

# The Neo-tropical red squirrel (*Sciurus granatensis*) as a pest of cacao (*Theobroma cacao* L.) in the International Cacao Genebank, Trinidad; Trinidad

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Surveys were conducted at the International Cacao Genebank, Trinidad to investigate the damage done to cacao pods by the Neotropical Red Squirrel (*Sciurus granatensis*). The ratio of ripe cacao pods to the number of pods with signs of squirrel attack was determined. The rodents were found to attack the pod on its abaxial surface, by nibbling oval holes through the pod wall to extract the beans and feed on the pulp. The majority of damaged pods was located in areas of the fields where ripe pods were densely distributed. The total number of ripe pods bore a significant correlation to the number attacked by squirrels ( $P < 0.0001$ ). Correlations between the percentage of squirrel attack and ripe pod hardness, and pod length as an indicator of size, respectively were not significant. There was no relationship between the percentage of pod damage due to squirrel attack and the genetic grouping of the surveyed accessions, and pod wall colour, respectively.

Keywords: Squirrel; Cacao pod; Damage; Pod hardness; pod length

The World's cocoa bean production averaged 3.18 million Mt (metric tonnes) between 1999 and 2001, valued at an estimated US\$5 billion (ICCO, 2006) produced from cacao pods harvested from approximately 7 million hectares of estates throughout the cacao-growing nations (FAO, 2004). Cocoa, the commercial product of *Theobroma cacao* L. (Malvaceae) (Alverson et al., 1999) has contributed significantly to the socio-economic development of The Republic of Trinidad and Tobago, West Indies for over 200 years. However, this contribution subsequently declined due to numerous factors including aging plantations, depressed crop prices, the ravages of witches' broom [*Moniliophthora perniciosa* (Stahel) Singer] (Aime and Phillips, 2006) disease and a shortage of labour during and after the second

world war. Annual exports declined to 3,000 Mt by the early 1950s (Krug and Quarty-Papafio, 1964). Rehabilitation efforts in the 1950s and 1960s increased exports to 9,000 Mt. Steady declines thereafter culminated in present exports of just over 1.2 Mt. However, more recently, the Ministry of Agriculture, Land and Marine Resources has been instituting rehabilitation strategies to increase the level of cocoa production in Trinidad.

Rodents are listed as pests of cacao in different cacao growing regions (Urich, 1911; Hall, 1932; Chatt, 1953; Wood, 1975; Bhat et al., 1981; Kamarulin, 1983; Laurence, 1991; Mossu, 1992; Hafidzi and Davison, 2000). Globally, rodents and other wildlife pests account for approximately 10% of economic losses to cacao pods (Are and Gwynne-Jones, 1974; Han and Bose, 1979; Bhat et al., 1981;

Entwistle, 1985; Smith and Nott, 1988; and Idris *et al.*, 1993). In Trinidad, the Neotropical Red Squirrel (*Sciurus granatensis*) accounts for up to 30% of cacao crop losses. This pest is controlled by applying RoZol bait at an estimated cost of US\$1.50 per 50gm for cocoa farmers. Pods that are even slightly damaged are quickly lost to fungal pod rot (Coulibaly, 1982). In addition, damaged pods can result in slimy fermentations and off flavours in the cacao beans (Quesnel and Lope, 1975).

Control methods for squirrels in cocoa plantations basically attempt to accomplish one of two objectives: kill or repel the pest. Lethal methods include a host of various poisons often applied in baits, trapping and euthanasia and shooting (Wood, 1975; Han and Subash-Bose, 1979; Lee and Arikah, 1984). Repellents ward off the pest, by offending its senses (noise, foul taste, unpleasant smell), from cocoa fields. It was also suggested by Mossu (1992) that rodents can be controlled by keeping a clean plantation, separating the plantation from the forest by a road and frequent inspections of the cocoa field.

This preliminary study was undertaken to meet the following objectives: (i) to describe the nature and severity of damage done by the Neo-tropical red squirrels (*Sciurus granatensis*) to cacao pods at the International Cacao Genebank, Trinidad (ICG,T) using a survey approach; (ii) to evaluate whether the squirrels exhibited a preference for pods based on genotype (the presence of an attractant under genetic control) or phenotypic traits.

