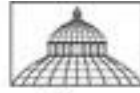




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Areca nut: India's Popular Masticatory: History, Chemistry and Utilization

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Arecanut: India's Popular Masticatory — History, Chemistry and Utilization

To the Indians, Malayans, or the Indonesians, betel-nut chewing is as familiar as chewing gum to the Americans. In India the use of arecanut and its cultivation constitute a distinct agricultural practice scarcely less important than that of other economic crops, but little attention has been given to a proper assessment of the fruit either in India or elsewhere.

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Introduction

The subject of this communication is a tall palm commonly known as arecanut palm or betel-nut palm, bearing the scientific name *Areca catechu* Linn., and included in the tribe Areceae of the family Palmae. The palm owes its rating of importance to the fruits known as arecanuts or betel-nuts, which form the principal chewing material in India and in the far eastern countries. When the arecanut is employed as a masticatory, it is often associated in fresh or processed form with the betel leaf (*Piper betle* Linn.) and a little lime producing a deep wine red coloration in the mouth. Arecanut is almost symbolic of the great culture of some of the oriental nations, and to the Indians, Malayans, or the Indonesians betel-nut chewing is as familiar as chewing gum to the Americans. India shared the monopoly for this crop

with the Strait Settlements and Ceylon until it was partitioned in 1947, when a large part of the arecanut tracts, particularly in Bengal, went to Pakistan. Since then there has been considerable activity on the part of the Government through the Indian Central Arecanut Committee, Kozhikode, to foster the production of arecanuts in the country especially by increasing the acreage under cultivation and obtaining higher yields from the existing gardens through improved methods of cultivation. This review is an attempt to stress the importance of this commodity crop, particularly in the light of certain recent contributions. In the preparation of this paper the published works on this plant have been freely drawn upon, but this does not by any means represent a mere compilation. On the contrary, effort has been made not only to evaluate the many observations critically and comparatively but also to indicate future lines of work which can be profitably pursued.

The arecanut essentially consists of a hard and fibrous outer covering commonly called the husk, enclosing within it the endosperm which is the edible nut. In India the use of arecanut and its cultivation constitute a distinct agricultural

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practice scarcely less important than that of other economic crops. Watt (151) referring to the cultivation and marketing of arecanuts in India writes, ". . . in Eastern and Northern Bengal and some portions of Assam its cultivation has assumed still greater dimensions. In certain districts of these provinces regular plantations of 5 to 20 or even 100 acres in extent occur (exclusively of betel-nuts) . . .". Its cultivation has proved to be of the greatest value from the commercial and industrial standpoint. He further states, "The magnitude and importance of the Indian production of betel-nuts may, however, be judged by the extent of coasting trade. . . . From the published returns of foreign imports and Indian production, . . . it would seem safe to affirm that the annual consumption of betel-nuts in India itself cannot be too far short of a valuation of Rs 225 lakhs, or say £1,500,000". However, it is apparent that the present production and consumption have exceeded many times the 1908 level, and arecanut has proved to be of considerable significance from the commercial and industrial standpoint, the import of betel-nuts now exceeding more than Rs 50,000,000 annually. In spite of the increasing economic importance of the fruit, little attention seems to have been given to a proper assessment of the fruit either in India or elsewhere, and for this reason arecanut has not been exploited to the same extent as coconut or other fruit trees.

History

Early History. The derivation of the name arecanut is not definitely known; it can possibly be traced to the Kanarese "adeke" or the Malayalam "adakka". In many other Indian languages the words "supari" or "tambul" refer to betel-nuts or to betel-nuts mixed with betel leaf and lime. In India arecanut

has a long history as evidenced by a reference to it in early Sanskrit works under the name "Gouvaka" and by its prominence in Hindu mythology and religious observances.

The widespread occurrence of the habit of betel chewing is itself an indication of its great antiquity. In Somadeva's *Katha Sarit Sagara* there is a mention of betel-nuts flavored with five fruits. Reference to betel chewing is available both in the *Jatakas* and in several other Pali works as well as in Jain scriptures. In the *Hitopadesa* betel-nut is described as pungent, spicy, bitter, and sweet; it is also said to expel wind, to remove phlegm, to kill germs and to subdue bad odor, to beautify the mouth, to remove impurities, and to induce love. Sushruta has mentioned in the first century A.D. that after a meal, the intelligent eater will take either some fruit of an astringent, pungent, or bitter taste or chew betel leaf prepared with broken arecanut, camphor, nutmeg, or clove. Some of the early travellers who visited India mentioned the custom of betel chewing and the use of arecanut. Abd Allah Ibn Ahmad has paid a tribute to betel chewing in India in his treatise on drugs. He has quoted several Arab authors and mentioned Sheriff chiefly, according to whom "the betel brightens the mind and drives away the cares . . . whoever uses it becomes joyful; he has a perfumed breath and perfect sleep . . . betel-nut replaces wine among Indians by whom it is widely used". Chau Ju-Kua in 1250 A.D. spoke in his work on the Chinese and Arab trade of arecanut in Annam and of arecanut wine of the east coast of Sumatra. He has also mentioned Ceylonese kings making use of arecanut paste and pearl ashes; he spoke of arecanuts as one of the products of the Coromandel coast, Java, Borneo, and the Philippines (93).

The arecanut was first described by Herodotus in 340 B.C. The earliest his-

toric reference by a European to the habit of betel chewing among the orientals occurs in the writings of Marco Polo (1298). Subsequently Vasco da Gama (1498), Varthema (1510), Barbosa (1516), Garcia de Orta (1563), Acosta (1578, 1594), Abul Fazal (1590), Linschoten (1598), Francis Pyrard (1601), Roe (1615), Jacobus Bontius (1629), Bernier (1656–58), Boym (1656), Vincenze Maria (1672), Tavernier (1676) and Catchpoole (1703) have given similar accounts (68, 151).

Origin. The actual source of origin of arecanuts is, as in the case of many other crop plants, still a matter of speculation because of the many diverse views, but according to von Martius it is probably the Sunda Islands. Its cultivation is said to date back to the pre-Christian era. There is a reference to it in a Chinese work 'San-fu-huang' supposed to have been written during 140–80 B.C. under the name 'Pinlang', evidently a form of the Malayan equivalent of the fruit 'Pinang' (122). Garcia de Orta mentions it as being cultivated in Malacca before 1593, a fact later corroborated by Ridley (135). de Candolle (49) in his classical work on "The Origin of Cultivated Plants", quoting von Martius says, "Its country is uncertain, probably the Sunda Islands". Bretschneider's works indicate that the palms were found in the Malayan Archipelago and India in the first century A.D. Blume says that the habitat of the species is the Malay Peninsula, Siam, and the neighboring islands (21). The habit of the present system of betel chewing is mentioned in a work of the fourth century. The ancient Arabic writers seem to have recognized the importance of arecanuts and call it "Fobal" or "Fufal", referring to the habit of Indians masticating it with lime. Arecanut palms obviously growing wild in Malabar (India) have also been noted (21, 142). There has been no record of the fossil remains

of the genus *Areca*, but the abundance of the palm genera discovered in the form of shells, leaves, and stems from the Tertiary period probably indicates that this genus was in existence as long ago as that time.

According to Beccari (19), the Philippine Islands were the original home of the arecanuts; he has described from this region various forms of *Areca catechu* occurring closely allied and presumes that it was in the Philippines that the edible variety finally assumed its present specific characters. Favoring the greater antiquity of the species in the Philippines, Beccari argues that in no other part of south or east Asia is any species found which in any way approaches the cultivated variety. *Areca catechu* var. *sylvatica* probably represents the wild variety of *Areca catechu* Linn. However, the large number of varieties of arecanuts described from Malaya seems to suggest that the species originated in Malaya. This is also supported by the fact that the largest type of arecanuts (*Pinang wangi*), decidedly one of the important types which is almost on the verge of extinction, is described from Malaya. Indeed, arecanut has been a source of trade between India, Ceylon, Indonesia, and Malaya from the remotest periods of history (63).

Distribution. Arecanut palm is essentially tropical, its distribution being confined to the southeast Asian countries like India, Pakistan, Ceylon, Malaya, the Philippines, and Japan. These countries form the main belt of arecanut cultivation in the tropics. Arecanuts are also reported to occur in Indo-China (114), East Indian Islands, and southern China (72), Formosa (156), Arabia (22, 29), Egypt (142), and Java (94). Ridley (135) reports its occurrence northward as far as Canton, Amoy, Formosa, and the Bonin Islands, westward as far as Socotra, Madagascar, and East Africa, and east-

ward in the central Pacific and lately in Fiji. The arecanut palms are also found in cultivation in certain areas of the Persian Gulf and Zanzibar and as an ornamental in some warm regions, especially Florida and Hawaii (135, 60, 10, 109). Whether the palms are indigenous to these regions still remains undetermined because of their restricted occurrence and the absence of any wild species. It might be that during Tertiary times the species was distributed throughout the world; in the later periods the continuous distribution of palms was disturbed because of still uninvestigated factors. A large number of genera and species disappeared from the tropics of the hemisphere, leaving only isolated types in the protected areas, or the fortuitous dissemination of the fruits by man principally for mastication is also a highly probable factor for the wide distribution of the species.

The range of distribution of the species in India appears to be restricted and is chiefly confined to the southwest coast, Mysore, Coorg, Bombay, Bengal, and Assam, the palms being conspicuously absent from upper and central India. Statistical data concerning the cultivation and production of arecanuts in India are far from satisfactory. Ac-

ording to information supplied by the Indian Central Arecanut Committee, the total area under cultivation of arecanuts in India in 1956 was 2,161,500 acres with an annual output of 21.76 lakhs of maunds of arecanuts.

