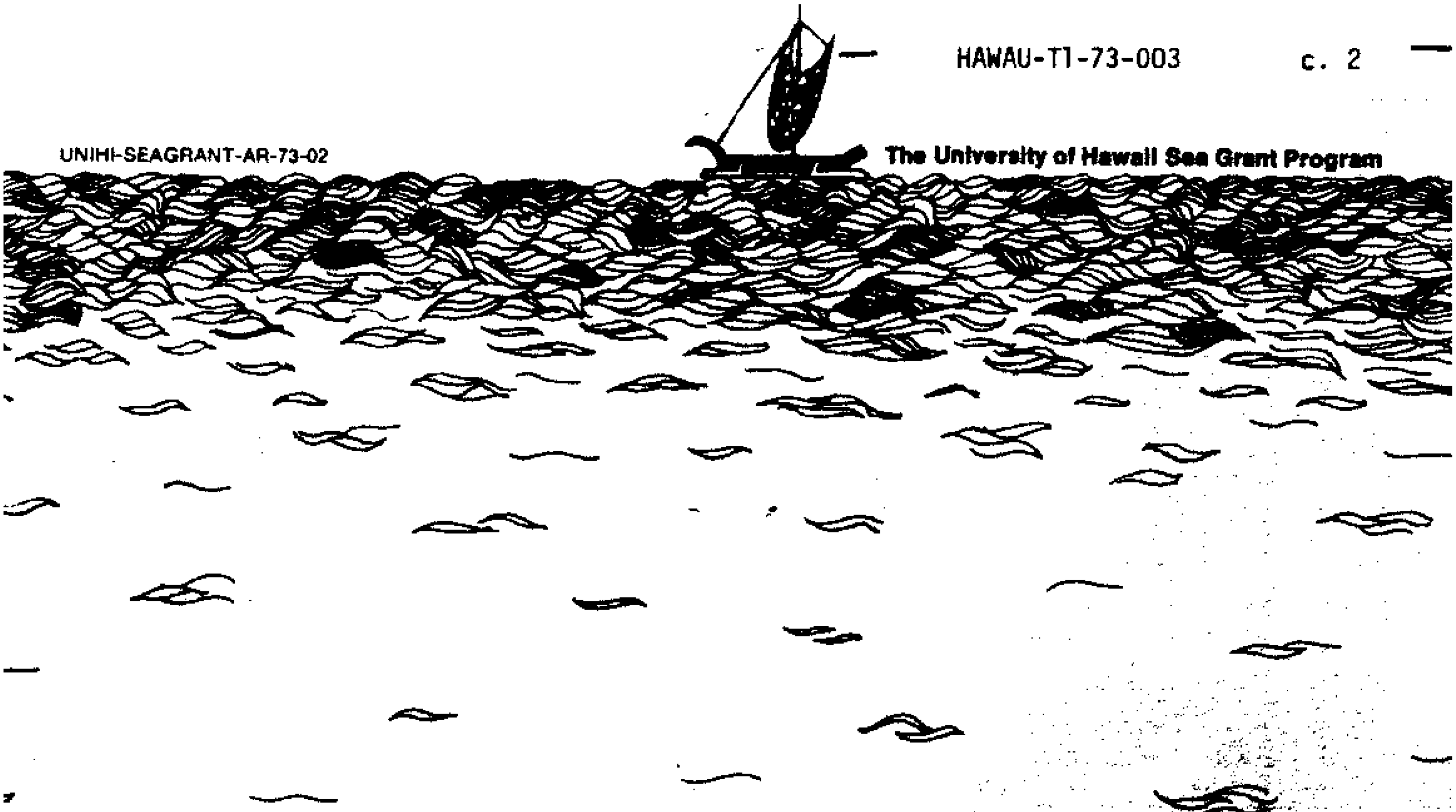
UNIHI-SEAGRANT-AR-73-02

The University of Hawaii Sea Grant Program



Eucheuma Farming for Carrageenan

Maxwell S. Doty

April 1973

EUCHEUMA FARMING FOR CARRAGEENANS

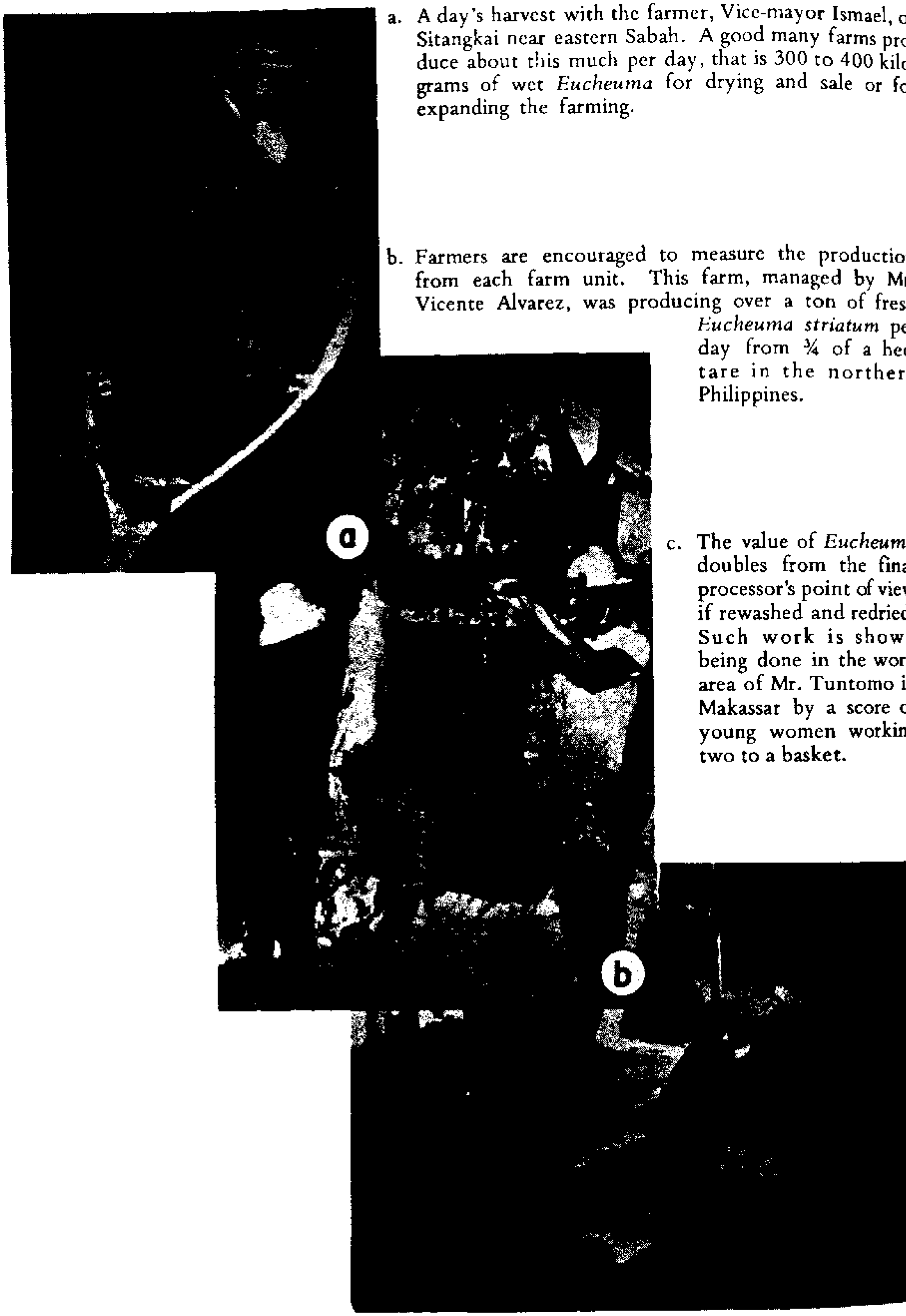
by

Maxwell S. Doty

The present Sea Grant Bulletin was prepared for distribution to accelerate dissemination of the contents to U.S. industry. It is essentially a pre-print of a manuscript to be published soon in the professional journal *Micronesica*, where it will have a slightly different text and illustrations.

