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FOOD COMPETITION BETWEEN VERVETS  
(*CERCOPITHECUS AETHIOPS SABAEUS*) AND FARMERS  
IN BARBADOS : IMPLICATIONS FOR MANAGEMENT

Julia HORROCKS\* and Jean BAULU\*\*

ABSTRACT

Vervets have been crop pests in Barbados since the late 1600s. Barbados consists of cultivated land (primarily sugar cane) dissected by wooded ravines or gullies. Conflict between people and vervets increased over the last thirty years. This is partly due to an increase in vervet numbers attributable to the increase in cover that resulted when gullies were no longer cleared for firewood, and partly due to a shift towards cultivating more fruits and vegetables which vervets prefer. A survey conducted in 1980 assessed levels of damage to 34 crops grown in Barbados. To investigate why certain crops are preferred over others, the nutritional composition of crops, their growth form and their skin characteristics were analysed. Although tree crops are generally less nutritious than sub-soil and ground level crops, vervets preferred them perhaps because predation risk is lower when harvesting crops off the ground. Considering only tree crops, nutritional composition did not predict preferences. Vervets tended to prefer tree crops whose skins were edible and yellow when ripe. Based on these results, planting strategies that farmers can use to minimise crop damage in the future are proposed. Only in recent years can vervets in Barbados be characterised as commensal with people, in the sense that their value for the biomedical research and tourism markets buffers the costs associated with their feeding habits.

Key words : Vervet, *Cercopithecus aethiops sabaeus*, food choice, competition, crop damage, nutritional composition, planting strategies.

INTRODUCTION

Commensalism is generally defined as an interspecific relationship in which one party benefits and the other is unharmed. This may characterise the nature of the relationship between non-human primates and people in some parts of the world, but it is perhaps less appropriate for describing the direct food competition

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that occurs between vervets and people in Barbados. In order to characterise the relationship between vervets and people in Barbados as one in which one party (vervets) benefits, and the other party (humans) is unharmed, it is necessary to take the broader perspective that Barbadians benefit in other ways from the presence of monkeys that are sufficient to buffer the cost of crop damage and loss.

Vervets, or more specifically green monkeys (*Cercopithecus aethiops sabaesus*), were brought to Barbados in the seventeenth century following colonisation of the island in 1627. They are thought to have been brought from west Africa, probably Senegal and Gambia, on slave ships, presumably as sailors' pets or gifts for settlers.

The early years of settlement in Barbados resulted in extensive clearance of the natural vegetation and the planting of firstly tobacco, cotton and indigo and then later, sugar cane. Tree felling was widespread on flat land and the landscape changed quickly from forests to plantations. Today the island initially appears almost devoid of woodlands and covered with sugar cane ; but this first impression is deceptive. Six-sevenths of the island is coral-capped and dissected by steep-sided vegetated gullies or ravines. These gullies are estimated to stretch for a total of about 400 kilometres. Historically, gullies were important access routes for people, the vegetation being regularly cleared for firewood. With the advent of gas and electricity and an improved road system, the gullies were allowed to return to their former vegetated condition.

From the time of their arrival in the 1600s, monkeys have been crop pests. Although they feed on the shoots, pith, bark, fruits and flowers of a wide variety of naturally growing trees, shrubs and grasses as well as insects, lizards, and birds' eggs, cultivated foods are an important part of their diet. Crop damage ranges from complete consumption of items, to biting (presumably to sample), to damage caused by jumping onto and through crop plants. Although crop damage by monkeys has probably never been as substantial as that caused by insects and fungi, and probably rats also, most of these latter pests can be effectively controlled by chemicals. Monkeys are very sensitive to bait and are consequently very difficult to poison.

The initial population of vervets that were released or escaped into the wild must have been small, but in the absence of any predators apart from man and dogs and with a plentiful supply of food, their numbers evidently grew rapidly. The ability of vervets to adapt successfully to marginal, human-disturbed habitats and to exploit human activities is well documented (Kavanagh, 1980 ; Brennan *et al.*, 1985). By 1682, monkey crop damage in Barbados was so severe that an Act was passed placing a bounty on monkey tails. This bounty remains to the present day. Several factors have since contributed to the increasing conflict between people and monkeys seen over the last thirty years. Firstly, many gullies have become impassibly wooded, resulting in safe refuge for monkeys, presumably a reduction in the numbers killed, and possibly an increase in population size. Secondly, a law that had been passed during World War II requiring plantations to grow staple root crops like yams and sweet potatoes on 12 % of their land area was no longer enforced. Some plantations started to use this land to grow green vegetables and fruits to support the newly developing tourist industry. More recently, indebted plantations have begun to reduce planting and have begun selling off land for development. The effect of this may have been to reduce the amount of food available for monkeys, and therefore perhaps to increase the proportion of total crops damaged by monkeys. A final factor that has contributed to antagonism

between monkeys and people is that many Barbadians are attempting to offset the effects of economic recession by growing their own food on a small backyard scale.

In 1980, in response to growing complaints from farmers, a survey of monkey crop damage was conducted by the Caribbean Agricultural Research and Development Institute. The results of the questionnaire provided information on the interaction between monkeys and people in Barbados and permitted the identification of those areas of the island where crop damage was most substantial. Capture of monkeys using a multiple cage system or shooting net began in 1980 and continues today, operated by the Barbados Primate Research Centre.