Biology

Botany. *Areca catechu* Linn. is one of the species of the genus *Areca* established by Linnaeus. Four species, namely, *A. catechu* Linn., *A. concinna* Thw., *A. triandra* Griff. and *A. nagensis* Griff. are indigenous to India, but a few other species like *A. madagascariensis* Mart. (= *Chrysalidocarpus madagascariensis* (Mart.) Becc.) are grown in gardens as ornaments (69, 59, 90). The edible arecanuts belong exclusively to *A. catechu*. In Ceylon, however, the fruits of *A. concinna* are reported to be occasionally chewed as a substitute for arecanut (89). There are no widely divergent and distinct morphological types of arecanut palms, although there are differences in size and shape of the fruits and such other characters by which types or varieties of fruits are distinguished. The fruits of the palms in different regions and on different trees in the same region exhibit variation in size, and on this basis the palms have gained

TABLE 1
TYPES OF ARECANUTS DESCRIBED FROM DIFFERENT COUNTRIES

India	Ceylon	Malaya	Philippines
Round big, Round small, Convex shaped, Pointed top, Narrow base, Long (3, 136), <i>A. catechu</i> var. <i>deliciosa</i> (132), Big oblong, Large oblong, Big round, Apex round, Long, Small ellipsoid, Small oblong, Small apex pointed, Small round (121).	Sinhalapuwak, Ratapuwak, Himbapuwak, (97, 100), <i>A. catechu</i> var. <i>alba</i> (110).	Pinang wangi, Pinang telor, Pinang jambu, Pinang lemak, Pinang kuning, Pinang betel, Pinang malan, Pinang bento-tabon, Pinang small round, Pinang ranggong, Pinang selung, Pinang rambai, Pinang kerdu (64, 101, 136).	<i>Areca catechu</i> forma <i>communis</i> , <i>A. catechu</i> var. <i>sylvatica</i> , <i>A. catechu</i> var. <i>longicarpa</i> (19), <i>A. catechu</i> var. <i>batanensis</i> (27).

specific or varietal status from some botanists. The different types of arecanuts are normally seedling races which breed true to seed except for some simple fluctuating variations. It is said that more

delimitations. The types of arecanuts described from different countries are summarized in Table 1. They are mostly based on the size of the fruits (Fig. 1); this delimitation is somewhat

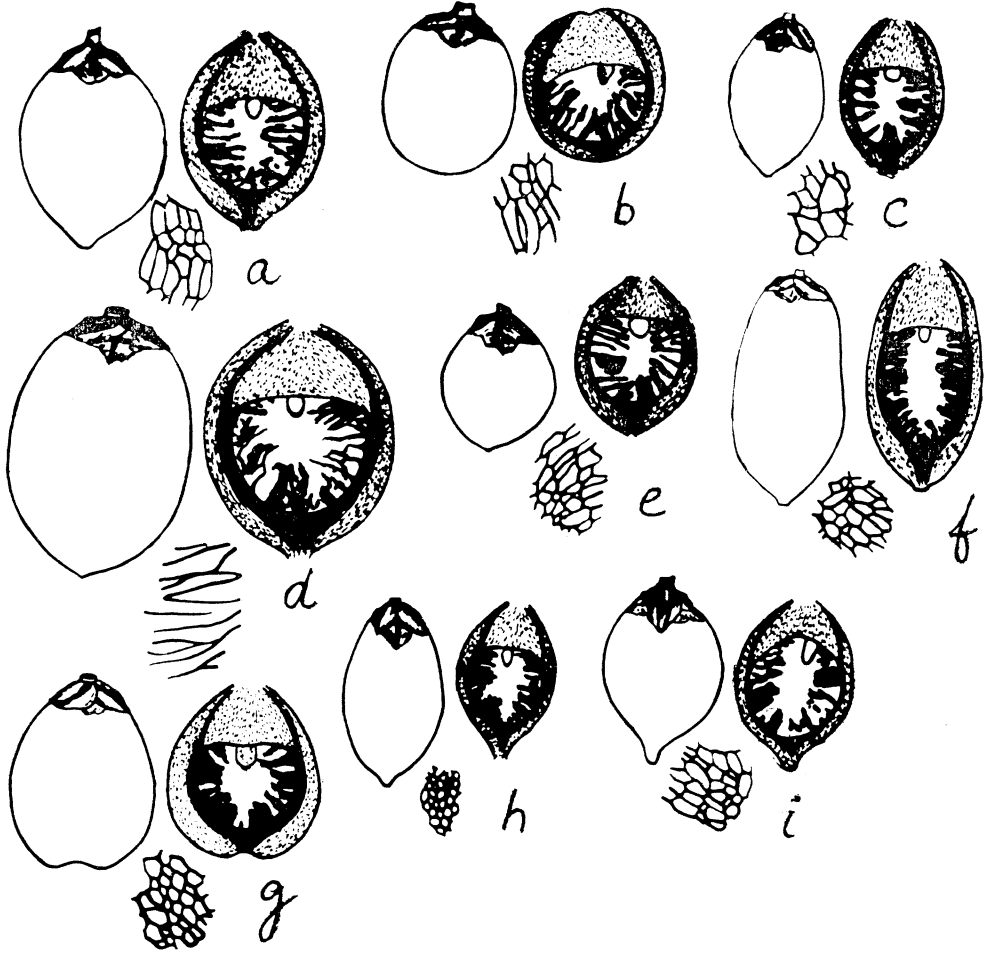


FIG. 1. Types of arecanuts. Each group represents outline of the fruit, vertical section of the fruit and pattern of network on the surface of the nut. (a) Big oblong; (b) Big round; (c) Small oblong; (d) Large oblong; (e) Small round; (f) Long; (g) Apex round; (h) Small ellipsoid; (i) Small apex pointed.

than seventeen varieties of arecanuts are known in India itself (11). The names of the types of arecanuts given by the local population based on the size and shapes of the fruits and even on the degree of astringency of the kernels are often unreliable for specific or varietal

arbitrary, but the nomenclature is convenient and widely used.

The morphology of the arecanut palms and the variations in the types of arecanuts have been described by different workers (3, 21, 69, 100, 121, 136, etc.), and hence only their salient features

along with notes on their ecological anatomy will be considered here.

Arecanut palms are tall and erect with typically unbranched stems (Fig. 2), attaining a height of 12–30 meters and a diameter of about 30–45 cm. The palms terminate in a crown of long graceful pinnate leaves, which are normally bright green but which on aging turn golden yellow and finally brown. Like all other monocotyledons the arecanut palm has

distinct layer resembling a periderm, characteristic of the dicotyledons. The periderm-like layer peels off easily in mature stems exposing the hypodermis which become reddish by this time. In the younger stages the hypodermal cells contain abundant chloroplasts. Vascular bundles are numerous and typically monocotyledonous. The ground tissue consists of symmetrically arranged rows of cells which form a sort of spongy net-



FIG. 2. A good arecanut garden in Malabar (India).

only a terminal bud and lacks a cambial cylinder. Branching of the arecanut palm is rare, but a few cases of fasciation of the top have been noted (48).

The stem is greyish brown, generally with epiphytic growths of lichens, and is ornamented with scars of fallen leaves in a regular annulated form. The stem possesses great mechanical flexibility. The epidermis of the stem in the early stages is covered with a heavy layer of cuticle, but in the older stems this layer together with a few of the hypodermal cells becomes thick-walled and forms a

work toward the center of the stem with small air spaces.

The arecanut palm has a fibrous root system. A mass of thick adventitious roots, each 0.60–1.25 cm. in diameter, arises from the base of the stem about 30–45 cm. below the ground and spreads into finer branches ramifying in all directions. In some the mass of roots is seen as a tuft above the soil at the base of the stem. The arecanut root has a structure adapted for growth in very moist soils. Outside the central portion of the root enclosing the main conduct-

ing tissues there is a large extra-stelar peripheral region filled with vertically arranged air spaces. Thick-walled stone cells are distributed in the cortex and the pith.

The leaves of the mature palm are large, 0.9–1.5 meters in length. The leaf has 20–30 pinnae, 0.6–0.9 meter in length; the basal region of each leaf forms a broad sheath which encircles the stem and forms a protective covering for the developing inflorescences until a few days prior to ripening. The structure of the leaf as a whole appears to be xerophyllous due to the presence of bands of sclerenchyma in the mesophyll and the thick cuticular covering of the epidermis. The stomata are small and distributed on the ventral surface. The conducting veins are also numerous and show strong xerophyllous adaptations.

Detailed studies on the morphological and floristic characters of the arecanut palms bearing different types of fruits have shown that the palms are strikingly similar showing no indication of a varietal distinction except in the size of the fruits. A statistical study of the height, circumference, and related features of the palms bearing different types of fruits has also led to the conclusion that the species as a whole is homogeneous, showing no appreciable differences in its vegetative and floral characters from which types can possibly be demarcated (119). Further, such characters of the palm relating to their vegetative development appear to be influenced by the ecological features of the locality rather than by the phylogeny of the types. Sands (136) in this connection writes, "As observations on the flowering of betel-nut palm have shown that the flowers are normally cross pollinated and that in all plantations and gardens there are numerous types, it will be realized that in the absence of breeding experiments, it is an almost hopeless task endeavoring to decide which of the large

number of forms are distinct varieties or races and which are merely unstable hybrids . . .".

