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Variability of Sap Yield in Kaong (*Arenga pinnata* (Wurmb) Merr.) in the Philippines

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ABSTRACT

The study aimed to find the extent to which sap yield in kaong (Arenga pinnata (Wurmb) Merr.)*, a potential source of bioethanol and sugar with low glycemic index, varies from one tree to another within the same locality and from one locality to another. The study was carried out using randomly selected trees from six natural stands located in different parts of the Philippines: Makiling Forest, College, Laguna; Cavinti, Laguna; Santor, Tanauan, Batangas; Cavite State University, Indang, Cavite; Sigma, Capiz; and Binaton, Digos, Davao del Sur. One inflorescence was tapped from each of the trees used in the study. The results showed that within the same locality, significant tree to tree variations exist in terms of tapping duration (total number of days a tree exudes sap) and in terms of average daily sap yield. Significant differences were also observed between morning (AM) and afternoon (PM) sap yields. PM yields were consistently higher, presumably because photosynthesis occurs at daytime.*

Trees differed widely in terms of tapping duration (range: 24 to 604 days; mean: 150 days). Average daily sap yield varied from one location to another. The highest yields were found for Mt. Makiling and Binaton. In all localities studied, tree to tree variation in sap yield was high. Yields of eight liters or more per day were recorded for some trees in Binaton, Indang, Sigma and Makiling. Sap yield showed no significant correlations with elevation, dry season length, soil pH and N and P content. The highly significant variations in sap yield among trees within the same locality indicate the possibility of raising high sap yielding plantations by obtaining planting materials from high yielding trees. This is just speculation though, since has not yet established the role of genetics in sap yield variability among kaong trees.

Keywords: Arenga pinnata, bioethanol, low glycemic-index sugar, sap yield variability

INTRODUCTION

The increasing demand for two types of products may have been responsible for the emergence of *Arenga pinnata*, known as kaong in the Philippines, from an obscure palm into a species of considerable scientific interest especially in Southeast Asia. These products are palm sugar and bioethanol.

Palm sugar

Palm sugar has increasingly become popular in Asian and Western markets in recent years due to the discovery that the product has a low glycemic index, 40±3, (Dr. Lorenzo Lapitan, Jr., personal communication, January 2014), which makes it appealing to people desiring to lose weight or control their blood sugar. In the Philippines, the primary source of palm sugar is fresh sap from the inflorescence of coconut. In Thailand and Cambodia, the main source of palm sugar is sap derived from Palmyrah palm (*Borassus flabellifer*).

The Philippines has been exporting palm sugar (from coconut) since 2009. Currently, the foreign market for palm sugar consists of the following countries: US, Canada, Norway, France, Middle East, Japan, Korea, Australia and New Zealand.

The demand for palm sugar is sure to increase in the years ahead as the health advantages of consuming a sweetener with a low glycemic index becomes more widely known among diabetic and obese people. With millions of people afflicted with diabetes all over the world, the demand for palm sugar as a sweetener would surely follow a rising trend.

Biofuels

Palm sap, such as those produced by coconut, palmyrah and nipa (*Nypa fruticans*) can also be processed into bioethanol, a type of biofuel that is of considerable interest not only in the Philippines but almost throughout the world. A sufficient supply of bioethanol would help the Philippines, or any country for that matter that is in a similar situation, to reduce its dependence on imported oil to satisfy its fuel requirements.

In recognition of the importance of biofuels (bioethanol and biodiesel), the Philippines passed Republic Act 9367 otherwise known as the Biofuels Act of 2006. Cited as objectives of the law are the following:

1. to reduce dependence on imported oil by using indigenous, renewable and sustainable sources,
2. to mitigate the toxic and greenhouse gas emissions,
3. to increase rural employment and income, and

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4. to ensure the availability of alternative and renewable clean energy without any detriment to the natural ecosystem, biodiversity and food reserves of the country.

The law mandated the incorporation of 1% biodiesel in diesel and 5% bioethanol in gasoline by 2009. On April 1, 2013, the required amount of bioethanol was raised to 10%.

