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CROWN-BAITING IN COCONUT TREES WITH ANTICOAGULANT RODENTICIDES TO REDUCE RAT DAMAGE

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ABSTRACT

Four one-hectare coconut plots with chronic rat problems near Victoria, Mindoro Oriental, were crown-baited with anticoagulant rodenticides. Two plots were baited (25 percent of the trees per plot) and two assigned as reference plots during the first year. All plots were baited during the second year. We kept monthly records of bait used, rat activity (with tracking tiles), and numbers of fallen (undamaged and obviously rat-damaged) nuts; counted nuts at harvests; and measured copra content of harvested nuts and recorded market values of copra during the second year. We collected *Rattus rattus mindanensis, R. argentiventer,* and *R. exulans* at ground level, but suggest that *R. r. mindanensis* was the major coconut pest. Rat activity and fallen nuts were greatly reduced by baiting. Coconut production (nuts per tree per month) for all plots averaged about 2.5 times the pre-treatment levels. Cost/benefit of the method averaged 1/24 during the second year. Fallen, rat-damaged nuts accounted for only 4.5 to 5.8% of the estimated increases in yield, and assessments based on these counts (as commonly done) would have greatly underestimated actual benefits of the method. The crown-baiting method effectively reduced damage in experimental plots with good economic return, and holds promise of providing long-term relief from chronic rat problems on small coconut farms.

INTRODUCTION

Rat damage to growing coconuts is a serious problem in the Philippines. Damage occurs at all stages of growth and damage intensity may change seasonally when groves are adjacent to other crops such as corn, rice or sugarcane. Girdling trees with metal or plas

tic bands and ground-baiting with acute or chronic toxicants are often used for rodent control in large plantations, but many farmers with small groves use no control. Studies of banding and ground-baiting that have been conducted in the Philippines (Montenegro, 1962; Hoque, 1972-1973; Kurylas, 1974) and elsewhere (e.g., Smith, 1967; Wodzicki, 1969; Williams, 1975) usually indicate good results, but cost factors are typically judged as high. Woronecki *et al.* (1973) and Elias and Valencia G. (1973) have recently completed experimental work in Columbia and concluded that crown-baiting with anticoagulant rodenticides can be used to good advantage for damage reduction. A problem with most of these evaluations is that estimates of losses and economic benefits are based on the number of fallen, rat-damaged nuts without consideration of actual changes in coconut production. Williams (1974a) has postulated that coconut trees can compensate for about one-half of the nuts that are lost to rat damage.

We designed this study as a preliminary test of crown-baiting in the Philippines, using individual trees as the unit of evaluation. A long-term damage reduction on small farms was the major objective. In addition to assessment of damage by counts of fallen, damaged nuts, we measured rat activity with tracking tiles, kept records of nut production, and measured copra content so that we could estimate actual economic benefits. The study, begun in March 1975, is still in progress; we report here results from the first two years.

MATERIALS AND METHODS

In a 150-hectare site with a history of chronic rat problems at Barrio San Gelacia, Victoria, Mindoro Oriental, we chose four plots (numbered 1 to 4), each one hectare with 100 trees. Plots were separated by at least 150 meters and were at least 200 meters from the nearest edge of the coconut grove. Coconut trees are native varieties, 10-25 years old, from 15-20 meters tall. A slough transects the grove, surrounds Plot 4 on three sides and Plot 1 on one side, and separates Plot 1 from a small calamansi (citrus) plantation. A second slough borders one side of Plot 2. Both sloughs and their weedy banks, however, are separated from the experimental plots by several rows or more of coconut trees. The study sites were chosen on the basis of tree varieties, ages of trees and surrounding habitats. Crop management practices are similar, and records maintained by the farmers indicated comparable levels of nut production and rat infestation in the past. During the first year of the study, we randomly assigned two (Plots 1 and 3) for treatment and two as reference (untreated) plots. During the second year, we treated all plots.

In each of the plots, we randomly chose 25 trees and numbered them for detailed studies. In the treated plots, a single packet of poison bait was placed in the fronds of numbered trees each month, i.e., 25 of the 100 trees were baited. Packets consisted of 0.025% warfarin mixed with binlid (rice shorts) or polished rice and placed in smalll plastic bags. Packets were placed in trees by climbers (who were also making observations) or with the aid of long bamboo poles. We roughly adjusted the amount of bait placed in each packet to correspond with its disappearance (assumed due mainly to consumption), so packet sizes varied from 100 to 200 grams. We used a total of 175 kg of bait in Plots 1 and 3 during 25 months of treatment, or 3.5 kg per month per plot (hectare); in Plots 2 and 4, we used 75 kg of bait during 13 months (second year of study) of treatment, or 2.9 kg per month per plot (hectare).