Sea Grant Advisory Report
UNIHI-SEAGRANT-AR-73-02
April, 1973

This work is a result of research sponsored by NOAA Office of Sea Grant, Department of Commerce, under Grant No. 2-35243; and U.S. Atomic Energy Commission contract AT(04-3)-235. The U.S. Government is authorized to produce and distribute reprints for governmental purposes notwithstanding any copyright notations that may appear hereon.



a. A day's harvest with the farmer, Vice-mayor Ismael, of Sitangkai near eastern Sabah. A good many farms produce about this much per day, that is 300 to 400 kilograms of wet *Eucheuma* for drying and sale or for expanding the farming.

b. Farmers are encouraged to measure the production from each farm unit. This farm, managed by Mr. Vicente Alvarez, was producing over a ton of fresh *Eucheuma striatum* per day from ¾ of a hectare in the northern Philippines.

c. The value of *Eucheuma* doubles from the final processor's point of view if rewashed and redried. Such work is shown being done in the work area of Mr. Tuntomo in Makassar by a score of young women working two to a basket.

FOREWORD

Somewhat by chance, in 1957, the author became interested in the ecology of the marine red algal genus, *Eucheuma.* During the mid-1960's the American supply became greatly reduced by the Indonesian political situation and industry began seeking new sources. Knowing the author's interests, the late Dr. E. Yale Dawson deflected its enquiries to him and as a result, with Mr. N.R. Pellicani's active support while he was responsible for raw product procurement for Marine Colloids, Inc., of Rockland, Maine, an ongoing research and development study was instituted.

The author's initial stimulus to work with Philippine seaweeds was provided by Dr. Gregorio Velasquez of the University of the Philippines and by Mr. Inocencio Ronquillo of the Philippine Fisheries Commission. There have been far too many contributing to this program to mention them individually, though some of the most significant contributors are mentioned in the text. During development of the farming to be described, Mr. Vicente B. Alvarez has worked closely with the author and has been a fountain of information as well as the author's almost constant companion while in the country. While initially the financing was from the U.S. National Science Foundation, the U.S. Office of Naval Research, and the U.S. Atomic Energy Commission, further such assistance came from both the Philippine National Research Council and the Philippine Bureau of Fisheries. Recently the U.S. Sea Grant Program and Marine Colloids, Inc., have been providing most of the financial assistance. The author is appreciative and grateful for all of this.

Tables 3, 4, and 5 were assembled from data obtained by Mr. Barry H. Hill while on a fellowship provided by Marine Colloids, Inc., of Rockland, Maine. The author particularly appreciates the assistance provided by Mr. Vicente B. Alvarez, Manager of Marine Colloids (Philippines) Inc., and Mr. W. W. Gentry of Marine Colloids, Inc., Rockland, Maine.

TABLE OF CONTENTS

INTRODUCTION

The different species of the seaweed genus *Eucheuma* produce quite purely one or another form of carrageenan. Carrageenans are colloids or gels; they are key ingredients in a great many products of the modern American food and dairy industry. Southeast Asia is the major source of this seaweed.

Few phycologists are familiar with the genus, *Eucheuma*, as are perhaps fewer people in industry. Thus it is of interest to note that records of *Eucheuma* are as old as Linnaean botanical literature itself. It has long been used in Southeast Asia as a green salad vegetable and for its gel content. Hesse's introduction of **agar agar** to microbiology (Hitchens & Leikind, 1939) was apparently the first scientific use of the gel, kappa carrageenan, from the *Eucheuma* "cottonii" group of species. The terms **agar** and **agar agar** are now applied in the Western World to a different gel substance from different algae.

The meanings of the following technical or colloquial terms are provided here for clarity. A **thallus** is one of the individual algal bodies that grow and it is the **thalli** (plural) that are harvested for their carrageenan content. **Carrageenans** are complex carbohydrate molecules that form unusual gels or colloid combinations in water and milk. They often contain as much as 30 per cent sulfate by weight. The different forms are designated by Greek letters.

The culture of a very different seaweed in Japan, *Porphyra*, has provided certain of the *Eucheuma* farming techniques. The term **monospecific product** is used to indicate *Eucheuma* produces either one or the other of the different carrageenans. Finally **basic production ecology** is the study of the environments in which *Eucheuma* grows well and the use of this information in the empirical farming methods now in use.