Raghavan and Baruah (121) have published a descriptive list of the characters employed by them to describe the types of arecanuts from Assam. Several growth and structural characters of arecanuts are relatively reliable in classifying and identifying the types. The nature of the rumination of the endosperm, the pattern of the network on the seed coat, and the range in proportion of the husk and the endosperm are regarded as relatively constant for identification purposes. Certain of the inflorescence characters, namely, color of the emerging inflorescence, nature of the inflorescence axis, and taste and degree of hardness of the kernels have also been used by some to determine a particular type (50, 132). The types may differ in the color of the mature fruits. Differences have also been noted in the maturity of the palms, some bearing early and others late. Work on the morphology of the pollen grains (120), anatomy of the fruit stalks, and the cytology of the different types (119) have further given a clue to the understanding of the probable genetic status of the types of arecanuts occurring in nature. The pollen grains of the types show a similar morphology in having monocolpate grains. The anatomy of the fruit stalk shows that all the types are similar with minute variations in the frequency of occurrence of the bundles and length of the vessel elements, whereas the types show a similar chromosome number, all having $2n = 32$, with minute differences in the length of the chromosomes and position of the constrictions. It has thus been apparent that the range of variation in *Areca catechu* is limited in so far as there are many types with border-line affinities and, therefore, standing at the same level of evolution. In view of the minute cytological changes delimiting the

types, it is possible that the types of arecanuts existing today have originated from the ancestral ones through gene mutations. Furthermore, the compatibility between the types being very close due to the close similarity in their karyotypes, hybridization occurring freely in nature induces the production of new types. This seems to be supported by the fact that arecanut palms bearing the different types of fruits occur freely intermixed in the plantations, thereby giv-

of the older trees do not bear any inflorescences at all in some years. A full grown spadix of arecanut produces on an average 250 to 550 female flowers and 2,000 to 3,000 male flowers, the former being confined to the basal region and the latter forming the filiform panicles of the spadix. The inflorescence (Fig. 3) is formed in the axil of each leaf on a mature tree and is enclosed in a spathe which splits open to expose the flowers. The spadix is composed of a transversely

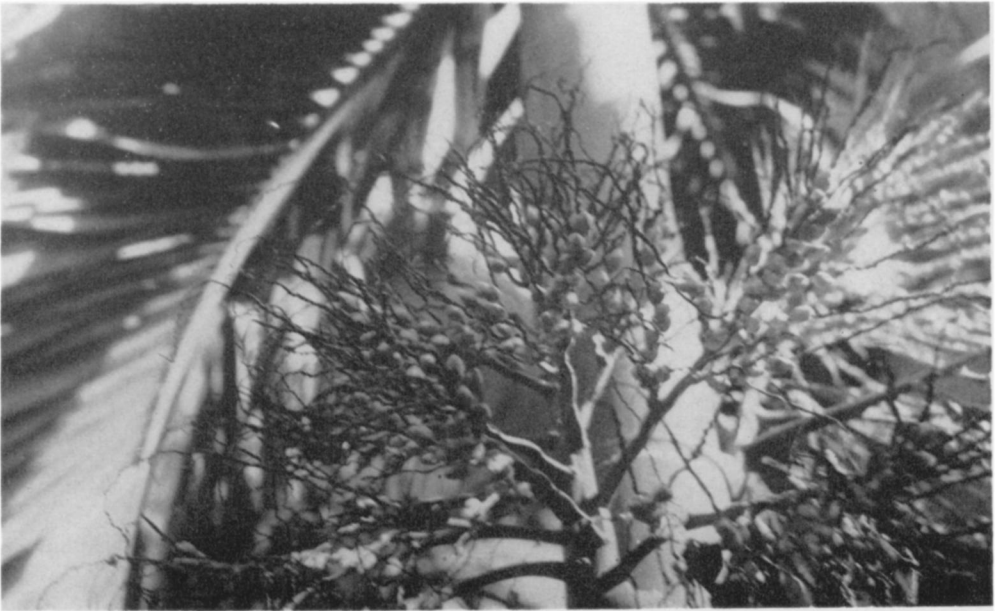


FIG. 3. Inflorescence with young fruits (buttons).

ing opportunities for cross pollination between the types (119). The exact status of the types can, therefore, be ascertained by intervarietal crosses in the field; such studies offer ample scope full of potentialities in the evolution of vastly improved types of arecanuts.

Floral Biology. The arecanut palms are monoecious, male and female flowers occurring on the same spadix. Young trees during the first few years of their bearing do not possess any female flowers and yield no fruits; similarly some

compressed main axis about 30 to 60 cm. in length which bears some 20 to 25 secondary branches. The latter in turn form the tertiary branches. In certain cases bisexual flowers have been recorded; they occur on the same rachis between the male and female flowers (126). Usually the female flowers are confined to the base of the rachis or occasionally to the end (108); or sometimes, a male flower may be found adjoining a female flower. Each female flower has two whorls of perianth, the

outer boat-shaped green whorl of sepals and the inner petals. The ovary is ovoid-globular with a dome-shaped tip formed by the three stiff stylar projections. The whorl outside the ovary is formed of six staminodes which are closely appressed to the ovary. The male flowers are minute, cream-colored, triangular structures, comprising two whorls of perianth, six stamens, and a central pistillode. However, the male flowers in some of the spadices exhibit varying degrees of abnormality which have been described by Raghavan (118). Both the male and female flowers are very fragrant.

Megasporogenesis and the events leading to fertilization have been investigated by Swamy (141) and Rao (129, 130). Development of floral organs of both male and female flowers is acropetal. They arise as follows: sepals, petals, stamens or staminodes, pistil or pistillodes. The ovules are amphitropous until fertilization and later become anatropous. They are crassinucellate and bitegminous. The outer integument is massive and is traversed by branching vascular bundles. Soon after fertilization the outer integument sends off folds of ruminations which grow centripetally though they never meet in the center. These form the characteristic lamella of the endosperm, giving them a marbled appearance in section. The development of the embryo conforms to the 'Onograd' type of Johansen (131).

The male phase of the arecanut palms begins as soon as the spadix frees itself from the spathe. The flowers commence to open indiscriminately, and this phase is continued for two to four weeks until all the male flowers are exhausted. The individual male flowers open early in the morning and remain in that position until they wither in the evening, maximum dispersal of pollen grains occurring between 9 and 12 A.M. There also appears to be an optimum period during

the first eight to ten days after opening of the spadix when the maximum discharge of pollen grains is effected (119).

At the close of the male phase, the green petals of the female flowers lengthen and change their color to yellowish-white. The petals slightly open at the tips, and soon after the receptive trifid stigmas are open to pollination. The female phase generally lasts for four to five days, and the flowers remain open during this entire period exposing their receptive stigmas. The surface of the stigma is constituted of a special kind of thick-walled palisade cells which are closely packed in the young flowers but become club shaped and elongated at maturity of the flowers leaving interspaces between them for the reception of the pollen grains. It is thus evident that the male and female flowers never open simultaneously thus necessitating cross pollination which is generally effected by wind. Bees and insects regularly visit the male flowers, but they have not been seen on the female flowers; their role in pollination is, therefore, doubtful. It is noted, however, that some palms develop spadices in such quick succession that the male phase of the freshly opened spadix overlaps the female phase of the one preceding it, so that self-pollination is possible. Cross-pollination, as already noted, effects considerable variation in the progeny and induces production of new types (136, 138).

It is observed that all the female flowers that are borne on the spadix do not set fruits, a considerable majority of them falling off prematurely. The extent of sterility caused by such flower fall in some of the plantations in Assam (India) has been estimated to vary from 35 to 55 percent (120).

The reasons for the low fruit-set in relation to the large number of female flowers produced in each spadix are primarily due to: (1) non-uniformity in the time of maturity of the male and

female flowers with considerable lag between, (2) differences in the proportion of the sterile pollen grains in the male flowers, (3) failure of a considerable number of pollen grains to germinate on the stigma, (4) slow growth of the pollen tubes and their subsequent death inside the stylar canal resulting in failure of fertilization, (5) short life of the pollen grains and the degree of receptivity of the stigma being most favorable when the flowers are slightly open, (6) conditions of temperature, humidity, and other factors which affect the successful dispersal of the pollen grains and their subsequent germination, and (7) association of air-spores originating from fungi, bacteria, and actinomycetes with pollen grains in the plantations and its effect on the subsequent process of pollination and fertilization (120, 13, 14).

From the foregoing it is evident that lodging of the pollen grains on the stigma under natural conditions and its subsequent germination and growth leading to the fertilization of the ovule are important factors controlling fruit-set in arecanut palms. Ordinarily, not more than 75% of the female flowers actually receive pollen grains on their stigmatic surfaces. The main problem, however, resolves itself in the active growth of the pollen tubes inside the stylar canal leading to the fertilization of the ovule. The failure of the pollen tubes to fertilize the ovules has been due to the length of the pollen tubes formed being inadequate to reach the ovule, the length of the style of the female flowers generally varying from 0.8 to 1.3 cm. Detailed field studies on the problem conducted in Assam have indicated that various fungi like *Aspergillus*, *Penicillium*, *Actinomycetes*, and bacteria colonize the stigmatic surfaces of arecanut flowers during the early days of their opening; the subsequent growth of the pathogens on the stigma releasing toxins into the stylar canal greatly inhibits successful germi-

nation of pollen grains and growth of the pollen tubes (14). This phenomenon of antagonism would be of considerable significance in determining the factors that can check the large amount of fruit loss in arecanuts. Experiments on the germination of pollen grains *in vitro* in cultures using various synthetic auxins, vitamins, and trace elements have also indicated that the percentage of germination of the pollen grains and the rate of growth of the pollen tubes can be enhanced to a considerable extent (123), but the practical application of the results still remains to be assessed in field trials.

