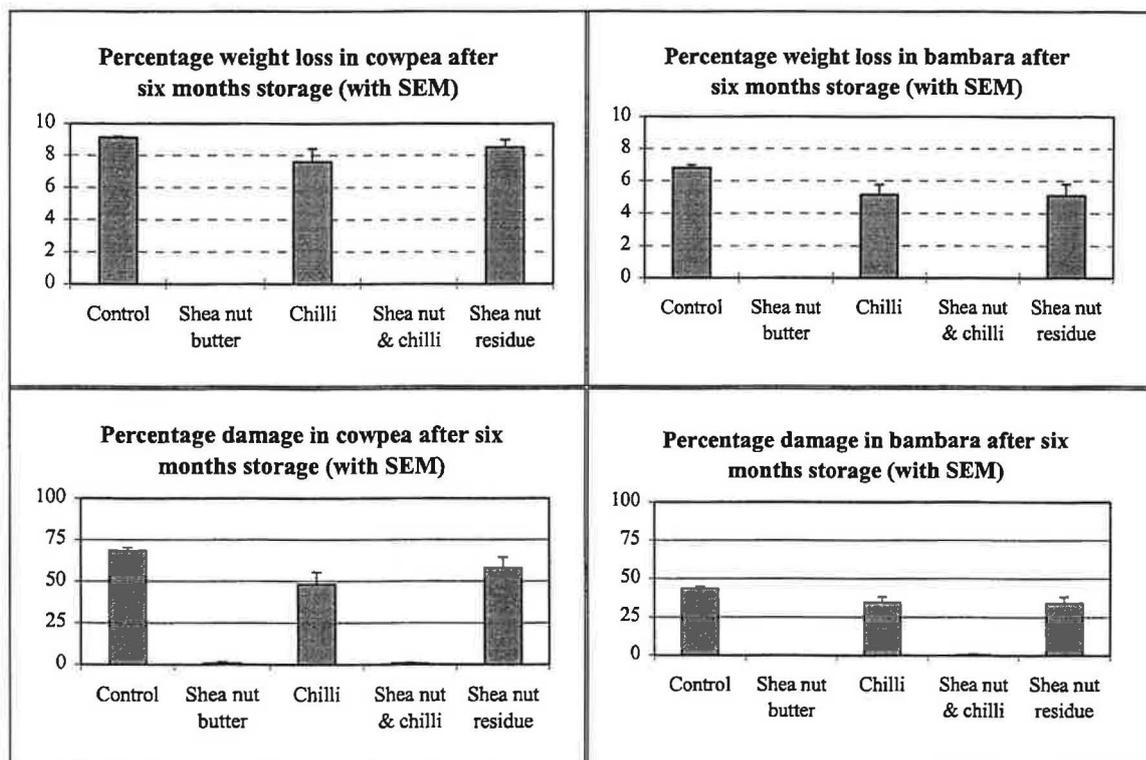
Figure 9: Loss and damage in pots, with additives



121. However, F1 emergences on cowpea treated with ash showed an increase in adults emerging after six months compared to the control and the cowpea treated with admixture of chilli.

122. When protectants were added to grain stored in sacks, shea nut butter proved to be very effective, with no damage recorded on the cowpea treated (figure 10), compared to losses of 7 and 9% on the controls for bambara and cowpea (corresponding damage of 40 and 60%). F1 emergence showed the same results, with very few adults emerging from the cowpea treated with shea nut butter with or without chilli.

Figure 10: Loss and damage in sacks, with additives



123. After six months storage, bambara stored unshelled after wetting and drying were significantly less damaged than those stored without this treatment.

124. The most effective additive proved to be shea nut butter, as demonstrated in the experiment using sacks. Admixture of ash, in a volume equivalent to the commodity to protect was effective for six months, in the pot experiment. These results were reflected in the on-farm loss survey.

Hermetic storage

125. Hermetic disinfection trials took place at SARI, from November 1997 to June 1998, a period of 29 weeks.

126. Six storage methods were tested for their ability to disinfest cowpeas through hermetic action, or by providing a barrier against infestation. They were as follows:

- i. clay pot closed with plastic sheet;
- ii. as (i)., but buried in the ground to its neck;
- iii. clay pot closed with a clay lid and filled with disinfested (frozen and re-warmed) cowpeas;
- iv. control, which was a clay pot with infested cowpeas with another pot on top as a closure method (a conventional cowpea storage method in that part of Ghana);
- v. large plastic water bucket (Oxfam, UK) with sealing lid;
- vi. local one gallon plastic bottles (¢1600 each) with screw lids.

127. The cowpeas were bought from the local market and showed a heavy infestation. The clay pots were approximately 0.45 m high with a 0.33m diameter round body and 0.15m diameter neck opening. Approximately 14kg of cowpeas were put into each pot.

128. CO₂ was measured in replicates of treatments (i) and (ii). The Oxfam buckets (treatment v) were filled with approximately 10kg of infested cowpeas each. Three one gallon bottles (treatment vi) were filled half filled and three were filled to the top with infested cowpeas. Insect damage was assessed at the start and end of the trial for all replicates using a rapid assessment method (percentage of 100 seeds with holes determined from two sub-samples).

129. All the infested clay pots suffered extensive damage during the trial. The increase in damage, i.e. the difference between the initial and final damage levels, ranged between 43.2% and 57.8%. ANOVA applied to the data showed no significant differences due to treatment. Two replicates of the pots with disinfested cowpeas (treatment iii) showed little increase in damage (6% and 7%), but one did suffer extensive damage of the same order as the infested treatments (58%). Two of the six replicates of the buried pots showed raised levels of CO₂ at the start of the trial but this did not last long. Otherwise there were no CO₂ levels above ambient. The gallon bottles and buckets showed much lower levels of increased damage, shown in the table below.

Table 7: Increase in percentage damage for hermetic storage.

Treatment	Damage increase/%
Oxfam bucket	21.8
Full gallon bottle	12.3
Half-full gallon bottle	25.2

130. ANOVA showed no significant differences due to treatment, though there was weak evidence ($t_6 = 2.05$, $P = 0.086$) that the full gallon bottles were more effective than the half full ones.

131. The clay pot treatments were all clearly ineffective in disinfecting cowpeas. This shows that they are not hermetic, and that was confirmed by the CO₂ measurements. The closed pots holding uninfested cowpeas showed that they might be able to prevent re-infestations. The failure of one of these pots may have been

because its sealing was insufficient or due to high initial infestation, though the latter would have been more likely to be apparent in the other replicates as well.

132. The plastic bottles and the buckets were clearly far better at controlling disinfestation. Any of these treatments may be recommended for further study.

On-farm trials

133. The most promising solutions identified in the station trials were tested in farmer stores. Participating farmers provided 20 kg of cowpea from their harvest that were treated, put in a woven polythene bag, and placed in their store. The level of damage was assessed, as well as the level of infestation, by rearing F1 insects from grains sampled.

