INVESTIGATIONS INTO THE ORIGIN, DEVELOPMENT AND CONTROL OF CARYEDON SERRATUS (COL. BRUCHIDAE) ATTACKING STORED GROUNDNUTS IN THE GAMBIA.

J. A. CONWAY
Stored Products Entomologist
Crop Protection Unit, Dept. of Agriculture
Yundun Experimental Station
Western Division
THE GAMBIA

ABSTRACT: *Caryedon serratus* Olivier (Col.: Bruchidae) is a pest of major significance to the groundnut industry and hence to the Gambian economy. Heavy attack takes place in two forms of storage, seed nuts in bag and trade nuts in bulk. Previous control work had been aimed at protecting nuts in storage against *C. serratus* attack.

The work described established that nuts coming into storage were invariably already infested in the field and the scale and distribution of this initial infestation was determined for all areas. A sequence of primary host species supporting *C. serratus* throughout the year was identified and the possibilities of suppressing *C. serratus* populations via the primary hosts in groundnut growing areas was examined. This work is continuing.

The development of *C. serratus* populations in seed and bulk stores was studied with the areas of heaviest insect attack in large bulks of nuts being shown to be at variance with previous laboratory findings. Migration of fourth instar larvae in both bag and bulk stores was found to be a common phenomenon with nuts in the vicinity of suitable pupation surfaces suffering heavy attack.

Elimination of the intake infestation by fumigation using phosphine or methyl bromide was shown to be the ideal as the need for residual insecticides is obviated. This is now the standard technique for all seed on agricultural stations and commercial farms and the entire confectionery groundnut production.

Where fumigation was not possible a range of insecticides was evaluated together with alternative application techniques for bag and bulk storage. A crude admixture of malathion at 10 p.p.m. gave very good control of *C. serratus* in large bulks for 16 weeks at a cost of 40 bututs per metric ton treated. Pirimiphosmethyl, lindane, phoxim, and iodofenphos were inferior to malathion at the same rate. Malathion at 20 p.p.m. gave excellent control of *C. serratus* in bagged seed nuts at a cost of 6 bututs per 57 Kg. bag.

INTRODUCTION: The economic structure of The Gambia hinges on the profitability of the country's groundnut crop on world markets. In 1954 a detailed investigation into the extent of damage to the crop during storage caused by the groundnut seed beetle, *Caryedon serratus* Olivier (Col. Bruchidae) produced an estimate of 5% damage resulting in a weight loss of 3% [1]. In the 1973/74 season a record crop of

137,000 tonnes was purchased but 1.43% of this, worth 1,109,460 Dalasis ($653,800) was lost due to *C. serratus* attack (Fig. 1).

