# OBSERVATIONS ON THE BLEEDING OF PALM TREES.

by

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(With plates I-II).

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## A. INTRODUCTION.

In the tropics a sugar-containing juice is tapped from various species of palms; large quantities of this juice

being used locally for the manufacture of sugar and alcoholic beverages, the so called toddy.

The tapping of this juice may take place in different ways. All methods, however, have in common that a bruise or a wound is made at the spot where the plant is to be tapped. Generally only the inflorescences of the trees are tapped, e.g. Cocos, Nipa and Arenga. In some cases, however, the stem is tapped, e.g. Phoenix.

The quantity of juice obtained is very variable. Nipa may yield about 1 liter of juice and Cocos about 1½ liter in 24 hours. Arenga may attain 10 liters. Gibbs (1911) even mentions 42 liters per 24 hours for an inflorescence of Corypha utan. Usually, however, the inflorescences yield a much smaller quantity.

Much less variable is the concentration of the juice. From a number of analyses Gibbs (1911) derives the following average values for the total solids of the juice.

Nipa fructicans Wurmb	18 %
Cocos nucifera Linn	17.5 %
Arenga saccharifera Labill	17.5 %
Corypha utan Lamk	17 %

The fresh juice consists mainly of a saccharose-solution. Reducing sugars are totally lacking. Other components of the juice are inorganic salts, proteins and gums; amounting together to about 1 % of the juice. The gum probably exudes independently from the juice. I found for instance that in a cut inflorescence of Arenga, which had stopped bleeding, gum was still produced in great quantities, showing as sticky drops on the cut surface.

Originally it was thought that bleeding in palms was caused by root-pressure. Molisch (1930), however, pointed out that the bleeding is local in character. If, for instance, a hole is bored in the stem of a tree bearing a bleeding inflorescence, no juice flows from this bore-hole.

The local character of the bleeding may also be demon-

strated in another way. I found for instance that tapped inflorescences of *Cocos* and of *Arenga*, may continue bleeding for some time after being cut off.

On such separated inflorescences I performed some experiments in order to try to elucidate the nature of bleeding.

Owing to my sojourn in the Minahassa, where fermented palmjuice is a national beverage, I could easily get at my disposal a number of inflorescences brought into tapping, which facilitated the work greatly.

#### B. MATERIAL AND METHODS.

Inflorescences were used throughout the experiments of Arenga saccharifera Labill. and Cocos nucifera Linn. In the Minahassa the natives only use the inflorescences of Arenga. The method of tapping for these is as follows:

An inflorescence with male flowers (photo's 1 and 2) is cleaned and the enveloping leaves round the stalk of the inflorescence are cut away. For support the inflorescence is often tied with a rope to a higher leaf. Next the stalk of the inflorescence is beaten with a piece of wood twice or more times a week for some minutes. This beating is repeated until, on pricking the stalk with a pointed object, a drop of juice appears. Then the stalk of the inflorescence is cut through close below the branching and tapping commences. Each morning and evening a slice 3 tot 4 mm thick is shaved from the cut surface with a sharp knife, because otherwise the bleeding diminishes and finally stops (photo 3).

In the case of *Cocos* which is not tapped by the natives a different method was followed. A young inflorescence still enveloped in the spatha is firmly wound with string and at the end a piece of about 20 cms is cut off. After this the wound is covered with a leaf or a piece of paper. After 4 or 5 days a slice is cut off; in most cases

a slight bleeding ensues from the various cut lateral branches of the inflorescence. This method of tapping was especially used, because it appeared that in this way the bleeding was localized in the extreme ends of the branchlets. Consequently the cut- off branches were very well suited for experimental purposes.

For the analysis of the juice some precautions should be taken, for the juice ferments very easily, which changes its composition. Therefore the juice was always collected directly from the inflorescence into a clean glass tube and either boiled up as soon as possible or provided with a drop of formalin.

