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HOW HARD ARE *ENTEROLOBIUM CYCLOCARPUM* (LEGUMINOSAE) SEEDS?

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ABSTRACT

A weight-loading machine was used to measure the force required to break mature seeds of *Enterolobium cyclocarpum.* The force required to break the seeds increases with increased weight of the seed, and seeds on the flat side require more weight to break than on edge. Peccaries eat the fruits of *E. cyclocarpum;* they crush some seeds and spit out others. This variation in seed weights, and therefore force necessary to break them, is important if the peccaries are to be seed dispersal agents as well as seed predators.

When mature fruits of *Enterolobium cyclocarpum* were offered to captive Costa Rican collared peccaries (*Dicotyles tajacu*), they chewed up the fruit and swallowed some portions. Some of the large seeds were spit out, a few were swallowed entire, but most were broken between the molars before swallowing. When individual clean seeds were fed to a peccary one at a time, they were all broken, ground up, and swallowed. However, the seeds of *E. cyclocarpum* appear to be very hard when broken with a hammer.

Here, we explore the force required to break mature seeds of *E. cyclocarpum.*

Methodology

E. cyclocarpum is a common indigenous canopy-member tree in deciduous forests of the Pacific northwestern lowlands of Costa Rica. Its common name is "guanacaste". Mature fruits were collected from the ground below large permanently marked trees in Santa Rosa National Park (Guanacaste Province, March 1976; Figure 1). The seeds were shelled out of these naturally dried fruits in September and November 1976, and stored at laboratory humidity until January 1977, at which time they were weighed to the nearest milligram. In April-May 1977, they were broken in a weight-loading machine (Universal Testing Instrument, Instron Corp., Canton, Massachusetts).

The seed was placed between two flat steel surfaces and pressure applied at a rate of 0.1 inch per minute. The seed of *E. cyclocarpum* is slightly dome-shaped on all surfaces, and therefore the machine began to apply pressure at two points rather than over measurable area. However, as the pressure was increased, the surface of the seed deformed slightly so that the pressure was applied to two areas of 1–4 mm^2 each. The variation in size of this deformation area may have been in part responsible for the variation in force required to break the seeds.

Owing to the slippery nature of smooth steel surfaces, seeds could be broken only through pressure on seeds laying flat or on edge (at approximately right angles to the seed in its "laying flat position"). About 3% of the seeds were sufficiently asymmetrical that they could not be broken on edge between the two surfaces. Seeds to be broken were not selected at random from the array of seed weights available from one tree. Rather, a sample of 30 to 50 was drawn randomly from the array of seeds at the center and the two extremes of seed weights. For seeds to be broken on edge, only seeds in the center of the weight distribution were used.

The machine recorded continuing increase in force applied on a strip chart moving 1 inch per minute. When the seed broke, the chart recorded a sudden release in force as the seed collapsed away from the two steel surfaces. The force applied to break a seed is the greatest force recorded before this collapse occurs. If the force were applied at a different but similar rate, we doubt that the force required to break the seed would change much until the speed was fast enough to approximate a sudden blow. We assume that the rate of force applied in this study reasonably approximates that which a peccary applies when breaking a seed.

Results

Within a seed crop, the force to break an *E. cyclocarpum* seed lying on its flat side varied linearly with the weight of the seed, and the heavier the seed, the more weight was required to break it (Figure 2).

Within all three trees, the weight required to break the average weight seeds was significantly different from the weight required to break seeds at either the light or heavy end of the weight distribution for that tree. Tree 17 and 19 had seeds that broke with the same amount of weight, but tree 18 had seeds that are clearly harder than those of 17 and 19.

When the seeds are placed on edge, the relationships all disappear. For all three trees, the load to break was not significantly different, despite the 100 mg range in mean seed weight of the seeds broken. Seeds on edge break at about 1/2 to 1/3 of the weight as those on their flat side.

Discussion

Seeds embracing the range of seed weight tested in our study can be found in a single fruit. Since lighter seeds break more easily than heavier seeds, this may explain in part why certain seeds are spit out and others broken when a peccary chews up a fruit of *E. cyclocarpum.* If the pressure to break a seed is anywhere near that which endangers the teeth of the peccary (and we have found skulls in nature with the cusps broken off), it would not be surprising to find that peccaries have learned to search for smaller seeds. They may also learn to seek out those trees whose seed crops contain seeds that break more easily on average (e.g., tree 17 and 19 rather than tree 18). If peccaries act as dispersal agents as well as predators of *E. cyclocarpum* seeds, then it may be through a delicate balance of having seeds that are sometimes hard enough to resist cracking, but not hard enough that the animal never visits the tree. Non-visitation is probably a real danger if it is seed nutrients that are of most importance to the peccary, rather than the fruit wall.

When a peccary takes an *E. cyclocarpum* seed in its mouth, there is a moment of jaw motion during which it appears that the seed is being adjusted in position between the molars. The difference in ease of breaking guanacaste tree seeds on edge as compared with the flat side suggests that the animal may be placing the seed on edge before biting down on it. Peccary molars have high cusps and appear as though they could probably hold a smooth oval seed in almost any position while applying a strong force to it.