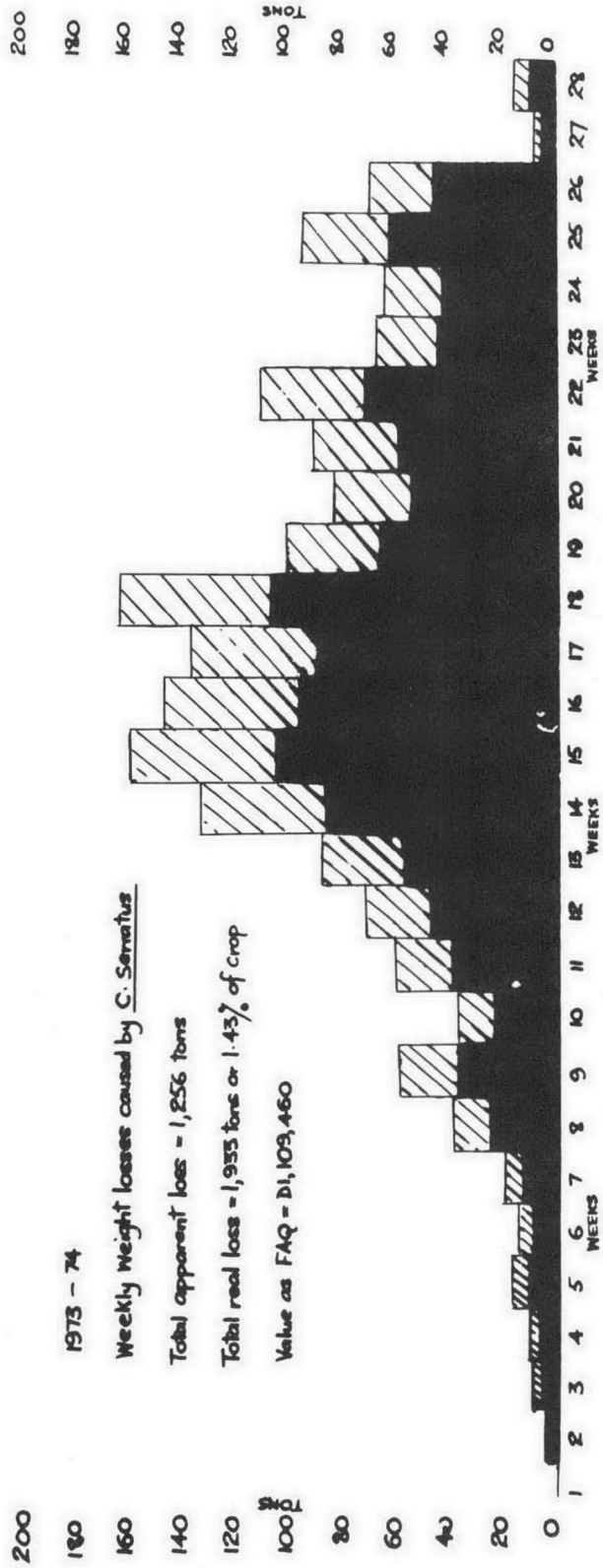

FIGURE 1. Weekly Weight Losses in Gambian Groundnut Crop Caused By *Caryedon serratus* - 1973/74 Season

Considerable losses during storage of groundnut seed have traditionally occurred and a survey of 50 village seed stores in 1974 showed that damage levels of 100% in farmers' seed stores were not uncommon where the Department of Agriculture's recommendations were not being followed.

Prior to 1971 a control programme for *C. serratus* based on lindane had been in operation both for trade nuts stored in bulk in the open and bagged seed nuts in village seed stores [2]. This programme was aimed at protecting nuts from *C. serratus* attack which was considered to take place initially within the storage system [3] [4].

Dissatisfaction with the level of control being achieved led to suggestions of insecticidal resistance and work on Gambian *C. serratus* in England demonstrated a low resistance factor but doubts were expressed as to the significance of this factor at field level.

The author was engaged on loan from the Ministry of Agriculture, Fisheries and Food, U. K., to investigate the *C. serratus* position in all sectors of the groundnut trade and to suggest alternative control methods if necessary.

ORIGIN OF INFESTATION: Groundnuts - In Northern Nigeria *C. serratus* was recorded in 1941 laying eggs on groundnuts being sun-dried in the field [5]. Workers in Senegal [4] and The Gambia [3] in the 1950's, however, concluded that initial infestation took place within the storage system.

Investigations carried out in 1970/71 at four bulk stores and four village seed stores in different parts of The Gambia showed that at all bulk stores nuts submitted for sale by farmers were already infested by *C. serratus* at the beginning of the buying season in December. The level of this initial infestation was in the range of 0.2% of nuts attacked to 4% during the eleven week buying period. At village seed stores 81% of 187 bags selected at random from seed brought in by farmers in late December were already infested. The mean level of this infestation was 0.87% of nuts attacked.

In order to explore the situation further a 500 sq. km. area of a groundnut growing district was surveyed immediately prior to the start of the 1971/72 storage season. All storage premises in the area were inspected for viable *C. serratus* infestation and in 12 trader's stores, 15 village seed stores, 2 mixed farming centres and 160 village food stores only two living *C. serratus* adults were found. At the same time a series of samples was taken in the area from nuts drying in windrows and stacks in farmers' fields. 37% of the windrow samples and 44% of the stack samples were infested to some degree with *C. serratus*.