In as much as the principal component of the juice is sucrose, and as other substances are but present in slight quantities it suffices in most cases to make a determination of the dry residue in order to get an impression of the concentration of the juice. For the determination of the dry residue of the juice 10 cc of the juice were evaporated in a flat dish and finally kept in a vacuum exsiccator for two days, before weighing. For some sugar determinations the biochemical fermentation method according to Kluyver (1914) was used. The species of yeast used for this were Torula monosa, Torula dattila and Saccharomyces cerevisiae. It appeared to be necessary to dilute every cc of juice with 4 cc of water. Addition of yeast water is not necessary in as much as the juice contains a sufficient quantity of nutritive components. For the rest we refer here to Kluyver's publication.

### C. EXPERIMENTS ON COCOS NUCIFERA.

# § 1. The composition of the juice.

On the composition of the juice some data were already available. Prudhomme (1906) gives the results of an analysis of fresh juice as follows:

Total solids	15.58 %
Sugar	14.60 %
Gum	0.56 %
Fat	0.04 %
Albumen	0.12 %
Ash	0.26 %

Gibbs (1911) made a number of determinations of the fresh juice; Table I summarizes some of his data.

TABLE I.

Sample No.	Flow from one flower- stalk during the night c.c.	Density 15°	Total solids	Ash	Polarization	Sucrose in 100 cu. cm.	Invert Sugar	Preservative employed
1	665	1,0675	17.75	-0,38	15,02	15,66	0,87	) 1 c. c.
2	635	1,0686	18,08	0,40	14,28	14,99	1,78	formalin
3	575	1,0670	17,25	0,34	14,92	15,55	0,39	1 11-01
4	470	1,0683	17,97	0,36	15,23	15,89		1 gr HgCl,
5	360	1,0670	17,95	0,39	10,75	12,95	7,13	1 c. c.
6	360	1,0670	17,95	0,32	14,12	14,42	1,53	formalin
7	440	1,0720	19,13	0,39	15,31	16,02	0,71	1 am Harri
8	440	1,0680	18,32	0,47	14,99	16,49	0,71	l gr. HgCl.

No reducing sugars are present in absolutely fresh juice, evidently a slight fermentation occurred in all samples. On the ground of the above analyses and a number of others Gibbs (1911) arrives at the following composition of the juice of Cocos.

Density	1.07
Total solids	17.5
Acidity	Trace
Sucrose	16.5
Invert sugar	Trace
Ash	0.40
Undetermined nitrogenous compounds	0.60

In connection with the lack of reducing sugars, some samples of fresh juice were gathered directly by me.

Fehling's reaction was negative, substantiating Gibbs' opinion (1911) that there are no reducing sugars in the fresh juice. The occurrence of reducing sugars, therefore, must be due to subsequent fermentation.

Fermentation experiments of the fresh juice with various species of yeast had the following result.

Torula monosa, no fermentation.

Torula dattila and Saccharomyces cerevisiae ferment to exactly the same degree.

The first-mentioned species of yeast ferments (from the sugars occurring in higher plants) only monoses. Torula dattila ferments monoses and sucrose. Saccharomyces cerevisiae ferments monoses, sucrose and maltose. The sugar in the juice therefore consists mainly of sucrose.

## § 2. The polarity of the bleeding.

When a tapped inflorescence is cut off close to the stem of the tree, the flow continues for some time, growing less and less.

The bleeding in this case, however, is absolutely limited to the apex, in other words the bleeding is polar and therefore occurs only on one side. At the cut off lower surface of the inflorescence not a drop of fluid appears, no matter in what position the inflorescence is placed. Cut off ends of branches placed upside down in water also show the original polarity. Only very short (about 7 cms) ends of branches show a slight flow on both sides after having stood in water upside down for a night. With the exception of this latter case it appears that the bleeding is polar.

# § 3. The localization of the bleeding tissue.

In Cocos the bleeding tissue is found in the extremities of the lateral branches of the inflorescence, close, therefore, to the cut surface from which the juice flows.

