RESEARCH PRIORITIES FOR SAGO PALM DEVELOPMENT IN INDONESIA AND SARAWAK: AN AGENDA FOR RESEARCH

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Abstract

During travelling through Indonesia and Sarawak the latest developments in sago palm cultivation have been evaluated in a technical sense. In the coming two decades quite an increase in the production of sago palm starch is to be expected through both new plantings and exploitation of natural stands. The agronomy for this development is based nearly solely on observation of small scale farmers' practices. Research lags dangerously behind, although more so in Indonesia than in Sarawak.

Three groups of research questions have been identified. The most pressing is (1) the necessity to apply fertilizer for a sustained high yield. This is of even more importance on the notoriously poor deep peat soils than it already is on mineral soils. Without a solution to this problem the large scale cultivation of the crop is at a dead end. A good second in importance is (2) how to obtain optimum starch yields from trunks per unit of time and area, combined with the reduction of starch losses in processing. On the somewhat longer run should be studied (3) the taxonomy of the sago palm, in relation to its growth pattern. For each group of research questions holds that research personnel working at it should be experienced with or at least be well acquainted with the sago palm.

Two pioneer-operations are important to obtain part of the necessary practical experience: (1) the large scale deep peat plantings by *Estet Pelita*, especially the first close to Mukah in Sarawak; (2) the exploitation by *INHUTANI I* of a natural stand on mineral soils on Halmahera in the Northern Molucca's.

In Sarawak, Estet Pelita just started with a research programme. Agronomic research is developed there also mainly on the deep peat experiment station of *the Research Branch of the Sarawak Department of Agriculture* at Dalat, close to Mukah. Small collections of genetic material have been started in this experiment station and in Makariki on Seram in the Molucca's. The small model-planting on clay soils run by *B.P.P.Teknologi* close to Bogor, West Java aims at solving some practical questions.

There still is a lack of manpower, trained in sago palm growth and development. Training of sago palm agronomists should be a joint concern of the countries involved in the development.

1.3 Exploitation by small scale farmers

The exploitation of existing stands, both natural and planted, by small scale farmers is rather uniform. The stands are irregular, they are hardly weeded, only occasionally pruned and never fertilized. It is not well possible to make a distinction between planted and natural stand on appearances alone. Often other trees are found in the stands, occasionally fruit trees.

New planting is nearly always done by means of well-sized, especially selected suckers of special cutivars. For planting the farmers select the somewhat drier spots. The situation as described by Flach (1977) for Batu Pahat in Johor, West Malaysia appears to be exceptional. If asked, however, the farmers know how to change plantings into plots with a high yield per unit time and area, by weeding and pruning.

Harvesting may be spread over a period of roughly two years, i.e. from just before or just after flower initiation till the start of fruit formation. If asked, the farmers are well aware of the possibility of earlier harvesting. Only if the farmer is selling to a factory, harvesting may be done two years earlier than when the farmer is producing for subsistence or on a small scale for the local starch market. Production of the stands can be estimated at normally 15 - 20 trunks per ha and year. Exceptional yields on good soils may be double. The yield of dry starch may then be estimated normally at 3 - 4 tonnes and exceptionally at 8 tonnes per ha and year. Farmers also are of the opinion that a variety with a short duration of growth is best for a high production per unit time and area.

Most striking is the knowledge of sago palm growers. It is probably passed on from parent to child through many generations. Varieties of sago palms are easily recognized, even from colour photographs. The farmers are always willing to discuss or answer interested questions. For the sago palm farmer the crop is the staff of life, interwoven with belief and religion. Anybody really interested in the crop is really welcome, anybody who wants to interfere with it is met with suspension and anger.

1.4 Intensive harvesting from natural stands

At present rather intensive harvesting from natural stands is done in Indonesia:

(1) The semi-governmental forest exploitation company *INHUTANI I* operates close to Kao on the island Halmahera in the Molucca's. Trunks are harvested from existing wild stands in co-operation with the local population. Harvesting started in august 1991 in a well-organized operation on mineral soils. The factory has a capacity of 20 tonnes of dry starch per 24 hours. Although the factory is not yet working at full capacity, the operation appears to be close to the break-even point. Main draw-backs are (1) too low starch

contents of trunks, possibly because part of the trunks is harvested too young. This leads to incomplete recovery of the too small starch grains (Fujii *et al.*; 1986). And (2) the 80 km distance from the factory to the shipping harbour at Tobelo leads to excessive transport costs. The (3) long distance from the natural stands to the factory site will make the application of fertilizer in future quite expensive and difficult. Unfortunately, exactly this area was hit in January 1944 by an earthquake of 6.8 on the scale of Richter. In Kao itself there were casualties, but none are reported from the factory. How serious the damage to the factory is, is as yet unknown. No doubt it will seriously hamper the operation.

(2) A private company *PT Sagindo Sari Lestari*, a subsidiary of the Djajanti Group, exploits natural stands at Arandai, Kepala Burung in Irian (Sudwikatmono; 1991). Our group was not allowed to visit this exploitation. The company uses a floating starch extraction plant and probably operates on shallow peat soils. They are said to face also too low starch contents. A new factory is being built on land in the area. The floating starch plant will be used in another concession in southeastern Irian Jaya.

(3) Nearly all areas with good natural sago palm stands in Kepala Burung in Irian Jaya have been given out in concessions to private companies.

(4) Also a small private factory is being established by an entrepreneur from Selat Panjang close to Muara Siberut on Siberut of the Mentawei islands.

1.5 New plantings

(5) In Indonesia on Selat Panjang of the Riau islands a 3000 ha sago palm enterprise is being established by a private group. The latter planting was not visited. This group appears to be working on fairly shallow peat.

1.6. Research

In all these cases, be it exploitation of existing stands or new plantings, we have to do with more intensive cultivation and harvesting. As with any other crop, production of a high standard should be accompanied by research. Both types of production have to adhere to the laws and rules of biology and agronomy. Research to accompany the development is being done:

(7) In Indonesia on a small and rather well-run model-planting on clay soils under responsibility of the sago palm group of *B.P.P. Teknologi*, in the neighbourhood of Bogor, West-Java. This planting was set up as described by Flach (1977) for Batu Pahat in Johor, West Malaysia. Studied are general growth, the effect of water level and the system of desuckering. The planting is now around eight years old and harvesting should commence.

(8) In Sarawak close to Dalat, on the Sungei Talau 60 ha deep peat research station run by the *Research Branch of the Sarawak Department of Agriculture*. The station was started in 1988. Studied are planting density, desuckering and fertilizer use. Also a small collection of genetic material has been started.

2. Nutrient withdrawal from the exploited fields

2.1 Consequences of factory processing

Originally the sago palm was, and still is, harvested and processed in the fields where it grows. Only the wet starch is taken home by the small scale processors, mostly for their own food. All other material, containing all plant nutrients, is left in the field and thus returned to the soil.

In factory processing, however, harvesting and processing are being separated from each other, both in time and in place. The trunks are brought to the factory and processed there. The refuse including the bark, containing all plant nutrients, is usually discarded in the factory neighbourhood.

Especially at a production far above the traditional level of 20 trunks per ha and year, this will lead to depletion of plant nutrients in the soil in the plantings. All nutrients are transported to the factory in the trunks. There these nutrients are deposited in the refuse, which usually is washed down to the sea in the surface water. The danger of pollution of the environment is not large as most operations are relatively small.

If leaves are harvested also, e.g. for 'atap' or thatch, also the plant nutrients in them are exported to the area where they are used. The hard bark, also containing plant nutrients, is usually left to decompose in the neighbourhood of the factory.

2.2 Estimate of nutrient withdrawal

The withdrawal of major nutrients by sago palms, as estimated by Flach & Schuiling (1991), is presented in table 1. The table makes clear that continuous harvesting at a high level of around 100 trunks per ha and year will deplete the soil and result in a serious threat to productivity. First potassium will be minimized. And if the 70 - 80 fully grown leaves the smallest sago palm type produces during its life cycle are harvested to be used for roofing, depletion of the soil even occurs much faster. This may, of course depending on its availability in the soil, start off with a lack of calcium. Depletion will be even more important on the notoriously very poor deep peat soils.

2.3 Research on fertilizer application

No fertilizers whatsoever are being used, even when the sago palm is cultivated. Research into the nutrition of the sago palm is being done only in Sarawak (Ann. Rep. Sarawak and Sim & Ahmed; 1991). As shown by Kueh (this volume) until now no responses to fertilizer applications have been found.