To encourage the active participation of a huge number of investors in the production and distribution of biofuels, the framers of the Biofuels Act incorporated several important incentives, among which are the following:

1. zero tax for locally produced and imported biofuels,
2. sale of biofuel raw materials exempted from value-added tax or VAT,
3. considering water effluents as "reuse" for which there shall be no water charges, and
4. government lending institutions' high priority to investments in biofuel production.

Kaong as the subject of this study has been reported as having a higher sap yield per tree than coconut, palmyrah and nipa. Higher sap yield implies higher yield of sugar and higher yield of bioethanol in terms of volume, assuming of course that all other things are equal.

Unlike coconut, kaong is not grown in plantations in the Philippines. Although not considered as a native species, kaong grows in many provinces. They are usually found near human settlements, making some scientists think that they originated from plantings undertaken by early settlers in the country. In the course of many centuries and in the absence of human intervention, local populations of the species increased in size producing wildlings from seeds that were believed to be dispersed by wild animals such as the civet cat. This belief that the dispersal of the seeds of kaong is due to wild animals is now being questioned by some scientists, who argue that minute needle-like crystals present in the fruits of the species, which is known to cause severe itchiness among humans, would deter any animal from eating and spreading the seeds.

Guide questions that helped in formulating the objectives of the study

Several questions were considered in the formulation of the objectives of the study. These questions were:

1. Is the sap yield of kaong in a given stand constant? This question was raised based on the review of literature (Brown & Merrill 1920; Eberson and Oyean 2010; Florido & de Mesa 2003) which never mentioned sap yield as being variable from one tree to another.

2. Within a particular stand or community, how long can a tree be productively tapped? Would the duration of tapping be the same for all trees or is it variable? This question was raised because available literature (Brown & Merrill 1929; Eberson and Oyean 2010; Florido & de Mesa 2003) gave the impression that the period of tapping is more or less the same for trees growing in the same stand.

3. Is sap yield more or less the same for stands occurring in different geographic locations? If so and if not, what could be the possible reasons?

Importance of the Study

Knowing how sap yield varies among and within stands in kaong (and for that matter, other palms as well) is of primary importance in developing realistic plans for the production of various sap products from the species. Reliable data on sap yield are necessary for making estimates of ethanol yield, sugar yield, volume of obtainable animal feeds, and for estimating potential economic returns from future kaong plantations. With reliable sap yield data, potential sources of planting stocks with superior characteristics can be identified, making it possible to undertake a genetic improvement program for the species.

The study is based on the knowledge that geographic location can affect many of the structural, physical, mechanical and chemical properties of plants. This is because environmental conditions among different geographic locations are seldom uniform. Climate, topography, soil and altitude vary from one location to another and different species of plants adapt to their environment in order to survive, grow and reproduce. In the process of adapting to a particular environment, plants are able to acquire certain morphological, physiological and even chemical characteristics that may not be present in plants exposed to other environments. In this study, it is hypothesized that sap yield would show significant variations from one location to another.

In the process of adapting to their respective environments, modifications in the genetic composition of the plants could also occur. It is on the basis of this knowledge that developers of tree plantations give so much weight to seed sources (or provenance) in the production of high quality planting stocks. Another hypothesis in this study is that within a particular location, sap yield would exhibit significant tree-to-tree variations. In nature, no two individuals of a given species are exactly alike in terms of a set of traits. There is variability particularly when the individuals are products of open (natural) pollination.

Objectives of the Study

1. To determine the variability of sap yield among and within existing stands of kaong in the Philippines.
2. To draw up recommendations regarding the development of plantations of kaong.

Botanical Characteristics

Kaong reaches a height of 12 to 15 m and a diameter 40 cm when it reaches maturity. It has long ascending pinnate leaves up to 8.5 m in length that bear 100 or more pairs of linear leaflets that are whitish underneath. Once maturity is reached, huge clusters of flowers begin to appear. Male and female flowers occur in separate clusters. The male flower clusters are about 1.3 m in length, purple in color and with an unpleasant odor. The female flower clusters are longer than the male and ripen very slowly into glossy, brown, plum-sized fruit. Flowering starts at the uppermost leaf axil and proceeds downward to the lowest leaf axil. After the fruits in the lowest leaf axil have ripened, the tree dies.