The place where the bleeding occurs may be localized by repeatedly cutting slices from the basal part and by subsequently putting the branch in water. Up to a length of about 6 cms nothing special occurs and the flow continues as usual. In three branches it appeared that when the length was below 6 cms the flow rapidly decreases.

Conversely it appeared that the flow decreases markedly on cutting slices from the top; at 1 cm the flow decreased already greatly, while at 2 cms the flow had almost stopped, and in 5 minutes an uninterrupted film of sap had not yet been formed on the cut surface, while this film forms as a rule within 30 seconds (number of branches 3).

Anatomical differences between bleeding and ordinary ends of branches appeared to consist only in the frequent occurrence of clogged vessels. Nearly all the vessels are closed here. This closure may be demonstrated in another way, viz. by blowing through air. Through normal branches of an inflorescence cut off on both sides, air may easily be blown. When one end is held under water a steady flow of air bubbles is seen to rise. If the same is done with bleeding ends of branches not a single air bubble is seen or an occasional small air bubble.

With some precaution the presence of sugar in the tissues may also be demonstrated; it is exclusively restricted to the vascular bundles. For this purpose I used the sugar test of Molisch. This is based on the appearance of a red colour, when sugar and thymol are brought together with sulfuric acid.

Thick slices of living tissue of bleeding ends of branches were for a moment pressed between filter paper; next moistened on both sides with a solution of 10 % thymol in alcohol. Then the slices were placed on a slide and covered. After focussing at low magnification, sulfuric acid was added.

The red colour appears in the vascular bundles and spreads after some time. Sugar, if present, must therefore be localized in the vascular bundles. Normal and bleeding ends of branches gave the same reaction.

A close connection exists between the absorption of water and the bleeding. From cut off branches not placed in water the flow already diminishes in the first minutes. When the branches were put in water after about 5 minutes, a distinct increase of the flow ensued.

Further it could be observed with the aid of the microscope that the juice flows from the vascular bundles. A branch-end bleeding slightly was fixed in the condensorhole with a plug of wadding in such a way that the bleeding surface lay just on a level with the stage. The cut surface was thoroughly dried with filter paper and observed in reflected light at  $\pm 90 \times$  magnification.

The vascular bundles are distinctly visible; we can see how the drops of juice form on the vascular bundles and afterwards unite to a film of sap.

# § 4. Absorption of ferrocyanide by bleeding ends of branches of the inflorescence.

Some three bleeding ends of branches were cut off and placed in a 0.1 % aqueous solution of acid fuchsin for two hours. The acid fuchsin is absorbed by that time, which is noticeable from the male flowers, which closely cover the ends of the branches. The vascular bundles are externally visible as red lines. At the bleeding cut surface, however, nothing is coloured as yet.

Slices cut at different levels show that the acid fuchsin has risen in the vessels and is only present in the xylemelements. In the bleeding cut surface none or but a few vascular bundles are coloured. No acid fuchsin gets into the juice.

As contrasted with acid fuchsin a 1 % aqueous solution

of ferrocyanide does get into the juice. After 2 to 4 hours its presence may be demonstrated in the juice with the aid of ferric-chloride, which causes a precipitation of Prussian blue. In a number of branches which had undergone such a treatment, slices were cut at various heights. Then the slices were fixed in alcohol to which a little ferric-chloride had been added. The ferric-chloride gives

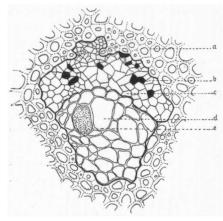


Fig. 1. Deposit of Prussian blue in a vascular bundle of Cocos nucifera L. a. selerenchyma. b. phloem elements with deposit of Prussian blue. c. colourless phloem elements. d. xylem elements. e. clogged vessel. xylem and phloem have been surrounded by a line to show their limits.

a dark deposit with the alkaline salts, while with the ferrocyanide, it gives a bright blue colour, which may be easily distinguished from it.

