Fruit and seed yields in chataigne (*Artocarpus camansi* Blanco) in Trinidad and Tobago

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Abstract — **Introduction**. The chataigne or breadnut, *Artocarpus camansi* Blanco, has high nutritive value but it is an under-utilised food source. Yield losses due to tree height and limited information on productivity are constraints to commercial production. Our study was undertaken to determine fruit yield and seed yield, the relationship between fruit size and seed yield, and the response of yield to pruning. **Materials and methods**. Fruit and seed yield data were collected from 1996 to 2002 from three seedling trees established at the University of the West Indies in Trinidad and Tobago in 1993. The trees were pruned in December 1998. **Results**. The highest fruit mass per tree (139.7 kg), fruit number per tree (126) and seed mass per tree (59 kg) were obtained in 5-year-old trees. Fruit and seed yields were significantly ($P < 0.001$) lower in the years after pruning. Fruit mass per tree was positively correlated with fruit number ($r = 0.99$). Seed mass per fruit was positively correlated with seed number per fruit ($r = 0.87$) and both variables had strong, positive correlations with mean fruit mass ($r = 0.83$ and $r = 0.77$, respectively) and fruit volume ($r = 0.63$ and $r = 0.67$, respectively). **Discussion and conclusions**. Chataigne fruit and seed yield potential is greater than originally estimated. Both are strongly related and selection for high seed number per fruit with more effective pollination, disease control and proper tree height management may further increase productivity. In the field, estimated fruit volume is the most practical indicator of seed yield.

Trinidad and Tobago / *Artocarpus camansi* / fruits / seeds / yield components / pruning / crop management

Rendements en fruits et graines du châtaigner des Antilles (*Artocarpus camansi* Blanco) à Trinité-et-Tobago.

Résumé — **Introduction**. Le châtaigner des Antilles, *Artocarpus camansi* Blanco, a une forte valeur nutritive, mais sa consommation est limitée. Les pertes de rendement dues à la dimension de l'arbre et au manque d'informations sur sa productivité sont des obstacles à son exploitation commerciale. Notre étude a été entreprise pour déterminer, sur cette espèce, le rendement en fruits et en graines, le rapport entre la dimension du fruit et son rendement en graines, et l'effet de la taille de l'arbre sur son rendement. **Matériel et méthodes**. Des données de rendement en fruits et en graines ont été collectées de 1996 à 2002 sur trois arbres issus de graines établis à l'université des Indes occidentales à Trinité-et-Tobago en 1993. Les arbres ont été taillés en décembre 1998. **Résultats**. Le poids de fruits par arbre le plus élevé (139,7 kg), le nombre de fruits par arbre (126) et le poids de graines par arbre (59 kg) ont été obtenus sur des arbres âgés de 5 ans. Les rendements en fruits et en graines ont été significativement ($P < 0{,}001$) inférieurs au cours des années qui ont suivi la taille des arbres. Le rendement de fruits par arbre a été très corrélé avec le nombre de fruits ($r = 0{,}99$). Le poids de graines par fruit a été très corrélé avec le nombre de graines par fruit ($r = 0{,}87$) et les deux variables ont eu de fortes corrélations positives avec le poids moyen de fruit ($r = 0{,}83$ et $r = 0{,}77$, respectivement) et avec le volume du fruit ($r = 0{,}63$ et $r = 0{,}67$, respectivement). **Discussion et conclusions**. Les possibilités de rendement en fruits et en graines du châtaigner des Antilles se sont révélées plus grandes que celles estimées auparavant. Ces deux caractères sont fortement connexes et la recherche d'un nombre élevé de graines par fruit du fait d'une pollinisation plus efficace, un meilleur contrôle des maladies et la gestion appropriée de la taille des arbres pourrait augmenter à terme leur productivité. Sur le terrain, l'estimation du volume des fruits est l'indicateur le plus fiable du rendement en graines.