134. Ninety-four farmers were selected from five villages around Gushiegu (Northern Region). They were selected on the basis that they store at least 40 kg of cowpea, for at least four or five months, and that they can spare 20 kg for the treatments, which remained in the store for the duration of the trial.

135. Nine treatments were tested, each with at least 10 replicates:

- Thermal disinfestation: at least three hours exposure to the sun, on jute sacks, and covered with a transparent plastic sheet.
- Shea nut butter: admixture of one ball of shea (approximately 60 g) nut butter for each bowl of cowpea.
- Thermal disinfestation and shea nut butter: the two previous treatments, used successively.
- Hermetic storage: cowpea is stored in sealed plastic buckets.
- Ash (1:1 v/v).
- Chilli 1% (w/w).
- Palaga¹: admixture of powdered roots of *Securidaca longipedunculata* Fres. (Polygalaceae), at a concentration of 1 % (w/w).
- KimKim: 200 g of fresh *Synedrella nodiflora* Gaertn. (Labiatae) boiled in water for each sack of 20 kg. Cowpeas were placed in a woven basket and the freshly boiled infusion was poured over the cowpea, which was then put in the sun to dry.

136. Sampling was carried out every 6 weeks, by the MoFA extension officer. At each sampling, the following data was collected:

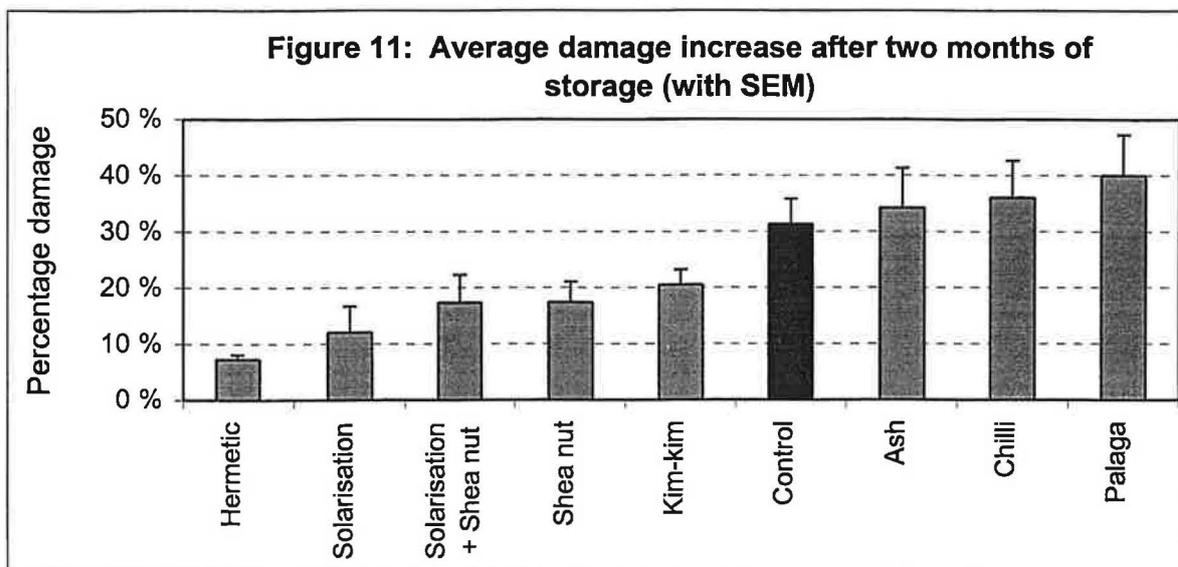
Damage: measured as the number of grain with holes, out of 100 grain. The procedure was repeated twice.

Insect population: A sample of 200-220g of grain was retained for F1 assessment.

¹ Laboratory and field trials undertaken in the CPHP project A0493, also based in northern Ghana, showed that the most effective plant material in controlling storage insects was *Securidaca longipedunculata*.

137. The infestation was severe when the trial was set up. The percentage damage recorded before the treatments varied between 2 and 31%, with an average of 7.9% (SEM: 0.462). After six weeks, it had increased to up to 50% in some of the samples.

138. Figure 11 shows that the most effective treatment proved to be hermetic storage, with under 10% damage. Other treatments which provided some control were thermal disinfection, shea nut butter, and kim-kim. The levels of damage recorded on the remaining treatments were comparable to those of the controls. None of the treatments differ significantly from the controls.



139. The most effective treatment is also the most expensive, and therefore the least likely to be adopted by farmers. Thermal disinfection has proved to be very valuable, on-farm as in the station trials.

140. Admixture of ash, palaga or chilli did not provide protection under these conditions. This could be a consequence of the high level of initial infestation before the treatment was applied, and it is essential to repeat this trial with lower levels of initial infestation.

Methods for traders

Traders' stores

141. Surveys showed consistently that losses were comparatively limited at the farm level although the percentage of damaged grain was significant. Damage is much more significant when legume grain is stored by traders (Golob *et al.*, 1996).

142. The most effective method of control that traders could use is fumigation, which allows disinfection of large quantities of commodity, under proper conditions, and by trained personnel.

143. Tamale market is the focal point for marketing for Northern Region, an important meeting place for trade between the south, the upper regions and beyond the northern border to Burkina Faso. In addition to perishable crops, local production

of groundnuts, cowpea, bambara, sorghum, millet, rice and maize is trucked into Tamale market for onward distribution or speculative storage (Tyler and Andan, 1997).

144. An analysis of the storage of cowpea by traders on Tamale market (Tyler and Andan, 1997) pointed out the problems and the needs. It was estimated that over 350 stores were used by about 1000 traders, to keep bagged cowpea. The sacks used are mainly 100 kg maxi-bags, second hand jute sacks. On average, a trader stores 20 to 80 bags, but some have 300 or more.

145. There is either no attempt at pest control or if there is, it is performed so badly that it is certainly ineffective, if not hazardous. The conditions in the stores lack the most basic storage hygiene, which makes cross-infestation (from neighbouring stores), and re-infestation from one storage season to the next, unavoidable.

146. Control methods were therefore devised and their effectiveness tested. These trials also acted as demonstrations for the traders.

147. Three small stores were rented at Tamale market and filled with a total of nine tonnes (90 x 100 kg bags) of cowpea which was supplied by several traders. The commodity was fumigated with phosphine under a gas proof sheet in the open. The dosage applied was three tablets of aluminium phosphide (Gastoxin) per tonne for five days exposure. Gas concentrations were monitored during fumigation to ensure effectiveness of the treatment.

