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Viability of Coconut Seeds After Floating in Sea

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INTRODUCTION

The origin and distribution of the coconut palm, *Cocos nucifera* Linnaeus, has for many years been the subject of controversy. An American origin has wide favor among certain students of plant distribution. Cook (3, pp. 257-293; 4, pp. 271-342)[1] and Ridley (7) were especially strong defenders of this viewpoint. Beccari (1, pp. 27-43) criticizes Cook's argument and presents a case for Polynesian or Asiatic origin of the plant. Hill (6, pp. 133-134, 151-153), in reviewing the observations of others, favors an East Indian origin. Of particular significance is the announcement by Berry (2, pp. 181-184) of the discovery of a coconut (*Cocos zeylandica*) in the Pliocene of New Zealand, apparently similar to the recent form except in size.

In the question of distribution two phases immediately present themselves—the viability of the seed of the palm after having drifted for an indefinite period on the ocean, and the possibility of its development and maintenance if, by chance, it were cast upon some tropical shore.

Opposing the popular belief that the coconut may be distributed through drift and establish itself unaided, Cook (3, p. 261; 4, p. 339) accepts the view that it is found only on those islands to which it has been carried by man and concludes that "the theory that it has been disseminated by ocean currents is gratuitous, unproved and improbable." Hedley (5, pp. 10-71), after his investigations on Funafuti, wrote "I doubt whether, despite popular opinion to the contrary, a wild coconut palm is to be found throughout the breadth of the Pacific."

[1] Numbers in parentheses refer to Literature Cited, p. 304.

The high degree of specialization of the seed of the coconut is recognized by all, but the function of the thick, fibrous husk has been variously interpreted by investigators. Cook (3, pp. 261, 276), though he asserts that the coconut seed is rather delicate and short lived, sees in the thick husk a protection to the seed as it falls from the tree, and a provision for water storage during germination and early development, but no adaptation for water distribution. Ridley (7, p. 323), however, supporting the drift theory, attempts to refute Cook's argument, pointing out that seeds that are dispersed by ocean currents typically possess thick husks and that some heavy fruits not so protected fall from trees (durians) taller than coconut palms. Ridley, a student of plant dispersal, believes the coconut may have drifted from Central America to Polynesia and from there to Malaya. He gives credence to reports that seeds of coconuts have germinated after having drifted long distances in the sea. Beccari (1, pp. 41-42) stresses the halophilous nature of the coconut palm, its need for and resistance to large amounts of salts characteristic of the ocean, and concludes that the plant might have been easily dispersed by ocean currents from its Polynesian or Asiatic origin. Berry (2, p. 184) observes of the coconut discovered in the Pliocene of New Zealand that the existence of the plant at that remote period precludes the agency of man in its early distribution although that agency may be a factor in recent dispersal.

Most objections to ocean-current dispersal of the coconut are directed against the possibility of the plant maintaining itself unaided by man after having been cast ashore by the waves, and few against the possible deleterious effect which prolonged contact with the sea might have upon the germination of the seed. Cook (3, p. 276) sees an optimum of moisture essential to normal development of the coconut, too little being fatal to germination or later growth while too much may cause the seed to rot. After floating in the sea for several weeks, the fibrous husk becomes saturated with water and the hard seed coat within enclosing the vital elements constantly rests in a film of saline moisture. Hazards to germination under such conditions are lack of proper oxidation and infection from microorganisms.

The following report is concerned only with the viability of the coconut seed after floating in the ocean for various periods up to nearly four months. In previous records of drifting coconuts, the periods the seeds were in contact with sea water seem to be matters of doubt or conjecture. I believed that controlled experiments to determine the duration of drifting and its effect upon the germination of the seed would be an initial step in answer to the mooted question of coconut dispersal. Such experiments were begun about Oahu in 1938.