Trinité-et-Tobago / *Artocarpus camansi* / fruits / graine / composante de rendement / taille / conduite de la culture

1. Introduction

Artocarpus camansi Blanco, commonly known as the chataigne, breadnut, *pana de pepita* or *castaña* in the Caribbean and as *kamansi* in the Philippines, is an under-exploited species with significant potential as a tropical tree nut and a highly nutritious food source. It is a distinct species from the breadfruit [*A. altilis* (Park.) Fosberg, syn. *A. communis* Forst., *A. incisa* L.] [1], with which it has been confused as a seeded type but, apparently, it could be an ancestor [2].The fruit contains numerous ovoid to sub-globose seeds that are approximately 2.5 cm long and enclosed within a dark brown, woody endocarp. A 100-g portion of dried seed consists of (13.3 to 20) g protein, (6.2 to 12.8) g fat, 76.2 g total carbohydrates and (2.5 to 3.9) g fibre, and methionine, leucine, isoleucine and serine account for more than 50% of the amino acids [3, 4]. With its high protein content and carbohydrate content but low fat content, chataigne is similar to the African breadfruit (*Treculia africana* Decne. ex Trécul) as a healthier food source [5] than other tropical tree nuts with high fat content such as cashew (*Anacardium occidentale* L.), Brazilian nut (*Bertholletia excelsa* Bonpl.), and macadamia nut (*Macadamia ternifolia* f. Muell.) [6]. It also contains lectin, a carbohydrate-binding protein usually found only in legumes [7].

In the Caribbean, the seeds of mature fruits are consumed after boiling, frying or roasting. The immature fruits are eaten as a curried dish in Trinidad and Tobago and Guyana, where chataigne is most popular. Baked products made by substituting (25 to 50)% wheat flour with chataigne seed flour [8] and seeds canned in brine after chemical peeling [9] have good acceptability. In Trinidad and Tobago, where seeds and fruits are sold in local markets and fruits are exported, most production comes from trees in backyards or scattered throughout cocoa estates. Two constraints to commercial production are that data on chataigne fruit and seed yield are limited [3, 4, 10, 11] and the considerable seed loss from fallen, over-ripe fruit, because it is difficult to assess fruit maturity due to tree height. Information on tree productivity and the relationships between yield components are critical for improving the management and harvesting of the crop. Our study was undertaken to investigate chataigne fruit and seed yields before and after tree pruning to reduce tree height and the relationships between seed yield and fruit size.

2. Materials and methods

From 1996 to 2002, data on chataigne yield were collected from three trees growing in an *Artocarpus* germplasm collection at the University of the West Indies Field Station in Valsayn, Trinidad and Tobago (lat. 10° 2' to 11° 12' N, long. 60° 30' to 61° 56' W). The soil type at the site is River Estate Loam, classified as a Fluventic Eutropept, fine loamy, micaceous isohyperthermic. Mean diurnal temperature, relative humidity and annual rainfall receipt at this location over the study period was 26.8 °C, 73.3% and 1 575 mm, respectively. These trees were established in 1993 as seedlings. In December 1998, after harvesting, the trees which had grown to approximately 7.6 m tall were pruned to a height of 4.5 m to facilitate harvesting.

On each tree, all fruits were harvested at the mature to slightly ripe stage, counted and weighed. On a randomly selected sample of 35% of the harvested fruit, fruit length (l) and diameter (d) were measured and the volume (v) was estimated using $v = 3.14 \times r^2 \times l$, where $r = 0.5\ d$. From this sample, 20% of the fruit were selected randomly for information on seed yield (in the shell or endocarp). Data were analysed using descriptive statistics and analysis of variance. Regression analysis was used to determine the relationships between fruit yield, seed yield, yield components and fruit dimensions. The statistical program Minitab for Windows (version 12.21, 1998) was used for these analyses.