Agronomy

Soil. The type of soil in which the palms are grown is important for best production of the crop, but it is not a limiting factor because arecanut palms grow in many kinds of soils varying in texture from laterite to loamy types. In India the largest areas under arecanut cultivation occur in the laterite soils of Mysore and Kerala, although generally in laterite soils the palms do not grow well unless compensated by heavy manuring. In Fiji the palms are found in the alluvial soils of the coastal areas, while in Malaya the crop is cultivated in a wide range of soils from granite to limestone and calcareous types; these soils are generally considered poor in plant foods (101). A good crop of arecanut can be raised in nearly all types of soils provided they have a capacity for thorough drainage and ability to retain optimum moisture required by the palms. Light and sandy soils are not suitable unless copiously irrigated and manured.

The cultivation of arecanut in the Bombay State is chiefly confined to the coastal areas which consist of sandy soil with an admixture of laterite loams. In Mysore, especially in the Malnad regions, most of the arecanuts are grown

in laterite soils of loamy and clayey character. In West Bengal the soil is of alluvial formation with large admixture of sand or light loam, whereas in Assam the soils are of a sandy loam type. They are fairly rich in nitrogen and generally low in available potash and phosphate. In Assam the presence of lime in certain soils appears to be a limiting factor for proper growth and good yield of arecanuts (119).

Climate. The arecanut palms thrive in regions of high rainfall (200 inches or above); they can also survive on as little as 30 to 60 inches of rainfall if the ill effects of low rainfall are compensated by copious irrigation in summer. More important than the rainfall are the drainage facilities and the seasonal distribution of rainfall. For good remunerative yield in arecanut gardens the important factors are a uniform distribution of rainfall, good retentive capacity of soil, and irrigation when necessary. Investigations on the comparative yields of arecanuts in different places in Assam have shown that the output at Cherapunji is poor, the soil here being surprisingly low in moisture-retaining capacity, despite the fact that the annual rainfall here is great (119).

In arecanut plantations the maximum temperature should not exceed 100° F., but a continuous temperature of 60° to 100° F. is preferable. The ill effects of summer temperatures are compensated by profuse irrigation. The palms are unable to withstand extremes of temperatures and wide diurnal variations. They are tolerant to moderate elevations on mountains but generally thrive best at low altitudes.

Arecanut is a shade-loving plant and is usually grown as a mixed crop with fruit trees such as mango, jack, guava, orange, plantain, coconut, etc. (Fig. 4). Subsidiary crops like cardamom and pepper (Fig. 5) are also cultivated in gardens in Mysore (5). A mixed plan-



FIG. 4. Coconut and plantains as border crops in arecanut gardens.

tation is said to cool down the atmosphere which is so essential for the palms (3); however, it is possible that the presence of a large number of fruit trees in a garden subjects the crop to competition, thus reducing yield (119).

Propagation. Arecanuts are exclusively propagated by seeds. Selection of the seed nuts is the first step in producing a profitable crop of arecanuts. In south India, seed nuts are gathered from about 30-year-old trees or from young trees. In Assam and Bengal no importance is attached to the matter of selection of seed nuts for planting. They are collected from all trees irrespective of age. The Malayan growers also follow a similar method in the selection of seed nuts. Even in the matter of selection of the particular bunch from which the seed nuts are later gathered, the methods followed in the different parts of India vary considerably. It is a custom in many places to fix up the middle bunch for seed purposes, while in certain areas the last bunch of the season is preferred. The seed nuts are allowed to ripen completely on the tree and are dried in the

sun for one or two days or in the shade for three to seven days before being sown. However, drying of the nuts does not increase their capacity for germination (3, 138, 83).

No elaborate preparatory land tillage is, as a rule, necessary for raising the seedlings. Generally, well-tilled land in a well-drained area in the garden or on the sides of the irrigational channel forms a good bed for sowing the seeds. The seeds are sown in rows 15 to 22 cm.

Recent studies on the merits of different nursery practices in arecanut cultivation have shown that sprouting the seednuts in loosely tied straw bundles and then planting them in nursery beds gave low germination (84.5 percent) and poor establishment in the nursery (76 percent). Direct sowing in the nursery gave 95 percent establishment; seedling growth was stronger after direct sowing than after transplanting and in earlier germinated ones than in late germinated ones



Fig. 5. Pepper vines trailed on arecanut palms.

apart or in groups of 20 to 50 seeds in pits deep enough to cover them but shallow enough to permit the young plants to reach the surface of the soil (Fig. 6). Since the harvesting seasons in the different states in India vary, the time of seeding also varies with location and weather conditions. In many gardens a large number of seedlings sprout from naturally fallen nuts which are allowed to grow in situ into adult palms. The rate of growth of the seedlings depends upon the after-care bestowed on them.

(16, 17). The husk is sometimes artificially rotted to facilitate germination.

Usually three months after sowing, the seedlings (Fig. 7) are ready to be transplanted in nursery beds, but the time allowed for seedlings may even be up to four years. The area required for the nursery is to be well dug or ploughed and a shade crop of bananas planted about 2.7 meters apart in the north-south direction. Planting of banana suckers may be taken up prior to planting of the seedlings so that they may be

come well established and give sufficient shade for the young palms. Watt (151) has reported that in Bengal in the earlier stages of plantation, *Erythrina indica* Linn. is planted for shade. The interspaces between the banana rows (3.6 meters apart) are to be thrown into raised beds 1.2 meters wide and 15 cm. high and of a convenient length in the north-south direction. Two nursery beds each 1.2 meters wide will run between the two banana rows with a central

trees in the garden are replaced by fresh seedlings. Thus, some of the older gardens may often have 800 to 1200 trees per acre. After the seedlings have been planted, the beds are to be mulched with green or dry leaf, cattle dung, wood ash, or ground nut cake according to the demands of the local conditions. Beds are to be made only in the rainy season and should be well irrigated in summer.

Cultural Practices. No systematic study of the cultural practices generally



FIG. 6. Young seedlings in seed bed.

drainage-cum-irrigation channel of 45 cm. width. To supplement the shade of the bananas, legumes like *Sesbania* may be sown in the western margin of each nursery bed (111).

The young seedlings are to be planted in the nursery beds at a distance of 30 × 30 cm., and in each bed three rows of plants can be planted leaving 30 cm. margin on either side. Spacing in the garden is a matter of choice, but about 400 to 600 trees per acre is usual. After about 20 years the older unproductive

necessary in arecanut plantations has been undertaken either in India or elsewhere. Hoeing the garden, weeding, and intercultivation are some of the more important operations attended to in south India.

No attempt has been made to determine the manurial requirements of arecanut palms under controlled cultural conditions. In the Malnad region of Mysore, ten cwts. per acre of farmyard manure is applied yearly, and a mixture of ground nut cake is applied once in

three years. Ammonium sulphate, superphosphate, and potassium sulphate have also been found to be beneficial. Leaf and green manures are used frequently (153).

Flowering. Under average conditions the palm flowers in about the seventh year, reaching its full bearing potential in about 10 to 15 years. Given the best conditions, the palms start to bear even in the fourth year. In the different arecanut growing regions in India there are well-defined flowering seasons and corresponding harvesting seasons. The fruits take about six to eight months to ripen. In the younger stages they are green and at maturity gradually change from green to orange-yellow or scarlet red. The economical life of the palm in India is considered to be 45 to 70 years.

Harvest. The arecanuts are generally harvested when they are ripe and are bright red; this, again, is a matter of choice to suit the requirements of the particular market. Shedding of a few

nuts in a bunch is a sufficient indication that it is ready for harvest. Because of the tall and slender nature of the palm, harvesting of arecanuts is a process which calls for considerable skill and dexterity, and often primitive methods are employed for the purpose. On the southwest coast of India there are special classes of people who can climb the palms at a fast rate. Not uncommonly, in closely planted gardens, the laborers manage to swing from the top of one tree to another without coming down, thus harvesting a number of trees at a stretch. In certain places in India and in Malaya a long bamboo pole with a sharp sickle attached to it is used for harvesting purposes. The use of trained monkeys for harvest is also a common feature in Malaya (100, 101).

Yield. Each tree on an average yields two to three bunches per year, each containing about 150 to 250 fruits (Fig. 8). These figures vary easily one way or the other, for they depend on numerous fac-

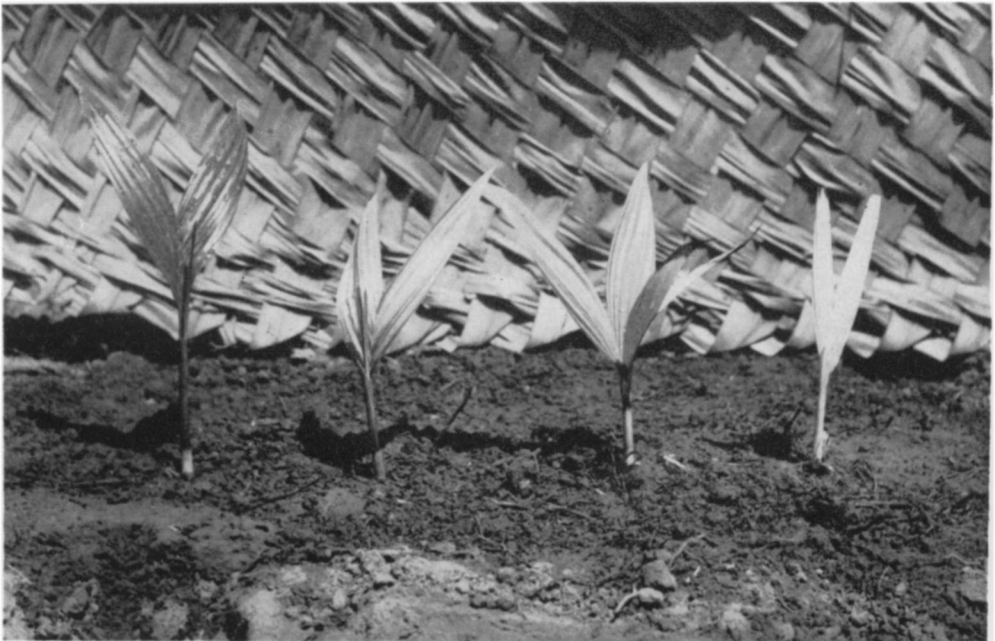


FIG. 7. Arecanut seedlings having different tones of color.



