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Losses caused by insects to groundnuts stored in a warehouse in India

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Abstract *Sacks of unshelled groundnuts with a total weight of 1·5 t were stored in an oil mill warehouse in Andhra Pradesh, India. Samples were removed at monthly intervals from a proportion of the sacks. The insect populations in the samples were monitored, and the damage to the kernels caused by each species was assessed. After 5 months, the total dry weight loss of kernels was approximately 20%.* Caryedon serratus *was responsible for almost all of the damage. The development of the insect populations and the accuracy of the loss measurements are discussed.*

Keywords: groundnuts, storage, insects, *Caryedon serratus*, damage, loss assessment

Introduction

Groundnut (*Arachis hypogaea* L.) is an important cash and food crop in many parts of the tropics, particularly in semi-arid areas. The kernels are consumed directly or used to produce cooking oil. When stored before utilization, groundnuts are susceptible to attack by insects (Feakin 1973). In West Africa the extent of post-harvest losses has prompted several studies of insect population development on stored kernels and pods (Green 1959, Smith 1963, Prevett 1964, Conway 1973). No detailed information is available on losses to stored groundnuts in Asia despite the fact that two thirds of the world crop is grown in this continent (FAO 1984).

In India, the bulk of the groundnut crop is used for oil production. Most farmers sell their crop soon after harvest, either to wholesalers, brokers or direct to oil millers, storing only what they require for seed. The risk of serious storage losses at the farmers' level is therefore small. To examine the build up of insect pest populations at centralized storage sites, a study was carried out at an oil mill warehouse, near Kurnool in Andhra Pradesh, managed by the state Cooperative Oilseed Growers Federation. The Cooperative consists of village 'societies' which purchase the groundnut crop from farmers at a guaranteed price and transport it to central storage sites. The groundnuts are stored in shell until they can be processed. The storage period can be as long as 9 months (Chiranjeevi, personal communication 1985).

The study included the evaluation of a simple method of assessing the quantitative losses to groundnut stored in shell. No attempt was made to measure the qualitative losses

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known to occur as a result of insect damage to stored groundnut (Howe 1965). As patterns of stock removal for processing are unknown, this factor could not be considered when calculating total weight loss at the end of the experiment.

Materials and methods

The warehouse chosen for the study had a capacity of several thousand tonnes. Storage management and store hygiene were poor. The staff made little attempt to separate old and new stock, or to separate kernels being retained for seed supply from material destined for oil extraction. New stocks arriving at the site were frequently processed before material already in store to save on the cost of labour required to move sacks from the storage area to the processing units.

The experiment was begun in the first week of July, 1985. Forty-eight bags of unshelled groundnuts (total weight 1·5 t) were taken from a consignment of groundnuts arriving at the warehouse approximately 1 month after they had been harvested. Six of the sacks sampled held the variety JL 24. All the other sacks contained the variety TMV 2. The sacks chosen for the experiment were numbered and formed into a stack (four layers of 12 bags) inside the warehouse, at least 1 m away from any other bags.

When the stack was constructed, and at monthly intervals thereafter, samples were collected from 10 bags (chosen at random before each sampling date) using the 'coning and quartering' method (Golob 1976). The stack was dismantled on each occasion and then rebuilt with each bag in its original position. The samples taken at the beginning of the experiment each contained 800–1200 pods (approximately 0·5 kg dry weight of kernels). However, as increasing levels of damage lengthened the time required for analysis, the sample size was reduced to 300–400 pods as the experiment progressed. The last samples were collected in the first week of December 1985.

The 10 'primary' samples collected each month were analysed individually, using the entire quantity of pods removed from each sack. Laboratory analysis (Figure 1) of the samples first involved the separation of sound pods from those which were split or holed to the extent that the kernels were exposed. The damaged pods were then further divided into those which were damaged by post-harvest pests and those which appeared to have been damaged prior to storage. The numbers in each category were recorded. Although most of the damage to pods caused prior to storage was mechanical, a few pods had been damaged by pod-boring insects (earwigs or wireworms) before the crop was harvested (Amin, personal communication).

Both damaged and undamaged pods were shelled and the insects inside each pod identified and counted. The damaged seeds were examined for the presence of bruchid emergence holes, moth frass and webbing, or the fine dust created by adult beetles feeding on groundnut. The seeds were then separated according to the species, or group of species, causing the damage. They were cleaned individually with a fine brush to remove dust, frass and insect fragments and then counted.