Before the first baiting, we set 25 rat traps at ground level in each plot for three consecutive nights to determine rat species composition. For each month of the study, we measured relative levels of rat activity by placing inked tracking tiles at the base of 24 randomly selected palms in each plot for three consecutive nights and recording the number of tiles with rodent tracks. Before baiting, we removed all fallen nuts from the plots. Thereafter, we kept monthly records on the numbers of fallen nuts (with and without obvious signs of rat damage) in each plot and under each numbered tree. We removed fallen nuts from the areas after they were counted.

The farmer had kept careful records on individual tree production for his entire farm including the study plots, since July 1973. He used these records as accounts of nut production and to determine wages for harvesters. During the period of study, we recorded counts of nuts harvested from each of the numbered trees and from each of the plots. In addition, we maintained harvest records for each tree north of a numbered tree to determine if effects extended beyond trees containing bait. During the second year of the study, we also kept records of copra values during each month of harvest and measured the copra content from samples of harvested nuts. To determine if coconut palms are able to compensate for rat damage by increasing copra content of undamaged nuts, we selected randomly 60 nuts from those harvested in Plot 1 (after 21 months of baiting), and compared their copra weights with 60 nuts also randomly selected from those harvested in a nearby area which had received no rat control and was sustaining heavy damage.

RESULTS

We captured 59 animals for 300 trap nights, or about 20% trap success. Thirty-four were taken from the treated plots and 25 from the reference plots. *Rattus rattus mindanensis* was most common (49%), followed by *Suncus murinus* (20%), *R. argentiventer* and *R. exulans* (14%).

Rat activity, as measured by tracking tiles, was similar (27% in treated vs. 31% in reference plots; Figure 1) in all plots at the onset of the study. By the second month after baiting, activity in the treated plots (1 and 3) had dropped to a negligible level and remained low thereafter. In contrast, rat activity in the reference plots (2 and 4) increased during the rainy season (4 to 7 months after baiting began in the treated areas; by the sixth month, 60% of the tiles were tracked), then returned to lower levels with the onset of the dry season.

We began baiting the reference plots on the twelfth month of the study. Rat activity rose after the first month of baiting, then dropped to levels similar to those observed in the other plots and remained low (compared with pretreatment levels) thereafter. We observed a rise in rat activity in all plots during the last two months of the reporting period. This coincided with harvesting of camote and ricefield crops in areas surrounding the coconut groves and might have been due to immigration of rats from these areas.

Numbers of fallen rat-damaged nuts in the treated plots (1 and 3) decreased in a manner similar to rat activity, i.e., by the second month, numbers of dropped, damaged nuts had reached a negligible level and remained low thereafter (Figure 2). In reference plots (2 and 4), number of fallen, damaged nuts increased sharply at the beginning of the rainy season (from averages of eight to 44 per month at five months after baiting in the