Recently the deep-peat experiment station on sago palm in Dalat, Sarawak, showed a serious nutritional disorder occurring in the young sago palms. Only three to four of the youngest leaves, out of normally 15 - 17, remain green on the trunk; all older leaves have died. It appears to be a potassium deficiency that may have been triggered off by drainage of the peat swamps some time after planting. In hothouse experiments in Wageningen it was shown that at an abrupt change of the water level sago palms form a completely new root system. It is not unlikely that in the field a similar effect occurs. The nutritional disorder then may disappear after some time.

Haska (this volume) showed rather clearly that the sago palms still growing in West Java are too small and contain only little starch. This probably is due to continuous cutting of leaves for thatch. Often palms grow with only 3-4 leaves. Such palm grooves would offer an unique opportunity to start research on fertilizer application. It may well be possible to increase both starch production and leaf production through a programme of fertilizer application.

2.4 A new proposal for research on fertilizer application

It is thus of paramount importance to continue and improve research on fertilizer application. Such research will meet a peculiar and interesting difficulty. Sago palms are, although not necessarily so, usually grown under rather wet and often even flooded conditions. These conditions will result in on the one hand the possibility of enrichment of the soil by the short-duration flood water (Flach; 1977) and on the other the danger that applied fertilizer will wash away. Flooding of palms for short periods appears to do very little harm, but continuous flooding or flooding for extended periods appears to hamper growth (Flach *et al.*; 1977; Kraalingen; 1986).

Sago palms are able to form roots along their trunks. For research purposes one could thus think of applying a fertilizer solution in a band of plastic fastened around the trunk. The plastic should be fastened on its lowest side around the lower part of the trunk. The plastic than should be formed into a bag around the trunk. In the bag with fertilizer solution roots will develop. In this way the trunk itself will be fertilized and no fertilizer will go into the soil. This would ultimately result in knowledge about the individual needs of fertilizer per trunk. It may even be possible to develop this method into a practical way of fertilizer application especially on deep peat.

It may also be possible to design an experimental plot in an existing planting. The treatments in the experiment should then be separated by means of deep and watertight, possibly metal, dams. Such structures, however expensive, may help to provide an answer to the problem of fertilizer application.

2.5 Returning refuse to the field

For the farther future, however, large scale operations should be designed in such a way that the refuse of processing either can be returned to the field or can be put to other economic uses. It will become ever more unacceptable to just dump the valuable refuse in the surface water, even if it is close to the sea. The world population will become ever more aware of the value of the natural surroundings.

The work of Bintoro (this volume) shows that returning refuse to the fields may have its own problems. Nitrogen will be needed to decompose the organic matter.

3. The importance of taxonomy for cultivation

3.1 A simple model of sago palm growth

Understanding of the growth and development of the sago palm is necessary not only for cultivation but also for harvesting from natural stands. It is also necessary for the taxonomy of the sago palm.

A preliminary model of growth and development of a common type of sago palm, in Indonesia called 'molat', is given in table 2 and figure 1. In this model the ideas given by Corner (1966) concerning palm growth have been applied. Palm growth is strictly regular. There are as many unfolded leaves visible in the crown as there are developing, still folded, within the growing point. The newest appearing leaf, the spear leaf, is exactly in the middle of, on the one hand the developing leaves in the growing point and, on the other those visible in the crown. That this holds for all palms is doubted by Tomlinson (1990). Be this as it may, for the sago palm in the trunk forming stage it probably is valid, although possibly not as strict as Corner assumes.

Only if the number of leaves increases (resp. decreases) the number of developing leaves within the growing point has to have been larger (resp. smaller) than in the visible crown. So, one must expect the number of leaves in the growing point to be larger in the rosette-stage, as then the number of leaves increases.

In most monocotyledonous and once flowering crops with a terminal inflorescence, flowering starts after a fixed number of leaves has been formed. This holds, of course within certain limits, for e.g. rice, banana and sisal. It is assumed that this holds also for the sago palm, at least it does in cv molat. In the model then the duration of the stage of trunk growth can be estimated by counting the number of leaf scars on the trunk at flower initiation. In 'molat'grown under optimum ecological circumstances there would be 54. At one leaf per month this would amount to 4.5 years. After the physiological trunk age of 54 leaf scars on the trunk, flower initiation starts. The number of 54 is achieved under optimal eco logical conditions and with uniform planting material. Deviations from this number might be interesting for research.

In the model of this sago palm the leaf production in the rosette-stage, the stage without formation of a visible trunk, was established to be two leaves per months on the average; then the leaves become progressively larger. After flower initiation the leaves become progressively smaller; the speed of leaf formation at that time is also assumed to be two per month on the average.

The value of such a model is as yet limited. The figures given in table 2 are only averages; they show, of course, deviations around a mean. For the time being we assume that the speed of leaf formation is more constant than the leaf longevity. This means that at a constant lack of plant nutrients the leaf longevity will become shorter, whereas the speed of leaf formation will remain constant. At sudden changes in ecological conditions the speed of leaf formation may slow down first.

Some of the difficulties to be expected with the interpretation of the model have been shown by Azudin et al. (this volume). Sago palms grown on mineral soils showed a lower number of leaf scars at flower initiation than those grown on peat soils. Those grown on less deep peats were in between the former two.

Nevertheless, if one is able to understand it, the model may be of help in classifying the varieties if developed for other varieties as well.

3.2 Size of trunks *and their starch content*

Physiological trunk age is determined by the number of leaf scars. Ideally the palm forms one leaf per month from after completion of the rosette-stage until the initiation of flowering. Physiological trunk age, as counted by the number of leaf scars, may differ from on the average four and a half years on the one hand in 'molat' as described in table 2 and fig. 1 till over twenty years in the variety, possibly classified by Beccari (1918) as 'sylvestre'. Probably the shortest physiological trunk age is best for cultivation. This is an important difference between varieties. Of course such differences in age and size of trunks should lead to different systems of cultivation.

The amount of pith in a trunk is related to the volume of the trunk. Trunk height is related to age of the trunk, as under good ecological conditions one leaf per month is being produced and each leaf has its own internode, the distance between two leaf scars. Circumference of a trunk is more important for volume than height. In volume, calculated as $\pi * r^2 * h$, the radius (r) has a quadratic contribution, whereas the height (h) only has a linear contribution.

Thus short stout trunks give more pith than tall slender trunks. This holds within one variety. Between varieties there may be quite some other differences such as more (respectively less) and/or larger (respectively smaller) sized leaves in a crown. Both will lead to a larger (respectively smaller) circumference of the trunk. A larger number of leaves formed during the period of trunk growth until flower initiation, will lead to an increase in trunk life and consequently a taller trunk. We thus may safely conclude that stout short trunks of one and the same variety produce more starch than slender tall trunks.

3.3 The 'species' question

We do not yet know whether the different cultivated varieties of the sago palm deserve only cultivar status or should be considered as separate species or (sub)varieties. Many of them appear not to produce seeds. Beccari (1918) distinguished nine species, with in total 25 varieties and subvarieties. In table 3 his species and only 12 of the varieties are presented; the varieties in *M. squarrosum* have been neglected. Beccari mentions them but considers them 'barely distinguishable'. For his treatment he received material from the places mentioned in table 3. He did not mention the (physiological) duration of the stage of trunk growth.

One may doubt his division into non-spined versus spined, i.e. *Metroxylon sagus* Rottb. versus *Metroxylon rumphii* Mart. Beccari himself, however, shows some doubt on the division into spined versus non-spined. Recently it has been established several times that within a number of varieties considered non-spined also spined ones exist (see e.g. Flach; 1983). This also is true for 'molat'. If asked, the farmers admit that there is spined 'molat' (berduri). Therefore, these two species now are put together in the original species *Metroxylon sagu* Rottb. The west-Seramese *M. squarrosum* was found by Beccari (1918) to possess 24-29 vertical rows of scales on the seed coat in stead of 18 as the other two do. It still may have to be considered a separate species.

In his recent treatment of the genus Rauwerdink (1986) puts Beccari's species *sagus, rumphii* and *squarrosum* together into the species *Metroxylon sagu.* This species he subdivides into four *formae* according to spininess, i.e. *forma sagu* (without spines), *forma tuberatum* (knoblike spines), *forma micracanthum* (spines up to 4 cm length) and *forma longispinum* (spines of 4-20 cm length). Although the treatment has the merit of being simple and logical, all varieties distinguished by Beccari and also in folk taxnomy, disappear.