## Materials and Methods

The ICG,T is located at La Reunion in the center of the island. There are approximately 2,300 different cacao accessions within the genebank. Most of these were collected in South American countries, the majority in Peru and Ecuador (Kennedy and Moolledhar, 1993). Accessions are planted in individual plots of 12 to 16 plants. The ICG,T consists of over 12,500 plants with shade provided by *Erythrina spp.* and non-commercial bananas.

The accessions are identified by alphanumeric codes usually consisting of an acronym denoting the place of collection followed by accession numbers as exemplified by CRU 146, POUND 1/B or SPEC 41/6-18 (Moolledhar *et al.*, 1991; Wadsworth *et al.*, 1997).

The cacao plant exhibits an unusual branching structure. It grows as an unbranched single stem to a height of 1 to 2 metres where its terminal bud stops growing. Three to five lateral branches then develop at this level to form the "jorquette". The jorquette then grows vertically into the chupon (watershoot). This is usually repeated twice. Plants can reach heights of 8 to 10 metres. The flowers and fruits are borne on the old wood of the trunk and main branches (Wood and Lass, 1985). In Trinidad, there are two main harvest periods, December to February and May to July.

Cacao pods were assessed for signs of squirrel (*Sciurus granatensis*) attack in the ICG,T. The total number of ripe pods and the quantity of ripe pods with evidence of squirrel damage were counted and recorded. The nature of the damage was also described. The following parameters were recorded: correlations between squirrel damage and pod length, measured in cm as an indicator of size, pod wall colour (the absence or presence and intensity of anthocyanin, assessed visually), pod hardness measured as described by Bekele *et al.* (1997), tree density and location, and genetic origin of pods (Table 2), respectively. This exercise was first conducted during the wet season in July 2000 (Damage Census 1 (DC1)) and repeated during the dry season in February 2001 (Damage Census 2 (DC2)). This approach allowed for a comparison of the squirrels' behaviour during the two seasons in Trinidad.

## Statistical analyses

In order to cater for the differences in times of the year of the two surveys, DC1 and 2, the percentage of rather than absolute incidence of squirrel damage for each survey period was compared between surveys. Correlation

analysis of the degree of damage with the aforementioned variables was also performed. A  $\chi^2$  square test was used to test for an association between degree of damage and genetic origin of pods. All statistical analyses were performed using MINITAB version 12.21 (Minitab Inc).



Plate 1: Aperture made by a squirrel near the median of a cacao pod at the ICG,T

## Results

### Qualitative damage to pods

Squirrels were sighted at the ICG,T predominantly in the early morning and late afternoon. Squirrels were observed to nest within the epiphytes that grew on the shade trees (*Erythrina* spp.). Oval holes observed near the median or terminal portion of several mature ripe cacao pod walls (Plate 1), typified their feeding on and damaged to pods. Cacao seeds devoid of their mucilage were found strewn on the ground and on various tree parts below damaged pods (Plate 2). Squirrels were also observed to attack the abaxial surface of the pod. In addition, the majority of pods attacked was located on the trunk of trees.

During DC1, eighteen (21.4%) of the 84 accessions attacked were located in the

periphery of the various fields, i.e. the first row of trees on the borders. During DC2, eight (16%) of the 50 accessions attacked were also on the periphery of the fields. The degrees of squirrel attack within the fields for DC 1 and 2 were 66 (78.6%) and 42 (84%), respectively.

### Quantitative damages

The percentage of pods damaged by squirrels was 2.9% and 2.3% for DC1 and DC2, respectively, an average of 2.6%. During DC1 3.1% of the pods with yellow pod walls and 1.3% of those with red pod walls were damaged by squirrels. The damage expressed as a proportion of the total was 2.3% and 1.4% for yellow and red pod walls, respectively



Plate 2: Cocoa beans with mucilage removed after being discarded by squirrels on the ground the ICG,T.

### Location of attacked accessions

There was no squirrel damage recorded in Field 4A during DC2. When Figure 1 is compared to Figure 3, and Figure 2 compared to Figure 4, shifts in the location of attacked accessions were discernible during DC1 and DC2, respectively.

### Genotypic preference

Since representatives from the various

genetic groups are haphazardly distributed throughout the genebank, an attempt was made to determine whether there was any pattern of preference by squirrels for pods from particular genetic groups. The two major genetic groupings studied, Forastero, and Trinitario, have been described by Iwaro *et al.* (2003). The results of a  $\chi^2$  square test of

association between the observed levels of squirrel damage and the various genetic groupings indicate that squirrel damage is independent of genetic group ( $P>0.05$ ) (Refer to Tables 1 and 2). Table 3 lists the correlation coefficients ( $r$ ) for the various parameters correlated.

