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INTRODUCTION

The importance of coconut to the Philippines is reflected by the number of people that depend on the coconut industry for their livelihood. Approximately 35% of the Filipinos depend directly or indirectly on coconut production (Woodroof, 1979). There are about 500,000 farm holdings in the country with sizes ranging from less than 1 ha to over 50 ha (PCARRD, 1980). Owner/tenant-operated farms under 3 ha account for about 40%, farms 3–30 ha for about 30%, while less than 1% of the farms are 50 ha or larger. Among the coconut-producing countries in the world, the Philippines is the premier coconut-growing country and has been the leading exporter of coconut products. Between 1980 and 1984, the coconut industry was the second biggest dollar earner (Ignacio, 1983; 1985) and contributed US $570 million in 1982 and US$727 million in 1984 to the national income.

Coconut plantings over the years reflect the importance of the coconut crop. The number of plantings grew at the rate of about 53% during the period 1963–1973, 44% during 1973–1979, and the average annual increase was 1.2% during 1979–1983 (Abestilla, 1984). Of the 12.1 million ha utilized for agriculture in 1982, about 3.2 million ha were planted to coconut (Ignacio, 1983). It was also about 3.2 million in 1983 when 411.34 million palms were present, comprising 337.59 million bearing and 73.75 million non-bearing palms. The number of palms planted vs. replanted also increased, but at a much lower rate.

In spite of the country's status as the world's leading producer of coconut, there is still much to be accomplished to improve the yields of Philippine palms. The average harvest was 40.4 nuts/palm/yr (range 32–49) during 1975–1984 (Ignacio, 1985). In some locations, however, average annual harvests ranged from 100–120 nuts/palm/yr (Woodroof, 1979). The low yields have been attributed to (1) the predominance of old plams being past peak productivity; (2) low-yielding native varieties; (3) poor soil; and (4) other factors. Among the other factors, rat damage is frequently regarded as having an adverse impact on coconut yields.

Rat damage has been an important factor limiting coconut production in at least some coconut groves in the country (Montenegro, 1962; Hoque 1973; Kurylas, 1974; Sultan, 1978; Reidinger and Libay, 1980; Gallego et al., 1981; Fiedler et al., 1982). Losses up to 40% or more of harvested nuts have been reported. Nut harvests in research plots subjected to rat control methods increased dramatically -- up to 280%. Thus, the importance of rodent pests affecting coconut cannot be ignored. Work on rat problems in coconut by the National Crop Protection Center (NCPC) (then the Rodent Research Center) began in 1972. As information from field studies became available, various control strategies were tested and developed. We present here an overview of these studies and those of others who identified the rodent pests involved, described the nature of their damage, and determined the biology and behavior of rodent pests in coconut. This research was very helpful in designing control trials that eventually led to current recommendations for reducing rat damage in coconut.

PEST SPECIES, THEIR BEHAVIOR AND DAMAGE

Small-mammal Species in Coconut Groves

Small mammals collected in coconut groves included *Rattus rattus mindanensis* Mearns, *R. exulans* Peale, *R. argentiventer* Robinson and Kloss, and *Suncus murinus*, an insectivore not known to be a pest in coconut. Of these species, *R. argentiventer* has been reported only from the islands of Mindoro and Mindanao (Barbehenn et al., 1973) where it was not found in the crowns of palms. This was probably due to its limited climbing ability (Fiedler et al., 1982).

Table 1 shows the species composition of small mammals trapped on the ground in coconut groves in several locations of the country. More than 60% of the small mammals trapped in Mindoro, Mindanao, and Luzon were *R. r. mindanensis.* About 11% of the species collected in Mindanao and Mindoro were *R. argentiventer;* about 20% were *R. exulans.* These results indicate that *R. r. mindanensis* is the most prevalent rodent occurring in coconut plantations in the Philippines. Their prevalence in the field, both on the ground and in the crowns, discussed later, and their ability to damage nuts (Sultan, 1978), leave little doubt as to their destructive potential.

Table 1. Small-mammal species trapped on the ground in the coconut groves in Mindoro, Mindanao, and Luzon islands. Source: (Gallego et al., 1981; Fiedler et al., 1982).

	Species composition (%)				
	Rattus rattus mindanensis	*Rattus exulans*	*Rattus argentiventer*	Other [a]	No. trap nights
Mindoro and Mindanao					
	49	14	17	20	300
	64	19	16	0	150
	55	22	9	15	150
	52	30	9	9	50
	71	19	10	0	50
	80	13	2	5	300
Mean	61.8	19.5	10.5	8.2	
Luzon					
	95	0	0	5	1,332
	74	3	0	23	62
	24	3	0	73	40
	38	20	0	42	1,050
	76	15	0	9	225
Mean	61.4	8.2	0	30.4	

[a]Mostly *Suncus murinus.*

Nature of Damage

Rats directly affect coconut yields by gnawing at developing nuts (Fig. 1). Rats have also been observed visiting the inflorescence, but adverse effects are not presently known. Gnawing can result in superficial damage or a penetrating hole found at the basal, lateral, or distal portion of the nut. Depending on the severity and location of the damage, nuts will fall as early as 3–5 days after initial damage.