3. Results

3.1. Fruit yield

In 1996, one tree produced seven fruits with a total weight of 6.4 kg and all trees were in production from 1997. Most fruit were harvested in October and November but the

Table I.
Fruit yield and fruit size of *Artocarpus camansi* fruits measured in Trinidad and Tobago, before tree pruning (1997 and 1998) and after tree pruning (1999–2002).

Year	Total fruit mass per tree (kg)	Number of fruits per tree	Mean fruit mass (kg)	Mean fruit length (cm)	Mean fruit width (cm)	Mean fruit volume (dm^3)
1997	72.47 b	57.00 bc	1.21 a	15.24 b	13.32 a	214.52 a
1998	139.73 a	126.00 a	1.14 ab	16.16 a	13.18 a	221.50 a
1999	72.60 b	68.33 b	1.06 b	16.54 a	13.11 a	225.98 a
2000	21.37 c	25.33 d	0.89 c	14.41 c	12.40 b	176.04 b
2001	27.67 c	29.67 cd	0.92 c	14.52 bc	12.21 b	171.22 b
2002	33.17 c	32.00 cd	1.05 b	14.67 bc	12.46 b	181.08 b
$L.S.D_{(0.05)}$	30.91	30.63	0.12	0.74	0.50	20.87
Before Pruning	106.10	91.50	1.17	16.13	13.12	220.28
After pruning	38.70	38.83	0.98	15.97	12.94	214.43
$L.S.D_{(0.05)}$	32.13	31.12	0.09	ns	ns	ns

Values in the same column and followed by the same letter are not significantly (P < 0.05) different.
ns: not significant.

tree harvest period over the years varied from (5 to 26) weeks, with shorter harvest periods after pruning. Over the 7-year period, the mean total fruit mass per tree and per year was 52.7 kg and the mean fruit number per tree and per year was 49. The highest (P < 0.001) fruit mass per tree, 139.73 kg, and fruit number per tree, 126, were borne in 1998 before pruning (*table I*). Total fruit mass per tree and fruit number per tree were significantly (P < 0.001 and P < 0.003, respectively) lower after pruning. After pruning, little regrowth occurred in 1999. In subsequent years, a considerable number of branches showed dieback disease symptoms but, by 2002, the trees were recovering. Approximately 30% of all fruit produced annually fell prematurely.

All measurements of fruit size showed that generally the fruit were significantly (P < 0.001) larger from 1997 to 1999 than in later years (*table I*). Over all years, the mean fruit mass was 1.03 kg with individual fruits ranging from (0.38 to 1.85) kg. Fruit length ranged from (11 to 20.5) cm, and mean length was 15.2 cm, while fruit width varied from (9 to 16.5) cm and the mean width was 12.7 cm. The mean fruit volume was 1958 cm^3 and values ranged from (753 to 3918) cm^3.

3.2. Seed yield

The mean seed mass per tree before pruning was 42.3 kg, with the highest productivity among 5-year-old trees, one of which produced 66 kg before pruning. Subsequently, estimated seed mass per tree was significantly (P < 0.001) lower from 2000 to 2002 than in the previous years (*table II*). Seed mass per fruit, its components, and the seed mass to fruit mass ratio were not significantly different in the years before and in those after pruning. Over the 1997 to 2002 period, the average seed mass per fruit was 456 g and values ranged from (150 to 925) g. Seed number per fruit ranged from 15 to 98, with a mean of 56 seeds. The mass of an individual seed varied from (5.6 to 16.7) g and the mean was 8.3 g. The average seed mass to fruit mass ratio was 0.43 and the range was 0.19 to 0.67.

3.3. Relationships between fruit yield, seed yield and fruit size

There were no significant differences between the years before and those after pruning for any of the relationships; therefore, all years

Table II.
Seed yield of *Artocarpus camansi* fruits measured in Trinidad and Tobago, before tree pruning (1997 and 1998) and after tree pruning (1999–2002).