**Table 1** Squirrel damage assessed for various cacao genetic groups

Genetic Group	No. of Acc. in ICG,T	% accessions Surveyed		No. accessions attacked		% accessions attacked	
		DC1	DC2	DC1	DC2	DC1	DC2
Upper Amazon Forastero	587	37.7	39.5	34	30	15.4	12.9
Lower Amazon Forastero	47	21.3	8.5	0	1	0	25.0
Trinitario	362	22.1	16.3	13	2	16.3	3.4
Various	1028	33.8	28.5	34	15	9.8	5.1
Unknown	108	6.5	7.5	0	0		
<b>Total</b>	<b>2135</b>			<b>81</b>	<b>48</b>		

**Table 2** Results of  $\chi^2$  test to elucidate the relationship between degree of squirrel damage and genetic grouping of foraged material, and pod wall colour, respectively

Variable	$\chi^2$ test		P-value	
	DC1	DC2	DC1	DC2
Genetic groups				
Upper Amazon	0.96	0.93	0.514	0.525
Lower Amazon	-3.86	-10.13	0.161	0.063
Trinitario	0.74	0.31	0.593	0.806
Various	0.97	0.91	0.509	0.530
<b>Pod wall Colour</b>				
Yellow	1.02	0.99	0.494	0.504
Red	0.69	0.37	0.616	0.777

**Table 3** Correlations between the degree of damage and the other variables studied

Correlations	Sample size	Correlation value (r)		P-value	
		DC1	DC2	DC1	DC2
Tree density and Percentage of damage	693 (DC1) 628 (DC2)	0.307	0.173	0.0001	0.0001
Number of ripe pods and Percentage of damage	4712 (DC1) 3269 (DC2)	0.174	0.197	0.0001	0.0001
Pod hardness (MPa) and Percentage of damage per accession	250 (DC1) 272 (DC2)	.018	-0.211	0.782	0.0001
Pod length (cm) and Degree of percentage per accession	250 (DC1) 272 (DC2)	-0.027	0.033	0.703	0.482
Pod hardness (Mpa) and Pod length (cm) per accession	250 (DC1) 272 (DC2)	0.261	0.327	0.017	0.021

## Discussion

The nature of rodent attacks observed during

this study, oval holes ( $3.53\text{ cm}^2$  to  $18.60\text{ cm}^2$  in area with a mean of  $10.66\text{ cm}^2$ ) in mature, ripe cacao pods (Plates 1 and 2), was consistent

with squirrel damage to cacao pods reported by Lee (2002); Hafidzi (1993); Warren and Emamdie (1993); Coulibaly (1981); Bhat (1980); Juan and Bose (1979); Wood (1975); Hardy (1960); Montserin (1937); Hall (1932) and Urich (1911). It was also observed that squirrels only attacked ripe pods, as was reported by Warren and Emamdie (1993). Warren and Emamdie (1993) also suggested that the squirrels' preference for ripe pods was related to colour and smell rather than taste. However, the correlation between pod wall colour and the percentage of squirrel damage in this study was not significant ( $P>0.05$ ) (see Table 2). Most of the accessions attacked were located within the fields. However, the number of accessions with ripe pods in these areas of the field was greater (574 and 523 for DC 1 and 2, respectively), compared with 117 and 103 accessions with ripe pods on the periphery of the fields for DC 1 and 2, respectively. However, Hafidzi and Davison (2000) concluded, from their study on the status of squirrels in cocoa fields near oil palm plantations that they mainly fed on the edges of the cocoa fields. The differences in results may be ascribed to variations in the dimensions of the fields. Further study is warranted in this area.

Warren and Emamdie (1993) concluded that squirrels preferred harder pods hence their preference for the ripe cacao pods. Pod walls increase in hardness with maturity. However, there was a lack of correlation ( $P>0.05$ ) between the percentage of pod damage due to squirrels and the hardness of ripe pods observed in this present study (Table 3). Data on pod wall hardness were obtained from Bekele *et al.* (1997; 2000), who concluded that there was significant variability in ripe pod wall hardness within the ICG,T. There was no significant correlation between pod hardness and pod length or size ( $P>0.05$ ). The same applied for pod size and the percentage of squirrel damage ( $P>0.05$ ). Therefore, this study suggests that rodents do not display any preference for larger pods, a particular colour of pod wall or degree of pod wall hardness.