Most (47%) fallen, damaged nuts were large, greater than 16 cm in diameter (Table 2). However, larger nuts close to harvest are not normally damaged. Less than 1% were button size less than 5 cm in diameter, 23% small (5–10 cm in diameter), and about 30% medium (11–16 cm in diameters). Laboratory tests in a free-choice situation in cages showed that *R. r. mindanensis* preferred button-size nuts, while *R. exulans* inflicted damage only to nuts of 6–10 cm in diameter (Sultan, 1978). However, damage to button-size nuts has not been commonly observed in the field. Gallego et al., (1981) found that 4 to 5 mo old nuts constituted 59% of the damaged nuts they collected, while 5.5 to 8 mo old and 1 to 3.5 mo old nuts made up only about 21% in each category.

About 67% of fallen nuts received basal, 25% lateral, and 8% distal damage (Table 2). Apparently, the basal portion of nuts is more accessible to rats than the lateral or distal portion; hence, the higher incidence of basal injury. The descriptions of nut damage are consistent with the fact that rats are opportunistic foragers, adjusting their preferences in part according to food availability. Their preference to a particular stage of nut development could be influenced by several factors such as the relative abundance of different growth stages, nutritional content, palatability, or taste.

Fig. 1. Damage in experimental plots ranged from 12–65% of harvestable nuts.

Rat damage in coconut has been argued as unimportant because of the capabilities of palms in some geographic regions to compensate for the rat damage. Compensation may occur in two ways: (1) by at least replacing damaged nuts, thus, reducing the impact of rat-damaged nuts with undamaged nuts by harvest time; or (2) by increasing the size and weight of copra in undamaged nuts, thus, lessening the impact of rat damaged nuts by increasing copra yields. A simulated rat damage study in Fiji Island showed that female flower production increased, that yield remained stable, and that palms could fully replace damaged nuts by about 50% at harvest time (Williams, 1974). The second possible compensation mechanism was studied in the Philippines. Results showed that compensation by increased copra content of undamaged nuts played only a minor part (Reidinger and Libay, 1981). The difference in weight of nuts from plots with heavy rat damage and plots that had no rat damage (plots receiving rat control) was less than 10%. Reidinger and Libay (1981) concluded that this difference was minimal when compared to the economic benefits derived from rat control.

Additional studies are required to further describe the extent and nature of rat damage to coconut. Until such information is available, it seems prudent to base economic benefits of rat control practices on increased nut harvests and use actual measurements of fallen, rat-damaged nuts as a relative index for monitoring the progress of any control operations.

Table 2. Number of fallen, damaged nuts by damage location and size. (Source: Hoque, 1973; Sultan, 1978.)

Damage location[a]	Size[b]					% of total no. nuts
	Button (<5 cm)	Small (5–10 cm)	Medium (11–16 cm)	Large (>16 cm)	Total no. nuts	
Basal	8	529	696	996	2,229	67
Lateral	3	173	274	397	847	25
Distal	1	74	25	164	264	8
Total	12	776	995	1,557	3,340	
% of total	0.4	23.2	29.8	46.6		

[a]Basal, lateral, and distal damage denotes damage near the peduncle, on the side, or at the terminal portion of the nut, respectively.

[b]Size classes are girth diameter measurements (cm) also designated as button, small, medium, and large.

Extent of Losses

To estimate losses, most investigators count fallen, damaged nuts. This number (or the percent of damaged nuts to total fallen nuts) traditionally have served as a relative index for assessing damage. We have used this index primarily because of convenience. Premature nut fall is readily assessible and usually visible so that data are easily collected. Changes in the damage index have reflected the effects from rat control activities and seasonal damage patterns.

Table 3 includes this damage index from several studies comparing nut damage and harvests before and after rat control. Losses ranged from 12.9% (Gallego et al., 1981) to as high as 65.6% (Sultan, 1978). The pretreatment nut loss per palm per month ranged from 0.16 to 1.30, or a mean of 0.63 nut/palm/mo. Nut damage during treatment was reduced to 0.02–0.34 nut/palm/mo, with an average of 0.14 nut. The increase in harvested nuts during treatment ranged from 14.8% to 190.0%, or a mean of 92.4%.