The information gathered during the survey of farmers around the island included the amounts of different crops grown on each farm, as well as the amounts damaged. The objective of this paper is to use this information, combined with information about the crops themselves i.e. nutritional composition, growth form, and skin characteristics to identify which crops are preferred by monkeys, why they may be preferred, and how this information may assist farmers in making planting decisions in the future.

## METHODS

Ten farmers were randomly chosen from each of Barbados' eleven parishes and interviewed using a standard questionnaire. The amount of land under each crop and the amount of each crop damaged by monkeys were determined from each farmer. For each of the 34 crops investigated across the eleven parishes, the mean amount of a crop damaged increased linearly with the mean amount grown in the parish, the increase being statistically significant ( $P < 0.05$ ) for 25 of the 34 crops. Since the amount of a crop that is damaged increases with the amount grown, the percentage of a crop damaged (% damage) was considered to be a more appropriate index of monkey preference for the crop. Percentage data was arcsine transformed prior to parametric statistical analyses (Zar, 1974).

The calorific value, as well as grams of carbohydrate, fat, protein and water per 100 g of crop were obtained from food composition tables of the Caribbean Food and Nutrition Institute (1974). Skin toughness of fruits was ascertained using a penetrometer that measured the pressure in kg necessary to push a 1 cm<sup>2</sup> probe into a ripe fruit.

## RESULTS AND DISCUSSION

### DO MONKEYS SHOW CROP PREFERENCE ?

The mean islandwide percentage damage to each crop was calculated from % damage in each of the eleven parishes and compared across crops. Percent damage differed significantly between crops (Kruskal-Wallis test,  $W = 137.1$ ,  $P < 0.001$ ) indicating that monkeys do show preference. Crops could then be ranked by this preference index, as shown in Figure 1.

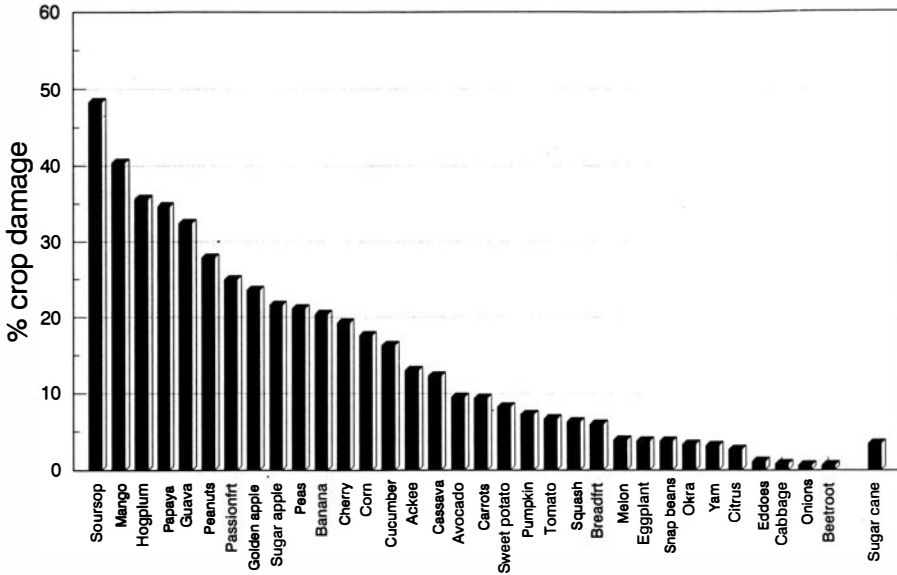


Figure 1. — The % damage by monkeys to thirty four different crops in Barbados.

## WHAT CROP CHARACTERISTICS MAY CAUSE THEM TO BE PREFERRED ?

### *Nutritional composition*

To assess the effects of nutritional composition of crops on preferences shown by monkeys, linear regression analyses (Pearson's  $r$ ,  $n = 34$ ) were conducted across crops of % damage of a crop versus each of the nutritional variables.

Percentage (%) damage was not correlated with fat, protein, water or calorific value of the crop, but there was a weak tendency for % damage to be higher in crops of higher carbohydrate content ( $r = 0.33$ ,  $P < 0.1$ , Fig. 2). However, as Figure 2 shows, carbohydrate content on its own explains very little variation in the % of a crop damaged.

This may suggest that preference of monkeys for crops is not sensitive to any of the nutritional variables. Alternatively, the absence of correlations between % damage and measures of nutritional composition may result from intercorrelations between the variables. Carbohydrate, fat and protein content were each negatively correlated with water content, and protein and fat were positively correlated ( $P < 0.001$  in all cases). Carbohydrate content was not correlated with either fat ( $r = 0.02$ ,  $P > 0.05$ ) or protein ( $r = 0.14$ ,  $P > 0.05$ ) content. This suggests that monkeys may face trade-offs in choice of particular crops. For example, if a monkey chooses a crop to maximise carbohydrate, fat or protein intake, it will be at the expense of water intake. However, if a monkey chooses a crop to maximise fat intake it is likely to be simultaneously maximising protein intake.