148. After fumigation, small stacks were constructed inside the stores and the following treatments applied:

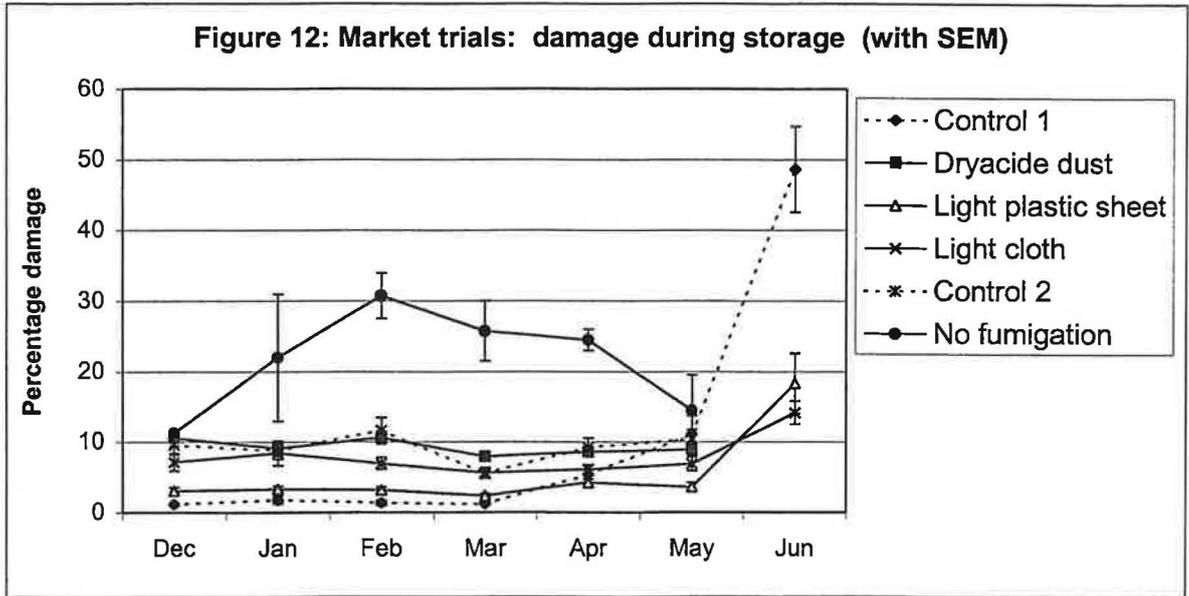
- none (control),
- Dryacide (commercially available inert dust with insecticide properties), dusted onto stack surfaces,
- a light plastic sheet was placed over the stack to provide a mechanical barrier, or
- a light cotton cloth was placed over the stack, also to act as a physical barrier to insect attack.

Two bags of commodity were also purchased and stored without being fumigated.

149. Percentage damage was recorded every month, for six or seven months, depending on the co-operation of traders from whom the bags were borrowed.

150. Figure 12 records percentage damage in the bags treated by fumigation. There was no re-infestation of the treated bags, the damage observed being sustained before the fumigation. The level of damage of the non-fumigated sample increases to 30% after two months storage.

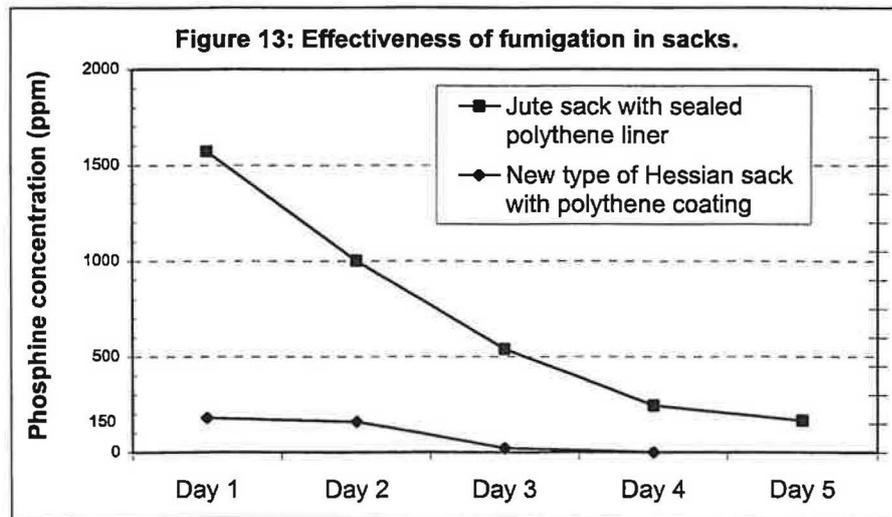
151. With good hygiene in the store, re-infestation did not occur until after the fifth month, as indicated by the control. When it did occur, light plastic or cloth sheeting appeared to provide a good level of protection. The effectiveness of Dryacide after six months of storage was not tested, as the trader insisted on selling the grain after the May sampling.



Lined bag test

152. A new type of hessian sack, with an open weave and internally coated with polythene was available at Tamale market. It was claimed that this type of bag could be used for disinfestation of the grain and would offer protection against re-infestation. However, the sack did not appear to be air tight. A fumigation test was undertaken to verify the claim, as this could make small-scale fumigation easier.

153. The new type of hessian sack was compared with a jute bag in which a double skin polythene liner was inserted, and sealed with plastic tape. The concentration of phosphine gas was monitored for five days (Figure 13). The new type of hessian sack proved to leak severely, and the gas was lost very quickly.



154. Current traders' stores have uneven floors, either bare earth or with a thin cement rendering that is cracked. Partition walls are mostly timber planks with spaces

between, or occasionally of cement plastered block construction. Re-infestation is therefore very likely to occur, and protective measures are therefore necessary.

155. The first season demonstrations were very successful at attracting the attention of the traders. Those who volunteered for the trials benefited from clean commodity that fetched a high market price. In the following year, many more traders wanted to benefit and volunteered to participate in a second trial. The stores were rented again, and further demonstrations were organised.

Fumigation site

156. The extent of the success of the fumigation demonstrations led also to suggestions for the development of a larger scale facility for the fumigation of traders' commodities. Traders' own stores at Tamale market are not well suited for fumigation (see 154 above), as it is not possible to retain the gas in situ for the necessary five day exposure period.

157. A central fumigation site would provide the following advantages to the traders:

- Fumigation of bags for five days without disturbance
- Successful fumigation guaranteed
- Safer than current practice
- Cost-effective

158. The feasibility of identifying a single site within the market area where individual traders would agree to bring their grain for fumigation was first investigated (Tyler and Andan, 1997). However, space is at a premium and congestion, especially on market days, would restrict bag movements. On safety grounds, medium to large-scale fumigation in such a busy area would be potentially hazardous.