Sampling at 45 points throughout the country from farmers' fields showed that unlifted nuts were very occasionally attacked but 21% of samples from windrows and 40% of samples from stacks were infested. The level of this initial infestation was normally in the range of 0.1% - 2.0% of pods attacked but one figure of

27.4% was recorded.

Primary hosts - Records of host plants of *Caryedon serratus*, (*Caryedon gonagra* and synonyms) are summarized by Davey [6]. *Tamarindus indica* Linn. is recorded as the principal host plant in Senegal [7] and Prevett [8] adds *Piliostigma reticulatum* DC and *Piliostigma thonningii* Schum for Northern Nigeria. All three species occur in the Guinea savanna flora of The Gambia.

Fruits from a wide range of Mimosaceae and Caesalpiniaceae were collected, examined and cultured in fibre-glass pollination bags. A short list of the following possible primary host species was then compiled:-

Acacia albida
Acacia senegal
Parkia biglobosa
Prosopis africana
Cassia sieberiana
Tamarindus indica
Piliostigma thonningii
Piliostigma reticulatum

Sampling of the fruits from the listed species in various parts of the country was carried out for a complete year at monthly intervals. Samples were cultured for six weeks. Then records of *C. serratus* emergence were made. Both *Acacia* species and *Parkia biglobosa* were eliminated as primary hosts leaving the annual sequence of infestation of the remaining species as shown (Table I).

TABLE I. Annual sequence of primary host infestation by *C. serratus* in The Gambia.

Primary Host	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Piliostigma thonningii	+	++	++	++	++	++	+	+	+	++	+	
Piliostigma reticulatum	+	++	++	++	++	++	+	+	+	++	++	+
Tamarindus indica	++	++	++	++	++	++	+	+	+	+	+	++
Cassia sieberiana	++	++	++	+	+	+					+	+
Prosopis africana	+					+					+	+

\+ Infrequently and lightly attacked
++ Consistently and heavily attacked

It was concluded that, because of the ubiquitous

distribution of the species, *Piliostigma thonningii* was the most important primary host of *C. serratus* in The Gambia.

As the point at issue was to determine the source of the *C. serratus* attack on newly-harvested groundnuts in November the possibility of a population emerging from a resting stage had to be considered.

Observations on hibernation of *C. serratus* in Pakistan and Japan have been recorded [9] [10] and Donahaye [11] describes winter hibernation of the species in Israel.

Routine soil sampling and light trapping in bush known to have supported *C. serratus* was carried out during the rainy season prior to the groundnut harvest. No *C. serratus* specimens were taken. Laboratory work established that larvae emerging from field-infested fruit pods always pupated in the top 2 cms. of the surface litter. When soil cultures were kept completely dry some 10% of pupal cases contained living non-emerged adults after 16 weeks. When cultures were soaked weekly in an attempted simulation of wet season conditions all adults emerged within 20 days of pupation thus indicating that whereas *C. serratus* may be equipped to withstand adversely dry conditions by entering a resting stage in the pupal case the species is not equipped to withstand adversely wet conditions. The surface litter in the bush is waterlogged many times during the rainy season therefore a resting stage during this period seems improbable.

The conclusion appeared to be that the remaining fruit pods of the primary host species constituted the sole source of *C. serratus* attacking harvested groundnuts. Due to the localised nature of *T. indica* and the relative rarity of mature fruits of *P. thonningii* prior to the groundnut harvest the possibility of depressing *C. serratus* numbers at the primary host stage is being pursued.

Relative rates of development of *C. serratus* on host fruits are shown (Table II).

TABLE II. Summary of Adult *C. serratus* Emergence

	Number of weeks from egg-laying date										
Host Species	6	7	8	9	10	11	12	13	14	15	16
T. indica	2	-	-	9	16	10	7	14	3	1	2
P. thon/retic.	-	-	1	4	19	21	5	1	2	3	-
C. sieberiana	-	-	-	-	3	9	11	7	5	2	-
*P. africana**											
Arachis hypogea	-	-	3	20	30	100	123	97	69	43	24

* No emergence - all larvae failed to develop beyond first instar

DEVELOPMENT OF C. SERRATUS IN STORED GROUNDNUTS: Trade nut storage - Field work had shown that initial attack on groundnuts takes place from the first day of harvest throughout the drying period when the nuts are exposed in the fields.