Given the above intercorrelations, the effects of fat and protein content of crops on % damage were investigated by correlating residuals of % damage versus

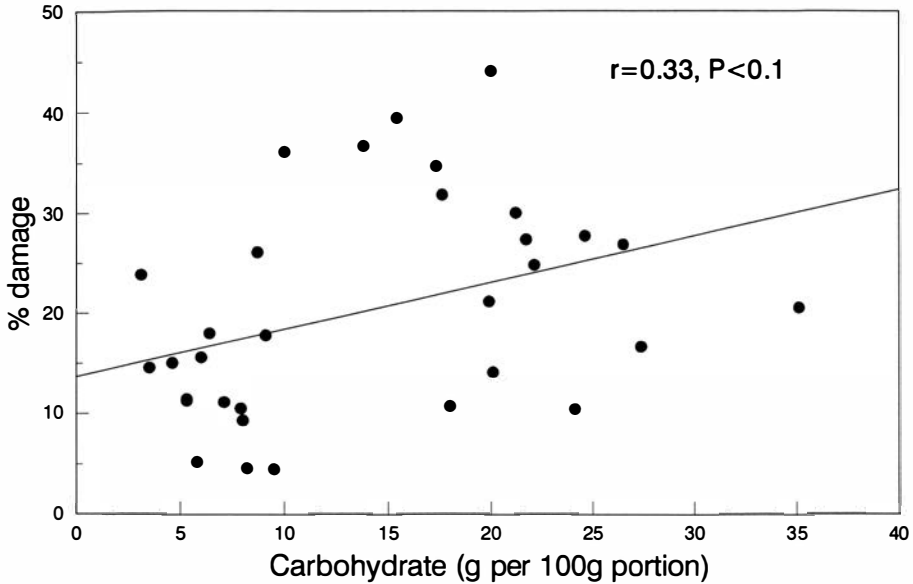


Figure 2. — The % damage by monkeys versus carbohydrate content (g per 100 g portion) of crops.

carbohydrate with fat and protein content. The residual of carbohydrate versus damage was positively correlated with fat content ( $r = 0.39$ ,  $P = 0.02$ ), indicating that crops with damage greater than predicted by their carbohydrate content were those higher in fat. The residual of carbohydrate versus damage was not correlated with protein content ( $r = -0.24$ ,  $P > 0.05$ ). These results suggest that, for all crops combined, the variables measured are poor predictors of % damage, but that there is some effect of carbohydrate on damage and some effect of fat on damage when effects of carbohydrate are controlled.

### *Growth mode of crops*

One reason why the nutritional variables measured may appear to be poor predictors of % damage is that crops may differ markedly in their accessibility, i.e. the ease with which the crop can be raided. Crops were therefore divided into three groups on this basis : sub-soil crops, ground level crops and tree crops. Sub-soil crops must be dug out or pulled from the soil and are grown in open fields away from cover. Ground level crops do not need to be dug or pulled out of the soil, but they are also grown in open fields. Tree crops can be accessed by monkeys whilst they are off the ground and inconspicuous.

Mean carbohydrate content differed significantly between sub-soil crops, ground level crops and tree crops ( $F = 4.8$ ,  $P < 0.02$ ) ; sub-soil crops having the highest carbohydrate content (Fig. 3). Sub-soil crops also had higher mean fat and mean protein content than ground level and tree crops, but differences between crop groups were not statistically significant (fat,  $F = 1.2$ ,  $P > 0.05$  ; protein,  $F = 1.7$ ,  $P > 0.05$  ; Fig. 3). Despite the lower nutritional value of tree crops

compared to sub-soil crops, % damage to tree crops was significantly higher (22.9 %) than for ground level crops (8.3 %) and sub-soil crops (7.04 %,  $F = 8.72$ ,  $P = 0.001$ ). This suggests that monkeys face a trade-off when foraging, between maximising nutritional returns and minimising risk of predation, and that minimising risk of predation may be particularly important. Therefore, the effects of nutritional composition on % damage were analysed separately within the three crop groups.

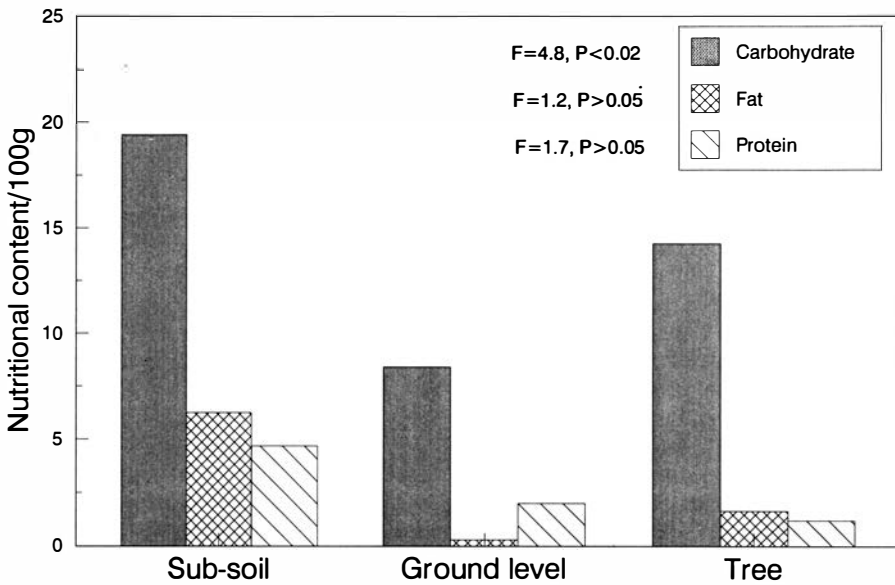


Figure 3. — Mean carbohydrate, fat and protein content (g per 100 g portion) of sub-soil, ground level and tree crops.