At the base a precipitate of Prussian blue was to be found in xylem and phloem. At the cut surface, however, only in part of the phloem elements.

With higher magnification it was visible in some cases that the precipitation was restricted to certain cells in the phloem (Fig. 1).

ded by a line to show their limits. As soon as the first minimal traces of ferrocyanide may be demonstrated in the juice, it is found back in the phloem. The colouring in the xylem is not yet noticeable by that time. After a certain time a very faint colouring in the xylem becomes noticeable. The above observations, and the fact that the xylem elements are clogged for the greater part, prove that the ferrocyanide finds its way into the juice by way of the phloem.

# D. EXPERIMENTS ON ARENGA SACCHARIFERA LABILL.

### § 5. Amount and concentration of the juice.

The largest quantity of juice which was recorded by me, was 7.4 liters in 24 hours. Tappers, however, state that a stalk may yield up to 10 liters of juice in 24 hours. Usually, however, the quantity is about 5 liters.

The time during which a stalk can be tapped, depends on the length of the stalk and on the thickness of the cutoff slices. If one cuts very economically and if the stalk

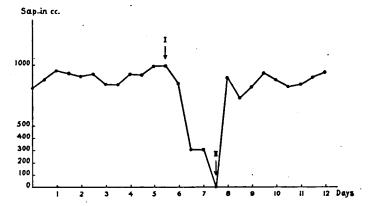


Fig. 2. Flow of sap from a flower-stalk of Arenga. Twice daily a slice was cut from the stump of the stalk. From I to II no slice was cut, which promptly resulted in a decreased flow of the sap. Sap-flow recorded at 6 a.m. and 5 p.m.

is very long, tapping may go on for 6 months. Usually, however, the period of tapping of a stalk lasts for about two months. When the whole stalk has been cut away, the bleeding is transferred to the stem. Finally a very short stump of the stalk is left. No more slices can be cut now and consequently the flow suddenly stops.

When the cutting of a slice is omitted, a strong decrease of bleeding ensues and finally no more juice is produced.

If, however, after the flow has stopped, a new slice is cut off, the bleeding continues as before. In fig. 2 this has been graphically represented. The bleeding of a stalk was measured for some days at regular intervals. After that no more slices were cut till the bleeding had altogether

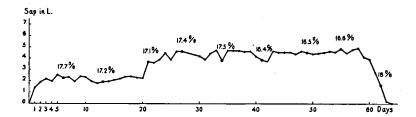


Fig. 3. Daily amount of sap from a stalk of Arenga during the period of tapping. The percentages show total solids at intervals of about a week.

stopped. Then new slices were cut. The amount of juice now immediately attained its original value.

The quantity of juice from two stalks was recorded

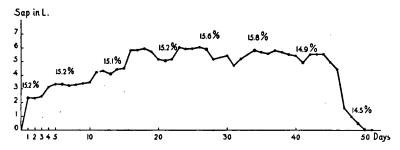


Fig. 4. Daily amount of sap from a stalk of Arenga during the the period of tapping. The percentages show total solids at intervals of about a week.

daily. Once every week the dry solids and the sugarcontent of the juice were determined. The result of these observations are to be found in the tables II and III and in figs 3 and 4.

The values for the sugar-content, are accurate to  $\frac{1}{2}$  %. The determination was carried out by the above-mentioned fermentation method of Kluyver; using Saccharomyces cerevisiae.

The amount of outflowing juice shows considerable fluctuations, whereas the concentration of the juice remains remarkably constant.

TABLE II.

