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NUTRIENTS IN THE GIANT EMBRYOSAC-VACUOLE OF THE COCONUT

P. M. L. TAMMES
(*Wageningen*)

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INTRODUCTION

The large vacuole in the embryosac of the coconut makes it possible to analyse vacuole sap without admixture of protoplasmatic substances, and thus to find out what nutrients are present or lacking. This vacuole is probably the second largest in plants. Another palm, *Loidoicea Seychellarum*, has still larger nuts.

The analyses were carried out by Mr. A. C. Spoelstra and Mr. H. J. Immink under supervision of Dr. W. B. Deys of the Institute for Chemical and Biological Research on Field Crops at Wageningen. Amino acids were determined by Dr. J. van Die of the Laboratory for Plant Physiology, also at Wageningen. Samples of the sap and leaves were taken by Ir. H. Hoestra at Togo. The author is much indebted to these gentlemen for their kind help.

MATERIAL AND METHODS

On a fullgrown coconut a new leaf appears every four weeks. In the axle of each leaf a spadix develops with male and female flowers. After opening of the spadix the male flowers bloom first and then the female flowers are open at the time when the spadix of the next leaf opens. The inflorescence with flowers develops into a bunch of nuts, the successive bunches thus having difference in age of about four weeks.

The female flower of the coconut palm contains three ovules, one to each carpel. Of these only one develops after pollination. The embryosac of this ovule increases enormously in size and becomes the large cavity filled with sap in the nut. The final size is attained about six months after opening of the spadix (Fig. 5) and a nut may then contain more than half a litre of sap. At this time the formation of endosperm starts and can first be observed as a small jellylike patch on the apex of the cavity. At the base of the cavity the embryo will form (Figs. 1–4). As long as no endosperm is formed the cavity is the vacuole of the single large embryosac cell. The liquid is under pressure and a little sap spouts out when a hole is made in the wall, e.g. for drinking coconut water. When the endosperm is formed the pressure disappears gradually and a gasbubble is formed in the end. The liquid then thumps when the nut is shaked. Samples were taken from nuts of the oldest bunch where no endosperm could be found (Fig. 2). These samples were taken at Togo, preserved with a little toluene and sent to Europe.

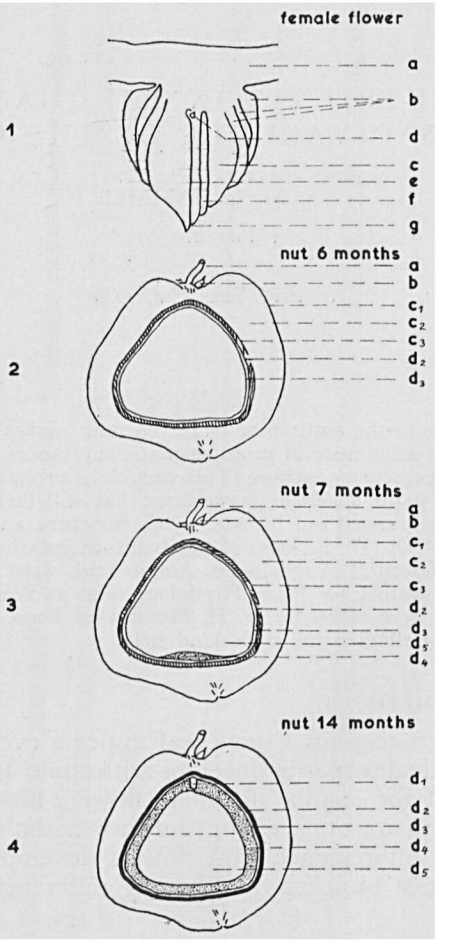

Fig. 1. Female flower; Figs. 2 and 3. Unripe nuts; Fig. 4. Ripe nut of the coconut palm. Samples of fluid were taken from stage 2, that is about 6 months after opening of the spadix. a. stalk; b. perianth; c. gynoecium in flower and in fruit: c_1 exocarp, c_2 mesocarp (husk), c_3 stony layer of endocarp (shell.); d. ovule in flower and in fruit: d_1 embryo, d_2 and d_3 outer and inner seed coats, d_4 endosperm (coconut meat), d_5 cavity filled with fluid, in ripe nuts only partly filled; e. conductive channel; f. nectarium; g. stigma.

Samples, analysed by other authors, are from sap of ripe nuts and may therefore differ from the above mentioned samples (SALGADO, 1954). Such samples being intended for other purposes cannot give an impression of the vacuole sap, as in the later stages the character as a vacuole is lost.

For comparison of the analysis of the sap, leaf samples were taken, according to the method described by PRÉVOT (1954) for oil palms. This was done by taking the first fully developed leaf and from it a sample from the middle leaflets and the centre part of each of

these leaflets. The leaves were oven dried, but wet weight was calculated on a basis of 75 % water.