The undamaged kernels were graded using a wire sieve (4·00 mm Laboratory Test Sieve, Endecotts Ltd). Seeds passing through this sieve were immature and were invariably undamaged. They were discarded to avoid them affecting a reduction in the mean

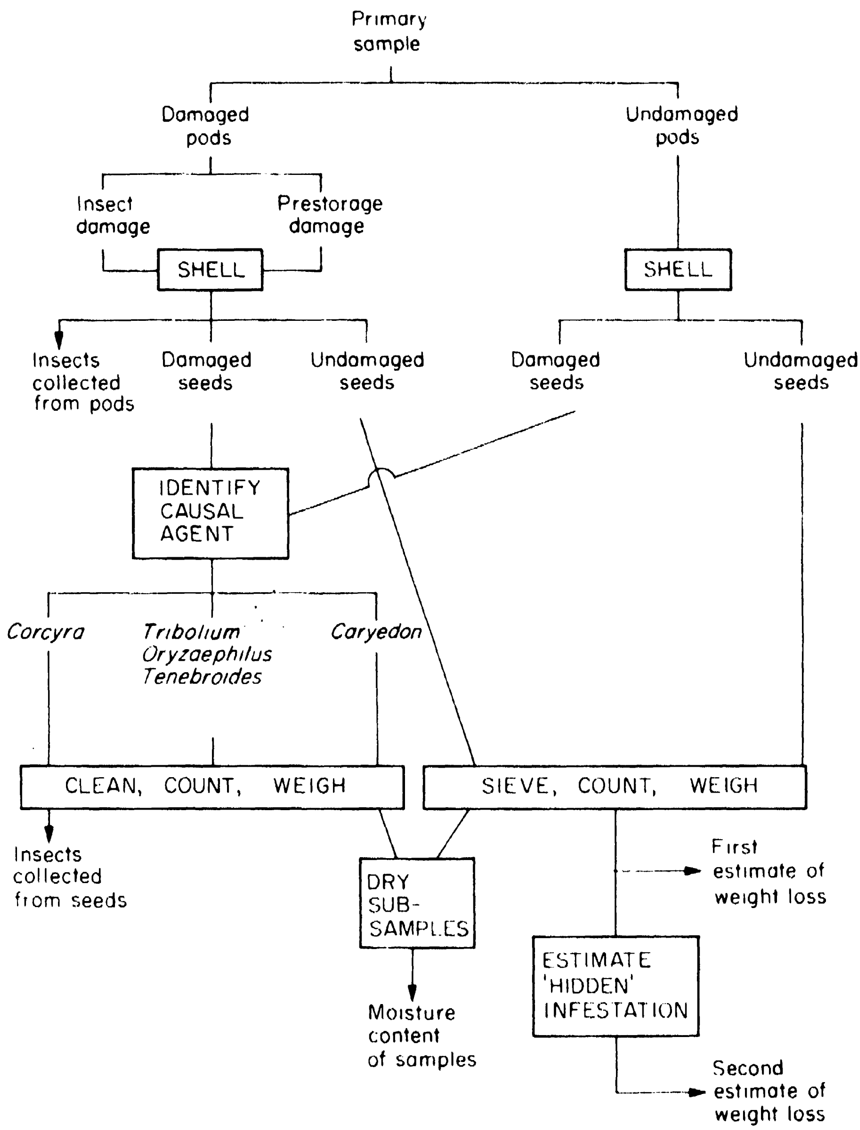

Figure 1. Procedure for laboratory analysis of groundnut samples.

weight of the undamaged seed to the point where losses caused by insects could be masked. The cleaned, damaged seed and the undamaged seed retained after sieving constituted the 'working' sample for the measurement of weight loss caused by insect infestation.

The loss, in dry weight, was determined by the 'count and weigh' method (Adams & Schulten 1978). This involves the calculation of the percentage weight loss using the formula:

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

where U = weight of undamaged grain, Nu = number of undamaged grains, D = weight of damaged grain, and Nd = number of damaged grains.

The moisture content of each working sample was obtained by first recombining the damaged and undamaged fractions. Three 10 g sub-samples were then removed from each working sample and dried at 105 °C for 16 h. The moisture contents of the sub-samples were calculated and the mean value used to obtain the dry weight of seed in each working sample.