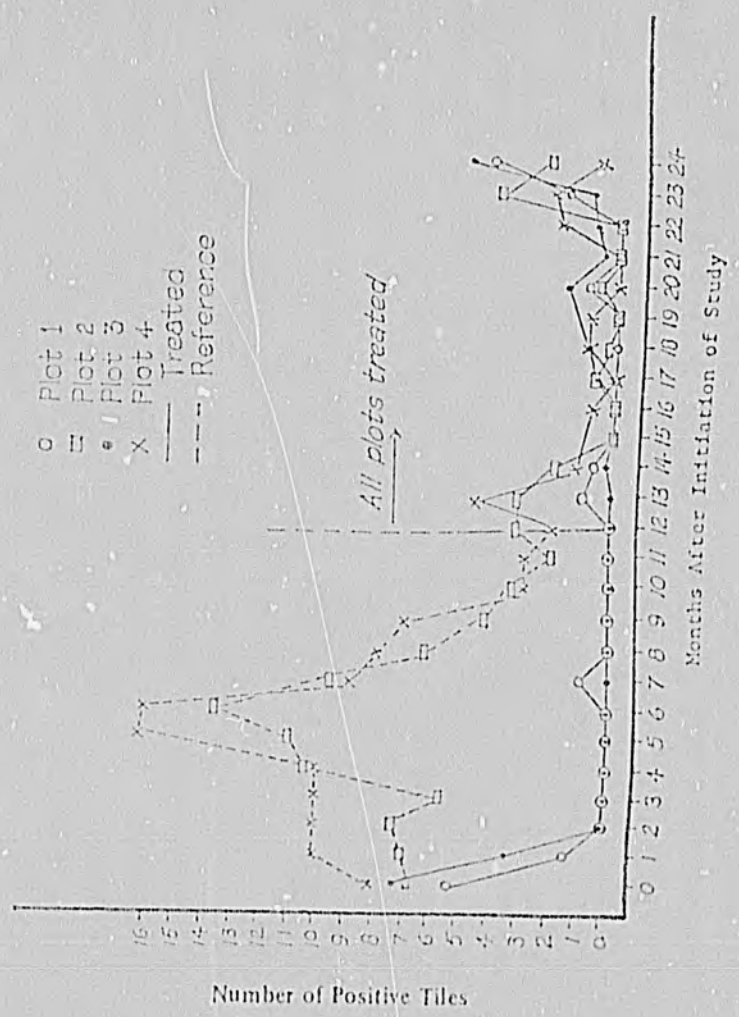

Figure 1. Rat activity in four coconut plots, each one hectare with 100 trees, near Victoria, Mindoro Oriental. Plots 1 and 3 were treated and Plots 2 and 4 were reference plots during the first year; all plots were treated during the second year. For treatment, 25 trees in each plot were crown-baited monthly with anticoagulant rodenticides.

treated plots), then returned to lower levels during the dry season. Three months after we began baiting in these plots (fifteenth month of the study), the numbers of dropped, damaged nuts had reached a negligible level and remained low thereafter.

The total numbers of fallen nuts, including those damaged by rats and those not obviously damaged, generally followed the same patterns as the damaged, fallen nuts with three exceptions: relative increases of fallen, undamaged nuts occurred during the eight through the twelfth and the twentieth through the twenty-fourth month of the study. In both years, the increase was during November through March but the causes are unknown. Typhoon Didang, an unusually strong tropical storm, swept through the Philippines in May 1976 (fourteenth month of the study) and its dramatic effect on numbers of fallen, undamaged nuts is shown in Figure 2.

During the period of study reported here, there were seven harvests during treatment for Plots 1 and 3 and four for Plots 2 and 4. For numbered trees in Plots 1 and 3, numbers of nuts harvested per month during treatment averaged about 2.5 times those of the last pretreatment harvest; in Plots 2 and 4, harvests during treatment for numbered trees averaged about 2.2 times those of four pre-treatment harvests. Trees north of numbered trees followed the same pattern of coconut production as the numbered trees, only increases were less accentuated (1.9 times pre-treatment levels; Figure 3). For entire plots (Figure 4), harvests (nuts per tree per month) averaged 2.92 before treatment and 7.39 during treatment in Plots 1 and 3, and 2.57 before treatment and 6.04 during treatment in Plots 2 and 4.

Copra content of nuts sampled from those harvested in Plot 1 after 21 months of treatment averaged 368 g, slightly but significantly ($P<0.005$, one-sided Student *t* Test) less than the copra content (406 g) of nuts taken at harvest from a nearby untreated area with heavy rat damage.

DISCUSSION

In studies conducted elsewhere, *R. rattus* is generally considered the major coconut pest (Taylor, 1972), although *R. exulans* causes damage in areas not invaded by *R. rattus* (Smith, 1969). In studies conducted in the Philippines, Montenegro (1962) and Kurylas (1974) did not identify pest species, while Hoque (1972-1973) reported only *R. r. mindanensis* in her study plots in Laguna province, Luzon. Z. Sultan (*personal communication*) has recently found both *R. r. mindanensis* and *R. exulans* in his account study site, also in Laguna province.