### Sub-soil crops

Considering sub-soil crops only ( $n = 8$ ), % damage was significantly correlated with calorific value and fat content (Calorific value  $r = 0.8$ ,  $P = 0.03$ ; fat  $r = 0.77$ ,  $P = 0.04$ ; Fig. 4), weakly correlated with protein ( $r = 0.74$ ,  $P = 0.06$ ; Fig. 4), and not correlated with carbohydrate ( $r = 0.14$ ,  $P > 0.05$ ).

In sub-soil crops, as was true for all crops, carbohydrate content was not correlated with either fat or protein content, but fat content was positively correlated with protein content ( $r = 0.99$ ,  $P < 0.001$ ). The tendency for protein content to be correlated with % damage could therefore result from its correlation with fat content; and perhaps vice versa. Given the strength of the correlation between fat and protein, it is not possible to detect independent effects of either on % damage. The most appropriate conclusion may therefore be that % damage to sub-soil crops is highest to those in which both fat and protein content is high.

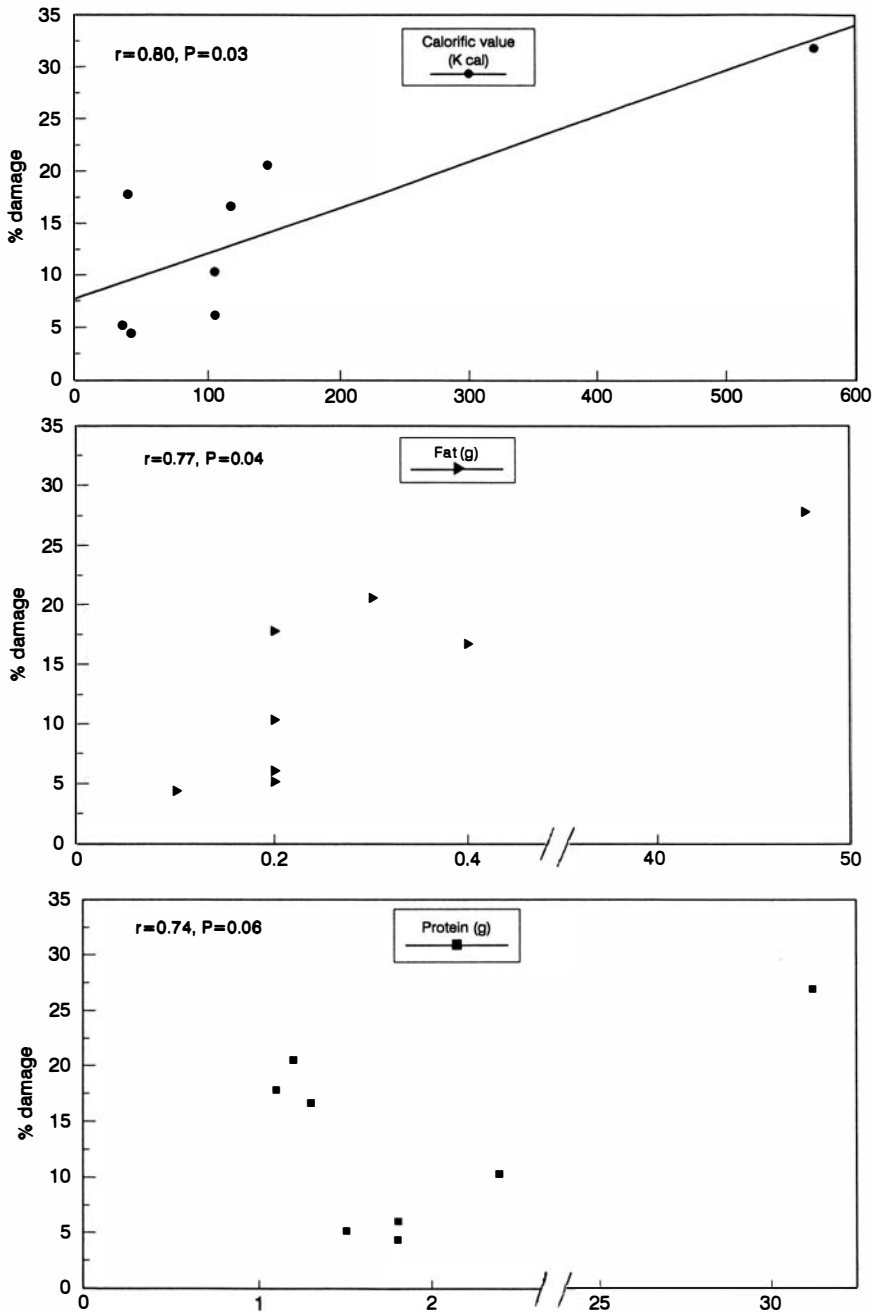


Figure 4. — Mean % damage by monkeys to sub-soil crops versus caloric value, fat and protein content (g per 100 g portion of crop).