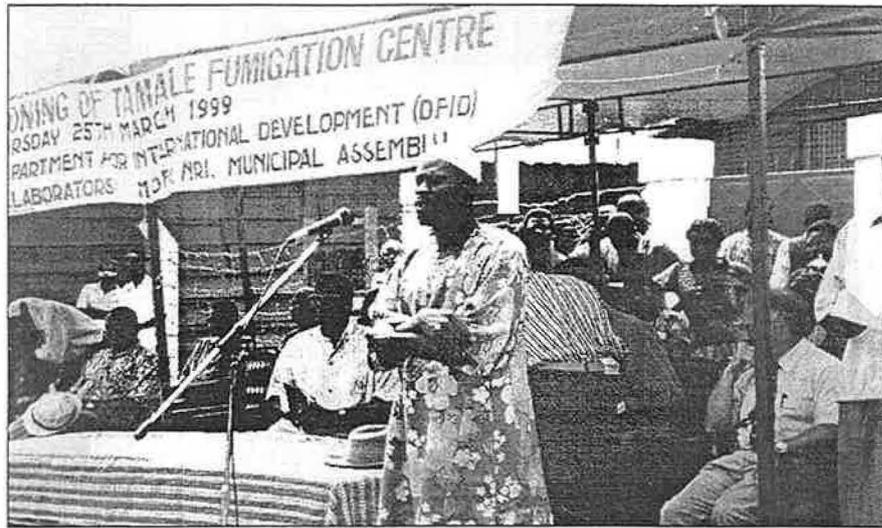
159. Discussion took place with the traders, the Municipal Assembly and the Municipal Planning Officer and a general agreement was drawn up. A location belonging to the Municipality was identified just outside the main market storage area, and a preliminary costing undertaken. Funding for the construction was obtained from the British High Commission's Small Projects Fund.

160. Some basic civil work was required on the site before building work could start, including levelling of the land and clearance of rubbish, a bridge put over a small culvert to provide access to vehicles and provision of electrical power.

161. The Fumigation Centre was completed and formally commissioned in February 1999, in readiness for the 1999/2000 storage season. During the first year, operations will be supervised by NRI and MoFA personnel and thereafter will become the responsibility of the Municipal Assembly and the traders' association.

162. The site is approximately 120 x 30 m. It comprises an office, a raised platform for fumigation under sheets, a container for use as a fumigation chamber of up to 200 bags, and a large area for loading/unloading of the trucks. The site is surrounded by a perimeter fence for security.

Commissioning of the Fumigation Centre in Tamale



163. Traders will be able to direct the lorries bringing bagged cowpea (and other commodities) to the market to the fumigation site. A charge will be levied for fumigation, to cover running and maintenance costs.

164. For the full benefits of the fumigation to be felt, there remains a need to improve the conditions of the traders' stores and the level of hygiene therein. At the opening of the Fumigation Centre, the Tamale District Chief Executive committed the Town Council to improve the traders' facilities. Training traders in good storage practice remains a priority.

RESISTANCE TO BRUCHIDS AND QUALITY OF LEGUMES VARIETIES

165. The control methods described can be regarded as short-term measures. One longer-term approach would be to develop grain varieties that are inherently resistant to insect attack. To begin it was necessary to determine resistance in local cultivars.

166. There are several points in the life cycle of bruchid beetles where resistance can take place. Resistance can be expressed first at oviposition. In stores, female bruchids lay their eggs on the seeds. They are sensitive to physical and chemical characteristics of the testa; the smoothness of the surface, the size of the bean and the chemical composition of the testa can all elicit egg laying. In a situation of choice, a variety of cowpea or bambara could remain less infested if its testa was not recognised as being suitable by the females. In practice, there is limited choice and resistance would need to be strong to deter bruchids from egg laying.

167. Resistance may also inhibit larval development. It may be either physical or chemical, translating into higher larval mortality. This is a more suitable type of resistance for stored legumes. The aim of this preliminary study was to identify possible resistant traits in local varieties of cowpea and bambara, which could be incorporated in improved varieties by breeders.

168. Previous attempts at providing farmers with such improved varieties have not been very successful, as the improved varieties were not readily adopted. This project investigated simultaneously the characteristics that make cowpea and bambara attractive to local consumers.

Varietal resistance in cowpea

169. Seven varieties of cowpea from northern Ghana were tested for their resistance to *C. maculatus* at the Savannah Agricultural Research Institute. The seven varieties were defined according to the colour of the seed coat, following local tradition. The fecundity of bruchids on these varieties, their developmental time in these seeds and the average weight of adults on emergence from them were recorded. Resistance can be expressed by: lower fecundity, indicating that the seeds are less suitable for oviposition; by a delay in development of the larvae inside the grain; and by smaller adults, because their fecundity will be reduced. However, increased development time can be traded off against larger adults and an increase in fecundity.

170. The fecundity did not differ significantly for the varieties tested. The developmental time was significantly longer on two of the varieties (large white, black eye and large white, brown eye), and shorter on one (small white, brown eye). Adult weight at emergence differed significantly as well, but the varieties with longer developmental time did not exhibit a decrease in the size of adults (figure 14).

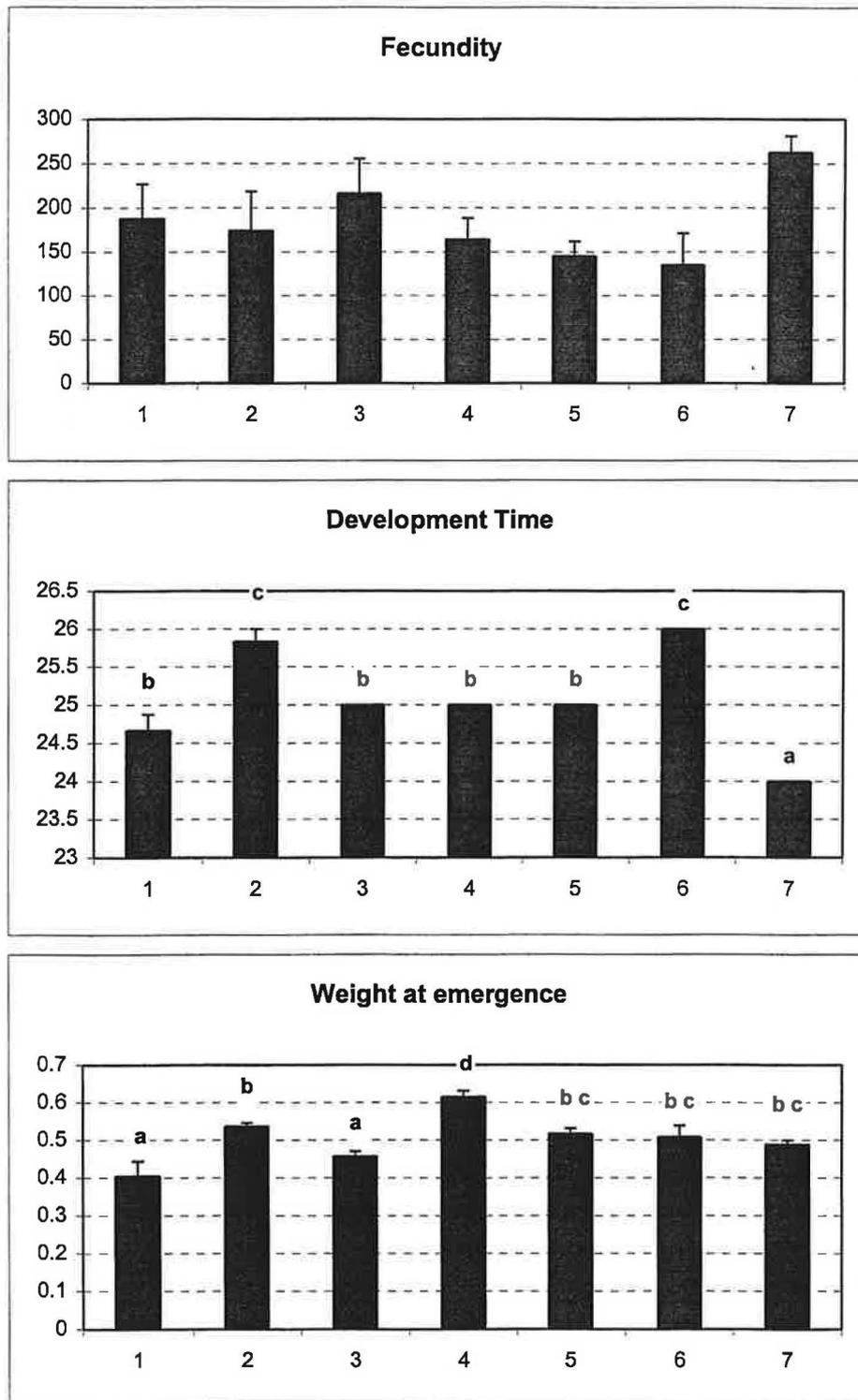
171. The varieties tested are not resistant themselves, but some of them exhibited traits which could be selected by breeders, and which, incorporated together, would provide resistance to the bruchids.