Tuwan (1991), guided as a student by Anema (pers. comm.; 1991), found differences in the shape of pollen between 'tuni', 'ihur' and 'makanaru'. Differences in shape of pollen may shed new light on the taxonomy. 'Ihur' might well be Beccari's *M. rumphii var. sylvestre.* Jong (pers. comm.; 1992) states that Sarawak palms again show a different shape of pollen. But nothing of the kind is shown by either Thanikaimoni (1970) or Sowumni (1972).

3.4 Folk taxonomy

We must conclude that as yet there is insufficient information on the taxonomy of sago palms. As an example: in northern Papua New Guinea the local population in the Sepik River Basin distinguishes 12 cultivated varieties and in addition 3 wild ones. Ohtsuka (1983) reports for the Fly River area in southern Papua New Guinea some 23 local names out of which 14 were confirmed by aged men. And there is as yet no certainty that these cultivated varieties are the same as those in southeast Asia.

More west, on the island of Halmahera 8 varieties were reported in 'folk-taxonomy' by Yoshida (1980). On the western coast of Sumatra there probably is only 1 variety, seeds of which may develop nonspiny ones and, in addition, all kinds of different spines. This variety appears to be 'molat'; at least people in the Sepik River Basin in Papua New Guinea recognised the author's pictures of this variety immediately as such, with their own name 'ambutrun'.

Schuiling (this volume) is approaching the matter in more detail in his paper.

3.5 Centre of diversity

Travelling through these area's one may easily get the impression that we have to do with on the one hand a number of separate cultivated varieties (cultivars or cv's), possibly spread by man and on the other a number of landraces, each of the latter adapted to its own region. Sago growers usually are rather eager to collect new cv's. In the Sepik River Basin the author noticed that a local inhabitant, who had visited the Pacific had taken along one of the sago palms from that area and had it planted in his village. In Sarawak, on the deep peat experiment station, the sago palm material collected by Jong has to be hidden among other sago palms to prevent the by local sago palm growers (Jong; pers. comm.; 1992).

As stated by Leon (1986) in the centre of diversity of a plant species usually a large number of varieties is found, but at the border of the natural dispersion the number diminishes. Looking at the number of varieties we now assume that the centre of diversity is New Guinea and not, as Beccari (1918) stated, Seram.

3.6 A new taxonomical treatment

We do not yet know the length of the life cycles from seed to seed of each of the species, varieties and sub-varieties given by Beccari. Especially the (physiological) duration of the stage of trunk growth appears to be a major criteria for the choice for cultivation and should become important also for taxonomy.

It is thus rather clear that a new taxonomical treatment of the genus, incorporating all available knowledge through a study in depth by a taxonomist experienced and knowledgeable in sago palm, is badly needed.

4. Starch - contents and recovery

4.1 Starch content of the pith

Starch content of the pith should be used to evaluate starch production. In evaluation it is rather practical to use the starch density, the dry starch weight per volume of pith. A volume of water-saturated starch of 1 cm^3 weighs after drying in an oven approx. 0.65 g. Its weight varies of course with its water content, which varies again with the air humidity.

The starch content of pith appears to vary from hardly any till 300 kg of dry starch per m^3 of pith in Batu Pahat (Flach & Schuiling; 1989). Lowest starch contents per volume of pith have been reported in wild sago palms under partially flooded conditions, in the Sepik area in Papua New Guinea (Kraalingen; 1986). In the years 1950 - 1957 in a wild stand on the island of Salawati, Irian Jaya, a statistical average of 167 kg per m^3 was found (Holmes *et al.*; 1984).

4.2 Payment for starch contents

Starch contents vary along the trunk too. This mechanism is not yet understood, albeit as discovered by Kraalingen (1984) there is some reason to believe that after flower initiation starch is moved upwards in the trunk. This may also explain that, after flower formation the lowest part of a trunk tends to become just about empty. This probably is the reason why small scale sago processors aiming for high yields per trunk, harvest when the inflorescence has been developed. They leave the lowest part of such a trunk standing in the field. Cultivators in Batu Pahat, however, aiming for high yields per unit time and area and harvesting around flower initiation, take the lowest part of the trunk also.

Harvested trunks (or trunk parts) containing more starch per volume of pith are submerged deeper in water than trunks with less starch. It thus may be possible to develop a correlation matrix between starch content on the one hand and measured trunk volume combined with the percentage of trunk diameter submerged in water on the other. Such a correlation matrix may offer an opportunity to pay for starch contents rather than for trunks. Farmers are well aware that trunks differ in starch content even within the same variety. They would be quick to catch up on price differences between good and bad trunks. By means of such differential payment in harvesting operations with private farmers-harvesters the economics of the factory may be improved.

4.3 Starch recovery in quality and quantity

The starch technologist Cecil (1986), after a number of years working in Sarawak, gives points 2 - 8 of the following survey of losses; point 1 was added by the author, after Fujii *et al.* (1986):

1. Harvesting of trunks before flower initiation Harvesting of immature trunks should be avoided as the starch grains then may be too small for easy settling. A trunk is considered to be mature close to flower initiation, the first start of flower formation in its growing point.

2. Log storage Logs should not be stored longer than 2-3 days at the very most and preferably in water; both longer and dry storage lead to deterioration of starch quality and to a diminishing starch quantity.

3. Bark thickness Bark should be removed carefully and as sparsely as possible as there still is quite some starch in the inner layers of the bark; the bark layer itself usually is thinner than 2.5 cm, but this may also depend on the variety.

4. Milling of pith Pith must be grated or milled finely, in order to wash out the starch grains; if the fibres remain too long they still may contain starch. Colon & Anokkee (1986) advocate the use of the old-fashioned hammermill for this purpose.

5. Sieving out fibre Before sedimentation the starch slurry should be passed through a screen no coarser than 120 mesh (125 micron). It removes remaining fibre particles that may be instrumental in the microbial deterioration of the starch. This will also lead to some loss of large starch grains, but these are less than 1%.

6. Settling Settling tanks should be extensive and shallow rather than compact and deep; the same holds for settling tables; in this way also small starch grains may be captured.

7. Storage of wet starch Starch should not be kept wet for more than 24 hours; where there is no alternative for storing wet starch it must be treated with SO_2. If kept wet too long the starch grains may erode. This results in gas-pockets in the grains. It makes settling more difficult and also diminishes starch quality.

8. Cleaning of factory equipment at stops Equipment should be cleaned thoroughly after each stop of the factory; if this is not done the new start will be accompanied by an enhanced microbial activity.

The combination of these measures may lead to an improvement in starch recovery in the factory of 30% to 50%. It is thus of paramount interest that a good starch technologist well versed in sago palm cultivation and harvesting continues the research started by Cecil and his group.

5. Use of presently discarded parts

Provided the fertilizer use problem has been solved and returning the refuse to the field is not necessary any more, it may be possible to make use of side products of sago palm.

Bark Most factories that have been working for a number of years are literally surrounded by large heaps of discarded sago palm bark. Only the government-owned factory in Sarawak is using its bark for drying of the starch. It is reported that the smoke of bark burning attacks the chimney, which has to be replaced rather rapidly. Other factory owners in Sarawak say jokingly that they can afford to do so, because the government pays for it (Jong; pers. comm.; 1992).

The aggressiveness of the smoke may be caused by a high silica content of the bark as is the case with the shells of oil palm seeds. A solution may be found in using the *Waterwide* burner. This type of burner is less heat-efficient than others, but does not cause difficulties with respect to silica (Vugts; pers. comm.; 1992). The matter should be under research, as using the bark for drying would make the operation of a factory on the one hand more efficient and on the other do away with a refuse problem.

Hampas The refuse of starch extraction, the ground fibrous material out of the pith is usually just discarded and polluting either the surface water or the surroundings of the factory. Normally it is too expensive to transport refuse back to the plantings. There have been successful efforts to use it for manufacturing of particle board. This matter should also be under research as it may offer an interesting sideline for large scale starch factories.

Growing point In other palms the growing point is used as a vegetable under the names of 'palm heart', 'palm cabbage' or 'kings salad'. Occasionally the local population also eats the growing point of the sago palm fresh. In Costa Rica another tillering palm (pejibaye; *Bactris gasipaes*) is especially grown for this purpose and the hearts are being brought on the market, recently even canned. It appears to be worthwhile taking this possibility up in research also in sago palm.

6. Conclusions

Considerable progress has been achieved in sago palm exploitation and also in cultivation. A rather quick increase in production is to be expected in the coming twenty years. But research still lags dangerously behind.

Four items for research have been identified in this paper.