Year	Estimated seed mass per tree (kg)	Total seed mass per fruit (g)	Number of seeds per fruit	Mean seed mass (g)	Seed mass per fruit mass (%)
1997	25.25 bc	442.86	53.43	8.51	0.38 b
1998	59.35 a	471.28	59.62	8.14	0.41 ab
1999	34.37 b	502.79	61.21	8.34	0.46 a
2000	8.13 c	327.78	44.11	7.56	0.36 b
2001	14.09 c	475.00	59.25	8.17	0.42 ab
2002	13.43 c	416.67	45.00	9.33	0.42 ab
$LSD_{(0.05)}$	19.01	ns	ns	ns	0.08
Before pruning	42.30	462.62	57.92	8.23	0.41
After pruning	17.53	461.12	56.81	8.22	0.43
$LSD_{(0.05)}$	48.77	ns	ns	ns	ns

Values in the same column and followed by the same letter are not significantly ($P < 0.05$) different.
ns: not significant.

from 1997 to 2002 were pooled to derive the regression models; only models showing significant relationships with at least moderately strong correlations were presented (*table III*).

3.3.1. Relationships between fruit yield per tree, fruit yield components and fruit dimensions

There was a very high positive and highly significant correlation between fruit mass per tree and fruit number per tree ($r = 0.99$; $P < 0.001$) (*table III*). Moderate positive correlations were found between fruit mass per tree and mean fruit mass ($r = 0.54$; $P < 0.02$) and between fruit number per tree and mean fruit mass ($r = 0.46$; $P < 0.05$).

The relationships between mean fruit mass and the other measurements of fruit size were strongly to moderately positive (*table III*). Mean fruit mass was more strongly correlated with fruit volume ($r = 0.73$; $P < 0.001$) than with fruit diameter ($r = 0.64$; $P < 0.001$) or with fruit length ($r = 0.59$; $P < 0.001$).

3.3.2. Relationships between seed yield per fruit, seed yield components and fruit size

There was a strongly positive correlation ($r = 0.87$; $P < 0.001$) between seed mass per fruit and seed number per fruit (*table III*), but seed mass per fruit and mean seed mass were not significantly related. The relationship between mean seed mass and seed number per fruit was weakly positive ($r = 0.31$; $P < 0.004$).

The relationships between seed mass per fruit and seed number per fruit, and all measurements of fruit size, were positive and very highly significant ($P < 0.001$) (*table III*). There were strong positive correlations between seed mass per fruit and mean fruit mass ($r = 0.83$) and between seed number per fruit and mean fruit mass ($r = 0.77$). The positive correlations of seed mass per fruit and seed number per fruit with fruit length were both moderately strong ($r = 0.68$ and $r = 0.64$, respectively). The positive correlations between seed mass per fruit and fruit diameter ($r = 0.47$) and between

Table III.
Relationships between fruit yield, seed yield and fruit size of *Artocarpus camansi* fruits measured in Trinidad and Tobago, from 1997 to 2002 ($P < 0.001$).

y	*x*	*N*	Model	R^2
Fruit mass per tree	Fruit no. per tree	18	$y = -2.73 + 1.13\,x$	0.98
Mean fruit mass	Fruit length	364	$y = -290.0 + 87.9\,x$	0.35
Mean fruit mass	Fruit diameter	364	$y = -844.9 + 149.11\,x$	0.41
Mean fruit mass	Fruit volume	364	$y = 294.0 + 0.39\,x$	0.54
Seed mass per fruit	Seed no. per fruit	80	$y = 57.1 + 7.06\,x$	0.75
Seed mass per fruit	Mean fruit mass	80	$y = -74.88 + 0.49\,x$	0.69
Seed mass per fruit	Fruit volume	80	$y = 69.8 + 0.181\,x$	0.40
Seed mass per fruit	Fruit length	80	$y = -459 + 57.4\,x$	0.46
Seed no. per fruit	Mean fruit mass	80	$y = -3.60 + 0.056\,x$	0.59
Seed no. per fruit	Fruit volume	80	$y = 16.20 + 0.02\,x$	0.45
Seed no. per fruit	Fruit length	80	$y = -49.9 + 6.68\,x$	0.41