An estimate of the weight loss attributable to 'hidden' infestation of apparently undamaged seed was obtained for each working sample collected after 2, 3, 4 and 5 months. In the absence of any standard procedure for estimating hidden losses, the following method was adopted. For each sample the total number and weight of kernels containing hidden larvae was determined. To calculate the number of 'undamaged' seeds which were in fact infested, a sub-sample of 100 kernels, initially recorded as undamaged, was selected at random from each working sample. These kernels were dissected and from the number containing larvae in the sub-sample the total number of seeds with hidden infestation in the working sample was estimated.

The total weight of seed containing hidden larvae could not be obtained by direct measurement because in many of the working samples the mean weight of seed in which hidden larvae there were (and removed before weighing) was found to be greater than that of undamaged seed. Using the actual weight of seed would thus have recorded a reduction in weight loss as a result of hidden infestation. The mean weight of kernels with hidden infestation was, therefore, estimated by taking an average of the mean weight of visibly damaged seed and the mean weight of undamaged seed. This mean value was then multiplied by the total number of kernels containing hidden larvae to give an estimated total weight of seed with hidden infestation for each working sample.

The count and weigh method was then used to calculate the percentage weight loss caused by hidden infestation. It is recognized that a greater degree of estimation is involved in this procedure than in the initial calculation of visible loss.

Results

Five species of insect were present in the stack: the groundnut bruchid *Caryedon serratus* (Olivier), the rust red flour beetle *Tribolium castaneum* (Herbst), the rice moth *Corcyra cephalonica* (Stainton), the merchant grain beetle *Oryzaephilus mercator* (Fauvel) and the Cadelle beetle *Tenebroides mauritanicus* (L.). As adult moths were unlikely to be present inside the sacks and adult beetles were able to leave the groundnuts when the bags were emptied for sampling, only the numbers of larvae (and *C. serratus* pupae) were recorded, as a measure of population size. No larvae of *O. mercator* were found despite the presence of adults in the samples.

During the first 2 months in storage, the larval population densities of these species were close or equal to zero. Thereafter, the number of *C. serratus* increased rapidly, reaching a peak (for larvae) after 4 months when there were more than 200 larvae/kg dry weight of kernels (Figure 2). The number of *T. castaneum* larvae also increased during the storage period (Figure 3), although to a lesser extent than *C. serratus*. The

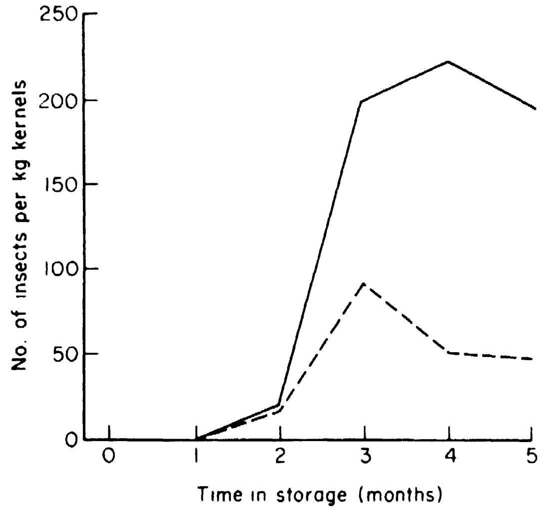

Figure 2. Mean number per kg dry weight of kernels of *C. serratus* (larvae and pupae). – – – = larvae; —— = pupae.

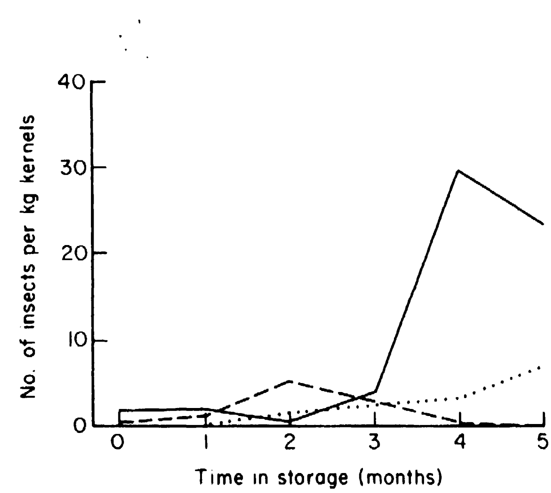

Figure 3. Mean number per kg dry weight of kernels of *T. castaneum* (– – –), *C. cephalonica* (——) and *T. mauritanicus* (· · · · ·) larvae.

other species present did not increase in numbers and, in fact, by the end of the experiment *C. cephalonica* appeared to have died out.