The average squirrel damage of 2.6% recorded is lower than the average

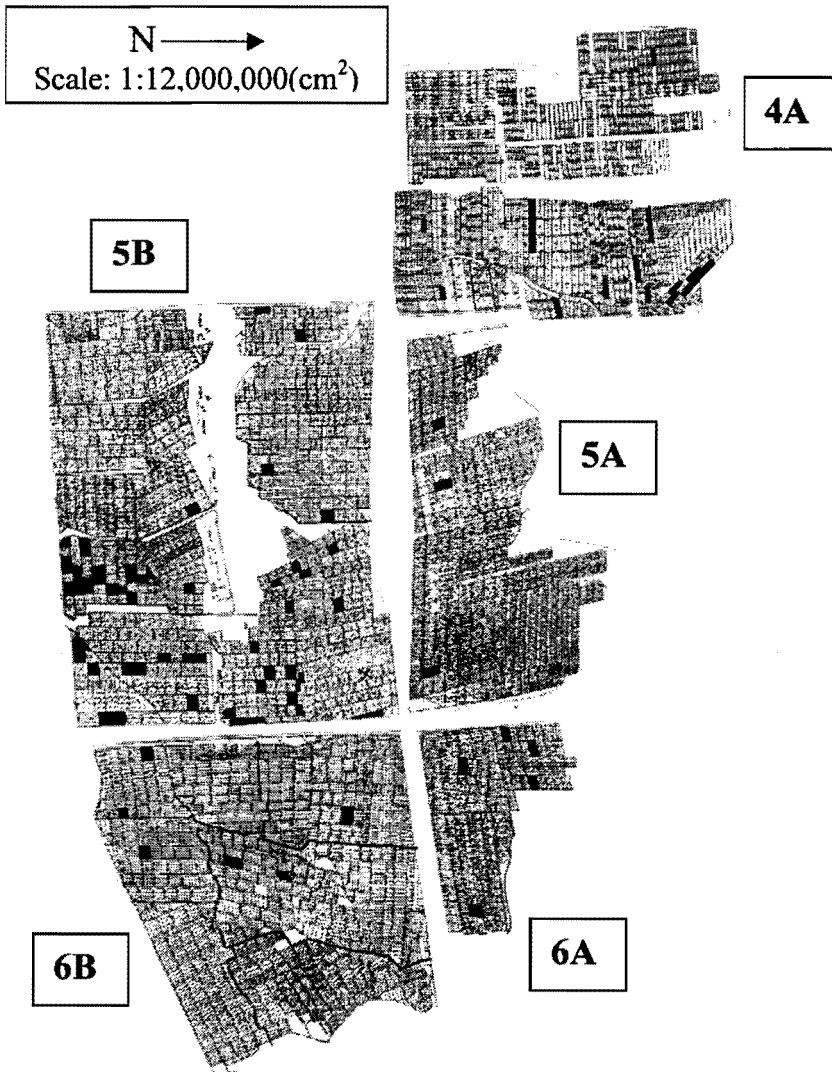
international losses of 5% to 10% quoted for vertebrate damage to cacao by Wood (1975); Hopf *et al.* (1976); Entwistle (1985); Wood and Lass (1985). The significant positive correlation ( $P<0.0001$ ) obtained between the availability of healthy, ripe pods and the percentage of pods damaged by squirrels during both observation periods, in addition to the significant correlation ( $P<0.0001$ ) between tree density and the percentage of pods damaged by squirrels, indicate that as tree density and the number of ripe pods increase the percentage of damaged pods also increases. The shifts in the location of concentrated squirrel attack corresponded to the changed concentrations of accessions with ripe pods (Figures 1 and 3; and Figures 2 and 4, respectively). This would naturally allow the rodents to be more selective in their choice of food. There was only 28.1 mm of rainfall (Trinidad and Tobago Meteorological Services, 2001) during DC2 compared to 200.3 mm (Meteorological Services, 2000) during DC1. The reduced rainfall probably resulted in drier and unfavourable conditions during DC2 for the squirrels. Since squirrels tend to move away from unfavourable areas (Rampaul, 2001), they may have relocated to more attractive surroundings. Therefore, the reduction in their numbers recorded for DC2 was expected.