These results indicate that rats cause yield losses much greater than the number of damaged nuts found on the ground. Thus, Reidinger and Libay (1980) suggested that actual losses by rats may be generalized as much greater than presently realized and further suggested that assessment of losses due to rats should include not only fallen damaged nuts, but fallen, undamaged nuts as well. They observed that the number of fallen, undamaged nuts was also reduced when effective rat control was practiced.

Significant increases in yields after rat control was initiated were found in each study (Table 3). From pretreatment levels of 2.2–3.0 (average of 2.6) nuts/palm/mo, harvests increased to 3.1–6.7 (average of 4.9) nuts/palm/mo during treatment. This increase amounted to about 2.3 nuts/palm/mo in treated plots, and only 0.7 nut/palm/mo in the untreated reference plots. Nut harvests increased more than 50%, except when trunk-banding was used (Gallego et al., 1981).

Economic benefits from control procedures and the value of losses from studies in Table 3 are noteworthy. While losses on experimental plots selected by researchers may not be representative of most coconut groves in the country, potential monetary losses even from low rat damage levels are still significant. Assuming a mean loss of only 15.0% of harvested nuts would mean that 2.604 billion nuts are lost annually in the Philippines (based on the reported average of 14.754 billion nuts from 1979 to 1983 by Abestilla [1984]. This constituted a loss of about 650,000 kg copra, valued at P2.031[2] million, which could have been additional income for the coconut farmers.

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[2] ₱ 1 = US $0.05

Table 3. Estimates of nut loss due to rats and harvested nuts before and during treatment.

Control method	Duration: During treatment	Duration: Before and during treatment	Mean damage nuts/palm/mo: Pre-treatment	Mean damage nuts/palm/mo: Post-treatment	Mean harvest nuts/palm/mo: Pre-treatment	Mean harvest nuts/palm/mo: Post-treatment	Nut loss [a] (%)	Harvest nut increase [b] (%)	Source
Crown-baiting	7 mo	1 yr, 7 mo	0.42	0.02	2.7	4.3	37.2	59.3	Hoque, 1983
Ground-baiting	7 mo	1 yr, 7 mo	0.65	0.04	2.5	4.7	46.8	58.0	Hoque, 1983
Ground-baiting	1 yr	4 yrs	1.30	0.34	2.3	3.5	34.3	52.2	Gallego et al., 1981
Trunk-banding	1 yr	4 yrs	0.64	0.20	2.7	3.1	12.9	14.8	Gallego et al., 1981
Crown-baiting	1 yr	2 yrs	0.22	0.02	2.7	6.7	59.7	148.1	Reidinger and Libay, 1980
Bi-weekly trapping	5 mo	1 yr	0.16	0.06	2.2	6.4	65.6	190.9	Sultan, 1978
Ground-baiting	1 yr	2 yrs	0.99	0.31	3.0	5.8	48.3	93.3	Sanchez et al., 1976
Mean treated plots			0.63	0.14	2.6	4.9	43.5	92.4	
Mean untreated plots [c]					2.7	3.4	40.6	25.9	

[a]Percent nut loss = (harvest during treatment – pretreatment harvest ÷ harvest during treatment) x 100.

[b]Percent nut increase = (harvest during treatment – pretreatment harvest ÷ pretreatment harvest) x 100.

[c]Excluding data from Reidinger and Libay (1980) and Sanchez et al. (1976).

Rat Movement in Coconut

Rats tend to visit the palm during the night to feed on developing nuts and return to the ground during the day. Both *R. r. mindanensis* and *R. exulans* actively move from the ground to the crown. This was demonstrated in a study conducted in Mindoro Oriental (Sanchez et al., 1976; Fiedler et al., 1982), where bait containing tetracycline was placed in palm crowns in one plots and at ground level in another. By subsequent trapping in the crowns in the ground baited plot and trapping on the ground in the crown-baited plot, rats that had eaten the bait were identified by fluorescence of the bone due to the presence of tetracycline (Figure 2). Trapping results indicated that *R. r. mindanensis* and *R. exulans* moved between ground and crown levels and that *R. argentiventer* did not (Table 1). All *R. r. mindanensis* and *R. exulans* collected in palm crowns were marked by consuming bait located on the ground; however, only a portion of the rats collected on the ground had been previously marked by bait placed in the crowns. About twice as much bait was consumed from ground feeding stations compared to crown placement. These results indicated that most rats that enter crowns have previously fed at the ground level, while a substantial number of rats at the ground level never enter crowns.

Rat movements within coconut groves were also monitored by radiotelemetry. Sultan (1978) radio-equipped five *R. r. mindanensis* and six *R. exulans* live-trapped at the ground level. He followed the movement of these animals for 48.2 h and 292 location changes for 1 mo. *R. r. mindanensis* had generally larger home ranges on the ground (mean of 963 m^2) than *R. exulans* (611 m^2).