Varietal resistance in bambara

172. Preliminary resistance screening of bambara seeds from 4 seed collections, made from areas in the Northern and Upper East Regions of Ghana, in February of 1995 (1 collection) and 1998 (3 remaining collections) was undertaken at Royal Holloway, University of London. Each collection contained a mixture of seed types.

173. The purpose of this study was to investigate whether any bambara resistance was evident among available seed types, by examining differences in the developmental success of *C. subinnotatus*. Since there are no classified varieties of bambara in Ghana, and Ghanaian farmers tend to use the seed testa colour and pattern to identify and distinguish between locally grown cultivars, the four collections were sorted qualitatively into their different seed types on the basis of difference in testa and eye colour and pattern using 'Descriptors for bambara groundnut' (1987), Section 4.3. (See table f, appendix 3, for the details of each of the four collections and the different seed types within them).

Figure 14: Resistance of 7 local varieties of cowpea to bruchids (means with SEM).



Cowpea varieties:

1. Reddish-brown
2. Large white, black-eye
3. Shiny red
4. Light brown
5. Rusty brown
6. Large white, brown-eye
7. Small white, brown-eye

Homogeneous subsets:

Letters **a**, **b** and **c** show homogeneous groups (ie. varieties that do not differ significantly regarding this character), as determined by a posteriori tests following the Anova.

174. For each seed type and for the 'susceptible' cream bambara accession used in previous experiments, a sample of conditioned seeds was exposed to approximately 150 newly emerged *C. subinnotatus* individuals taken from laboratory cultures for not more than 4 hours, in order to obtain seeds containing synchronously developing beetles. Where the total number of seeds representing a single seed type was less than 25, all seeds were exposed, where the number of seeds available for testing was at least 25, this was used as the sample size. Approximately 48 hours after oviposition, the seeds were examined individually and excess eggs removed using a mounting pin, so that each seed supported only a single egg.

175. Egg-laden seeds were isolated in repli-dishes, which were kept under constant temperature and relative humidity for the duration of beetle development.

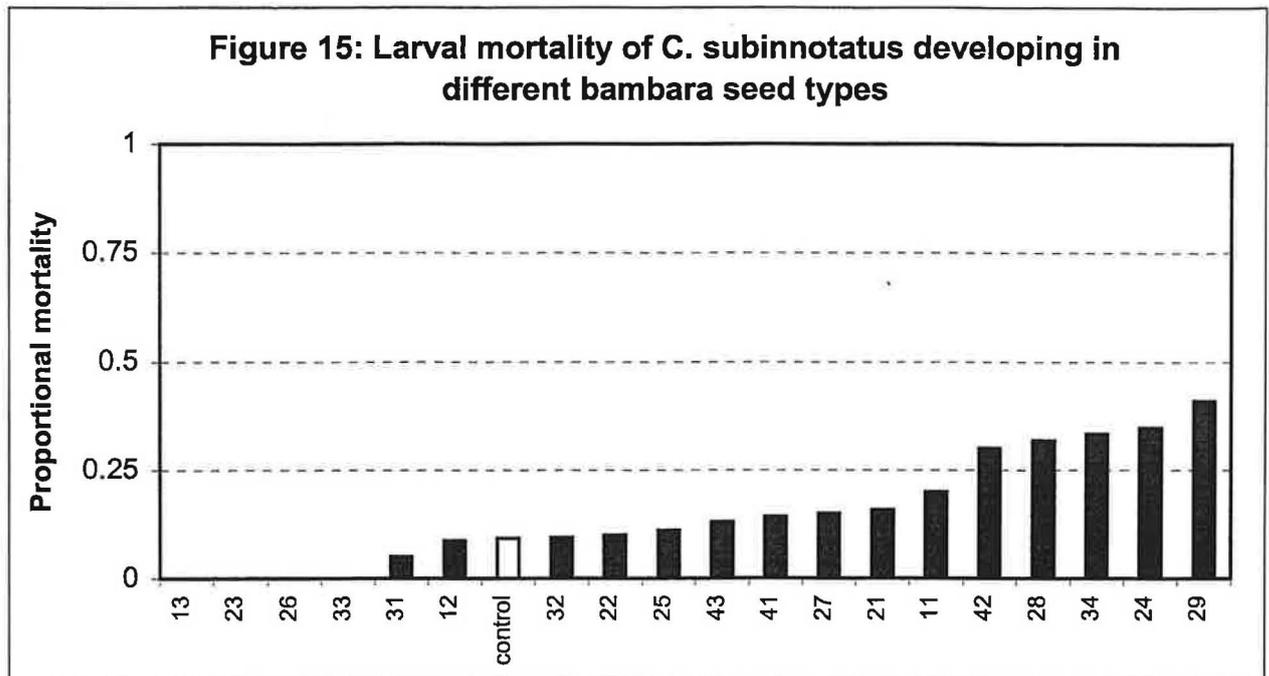
176. From 25 days following oviposition onwards, daily recordings of the emergence, sex, development time and live weight of each emerging beetle were made. In situations where less than 3 males or less than 3 females successfully emerged from a replicate, these data were excluded from statistical analyses of adult weights and development times.