The observation that squirrels attack the abaxial surface of the cacao pod is not surprising since this is the most exposed surface of the pod. It is unfortunate that most of the cacao pods attacked were located on the trunk of trees where the majority of pods are usually produced especially on seedling as opposed to clonal trees.

The reduction in the percentage of squirrel damaged pods within the Trinitario population from 16.3% during DC1 to 3.4% during DC2 could be attributed to the absence of squirrel damage in field 4A, which contains a majority of Trinitario cacao trees. However, the association between genetic group and the percentage of squirrel damage was not significant ( $P>0.05$ ). Warren and Emamdie (1993) indicated that IMC 6, a member of the Forastero group, is immune to squirrel attack.

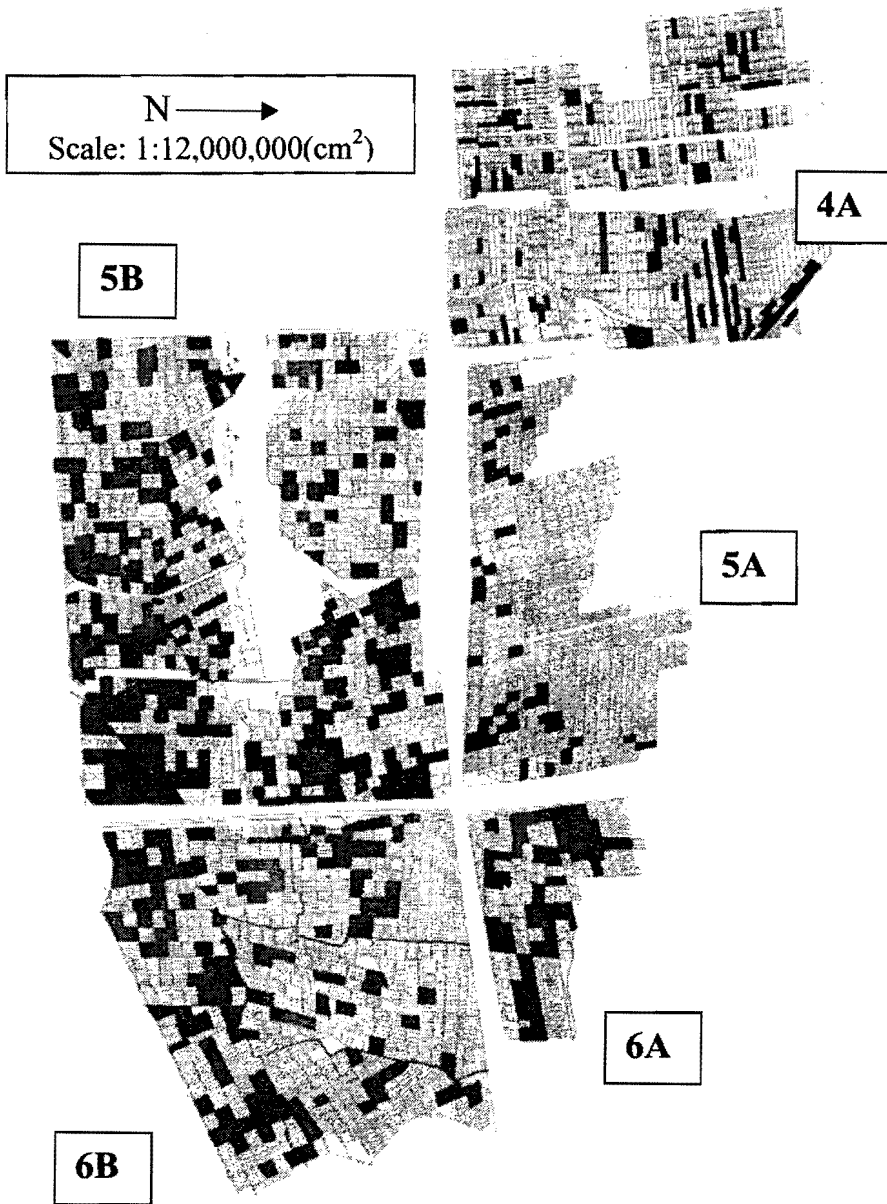
During this study, none of the pods of IMC 6 was attacked in either of the observation periods. However, it would require several such observations over a number of seasons before such a firm conclusion can be made. Furthermore, only seven accessions were attacked during both DC1 and DC2. These were CRU 28, CRU 83, JA 1/3, POUND

25/A, PA 67, PA 82 and PA 299. It would be interesting to determine whether there is a genetic basis for the attraction of this squirrel to these pods. The identification of an attractant, perhaps olfactory, linked to genotype in the feeding behaviour of the squirrels could facilitate selection of resistant genotypes.