## Ground level crops

Considering ground level crops only ( $n = 12$ ), % damage was significantly correlated with calorific value ( $r = 0.64$ ,  $P = 0.03$ ), carbohydrate ( $r = 0.64$ ,  $P = 0.03$ ), fat ( $r = 0.63$ ,  $P = 0.04$ ) and protein ( $r = 0.6$ ,  $P = 0.05$ ; Fig. 5 et 6). However, protein, fat and carbohydrate were strongly positively intercorrelated ( $r > 0.8$  in all cases). Given this, it is not possible to detect independent effects of either carbohydrate, fat or protein on % damage. Therefore, the most appropriate conclusion may be that % damage to ground level crops is highest on crops that are simultaneously high in carbohydrate, fat and protein.

## Tree crops

Considering tree crops only ( $n = 14$ ), % damage was not correlated with either calorific value ( $r = -0.19$ ,  $P > 0.05$ ), carbohydrate ( $r = 0.05$ ,  $P > 0.05$ ), fat ( $r = -0.25$ ,  $P > 0.05$ ) or protein ( $r = 0.21$ ,  $P > 0.05$ ) contents. Moreover, carbohydrate, fat and protein were not significantly intercorrelated ( $P > 0.05$  in all cases).

The above results suggest that crop preference based on nutritional composition may only be shown when choice of particular crops can simultaneously increase more than one food component. Among tree crops, where individual items are not simultaneously high in nutrients, monkeys may therefore have to select a range of items in order to obtain a balanced diet. An alternative explanation may be that monkeys are only selective under high-risk foraging conditions i.e. when maximising food returns per unit foraging time is critical because of the risk of predation. Finally, there may be other factors that affect foraging on tree crops strongly enough to diminish effects of food content at the level analysed. One possible factor is the skin characteristics of tree crops.

### *Skin characteristics of tree crops*

Two aspects of skin characteristics which may be important in this context are the toughness of the skin (i.e. the difficulty with which the skin is penetrated) and skin colour.

The % damage to tree crops was negatively correlated with skin toughness ( $r = -0.54$ ,  $P = 0.05$ , Fig. 7), indicating a preference for fruits whose skins are more easily penetrated. An additional benefit of foraging on tree crops with more penetrable skin is the possibility that the skin itself may be consumed, reducing handling costs associated with removing the skin and perhaps increasing the food value of the fruit. The mean skin toughness of tree crops whose skins are consumed is indeed significantly lower than that of fruits whose skins are not consumed (edible 3.35 kg, inedible 8.32 kg,  $F = 4.6$ ,  $P = 0.05$ ). Consistent with these results, mean % damage tended to be higher for tree crops whose skins are consumed than for those whose skins are not (31.8 % to 18.9 %,  $F = 3.59$ ,  $P = 0.07$ ). Tree crops with edible skins did not differ significantly from tree crops with inedible skins in either carbohydrate (edible 13.7 g, inedible 14.5 g,  $F = 0.03$ ,  $P = 0.86$ ), fat (edible 0.83 g, inedible 2.0 g,  $F = 0.19$ ,  $P = 0.67$ ) or protein content (edible 0.78 g, inedible 1.3 g,  $F = 2.18$ ,  $P = 0.16$ ), suggesting that the reason why these crops are preferentially damaged is their soft skin rather than their nutritional composition.

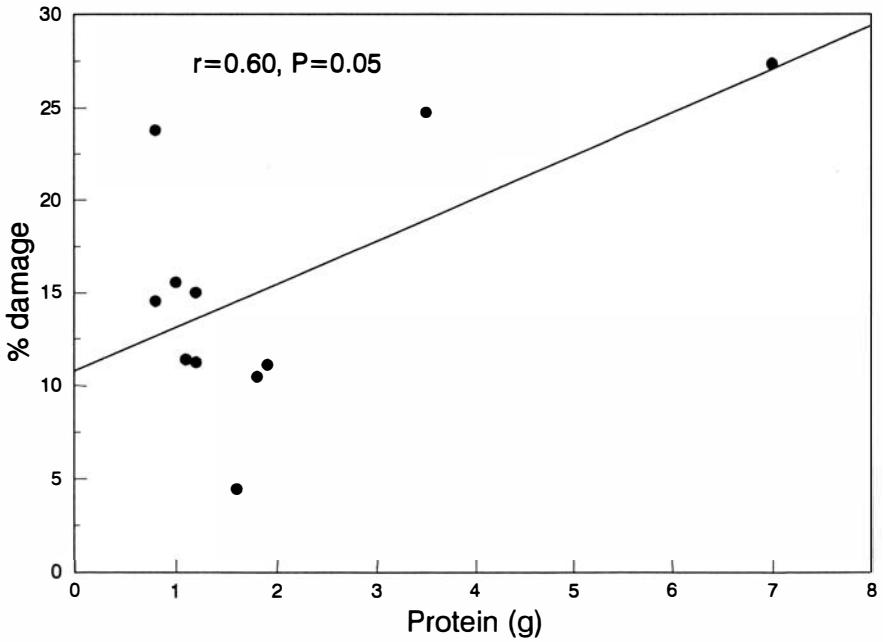
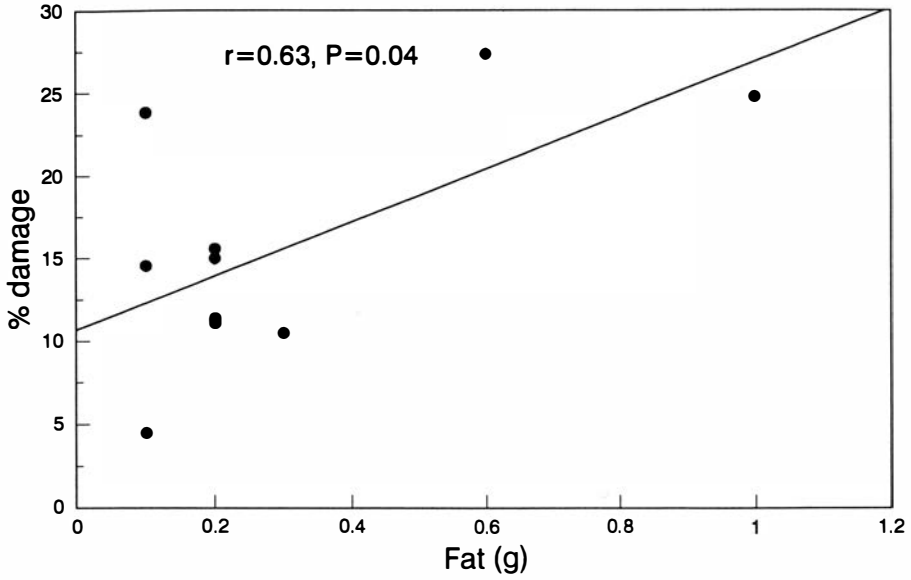