177. *Mean weights.* For any given seed type, the mean weight of *C. subinnotatus* males at emergence was nearly always heavier than that attained by females. Among the different seed types tested, the weights of males and females did not vary significantly ($F_{(19,133)} = 1.11$, $p = 0.348$ for female comparisons, $F_{(18,124)} = 0.804$, $p = 0.693$ for male comparisons).

178. *The mean development times* (from oviposition to adult emergence) of males and females also varied across different seed types, with those individuals developing in the 'susceptible' cream accession being relatively short, as expected. Significant differences in the development times of females reared in different seed types were apparent (Kruskal Wallis Chi-Square = 37.151, $p = 0.008$), with the development times of females reared in seed type 11 (a red cultivar originating from Yendi) being significantly longer than those of females reared in the susceptible control. Females reared in seed types 26 (a white cultivar with a red eye) and 41 (a white cultivar identical in appearance to seeds of the 'susceptible' control), also had longer development times than females reared in the control seed type. Male development times did not differ significantly among seed types. The unusually long mean development time for males emerging from seeds of type 24 (a black cultivar originating from Yendi) is explained by the emergence of several 'active' form individuals from this seed type, which have inherently longer development times than individuals of the normal form.

179. The proportion of individuals which successfully emerged as adults was compared among different seed types. Where eggs failed to develop even to the 1st larval instar (assumed to be caused by factors other than properties of the host seed), these were excluded from mortality determinations, so that the mortalities determined represent only post-embryonic mortality. A significant association between seed type and post-embryonic mortality was found (Chi-square = 35.316, $p = 0.0128$), indicating that mortality levels were not equal across different seed types. Figure 15 shows proportional mortality for each seed type, arranged in ascending order. Mortality ranged from 0% to 41% across different seed types. There appears to be no

consistent pattern in terms of the level of mortality and the colour of the seed type tested.



(The code numbers used for the bambara seed types are explained in appendix 3. The control is the variety used for culturing *C. subinnotatus* in the laboratory)

180. Reports from farmers in Ghana and work by Amuti & Larbi (1981) on assessing losses from bambara collected from the field, have indicated that cultivar differences in post-harvest losses of bambara exist. More specifically, the incidence of insect damage was greatest in cultivars with pale seed coats (cream coloured seeds), and lowest in cultivars with black or purple seeds, suggesting that cultivars with darker seed coats may be more resistant to infestation by bruchid beetles. In addition, variation in the level of post-harvest damage observed depended upon the location from which seed samples were collected, with seeds collected from market centres having higher infestation levels than seeds collected from farmers' stores.

181. Although differences in all three of the parameters measured (development time, adult weight and larval/pupal mortality), were apparent among the different seed types tested, the only significant differences were in female development times, and these differences did not appear to be linked to seed colour. In addition, the significant relationship between the level of post-embryonic mortality and seed type, did not appear to be attributable to differences in seed colour. Therefore, although the results provided evidence of differing susceptibility among the seed types to *C. subinnotatus* infestation, there is no evidence linking these differences to differences in coat colour.

182. This study examined the effect of seed type on the developmental success of individual beetles on a small scale but did not investigate differences in the fecundity of beetles subsequently emerging from different seed accessions. In screening

'varieties' for resistance in this way, data relating to development times and weights of emerging beetles have to be treated separately in statistical analyses due to inherent sex differences in these parameters, something that has not always been taken into account in the past, reducing the definitive sample sizes further. Thus sample sizes were in some cases very small ($n < 10$ in some cases) and the high individual variation inherent in most bruchid species, may have masked minor differences between seed treatments. It was expected however that any major differences among seed types would become apparent despite the experimental limitations. In order to carry out a larger scale resistance trial, using both insect species, larger collections of known origin would be imperative for the results to be of any practical use in identifying potentially resistant varieties.

183. These preliminary studies, on cowpea and on bambara varieties commonly used in northern Ghana have shown that there is variability in the traits that provide resistance to the bruchid pests. This was the aim of this project, and it is now possible for breeders to select these traits, by crossing the varieties. This preliminary work has also confirmed that the definition of variety used by farmers in Ghana does not correspond to the definition used by breeders and geneticists. Farmers and traders refer to colours of the testa, mainly, and this does not imply homogeneity in the genomic make up of these varieties. Therefore, the concept of variety will need to be clarified as the start of the selection work of the resistant traits that have been identified in the present project.

Qualities of varieties of legumes

184. Five varieties of cowpea and six varieties of bambara from the north of Ghana were analysed by the Food Research Institute, in Accra (Plahar *et al.*, 1998). The varieties studied are defined by the colour of the grains. Cowpea grains ranged from cream to mottled grey, and bambara from cream through brown and maroon to black.

185. The characteristics studied were as follows:

Physical and functional characteristics:

- Size of seeds and germ and thickness of seed coat;
- Test weight per hectolitre;
- Average seed weight;
- Water absorption.

Proximate composition:

- Moisture, protein, fat and ash;
- Iron, calcium and phosphorus;
- Carbohydrates.

Tannin and trypsin inhibitor content;

Amylograph pasting characteristics:

- 10% slurry of flours were heated uniformly from 25 to 95°C;
- Pasting temperatures, peak viscosities, viscosity at 95°C, starch stability and cooking times.

Sensory properties in relation to specific food uses:

- Sensory evaluation: acceptability scores of local foods: 10 member trained panel;

- Estimation of cooking quality: samples ranked for softness after soaking and boiling.

186. All characteristics under study were found to differ among varieties, except for the moisture and ash contents.

187. *Cowpea physical characteristics.* The mottled grey cowpea variety was smallest with a seed length of 6.72 mm, a seed width of 5.05 mm and a weight of 95.47 g for 1000 seeds. The cream black-eye variety from Bolgatanga was largest in size with a length of 8.48 mm, a width of 6.36 mm and a weight of 178.33 g for 1000 seeds. Seed coat thickness ranged from 0.01 mm for "tee pielga" (another cream black-eye variety) to 0.05 mm for the cream brown-eye seeds. Germ sizes were found to constitute about 40 -50% of the seed size in term of length or width. In general the cream black-eye varieties of cowpea studied were found to have similar germ sizes.

188. *Bambara physical characteristics.* The seed sizes were not significantly different from each other with the exception of "sum pielga" (cream brown-eye) which was relatively small and had the lowest weight for 1000 seeds (638.15 g). Seed coat were thickest for the cream coloured seeds (0.11 and 0.12 mm). Germ sizes in the case of bambara were found to constitute about 50 - 60% of the seed size.