Days	Amount of sap in L.	Total solids	Sugar	Days	Amount of sap in L.	Total solids	Sugar
							ļ
1	0	_	<b></b> ·	26	5,91	_	_
2	2,31	15,2	<b>-</b>	27	6,03	<b>—</b>	_
3	2,26	-	-	28	5,87	15,6	14,2
4	2,39	<b>—</b>	_	29	5,20	-	
5	3,09	_	_	30		_	_
6	3,29	_	_	31	5,36		_
7	3,27	15,2	13,7	32	4,71	_	
8	3,20		_	33	5,16	_	_
9	3,25		<b>-</b>	34	<b> </b>	_	_
10	3,35	<b>—</b>	<b>–</b>	35	5,78	15,8	14,2
11	3,45	_	-	36	5,70	_	_
12	4,15	—	—	37	5,64	_	i —
13	4,25	_	-	38	5,76	_	_
14	4,06	15,1	14,3	39	5,65	_	_
15	4,36			40	5,50	—	_
16	_			41	5,43	_	_
17	5,82	_		42	4,94	14,9	14,8
18	5,83	_	_	43	5,52	_	_
19	5,88	_	-	44	5,50	_	<b>—</b> .
20	5,77	-		45	5,48	-	
21	5,19	·		46	4,88		_
22	5,05	15,2	14,3	47	4,47	_	_
23	5,66		<u> </u>	48	1,63		
24	5,96	_		49	1,04	_	_
25	5,92	<b>-</b> .	-	50	0,59	14,5	13,5

TABLE III.

TABLE III.							
Days	Amount of sap in L.	Total solids	Sugar	Days	Amount of sap in L.	Total solids	Sugar
1	0		i	34	4,69		
2	1,37		_	35	4,67	_	
3	1,89		_	36	4,64		_
4	2,16		_	37	3,59	_	_
5	1,98			38	4,62		_
6	2,52	_		39	4,17	_	_
7	2,29	17,7	_	40	3,86	16,4	15,6
8	2,34		_	41	3,74		
9	1,99	!	_	42	4,63	_	
10	2,39	_		43	4,47		_
11	2,30		_	44	4,50	_	_
12	2,04	<b>_</b>	l <u> </u>	45	4,50	_	
13	1,83			46	4,39		_
14	1,95	17,2	16,—	47	4,64	_	_
15	1,97			48	4,45	16,5	14,9
16	2,12	<b> </b>		49	4,39		
17	2,20		_	50	4,37	l _	
18	2,37	<b> </b>		51	4,51		
19	2,36	_	l <u> </u>	52	4,55	_	
20	2,33			53	4,49		l
21	2,31	<u> </u>	_	54	4,82	16,6	
22	3,69	17,1		55	4,36		]
23	3,56			56	4,65		i `
24	3,89	_		57	4,77	l _	
25	4,49	_		58	4,10		
26	3,94	<u> </u>		59	3,96	· _	
27	4,66	<u> </u>		60	2,67		_
28	4,56	17,4	15,8	61	1,55	18,	
29	4,20	_		62	0,20		
30	3,87		_	63	0	l _	
31	4,42	<u> </u>	-	64	Ŏ		l —
32	4,70		_	_	_	_	_
33	3,82	17,5	17,—	l	_		_
	-,					ļ	

The quantities of sap, sugar and dry solids yielded during the whole period of tapping for the two stalks are as follows:

1.	Sap	220 liters
	Total solids	30 Kgs.
	Sugar	28 Kgs.
2.	Sap	211 liters
	Total solids	36 Kgs.
	Sugar	-

Besides water and sugar the sap also contains still other substances in small quantities. From an analysis of Gibbs (1911) I derive as follows:

Total solids	17.15 %
Sugar	15.18 %
Ash	0.37 %

From the analysis of the evaporated sugar by Prinsen-Geerligs (1893) we obtain a more complete impression of the composition of the sap. Besides sugars the dry mass contained the following substances:

Water	4.93 %
Gum	1.41 %
Mannitol	1 %
Ash	1.30 %

Converted to sap of normal concentration we arrive at the following percentages:

Gum	0.25 %
Mannitol	0.17 %
Ash	0.2 %

The juice, however, also contains proteins, which may be the cause of its fermentability. Precipitation of the proteins by alcohol and weighing the precipitate, gave a value of about 0.04 % protein. A Kjeldahl determination gave a N content of the dry substance of about 1,20 %.