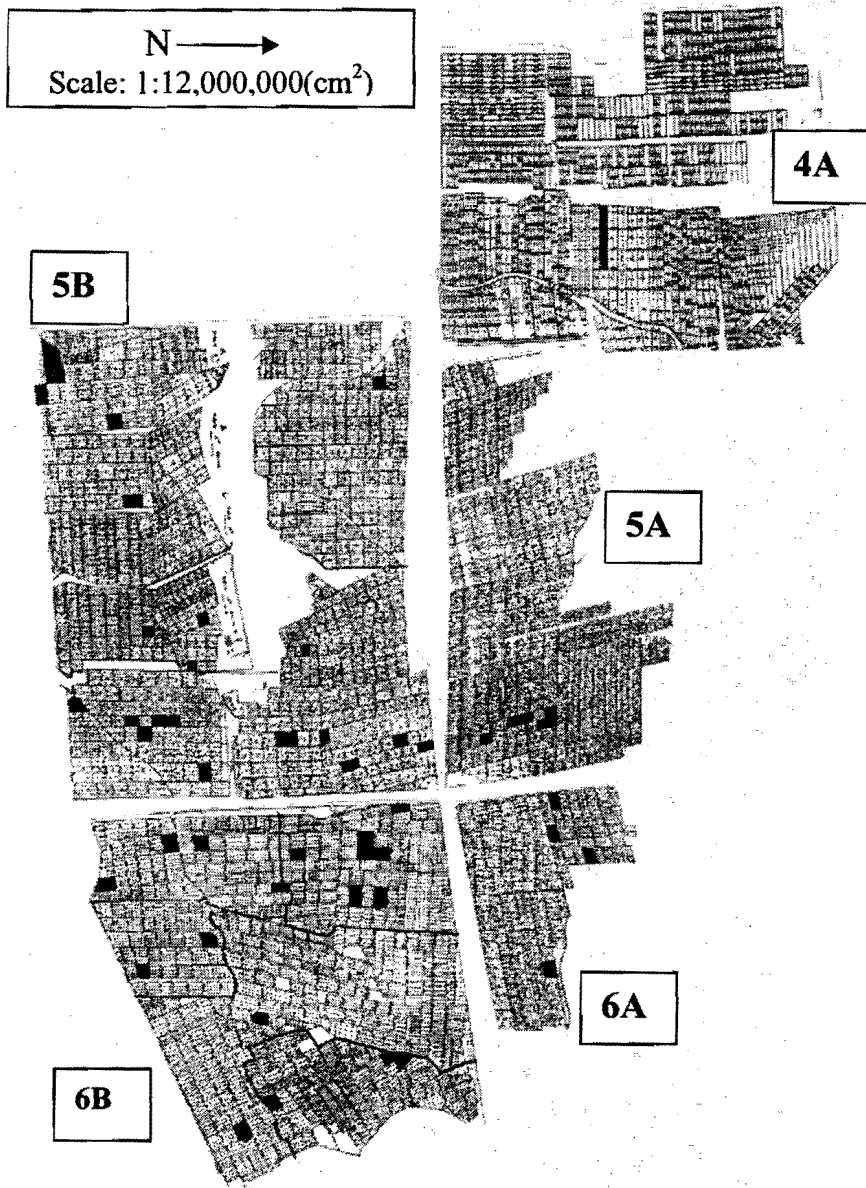
**Figure 1** Distribution of accessions attacked by squirrels during damage census 1

The darkened areas in Figure 1 depict the locations of accessions which were attacked by squirrels during DC1