Fig. 2. Marked rat jaw with tetracycline indicate active movement of rats between the ground and crown.

The use of tracking tiles (West et al., 1976) or activity boards is one method for assessing rat activity in coconut groves and adjacent habitat (Figure 3). It has proven to be a particularly useful tool for estimating rat activity in coconut plantations. Normally, 25–50 tracking tiles/ha were placed near the base of randomly or systematically selected palms for 3 consecutive nights. The number of tiles with rodent tracks (positive tiles) were recorded daily. Monthly use of this method can provide a continual index of activity in coconut plots. This tool has also been used to assess rodent control effectiveness in rice and corn (Sanchez et al., 1976) and in pineapple (Hoque, 1980)

Changes in rat activity within a coconut grove were sometimes associated with changes in adjacent habitat or the presence of ground crops. For example, increased rat activity and sometimes damage was observed within experimental plots shortly after harvest or land preparation in adjacent rice or corn fields (Bruggers, 1979; 1980). Reindinger and Libay (1980) also observed increased rat activity when nearby sweet potato and rice fields surrounding coconut experimental plots were harvested. Lowest rat activity in coconut plots occurred during late vegetative and mature stages of adjacent rice crops that provided favorable cover and food for rats. After rice harvest and during land preparation when fields were flooded for plowing cover was eliminated and food was scarce. Thus, in situations where coconut groves were near other crops, the available data suggest a dynamic pattern of rat movements between coconut groves and adjacent crop lands. Such movements need to be considered in the evaluation of potential control practices.

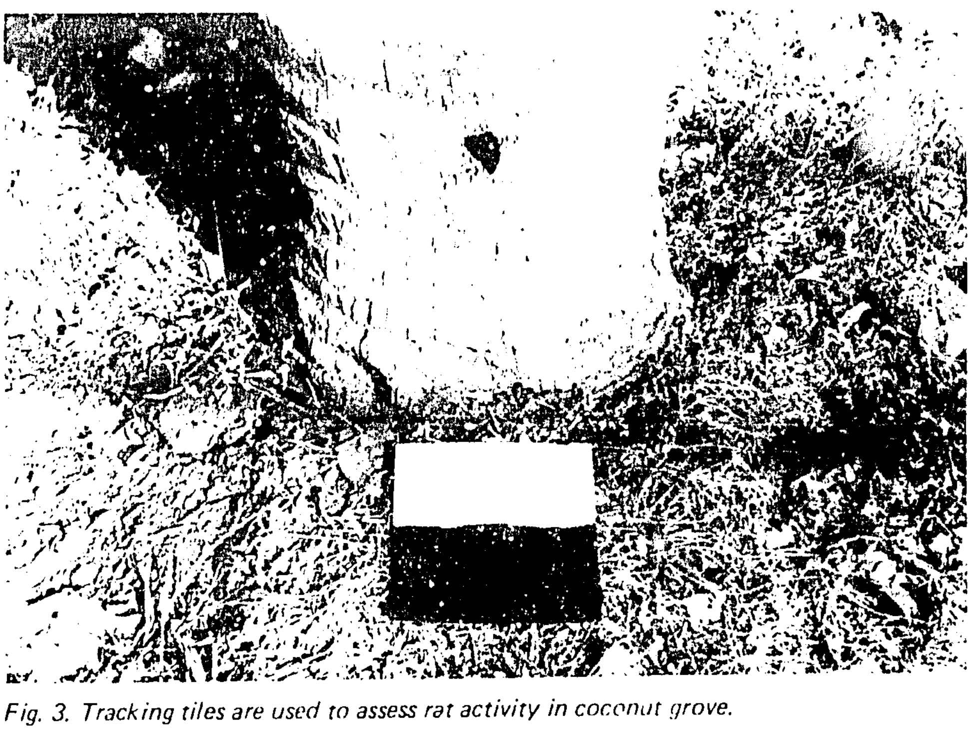

Fig. 3. Tracking tiles are used to assess rat activity in coconut grove.

CONTROL METHODS

Trunk-banding

In trunk-banding, a 25 to 45-cm-wide metal or plastic band is tightly wrapped around and nailed to the trunk 3 m above the ground (Figure 4). Several workers have demonstrated that trunk-banding with metal bands of plain galvanized iron (G. I. sheet) could effectively reduce rat damage in coconut, provided the bands are kept in good repair, and the overlapping fronds are regularly trimmed. Montenegro (1962) reported that a 23-cm-wide plain G.I. sheet wrapped around a palm trunk increased the number of harvestable nuts in study plots by 21.5% over a 5-year period. Hoque (1973) recorded zero nutfall in 10 banded palms and 405 fallen, damaged nuts in 10 reference palms during a 17-week observation. Gallego et al (1981) reported an increase of 14.3% harvestable nuts during the first year when bands were installed. However, several fallen, damaged nuts were observed under banded palms.