At commercial trade nut stores all nuts purchased from farmers are bulked together in outdoor heaps varying in size from 200 - 2,000 tons. *C. serratus* infestation is distributed heterogenously throughout the heaps and adults will emerge over a period dependent upon the date of the initial egg-laying in the fields and the effects of the microclimate within the bulk of nuts.

Previous workers had stated that *C. serratus* adults emerging within a bulk of nuts must travel to the surface to mate and lay eggs and thereafter activity and damage was confined to the surface layers [2] and [6]. The previous control technique of surface insecticidal dusting had been based on these observations. However, it had also been stated that *C. serratus* could live up to 50 cms. below the surface of a groundnut heap [12] and commercial experience in The Gambia indicated that nuts removed from stores late in the season, and representing the lower layers of the heaps, were traditionally more heavily damaged than those from the rest of the bulk.

Twenty-four ten kg. samples of fumigated nuts in mesh bags were installed at various points during the build-up of heaps at four stores. These were removed and analysed progressively as the heaps were broken down. Results indicated that damage at the bottom of the heaps was more severe than either at the surface or the central store. In the following season this picture was confirmed with a more intensive placement of samples at one secco. It was also found that the sides of heaps where these were held by retaining walls were more heavily attacked than the surface (Fig. 2).

Sieving of nuts from various parts of heaps revealed considerable numbers of free-living fourth instar larvae which had emerged from nuts via a 1 - 1.5 mm. hole. This is the invariable form of *C. serratus* emerging from the primary host fruits but adult emergence from a 2 - 3 mm. hole has hitherto been recorded as the norm in stored groundnuts. That larval migration in groundnut heaps is a significant factor was shown by observations when heaps were broken down. The basal layers of heaps at ground level were often matted together with pupal cases as were the areas adjacent to retaining walls. As nuts in these areas were always very heavily attacked it was obvious that adults emerging from these concentrations of pupal cases were quite capable of mating and laying eggs on nuts in the immediate vicinity. Pupation in the surface layers can be expected to be adversely influenced by the extremes of temperature and relative humidities to which these areas are subjected and also by the effects of bird predation.

Sticky trapping on the surface of heaps throughout a storage season showed that a considerable amount of adult activity takes place here but because of high daylight temperatures this activity is restricted to the hours of darkness and a short period before and after dusk and dawn respectively.