seed number per fruit and fruit width (r = 0.57) were moderate. There were moderately strong, positive correlations between seed mass per fruit and seed number per fruit, and fruit volume (r = 0.63 and r = 0.67, respectively) (*table III*). There was little or no positive correlation (r < 0.30) between mean seed mass and any measurement of fruit size.

4. Discussion and conclusion

Our results showed that the productivity of chataigne is greater than previously estimated. It was reported that during its first year of bearing, a 6-year-old chataigne tree produced 32 fruits with a mean seed weight of 350 g [10]. The estimated total seed yield was, therefore, 11.2 kg. The estimated seed yield from another report [11] was 19.2 kg based on fruit mass per tree of 48 kg and percentage seed mass of 40%. Our study indicated that chataigne seedling trees commenced bearing 3 to 4 years after field establishment and produced an annual seed yield of 59 kg per tree by the second to third year of bearing. This yield compares favourably with the annual nut-in-shell yield of (14 to 21) kg per tree from 6-year-old cashew trees[1] and the 10 kg per tree for 8-year-old macadamia trees[2]. A chataigne seed yield of 11 $Mt \cdot ha^{-1}$ was estimated based on data from previous studies and assumptions of fruit yield of 200 fruits per tree, as for breadfruit, and 100 $trees \cdot ha^{-1}$ [12]. With a similar plant density assumption, the seed mass per tree of 59.4 kg from 126 fruits per tree obtained in our study would yield approximately 6 $Mt \cdot ha^{-1}$. However, these estimates of productivity on an area basis may be unreliable given the low number and young age of the trees that we studied and the relative absence of data on the production system, fruit and seed yield per tree, tree number and age, and small number of fruits used in the earlier studies.

High variability in seed mass per tree before and after tree pruning was attributable to the variability in fruit number per tree and to the variables that were most strongly correlated with seed mass, mean fruit mass and seed number per fruit. The even greater variability in seed yield components obtained in our study than that previously reported

[1] Grundon N., O'Farrell P., Growing cashew before you start, www.dpi.qld.gov.au/horticulture/5342.html (accessed 24/03/05).

[2] Growing macadamia in NZ: the macnut guide, www.macnut.co.nz/grow.html (accessed 24/05/05).

[10, 11] emphasise the need to select high-yielding germplasm for cultivation. Based on their relationships with seed mass, seed number per fruit appears to be a more suitable selection criterion for high yield than mean seed mass, but the potential exists for both yield components to increase the seed mass per fruit and the seed mass to fruit mass ratio considerably. For commercial production, fruits with large seed numbers, high mean seed mass and high seed mass to fruit mass ratios are desirable. Since seed number per fruit was weakly correlated with mean seed mass and, on average, seed mass was less than 50% of fruit mass, orchard management practices can potentially further improve yield through manipulating pollination and environmental variables. Self-pollination and cross-pollination, both wind- and insect-assisted, occur in chataigne [11]. Bee hives and manual pollination might be effectively employed to increase seed yield in chataigne, as has been achieved with jackfruit [13]. The seasonal peaks in bearing suggested that environmental factors could be managed to improve both fruit and seed yield.