METHODS AND MATERIALS

The coconuts used in this study were grown on Oahu, some in the district of Kailua and others in the aquarium grounds in Honolulu. Large well-formed specimens were selected, all recently fallen from the trees and all containing water. To secure the coconuts and keep them under observation while they were exposed to the sea, galvanized wire netting of large mesh was formed into baskets each just large enough to enclose the husk of a nut. These were then anchored by

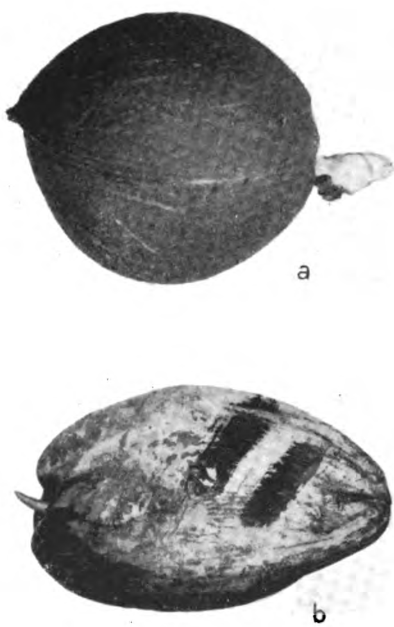

FIGURE 1.—Development of the coconut while wholly or partially submerged in sea water: **a,** development while wholly submerged for 30 days; embryonic stem extends 40 mm. into the husk saturated by sea water. **b,** development of a coconut so weighted as to float half submerged in quiet sea water for 57 days. Visible sprout 28 mm. long.

means of a stout rope or light chain of sufficient length to permit the specimen to float and rise and fall with the tides. The added weight of the wire netting and the rope or chain caused the coconut to sink slightly lower in the water than if it were floating freely. None of the specimens, however, were incapable of floating after the longest contact with the sea, although some were water-logged and resting low in the water.

Coconuts were floated, a few at a time, in three ocean localities—Pearl Harbor, Kaneohe Bay, and Waikiki reef. Some coconuts were floated in sea water tanks in the Marine Biological Laboratory, where the water was but slightly agitated and were not weighted in any way. Most of the coconuts were weighed preceding exposure to the sea and again at the end of the floating period.

At various intervals, ranging from 22 to 116 days, coconuts were removed from the sea and some of them planted, as described below, while others were opened to determine whether germination had begun and to observe the state of the endosperm. The final phase of the study was to ascertain whether the sea water exposure rendered the seed incapable of germinating and developing when placed under conditions similizing in some degree those which it might contact if it were cast ashore by the waves.

Fifteen coconuts were taken from the sea and planted in Bowers' Tropical Gardens, Honolulu, where they were placed on prepared soil containing a large proportion of sand. Some occupied shade and others were exposed to the sun for the greater part of the day. Ten germinated and developed into young healthy plants. For further data, including the floating time and the interval between removal from the water and the visible sprouting time, see table 1.

Table 1. Data on 10 coconuts planted in Bowers' Tropical Gardens

Floating time in sea water, in days	Sprouting time after planting, in days
27	87
31	89
36	142
37	107
41	190
48	(record lost)
54	120
55	141
91	238
110	107

Five coconuts placed in Bowers' Tropical Gardens showed no evidence of development after planting periods ranging from 335 to 515 days. These specimens had previous contact with the sea for 22, 30, 74, 112, and 116 days.

One other coconut, after having been in the sea 28 days, was planted in Manoa Valley on prepared soil consisting largely of black sand. It was so placed as to receive direct sunlight during several hours of the day, and was wholly exposed to the weather. During 328 days frequent observations revealed no visible development. After an interval of 210 more days, examination showed roots having pene-

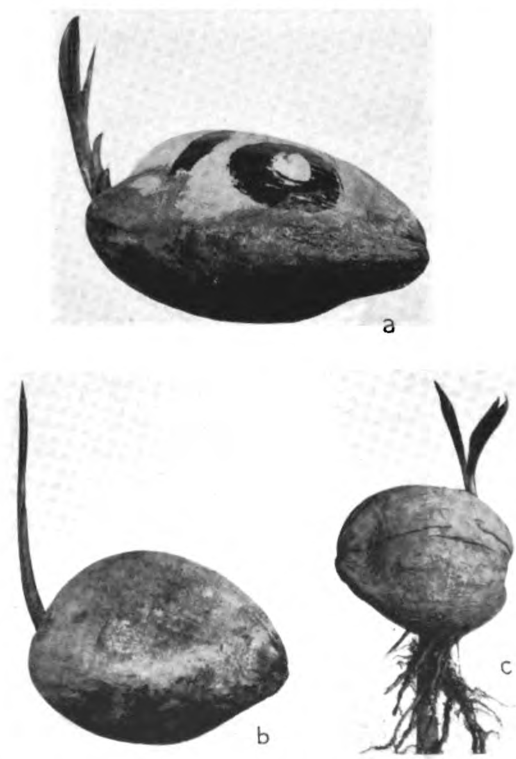

FIGURE 2.—Development of coconuts after contact with sea water: **a,** sprouting of a specimen while floating on quiet sea water for 58 days; visible stem 6 inches in height. **b,** a coconut under conditions similar to *a,* but for 74 days; visible stem 9.37 inches in height. **c,** a specimen requiring 582 days for the stem to emerge from the husk, following a floating period in the ocean of 28 days; the roots appeared at least 60 days before the stem.

