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A rapid assessment technique for predicting weight loss in cowpea and bambara groundnut due to insect infestation

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Abstract

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, which 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 of them to a laboratory for examination. This is time-consuming and tedious. A method was therefore developed to enable a much more rapid determination of loss that could be used *in situ* on the farm.

The development of the method is described in the paper. It depends on relating grain damage, a function of the number of grains exhibiting insect emergence holes, with 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 repli dishes, is described.

Introduction

Cowpeas (*Vigna unguiculata*) (L.) Walp. and bambara groundnuts (*Vigna subterranea* (L.) Verdc) are an important component of the diet for small-scale farmers in Northern Ghana. Both crops are susceptible to insect attack, particularly from bruchids, after harvest. Estimates of loss from previous studies in West Africa and elsewhere suggest cowpeas may experience up to 30% losses during the storage period (Table 1) but these figures are often unsubstantiated.

Table 1. Summary of previous studies on post harvest losses in grain legumes and pulses

Crop / Country	% Damage*	% Weight loss	Storage period	Source
Bambara Ghana		3.7%	5 months	Amuti and Larbi (1981)
Bambara ? Kenya		Wide range		Mbata (1993)
Bambara Ghana	14-100%		6-8 months	Golob *et al.* (1996)
Bambara and cowpeas Ghana	22%		8-9 months in Northern Region	Gudrups *et al.* (1996)
Beans Ghana	?	19.5% (unshelled) 45.1% (shelled)	5 months	Adams (1977)
Beans Colombia	20%	7.4%	45 days	Schoonhoven and Cardona (1986)
Beans E Africa		Total (because of quality decline)	4-5 months	Giga *et al.* (1992)
Beans Colombia	c. 60%		9 months	Baier and Webster (1992)
Beans Uganda		3% 8%	3 months 6 months	Silim (1994)
Beans Uganda	25% 65%		6 months 9 months	quoted in Gudrups *et al.* (1996)
Cowpeas Nigeria	14-37%			Caswell (1968)
Cowpeas Nigeria	9-30%	1.6-5.4%		Caswell (1981)
Cowpeas ? Nigeria	Up to 70%	Up to 30%		Singh and Jackai (1985)
Cowpeas Ghana	15-94%		7-9 months	Golob *et al.* (1996)
Cowpeas Uganda		5.9%	6 months	quoted in Gudrups *et al.* (1996)

* Damage is the proportion of a sample showing signs of insect infestation

If resources are to be allocated to improving storage of these two crops and reducing post-harvest losses it is essential that an indication of losses suffered by Ghanaian farmers be established. Several methods exist to determine weight loss due to insects. Each has its own shortcomings based on the assumptions made during calculations. The relative merits of each are fully discussed by Boxall (1986). Most existing loss assessment techniques are time consuming but give precise results for those samples evaluated. However, losses tend to be very location and time specific so that these techniques may give rise to a misleading sense of precision; if losses are shown to be 10% in one village in a given year, it cannot be assumed that the same will be true the following year or in neighbouring villages.

Current standard methods were dismissed as being too time-consuming and not applicable for field use and it was decided to develop, if possible, a quick technique for use by extension personnel. Some rapid methods have already been developed for use in the field, notably for disease and pest assessment of growing crops by using reference drawings (e.g. Jago, 1993), but also for stored cassava chips and maize cobs using reference photos as guides to loss (Compton *et al.*, 1992). These techniques assume that there is a strong correlation between the visual appearance of the sample and the measurable loss.

Bruchid damage in cowpeas and bambara groundnuts is typified by very clear exit holes produced as the new adults emerge from the grains (Figure 1). 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 emergence holes it seemed likely that damage (the proportion of grains showing holes) could be used as a direct correlate of weight loss.

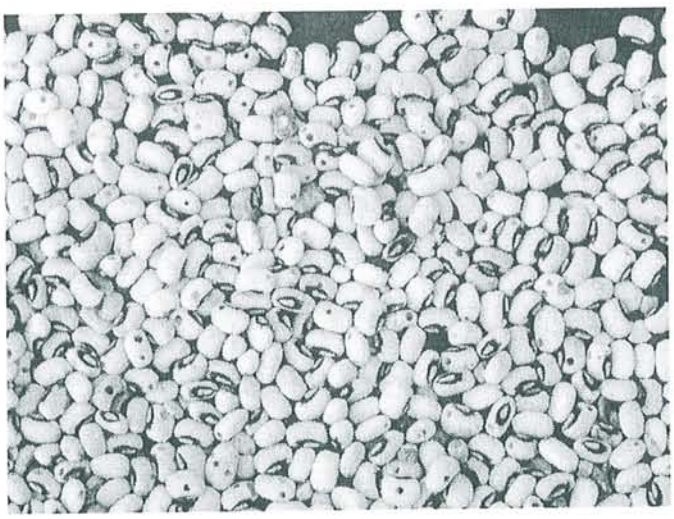

Figure 1. Bruchid damaged cowpeas showing 70% damage level

For some of the pulses it has previously been shown that visual damage can be related to weight loss. Caswell (1968), working in Nigeria, deduced that each *Callosobruchus maculatus* (F.) (Bruchidae: Coleoptera) larva consumed 5-10% of a cowpea grain. By counting the number of holes and adjusting for the number of damaged beans he could relate damage to loss. This method was refined by Caswell (1981) acknowledging the fact that loss per emergence hole varied with intensity of attack. Therefore cowpeas showing the following number of holes per grain exhibited the following losses:

No of holes	% Weight loss per hole
1	13.4

2	11.81
3	8.24
4	7.19

He therefore proposed using 10% as a typical figure.