In July and August, large numbers of the lygaeid bug *Elasmolomus sordidus* F. were present on the surface of exposed sacks, and inside those sacks which were damaged. This bug pierces the pod with its mouthparts and feeds on the kernels (Conway 1976). It was not found in the samples because it dispersed rapidly from the sampling area when the sacks were emptied. No attempt was made to measure the effect of its feeding on the groundnuts.

As there was virtually no insect infestation when the pods were placed in store, the percentage of damaged pods in the initial samples (approximately 10%) indicates the level of pod damage caused by factors operating prior to storage (Figure 4). Although some sacks were sampled more than once during the experiment this did not, in itself, increase the portion of damaged pods in the samples. The increase in pod damage after 2 months in

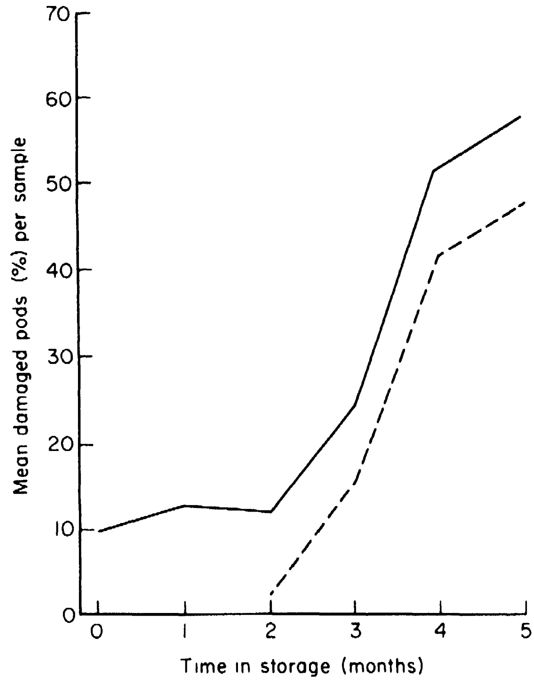

Figure 4. Mean percentage of damaged pods in samples. —— = total damaged; - - - = damaged by *C. serratus*.

storage was due to the marked rise in the number of pods bearing holes created by the emergence of bruchid larvae and adults. After 5 months, almost 50% of the pods in each sample were damaged by this pest. Only 1·4% of the pods contained insects of other species by this time.

No appreciable weight loss had been caused by insects when the sacks were placed in store (Figure 5). After 5 months in storage the mean loss, in dry weight of kernels, attributable to insect infestation, was approximately 20%. Comparison of the combined data for all the species present with that for *C. serratus* alone, indicates that almost all the weight loss was caused by *C. serratus*. The weight loss attributable to hidden infestation increased from 0·7% at the 2-month sampling to 1·6% after 5 months. Feeding by young bruchid larvae was responsible for almost all of the hidden loss.

The standard errors of the mean percentage weight loss increased, as would be expected, in response to the increase in percentage damage in successive months (Table 1). The coefficients of variation decreased steadily, however, indicating that variation in the amount of weight loss between samples taken on any particular sampling date decreased, despite the reduction in sample size. It is possible that, as the experiment progressed, the population density of *C. serratus* became such that in some bags reproductive performance had peaked and had begun to decline, whereas in other bags it was still increasing, thereby reducing the variation in weight loss between samples. The repeated disturbance of the stack may also have helped to promote a more even distribution of insects among the bags as the experiment progressed.

There is no evidence that the position of a bag within the stack influenced the level of infestation by *C. serratus*. However, this may be due to the small stack size. The small