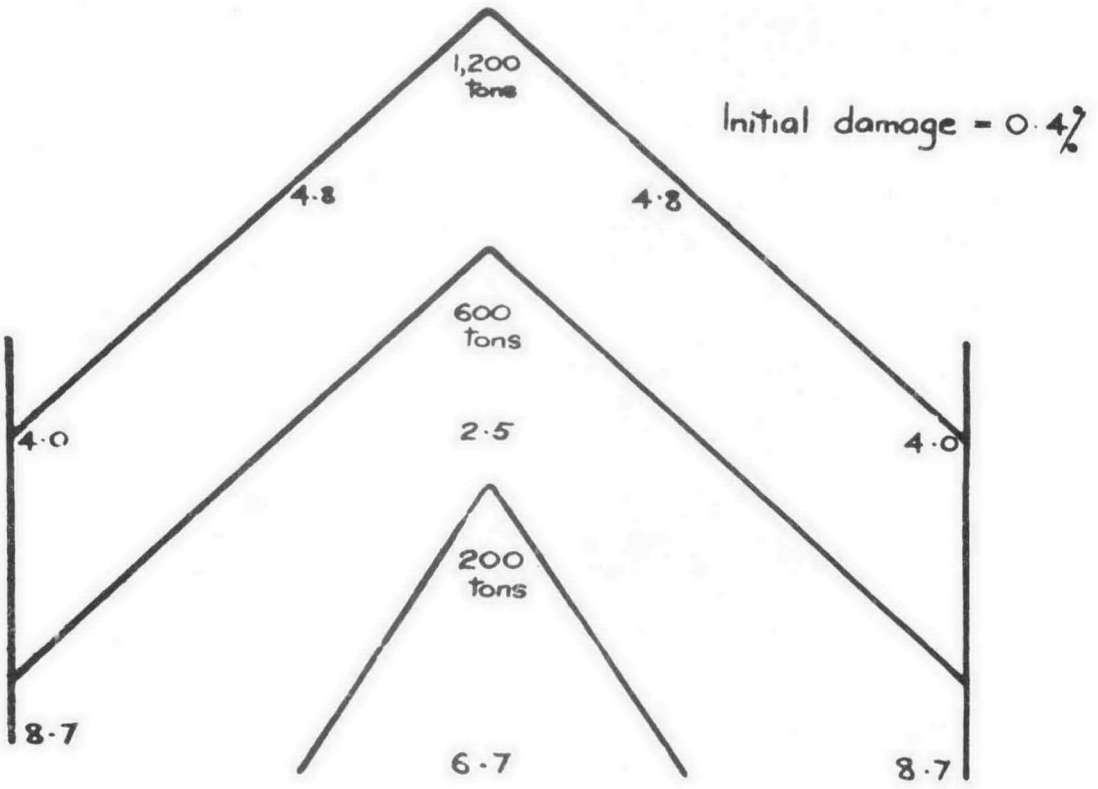

FIGURE 2. Diagrammatic representation of development of *Caryedon* serratus in bulk groundnuts - figures represent percentage damage by zones.

Fumigated samples with newly-emerged *C. serratus* adults added were placed in various positions in heaps in commercial stores and egg-adult periods plotted weekly. Adult emergence took place from 8 - 13 weeks after egg laying with a peak at 9 - 10 weeks. For many commercial stores this will mean 3 - 4 generations of progressively increasing *C. serratus* infestation before the last nuts are sold for processing. Damage levels during this period have been shown to rise from 0.2% for early deliveries to 83% for the last consignments.

Seed nut storage - Preliminary surveys of *C. serratus* damage to bagged seed in village seed stores at the end of a storage season had shown wide variations in damage levels between bags in the same store. This could now be explained by the findings of extensive infestation taking place in the field during the sun-drying process. This infestation varied in intensity from locality to locality and was influenced by the length of time the seed nuts had been exposed. In a village seed store the seed brought in by farmers is labelled and remains the property of the individual thus the level of the intake infestation is reflected in the subsequent insect development within each bag. The walls of a jute bag considerably impede the movement of *C. serratus* in both directions.

Emergence of *C. serratus* adults from a 30 ton stack of

seed was plotted at two-weekly intervals at a typical village seed store (Fig. 3). As culturing studies showed that the egg-adult period in seed stores was virtually identical to that in large bulks of nuts, i.e. a peak of 9-10 weeks, the count at week 16 represents the emergence of F3 adults.