Geographic Distribution

Kaong is widely distributed in many Asian countries (Figure 1). It has been reported to occur in the following countries: Bangladesh, Brunei, Cambodia, India, Indonesia, Laos, Malaysia, Myanmar, Papua New Guinea, Philippines, Singapore, Sri Lanka, Thailand, and Vietnam. The exact origin of kaong is not known but the present belief is that the species originated in what is now known as Kalimantan in Borneo.

Kaong was introduced to the Philippine islands long before the Spaniards discovered the country in 1521. This is indicated by the fact that, until now, kaong is found mostly near settlements, not inside virgin forests.

In the Philippines, kaong is known to occur in various provinces as shown in Table 1. It occurs in areas where total annual rainfall ranges from less than 1800 mm to greater than 2600 mm. As Table 1 indicates, it can withstand drought periods of up to 7 months.

Figure 1. Geographic distribution of kaong.

Products from Kaong

Kaong is a palm of considerable utility in the Philippines. Its leaves are used for thatching and making brooms. Its fruits are used for making a highly popular dessert and an ingredient for a delicious refreshment called *halo-halo* (a mixture of crushed ice, milk and different kinds of fruit preserves. Sap extracted from its young inflorescence is used for making sugar, vinegar, alcohol and liquor. At present, the most important use of kaong in the country is for the production of fruit preserves.

Table 1. Distribution of kaong in the Philippines

Zone	Province	Total Annual Rainfall (mm)	Dry Season Length (mos.)
Luzon	Camarines Norte	> 2600	0 - 1
	Laguna,Eastern	> 2600	0 - 1
	Polillo Is.	> 2600	0 - 1
	Quezon	> 2600	0 - 1
	Zambales	> 2600	6 - 7
	Abra	1800 - 2600	6 - 7
	Bataan	1800 - 2600	6 - 7
	Cavite	1800 - 2600	6 - 7
	Ilocos Norte	1800 - 2600	6 - 7
	Ilocos Sur	1800 - 2600	6 - 7
	La Union	1800 - 2600	6 - 7
	Laguna, Western	1800 - 2600	4 - 5
	Mindoro	1800 - 2600	4 - 5
Visayas	Antique	1800 - 2600	2 - 3
	Bohol	1800 - 2600	4 - 5
	Capiz	1800 - 2600	4 - 5
	Negros Occidental	1800 - 2600	4 - 5
	Negros Oriental	1800 - 2600	4 - 5
Mindanao	Surigao	> 2600	0 - 1
	Davao del Norte	1800 - 2600	2 - 3
	Lanao del Norte	1800 - 2600	6 - 7
	Misamis Occidental	< 1800	2 - 3
	Misamis Oriental	< 1800	2 - 3

Ethanol, sugar and animal feeds are the products of kaong that are presently gaining the most interest.

Sap, Ethanol and Sugar obtained from Kaong

Ethanol and sugar can be derived from the sugary sap of palms like kaong, coconut (*Cocos nucifera*) and nipa (*Nypa fruticans*). Ethanol is produced when fresh sap obtained from these palms is subjected to distillation. The amount of ethanol obtainable is usually in the range of 6 – 8%.

Sugar is produced from the sap of kaong by slow boiling. The sugar has a low glycemic index and is good for diabetics and obese people who want to cut down their calorie intake in order to lose weight. One kilogram of sugar can be obtained from about eight liters of fresh kaong sap. In the Philippines, a kilo of palm sugar (from coconut or kaong) sells for PhP 250 or more. In comparison, a kilo of sugar from sugar cane sells for only PhP 60.