No reducing sugars occur in the absolutely fresh sap. Fehling causes no discolouration and with the fermentation method only sucrose may be demonstrated. The fresh juice therefore consists of water and sucrose with an admixture of traces of Gum, Mannitol, protein and

inorganic salts to a total amount of about 1 % or slightly more. The sugar-content is about 16.5 % or less. Owing to the but slight admixture of other substances the dry solids of the juice may serve very well as an estimate for the sugar content. There are data available in the literature on the influence of meteorological conditions on the bleeding of Cocos. In fine sunny weather the amount of juice is supposed to increase.

For Arenga I could not find anything of this kind. Tappers also informed me that they did not perceive any influence of the weather. The amount of juice only increases towards the end of the tapping-period, probably because a heavier part of the stalk is reached by that time.

## § 6. The polarity of the bleeding.

Just as in the case of Cocos the bleeding in Arenga is polar. A cut off inflorescence only bleeds at the side turned away from the stem. Neither does a cut off inflorescence, which is placed upside down in water, show any bleeding at the side turned towards the stem.

# § 7. The localization of the bleeding tissue.

The bleeding tissue is mainly found in the stalk of the inflorescence. The bleeding zone moves more and more towards the stem during the period of tapping. During the tapping two slices are cut off each day; consequently the stalk grows shorter and shorter. Finally the whole stalk is cut away and the juice flows from the stem.

When a long stalk of a tapped inflorescence is cut off at the base, no sap flows from the stump. The stump, of a very short inflorescence, however, will yield sap. I found, moreover, that a long stalk, half of which was cut off, continued bleeding from the stump. In this latter case the bleeding occurred both from the cut off part and from the part still attached to the tree. In comparison with the observations on Cocos it appears that the bleeding zone extends over a much greater distance. In the beginning of the period of tapping the bleeding is still limited to the stalk, while the process can afterwards be shifted towards the base as more of the stalk is cut away.

## 8. Supply of water and sugar.

The amount of water and sugar produced may be very considerable. A stalk the bleeding of which was measured for five days yielded the following amount of juice.

first day	6.3 liters
second day	6.7 liters
third day	7.4 liters
fourth day	6.9 liters
fifth day	6.7 liters
Total	

In five days, therefore, this inflorescence yielded an amount of 34 liters of juice. Computed at a sugar content of about 16 % we arrive at an amount of  $5\frac{1}{2}$  Kgs of sugar and about 29 liters of water.

Subsequently the stalk was cut off. From the stump on the tree no sap exuded. After that the stalk was dried and weighed. The dry weight amounted to 1.3 Kgs.

The dry weight of the bleeding stalk is therefore shown to be much less than the quantity of sugar or water produced. These substances must therefore be supplied from elsewhere. So a regular transport must take place of these substances to the bleeding stalk.

Two inflorescences of which the quantity of outflowing sap was recorded regularly, yielded 220 and 211 liters of juice respectively. Converted, this amounts to about 30 and 36 Kgs of dry solids or 28 and 33 Kgs of sugar.

It goes without saying that such quantities are not directly produced by the plant, but that in this case probably the reserve-materials are mobilized. These reservematerials are present in a large quantity in the pith of the stem, in the form of starch. The quantity is so large that in times of dearth sagoe is made from the pith. (In normal times sagoe is made only from the pith of Metroxylon). A tree yields about 60 Kgs of sagoe.

When more inflorescences are being tapped, a great part of this store will be used up, so that it is very likely that in course of time a decrease of the juice or of the concentration of the juice will occur. Practical experience is in accordance with this supposition. From the second and third inflorescences we obtain less juice and proportionally less sugar. Heyne (1927) states that the first inflorescence vields about 7 liters of juice per day containing 2 Katties of sugar (1 kattie = 620 gr). The second inflorescence on the other hand would yield only an average of 51/2 liters of juice, containing but 1 Kattie of sugar. Converted this respectively amounts to 17.7 % and 11.3 % of raw sugar. Further some tappers informed me of the fact that after tapping a tree is no more suited for the manufacture of sagoe. By that time the starch has almost entirely disappeared from the stem.