Since our preliminary trapping was conducted only at the ground level, we cannot deduce species composition in the palm canopy nor can we conclude which species cause the most damage. However, we have recently studied movements of rodents in an area adjacent to the study plots (Sanchez *et al.*, 1976). We used bait containing a marking agent which was alternately placed in tree crowns and at the ground levels, and suggested from the results that two species, *R. r. mindanensis* and *R. exulans*, move actively between the levels, that their relative densities are lower in tree crowns than on the grove floor, and that movement of *R. argentiventer* from the ground level to the tree canopy is either absent or severely restricted. In caged feeding trials, Z. Sultan (*personal communication*) has found that *R. r. mindanensis* is the major pest directly affecting growing coconuts in our study plots, although more studies are certainly required on the roles of each

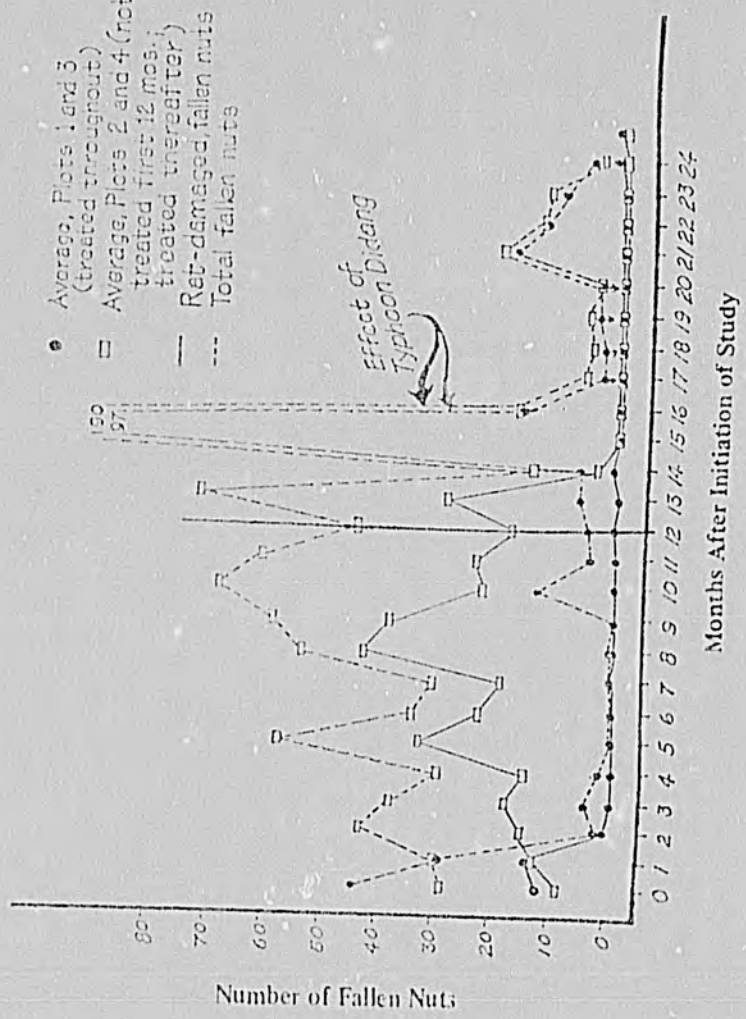

Figure 2. Number of fallen nuts in four coconut plots, each one hectare with 100 trees, near Victoria, Mindoro Oriental. Plots 1 and 3 were treated and Plots 2 and 4 were reference plots during the first year; all plots were treated during the second year. For treatment, 25 trees in each plot were crown-baited monthly with anticoagulant rodenticides.