189. *Cowpea functional characteristics.* For all cowpea varieties examined maximum water absorption was attained within twelve to eighteen hours. The mottled grey ("summpupura") variety exhibited the fastest initial water absorption rate (91.29 g / 100 g solids / h) after 18 h of soaking. On the other hand, the cream brown-eye, which had the slowest initial water absorption rate (45.03 g / 100 g solids / h) attained the highest maximum water absorption capacity of 118.99 g / 100 solids also within 18 h of soaking. The cream black-eye variety ("tee pielga") which had the thinnest seed coat showed a relatively fast water absorption rate and attained maximum water absorption in a very short time (12 h). With this exception, all cowpea varieties exhibited a stage of readjustment resulting in a dip at 9 h of soaking. After the readjustment period, more water was absorbed until the seeds reached their maximum absorption limit.

190. *Bambara functional characteristics.* Three varieties, namely "siatalanu" (cream black-eye), mottled cream and "sum pielga" (cream brown-eye), attained maximum water absorption at 60 h while the other three varieties, "simpkli sabila" (black white eye), "simpkli zei" (maroon white-eye) and brown white-eye showed the capacity to absorb more water after 60 h. Very low initial water absorption rates were observed for all varieties (0.84 - 5.34 g / 100 g solids / h). This can be explained by the thick seed coats of bambara seeds (0.11 - 0.18 mm). The varieties with the thinnest seed coats ("siatalanu" : 0.11 mm and "sum pielga": 0.12 mm) attained the highest water absorption capacities after 12 h (68.24 63.87 g / 100 g solids, respectively) while varieties with the thickest seed coats ("simpkli sabila" and "simpkli zei": 0.18 mm) showed the lowest water absorption capacities after 12 h soaking. The results indicated that water absorption characteristics cannot be explained by seed coat thickness alone, and variations in the seed coat and hilum surface deposits may have an influence as well. No stage of readjustment resulting in dips in absorption curves were observed in bambara.

191. *Cowpea proximate composition.* Moisture content of the cowpea varieties were not significantly different from each other and ranged from 6.4% to 8.4%. Similar protein contents were observed for the mottled grey ("summpupura"), cream black-eye ("tee pielga") and cream black-eye (Bawku, medium) varieties ranging from 25.5 to 26.3% while the cream brown-eye and cream black-eye (Bolgatanga, large) had slightly lower protein contents of about 24.3%. With the exception of the cream brown-eye variety which had the lowest fat content of 1.1%, fat contents were not significantly different and ranged from 1.6 to 2%. Ash content ranged from 3.4 to 4.2% and were not significantly different either. Carbohydrates ranged from 61.2 to 64.7%. Iron, calcium and phosphorus contents fell within the literature values for most cowpeas.

192. *Bambara proximate composition.* Moisture content ranged from 5.6 to 8%. As is typical for legumes, high protein values are offset by low fat contents and vice versa. The black bambara variety ("simpkli sabila") was found to have the highest protein content (26.5%) and lowest fat content (4.5%) while the cream black-eye ("siatalanu") had the lowest protein and highest fat contents (22.6% and 6.5% respectively). Ash contents did not differ significantly and ranged from 3.3% to 3.6%. Carbohydrate content ranged from 57.5% to 62.0%, and values for calcium, phosphorus and iron were observed to be about half those in cowpea.

193. *Tannins and trypsin inhibitor content.* In cowpea varieties, the seed tannin contents ranged from 0.10 to 0.75 mg Catechin equivalent (CE) / g sample. Tannin concentrations in bambara seeds were several-fold greater than in cowpea seeds, ranging from 3.6 mg CE / g sample to 14.5 mg CE / g sample for the black white-eye ("simpkli sabila") variety. Tannins were found to generally increase with increasing seed coat colour intensity. Trypsin inhibitor activity in cowpea seeds ranged from 6.71 mg / g sample in the mottled grey ("summpupura") to 13.00 mg / g sample in the cream brown-eye variety.

194. *Amylograph pasting characteristics of the flours.* In general, the cowpea samples produced amylograms with typical starch pasting viscosity curves while bambara samples produced curves with no clear-cut peaks with a high resistance to prolonged heating. The most significant varietal differences in the pasting properties of cowpea flours were in the gelatinisation temperatures (ranging from 77.0 °C to 81.5 °C), peak viscosities, starch stability and ease of cooking. Mottled grey variety recorded the lowest peak viscosity (214 BU), the greatest starch stability and the longest cooking time of 10.9 minutes. Bambara varieties gave negative values for starch stability which were the result of the continued increase in viscosity during holding. Gelatinisation times and temperatures were longer and higher (82 °C), respectively, than for cowpea, but did not differ between varieties.

195. *Sensory evaluation.* Results from the panel sensory evaluation show that among cowpea varieties, the cream black-eye, from Bolgatanga, was the preferred choice, for all recipes (based on fried or boiled cowpea, cowpea stew and cowpea with rice). Among the bambara varieties tested, the light coloured variety cream brown-eye ("sum pielga") was preferred. However, this may be a particular preference to the south of the country, where black coloured bambara is not popular. For softness after cooking the panel preferred the aforementioned varieties for both cowpea and bambara.

196. *Cookability.* This was found to vary widely between the two species of legumes. For cowpea varieties: water absorption took nine to 24h, whereas for most varieties of bambara, it took over 60h. The cream black-eye cowpea varieties cook faster than the mottled grey and the cream brown-eye varieties. For bambara, the black white-eye variety was the toughest, when cream brown-eye ("sum pielga") and mottled cream were the fastest cooking varieties.

Conclusion

197. This part of the project provides the basis of future work in collaboration with plant breeders. The results obtained from the varietal resistance studies have shown that there is potential for selection of resistant traits in cowpea and bambara. However, as the varieties studied have exhibited a strong variability in their chemical, physical and organoleptic qualities, breeding programmes will have to take into account the acceptability of improved varieties in respect to customers' tastes.

SUMMARY AND FUTURE WORK

202. This project has assembled data concerning the quantity of cowpea and bambara typically stored by farmers in northern Ghana; the duration of storage, the reasons why this storage is not prolonged, the extent of the damage due to bruchid pests, and the ways used by farmers to attempt to limit this damage. Information on storage and marketing by traders was also obtained. This included the duration of storage, the extent of damage, the methods of insect control, and the price fluctuations in time, and due to insect damage.

203. It is clear that damage due to bruchids is an important limiting factor for storage, both at the farmers' level and for traders. The methods of control currently used are largely ineffective, and new or improved methods have been developed and tested. These methods were selected for both their effectiveness and their acceptability.

204. For farmers, this means mainly that the control methods have to be easy to apply and that their cost must be minimal. The recommended methods provide a choice for farmers including solar disinfestation, hermetic storage and admixture of plant or inert materials.

205. Recommendations for traders include fumigation with phosphine before storage, basic store hygiene and the use of inert dusts or physical barriers to protect grain stacks. Some of these measures have been tested, and proper fumigation techniques have been demonstrated and a pilot fumigation centre has been opened at Tamale market to provide this service cost-effectively.