Generally, tappers wait until the first male inflorescence in a tree appears. Tapping is restricted to male inflorescences because they produce higher quality sap. Furthermore, female inflorescences are said to be more fibrous and more difficult to prepare for tapping (World Agroforestry Center 2013).

Since 1914, there has been no scientific study about sap yield in kaong in the Philippines. Brown and Merrill (1920) cited a work of Hines (1914) who purportedly claimed that the yield gradually diminishes from 10 to 12 liters a day to 2 liters a day after two and a half months. An earlier study (Gibbs 1911), however, reported a sap yield of just over two liters per day on two trees tapped under his direction. None of these reports was accompanied by data representing day-to-day observations of individual trees.

In a species review, Florido and de Mesa (2003) stated that the average sap yield of kaong is 10 to 12 liters per day for a tapping period of one to two and a half months (Table 2). These authors, however, did not mention how the data were obtained. Curiously, these figures are exactly the same as those cited by Brown and Merrill (1920). It is not clear from the very limited early observations whether sap yield is variable or not from one tree to another and whether the duration of sap flow is the same for all trees.

Table 2. Sap yield comparison between coconut and kaong

Species	Yield/day/	Source
Coconut	2	PCARRD, 2010
Kaong	10-12	Florido and de Mesa, 2003 FACT Foundation, 2010
	5-7	Mogea, Seibert and Smits, 1991
	12-15	Mogea,Seibert and Smits, 1991

METHODOLOGY

Sites Where Sap Tapping was Conducted

In Table 3, distribution refers to the way the kaong trees are arranged spatially. In all sites, except Santor, Tanauan, Batangas, the topography is rather rugged and sloping, the trees are widely scattered, many meters away from each other with different kinds of trees and shrubs growing in-between.

In Santor, the trees are located close to each other as though they have been intentionally arranged that way. The stand in Santor is actually unique in that it lies on a more or less flat 6-hectare area and is almost made up purely of kaong. The sites were selected from a long list of sites where kaong is known to occur.

Table 3. Summary of sites where tapping was conducted

Province	Locality	Topography	Distribution	Trees sampled
Laguna	Cavinte	hilly	Sporadic, scattered	8
Laguna	Makiling Forest	hilly	Sporadic, scattered	10
Batangas	Santor, Tanauan	flat	Almost pure stand	19
Cavite	Indang	hilly	Sporadic, scattered	17
Capiz	Sigma	hilly	Sporadic, scattered	9
Surigao DS	Binaton, Digos	hilly	Sporadic, scattered	10

The final list was selected on the basis of several criteria: dry season length, accessibility and availability of a contact person in the locality. Dry season length was included in the set of criteria because of its known relationship to photosynthetic period. All of the sites were parts of natural stands.

Two plantations (one in La Mesa Dam, Quezon City, and one in Batac, Ilocos Norte) were considered in the selection but were eventually dropped from the final list because they have not borne flowers despite having reached normal flowering age. It appears that the long period of dry months (6 – 7) in Ilocos Norte and exposure to vehicular pollutants in Quezon City have inhibited the onset of flowering in the trees planted therein. Further observations are needed to verify whether this is indeed the case. For each of the chosen sites, the following environmental data were obtained: a) topography, b) altitude in meters, c) soil texture, d) soil pH and e) soil NPK content.

Soil pH and NPK contents were obtained using a soil test kit developed by the University of the Philippines Los Baños (UPLB).

Studies Conducted

In the end, it was decided to pursue two separate studies:

1. a study aimed at determining how long sap can be tapped from kaong, and
2. a study aimed at determining how sap yield varies from one site to another and whether trees within the same site have comparable yields within a specified period of sap collection. The period of observation of sap yield was set at 45 days.

For study number 1, the Indang site was used. The study was actually carried out by a team of researchers working at the Cavite State University in Indang, led by Dr. Lorenzo Lapitan, Jr., a Professor of the University. The study had no definite duration owing to the nature of its objective. For study number 2, all the sites, except the Indang site, were used. Tappers were hired to do the tapping work in each of the sites. Only one inflorescence was tapped from each tree in all of the sites.