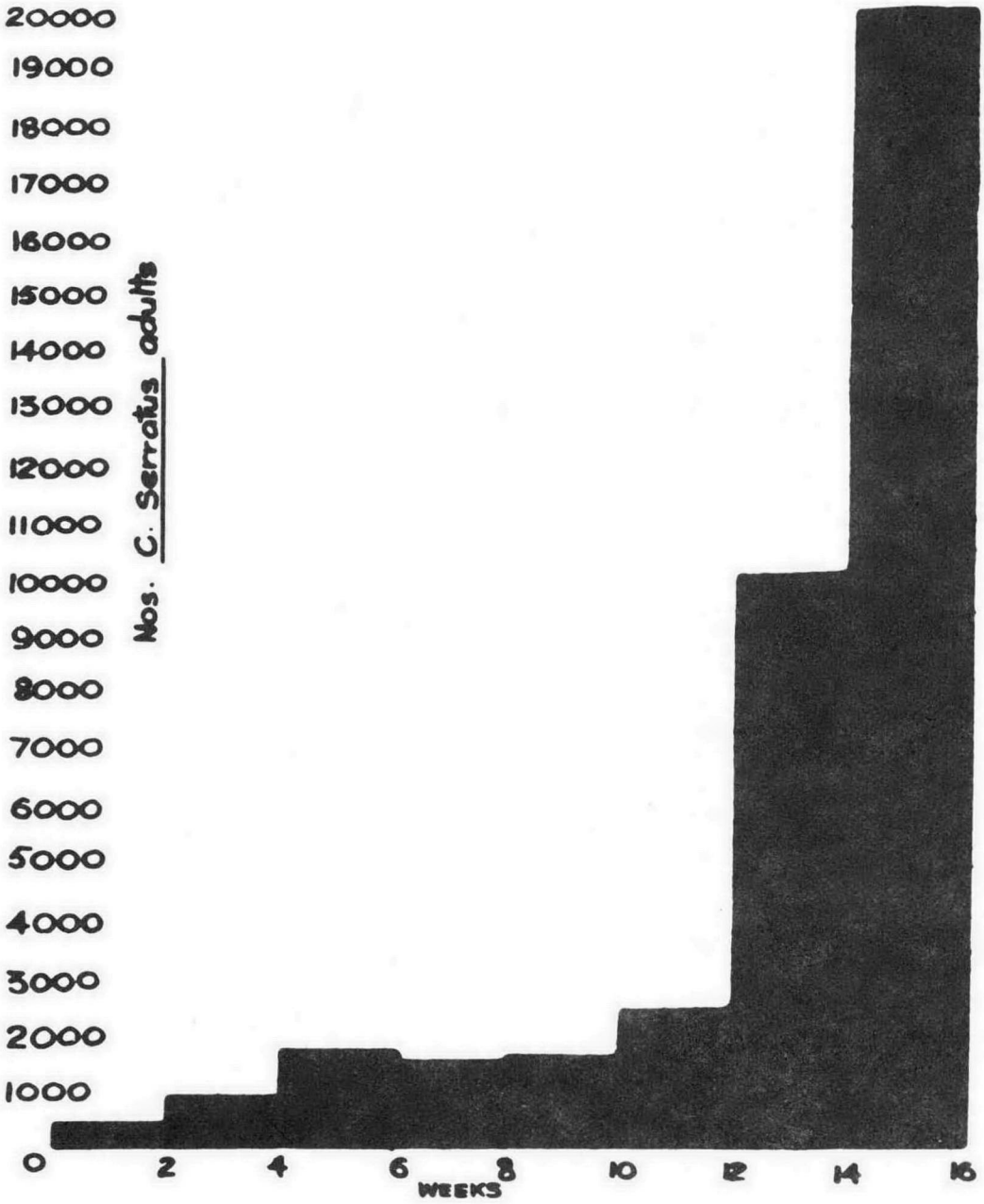

FIGURE 3. Emergence of *Caryedon serratus* adults from bagged groundnut seed in a typical village seed store

Trapping trials showed that surface activity on the stack was negligible whereas many adults were trapped in the lower layers.

As in the bulk studies migrating mature larvae were common and 45% of insects trapped leaving the stack were larvae. These larvae pupated in large numbers around the wall/floor angles of the store. Damage levels on 16 untreated bags of nuts rose from a 0.78% average on intake to 43% at the end of the 16 week period.

CONTROL INVESTIGATIONS: Trade nuts - As previously stated, a control programme based on lindane had been operating for some 12 years prior to 1971. For trade nuts in bulk the official recommendation was a surface dusting with 0.5% lindane at 45gms/m^2 at fortnightly intervals. In later years the frequency was increased to twice weekly at the same rate. Where the treatment was properly carried out this resulted in an insecticidal deposit for the storage season of some 5 p.p.m. at a cost in 1971 of D.0.66 ($0.38) per tonne stored. It should be borne in mind that as nuts are added to and taken from a typical storage bulk throughout the season the surface being treated will be constantly changing at one or more points over the surface area of the heap.