FIG. 8. A good bunch of arecanuts.

tors that operate jointly or separately. In certain large types the yield may vary from 50 to 100 fruits per bunch, or more commonly the small size of the nuts in a bunch is compensated by their large number. The yield of arecanuts in the different states of India on the basis of information supplied by the Indian Central Arecanut Committee is as follows:

State	Area in acres	Yield in Mds.
Kerala	1,49,400	10.06
Mysore	73,100	7.79
Assam	25,500	2.90
West Bengal	5,500	0.50
Bombay	5,000	0.56
Madras	3,000	0.25

Diseases and Pests

Fungal Diseases. Like many other crop plants, arecanut also has its share of fungal and insect pests, many of which have not been adequately investigated. Among the fungi responsible for diseases the most important is *Phytoph-*

thora arecae (Col.) Pethy. which causes the "Koleroga" (fruit rot) disease of the arecanut palms. More than two strains of the pathogen are reported to be parasitic on the palms (128). It is possible that the disease was in existence for a very long time, but in India it appeared in an epidemic form only about 40 years ago in western peninsular India. It has also been reported recently from Assam (98). The havoc caused by the disease may be judged by the fact that it usually reduces the yield to less than 75%.

The "Koleroga" usually appears two to three weeks after the onset of monsoon. The fungus attacks the fruits when they are still green. The spores germinate on the moist surface of the green nuts and penetrate the tissues of the husk and the fruit stalk, thereby weakening the attachment of the fruits resulting in their fall. Fallen fruits have a felty white mycelial mass on their surfaces which soon covers the whole fruit. Alternate warm and damp spells as well as close

planting of trees in the garden favor multiplication of the spores and spread of the disease. If the activity of the fungus goes unchecked, the disease spreads into the central shoot and finally causes the death of the tree in about two to three years (100).

The most effective method of controlling the disease is by spraying Bordeaux mixture with or without an adhesive (3, 43, 92); the entire operation, however, appears to be somewhat difficult because of the nature of the palm. Recent investigations have proved that the crown of the palm harbors latent infection during the warm periods without showing any external symptoms whatsoever. These plants later become a potent source of infection of other trees during the ensuing monsoon when enormous quantities of sporangia are produced and disseminated (98). Elimination of trees that harbor latent infection and spraying of the affected palms to localize infection are methods employed to check the spread of the disease. The areca growers in Mysore (India) protect the bunches of fruits during the rainy season by an improvised covering of leaf sheath or dry grass. This is supposed to prevent the contamination of fruits by the fungal spores; the operation is laborious and costly and of doubtful utility for large-scale trials (100).

In Mysore the arecanut is also subject to a disease called "foot rot", locally known as "anabe", the causal organism being *Ganoderma lucidum* (Leys.) Karst. Butler (30, 31) refers to this disease as the 'betel-nut plague in Sylhet' apparently caused by *Fomes lucidus*. The first reference to this disease is by Coleman (42). The symptoms of the disease have been described by Watt (152), Butler (30), Rau (133), Venkatakrishniah (145), and Venkatarayan (146) and are akin to those of drought. There is at first a drooping or yellowing of the lower leaves, not infrequently followed

by a reduction in size of the crown which subsequently dries up. Butler (30) states that one of the earliest symptoms of the disease is dropping of the nuts. The fungus later affects the interior of the stems and is marked outwardly by minute holes on the stem which exude a gummy secretion. This is subsequently followed by the roots becoming brittle, discolored, and dry, the final external symptom being the appearance of characteristic leathery, disc-like outgrowths called "anabe". The affected palms eventually dry up and die. The diseased palms on examination show a dark brown color inside and emit an unpleasant smell.

No proper remedial measures have been adopted for this disease. The local cultivators eradicate the infected palms by applying sulphur at the root, they isolate the attacked trees by putting them in trenches filled with lime, or they burn the diseased trees. However, these methods are presumably only partial remedial measures (100). Two brands of tree killers, "Globe" and "Borgia", are reported to have given promising results in easily eradicating the infected plants (145).

Other fungi that cause diseases on arecanut palms are *Gloeosporium*, which attacks the husk and the fruits causing brown spots, and *Thielaviopsis paradoxa* von Hon., which causes lengthwise splitting of the stem not uncommonly followed by exudation of colored sap (100). The stem is also reported to be attacked by *Polyporus ostreiformis* Berk., *P. zonalis* Berk. and *Lenzites striata* Swarts (82). Bud rot disease similar to that observed in coconut or palmyra palms has also been found in arecanut palms. The diseased trees show an internal injury in the crown in the form of a longitudinal cut confined to the greater portion of the bud with no symptoms of outside injury. The inflorescences, as they are formed, are also attacked. The subsequent de-

cay of the bud is enhanced by secondary infection by *Fusarium* sp. and bacteria (143, 147). In West Bengal, Nambiar and Sreenivasan (103) have reported seedling blight caused by *Phomes* sp. and *Colletotrichum catechu*. A storage disease of betel-nuts caused by *Aspergillus niger arecae* has been described by Lal and Chandra (88).

The incidence of stem splitting and breaking disease is also widespread in arecanut plantations. Exposure to the hot afternoon sun and the consequent scorching of the tender portions of the palms are the prime causes (127). Further damage is caused by the invasion of the affected tissues by more than one species of wound parasitic fungi such as *Ceratostomella paradoxa* (140), *Ganoderma lucidum*, *Lenzites* sp., *Polystichus* sp. (127, 148), and *Dadaelea* sp. (104). Provision of adequate shade for the palms is reported to be the best method for preventing the incidence of the disease (127). A disease condition characterized by cracking of the fruits is also known (18).

Physiological Diseases. "Band", locally known as "Hindimundigae" in Mysore, is a widely prevalent disease in certain parts of Bombay and Mysore. The symptoms of the disease are reduction in the size of the internode and tapering of the stem below the crown, followed by the appearance of the leaves and leaflets in a bush-like form in advanced state of the disease. This is also associated with a darkening of the leaves which acquire a leathery feel. Although the causes of the disease are still not established with certainty, it is presumed that the soil in which the band-affected palms are growing is deficient in some of the trace elements or micronutrients (74). For this reason treatment of the affected palms with copper sulphate and lime along with organic manure has given encouraging results in the control of the disease in Bombay Presidency.

Manganese and iron toxicity due to the abnormally high absorption of these ions by the palms has also been suggested as a probable cause of band disease (45).

Other diseases caused by nutritional deficiency or allied factors are only of local importance, and no satisfactory remedial measures have been adopted for them. Among these the stem-breaking disease is important. The symptoms are manifest in darkening of the stem and yellowing of the lower leaves. Subsequently, the stem loses its turgidity and shape and finally cracks and separates. The precursors of the disease are still imperfectly known, and it is presumed that certain environmental conditions prevailing in the area—high rainfall, absence of soil drainage, overcrowding of the palms, and lack of essential elements—are contributory causes for the diseased conditions. Root and leaf diseases similar to that in coconut have also been noted in arecanut palms (100).

Pests. There is no record of any serious damage on arecanuts by insect pests during any stage of its growth; however, rhinoceros beetle (*Oryctes rhinoceros*), leaf eating caterpillar (*Nephantis serinopa*), borer (*Arceerns fasciculatus*), white ants, and a number of other insects and mites, notably *Icerya aegyptiaca* Doughal, *Rodolia* sp., *Leucopholis lepidophora* Blanch are said to cause minor damages in certain areas of Mysore and in Malaya (100, 101, 115). The Acridian *Valanga nigricornis* Burm., has been recorded as feeding on leaves in Malaya. Numerous Coleoptera, Rhynchota, Thysanoptera, and the ant, *Plagiolepis longipes* Jud., have been found feeding on the inflorescences (64). Squirrels, rats, and monkeys may cause damage.

A disease prevalent in Kerala is "Chovakedu". The symptoms are yellowing of the leaves and shedding of both tender and mature nuts. The endosperm of such fallen fruit presents a

black appearance and is soft to touch. The disease is due to infestation by different species of mites; spraying the trees with wettable sulphur, "Folidol", or lime and sulphur is advocated as an immediate measure to check the disease (84).

Processing

The following discussion on the preparation of arecanuts for the market will be limited primarily to the procedures adopted in India, although certain differences in other countries will be pointed out.