For both studies, tappers were given instructions on how to prepare selected inflorescences for tapping. The preparatory phase consisted of beating the stem of the inflorescence for a few minutes each day for a period of two weeks after which the stalk of the inflorescence is cut with a sharp knife. A thin slice is removed from the wounded end of the stalk twice a day during the period of sap flow. One-gallon transparent plastic containers were used to collect the flowing sap.For all sites (including Indang), daily sap yield data (AM and PM) were recorded (Note: For clarity, AM means early morning while PM means late afternoon). In addition, data on altitude, latitude and longitude and soil properties were gathered.

Results of Study 1

The results of this study are summarized in Table 4 and Figure 2. Table 4 shows that there are marked differences among the trees in Indang in terms of tapping duration, total sap yield and average sap yield. The tapping period greatly varies from tree to tree, the shortest being 24 days (tree #14) or less than a month and the longest being 603 days or nearly 20 months (tree #2). The average or mean tapping duration is 146.7 days but this is believed to be rather high only because two trees (#2 and #3) had unusually long tapping periods, i.e. more than 500 days.

Note that only three of the 17 trees examined (see highlighted figures in Table 4) had mean daily yields of 6 or more liters. Of particular interest here is tree #11 which continued to yield an

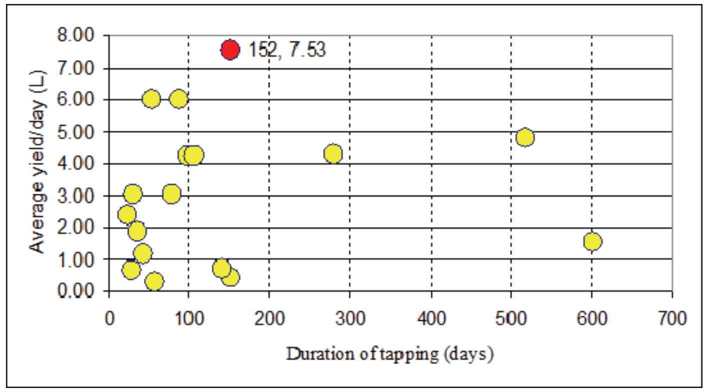

Figure 2. Scatter plot of average daily sap yield against length of tapping period.

average of 7.53 L of sap for 152 days, giving a total sap yield of 1,145 liters for that period. That tree (shown in red in Figure 2) should be properly marked in the field as a potential source of planting materials. Clearly, it is superior to the rest of the trees in Indang in terms of daily sap yield and in the length of time it remains productive. It is certainly the kind of tree that anyone would want to have in a plantation.

Figure 2 shows that a large proportion of the trees have maximum tapping durations of 150 days or less. When a linear correlation analysis was performed between sap yield data and length of tapping period, a correlation coefficient of 0.77 was obtained. This is quite high but not high enough to merit the calculation of a regression equation for prediction purposes. As can be seen clearly from Figure 2, there is really no indication of interdependence between sap yield and length of tapping period because of large tree-to-tree variations.

Table 4. Differences in tapping duration and sap yield among sample trees in Indang, Cavite

Tree #	Yield	Days	Mean
1	60.2	152	0.40
2	927.5	603	1.54
3	2,484.9	518	4.80
4	96.8	141	0.69
5	17.5	58	0.30
6	66.2	36	1.84
7	423.1	100	4.23
8	1,199.5	279	4.30
9	453.0	107	4.23
10	530.0	88	6.02
11	1,145.2	152	7.53
12	324.7	54	6.01
13	50.2	44	1.14
14	56.8	24	2.37
15	243.2	80	3.04
16	18.4	28	0.66
17	91.3	30	3.04
Mean	481.7	146.7	3.07
Maximum	2,484.9	603.0	7.53
Minimum	17.5	24.0	0.30

Results of Study 2

The results of the analysis of variance and the variance component analysis for sap yield are shown below.