206. Concomitant work has focused on identifying resistant traits in local varieties of cowpea and bambara that could be used by breeders for the selection of improved varieties that would suffer less damage from the bruchids. Attention was again given to the future acceptability of such resistant varieties, and the characteristics that make cowpea and bambara more acceptable to the consumer have been studied on these

local varieties. These results can now constitute the basis for selection of improved varieties by breeders.

207. Preliminary on-farm testing of the control methods has been undertaken, but this work will be repeated over more storage seasons, and in more geographical areas in the second phase of the project. The control methods recommended at the end of this first phase have been incorporated into a video, which will provide the basis for developing uptake mechanisms through extension systems. Other means of dissemination in collaboration with local partners will also be considered in the second phase.

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APPENDIX I

RAPID LOSS ASSESSMENT TECHNIQUE

Table a: Damage and loss parameters in cowpea

Sample descriptor	% damaged	% loss (C&W)	Total number of holes	Mean no. of holes / grain	% wt loss due to one hole
Cpea 1	14.61	0.44	118	0.21	2.11
Cpea 2	19.07	0.93	194	0.28	3.28
Cpea 8	27.05	8.64	293	0.59	14.72
Cpea 7	27.38	4.71	257	0.52	9.03
Cpea 10	30.30	4.68	283	0.60	7.81
Cpea 9	31.21	3.48	294	0.60	5.76
Cpea 6	41.10	9.51	442	0.86	11.00
Cpea 5	41.24	7.27	420	0.84	8.69
Cpea 3	49.83	7.34	568	0.97	7.60
Cpea 4	71.57	10.42	880	1.26	8.29
				Mean = 0.68	Mean = 7.83 (±3.52 SD)

Table b: Damage and loss parameters in bambara groundnut

Sample descriptor	% damaged	% loss (C&W)	Total number of holes	Mean no. of holes / grain	% wt loss due to one hole
Bbara 1	29.64	3.08	240	0.47	6.49
Bbara 2	15.40	0.97	109	0.19	5.12
Bbara 3	6.53	1.64	43	0.08	(19.83)
Bbara 4	13.44	1.10	130	0.19	5.84
Bbara 5	36.36	2.82	326	0.80	3.52
Bbara 6	39.87	6.07	558	1.18	5.16
Bbara 7	29.98	2.50	183	0.45	5.57
Bbara 8	19.82	2.29	202	0.30	7.61
Bbara 9	38.51	8.36	753	1.56	5.36
Bbara 10A	30.42	5.47	338	0.67	8.15
Bbara 10B	30.96	5.36	307	0.84	6.37
Bbara 11	36.44	2.87	1063	1.87	1.54
				Mean = 0.69	Mean = 5.52* (±1.82 SD)

* The bracketed outlier from the March sample has been ignored in determining the mean.

Table c: Effect of number of holes on proportionate weight loss

Number of holes per grain	% loss per grain per hole	
	Cowpea*	Bambara groundnut
1	17.88 (13.40)	6.50
2	9.62 (11.81)	7.50
3	8.60 (8.24)	5.59
4	7.20 (7.19)	3.84
5	5.94	3.63
6	5.79	3.61
7	4.76	3.51

* Figures in brackets show results from Caswell (1981)

Caswell (1981) used a larger-grained variety of cowpea than was used in the current study which may explain why the proportional loss per grain is lower for single hole infestation rates in his samples.

APPENDIX II

METHODS OF TREATMENT USED ON COWPEA AND ON BAMBARA

Table d presents the methods of treatment used on cowpea, ranked according to the percentage damage suffered on the treated stock. In table e, 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. Data from the 1996-97 survey.

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

Treatment	Region	Mean % damage	Transformed mean \pm 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 \pm 0.059	8
Sumicombi (Fenitrothion + Fenvalerate)	NR	44.5	0.679 \pm 0.126	4
sun dried	NR	40.5	0.646	1
not treated	NR	36.2	0.608 \pm 0.087	9
Cypermethrin / Sumicombi	NR	36.0	0.607 \pm 0.003	2
Napthalene	NR	23.4	0.486 \pm 0.053	2
Phosphine	NR	17.4	0.419 \pm 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 \pm 0.200	2
Heat over fire and mix ash	UER	6.2	0.248 \pm 0.019	31
Heat over fire and mix ash and orange peel	UER	3.5	0.187	1

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

Type of treatment	Treatment	Region	Mean % damage	Transformed mean \pm SEM	Number of farmers
Not treated	-	NR	6.0	0.244 \pm 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 \pm 0.168	2
	Mixed with ash and kul-enka	UER	2.1	0.146	1
	Kimkim mixed with seed	UER	0.9	0.095 \pm 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 \pm 0.070	3
	Immerse in warm water, dry, mix in ash	UER	0.6	0.077 \pm 0.045	3
	dawadawa Dawadawa seed boiled in water, poured over grain	UER	10.7	0.328 \pm 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 \pm 0.066	12
	Immerse in kimkim boiled water	UER	6.4	0.253 \pm 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 \pm 0.003	2
	Immerse in kimkim boiled water, dry,	UER	0.6	0.078 \pm 0.051	5
	shea butter Soak in shea butter waste water	NR	2.0	0.141 \pm 0.138	6
neem & orange peel	Immerse in water in which shea butter dissolved	UER	1.6	0.125 \pm 0.003	2
	Added orange peel to water with neem	UER	0.0	0.000	1

Kul-enka: Graminae sp. (not yet fully identified)
Dawadawa: *Parkia clappertonia*
Neem: *Azadirachta indica*.

Kimkim: *Synidrella nodiflora*
Shea: *Vitellaria paradoxa*

APPENDIX III

RESISTANCE SCREENING OF BAMBARA VARIETIES.

Table f: Details of origin and composition of the four bambara collections used for preliminary resistance screening at Royal Holloway, University of London.

	Accession 1	Accession 2	Accession 3	Accession 4
Site of collection	Tamale market	Navrongo market	Tamale market	Bolga market
Origin of collection	Yendi	unknown	Tiduyili (Damongo)	unknown
Date of collection	26/02/95	25/02/98	26/02/98	25/02/98
Name of collection	Simkpli Zei (red)	Siatalanu	Simkpli-Sabila (black)	Sum Pielga (white)
no. seed types within collection based on differences in testa and eye colour and pattern	3	9	4	3
Seed type code: Seed type description / approx. seed quantity available for testing	11:Red / (400), 12:Black / (40) 13:Orange / (15)	21:White / (50) 22:Purple / (11) 23:Red / (8) 24:Black / (42) 25:Orange / (9) 26:White, red eye / (9) 27:White, black butterfly eye / (250) 28:White, black blotchy eye / (200) 29:White, black blotchy eye + black stripes (200)	31:Black / (450) White, black butterfly eye / (250) 32:White, red eye / (5) 33:Red (11)	41:White / (1200) 42:White, black splash on eye / (30) 43:White, black bar eye / (150)