Arecanuts are consumed in India either raw or cured. In some places, as in Assam and in the West Coast, no curing or processing methods are in vogue, and ripe nuts are masticated during the harvest season. The surplus of the nuts is stored in pits in the soil or in water in earthenwares for a period of five to seven months. During the off-season they are taken out and chewed. In South Kanara (Mysore), ripe nuts are collected, dehusked or cut into two, dried and marketed without shells. Sometimes ripe nuts are dried in the sun for six to seven weeks and marketed as such (Fig. 9). In Indian markets these nuts are known as "Chali" nuts. In Malaya also the arecanuts are marketed after similar treatment, the products being known variously as "Pinang blah", "Pinang kossi" or "Pinang salai" or "Pinang awak", depending on whether the nuts are dried, unsplit, or split or whether they are sun-dried or oven-dried. When perfumed by the smoke of benzoin, they are "Pinang ukup" (101, 28). Dried nuts in Malaya are marketed as "Pinang bunga" or "Pinang kasar". Ripe whole-dried nuts are also exported from Ceylon under the name "Karunka" or "Kotta puwak" (97).

Processing of the immature nuts is a costly and laborious operation and is undertaken on a commercial scale in

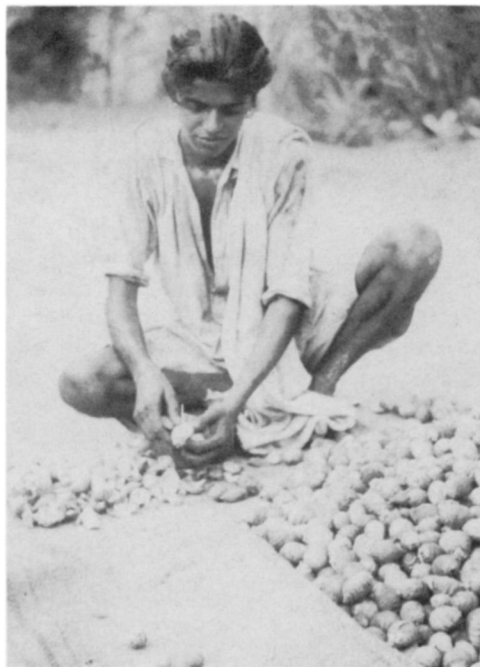


FIG. 9. Husking of dried arecanuts.

Malabar and Mysore. Processing is to improve the color, taste, palatability, and keeping quality of the nuts. In Mysore where traditionally the best processing methods are employed, the fruits are collected when they are nearly three-fourths ripe. The selection of nuts of the correct stage of maturity is important in so far as any deviation on either side badly affects the quality of the product later. For instance, if under-ripe nuts are used, the cured product is said to be poor and shrunken while over-ripe nuts tend to be hard and light-colored. The sliced nuts are then boiled in a mixture of water and the previous year's extract called "Chogaru" for two to three hours in cauldrons. A common substitute for "Chogaru" is prepared by pounding barks of *Syzygium jambolanum* DC., *Pterocarpus santalinus* Linn., *Adenantha pavonia* Linn. and *Ficus religiosa* Linn. with a few betel leaves and boiling them in water;

a little lime, jaggery, and gingili oil are added to give a shine to the nuts. The correct stage at which boiling is to be discontinued is determined when the embryo drops out and the slices assume a concave appearance. They are then removed and dried over mats. The decoction obtained after the charge is removed is boiled to the correct consistency to obtain "Chogaru"; this can be dried and preserved for use in subsequent years (50, 100, 153).

There are several variations in the method of processing and curing, viz., boiling in several changes of water, finished in boiling milk, boiling the whole nut with or without the husk intact in water and drying, or grinding the boiled kernels with spices and flattening them before boiling (50). These variations in the methods and in the state of maturity of the nuts collected for processing have induced the production of different grades of betel-nuts (61). Sometimes the nuts before export are boiled in water containing lime and dried (144).

In Malaya the tender nuts are processed in two different ways. "Pinang asin" is a preparation of tender nuts packed in gunny bags and mixed with salt. Storage for two to three months makes them ready for use. Sliced and dried tender nuts called "Pinang iris" are also prepared in Malaya for export (101).

When properly cured and dried, the nuts are dark brown with a glossy finish. Processed betel-nuts are always marketable as long as they are well cured and are of sound keeping qualities. The value of processing depends mainly on the selection of fruits of the correct stage of maturity and strict adherence to the intimate details of processing.

Chemistry of Arecanut

The arecanut, as already stated, consists of two distinct parts, the husk and the endosperm. In view of the distinc-

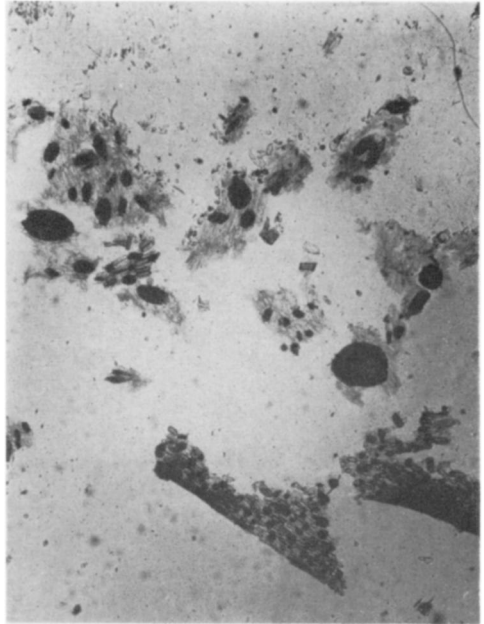


FIG. 10. A section of the husk showing separation of the individual fibers after maceration.

tive nature of the parts comprising the fruit, details of their chemical composition are discussed separately, although it will be apparent that the husk is comparatively little investigated.

Husk. The husk consists of a large number of short staple fibers embedded in a matrix of thin parenchymatous tissue (Fig. 10). It varies in thickness from 1.0 to 1.5 cm. and can be divided anatomically into three zones: (1) the outer epidermal layer covered with the cuticle, (2) the middle layer which encloses the fibers, and (3) the hard and stony innermost layer appressed to the nut. The fibers adjoining the hard and innermost stony layer are large irregularly lignified groups of cells girdling the vascular bundles of the husk (hard fibers); the portion of the middle layer below the outer epidermal layer is composed of small groups of thick-walled cells, each group representing a fiber in cross section (soft fibers). No vascular

bundles are seen in this portion of the husk.

The first attempt to analyze the chemical composition of arecanut husk was made in investigations at the Imperial Institute, London (1922). These investigations produced the following data (134):

Analysis of Arecanut Husk

Moisture	10.1%
Ash	6.8%
Cellulose expressed on husks as received	42.6%
Cellulose expressed on moisture free husks	47.6%

According to Narayanamurti, Ranganathan, and George (106) and Harcharan Singh (66) the husk contains: moisture, 8.8; ether soluble, 0.933; alcohol-benzene soluble, 2.04; water soluble, 17.13; lignin, 27.04; cellulose, 64.80; pentosans, 23.43; and ash, 4.4 percent. Distillation with acid gave 18.75% of furfural.

Recently Baruah, Raghavan, and Murthy (15) have thrown further light on the chemical composition of arecanut husk at various stages of their development. A summary of their results is given in Table 2. From these investigations, it is immediately apparent that the principal constituents of the cell-wall materials of the husk are cellulose, lignin, and hemicellulose. The first two exist in combination as lignocellulose,

but the nature of this combination is not determined. The husk is also reported to contain traces of tannins (8).

Erfan Ali and Khundkar (52, 53, 54) have analyzed chemically the lignin obtained from arecanut husk; nitration of the lignin gave three different fractions of nitrolignin of the minimal formula $C_7H_7O_5N$, $C_{13}H_{15}O_8N$, and $C_{17}H_{20}O_{10}N$. Oxidation of the lignin with nitric acid yielded 44% of oxalic acid.

Although it is difficult to make critical studies on the nature of the different cell-wall constituents of the husk with the data at hand, the results so far obtained have brought to light some phenomena which may be of far-reaching importance in any future studies on arecanut husk. It is now apparent that the cell-wall substances of the husk exhibit a series of changes associated with the degree of maturity, the cellulose and lignin attaining the maximum in the fully ripe husk. Generally, the mature husks contain less hemicelluloses than the immature ones. The epidermal and hypodermal cells of the husk also contain the green chloroplastid pigments which in the ripe husk are changed to carotin and xanthophyll giving the characteristic color to the fruit (15, 119).

The fibers of the husk are noted for their short staple length. The hard and soft fibers vary greatly in their physical appearance, the former being more ro-

TABLE 2
CHANGES IN THE PROPORTION OF THE HUSK CONSTITUENTS DURING MATURATION

Stages after 20-day intervals	Pectin %	Protopectin %	Hemicellulose %	Cellulose %	Lignin %
1	3.3	1.30	11.0	40.0	13.0
2	3.5	1.40	16.0	44.0	15.0
3	3.6	1.80	14.5	43.5	16.0
4	3.6	1.30	14.0	41.0	17.0
5	3.6	1.30	14.0	40.0	19.1
6	3.6	1.20	13.5	40.5	19.2
7	3.6	1.20	12.5	41.0	20.0
8	3.2	1.35	12.0	42.5	20.4
9	3.0	1.50	9.50	46.0	21.8

bust and brittle than the soft fibers (Figs. 11 & 12). The soft fibers are of a woolly nature with a smooth feel. A number of tests have been made to establish the chemical nature of the fibers, and it has been found that they answer all the reactions characteristic of lignocelluloses exactly in the same way as those of jute. A sample analysis gave the following: soft fibers—cellulose, 53.56%; lignin, 32.8%; hard fibers—cellulose, 71.32%; lignin, 26.6% (119).