Source	df	SS	MS	F	p
Locations (L)	4	131.279	32.820	2.98	0.0269
Trees/Location	53	582.822	10.997	-	-
Variance components			Value		%
Locations			1.8813		14.61
Trees/Location			10.9970		85.39

The analysis of variance demonstrates the existence of significant differences among locations in terms of their mean sap yields. However, as the variance component analysis shows, tree-to-tree differences within locations have a much bigger contribution to the total variance of sap yield (85.39% compared to only 14.61% for locations). The large percentage of variation accounted for by differences among trees within locations is backed up by the chart shown in Figure 3. It is evident that the different locations do not have the same range of variation. In Cavinti, for example, the range is several times wider because of the occurrence of an

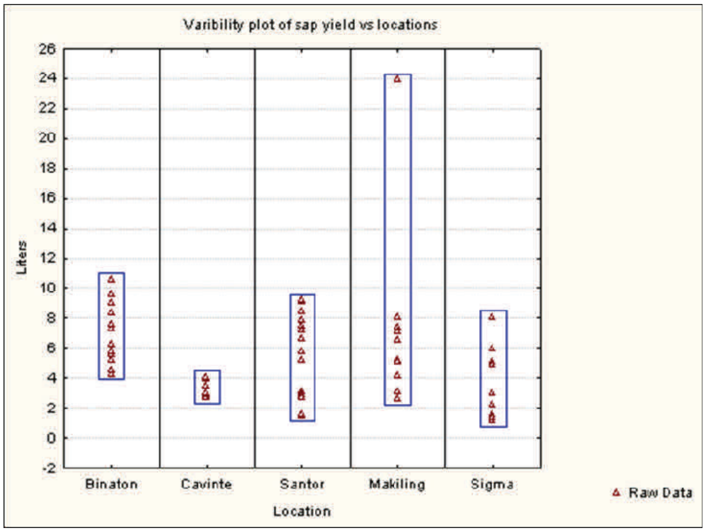

Figure 3. Variability plot of average daily sap yield against locations.

extreme value that is way above the values of the other trees. It is interesting to see the occurrence of high yielding trees (yield = eight liters or more) in Binaton, Santor, Mt. Makiling and Sigma as shown in Figure 3. In Mt.Makiling, there is even a tree that had an average yield of 24 liters. That tree, however, died two months after being tapped. Its death might be due to physiological exhaustion. For the Cavinti site, none of the trees had a yield greater than five liters. The box plots representing the different locations further confirm the existence of large tree-to-tree differences within locations. Note that the positions of the median, the vertical width of the rectangles and the widths of the outlier bands are different from one location to another. The presence of an outlier (extreme) value in Mt.Makiling is clearly evident in Figure 4.

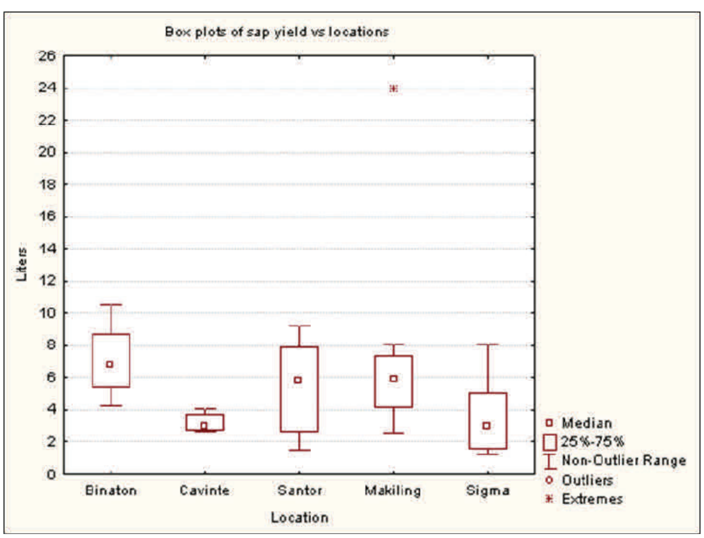

Figure 4. Box plots of sap yield data for the different sampling sites.