Figure 5. — Mean % damage by monkeys to ground level crops versus (upper) fat content and (low) protein content (g per 100 g portion of crop).

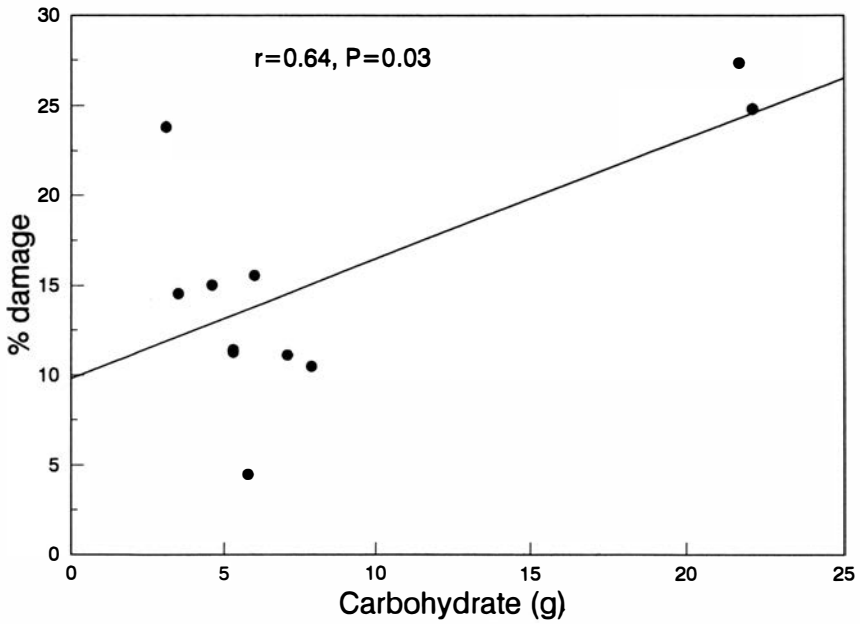
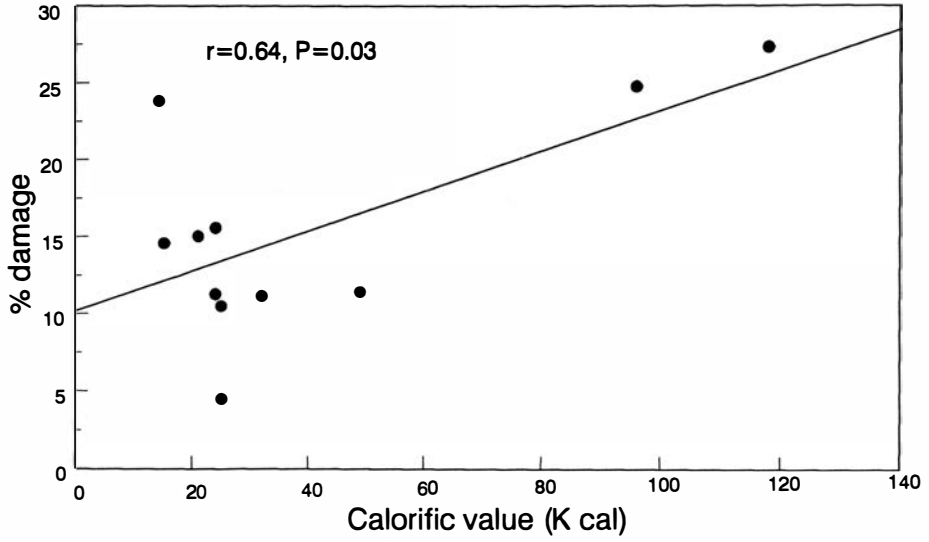


Figure 6. — Mean % damage by monkeys to ground level crops versus (upper) calorific value (K cal) and (lower) carbohydrate content (g per 100 g portion of crop).