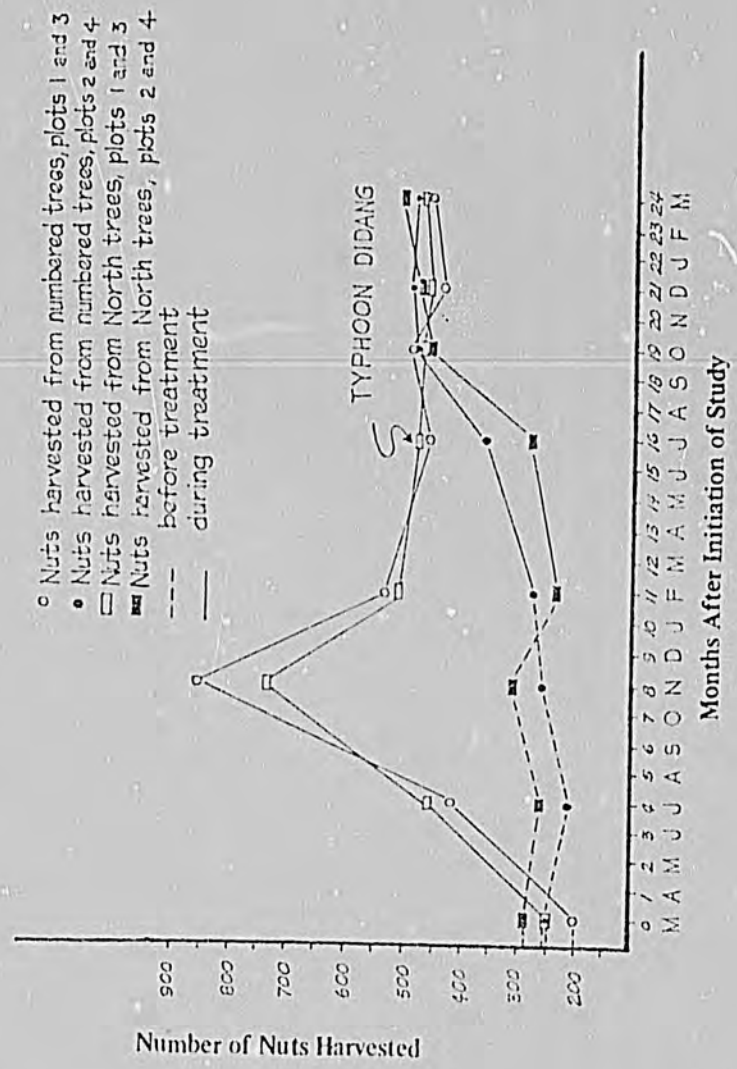

Figure 3. Nuts harvested from 25 numbered coconut trees and nearest trees north of numbered ones in four study plots near Victoria, Mindoro Oriental. Plots 1 and 3 were treated and Plots 2 and 4 were reference plots during the first year; all plots were treated during the second year. For treatment, numbered trees were crown-baited monthly with anticoagulant rodenticides.

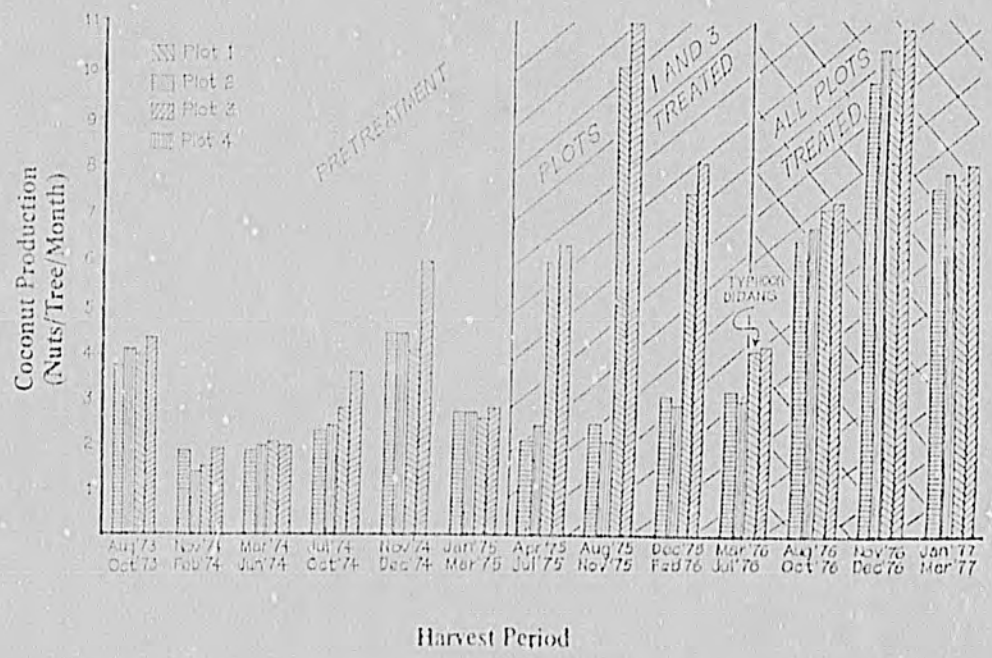

Figure 4. Nut production in four study plots near Victoria, Mindoro Oriental. Plots 1 and 3 were treated and Plots 2 and 4 were reference plots during the first year of the study; all plots were treated during the second year.

species in the coconut agroecosystem before their more subtle influences on production can be understood.