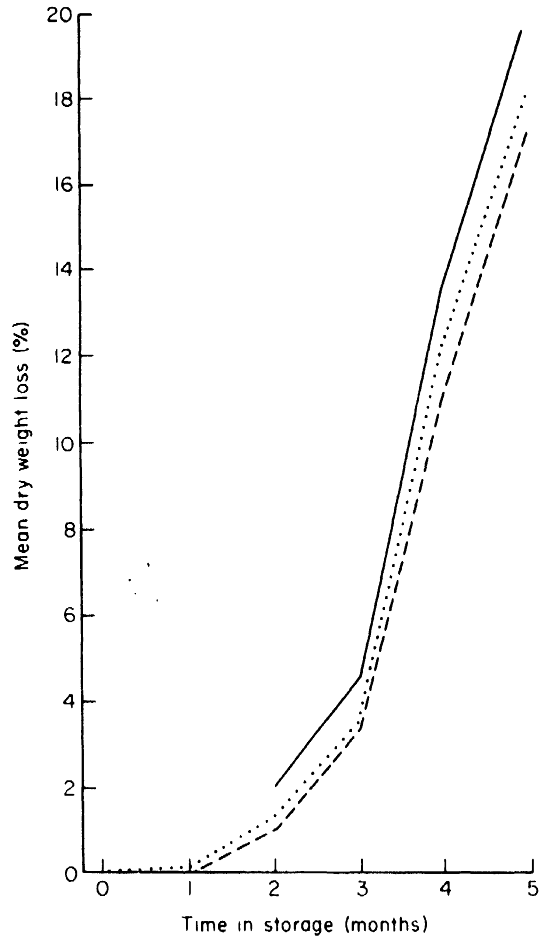

Figure 5. Mean percentage dry weight loss of kernels in samples, as a result of insect infestation. - - - = total loss (visible and hidden); · · · = visible loss (all species); —— = visible loss (*Caryedon*).

number of bags containing JL 24 prevented any valid comparison of weight loss suffered by the two varieties present in the experimental sacks and, therefore, the possibility that the insects responded differently to these cultivars could not be investigated.

Discussion

Insect populations

The groundnut bruchid, *C. serratus*, is the only insect species known to infest kernels inside intact pods, and is thus potentially the most important pest of unshelled groundnut. Reports of this insect causing serious damage to groundnuts have been confined to West Africa (Green 1959, Conway 1973, Pointel, Deuse & Hernandez 1979). *C. serratus* occurs throughout the semi-arid tropics, breeding on the seeds of common tree legumes such as *Tamarindus indica, Cassia* and *Acacia* species, as well as on groundnut (Davey 1958). There are, however, no detailed reports of *C. serratus* causing losses to groundnut in India, despite the ubiquity of its primary host genera throughout most of the country, including

Table 1. Mean sample size and mean percentage dry weight loss with coefficients of variation (CV%)

Sampling date	Mean dry weight of kernels (g) ±SE	Mean dry weight loss (%) ±SE	CV of transformed mean (%)
July (9.7.1985)	408·4 ±28·45	0·07 (1·27±0·250)	20·8
August (6.8.1985)	462·5 ±36·55	0·21 (2·35±0·383)	17·2
September (10.9.1985)	361·7 ±9·92	1·34 (6·14±0·863)	14·8
October (8.10.1985)	320·8 ±16·67	3·57 (10·21±1·293)	13·3
November (5.11.1985)	219·5 ±10·17	12·17 (19·55±2·170)	11·7
December (6.12.1985)	111·5 ±12·61	18·07 (24·56±2·062)	8·8

Values in parentheses represent arc sine transformation.

Andhra Pradesh. The results of this study indicate that this species is a more important pest, at least in Andhra Pradesh, than has hitherto been recognized.

Infestation of groundnuts by *C. serratus* may begin while the crop is drying in the field (Conway 1983), or when it is stored near infested stocks or crop residues (Green 1959). The source of the infestation in this study is unknown. Although no evidence of bruchid infestation was found in the samples until the groundnuts had been stored for 2 months, it remains possible that a small number of kernels were already infested when the groundnuts were placed in store. Alternatively, the experimental stack may have become infested after construction, either by cross infestation from other stocks in the warehouse or by *C. serratus* flying into the warehouse from outside. There was, however, no indication that the bruchid population was higher in the bags on the outside of the stack when the first evidence of infestation was found.

The bruchid population began to decline after 4–5 months in storage, even though only 40% of the pods had bruchid emergence holes at this stage. This suggests that factors other than intra-specific competition for food contributed to the decline in bruchid numbers. The most significant of these appeared to be migration of final instar larvae from the bags before pupation. As a result of this movement, large numbers of cocoons were formed on the under surface of the bags at the bottom of the stack. Conway (1983) reported that bruchid larvae pupated at the bottom of open-air bulk stores in the Gambia. The nuts at the base of the heap were invariably heavily damaged by further generations of the insect. These results contradict earlier findings which suggested that infestation by *C. serratus* is largely confined to the surface layers of a bulk or stack of groundnuts (Green 1959), and have important implications for the chemical control of this pest.

After 4 months, large numbers of the reduviid, *Amphibolus venator* Klug, were present in the sacks, although this insect was too mobile to be collected in the samples. Under laboratory conditions the bug readily attacked final instar *C. serratus* larvae when they left infested kernels to pupate. Predation by *A. venator* may also have reduced survival of bruchid larvae in the experimental sacks.