The most pressing is the problem of fertilizer use in sago palm cultivation. It should be taken up by an agronomist-soil scientist-fertilizer expert. Without a solution to this problem the developing intensive sago industry will be at a dead end.

The problem second in importance is a complex one, that already is being faced in harvesting: how to obtain a paying operation with acceptable starch yields from trunks, with reduced losses. It should be tackled by a starch technologist with quite some knowledge of sago palm agronomy.

The third one, of importance on the somewhat longer run, is pracical and agronomically appliccable taxonomy. The problem should be under research by a good taxonomist-agronomist, well versed in sago palm literature. Taxonomy should be combined with evaluation of starch production and of duration of trunk growth as shown in the simple modelling. The study of taxonomy will require extensive travelling and should be combined with establishment of a collection garden for genetic material.

All three specialists should obtain quite some knowledge and experience of recent advances in sago palm agronomy before they start off on their assignments.

A fourth item, only important on the longer run, is the use of presently discarded parts of the sago palm.

Especially three pioneer-operations are worth following in order to obtain experience. They are (1) the large scale planting of sago palm on deep peat by *Estet Pelita* in Mukah in Sarawak, (2) the exploitation of a natural stand on mineral soils by *INHUTANI I* on the island Halmahera and (3) the small model-planting on clayish soils of the *Agency for the Assessment & Application of Technology (B.P.P.Teknologi)*, close to Bogor, West Java, Indonesia. These three operations are done quite well and accumulate considerable experience.

Agronomic research can be followed in Sarawak in the 60 ha deep peat experiment station of the *Research Branch of the Sarawak Department of Agriculture*. Besides the collection started in Makariki Station on Seram, Molucca's, there appears no agronomic research to be done by the *Agency for Agricultural Research and Development (AARD)* in Indonesia as yet. The demonstration planting of *B.P.P.Teknologi* appears to be the only research on sago palm in Indonesia.

Also there is a lack of training of young agronomists in the field of sago palm cultivation. Such, preferably international, training could be offered in combination with the three pioneer-operations and on the research station mentioned here.

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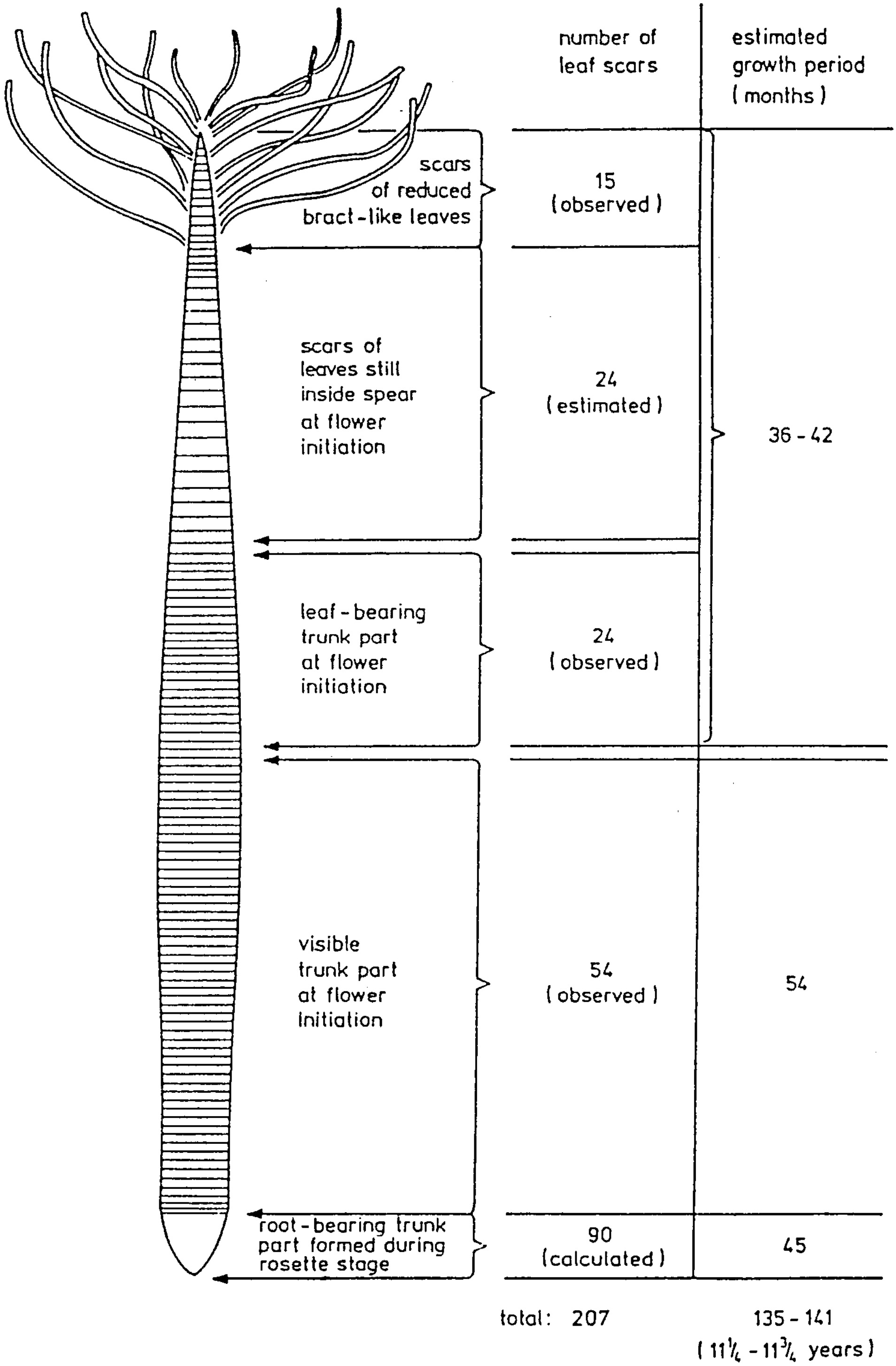

Figure 1.: Model of Sago 'Molat', for explanation see Table 2.

Table 1. Estimated nutrients contents in grammes of single trunks and single leaves; after Flach & Schuiling (1991).

Nutrient	in one trunk	in one leaf
N	590	37
P	170	6
K	1700	20
Ca	860	90
Mg	350	7

Table 2. Summary of data for a trunk forming sago palm with a seed to seed life of approximately 11 years (sago Molat) and growing under optimum ecological conditions (after Flach & Schuiling; 1989).

Rosette - stage	
Average number of leaves formed per month in the rosette-stage	2
Estimated total number of leaves formed during the rosette-stage	90
Estimated duration of the rosette-stage if grown from seeds (months)	45
Stage of trunk formation	
Optimum number of leaves in crown (n)	24
Number of leaves in growing point (n)	24
Number of days between successive leaves (p)	30
Estimated optimum leaf age in days (n * p)	720
Approximate flower initiation at visibility of leaf scar on the trunk, number	54
Approximate number of leaves in the crown (24) plus leaf scars on the trunk (54 leaf scars) at flower initiation (24 + 54)	78
Estimated duration of stage of trunk formation (months)	54
Stage of flower development	
Number of leaves already present at the start of flower development	24
Average number of leaves formed per month in during flower development	2
Estimated total number of leaves formed during flower development	24
Estimated duration of flower development (months)	12
Stage of fruit ripening	
Estimated at months	12

Table 3. The genus *Metroxylon* according to Beccari (1918).

Taxa	Location
1. *M. sagus* ROTTB. (forma typica)	Malay isl.
1.1. var. molat BECC.	Seram
1.2. var. peekelianum BECC.	North PNG
1.3. var. gogolense BECC.	North PNG
2. *M. rumphii* MART. (forma typica)	Malay isl.
2.1. var. rotang BECC.	West Seram
2.2. var. longispinum BECC.	Ambon
2.3. var. sylvestre BECC.	West Seram
2.4. var. ceramense BECC.	Seram
2.5. var. micracanthum BECC.	West Seram
2.5.1. subvar. tuni BECC	
2.5.2. subvar. makanaro BECC.	
2.6. var. buruense BECC.	Buru
2.7. var. flyriverense BECC.	Fly River PNG
3. *M. squarrosum* BECC.	East Seram
4. *M. warburgii* BECC.	New Hebrids
5. *M. upoluense* BECC.	Samoa
6. *M. vitiense* BENTH et HOOK.	Fiji
7. *M. amicarum* BECC.	Carolines
7.1. var. commune BECC.	
7.2. var. maius BECC.	
8. *M. salomonense* BECC.	Solomons
9. *M. bougainvillense* BECC.	Bougainville

RESEARCH PRIORITIES FOR SAGO PALM DEVELOPMENT IN INDONESIA AND SARAWAK: AN AGENDA FOR RESEARCH

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Abstract

During travelling through Indonesia and Sarawak the latest developments in sago palm cultivation have been evaluated in a technical sense. In the coming two decades quite an increase in the production of sago palm starch is to be expected through both new plantings and exploitation of natural stands. The agronomy for this development is based nearly solely on observation of small scale farmers' practices. Research lags dangerously behind, although more so in Indonesia than in Sarawak.