Figure 5 shows that sap yield is higher in the afternoon than in the morning for each of the trees. Morning measurements began at 7:00 am while afternoon measurements were taken before sundown or at about 5:00 pm. The morning measurements therefore represent a sap flow duration of 14 hours, while the afternoon measurements represent a sap flow duration of only 10 hours. Despite this four-hour difference in time, the sap yield obtained is consistently higher in the afternoon than in the morning. It is an indication that sap production goes on at a faster rate during daytime than during nighttime.

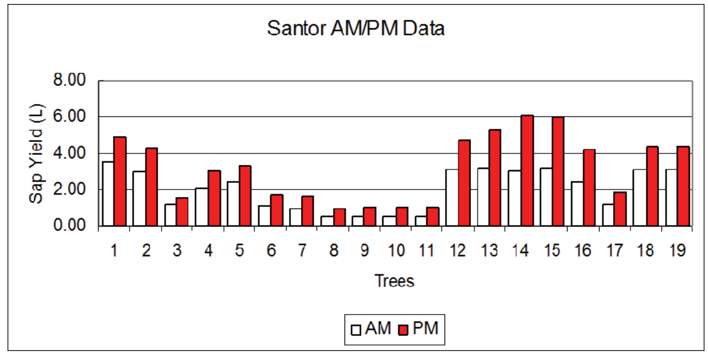

Figure 5. Observed tree-to-tree differences in sap yields taken in the morning and in the afternoon in Santor, Tanauan, Batangas.

The average difference between AM and PM yields is 1.20 liters. The minimum difference recorded was 0.37 and the maximum was 3.07.

In Cavinti, Laguna, where several trees were tapped, sap yield followed more or less quadratic patterns. In general, sap yield increased with increasing number of days up to day 17 to 20 and then decreased gradually up to day 33 (Figure 6). In Santor, no such pattern was observed (Figure 7). Fluctuations in sap yield occurred in each of the tree samples there, but no definite trend was observed.

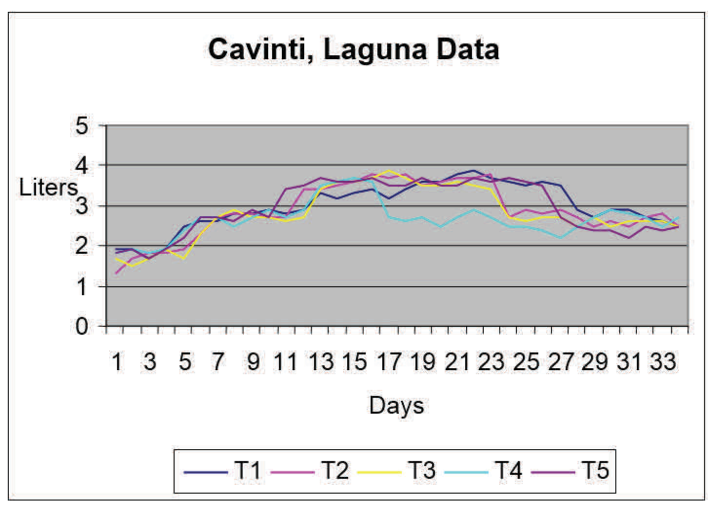

Figure 6. Day-to-day variations in sap yield in different trees, Cavinti, Laguna.

Sap Yield Correlations with Environmental Variables

How sap yield is correlated with environmental variables such as elevation, dry season length, soil pH and N and P content of the soil was also examined in the study (see Appendix Table 1). Numerical codes were assigned to the different environmental variables and the data was subjected to linear regression and correlation analysis using STATISTICA, a high end statistical software. The correlation coefficients and graphs of the linear equations obtained are shown in Figure 7.