Canopy growth was another major influence on seed yield, through its effect on fruit production. The chataigne tree attains considerable height even while relatively young[3] because of a continuously growing orthotropic main stem which can lead to the harvesting of only fallen fully ripe fruit [10]. The mean annual growth rate of trees in our study was 1.2 m. However, chataigne trees are also more sparsely branched and produce smaller and fewer fruit per tree than breadfruit trees of a similar age [14]. Therefore, an assumed yield per tree of 200 fruits [12] in mature, unpruned trees might be exaggerated, and a high percentage of fallen fruit could reduce marketable seed yield significantly. Pruning reduced yield one year later, because it did not stimulate the proliferation of proleptic shoots on chataigne trees to the extent the author has observed in pruned breadfruit trees. Pruning was following by severe and prolonged dieback of the shoots, and significantly limited canopy regrowth and yield. Therefore, dieback control is important to facilitate proper investigations on the effectiveness of pruning on chataigne yield.

[3] Ragone D., *Artocarpus camansi* (breadnut), Species Profiles for Pacific Island Agroforestry, www.traditionaltree.org (accessed 18/08/05).

Appropriate harvesting practices can improve marketable yield. Peel colour and the space between adjacent anthocarps are indices of chataigne fruit maturity [15], but they are not useful for harvesting fruit on tall trees. Similarly, mean fruit mass, which showed a fairly strong correlation with seed mass, is impractical. Physical dimensions are the most convenient measurements of fruit size, especially for fruit borne high on the tree, and the estimated fruit volume, a three-dimensional measurement, is more reliable as a predictor of seed yield than one-dimensional measurements.

Chataigne has remarkable potential as an alternative food source in the tropics based both on its nutritional content and on its level of seed production, and there is significant potential for further improving fruit and seed yield. This can be accomplished through selection and by crop management to reduce constraints to productivity and marketability, including the effectiveness of pollination, disease and tree size. In the field, the best predictor of seed yield is the estimated fruit volume.

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Rendimientos en frutas y semillas del castaño de las Antillas (*Artocarpus camansi* Blanco) en Trinidad y Tobago.

Resumen — **Introducción**. El castaño de las Antillas, *Artocarpus camansi* Blanco, posee un fuerte valor nutritivo, pero su uso alimentario es poco frecuente. Las pérdidas de rendimiento debidas a la dimensión del árbol y a la falta de informaciones sobre la productividad son obstáculos para su explotación comercial. Nuestro estudio se emprendió para determinar, en esta especie, el rendimiento en frutos y en semillas, la relación entre la dimensión del fruto y su rendimiento en semillas, y el efecto de la poda del árbol sobre su rendimiento. **Material y métodos**. Se recogieron datos sobre el rendimiento en frutos y en semillas de 1996 a 2002 en tres árboles resultantes de semillas, establecidos en la universidad de las Indias occidentales hasta Trinidad y Tobago en 1993. Los árboles se tallaron en diciembre de 1998. **Resultados**. El peso más elevado de los frutos por árbol (173,7 kg), el número de frutos por árbol (126) y el peso de semillas por árbol (59 kg) se obtuvieron en árboles de 5 años de edad. Los rendimientos en frutos y en semillas fueron significantemente inferiores a lo largo de los años que siguieron la poda de los árboles. El rendimiento de frutos por árbol fue muy correlacionado con el número de frutos (r = 0,99). El peso de las semillas por fruto fue muy correlacionado con el número de semillas por fruto (r = 0,87) y ambas variables tuvieron fuertes correlaciones positivas con el peso medio por fruto (r = 0,83 y r = 0,77, respectivamente) y con el volumen del fruto (r = 0,63 y r = 0,67, respectivamente). **Discusión y conclusiones**. El potencial del rendimiento en frutos y en semillas del castaño de las Antillas resultó ser mayor que el que se estimó anticipadamente. Estos dos caracteres están fuertemente ligados y la búsqueda de un número elevado de semillas por fruto debido a una polinización más eficaz, un mejor control de las enfermedades y la gestión apropiada de la poda de los árboles podría aumentar, a largo plazo, su productividad. In situ, la estimación del volumen de los frutos es el indicador más fiable del rendimiento en semillas.

Trinidad y Tobago / *Artocarpus camansi* / frutas / semilla / caracteres de rendimiento / poda / manejo del cultivo