Three groups of research questions have been identified. The most pressing is (1) the necessity to apply fertilizer for a sustained high yield. This is of even more importance on the notoriously poor deep peat soils than it already is on mineral soils. Without a solution to this problem the large scale cultivation of the crop is at a dead end. A good second in importance is (2) how to obtain optimum starch yields from trunks per unit of time and area, combined with the reduction of starch losses in processing. On the somewhat longer run should be studied (3) the taxonomy of the sago palm, in relation to its growth pattern. For each group of research questions holds that research personnel working at it should be experienced with or at least be well acquainted with the sago palm.

Two pioneer-operations are important to obtain part of the necessary practical experience: (1) the large scale deep peat plantings by *Estet Pelita*, especially the first close to Mukah in Sarawak; (2) the exploitation by *INHUTANI I* of a natural stand on mineral soils on Halmahera in the Northern Molucca's.

In Sarawak, Estet Pelita just started with a research programme. Agronomic research is developed there also mainly on the deep peat experiment station of *the Research Branch of the Sarawak Department of Agriculture* at Dalat, close to Mukah. Small collections of genetic material have been started in this experiment station and in Makariki on Seram in the Molucca's. The small model-planting on clay soils run by *B.P.P.Teknologi* close to Bogor, West Java aims at solving some practical questions.

There still is a lack of manpower, trained in sago palm growth and development. Training of sago palm agronomists should be a joint concern of the countries involved in the development.

1.3 Exploitation by small scale farmers

The exploitation of existing stands, both natural and planted, by small scale farmers is rather uniform. The stands are irregular, they are hardly weeded, only occasionally pruned and never fertilized. It is not well possible to make a distinction between planted and natural stand on appearances alone. Often other trees are found in the stands, occasionally fruit trees.

New planting is nearly always done by means of well-sized, especially selected suckers of special cutivars. For planting the farmers select the somewhat drier spots. The situation as described by Flach (1977) for Batu Pahat in Johor, West Malaysia appears to be exceptional. If asked, however, the farmers know how to change plantings into plots with a high yield per unit time and area, by weeding and pruning.

Harvesting may be spread over a period of roughly two years, i.e. from just before or just after flower initiation till the start of fruit formation. If asked, the farmers are well aware of the possibility of earlier harvesting. Only if the farmer is selling to a factory, harvesting may be done two years earlier than when the farmer is producing for subsistence or on a small scale for the local starch market. Production of the stands can be estimated at normally 15 - 20 trunks per ha and year. Exceptional yields on good soils may be double. The yield of dry starch may then be estimated normally at 3 - 4 tonnes and exceptionally at 8 tonnes per ha and year. Farmers also are of the opinion that a variety with a short duration of growth is best for a high production per unit time and area.

Most striking is the knowledge of sago palm growers. It is probably passed on from parent to child through many generations. Varieties of sago palms are easily recognized, even from colour photographs. The farmers are always willing to discuss or answer interested questions. For the sago palm farmer the crop is the staff of life, interwoven with belief and religion. Anybody really interested in the crop is really welcome, anybody who wants to interfere with it is met with suspension and anger.

1.4 Intensive harvesting from natural stands

At present rather intensive harvesting from natural stands is done in Indonesia:

(1) The semi-governmental forest exploitation company *INHUTANI I* operates close to Kao on the island Halmahera in the Molucca's. Trunks are harvested from existing wild stands in co-operation with the local population. Harvesting started in august 1991 in a well-organized operation on mineral soils. The factory has a capacity of 20 tonnes of dry starch per 24 hours. Although the factory is not yet working at full capacity, the operation appears to be close to the break-even point. Main draw-backs are (1) too low starch

contents of trunks, possibly because part of the trunks is harvested too young. This leads to incomplete recovery of the too small starch grains (Fujii *et al.*; 1986). And (2) the 80 km distance from the factory to the shipping harbour at Tobelo leads to excessive transport costs. The (3) long distance from the natural stands to the factory site will make the application of fertilizer in future quite expensive and difficult. Unfortunately, exactly this area was hit in January 1944 by an earthquake of 6.8 on the scale of Richter. In Kao itself there were casualties, but none are reported from the factory. How serious the damage to the factory is, is as yet unknown. No doubt it will seriously hamper the operation.

(2) A private company *PT Sagindo Sari Lestari*, a subsidiary of the Djajanti Group, exploits natural stands at Arandai, Kepala Burung in Irian (Sudwikatmono; 1991). Our group was not allowed to visit this exploitation. The company uses a floating starch extraction plant and probably operates on shallow peat soils. They are said to face also too low starch contents. A new factory is being built on land in the area. The floating starch plant will be used in another concession in southeastern Irian Jaya.

(3) Nearly all areas with good natural sago palm stands in Kepala Burung in Irian Jaya have been given out in concessions to private companies.

(4) Also a small private factory is being established by an entrepreneur from Selat Panjang close to Muara Siberut on Siberut of the Mentawei islands.

1.5 New plantings

(5) In Indonesia on Selat Panjang of the Riau islands a 3000 ha sago palm enterprise is being established by a private group. The latter planting was not visited. This group appears to be working on fairly shallow peat.

1.6. Research

In all these cases, be it exploitation of existing stands or new plantings, we have to do with more intensive cultivation and harvesting. As with any other crop, production of a high standard should be accompanied by research. Both types of production have to adhere to the laws and rules of biology and agronomy. Research to accompany the development is being done:

(7) In Indonesia on a small and rather well-run model-planting on clay soils under responsibility of the sago palm group of *B.P.P. Teknologi*, in the neighbourhood of Bogor, West-Java. This planting was set up as described by Flach (1977) for Batu Pahat in Johor, West Malaysia. Studied are general growth, the effect of water level and the system of desuckering. The planting is now around eight years old and harvesting should commence.

(8) In Sarawak close to Dalat, on the Sungei Talau 60 ha deep peat research station run by the *Research Branch of the Sarawak Department of Agriculture*. The station was started in 1988. Studied are planting density, desuckering and fertilizer use. Also a small collection of genetic material has been started.

2. Nutrient withdrawal from the exploited fields

2.1 Consequences of factory processing

Originally the sago palm was, and still is, harvested and processed in the fields where it grows. Only the wet starch is taken home by the small scale processors, mostly for their own food. All other material, containing all plant nutrients, is left in the field and thus returned to the soil.

In factory processing, however, harvesting and processing are being separated from each other, both in time and in place. The trunks are brought to the factory and processed there. The refuse including the bark, containing all plant nutrients, is usually discarded in the factory neighbourhood.

Especially at a production far above the traditional level of 20 trunks per ha and year, this will lead to depletion of plant nutrients in the soil in the plantings. All nutrients are transported to the factory in the trunks. There these nutrients are deposited in the refuse, which usually is washed down to the sea in the surface water. The danger of pollution of the environment is not large as most operations are relatively small.

If leaves are harvested also, e.g. for 'atap' or thatch, also the plant nutrients in them are exported to the area where they are used. The hard bark, also containing plant nutrients, is usually left to decompose in the neighbourhood of the factory.

2.2 Estimate of nutrient withdrawal

The withdrawal of major nutrients by sago palms, as estimated by Flach & Schuiling (1991), is presented in table 1. The table makes clear that continuous harvesting at a high level of around 100 trunks per ha and year will deplete the soil and result in a serious threat to productivity. First potassium will be minimized. And if the 70 - 80 fully grown leaves the smallest sago palm type produces during its life cycle are harvested to be used for roofing, depletion of the soil even occurs much faster. This may, of course depending on its availability in the soil, start off with a lack of calcium. Depletion will be even more important on the notoriously very poor deep peat soils.

2.3 Research on fertilizer application

No fertilizers whatsoever are being used, even when the sago palm is cultivated. Research into the nutrition of the sago palm is being done only in Sarawak (Ann. Rep. Sarawak and Sim & Ahmed; 1991). As shown by Kueh (this volume) until now no responses to fertilizer applications have been found.