64 per cent of the tree crops investigated were yellow when ripe ; 28.6 % were green when ripe. Mean percent damage tended to be higher for yellow crops

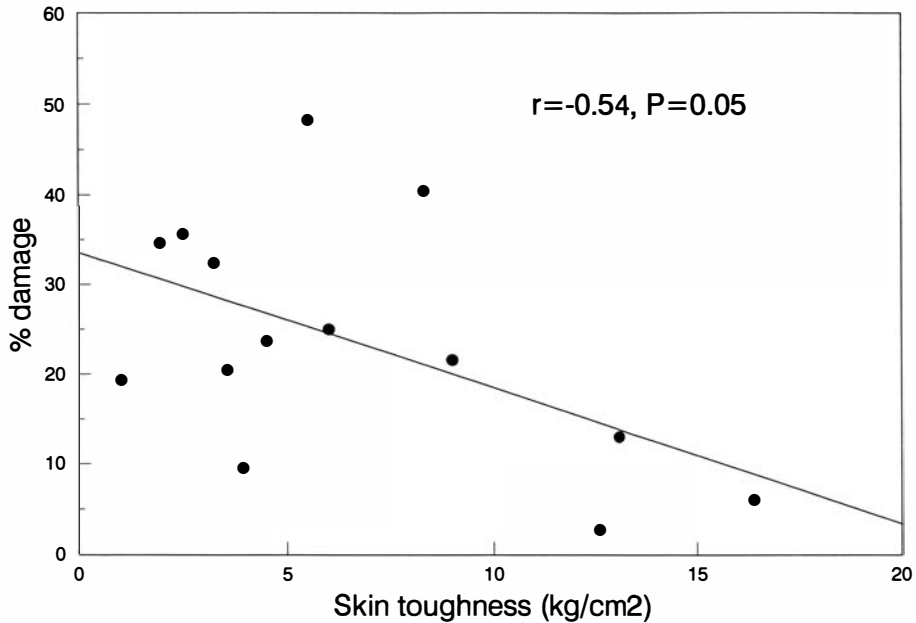


Figure 7. — Mean % damage by monkeys to tree crops versus skin toughness (kg/cm<sup>2</sup>).

(29.9 %) than for green crops (20.1 %,  $F = 3.16$ ,  $P = 0.10$ ), suggesting that yellow tree crops are preferred over green. A preference for yellow/orange/red fruits has previously been reported for several species of *Cercopithecus* in Gabon (Gautier-Hion *et al.*, 1985). Mean skin toughness of yellow crops in Barbados tended to be lower than that for green tree crops (for yellow 4.88 kg ; for green 9.74 kg,  $F = 4.03$ ,  $P = 0.07$ ). This suggests that yellow tree crops may be preferred over green tree crops because they have softer skin, and that yellow colour may be the means by which soft skin texture can be easily detected. Yellow tree crops did not differ from green tree crops in carbohydrate, fat or protein content (Carbohydrate, yellow 17.1 g, green 15.3 g,  $F = 0.19$ ,  $P = 0.67$  ; Protein, yellow 1.03 g, green 1.47 g,  $F = 1.75$ ,  $P = 0.22$  ; Fat, yellow 0.5 g, green 4.25 g,  $F = 2.0$ ,  $P = 0.18$ ) suggesting that they are preferentially damaged because of their colour, and associated skin texture, rather than the nutritional variables measured.

The correlations between skin characteristics and % damage are not strong however, indicating that much of the variation in % damage between tree crops remains unexplained. One factor that should be further investigated in this context is the proportion of total carbohydrate content that consists of simple sugars. The preference by monkeys for any tree crop increases as the crop ripens. This could partly be the consequence of skin texture softening with ripening. However, the proportion of simple sugars to complex carbohydrates also increases as fruits ripen. This suggests that, within any tree crop, the % of carbohydrate that consists of simple sugar may most accurately predict monkey preference, and that, between tree crop types at a given stage of ripeness, preference for a particular crop may be influenced by differences between crop types in the proportion of carbohydrate

that is simple sugar. Gautier-Hion *et al.* (1985) found fruit weight to be an important factor influencing fruit preference. Although weight was not specifically investigated in the present study, the majority of fruits preferred by monkeys were substantially heavier than those reported as preferred by *Cercopithecus* species studied in Gabon (5-50g), reflecting the fact that most of the fruits consumed in this study are cultivated. The difference between the two studies may therefore simply reflect differences in the availability of fruits of different weights. It should also be noted that, given their weight, many fruits in this study are consumed on the tree, reducing the importance of fruit weight in fruit preference.

#### WHAT FACTORS AFFECT LEVELS OF CROP DAMAGE ISLAND WIDE ?

The mean number of monkeys trapped per trap site (index of monkey abundance) in a parish is strongly correlated with overall mean % damage to crops in each parish (Spearman's rank correlation coefficient,  $r_s = 0.67$ ,  $P = 0.03$ ). There was no correlation between monkey abundance per parish and human population density ( $r_s = -0.42$ ,  $P > 0.05$ ), or between monkey abundance and total number of hectares of agricultural land in the parish ( $r_s = -0.25$ ,  $p > 0.05$ ). However, both monkey abundance per parish and overall mean % crop damage per parish were positively correlated with the total gully length within the parish (monkey abundance,  $r_s = 0.67$ ,  $P = 0.03$  ; overall crop mean % damage,  $r_s = 0.72$ ,  $P = 0.02$ ). Woodlands are largely restricted to the many gullies which traverse the island. This suggests that neither human population density nor food availability are as important in influencing the distribution of monkeys around Barbados as is availability of cover.