1970/71 trials - In an attempt to assess the effectiveness of the official control recommendations, staff of the Crop Protection Unit of the Department of Agriculture were based at four traders' stores in 1971. 0.5% lindane was applied by the staff in the recommended manner at two stores and 1% malathion was applied at the same rate as a comparison at two stores. Twice-weekly sampling over the heap surface was carried out throughout the season with damage analysis carried out in the laboratory. Comparative samples were taken from six stores where no control over the lindane treatment was exercised.

Results indicated that the level of *C. serratus* control achieved was no higher at our controlled stores where lindane was applied than at the stores where the normal level of application efficiency was operating. Malathion application did not give noticeably better results than lindane. Damage levels at our controlled stores rose from near zero at the beginning of the season to 26% after 20 weeks.

1971/72 trials - The surface dusting technique was based largely on the theory of a surface emergence of *C. serratus* adults. Observations on *C. serratus* behaviour in large heaps of nuts had indicated that surface emergence formed only a part of a more widespread movement of insects. This suggested that a form of insecticidal admixture might be a more effective control approach.

0.5% lindane and 2% malathion were applied giving a deposit of 10 p.p.m. at two stores for each treatment. Both insecticides were added to groundnuts being tipped on the storage heap. Damage evaluation was carried out by twice weekly sampling and comparisons were again made with stores where normal lindane treatments were being carried out.

Although *C. serratus* intake levels were similar to the previous year both lindane and malathion admixture gave superior results in suppressing damage levels than surface dusting. Again, malathion was better than lindane but by a small margin. The costs

of this form of treatment, in materials, were D.1.32 ($0.77) per tonne of nuts treated with lindane and D.0.45 ($0.26) for malathion. Although the levels of control being achieved left much to be desired it was felt that there were sufficient technical and economic factors to justify a change to malathion admixture as an alternative control method.

1972/73 trials - 2% malathion was added by volumetric measure at 10 p.p.m. to each bag of nuts after screening and before tipping on the heap at one store. Damage evaluation was carried out as in previous years and results at this store for the preceding two years of CPU - controlled lindane surface dusting and lindane partial admixture could be compared.

For the first time, damage levels over the 12 week storage period did not rise above the average intake damage level of 0.3%. Also for the first time the trader operating the store had no nuts rejected as substandard for insect damage by the Gambia Produce Marketing Board. Weight losses at the store for the season were 0.1% compared to the average for this store of 1 - 2%. Improved malathion admixture at a cost of D.0.45 ($0.26) per tonne was recommended as the official control measure for the trade.

1973/74 - Because of a large stock of lindane already in the country, malathion was purchased for the treatment of all nuts stored in the western half of The Gambia and lindane was used in the eastern half. As these two sectors have their own G.P.M.S. transit stations through which all nuts must pass and as all nuts are examined for insect damage on intake by G.P.M.B. produce inspectors a comparison of inspection results can be made.

At Kaur in the east where lindane was used, 12,654 tonnes or 24% of the intake was classified as substandard i.e. insect damage in excess of 5%. At Denton Bridge, in the west, 1,057 tonnes or 1.37% of the intake was declared substandard.

In collaboration with the Tropical Stored Products Centre, Slough, England, a comparison of the new official recommendation with three alternative organophosphorous materials was carried out. Four, one hundred ton heaps of unshelled groundnuts were treated and stored for 18 weeks at the CPS. The materials, all applied by measure to each bag at 10 p.p.m., were:- malathion, pirimiphos-methyl, phoxim and iodofenphos. At the beginning and end of the trial the square root of the number of bags forming each heap was taken and chosen bags removed systematically for sampling and damage evaluation. Intake infestation of *C. serratus* was shown to be equally distributed throughout the four heaps.

Damage levels for the four heaps at the end of 18 weeks of storage were as follows: -

Malathion	4.16%
Pirimiphos-methyl	19.40%
Phoxim	11.60%
Iodofenphos	18.12%

Seed nuts - The previous control programme had been based on an admixture of 0.5% lindane at 16 p.p.m. Incoming nuts were tipped onto a mixing platform outside each village store where lindane

was added and mixed, then nuts were re-bagged, labelled and stored for 16-20 weeks. The cost of this treatment, in materials, in 1971 was D.2.08 ($1.22) per tonne treated.