Recently the deep-peat experiment station on sago palm in Dalat, Sarawak, showed a serious nutritional disorder occurring in the young sago palms. Only three to four of the youngest leaves, out of normally 15 - 17, remain green on the trunk; all older leaves have died. It appears to be a potassium deficiency that may have been triggered off by drainage of the peat swamps some time after planting. In hothouse experiments in Wageningen it was shown that at an abrupt change of the water level sago palms form a completely new root system. It is not unlikely that in the field a similar effect occurs. The nutritional disorder then may disappear after some time.

Haska (this volume) showed rather clearly that the sago palms still growing in West Java are too small and contain only little starch. This probably is due to continuous cutting of leaves for thatch. Often palms grow with only 3-4 leaves. Such palm grooves would offer an unique opportunity to start research on fertilizer application. It may well be possible to increase both starch production and leaf production through a programme of fertilizer application.

2.4 A new proposal for research on fertilizer application

It is thus of paramount importance to continue and improve research on fertilizer application. Such research will meet a peculiar and interesting difficulty. Sago palms are, although not necessarily so, usually grown under rather wet and often even flooded conditions. These conditions will result in on the one hand the possibility of enrichment of the soil by the short-duration flood water (Flach; 1977) and on the other the danger that applied fertilizer will wash away. Flooding of palms for short periods appears to do very little harm, but continuous flooding or flooding for extended periods appears to hamper growth (Flach *et al.*; 1977; Kraalingen; 1986).

Sago palms are able to form roots along their trunks. For research purposes one could thus think of applying a fertilizer solution in a band of plastic fastened around the trunk. The plastic should be fastened on its lowest side around the lower part of the trunk. The plastic than should be formed into a bag around the trunk. In the bag with fertilizer solution roots will develop. In this way the trunk itself will be fertilized and no fertilizer will go into the soil. This would ultimately result in knowledge about the individual needs of fertilizer per trunk. It may even be possible to develop this method into a practical way of fertilizer application especially on deep peat.

It may also be possible to design an experimental plot in an existing planting. The treatments in the experiment should then be separated by means of deep and watertight, possibly metal, dams. Such structures, however expensive, may help to provide an answer to the problem of fertilizer application.

2.5 Returning refuse to the field

For the farther future, however, large scale operations should be designed in such a way that the refuse of processing either can be returned to the field or can be put to other economic uses. It will become ever more unacceptable to just dump the valuable refuse in the surface water, even if it is close to the sea. The world population will become ever more aware of the value of the natural surroundings.

The work of Bintoro (this volume) shows that returning refuse to the fields may have its own problems. Nitrogen will be needed to decompose the organic matter.

3. The importance of taxonomy for cultivation

3.1 A simple model of sago palm growth

Understanding of the growth and development of the sago palm is necessary not only for cultivation but also for harvesting from natural stands. It is also necessary for the taxonomy of the sago palm.

A preliminary model of growth and development of a common type of sago palm, in Indonesia called 'molat', is given in table 2 and figure 1. In this model the ideas given by Corner (1966) concerning palm growth have been applied. Palm growth is strictly regular. There are as many unfolded leaves visible in the crown as there are developing, still folded, within the growing point. The newest appearing leaf, the spear leaf, is exactly in the middle of, on the one hand the developing leaves in the growing point and, on the other those visible in the crown. That this holds for all palms is doubted by Tomlinson (1990). Be this as it may, for the sago palm in the trunk forming stage it probably is valid, although possibly not as strict as Corner assumes.

Only if the number of leaves increases (resp. decreases) the number of developing leaves within the growing point has to have been larger (resp. smaller) than in the visible crown. So, one must expect the number of leaves in the growing point to be larger in the rosette-stage, as then the number of leaves increases.

In most monocotyledonous and once flowering crops with a terminal inflorescence, flowering starts after a fixed number of leaves has been formed. This holds, of course within certain limits, for e.g. rice, banana and sisal. It is assumed that this holds also for the sago palm, at least it does in cv molat. In the model then the duration of the stage of trunk growth can be estimated by counting the number of leaf scars on the trunk at flower initiation. In 'molat'grown under optimum ecological circumstances there would be 54. At one leaf per month this would amount to 4.5 years. After the physiological trunk age of 54 leaf scars on the trunk, flower initiation starts. The number of 54 is achieved under optimal eco logical conditions and with uniform planting material. Deviations from this number might be interesting for research.

In the model of this sago palm the leaf production in the rosette-stage, the stage without formation of a visible trunk, was established to be two leaves per months on the average; then the leaves become progressively larger. After flower initiation the leaves become progressively smaller; the speed of leaf formation at that time is also assumed to be two per month on the average.

The value of such a model is as yet limited. The figures given in table 2 are only averages; they show, of course, deviations around a mean. For the time being we assume that the speed of leaf formation is more constant than the leaf longevity. This means that at a constant lack of plant nutrients the leaf longevity will become shorter, whereas the speed of leaf formation will remain constant. At sudden changes in ecological conditions the speed of leaf formation may slow down first.

Some of the difficulties to be expected with the interpretation of the model have been shown by Azudin et al. (this volume). Sago palms grown on mineral soils showed a lower number of leaf scars at flower initiation than those grown on peat soils. Those grown on less deep peats were in between the former two.

Nevertheless, if one is able to understand it, the model may be of help in classifying the varieties if developed for other varieties as well.

3.2 Size of trunks *and their starch content*

Physiological trunk age is determined by the number of leaf scars. Ideally the palm forms one leaf per month from after completion of the rosette-stage until the initiation of flowering. Physiological trunk age, as counted by the number of leaf scars, may differ from on the average four and a half years on the one hand in 'molat' as described in table 2 and fig. 1 till over twenty years in the variety, possibly classified by Beccari (1918) as 'sylvestre'. Probably the shortest physiological trunk age is best for cultivation. This is an important difference between varieties. Of course such differences in age and size of trunks should lead to different systems of cultivation.

The amount of pith in a trunk is related to the volume of the trunk. Trunk height is related to age of the trunk, as under good ecological conditions one leaf per month is being produced and each leaf has its own internode, the distance between two leaf scars. Circumference of a trunk is more important for volume than height. In volume, calculated as $\pi * r^2 * h$, the radius (r) has a quadratic contribution, whereas the height (h) only has a linear contribution.

Thus short stout trunks give more pith than tall slender trunks. This holds within one variety. Between varieties there may be quite some other differences such as more (respectively less) and/or larger (respectively smaller) sized leaves in a crown. Both will lead to a larger (respectively smaller) circumference of the trunk. A larger number of leaves formed during the period of trunk growth until flower initiation, will lead to an increase in trunk life and consequently a taller trunk. We thus may safely conclude that stout short trunks of one and the same variety produce more starch than slender tall trunks.

3.3 The 'species' question

We do not yet know whether the different cultivated varieties of the sago palm deserve only cultivar status or should be considered as separate species or (sub)varieties. Many of them appear not to produce seeds. Beccari (1918) distinguished nine species, with in total 25 varieties and subvarieties. In table 3 his species and only 12 of the varieties are presented; the varieties in *M. squarrosum* have been neglected. Beccari mentions them but considers them 'barely distinguishable'. For his treatment he received material from the places mentioned in table 3. He did not mention the (physiological) duration of the stage of trunk growth.

One may doubt his division into non-spined versus spined, i.e. *Metroxylon sagus* Rottb. versus *Metroxylon rumphii* Mart. Beccari himself, however, shows some doubt on the division into spined versus non-spined. Recently it has been established several times that within a number of varieties considered non-spined also spined ones exist (see e.g. Flach; 1983). This also is true for 'molat'. If asked, the farmers admit that there is spined 'molat' (berduri). Therefore, these two species now are put together in the original species *Metroxylon sagu* Rottb. The west-Seramese *M. squarrosum* was found by Beccari (1918) to possess 24-29 vertical rows of scales on the seed coat in stead of 18 as the other two do. It still may have to be considered a separate species.

In his recent treatment of the genus Rauwerdink (1986) puts Beccari's species *sagus, rumphii* and *squarrosum* together into the species *Metroxylon sagu*. This species he subdivides into four *formae* according to spininess, i.e. *forma sagu* (without spines), *forma tuberatum* (knoblike spines), *forma micracanthum* (spines up to 4 cm length) and *forma longispinum* (spines of 4-20 cm length). Although the treatment has the merit of being simple and logical, all varieties distinguished by Beccari and also in folk taxnomy, disappear.