T. castaneum, O. mercator, T. mauritanicus and *C. cephalonica* have all been recorded on stored groundnut in India (Srivastava 1970). These species are regarded as 'secondary' pests of unshelled groundnuts because they are unable to penetrate intact pods. Although the numbers of *T. castaneum* did increase, the populations of the other secondary pests failed to develop over the 5-month storage period, despite the increasing number of damaged pods and kernels in the sacks.

Prevett (1964) recorded a similar phenomenon in a study of insect infestation of bagged groundnut kernels in Nigeria. He attributed the elimination of *O. mercator* and *C. cephalonica* populations, after several months, to the development of adverse environmental conditions within the stack. In the present study, climatic conditions throughout the storage period appeared favourable for the development of post-harvest insect pests (the mean daily temperature and humidity ranged from 24°C to 38°C and 60% to 70% RH). However, the percentage moisture content of the seeds declined steadily from 7·0% in July to 4·1% in December. This suggests that the temperature within the stack was higher than the ambient temperature. Temperatures within a stack of this size can be up to 10°C higher than the air temperature within the warehouse (Smith 1963). As *T. casteneum* has a higher optimum temperature for development than *O. mercator* and *C. cephalonica* (TDRI 1984) it may have been able to survive in conditions unsuitable for these other species.

Alternatively, interaction among the different insect populations may have caused the suppression of some of the species present. Although *C. serratus* was by far the most numerous species the possibility that it suppressed the other insect populations seems unlikely because bruchids exploit suitable food resources in a different manner from these species (Feakin 1973). However, laboratory studies have shown that *T. castaneum* larvae and adults will feed on the eggs and pupae of *Oryzaephilus surinamensis* and *C. cephalonica* when these species are confined together on different food media (Crombie 1943, Le Cato 1975, Parshad 1976). *T. castaneum* also reduced the numbers of *C. cephalonica* infesting a stack of bagged kernels (Smith 1963). Thus the population of *T. castaneum* may have increased at the expense of other species.

Weight loss assessment

In assessing losses caused by insects to stored produce, a variety of devices are commonly used in obtaining representative samples (Golob 1976) and in their subsequent laboratory analysis (Adams & Schulten 1978). In the absence of such equipment, the methods used in this study were considered the most appropriate.

The 'count and weigh' method of estimating weight loss has one advantage over alternative methods in that it allows damage by different species to be recorded independently. With unshelled groundnut this can be done with a high degree of accuracy because each pod forms a unit which can be examined individually. This allows the exact number of seeds damaged by each species to be recorded, even when seeds are almost totally destroyed, a situation which would result in inaccuracies when dealing with other commodities.

With this method, in common with all similar procedures, some degree of underestimation is caused by the presence of 'hidden' infestation. This is a particular problem when, as with *C. serratus*, the entry hole made by the first instar larvae is virtually invisible to the naked eye. Estimates of loss resulting from hidden infestation can be made (as above), but a completely accurate picture can only be obtained by dissecting large numbers of seeds.

The 'count and weigh' method also assumes that the mean weight of damaged and undamaged 'grains' were identical initially. However, *C. serratus* larvae are commonly found infesting seeds of greater than average size (Dick, unpublished data). This suggests that, in common with certain other bruchid species, *C. serratus* females select large seeds (or pods) for oviposition (Avidov, Berlinger & Applebaum 1965, Mitchell 1975). Because of this, in estimating the weight loss attributable to hidden infestation, the mean of the average weight of damaged and undamaged seed had to be used rather than a figure obtained by direct measurement. De Lima (1979) used a similar method to estimate losses caused by the larvae of insects attacking stored maize. In the initial calculation of 'visible' loss, however, it is impossible to correct this for bias. Some degree of underestimation is therefore inevitable and as a consequence the values obtained from a few samples, taken at the beginning of the study, showed an apparent gain in weight as a result of infestation.

Despite these limitations, the overall methodology adopted in this study can be recommended for a number of reasons. No specific equipment is required either for analysis or for sampling and the method is not labour intensive. In addition, the 'count and weigh' method of estimating weight loss is particularly suited to work on unshelled groundnut, providing accurate information on the losses caused by individual species.

As storage loss estimates are highly location and season specific it is not possible to extrapolate from these results to provide national or even regional estimates of post-harvest losses to groundnut in India. More survey data, obtained using the techniques described here, are necessary to ascertain the distribution and pest status of *C. serratus* in other groundnut producing areas in Asia.

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