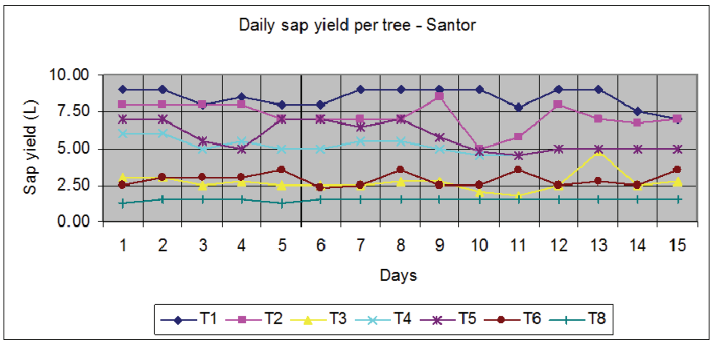

Figure 7. Day-to-day variations in sap yield in different trees, Santor, Tanauan, Batangas.

As shown, the correlations of sap yield with elevation (0.4158) and P (0.6989) were quite high but neither turned out to achieve statistical significance, signifying that variations in sap yield are not associated with variations in elevation and P. Needless to say, the same conclusion applies to the duration of dry months, soil pH and soil N content.

SUMMARY AND CONCLUSIONS

This study on kaong has established the existence of the following forms of variation in sap yield in the species: 1) among locations, and 2) among trees within the same location.

When subjected to statistical analysis of variance, locations turned out to be a significant source of variation in sap yield. Mean yields ranged from a low of 3.22 liters (Cavinti) to a high of 7.33 liters (Makiling).

The existence of tree-to-tree variations in sap yield within the same location was proven by variance component analysis and by graphical data analysis. The existence of such variations indicates the possibility of improving sap yield in kaong through selection (and breeding) of mother trees with superior characteristics.

Trees with an average yield of 8 liters or more can be found in some sites (Binaton, Indang, Sigma and Mt. Makiling). In Cavinti, tree yields never exceeded 4.1 liters.

As demonstrated by the analysis performed on the Indang data, the duration of tapping can be as short as 24 days and can be as long as 604 days. The average number of days for tapping is 146 days or nearly five months.

Observations made in Santor showed that sap yield before sundown (about 5:00 PM) is consistently higher than that taken at about 7:00 in the morning. This shows that sap production in kaong takes place at a more rapid rate during daytime than during nighttime.

It is strongly recommended that further studies be conducted on the sap yield of kaong, particularly in connection with the following aspects:

Identification of morphological indicators of sap yield. Morphological indicators refer to structural properties of the kaong plant that can be used to predict potential sap yield. Examples of such characters are length and diameter of the stalk of the inflorescence to be tapped, number of leaves and tree diameter. Some tappers swear about the usefulness of these characters, but unfortunately, no one has tested their reliability.

Effects of chemical stimulants.

Ease of sap collection. It is recommended to find out if there is an easier way of collecting sap from trees, one that would not require climbing the trees on a daily basis (*Note*: a system that makes use of plastic tubes connected to inflorescences is presently being tried on coconut. If successful, the system is expected to work also on kaong).

It is also recommended that trial plantations of kaong be established near areas where kaong occurs naturally but where the duration of summer is not more than 5 months. The trial plantations should make use of different planting distances so that the optimum spacing for the species can be determined. Also, the trial plantations should make use of seeds (or wildlings) gathered from known high-yielding trees.

Finally, promoting kaong as a livelihood option in upland ecosystems is highly recommended.

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Appendix Table 1. Profile of the study sites

Location	Topography	No. of dry months	Altitude (m)	Type	pH	N	P	K
Makiling	hilly	4-5	300	CL	7.2	M	L	S
Indang, Cavite	hilly	4-5	320	CL	7.2	H	L	S
Cavinte, Laguna	hilly	0-1	400	SCL	6.8	H	L	S
Digos, Davao	hilly	2-3	600	CL	7.2	H	H	S
Sigma, Capiz	hilly	4-5	<100	CL	6.7	M	L	S
Santor, Batangas	flat	4-5	< 100	CL	6.8	M	L	S

H = High; M = Medium; L = Low; S = Sufficient; CL = clay loam; SCL = Sandy clay loam