Tuwan (1991), guided as a student by Anema (pers. comm.; 1991), found differences in the shape of pollen between 'tuni', 'ihur' and 'makanaru'. Differences in shape of pollen may shed new light on the taxonomy. 'Ihur' might well be Beccari's *M. rumphii var. sylvestre*. Jong (pers. comm.; 1992) states that Sarawak palms again show a different shape of pollen. But nothing of the kind is shown by either Thanikaimoni (1970) or Sowunmi (1972).

3.4 Folk taxonomy

We must conclude that as yet there is insufficient information on the taxonomy of sago palms. As an example: in northern Papua New Guinea the local population in the Sepik River Basin distinguishes 12 cultivated varieties and in addition 3 wild ones. Ohtsuka (1983) reports for the Fly River area in southern Papua New Guinea some 23 local names out of which 14 were confirmed by aged men. And there is as yet no certainty that these cultivated varieties are the same as those in southeast Asia.

More west, on the island of Halmahera 8 varieties were reported in 'folk-taxonomy' by Yoshida (1980). On the western coast of Sumatra there probably is only 1 variety, seeds of which may develop nonspiny ones and, in addition, all kinds of different spines. This variety appears to be 'molat'; at least people in the Sepik River Basin in Papua New Guinea recognised the author's pictures of this variety immediately as such, with their own name 'ambutrun'.

Schuiling (this volume) is approaching the matter in more detail in his paper.

3.5 Centre of diversity

Travelling through these area's one may easily get the impression that we have to do with on the one hand a number of separate cultivated varieties (cultivars or cv's), possibly spread by man and on the other a number of landraces, each of the latter adapted to its own region. Sago growers usually are rather eager to collect new cv's. In the Sepik River Basin the author noticed that a local inhabitant, who had visited the Pacific had taken along one of the sago palms from that area and had it planted in his village. In Sarawak, on the deep peat experiment station, the sago palm material collected by Jong has to be hidden among other sago palms to prevent the by local sago palm growers (Jong; pers. comm.; 1992).

As stated by Leon (1986) in the centre of diversity of a plant species usually a large number of varieties is found, but at the border of the natural dispersion the number diminishes. Looking at the number of varieties we now assume that the centre of diversity is New Guinea and not, as Beccari (1918) stated, Seram.

3.6 A new taxonomical treatment

We do not yet know the length of the life cycles from seed to seed of each of the species, varieties and sub-varieties given by Beccari. Especially the (physiological) duration of the stage of trunk growth appears to be a major criteria for the choice for cultivation and should become important also for taxonomy.

It is thus rather clear that a new taxonomical treatment of the genus, incorporating all available knowledge through a study in depth by a taxonomist experienced and knowledgeable in sago palm, is badly needed.

4. Starch - contents and recovery

4.1 Starch content of the pith

Starch content of the pith should be used to evaluate starch production. In evaluation it is rather practical to use the starch density, the dry starch weight per volume of pith. A volume of water-saturated starch of 1 cm^3 weighs after drying in an oven approx. 0.65 g. Its weight varies of course with its water content, which varies again with the air humidity.

The starch content of pith appears to vary from hardly any till 300 kg of dry starch per m^3 of pith in Batu Pahat (Flach & Schuiling; 1989). Lowest starch contents per volume of pith have been reported in wild sago palms under partially flooded conditions, in the Sepik area in Papua New Guinea (Kraalingen; 1986). In the years 1950 - 1957 in a wild stand on the island of Salawati, Irian Jaya, a statistical average of 167 kg per m^3 was found (Holmes *et al.*; 1984).

4.2 Payment for starch contents

Starch contents vary along the trunk too. This mechanism is not yet understood, albeit as discovered by Kraalingen (1984) there is some reason to believe that after flower initiation starch is moved upwards in the trunk. This may also explain that, after flower formation the lowest part of a trunk tends to become just about empty. This probably is the reason why small scale sago processors aiming for high yields per trunk, harvest when the inflorescence has been developed. They leave the lowest part of such a trunk standing in the field. Cultivators in Batu Pahat, however, aiming for high yields per unit time and area and harvesting around flower initiation, take the lowest part of the trunk also.

Harvested trunks (or trunk parts) containing more starch per volume of pith are submerged deeper in water than trunks with less starch. It thus may be possible to develop a correlation matrix between starch content on the one hand and measured trunk volume combined with the percentage of trunk diameter submerged in water on the other. Such a correlation matrix may offer an opportunity to pay for starch contents rather than for trunks. Farmers are well aware that trunks differ in starch content even within the same variety. They would be quick to catch up on price differences between good and bad trunks. By means of such differential payment in harvesting operations with private farmers-harvesters the economics of the factory may be improved.

4.3 Starch recovery in quality and quantity

The starch technologist Cecil (1986), after a number of years working in Sarawak, gives points 2 - 8 of the following survey of losses; point 1 was added by the author, after Fujii *et al.* (1986):

1. Harvesting of trunks before flower initiation Harvesting of immature trunks should be avoided as the starch grains then may be too small for easy settling. A trunk is considered to be mature close to flower initiation, the first start of flower formation in its growing point.

2. Log storage Logs should not be stored longer than 2-3 days at the very most and preferably in water; both longer and dry storage lead to deterioration of starch quality and to a diminishing starch quantity.

3. Bark thickness Bark should be removed carefully and as sparsely as possible as there still is quite some starch in the inner layers of the bark; the bark layer itself usually is thinner than 2.5 cm, but this may also depend on the variety.

4. Milling of pith Pith must be grated or milled finely, in order to wash out the starch grains; if the fibres remain too long they still may contain starch. Colon & Anokkee (1986) advocate the use of the old-fashioned hammermill for this purpose.

5. Sieving out fibre Before sedimentation the starch slurry should be passed through a screen no coarser than 120 mesh (125 micron). It removes remaining fibre particles that may be instrumental in the microbial deterioration of the starch. This will also lead to some loss of large starch grains, but these are less than 1%.

6. Settling Settling tanks should be extensive and shallow rather than compact and deep; the same holds for settling tables; in this way also small starch grains may be captured.

7. Storage of wet starch Starch should not be kept wet for more than 24 hours; where there is no alternative for storing wet starch it must be treated with SO_2. If kept wet too long the starch grains may erode. This results in gas-pockets in the grains. It makes settling more difficult and also diminishes starch quality.

8. Cleaning of factory equipment at stops Equipment should be cleaned thoroughly after each stop of the factory; if this is not done the new start will be accompanied by an enhanced microbial activity.

The combination of these measures may lead to an improvement in starch recovery in the factory of 30% to 50%. It is thus of paramount interest that a good starch technologist well versed in sago palm cultivation and harvesting continues the research started by Cecil and his group.

5. Use of presently discarded parts

Provided the fertilizer use problem has been solved and returning the refuse to the field is not necessary any more, it may be possible to make use of side products of sago palm.

Bark Most factories that have been working for a number of years are literally surrounded by large heaps of discarded sago palm bark. Only the government-owned factory in Sarawak is using its bark for drying of the starch. It is reported that the smoke of bark burning attacks the chimney, which has to be replaced rather rapidly. Other factory owners in Sarawak say jokingly that they can afford to do so, because the government pays for it (Jong; pers. comm.; 1992).

The aggressiveness of the smoke may be caused by a high silica content of the bark as is the case with the shells of oil palm seeds. A solution may be found in using the *Waterwide* burner. This type of burner is less heat-efficient than others, but does not cause difficulties with respect to silica (Vugts; pers. comm.; 1992). The matter should be under research, as using the bark for drying would make the operation of a factory on the one hand more efficient and on the other do away with a refuse problem.

Hampas The refuse of starch extraction, the ground fibrous material out of the pith is usually just discarded and polluting either the surface water or the surroundings of the factory. Normally it is too expensive to transport refuse back to the plantings. There have been successful efforts to use it for manufacturing of particle board. This matter should also be under research as it may offer an interesting sideline for large scale starch factories.

Growing point In other palms the growing point is used as a vegetable under the names of 'palm heart', 'palm cabbage' or 'kings salad'. Occasionally the local population also eats the growing point of the sago palm fresh. In Costa Rica another tillering palm (pejibaye; *Bactris gasipaes*) is especially grown for this purpose and the hearts are being brought on the market, recently even canned. It appears to be worthwhile taking this possibility up in research also in sago palm.

6. Conclusions

Considerable progress has been achieved in sago palm exploitation and also in cultivation. A rather quick increase in production is to be expected in the coming twenty years. But research still lags dangerously behind.

Four items for research have been identified in this paper.