Table 4a shows the estimated costs for trunk-banding 100 palms on a 1-ha plantation. The projected total initial cost of materials was P1,900, which included P416 interest for money borrowed to purchase the banding material. Labor costs of P255 would be incurred during the installation of the metal bands as well as P60/yr for maintenance costs from the second to the tenth year. In the fourth and eighth year, additional major maintenance costs for materials and labor amounting to P118 would be incurred. Metal bands

Fig. 4. Metal bands when properly managed can effectively reduce damage.

Table 4a. Estimated expenses (P) over a 10-yr period of trunk-banding palms on a 1-ha plantation. Metal bands are assumed to have a 10-yr life span and are maintained regularly each year.

Item	Quantity	Unit cost	Total cost
Material (cash)			
Plain G.I. sheets (3m x 0.9 m)	14 pc	104.00	1,456
Nails (3.8 cm long)	2 kg	14.00	28
Interest on loan to buy materials[a]			416
Total initial cost of materials			1,900
Labor (noncash)			
Cutting and dividing G.I. sheet	4 man-hours	3.75	15
Wrapping G.I. sheet around trunk	24 man-hours	3.75	90
Cleaning coconut crowns	40 man-hours	3.75	150
Total initial labor cost			255
Cutting overlapping fronds of adjacent coconut palms (years 2 - 10)	144 man-hours	3.75	540
Additional material and labor cost (years 4 and 8)			
Nails	2 kg	14.00	28
Labor	24 man-hours	3.75	90
Total additional and labor cost			118
Total cost			P 2,813
Mean annual cost			P 281.3

[a]Assuming that to purchase the material the farmer borrows at 28% annual interest.

were assumed to last 10 years; the equivalent initial and maintenance costs were P281.30/ha/yr. Rubio (1980) estimated a 10-year benefit: cost ratio of 15:1 for banding based on a theoretical doubling of harvestable nuts, which may or may not be possible. In contrast, Gallego et al. (1981) indicated a negative return during the first 2 years and a positive return starting in the third year. Updated cost and return figures for their banding studies are shown in Table 4b. They determined production increases by estimating harvests in the banded plot at 2.7 nuts/palm/mo before and 3.1 nuts/palm/mo during banding. With copra valued at P3.12/kg, an average price for the 10-year period 1975–1984 (Ignacio, 1985), the benefits due to banding were P374.40 gross or P93.10 net/ha/yr. Considering the total annualized cost of P281.30, the estimated benefit: cost ratio was

Table 4b. Benefit: cost analysis (P) estimated for one year of trunk-banding palms on a one hectare coconut plantation to control rat damage.[a]

	Item	Amount
A.	Gross returns with banding	2,901.60
B.	Gross returns without banding	2,527.20
C.	Added returns from banding (A–B)	374.40
D.	Total rat control cost (from Table 4a)	281.30
E.	Net benefit (C–D)	93.10
F.	Benefit: cost ratio (C÷D)	1.3:1

[a]Based on Gallego et al. (1981), 14% increase in yield from 2.7 to 3.1 nuts/palm/mo, 4 nuts make 1 kg copra at an average price of P3.12/kg copra from a 10-yr period, 1975–1984, and average prices and cost of materials and labor from 1982–1986.

only about 1.3:1. Though trunk-banding was beneficial, the gains were small. Additional long-term studies and observations should be conducted to determine actual yields from trunk-banded palms and the life span of metal bands.

Trunk-banding has been impractical in most situations, in part because many growers are reluctant or unable to pay for the high initial costs of banding materials. Moreover, farmers who banded palms, frequently failed to (1) maintain the bands, (2) trim overlapping or remove drooping fronds, and (3) periodically cut the ground vegetation. In areas where coconut is intercropped with other tree crops such as lanzones, cacao, and coffee, banding may not be practical since rats can use the intercrop to bypass bands and reach the crown. Trunk-banding would not be practical on shorter coconut palm varieties where drooping older fronds are allowed to touch the ground. These drooping fronds provide a bridge for rats to bypass the bands.