#### MANAGEMENT IMPLICATIONS

Barbadians have begun to view monkeys, not solely as pests, but as a valuable natural resource. Over 7 000 monkeys have been trapped in Barbados since 1980 ; with 30 % (about 2 000) coming from a handful of locations where farmers have suffered high levels of crop damage. The Barbados Primate Research Centre has demonstrated that there is a bio-medical research market for healthy animals that can be supplied on a reliable and sustained basis. The affiliated Barbados Wildlife Reserve, where monkeys can be viewed in semi-natural surroundings, attracts many visitors and Barbadians each year. These two uses of monkeys have assisted in offsetting the negative feelings Barbadians have traditionally held towards monkeys, arising from the more narrow perception that they are nothing more than agricultural pests. Trapping has now virtually replaced shooting as a means of control. A more commensal co-existence of monkeys and people in Barbados may therefore best be achieved through two simultaneous strategies.

The first strategy is to continue trapping at a level where the population is held at a size at which losses due to monkey crop damage are tolerable, but at a size that does not risk population collapse. To ensure this, areas where monkeys are not considered serious pests should be protected from trappers, and trapping should be concentrated in areas where crop damage is most severe.

The second strategy should be to use knowledge of the distribution of monkeys, of their food preferences, and of the rationale behind these preferences, to modify planting in such a way that crop damage may be further reduced. This may be achieved in the following ways :

(1) Encouraging farmers in susceptible areas to grow proportionately more foods now quantitatively identified as being less preferred by monkeys. This would include a shift towards low-growing and sub-soil crops, and away from tree crops ; a shift towards greener, tougher skinned tree crops, and away from yellow softer skinned tree crops for those tree crops that are retained ; and perhaps a shift in ground level crops and sub-soil crops towards those in which carbohydrate, fat and protein contents are not positively correlated, and hence are less preferred by monkeys.

(2) Encouraging farmers in more susceptible areas who wish to retain the use of crops now identified as being most vulnerable to damage, to plant them in the immediate vicinity of their homes where monkeys must take greatest risks to raid them.

(3) Given risk aversion and the importance of cover to monkeys, encouraging farmers to clear vegetation away from the edges of fields ; and

(4) Given the clear patterns of monkey preference for crops, encouraging farmers in susceptible areas to consider : Planting small quantities of crops which are highly preferred by monkeys but of low economic value, alongside crops which are less preferred by monkeys but of higher economic value ; Encouraging farmers to consider the feasibility of harvesting tree crops prior to the point where ripening moves them into preferred status by reducing skin toughness (or perhaps increasing their proportion of simple sugars), or alternatively to develop techniques of covering tree crops during the most vulnerable later stages of ripening as is already practised in banana cultivation, and Encouraging farmers to explore the feasibility of cultivating crops most preferred by monkeys during the wet season (June-September), when naturally growing food alternatives are most abundant in the gullies and woodlands of Barbados.

With the fall in sugar production, the direction that agriculture in Barbados will take in the future is currently under discussion. Against this background, continuation of sustainable trapping and implementation of the planting strategies identified in this study become particularly important as a means of moving the relationship between vervets and people in Barbados from an overly competitive and often hostile one, to a less competitive and more commensal one.

## RÉSUMÉ

A la Barbade, les vervets vivent partiellement du pillage des cultures depuis leur introduction sur l'île à la fin du 16<sup>e</sup> siècle. La géographie de la Barbade se caractérise par l'alternance de terres cultivées (traditionnellement en canne à sucre) et de ravines boisées où les singes trouvent refuge. Les conflits entre les paysans et les singes se sont singulièrement accrus dans les 30 dernières années. Deux causes expliquent cette recrudescence : la première cause fut l'abandon de la coupe du bois de feu dans les ravines qui a entraîné l'accroissement du nombre des vervets pouvant y vivre et s'y cacher, la seconde fut le passage d'une agriculture sucrière à la culture des fruits et légumes, largement préférés par les vervets. Une enquête conduite en 1980 a décrit les types et l'étendue des dommages causés à 34 différentes cultures de la Barbade. Pour comprendre pourquoi certaines cultures sont préférées par les vervets, la composition nutritionnelle, la forme de croissance et les caractéristiques de l'enveloppe externe de ces 34 fruits et légumes ont été comparés.

Les fruits fournis par les arbres sont les plus attaqués, bien que ces fruits soient généralement moins riches que les légumes souterrains ou ceux qui poussent à la surface du sol. La consommation préférentielle de ces fruits serait liée à la diminution du risque de prédation. La composition nutritionnelle ne rend pas compte des préférences observées parmi ces fruits. Les vervets préfèrent les fruits dont la peau est comestible et de couleur jaune à maturité. Sur la base de ces résultats, de nouvelles stratégies de plantation ont été proposées.

Les vervets sont donc en compétition alimentaire avec l'homme, et pour pouvoir les considérer comme commensaux de l'homme, c'est-à-dire comme bénéficiant de l'activité humaine sans lui nuire, on doit élargir la perspective en incluant les bénéfices qu'ils apportent à la recherche biomédicale et au tourisme et qui compensent les pertes qu'ils occasionnent aux cultures.

Mots-clés : Vervet, *Cercopithecus aethiops sabaesus*, choix alimentaire, compétition, pillage des cultures, composition nutritionnelle, stratégies de plantation.

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