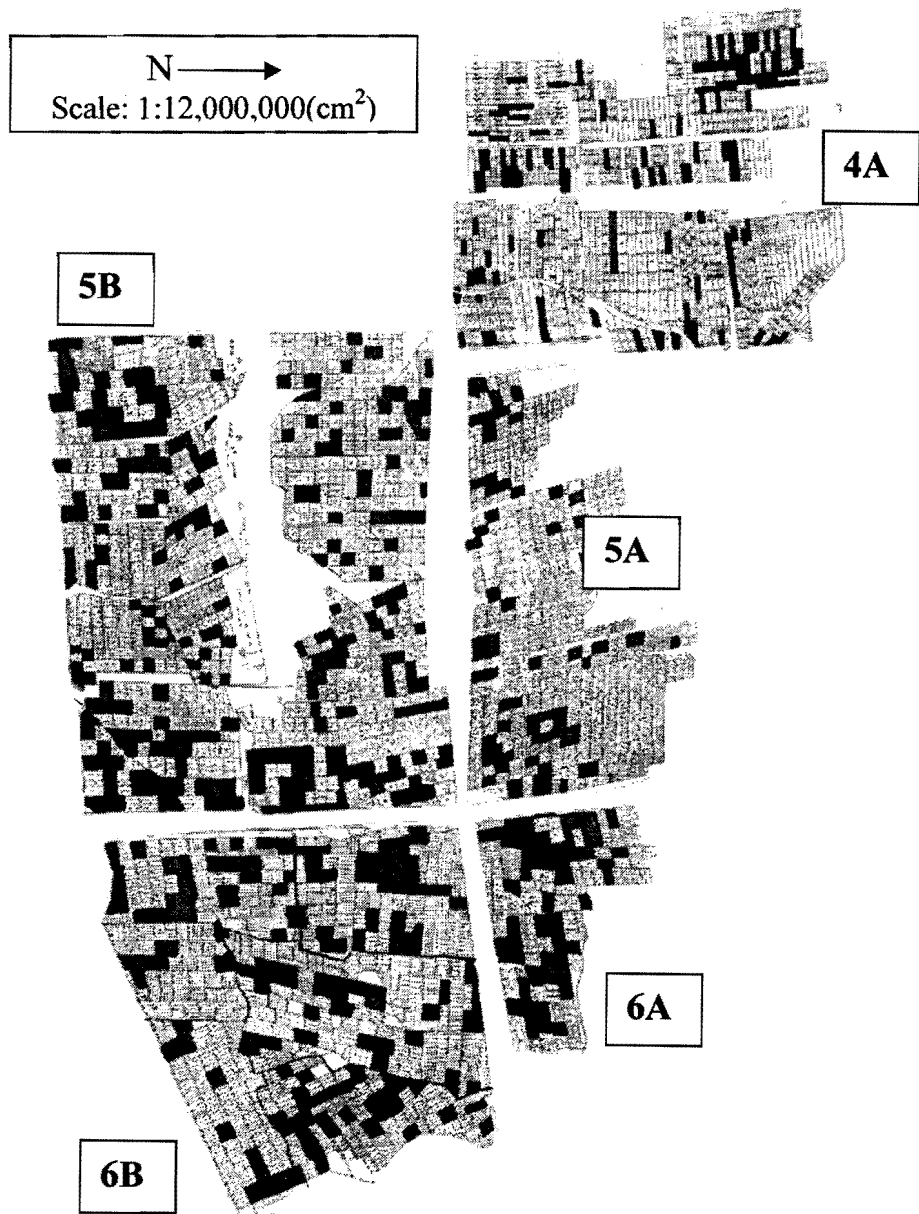
**Figure 2** Distribution of accessions with ripe pods during damage census 1

The darkened areas in Figure 2 depict the locations of accessions which bore ripe cacao pods during DC1



**Figure 3** Distribution of accessions attacked by squirrels during damage census 2

The darkened areas in Figure 3 depict the locations of accessions which were attacked by squirrels during DC2



**Figure 4** Distribution of accessions with ripe pods during damage census 2

The darkened areas in Figure 4 depict the locations of accessions which bore ripe cacao pods during DC2

## Conclusion

The relationship observed between ripe pod hardness and the incidence of squirrel attack ( $r = 0.018$ ,  $P > 0.05$  for DC1;  $r = -0.211$ ,  $P < 0.05$  for DC2) was ambiguous and warrants further investigation. Some insight was gained into the foraging behaviour of this rodent. It preferred to feed where there were clusters of ripe pods as opposed to a scarcity of such. Detailed studies are required, possibly involving captive and re-captive methods, to fully elucidate the foraging behaviour of this pest. It is also recommended that further work be undertaken to investigate the chemical properties of the cacao pods belonging to accessions IMC 6, CRU 28, CRU 83, JA 1/3, POUND 25/A, PA 67, PA 82 and PA 299 to determine the presence of chemical attractant(s) and deterrent(s) which influence the foraging behaviour of the Neo-tropical red squirrel.

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