Ground-baiting

In ground-baiting, anticoagulant rodenticides mixed with binlid or whole rice are placed in bait holders (Fig. 5). The bait holders are evenly distributed at a rate of about 15/ha, a number based on studies where 4, 12, and 27 baiting points/ha effectively reduced nut damage (Hoque, 1983; Gallego et al., 1981; Sanchez et al., 1976). The movement patterns of *R. r. mindanensis* are larger, requiring fewer baiting points; those of *R. exulans* are smaller, thereby requiring more baiting points per hectare. Inasmuch as the farmer may not even know which one of the two pest species is predominant, 15 baiting points should be sufficient to intercept both species. Bait is added once or twice per week, depending on bait consumption by rats. When more bait is consumed, more rats are present and feeding; thus, more bait is required.

Poison baiting as reported by Montenegro (1962) decreased rat damage in coconut by 75%. Although it was not mentioned what kind of poison was used, damage levels again increased 5 mos after baiting was discontinued. Fiedler et al. (1982) estimated the benefit: cost ratio from Kurylas (1974) at approximately 10:1 based on differences in fallen, damaged nuts recorded in 1-ha treated and untreated areas in Bohol. In another study, ground-baiting in a 5-ha coconut plantation for 13 mos decreased the number of fallen, damaged nuts. However, the decline required 5 mos to drop to 10% of initial levels (Sanchez et al., 1976). It then remained low. Where pineapple was intercropped with coconut and ground-baited, Hoque (1983) observed a faster decline in fallen, damaged nuts. Low nut damage occurred in about the third month after baiting and remained low through the seventh month.

The materials and labor requirements for ground-baiting are shown in Table 5a. Ground-baiting required a low initial capital, P40.50/ha/mo for materials and P33.75/ha/mo for labor. With a lower initial cost of materials for ground-baiting compared to trunk-banding, farmers are probably more inclined to initiate rat control. Total costs for rat control amounted to P891. The added returns, P1,872, were realized at a cost of P891/ha/yr or P74.25/ha/mo (Table 5b). The benefit: cost ratio resulting from ground-baiting was estimated at about 2.1:1. At a production level of 4.6 nuts/palm/mo or an increased harvest due to control of 2 nuts/palm/mo, ground-baiting appears economical. At a cost of P74.25/ha/mo farmers only need to protect about 1 nut/palm/mo to cover the cost of rat control.

When other rat-susceptible crops are grown under the coconut palms, ground-baiting may provide additional benefits not realized in a coconut monoculture. For instance, ground

Fig. 5. Weekly ground baiting with anticoagulant baits evenly distributed at 15/ha.

Table 5a. Estimated expenses (P) for ground-baiting 100 coconut palms/ha/yr. Fifteen baiting points/ha are baited weekly with anticoagulant rodenticides.[a]

Item	Quantity	Unit cost	Total cost
Material (cash)			
Rinlid	78 kg	4.50	351
rfarin	2 kg	45.00	90
Bait holder (coconut husk and bamboo stick)	150 pc	0.30	45
Total cost of materials			486
Labor (noncash)			
Construct bait holders	4 man-hours/mo	3.75	180
Service bait holders	5 man-hours/mo	3.75	225
Total labor cost			405
Total cost			891

[a]Based on material and labor cost from 1982-1986.

baiting in a pineapple-coconut intercrop resulted in a benefit: cost ratio of 18:1, compared to only 7:1 in a coconut monoculture (Hoque, 1983). However, only limited, short-term studies of 1 year or less have been conducted to evaluate the effectiveness of ground-baiting in coconut intercrops. Longer term studies of at least 3 years are more desirable.

Table 5b. Benefit: cost analysis (P) resulting from 1 yr of ground-baiting coconut palms on one hectare.[a]

	Item	Amount
A.	Gross returns with ground-baiting	4,305.60
B.	Gross returns without ground-baiting	2,433.60
C.	Added returns from ground-baiting (A–B)	1,872.00
D.	Total rat control cost (from Table 5a)	891.00
E.	Net benefit (C–D)	1,032.00
F.	Ben[illegible]: cost ratio (C÷D)	2.2:1

[a]Based on data from Sanchez et al. (1976) and Gallego et al. (1981), and an 80% mean increase in harvested nuts (2.6 to 4.6 nuts/palm/mo(; 4 nuts make 1 kg copra at an average price of P3.12 kg over a 10-year period (1975–1984) and average prices and cost of materials and labor from 1982–1986.

Crown-baiting

This technique targets rats that climb palms and damage nuts in the crown. Anticoagulant rodenticides are mixed with rice shorts (binlid) or whole rice. About 150 g of the mixture is put in small plastic bags. The bait packet is then placed in the crown of selected coconut palms once a month (Figures 6a and 6b)

The first reported study on crown-baiting in the Philippines was conducted in Mindoro (Reidinger and Libay, 1980). In the trial, 100–200 g of 0.025% warfarin (Ratoxin) in rice shorts or polished rice, packaged in a plastic bag, was placed randomly in 25% of the coconut crowns. The bait packet was placed monthly by a tree-climber or with the aid of a long bamboo pole in every fourth palm in 1-ha coconut plots. Since rats move easily from one palm to another using overlapping fronds, it seemed unnecessary to bait each palm. In subsequent trials (Fiedler et al., 1982), baiting rates of 0, 2.5, 5, and 16% were tested and results showed that the 10% baiting rate was a reasonable compromise between the higher rates originally tested by Reidinger and Libay (1980) and the lower rates that were more sensitive to periodic rat immigration when nearby crops were harvested.