trated the soil to a depth of 6 inches, and a thick shoot was visible at the broad end of the nut, but had not broken through the upper surface of the husk. The stem of the plant finally emerged from the husk 582 days after the nut was planted. The more rapid development of the root system than the stalk was probably due to an urgent need of moisture. The specimen was photographed 43 days after the stem emerged from the husk (fig. 2, *c*). If the roots of this specimen actually broke through the husk 60 days before they were observed, which they probably did, well over 400 days were required for visible development.

In addition to the above plantings, 11 coconuts, with floating time ranging from 16 to 44 days, were placed on beach sand in the Marine

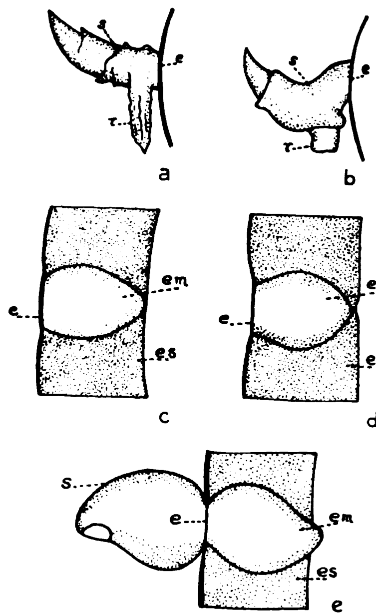

FIGURE 3.—Early development of the coconut after floating on sea water: **a**, stem and root development within the husk after 221 days subsequent to a floating period of 22 days in the ocean; shriveled from lack of moisture, × 2. **b**, development as the preceding after 243 days following 40 days in the ocean; shriveled from lack of moisture, × 2. **c**, embryo within endosperm of specimen after floating 91 days in the ocean, × 4. **d**, embryo of specimen after floating 112 days, × 4. **e**, embryo within endosperm and extending into the husk of a coconut after floating 58 days on quiet sea water, × 2. Symbols: *e*, eye; *em*, embryo; *es*, endosperm; *r*, root; *s*, stem.

Biological Laboratory where they were unexposed to the weather in a dry, warm atmosphere. None showed evidence of development after having been planted for periods ranging from 4.5 to 8 months. All were then opened on the same day to determine whether germination had begun. Six specimens with floating time from 16 to 30 days and planting time from 142 to 221 days showed various degrees of development. In four of the six, embryos were alive but had not yet pushed through the eye. In two specimens, each with floating time of 22 days and planting time of 221 days, differentiation of root and stem had taken place, the shoot being within one inch of the surface of the husk (fig. 3, *a*). From the state of these six coconuts it was apparent that development was proceeding but slowly, probably due to lack of moisture.

Three of the six above-mentioned coconuts had been floated on a sea water aquarium in the Marine Biological Laboratory and absorbed but little water during this period. One gained slightly less than one pound in 26 days, and each of the other two lost about two ounces of weight in 25 and 30 days, respectively.

Five of the eleven coconuts planted on beach sand in the laboratory were found to be in a state of decay or desiccation when opened. Two specimens, each with floating time of 40 days and planting time of 243 days, showed development of root and stem, but the shoot was shriveled and dead (fig. 3, *b*). It is doubtful whether any of the 11 coconuts would have developed very far in the dry atmospheric conditions which surrounded them even though more time were allowed. The husks of all were desiccated throughout.

Absorption of Sea Water

Although there may be various opinions regarding the chief function of the husk of the coconut seed, there is no doubt about its ability to absorb moisture if brought into contact with water for a considerable period of time. The fibrous husk is aided in its conservation of moisture by an ample supply of salt, lime and potash. Coconuts floating freely on the ocean doubtless acquire sea water less rapidly than did the experimental ones used by me because of the added weight of the chains and wire netting. However, there is great variation in the capacity of coconuts to absorb sea water, and little correlation is apparent between the original size and weight of specimens and the amount of water acquired in a given time. Nor is there much correlation between the period of exposure to the sea and the quantity of water absorbed. (See table 2.)