1970/71 trials - Farmers' nuts were taken at random on intake at one village seed store and treated at 15, 20, and 25 p.p.m. with lindane, malathion, iodofenphos, carbaryl, and pirimiphos-methyl. Insect damage levels were recorded at time of treatment and again after 18 weeks. Results are shown in Table III.

TABLE III. Summary of comparative treatments for control of *C. serratus* in a village seed store

Material	PPM Rate	Potential* Damage % 1.1.71	Potential Damage % 1.5.71	Residue Shell PPM	Residue Kernel PPM
Lindane	15	0.3	15.6	2.28	0.52
	20	1.1	38.7	2.38	0.65
	25	0.8	21.3	2.76	0.80
Malathion	15	1.1	4.7	3.56	0.61
	20	0.6	2.9	3.80	0.11
	25	0.6	4.2	5.88	0.53
Iodofenphos	15	0.3	2.6	3.44	0.12
	20	0.7	6.6	3.85	0.16
	25	0.4	2.5	4.52	0.25
Carbaryl	15	0.7	1.0	Figures not available	
	20	1.1	5.5		
	25	1.4	1.0		
Pirimiphos-Methyl	15	0.7	3.1	0.84	0.07
	20	0.5	1.0	1.80	0.11
	25	0.6	2.5	2.22	0.21
Controls	-	0.7	43	-	-

* Potential damage is the sum of damage already occurred plus hidden larvae and pupae

Lindane performed badly in comparison with all the other materials, none of which was noticeably superior to the others.

At two further stores an attempt was made to determine the importance of re-infestation by *C. serratus* following effective elimination of the intake infestation. Stocks of bagged seed nuts were fumigated under gas-proof sheets with aluminium phosphide tablets at 10 tablets/tonne. Floor counts were made at fortnightly intervals throughout the storage period and supported by sticky trap counts on stack and walls. Reinfestation from outside the store was shown to be no problem with the final damage levels at both stores unchanged from those on intake. It was obvious that

rapid, effective control of the endemic, intake infestation of *C. serratus* could be the sole objective of control methods in seed stores and that lengthy protection was unnecessary.

1971/72 trials - Fumigation of seed under sheets at 450 village seed stores was not a feasible proposition but fumigation remained an attractive means of control. As seed stores were of fairly robust construction an attempt was made to see whether they could be cheaply improved to retain enough phosphine to act as fumigation chambers. Using cement and plastic tape one typical store was sealed at all obvious gaps, the operation taking four man-days.

Two successive fumigations were carried out using aluminium phosphide tablets at a rate of 50/30m^3. Infested samples of nuts were suspended from roof trusses, and buried in a six tonne stack of nuts. Culturing of the samples after a seven day exposure period revealed that the treatments were surprisingly effective with very few survivals. It was concluded that existing seed stores could be simply modified to allow effective 'in-situ' fumigation of groundnut seed. The cost of such treatment would be D.1,00 ($0.58) for fumigant per tonne.

Fumigation under gas-proof sheets using both phosphine and methyl bromide was established both for the Department of Agriculture's Seed Multiplication Scheme and the first commercial purchases of confectionery grade groundnuts by the G.P.M.B. All stocks are fumigated at the first storage point as soon as possible after harvest and to date no failures or re-infestations have been reported. Using phosphine the cost has been reduced to D.0. 42 ($0.24) per tonne.

At four seed stores lindane and malathion were directly compared at 20 p.p.m. and whereas lindane gave much better control than in the 1970/71 work malathion was still markedly superior at half the cost. Malathion was recommended at 20 p.p.m. as a replacement for lindane.

1972-73 - 2% malathion was issued to all seed stores in Western Division. Bags treated by farmers were sampled at random by CPU staff at 20 stores both at time of treatment and at the end of the season. Complete control of the intake infestation was achieved at a cost of D.0. 96 ($0.56) per tonne of nuts treated.

1973/74 - Excellent results were obtained with malathion being issued to all seed stores in the country. The use of prepacked material was pursued in order to attempt to eliminate dosage irregularities.

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