# § 9. The decrease of the concentration in the juice of cut off inflorescences.

A cut- off stalk of an inflorescence continues to yield a slight quantity of juice for some time. The concentration of this juice decreases, however, considerably within a few minutes.

From an inflorescence a sample of juice was taken. After this the stalk was cut off and put in water, while the juice was collected and, subsequently, dry substance determined. The result is expressed below:

Original juice	19	%
After cutting	11.6	%
Number of co of juice after cutting	12.7	

A second inflorescence was treated in the same way and gave the following result:

The juice of a cut-off stalk decreases greatly in concentration. The amount of juice also decreases in a cut-off stalk. In the first case the amount of juice diminished from 17 cc per minute to 12.7 cc in 25 minutes or about 0.5 cc per minute. In a cut-off stalk therefore the quantity and concentration of the juice decrease rapidly.

#### E. DISCUSSION OF THE RESULTS.

The bleeding in palm-trees shows some characteristic features, which may be summarized as follows.

Molisch (1898) already found that the bleeding was local; which means that the sap flows only from the part of the plant that has undergone a special treatment. During the tapping such great quantities of sugar are produced that this cannot possibly come from the bleeding parts themselves. So the sap must be supplied to the bleeding organ from elsewhere. The presence of great quantities of starch in the stem of Arenga and their disappearance during the tapping give a plausible reason for the source of these quantities of sugar.

The bleeding is polar, i.e. the bleeding in a cut-off inflorescence always takes place at the side turned away from the stem. All observations on the localization of the bleeding tissue point to the vascular bundles. The xylemvessels, however, are clogged, so the only possibility left is the phloem as the cause of the bleeding. The rôle played by the phloem is demonstrated by the fact that a solution of ferrocyanide may be transferred by the phloem; in course of time the presence of ferrocyanide may be demonstrated in both the phloem and the juice.

For an explanation of the phenomena of bleeding, however, some points should be taken into consideration. In the first place the constancy of the concentration of the juice of a tapped inflorescence and also the rapid decrease of the concentration as soon as the stalk is cut off. The amount of outflowing sap is closely connected with the renewal of the wound-surface. If a renewal of this surface (by slicing) is omitted for some time, or if too little is cut off, the tree responds promptly with a diminished amount of juice.

The juice may exude from the phloem in different ways:

- a. By active secretion of sugar. The sugar would attract water; in this way the juice could be formed. Apart from the great amount of sugar which has to be converted for this purpose, this seems very improbable, considering the great constancy of the concentration of the juice during the period of tapping, a constancy which is, moreover, independent of weather conditions.
- b. By direct exudation of the sap from the cut phloem elements. This mechanism is also improbable inasmuch as the phloem does not show this phenomenon in the lower parts of the tapped inflorescence.
- c. by an increased permeability of the phloem in the bleeding organ. This may be illustrated as follows. Suppose we have a tube filled with an osmotically active substance. On either end the tube is closed by a semipermeable membrane. When the tube is placed in water with one of its ends, there arises in the tube a pressure, which is finally equivalent to the force of osmotic suction of the solution. If, however, the upper end of the tube is closed with a permeable, instead of a semipermeable membrane, a solution of the same concentration as the solution in the tube will be forced through this membrane. The pressure in the tube now depends on the filtration resistance of the two mem-

branes. The application of this principle to this study is evident. Through the phloem the stem regularly takes up sugar and water. In the tapped part of the plant the permeability has increased, which results in exudation of a sugar solution. That in the tapped part an increase of permeability may indeed occur, appears from the fact that a solution of ferrocyanide easily penetrates into the phloem and is even transported by the phloem. It is, therefore, most likely that the bleeding of the palms is caused by an increase in permeability of the phloem in the tapped organ, while a clogging of the water vessels probably prevents the sap from being sucked back.