Reidinger and Libay (1980) reported that rat activity and fallen, damaged nuts decreased about 2 mos after baiting and remained near zero thereafter. In the plots that were baited for 2 yrs, harvestable nuts increased by about 150% over the pretreatment yield (Reidinger and Libay, 1980). Crown-baiting in a coconut-pineapple intercrop showed an increase of 30% of harvestable nuts (Hoque, 1983). Based on these studies, the estimated

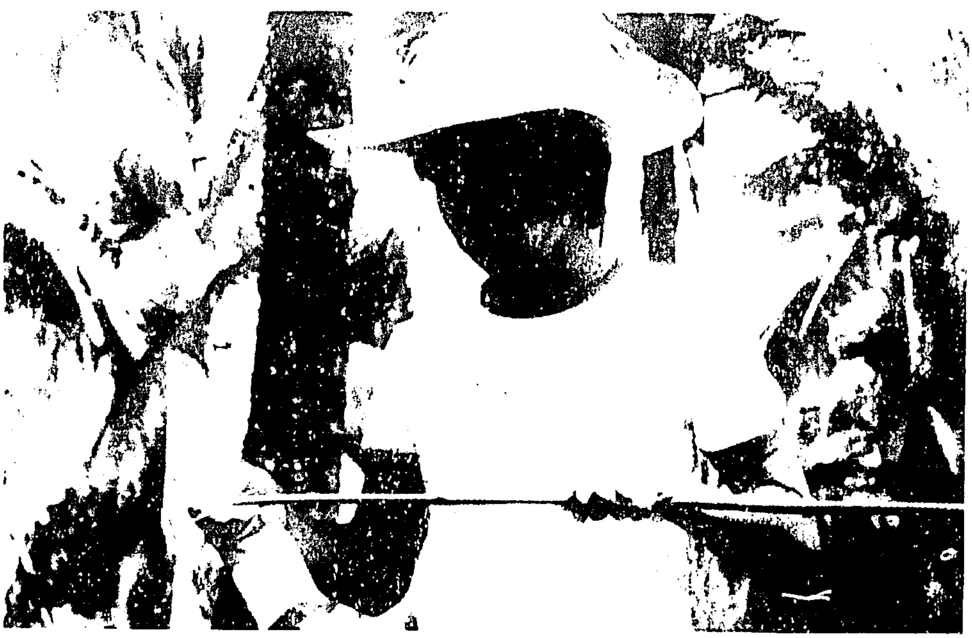

Fig. 6a. About 100 g mixture of rodenticides and rice shorts is put in small plastic bags.

Fig. 6b. Monthly baiting with 100 gram packet of anticoagulant bait placed at the crown of every 10th tree.

benefit: cost ratio for crown-baiting ranged from 7.3:1 to 41.3:1 (Reidinger and Libay, 1980), 8.8:1 for coconut alone, and 24.4:1 for coconut-pineapple intercrop (Hoque, 1983). Rubio (1980) estimated a benefit: cost ratio of about 25:1 for 10% crown-baiting, assuming a 133% increase in production.

Table 6a shows our estimated expenses for crown-baiting 10 palms in 100 per hectare. The total expenditures to protect 1 ha/yr were P337.80. This included P157.80 for baiting materials and P180 for labor costs and was based on average prices for commodities and labor over a 5-year period (1982–1986)

Increased harvest resulting from crown-baiting was 2.8 nuts/palm/mo (Table 6b). This increase (102%) amounted to P2,620.80/ha/yr, at a cost of only P337.80 for a benefit: cost ratio of about 7.8:1. Rubio (1980) assumed a 133% increase in nut harvest compared to our 102% increase, resulting in a lower benefit: cost ratio. Nevertheless, the crown-baiting technique was still more cost-effective than either trunk-banding or ground baiting.

Table 6a. Estimated expenses (P) for crown-baiting 10 of 100 coconut palms/ha/yr. A 100-g packet of anticoagulant rodenticide bait was placed in the crown of every tenth palm each month.[a]

Item	Quantity	Unit cost	Total cost
Material (cash)			
Binlid	18 kg	4.50	81.00
Warfarin	0.462 kg	45.00	20.80
Plastic bags	120 pc	0.05	6.00
Bamboo poles	2 pc	25.00	50.00
Total cost of materials			157.80
Labor (noncash)	4 man-hours/mo	3.75	180.00
Total cost			337.80

[a]Based on a 10% baiting rate and average cost of materials and labor from 1982 –1986.