Since the force applied to the seeds was recorded continuously, we were able to observe a potentially important trait of a breaking seed. If a seed is going to break at 450 pounds pressure, for example, at about 350 pounds pressure a slight "give" occurs in the seed. It does not crack, however, in any manner that can be seen by visual inspection. If a peccary head contains pressure receptors that can perceive this, it can then know how much further pressure will be required to break the seed. With this knowledge, the risk to unwittingly breaking its molars should be minimized. We have noticed a similar "give" in other hard seeds being broken by the machine.

There was no obvious difference in seed coat thickness between seeds of tree 18, and trees 17 and 19. Likewise, for all the seeds broken, the seed contents were so hard that they shattered when broken.

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Resumen

Se midió en el laboratorio la fuerza necesaria para partir las semillas maduras de *Enterolobium cyclocarpum*, una leguminosa frecuente en los bosques deciduos de la provincia de Guanacaste, Costa Rica.

La fuerza requerida para partir las semillas es diferente según se aplique al canto o a las superficies central/dorsal. Es necesaria una fuerza mayor para fracturar las semillas por sus caras, que la usada para sus cantos. Hay una relación directa entre el peso de la semmila y su dureza.

Se ha observado que el pecarí de collar (*Dicotyles tajacu*) coloca las semillas de *Enterolobium* en cierta posición entre sus molares antes de ejercer presión y masticarlas, escupiendo las más pesadas (y más duras). Se comparan los pesos y durezas de semillas de árboles selectos y se discute la importancia de estos factores físicos en el rol de dispersar y consumidor de semillas que desempeña el pecarí.

Table 1. Breakage parameters for *Enterolobium cyclocarpum* seeds from three trees in Santa Rosa National Park, Guanacaste Province, Costa Rica. All mean loads to break on flat side are significantly different from each other within a tree (t test, $p < .01$). All seeds on edge, all mean loads to break on edge are significantly different from the same weight class seeds within a tree (t test, $p < .001$). By inspection of Figure 2, the slope of load to break against seed weight is not significantly different among the three trees, but tree 18 has a different intercept from tree 17 and 19.

	n	$\bar{X}$ seed weight (mg)	s.d. seed weight (mg)	$\bar{X}$ load to break (pounds)	s.d. load to break (pounds)
E. cyclocarpum 17					
on flat side	36	673	15.3	323	50.4
	36	778	14.2	355	49.3
	36	862	7.7	402	50.6
on edge	31	779	13.3	164	38.8
E. cyclocarpum 18					
on flat side	36	564	23.1	339	32.0
	34	696	14.0	403	45.2
	40	842	30.2	459	46.9
on edge	40	699	16.3	176	17.8
E. cyclocarpum 19					
on flat side	45	638	58.9	297	56.1
	38	800	16.1	364	35.2
	46	985	55.9	413	40.3
on edge	31	803	12.5	168	22.5

Figure 1. Newly fallen mature fruits of *Enterolobium cyclocarpum* (April 1976, Santa Rosa National Park, Guanacaste Province, Costa Rica). Each oval raised area on the fruit contains one seed.

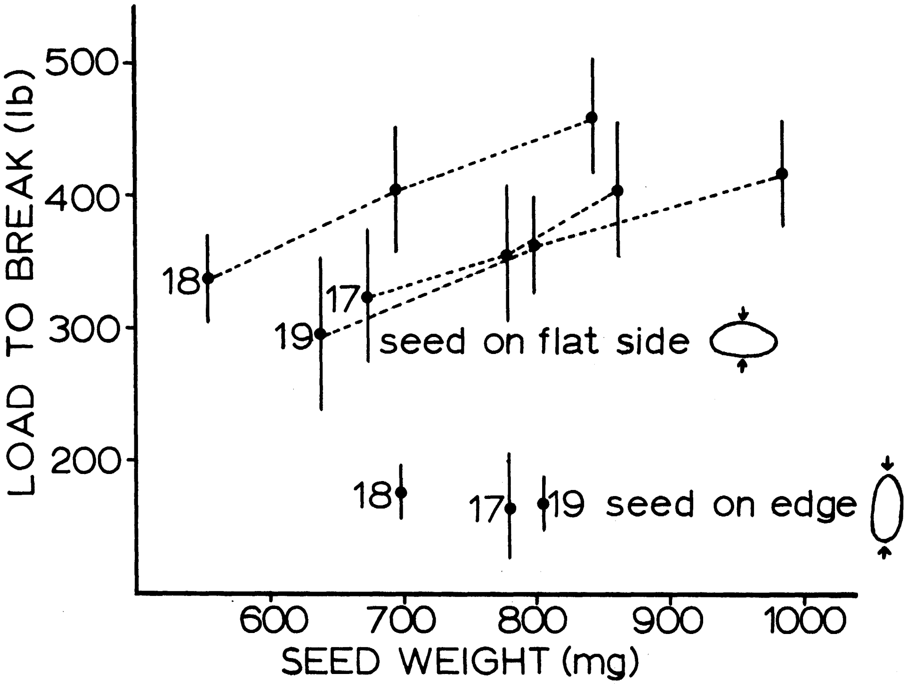

Figure 2. Relationship of *Enterolobium cyclocarpum* seed weight (mg) and individual tree to the load required to break the seed (pounds). Large dots are means of 30 to 50 trials, and entire lines represent one standard deviation on each side of the mean. The three subsamples were chosen to represent the center and the two extremes of seed weights in the entire sample from one tree.