Frey's assumptions (1929) according to which the bleeding should be caused by the emptying of vessels closed in their lower part, do not hold for the bleeding of the palms. The regular supply of sugar from the base is in direct contradiction to his assumption.

This research was carried out during the years 1931—1932 in the Minahasa (North Celebes). I am much indebted to Prof. W. H. Arisz for his criticism and to miss C. Schut for the translation of this publication.

#### F. SUMMARY.

- 1. The bleeding is local. (Molisch 1898, 1930). A hole bored in the stem of a tapped tree yields no sap. A cut-off tapped inflorescence also shows phenomena of bleeding.
- 2. The bleeding is polar. A cut-off inflorescence only bleeds at the side turned away from the stem.
- 3. The juice flows from the vascular bundles. In Cocos it could be observed that the drops of juice form on the cut vascular bundles.
- 4. The bleeding tissue is localized in the vascular bundles. Starch either does not occur in the bleeding organ or

- only sporadically; sugar can only be demonstrated in the vascular bundles.
- 5. The xylem elements of the vascular bundles in the bleeding part are clogged. Moreover, in tapped branches, the clogging of the vessels in Cocos is also proved by the fact that through cut-off bleeding ends of branches no air can be blown. Through normal branches air can easily be blown.
- 6. Branches of a tapped inflorescence of Cocos were cut off and placed in a 1% ferrocyanide solution. After some hours the presence of traces of the ferro-cyanide may be demonstrated in the juice with ferric chloride (Prussian blue). Slices cut from the bleeding cut surface and fixed in alcohol with addition of some ferric-chloride, show a deposit of Prussian blue in various elements of the phloem. (fig. 1). In course of time the other parts of the vascular bundle also begin to take on a faint colouring. The ferrocyanide therefore has entered the juice via the phloem.
- 7. Determinations of the concentration of the juice of *Arenga* showed a fairly constant concentration of the juice during the whole period of tapping.
- 8. In cut-off inflorescences of Arenga the quantity and the concentration of the juice decrease rapidly.
- 9. The sugar and the water are supplied from elsewhere. The dry solids of an inflorescence of Arenga are much less than the amount of sugar it produces. During the tapping the starch in the stem disappears.

On the strength of theoretical considerations Frey (1929) expressed his opinion that the bleeding in palms should be based on the emptying of vessels closed in their lower part, by which water would be withdrawn from the surrounding tissue. This conception, however, cannot be brought into line with the fact that water and sugar are regularly conveyed to the bleeding part. In connection

with the above the phloem appears to play a very important part in the bleeding and the facts observed may be entirely explained by the following assumption.

The wound stimulus causes a local increase of permeability of the phloem, resulting in the exudation of sugar-containing sap. The phloem, however, forms an entity with the other phloem elements of the tree; so there occurs a regular flow of sugar-containing juice, flowing toward the vascular bundles of the wounded part. Possibly the clogged xylem vessels prevent the sap from being sucked back.

This assumption gives a plausible explanation of the polarity and the local occurrence of the bleeding and also of the constancy in the concentration of the sap. In the cut-off inflorescence the concentration of the sap will rapidly decrease as the connection with the rest of the phloem is interrupted: the bleeding will finally be stopped. At the same time the above assumption explains the possibility of a flow of great quantities of sugar-containing juice from the tapped parts. The reservematerials in the stem are mobilized, enter into the phloem and from there into the sap.

Menado, July 7th 1932.

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Photo I. Arenga saccharifera Labill. Right. male inflorescence. Left. the same but tapped.



Photo II. Arenga saccharifera Labill. Tapping of an inflorescence. A thin slice is cut off. Under the stalk a bamboo vessel for collecting the juice.