Endosperm. The endosperm of arecanuts is a rich source of alkaloids, tannins, fats, carbohydrates, protein and non-protein nitrogen. The isolation of the alkaloids, which are reduced pyridine derivatives, can be credited largely to Jahns (75, 76, 77, 78), although it was Bombelon who made the preliminary attempts (67). In 1888 Jahns (75) reported the successful isolation of two alkaloids, a volatile liquid alkaloid, arecoline (methyl ester of arecaine— $C_8H_{13}O_2N$) which forms crystalline salts

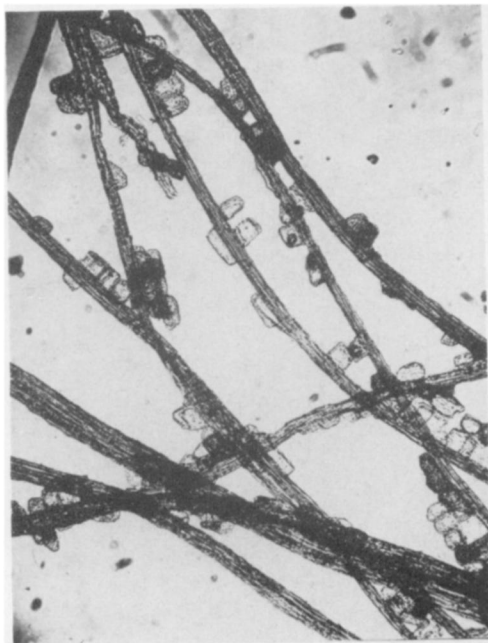


FIG. 11. Surface view of the fibers.



FIG. 12. Surface view of woolenized fibers.

and arecaine or arecaine (N-methyl derivative of guvacine). Two years later, he added a third alkaloid, arecolidine or choline (methyl ester of arecaine). Three other alkaloids like guvacine (1 : 2 : 5 : 6-tetrahydropyridine-3-carboxylic acid), guvacoline (methyl ester of guvacine), and iso-guvacine isolated by different workers were added subsequently to the list of alkaloids of arecanuts (23, 67, 144).

From the number of available reports on the alkaloid content of arecanuts, it seems reasonable to assume that the quantity varies in fruits of different regions; it is even said that seeds from different palms show considerable variation in taste and alkaloid content. For instance, Kariyone and Fwa Tung (80) have given the alkaloid content of some varieties from Formosa and the South Pacific as ranging from 0.29 to 0.67%. According to Ferguson (58) and Claus (41) the nut yields 0.35% of ether soluble alkaloids calculated as arecoline. Quisumbing (117) has given the proportion of the different alkaloids as are-

caine, 0.1%, arecoline, 0.07 to 0.1% and others in traces. Chemnitius (35) has given the yield of arecoline hydrobromide in arecanuts as 0.35 to 0.40%. In a sample investigated in Assam, Raghavan (119) found only 0.15% of alkaloids, arecoline forming from 58 to 100% of it. Arecoline thus appears to be the major alkaloidal principle of arecanuts, generally varying from 0.1 to 0.5% (41, 144); it also appears to be the first formed alkaloid. Arecoline is a colorless, oily liquid (B.P. 230° C.) and forms crystalline salts with acids.

The tannins of arecanut also seem to have been subject to considerable investigation. During mastication of the nut, astringency, which is so well known a property, may be due to the tannin-alkaloid complex in the fruits, for the young fruits are in many ways different from the mature ones in taste. Ishikawa (73) was probably the first to draw attention to the tannin content of betel-nuts, the percentage of tannin in terms of tannic acid being 18.03 percent. A few years later Kay and Bastow (81) determined the tannin content of another sample and found it (in terms of oxalic acid) to be 14.88 percent. Subsequently, the fruit has attracted the attention of a number of workers as a promising possible source of tanning material (70, 62, 7, 71, etc.).

The characteristic reactions given by the arecanut tannins are as follows:

Reactions of Arecanut Tannins

Reagents	Reactions
1. Bromine water	Precipitate
2. Iron salts	Green color
3. Ferric alum	Greenish black precipitate
4. Lime water	Pink color
5. Dilute acids	Phlobaphene formed
6. Sulphuric acid	Crimson color

The arecanut tannins are predominantly catechol tannins containing tannic acid, catechol (α -catechin), gallic acid, protocatechuic acid, pyrocatechine and

phlobatannin; they also yield phlobaphenes and coloring matters when boiled with dilute acids (73, 38, 157, 37, 154, 41, 119). In their general properties the arecanut tannins closely resemble *Mimosa* bark tannins. Notwithstanding the fact that various reactions have been regarded as dependable because of their assumed conservatism and, therefore, used rather freely, the determination of the relationships of the different constituents that form the "tannins of arecanut" must ultimately be based on the preponderance of their similarities between pure and isolated samples, rather than upon the reactions given in groups of compounds. Before valid confirmation can be given to the above conclusions, a great deal more work should be done on what one may term the "dynamics" of the individual constituents of the tannins of arecanut.

The endosperm of arecanut is also reported to contain fats varying from 1.3 to 17.0% (149, 153, 113, 26). The fats agree in their general properties with those belonging to the butter fat or coconut oil group. The Reichert-Meissl values are low in comparison to that of other vegetable oils and fats and closely resemble that of coconut oil. Similarly, the saponification and iodine values approach the figures for butter fats. A characteristic feature of the arecanut fats is their low unsaponifiable residue which yields sterols (sitosterol) (125, 86, 91).

The chief components of the fatty acids are lauric (19.5%), myristic (46.2%), and palmitic (12.7%) and in the unsaturated portion oleic (6.2%), linoleic (5.4%), and hexadecenoic acid (7.2%). Minor proportions of stearic, decanoic, and of unsaturated monoethylenic C₁₂ and C₁₄ acids are also present. The chief component glycerides are (1) 56% of fully saturated (trimyristin, dimyristins and lauromyristopalmitin); (2) 30% mono-unsaturated-disaturated

(mainly hexadecenolauromyristin with some oleo-(linoleo)myristopalmitins and dimyristins); (3) 14% of diunsaturated-mono-saturated (oleolinoleoglycerides, mostly oleolinoleopalmitin). The fully saturated glyceride content of the fat is 53.7%. The fully saturated components are found to contain: 19.4% of lauric, 54.6% of myristic, 19.2% of palmitic, and 6.8% of stearic acids. The proportions of the various acids in the fully saturated components are similar to the corresponding ones in the saturated portion of the whole fat (113).

In addition to the alkaloids, tannins, and fats which have been comparatively more investigated, the endosperm is also stated to contain carbohydrates, protein and non-protein nitrogen, gums, saponins and vitamin A (116, 119, 99, 2). The proportions of the different constituents of the endosperm are tabulated in Table 3.

In an elaborate study of the derangements of the constituents of the endosperm, Raghavan (119) has produced a reliable picture of the changes taking place within that tissue from the time of its initial development to the time of full maturity; the data may be of considerable significance not only in elucidating the chemical composition of the endosperm, but also in explaining and interpreting certain biochemical reactions involved in its development. From this point of view the changes in the tannin content of the endosperm seem to be the most important. Perhaps no phenomenon is so obviously remarkable as the "disappearance" of the water soluble tannins during the final stages of ripening of arecanuts; a sudden decrease in the tannin content from 28% in the green fruit to 11% in the ripe fruit during the course of a few days is a remarkable chemical change invariably associated with maturity of arecanuts. This phenomenon is universal in many tanniferous fruits like banana, achras, per-

TABLE 3
CONSTITUENTS OF THE ENDOSPERM

Constituent	Quantity	Reference
Tannins	11.4-26.0%	62, 119
Gallicotannic acid	18.03%	73
Gallic acid	...	154
D-catechol,	3 gm./800 gm.	157
$C_{15}H_{14}O_6$		
Phlobatannin	...	41
Alkaloids	0.15-0.67	119, 80
Arecoline	0.07-0.50	117, 41
Arecaidine,	Small quantity	67
guvacine		
Isoguvacine	Trace	67
Arecolidine,	Minute	67
guvacoline	quantity	
Fats	1.3-17.0	149, 113, 26
Sitosterol	Trace	91, 86
Carbohydrates	47.2-84.5	116, 149
Saccharose, re-	...	154
ducing sugars,		
galactan,		
mannan		
Protein	4.9-9.3	116, 149
Non-protein	0.22-1.6	119
nitrogen		
Saponins	...	37
Gums	...	99
Carotene (In-	5	116, 2
ternational		
vitamin A		
units/100 gm.)		
Mineral matter	1.0%	116
Calcium	0.0185-0.05%	149, 116
Phosphorus	0.13-2.352%	116, 149
Iron	1.5-11.5	116, 149
	mgm./100 gm.	

simmon, date, etc., and a number of hypotheses have been put forward from time to time to explain the specific transformation of the tannin during the final stages of maturity of the fruits. Study of the mechanism of the "tannin disappearance" in arecanuts has revealed that tannins of the unripe endosperm during the final stages of ripening are partly adsorbed by the cell-walls, partly transformed into granular carbohydrates, and in part used up in the formation of reserve celluloses (124).

It will be realized that certain constituents of the endosperm play a fundamental and unsuspected role in the events leading to the disappearance of the tannins. The total sugars of the en-

dosperm show an increase in amount with increasing maturity until the highest is reached in the fully ripe fruits. The non-reducing sugars which do not occur to any considerable extent in the young fruits show an increase at a rapid pace in the ripe fruits. The reducing sugars also register an increase in the ripe fruits. The mature fruits are also rich in protein and total nitrogen, total alkaloids, and fats in comparison with the young fruits. It is obvious that an elucidation of the relationship of the tannins and carbohydrates in the arecanut endosperm will indicate the *modus operandi* of the process of "disappearance" of the tannins and will have more than academic interest (119).