Table 6b. Benefit: cost analysis (P) resulting from 1 yr of crown-baiting 10 of 100 coconut palms/ha/yr.[a]

Item	Amount
A. Gross returns with crown-baiting	5,148.00
B. Gross returns without crown-baiting	2,527.20
C. Added returns from crown-baiting (A–B)	2,620.80
D. Total cost of rat control (from Table 6a)	337.80
E. Net benefit (C–D)	2,283.00
F. Benefit: cost ratio (C÷D)	7.8:1

[a]Based on a 102% increase in harvested nuts (2.7 to 5.5 nuts/palm/mo); 4 nuts make 1 kg copra at an average price of P3.12/kg over a 10-year period (1975–1984) and average cost of material and labor from 1982-1986.

The dramatic increases in nut harvest from plantations receiving crown-baiting and, to a lesser extent, ground-baiting treatment are not fully understood. That placement of bait in the crowns results in large increases in harvestable nuts is, however, an established fact. Just where this increased harvest comes from remains unclear since reduced fallen, damaged nuts alone do not account for the increase. Some researchers postulate that the increased harvest may be due to the short-term response of palms to interruption of damage to young coconuts and that production might stabilize at lower levels after several years of effective rat control. Studies are needed that monitor individual palm response to long-term rodent control efforts that reduce damage.

SUMMARY AND CONCLUSION

The success of crown-baiting over other methods in rapidly reducing damage and maintaining low damage levels is related to two factors (Fiedler et al., 1982). First, crown-baiting selectively kills only those rats that climb palms and damage nuts, thereby reducing bait material, labor, and total cost. Second, the bait used is highly preferred over growing nuts by rats, which are basically cereal eaters. Therefore, the crown-baiting approach holds the greatest potential for highly cost-effective protection of coconut from rats in the Philippines. Difficulty in crown-baiting may occur in areas with older, taller palms. However, a long bamboo pole, commonly used by coconut harvesters, may be used to place baits in the palm crowns.

Ground-baiting may be the method of choice in situations where coconut is interplanted with other susceptible crops. Possibly a combination of ground- and crown-baiting would improve the effectiveness of protecting the coconut and the intercrop from damage. Further studies are warranted to determine proper timing and use of ground-/crown-baiting applications in relation to the different intercrop combinations.

Trunk-banding is the least preferred method because of the prohibitive costs of materials and labor and maintenance requirements. If a coconut grower chooses trunk-banding, maintaining the bands and preventing vegetative bypasses as described earlier is essential.

RECOMMENDATIONS

Technology can only be beneficial when it is used. Rat control technology has not yet reached many coconut growers in the Philippines. Crown-baiting, an effective rat control technique developed by NCPC researchers, is now available. Ground-baiting may be used in combination with crown-baiting in certain coconut-intercrops. Both techniques require the use of safe, slow-acting rodenticides that rats do not detect. Training of and extension efforts by Coconut Development Officers (CDO's) of the Philippine Coconut Authority (PCA) can facilitate its adoption. The increase in yields derived from the use of these techniques will benefit the coconut grower. It is expected that farmers exposed to successes from using this technology will continue using these rat control methods even after extension efforts decline.

For faster adoption of rat control techniques, there is need for regional demonstrations of crown-baiting in study plots at the various PCA centers. Data gathered from provincial CDO's study plots compared with observations by CDO's and data gathered from farmers will serve as verification on the efficacy of the technology at the regional or provincial level.

One question that remains unanswered is why crown-baiting is so effective. Where does the increased harvest come from? Studies designed to follow individual palms and their nut development in treated and untreated plots may provide some clues. If increases in production are short-term responses of palms to interruption of damage to young coconut, then this possibility should be examined. Hence, the production pattern of coconut after extended periods of efficient rat control should be studied. Of equal interest is the level of damage that may be tolerated in palms if compensation occurs. Simulated damage studies (after Williams, 1974) would help.

With the growing adoption of coconut-intercropping by farmers, continuous availability of alternate food sources may sustain higher rat populations over longer periods of time, resulting in greater damage to coconut. Field research in intercropped coconut should be carried out in selected areas.

Except for a few reports on local losses to coconut, we do not yet know the extent of national losses due to rats. Damage assessment methods similar to those developed by Valencia (1980) in Colombia and Williams (1974) in Fiji are needed. It is necessary to estimate national losses in coconut due to rat damage to identify problem areas and to justify the level of effort required to reduce these losses.

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