The identification of the pure amino acids present, and the estimate of the amount of total amino and amide Nitrogen in the leaves was performed on fresh material, sent by airmail.

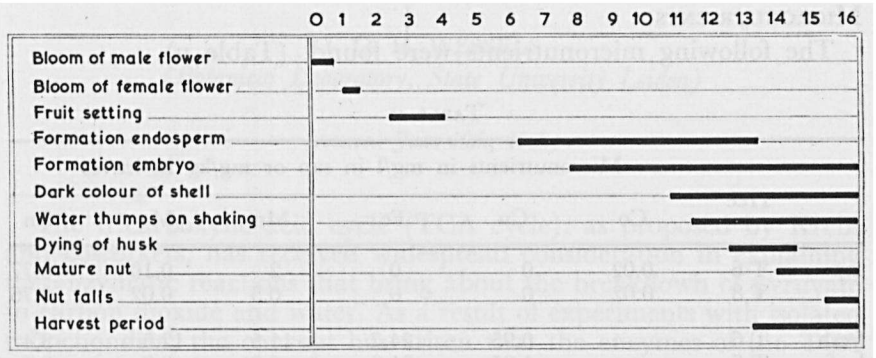

Fig. 5. Development of the fruit of the Coconut palm. On horizontal axis the time in months (after TAMMES 1940).

MACRONUTRIENTS

The sap from the vacuole contains about 2 % of monoses and a trace of sucrose. The sap is under pressure. Ph is about 5.8. The following nutrients were found (Table 1).

TABLE 1

	Tree	Macronutrients in mg/l in sap or mg/kg in leaves					
		N	N.amino acids	P	K	Ca	Mg
sap	T 6	90	78	58	3050	288	47
	T 8	73	31	59	2730	289	48
fresh leaf	T 6	5825	—	280	3125	785	315
	T 8	5280	—	270	1425	1040	312
dry leaf	T 6	23300	—	1120	12500	3140	1260
	T 8	21400		1080	5700	4160	1250

Nitrogen. Only 2 % of the total amount of nitrogen in the leaves is found in the sap of the vacuole.

Amino acids were differentiated with paper chromatography by Dr. van Die. In the sap the following amino acids were found: Asparagine, Glutamine and alanine, Glycine, Valine, Leucine–isoleucine Glutamic acid and Proline. In the press-sap from the leaves, about the same amino acids were found with the exception

of Proline. The leaves also contained Threonine, Arginine and Serine. The total amount of amino acids in the sap of the leaves was about 470 mg/l. *Potassium* is evenly distributed, and about the same values are found in the leaves and in the vacuole sap. Of *Phosphor*, *Calcium* and *Magnesium*, quantities are smaller than those found in the leaves.

MICRONUTRIENTS

The following micronutrients were found. (Table II)

TABLE II

	Tree	Micronutrients in mg/l in sap or mg/kg in leaves					
		Co	Cu	Fe	Mn	Mo	Zn
sap	T 6	0.02	0	0	2	0.10	0.77
	T 8	0.02	0	0	0.5	0.02	0.76
fresh leaf	T 6	—	0.95	24.7	11.5	12.5	3.4
	T 8	—	1.05	21.8	6.2	8.8	3.6
dry leaf	T 6	0.03	3.8	98.6	46	0.50	13.6
	T 8	0.03	4.1	87.1	25	0.35	14.3

No *Copper* or *Iron* was found in the vacuole sap. *Cobalt*, *Manganese*, *Molybdenum* and *Zinc* were present in the sap.

DISCUSSION AND SUMMARY

Many of the nutrients found in the leaf-tissue of the coconut palm can be found in smaller quantities in the vacuole of the embryosac, with the exception of Potassium which seems to be more evenly distributed in both. This concerns P. Ca, Mg, Co, Mn, Mo and Zn. Copper and iron, though present in the leaf-tissue, were lacking in the vacuole sap.

Nitrogen in the vacuole was only found in ± 2 % of the amount present in the wet leaves. In the vacuole a considerable part of this nitrogen is present as amino acids. In general the same amino acids were found in the leaves and in the vacuole.

Comparison is also possible with sieve tube sap of palms (TAMMES, 1933, 1958). Differences between vacuole sap and sieve tube sap especially exist in:

1. vacuole sap ± 2 % monoses, sieve tube sap 15 % of sucrose.
2. Calcium ± 288 mg/l in vacuole sap, only 19 mg/l in sieve tube sap. Copper and Iron are found in very small quantities in sieve tube sap and are probably nearly absent in vacuole sap. As far as the other substances are concerned, the same elements, even the same amino acids were found in sieve tube and vacuole sap.

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