Based on the measurements of rat activity and counts of fallen nuts, crown-baiting with anticoagulant rodenticides effectively reduced damage in all our plots during periods of treatment. With the exceptions noted earlier (Figure 2), fallen nuts without obvious signs of rat damage were also greatly reduced. We interpret this as reduced indirect effects by rats on maturing nuts, a consequence of the baiting program.

Based on records of harvests from trees north of numbered trees and entire plots, it appears that the effects of baiting extended beyond the numbered trees to include all trees within the experimental plots. In fact, we observed dramatic decreases of fallen nuts in coconut areas immediately surrounding the treated plots. Movements of rats between tree crowns by way of overlapping fronds have been commonly observed (and are frequently noted as an impedement to the effectiveness of tree banding), and our studies also indicate active movement of pest rats between the tree canopy and the ground. The high mobility of rats within a grove might explain our observation that it is unnecessary to bait each tree for effective control. We are uncertain why increases in production for the entire plots were greater than for numbered trees or trees north of numbered trees, but Williams (1974b) has reported that some coconuts within a grove are favored by rats. Perhaps a nonrandom distribution of damage biased the results of our random sampling within plots. For this reason, comparisons of yields for economic analyses are based on production records for all palms within the experimental plots.

The economic value of individual coconuts in the Philippines varies greatly with supply and demand which makes it difficult to estimate the potential economic benefit of the procedure. In 1973, farmers in Mindoro earned about ₱0.40 (₱1.00 = ca US$.14) for each coconut. In 1974, values ranged from ₱1.20 to as low as ₱0.15 per nut. Monthly values of copra for 1976 and part of 1977 are presented in Table 1. Bait for plots 1 and 3 cost about ₱15.00 (₱0.075 per tree per month, and for Plots 2 and 4, about ₱13.20 (₱0.066 per tree per month) per month. If wages for labor are included (about 3-4 hours per month), the direct costs for monthly treatment of each tree would be about ₱0.11-₱0.12. Based on the market value of copra, and assuming a harvest during treatment of 2.5 times the pretreatment levels, we estimate that the farmer gained about ₱14,960 gross worth of copra from direct and indirect effects of the crown-baiting program in the four hectares under study during the period when all plots were treated. We estimate total costs of control (assuming of₱0.12 per tree per month) at ₱624 during the same period, with an overall cost to benefit of about 1/24. Cost to benefit estimates for each harvest period varied considerably (from 1/7.3 to 1/41.3), according to the market value of copra.

Although the use of fallen, rat-damaged nuts is most commonly used as a quantitative measure of loss and in determining the economic benefit of potential control methods in coconuts, this measure would have greatly underestimated actual losses and economic benefits of the crown-baiting method in our experimental plots. During the two years of study, we recorded 129 fallen nuts (0.017 nut per tree per month) with obvious signs of rat damage in treated plots, 93% during the first 2 months after treatment. We recorded 593 (0.22 nut per tree per month) in untreated reference plots. The difference represents only about 4.5% - 5.8% of the estimated increases in yield, based on accounts of actual production. The obvious implication is that rats in our experimental plots cause far more damage than is recognized by measuring fallen, damaged nuts. Since many

Table 1. Estimated economic benefits of crown-baiting in coconuts at study plots near Victoria, Mindoro. Figures are based on costs and benefits for four hectares.

Harvest Month, Year	Harvest Period (Mo.)	Copra ₱/kg	Value ₱/nut*	Nuts Harvested (Total, 4 plots)	Gross Value (₱)	Estimated Benefit Due to Rat Control (₱)**	Estimated Costs of Control (₱)	Cost/ Benefit
July 1975	5	1.00	0.40	7,320	2,928	1,757	240	1/7.3
October 1976	3	1.80	0.72	8,310	5,983	3,590	144	1/24.9
December 1976	2	1.86	0.74	8,255	6,109	3,665	96	1/38.2
March 1977	3	2.70	1.08	9,180	9,914	5,948	144	1/41.3
				Total	24,934	14,960	624	1/24.0

* Assumes 2.5 nuts produce about 1 kg of copra (based on 171 nuts sampled over two harvests in treated plots; total 68.25 kg copra or 0.40 kg/nut)

** Assumes a 2.5-fold increase in nut production due to effects of rat control.

farmers in the Philippines also use fallen nuts as an indication of losses to rats, and if the findings of our work can be generalized beyond the study site, actual coconut losses to rats in the Philippines, and perhaps in other countries, may be much greater than presently realized.