Regardless of the amount of sea water absorbed by the husk little or none seems to find its way into the seed, at least during a floating period of several weeks. A specimen after floating 48 days contained 78 cc. of water in the seed, while a control nut of approximately the same original weight, after a similar time in the air contained 76 cc. of water. Little difference in quantity, pH or specific gravity of the water contained in these two nuts was evident (p. 302).

That the seed is quite impervious to sea water was also determined by two coconuts of nearly equal size and weight, both containing water. which were placed in a reservoir of quiet sea water. One was allowed to float freely on the surface, the other was weighted and wholly submerged. After 58 days, each was reweighed and examined for the amount of water contained within the seed and the condition of the embryo. The floating coconut had gained 0.63 ounces in weight; the embryo extended 18 mm. beyond the eye, and the seed contained 82 cc. of water which together with the endosperm was normal in color and odor (fig. 3, *e*). The submerged coconut gained 1 pound and 10.40 ounces in weight; the seed contained 72 cc. of water which was slightly turbid, and faintly rancid in odor, as was the endosperm. The embryo was 6 mm. in length, wholly within the seed but pressing against the eye. Although conditions were favorable for absorption of sea water by the seed of the submerged coconut, apparently none had penetrated the seed coat.

Another coconut wholly submerged in quiet sea water for 30 days gained slightly more than one pound in weight and developed a shoot 40 mm. long within the husk which was saturated with sea water. The seed still contained 92 cc. of water, slightly turbid but of normal odor (fig. 1, *a*, p. 295).

It is observed (table 2) that a coconut weighing slightly less than 1.5 pounds absorbed more than four pounds of sea water in 26 days. while one weighing more than two pounds gained less than one pound in 91 days. It is also noted that a specimen floating for 22 days gained more sea water than did one of almost equal size in 116 days. Individual variations among coconuts may account for the absorption of a greater or lesser amount of sea water when specimens are subjected to similar conditions. The size of the seed in relation to the thickness of the husk may be a factor, and doubtless the surface of the husk is less pervious to water in some specimens than in others.

After long exposure to the sea some coconuts may become heavily fouled by barnacles, bryozoans, serpulid worms, and algae. In experimental specimens the fouling organisms were carefully removed before the coconuts were reweighed. In Pearl Harbor the bivalve mollusk, *Martesia striata*, frequently infested floating coconuts burrowing deeply into the husks.

Table 2. Amount of water absorbed by 10 coconuts while floating on sea

Floating time, in days	Original weight, in pounds	Water absorbed, in pounds
16	2.12	0.92
22	3.43	4.50
25	2.10	3.30
26	1.40	4.25
31	2.12	1.40
34	3.50	6.12
74	2.43	3.50
91	2.40	0.70
112	3.00	7.17
116	3.25	4.00

Germination During the Floating Period

To ascertain what effect, if any, an extended contact with sea water may have on germination of the seed, a number of coconuts were opened and examined at the conclusion of the floating period. Brief observations on six specimens were as follows:

1. Floating time 28 days; husk absorbed nearly three pounds of sea water; seed contained 45 cc. of deep reddish water with rancid odor; meat grayish in color, soft and mushy with rancid odor; no evidence of germination.
2. Floating time 48 days; husk saturated with sea water; seed contained 78 cc. of clear water with rancid odor, pH 4.70, specific gravity 1.0174; meat, ash gray with rancid odor; no germination.
3. Floating time 74 days; husk absorbed nearly three pounds of sea water; seed contained considerable water, grayish in color with rancid odor; meat firm, color and odor as water; embryo well developed, extending 4 mm. beyond eye of seed.

4. Floating time 91 days; husk absorbed 9 ounces of sea water; seed contained 24 cc. of grayish water with rancid odor; meat of similar color and odor; embryo alive, wholly within the seed, 7 mm. long (fig. 3, *c*).

5. Floating time 112 days; husk saturated with sea water; seed without water; meat firm, grayish in color, slightly rancid in odor; embryo alive, wholly within the seed (fig. 3, *d*).

6. Floating time 116 days; husk absorbed 4 pounds of sea water; seed contained 110 cc. of slightly discolored and rancid water; meat firm, color and odor as water; embryo alive, wholly within the seed but pushing firmly against the eye.