In order to avoid having to count the number of holes, which is both awkward and time-consuming, the relationship between number and distribution of holes and damage was established, so that only the number of grains with holes need be used in calculating loss. For samples (of 100 grains) with less than 50% damage the relationship was linear:

$Y = 1.8077X$ Y = number of holes
X = % damage

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*. This was expressed as:

$Y = 0.2298X$ ($r^2=0.722$)   Y = % weight loss
X = no of holes in 100 grains

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 = % weight loss
X = 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.

Materials and method

The programme was carried out in collaboration with the Savanna Agricultural Research Institute (SARI) in Tamale, Ghana. Samples of each crop had been collected from the local markets on a monthly basis from January to April 1996 and kept in a cold room to slow insect activity. In addition, a further six cowpea and seven bambara samples were collected during August 1996, from Tamale and Yendi markets, so that a range of damage levels was represented by the samples. However, no highly damaged bambara nuts were found for sale [samples showing 100% damage were available, but these were invariably bambara that had been hand-picked from the general stock to make the produce look more appealing to consumers].

The cowpeas were of the local white-seeded type. They were small, having a mean weight of 0.12g (±0.023g SD). The bambara nuts were more variable but were also local types. They were usually light brown and had a mean weight of 0.6g (±0.14g SD). These two crops were sold by the bowl (approx. 2.5 kg) in the market. It is interesting to note that a standard price was applied to each crop with no account being taken of quality. Both the cowpea and the bambara were representative of the grains available throughout Northern Region in Ghana. Although improved cowpea varieties are produced they are only available in small quantities on markets. Larger grain varieties are produced in Upper East Region but these were not included in this study and a separate standard curve would need to be produced for these. There are no improved bambara varieties available in Ghana, local varieties are differentiated principally by colour.

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 advantages of not requiring a base-line sample or 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. Damage in cowpeas was due to *C. maculatus*. In bambara groundnuts both *C. maculatus* and *C. subinnotatus* (Pic) were present; slight moth damage (*Corcyra cephalonica* (Stainton)(Pyralidae; Lepidoptera)) was also evident. 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.

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

The percentage damage was determined at the same time:

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

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

Summary findings are given for cowpea and bambara groundnut in Tables 2 and 3 respectively.

Table 2. 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)
The following data were used to plot the calibration curve only (figure 2)					
Cpea11	14.29	2.55			
Cpea12	20.98	-0.29!			
Cpea13	9.78	1.04			
Cpea14	13.39	1.73			
Cpea15	10.11	0.46			
Cpea16	9.37	0.27			
Cpea17	12.72	0.17			
Cpea18	12.10	-0.35!			
Cpea 8b	40.98	7.25			
Cpea 19	64.26	7.13			

! The count and weigh method for assessing weight loss can result in negative values where the estimate is small.

Table 3. 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 following data were used to plot the calibration curve only (figure 3)					
Bbara 12	4.84	-0.29			
Bbara 13	4.96	0.51			
Bbara 14	4.22	0.41			
Bbara 15	6.01	0.60			
Bbara 16	3.76	-0.07			
Bbara 17	5.52	-0.25			
Bbara 18	6.78	0.50			
Bbara 19	6.04	-0.20			
Bbara 9b	48.15	10.65			
Bbara 20	8.99	2.29			

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

Tables 2 and 3 show the mean weight loss per hole, irrespective of the number of holes present. 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. The findings are summarised in Table 4 below:

Table 4. 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.

The purpose of the current work was to establish the link between physical weight loss and a parameter that could be readily measured in the field. Percentage damage is readily observable and so the relationship between damage and loss was investigated for the two crops.

Cowpea

Data from the 10 samples in Table 2 were used. In order to have sufficient data points for the calibration graph a further 10 cowpea samples were assessed for % damage and % loss (without detailing number of holes or hole distribution). Results for the cowpea samples are plotted in Figure 2. The best fit line for the graph at p=5% is given by:

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

The standard errors of the parameters are:

parameter	estimate	standard error
a	-3.31	1.35
b	0.3551	0.0903
c	-0.00252	0.00119

{where y=a+bx+cx

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%.

Bambara groundnut

As with cowpeas, a further 10 bambara samples were assessed and added to the data set given in Table 3 in order to have a sufficiently large total sample. Results for the bambara samples are plotted in Figure 3. The best fit line at p=5% is described by:

$y = -0.788 + 0.1735x$ where: y = % loss; x = % damage

parameter	estimate	standard error
a	-0.788	0.523
b	0.1735	0.0216

(where y=a+bx)

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%.