The possibility of compensation by palms for coconut losses remains a consideration. Williams (1947a), based on simulated rat damage to coconuts, postulated that palms can compensate for about 50 percent of losses to rats in Fiji. He noted that female flowers increase in trees sustaining rat damage, that setting rate remains the same, and suggested that this may provide one mechanism for compensation over long terms (two years or more), but that other more rapid mechanisms might also be involved.

We assume that major compensatory mechanisms affecting crop yields in our plots were already in operation before baiting was initiated, because the entire area has a long history of chronic rat problems. We assume also that the mechanisms continued operating in Plots 2 and 4 during the first year of the study, when these plots remained untreated. We use the dramatic increase in coconut production which resulted from effective control in the treated plots to attest that the cybernetic mechanisms, if any, were unable to compensate for the level of rat damage in the plots. We therefore, suggest that rat damage served as a factor limiting coconut production in the area. Although copra content (per nut) may have been slightly lowered (we measured about a 10% reduction) as the numbers of harvested nuts per tree in treated plots increased, the amount was insufficient for obvious separation from fluctuations in copra content over extended periods of time and inadequate to significantly affect the economic benefits which were gained by following the baiting program. Of course, the long-term effects of reduced damage on copra production require further study.

CONCLUSION

We conclude from the first two years of study that sustained crown-baiting with chronic rodenticides provided effective protection from rat damage in all plots during periods of treatment, with good economic return, and with the potential of providing long-term reduction of coconut losses to rats. Sustained crown-baiting, at a cost of ₱0.11 to ₱0.12 per month, is affordable to small farmers in the Philippines, but trials should be conducted to determine the general applicability in more diverse conditions under which coconuts are grown. Future studies with different baiting schedules and placement procedures may reduce the cost of control. We point to the need for additional studies on the direct and indirect influences of rats on coconut production, and for inclusion of actual production accounts in determining economic benefits of potential control approaches.

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REFERENCES

ELIAS, D.J., and D. VALENCIA G. 1973. Control de roedores en el cocotero. *In* ICA Informa No. 8. Instituto Colombiano Agropecuario, Bogota, Colombia. pp. 5, 6, 13, 14.

HOQUE, M.M. 1972-1973. Notes on rodent pest affecting coconut. Philipp. Agric. 56:280-289.

KURYLAS, H. 1974. One year of rat control in coconut plantations. Plant Production News (Philippines) 3:89-97.

MONTENEGRO, J. 1962. How to prevent rodent damage in a coconut plantation. Coffee Cacao J. (Manila) 5:192-197.

SANCHEZ, F.F., J.P. SUMANGIL, E.A. BENIGNO, M.M. ROQUE, J.L. LIBAY, B.E. MARGES, P.P. OCAMPO, and R.F. REIDINGER. 1976. Rodent Research Center 1976 Annual Progress Report (Philippines). Mimeo. 100 pp.

SMITH, F.J. 1969. Atoll rat research. South Pac. Bull. 19:41-45.

SMITH, R.W. 1967. A new method of rat control in coconuts. Trop. Agric. 44:315-324.

TAYLOR, K.D. 1972. The rodent problem. Outlook Agric. 7:60-67.

WILLIAMS, J.M. 1974a. The effect of artificial rat damage on coconut yields in Fiji. PANS 20(3): 275-282.

———. 1974b. Rat damage to coconuts in Fiji. Part I Assessment of damage. PANS 20(4): 379-391.

———. 1975. Rat damage to coconuts in Fiji. Part II Efficiency and economics of damage reduction methods. PANS 21(1):19-26.

WODZICKI, K. 1969. Preliminary report on damage to coconuts and on the ecology of the Polynesian rat (*Rattus exulans*) in the Tokelau Islands. Proc. N.Z. Ecol. Soc. 16:7-12.

WORONECKI, P.P., D.G. VALENCIA, D.J. ELIAS, E. VOGEL, R. BOJORGE, J.F. SEQUEIRA, J.M. RAMAKKA and V.F. RAMAKKA. 1973. Cali, Colombia Field Station 1973 Annual Progress Report. Mimeo. 42 pp.