Utilization

Uses of Arecanut. Arecanut finds its chief use as a masticatory. Chewing of the betel-nuts is a popular habit enjoyed by nearly one-tenth of the human population. Such utilization of the fruit throughout the south and middle east Asia developed since it came into prominence centuries ago.

In recent times, however, there has been considerable effort in India to explore the indigenous raw materials for industrial uses to keep pace with the country's many-sided needs. The development of the tanning industry of the country has led to a great demand for those plants which are the natural storehouse of synthetic tannins. The importance of the kernels of green betel-nuts as a good tanning material has been stressed by many, and some (8, 9, 137) have indicated their possible utilization in tanning leather hide. Whereas these works were responsible for bringing the fruit to the forefront as a tanning material, they did not individually or collectively create an atmosphere of commercial utilization of this raw material. Further work is in progress at the Central Leather Research Institute, Madras,

to bring the conclusions to a more satisfactory level, so that tanning of leather hide by arecanut tannins on an industrial scale may not be a long way off. The application of an extract of arecanuts for dyeing black and red shades has been in vogue in the Philippines for some time (26).

The betel-nut is also responsible for a number of medicinal uses. Of all the household remedies for tapeworm that filled the pages of some of the pharmacopoeias and standard textbooks on pharmaceutical botany, perhaps no other has as successfully withstood the test of time until recently as arecanut. Appraisal of the therapeutic value of arecanuts varies to the extremes. At the height of its exploitation as a drug, various magic effects of therapeutic interest were ascribed to the nuts, which today seem to be preposterous and ridiculous. The introduction of synthetic drugs has considerably depressed the value of betel-nuts in the indigenous medical world, but the following discussion will focus the esteem in which the fruits were held not long ago.

In the Yunani system of India, the betel-nut is considered as digestive, astringent, and emmenagogue. It is recommended as a cardiac and nervine tonic and is used as an astringent lotion for the eyes. In Ayurveda the unripe fruits are considered as cooling, laxative, and carminative; dried nuts are said to sweeten the breath, strengthen the gums, remove bad taste, and produce a stimulant and exhilarant effect on the system, improving appetite and taste. The use of betel-nuts is recommended in calculous and urinary disorders and as an aphrodisiac in the form of a decoction with other aromatic and stimulant substances. The nut also finds its use as an external application to ulcers, for bleeding gums, and for urinary discharges in women. Burned and powdered, the nut is used as a dentifrice. It is useful for

checking heartburn in pregnancy, for blood in urine, and, boiled and compounded with red betel and spices, as a gentle stimulant. An extract of arecanuts significantly impaired phagocytosis *in vitro* in human beings, while no effect was noticed in guinea pig leucocytes (32, 85, 51, 24, 25).

From Cambodia have come some reports of the use of unripe nuts against diarrhea, dysentery, and as a laxative. In China a decoction of the boiled nuts is used as a medicine in visceral affections. Doses of the powdered nut have been reported to give satisfactory results in the relaxed condition of the bowels (32).

The reputation of arecanuts as an anthelmintic and vermifuge is quite well known. It is said to be effective against *Lumbricus*, *Taenia solium*, *T. saginata*, *Hymenolepis nana* and *Fasciolopsis buski* (36, 4, 139, 72, 56, 57, 155). Arecanut has also been used for similar purposes in veterinary practice in poultry and dogs; it is said to be used mixed with food as a preventive against diarrhea in horses (23, 32). In spite of its long use as a vermifuge, the action attributed to arecanuts on tapeworms, nematodes, and flukes is now considered doubtful (46, 55). Its use as an antidote to snake-poison, previously recommended (95), has been disproved (33).

The medicinal properties of arecanuts are ascribed to the presence of the alkaloid complex in the fruits. Arecoline is cholinergic and has action very similar to pilocarpine. Its central stimulant action is more powerful than that of pilocarpine, and with large doses paralysis may ensue. Arecoline increases the tonus and reflex movements of the muscles, chiefly those of the alimentary canal. It also causes constriction of the pupil and slowing down of the heart-beat rate, besides being a powerful sialogogue. Arecoline hydrobromide is recognized by some of the continental pharmacopoeias and is given hypodermically for catarrh

in horses. It serves as a taenicide, anthelmintic, and diuretic (32, 23, 67, 26, 27, 153).

Vegetative parts of the palm have also been considered for a number of minor medicinal and other uses. In India the roots in decoction serve as a cure for sore lips, the buds as an abortifacient in early pregnancy in Malaya and as a cure for lumbago. The bark is useful for choleric affections and for flatulent, dropsical, and obstructive diseases of the digestive system; powdered young bark serves as an anthelmintic. An exudate from the tree is reported to form an inebriating lozenge. In Cambodia the roots form a remedy for liver disorders and jaundice and the leaves for cough and bronchitis. Half-rotted husks are used by the Chinese in Malayasia in dysentery. In the Philippines the buds of the palm (moisture, 91.48; ash, 1.23; CaO, 0.03, iron as Fe₂O₃, 0.003%) are eaten as salad (32, 6, 117, 28, 27).

An unfortunate phase in the development of the arecanut industry is that relating to the poisonous and other undesirable effects in human beings and livestock which at times become lethal. Chewing of the nuts in excess is said to give rise to temporary giddiness, griping, and strong intestinal irritations, followed by loose motions and may even lead to buccal carcinoma; mixed with opium the nut is administered in Malaya as a poison. In the indigenous medical system the unripe nut is described as pungent and saltish and causing biliousness and harm to the eyesight. Amateurs in betel chewing usually experience a disagreeable combination of symptoms including constriction of the oesophagus, sensation of heat in the head, red and congested face, and dizziness. The alkaloid arecoline is said to be highly toxic, its symptoms resembling those of fungus poisoning (muscarine) (87, 32, 12, 85, 26, 96, 107). A similar sensation is experienced while eating the buds.

Arecanuts are supposed to prevent the decay of teeth, but its continued use blackens them (153).

Uses of By-Products. The most important by-product of the betel-nut industry is the husk. It is estimated that in India at least 5,000 tons of husk may be available per annum. The possibility of utilizing the husk for industrial purposes has been an integral part of the previous investigations on this material. Although investigations carried out at the Imperial Institute, London, indicated the undesirability of utilizing this material for paper making, work undertaken later in India showed that boards of fine quality and insulating wool can be made of the husk. Boards, especially those prepared from the husk by the addition of certain sizing materials have shown high keeping qualities and finish (15). The husk can be used for the production of furfural (yield 13.45%), the residue left after furfural distillation being considered as a suitable filler for plastics (66, 105). Experiments on the production of activated carbon from the husk have also given encouraging results (1, 39, 40). The ash of the burned husk has been long used in Malaya as a dentifrice (28).

Manufacture of sundry articles from different parts of the palm has long been accomplished in the orient. Because of their hardness, the nuts are said to be used for making buttons. The stem has been used for inexpensive posts, rafters, trenails, beams, pillars, joints, scaffolding, water channel, spear handles, bows, walking sticks, and furniture. Leaf sheaths and spathes are now used in certain parts as a substitute for plantain leaves, for caps, and also for buckets, dishes, and wrappers. There is today an increasing use of the leaves in villages for thatching purposes. The central rib of the leaves is so strong that when dry and expanded it forms an excellent ready made splint. Inoculated with

Saccharomyces cerevisiae the leaves can be used as a fermentation stimulant in industrial alcohol production. The traditional Indian practice has been to use the flowers of the arecanut palm on ceremonial occasions (51, 79, 100, 44, 26, 27, 150, 47, 65).

Conclusions

In India the arecanut has not been accorded as much attention as it deserves. This is presumably because of the localized nature of the crop and the unnoticeable impact of the commodity on the general economy of the country. It is gratifying to note, however, that the industry has made great strides during recent years, especially in improving the conditions of the growers and in initiating research on the still unexplored aspects of the palm. The eventual success of the industry in India will depend mainly on production, consumer demand, and the prices received for the product.

Future work on the improvement of arecanut should pursue the following broad objectives (20, 34, 100, 102, 112):

1. Obtaining higher yields through systematic cultural operations. On the basis of preliminary results, it now seems definitely possible that arecanuts can be produced at a higher rate through proper cultural and manurial methods. To the average holder this will mean that, with reasonable remuneration, production on a plantation scale should be a profitable undertaking.
2. Obtaining high-yielding, disease-resistant varieties through breeding. The segregation of the progeny due to unknown male parent seems to be apparent, and, therefore, inheritance of economic characters and self-behavior in controlled crosses are to be studied. It can be said that, if stability in arecanut growing on a plantation scale is to be reached, many new varieties will have to be developed and tested in order

to evolve varieties suited to particular areas and particular characters.

3. Describing and enumerating varieties of arecanuts in India and elsewhere to assist in a program of acclimatization and introduction of indigenous or exotic varieties under particular conditions.

4. Studying the biology of the commonly occurring diseases and pests and finding effective and economic measures to check them.

5. Making technological studies on the parts of the palm to evolve effective uses. Aside from those already listed, many new and stable industrial uses for the by-products of arecanuts should be found. This lack of spectacular phases has been one of the factors that has relegated arecanuts to the level of a mere "masticatory".

The impact of western civilization and the resultant ferment in Indian customs and habits seem to have drastically affected the arecanut industry. The future of the industry is not assured. Chewing of arecanuts is now being looked upon with disfavor. The many magic effects attributed to betel-nuts in therapy are still to be scientifically tested. Such endeavor is clearly of the greatest interest, in view of the urgent need to save the industry from what seems to be a crisis. If it is possible to develop arecanuts in the lines indicated at a rapid pace, the industry may survive.

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