Field use of the methodology

Field workers are supplied with the two graphs and a results record sheet (Figure 4) for work in the field. A sample of approximately 200 grains is taken at random from the store, placed into a perspex titre block (Figure 5), and each grain quickly examined to determine the proportion of grains that are damaged.

Figure 5. Titre block used for examination of pulse samples

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 ±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.

This method for loss assessment is currently being evaluated in two regions of northern Ghana through collaborative working involving 130 farmers and traders in two district markets.

Figure 4. Results record sheet

LOSS ASSESSMENT: PULSES, NORTHERN GHANA

Region:

District:

Village:

Farmer's name:

Cowpea............... Bambara.............. (tick which)

Name of variety:

Date sample collected (sample period)	Replicate number	Number of damaged grain				Total no. of damaged grain	Percentage damaged grains	Percentage weight loss (from graph)	Mean % weight loss
		Sample 1	Sample 2	Sample 3	Sample 4	A+B+C+D=X	X / 2		(a+b)/2
		A	B	C	D				
1	a								
1	b								
	Mean								
2	a								
2	b								
	Mean								
3	a								
3	b								
	Mean								
4	a								
4	b								
	Mean								

Future research

Both graphs were developed using 20 data points. By increasing the initial data set it is likely that the goodness of fit of the calibration curve can be improved to increase the accuracy of the derived field data. This work is planned for the future, together with extending the bambara groundnut data set to include samples showing damage levels in excess of 50%.

These scales work well under single-species pest infestation conditions. In cases where more than one species occurs the graphs need to be re-calibrated for each species. This is true for bambara groundnut where both *C. maculatus* and *C. subinnotatus* occur regularly.

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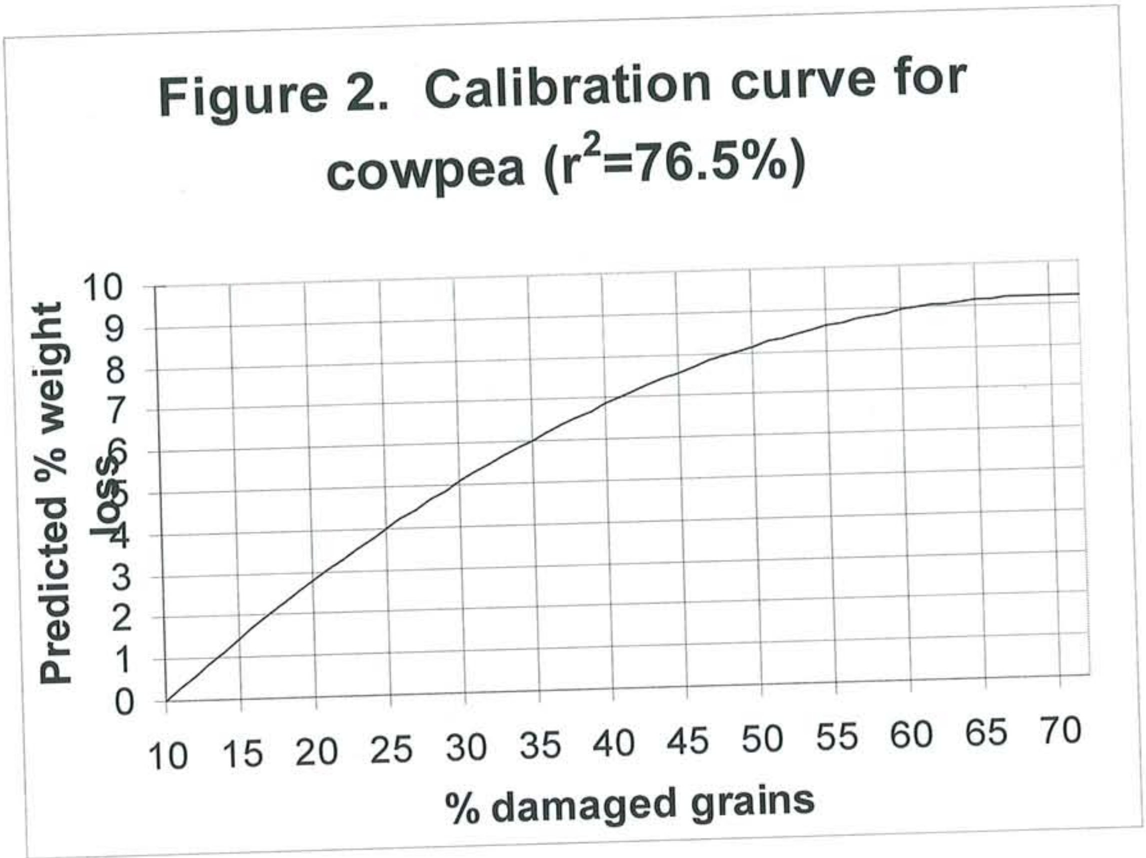
Figure 2. Calibration curve for cowpea (r^2=76.5%)
Predicted % weight loss
0
1
2
3
4
5
6
7
8
9
10
10 15 20 25 30 35 40 45 50 55 60 65 70
% damaged grains

Figure 3. Calibration line for bambara groundnut (r^2=75.1%)