Although there is no certainty that any of these specimens would have fully developed, the assumption is that some of them would have done so had they been planted under favorable conditions and given sufficient time. During the floating period they were given the same treatment as were those listed in table 1.

The absorption of large amounts of sea water by the husk of a floating coconut may not, apparently, prevent germination and development. A comparison of numbers 3 and 4 of the preceding list shows that in 74 days a coconut absorbing nearly four times as much water as one floating 91 days was even more advanced in its development. In the heavily saturated specimen the embryo was advancing into the water-soaked husk, indicating that the coconut might have sprouted in the sea had the floating time been sufficiently increased.

Changes in color and odor of the water and meat of the seed during the floating period are suggestive of the lack of oxidation or the presence of microorganisms. These conditions, however, are apparently not always fatal to embryonic development. Only slight differences in hydrogen ion concentration and specific gravity of the water of the seed were indicated in a coconut floating 48 days (number 3 of the above list) from those of a control specimen which, for a similar period, rested in the laboratory. The pH of the floating specimen was 4.70, of the control specimen, 4.76. The specific gravity of the water of the floating specimen was 1.0174, of the control specimen, 1.0172. There was 78 cc. of water in the seed of the floating coconut and 76 cc. in that of the control specimen. The meat of the control specimen was white, without rancid odor, and no evidence of germination was seen. The slight change in color and odor of the water and meat of the coconut wholly submerged in quiet sea water for 58 days (p. 300) may have been brought about by lack of oxygen.

Coconuts when floating on the surface of a quiet body of water are subjected to quite different conditions than would be met at times in a turbulent sea. On a placid surface of water the upper half of the coconut has no contact with the water, and evaporation of moisture from the husk may nearly equal the absorption of water by it. That coconuts will sprout while floating on the surface of unagitated sea water, has been demonstrated, and it is suggested that germination may even be hastened by such contact.

Thirty-nine coconuts, each containing water in the seed, after being weighed, were floated on the surface of a reservoir of quiet sea water openly exposed to the weather. The specimens were divided into four lots, and the experiment for each lot was started at a different time. At the time of recording the first results, 9 floating coconuts had developed visible stems but no visible roots. One coconut produced a visible sprout after floating 26 days; five had sprouted after 58 days, the most advanced one showing a stem 6 inches high above the surface of the husk (fig. 2, *a*); and three specimens after 74 days showed well-developed sprouts, the longest being 9.37 inches (fig. 2, *b*). Most of the coconuts showed an increased weight ranging from 0.5 to 5 ounces when reweighed, indicating but slight storage of water. One specimen, of 57 days floating time, which was weighted causing it to float low in the water, gained nearly one pound in weight and developed a visible sprout 28 mm. high (fig. 1, *b*). None of the developing specimens showed visible roots, but when the husk of one with a stem nearly 7 inches high was opened, an elaborate system of roots and rootlets was found, the longest units of which still lacked 30 mm. of reaching the surface of the husk.

Coconuts serving as controls for the preceding experiments were planted on beach sand close to the sea water reservoir immediately after they fell from the trees. None showed visible sprouting while under observation for nearly three months.

CONCLUSIONS

Investigation into the viability of coconut seeds, which floated in the sea for known periods of time, results in the following conclusions.

1. Coconuts were found capable of developing after having floated in the sea for periods up to 110 days. (A conservative estimate of the distance that might be traversed in that time, if carried by a favorable current, is about 3,000 miles.)

2. After contact with sea water experimental coconuts required

periods ranging from less than three months to much over one year to exhibit visible development.

3. There seems to be little correlation between floating time and subsequent time required for visible sprouting. The latter is probably affected by inherent qualities of the seed and conditions to which it is subjected during planting time.

4. While floating in the ocean the husk of the coconut may absorb large amounts of sea water, but the seed is well adapted for its exclusion and the young shoot is apparently not seriously affected by it. If the surface on which the coconut floats is undisturbed little sea water is absorbed by the husk.

5. Although changes in color and odor may occur within the floating nut, probably because of improper oxidation, development may proceed regardless of these changes.

6. Excessive dryness may completely inhibit development after germination has begun.

7. Germination may begin and continue while the coconut floats in the sea. The embryo may push itself out into the husk saturated by sea water which is suggestive that visible sprouting might occur in the open ocean if sufficient time were allowed. Little of the water is absorbed by the husk of the coconut while floating on an undisturbed surface of sea water, and germination and visible sprouting readily occur.

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The author is responsible for all statements in this paper.