The most pressing is the problem of fertilizer use in sago palm cultivation. It should be taken up by an agronomist-soil scientist-fertilizer expert. Without a solution to this problem the developing intensive sago industry will be at a dead end.

The problem second in importance is a complex one, that already is being faced in harvesting: how to obtain a paying operation with acceptable starch yields from trunks, with reduced losses. It should be tackled by a starch technologist with quite some knowledge of sago palm agronomy.

The third one, of importance on the somewhat longer run, is pracical and agronomically appliccable taxonomy. The problem should be under research by a good taxonomist-agronomist, well versed in sago palm literature. Taxonomy should be combined with evaluation of starch production and of duration of trunk growth as shown in the simple modelling. The study of taxonomy will require extensive travelling and should be combined with establishment of a collection garden for genetic material.

All three specialists should obtain quite some knowledge and experience of recent advances in sago palm agronomy before they start off on their assignments.

A fourth item, only important on the longer run, is the use of presently discarded parts of the sago palm.

Especially three pioneer-operations are worth following in order to obtain experience. They are (1) the large scale planting of sago palm on deep peat by *Estet Pelita* in Mukah in Sarawak, (2) the exploitation of a natural stand on mineral soils by *INHUTANI I* on the island Halmahera and (3) the small model-planting on clayish soils of the *Agency for the Assessment & Application of Technology (B.P.P.Teknologi)*, close to Bogor, West Java, Indonesia. These three operations are done quite well and accumulate considerable experience.

Agronomic research can be followed in Sarawak in the 60 ha deep peat experiment station of the *Research Branch of the Sarawak Department of Agriculture*. Besides the collection started in Makariki Station on Seram, Molucca's, there appears no agronomic research to be done by the *Agency for Agricultural Research and Development (AARD)* in Indonesia as yet. The demonstration planting of *B.P.P.Teknologi* appears to be the only research on sago palm in Indonesia.

Also there is a lack of training of young agronomists in the field of sago palm cultivation. Such, preferably international, training could be offered in combination with the three pioneer-operations and on the research station mentioned here.

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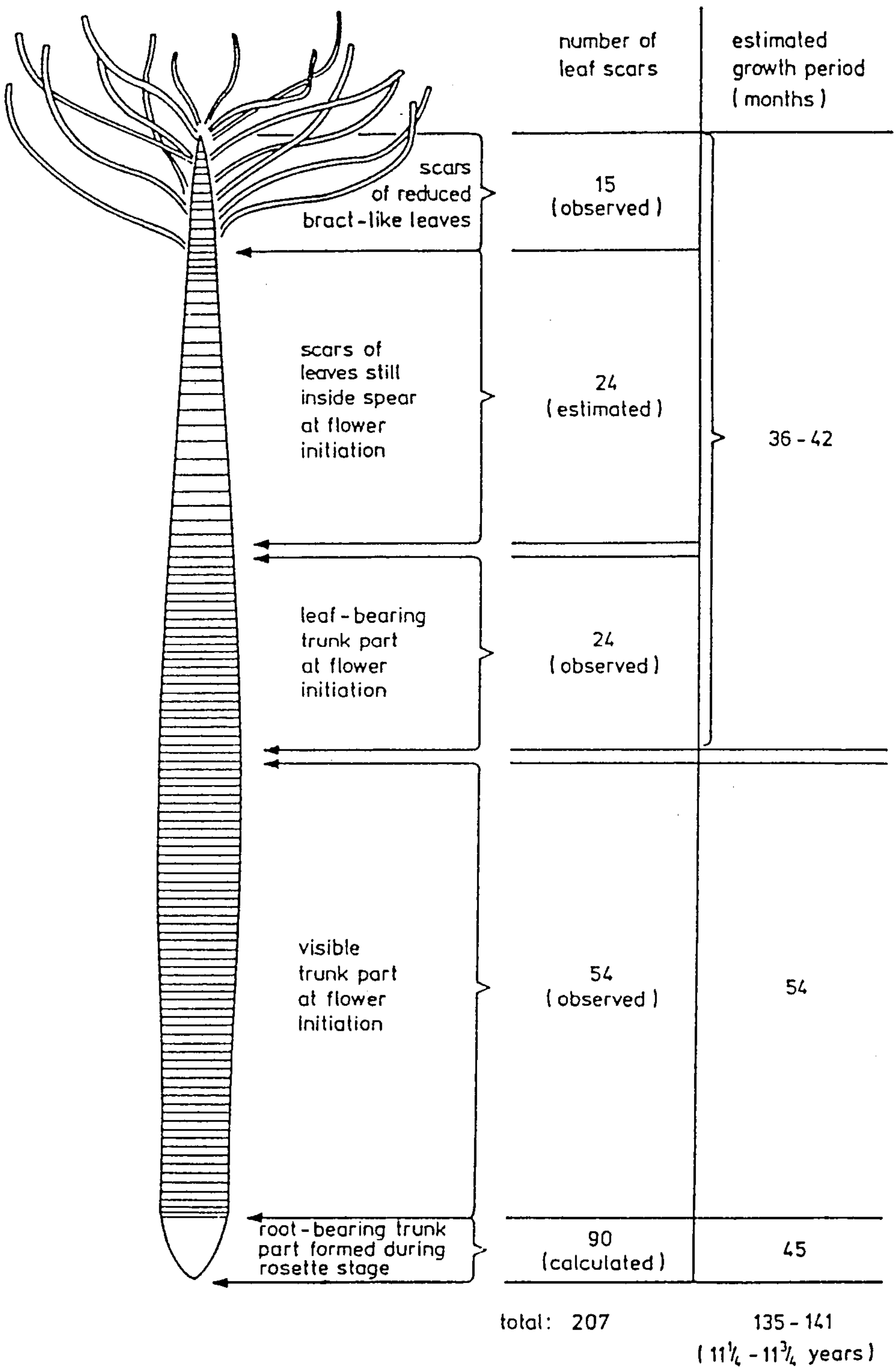

Figure 1.: Model of Sago 'Molat', for explanation see Table 2.

Table 1. Estimated nutrients contents in grammes of single trunks and single leaves; after Flach & Schuiling (1991).

Nutrient	in one trunk	in one leaf
N	590	37
P	170	6
K	1700	20
Ca	860	90
Mg	350	7

Table 2. Summary of data for a trunk forming sago palm with a seed to seed life of approximately 11 years (sago Molat) and growing under optimum ecological conditions (after Flach & Schuiling; 1989).

Rosette - stage	
Average number of leaves formed per month in the rosette-stage	2
Estimated total number of leaves formed during the rosette-stage	90
Estimated duration of the rosette-stage if grown from seeds (months)	45
Stage of trunk formation	
Optimum number of leaves in crown (n)	24
Number of leaves in growing point (n)	24
Number of days between successive leaves (p)	30
Estimated optimum leaf age in days (n * p)	720
Approximate flower initiation at visibility of leaf scar on the trunk, number	54
Approximate number of leaves in the crown (24) plus leaf scars on the trunk (54 leaf scars) at flower initiation (24 + 54)	78
Estimated duration of stage of trunk formation (months)	54
Stage of flower development	
Number of leaves already present at the start of flower development	24
Average number of leaves formed per month in during flower development	2
Estimated total number of leaves formed during flower development	24
Estimated duration of flower development (months)	12
Stage of fruit ripening	
Estimated at months	12

Table 3. The genus *Metroxylon* according to Beccari (1918).

Taxa	Location
1. *M. sagus* ROTTB. (forma typica)	Malay isl.
1.1. var. molat BECC.	Seram
1.2. var. peekelianum BECC.	North PNG
1.3. var. gogolense BECC.	North PNG
2. *M. rumphii* MART. (forma typica)	Malay isl.
2.1. var. rotang BECC.	West Seram
2.2. var. longispinum BECC.	Ambon
2.3. var. sylvestre BECC.	West Seram
2.4. var. ceramense BECC.	Seram
2.5. var. micracanthum BECC.	West Seram
2.5.1. subvar. tuni BECC	
2.5.2. subvar. makanaro BECC.	
2.6. var. buruense BECC.	Buru
2.7. var. flyriverense BECC.	Fly River PNG
3. *M. squarrosum* BECC.	East Seram
4. *M. warburgii* BECC.	New Hebrids
5. *M. upoluense* BECC.	Samoa
6. *M. vitiense* BENTH et HOOK.	Fiji
7. *M. amicarum* BECC.	Carolines
7.1. var. commune BECC.	
7.2. var. maius BECC.	
8. *M. salomonense* BECC.	Solomons
9. *M. bougainvillense* BECC.	Bougainville