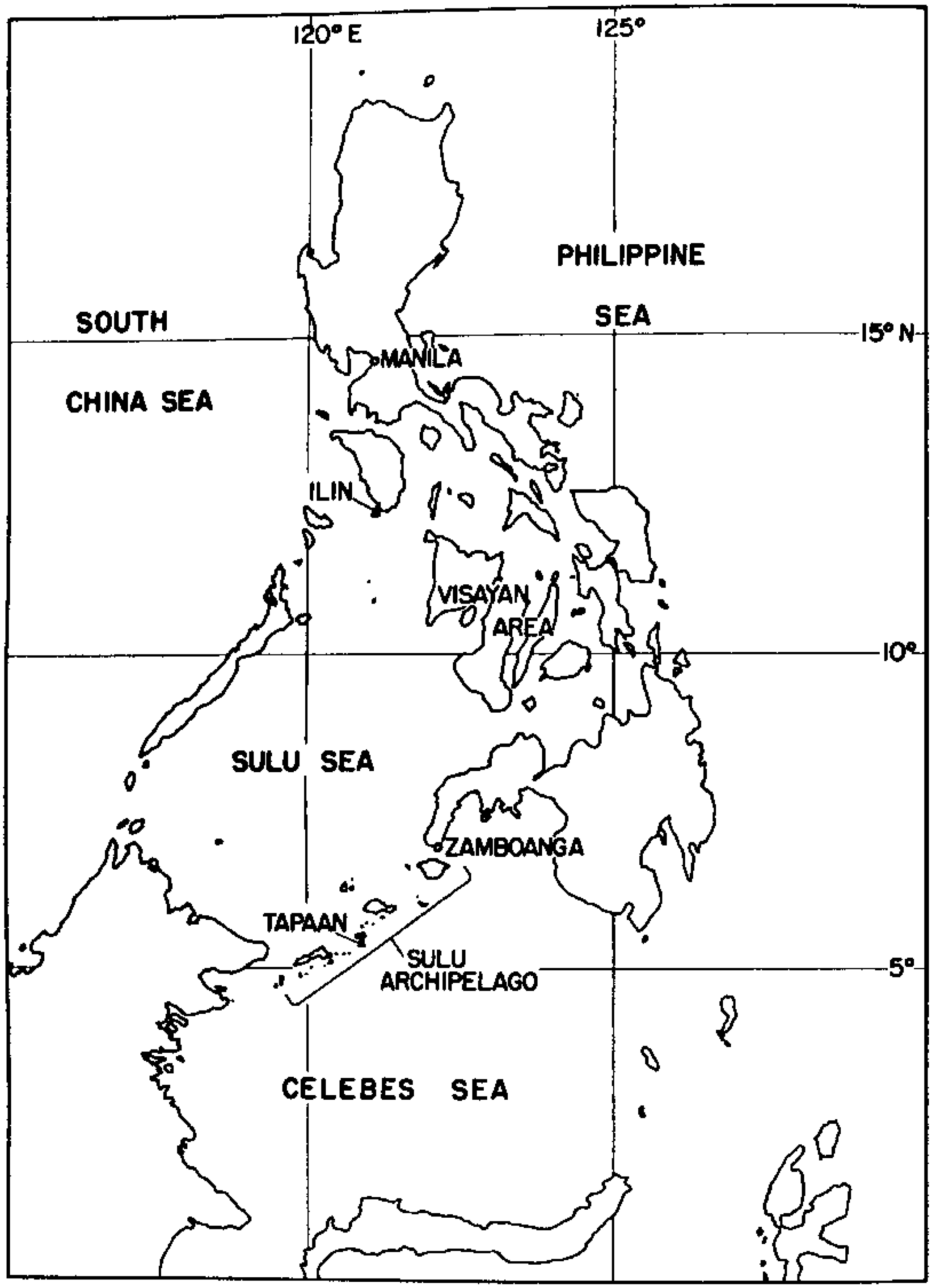


Figure 1. The Philippine *Eucheuma* farming and production areas.

SUPPLY AND DEMAND

The modern food industry requires 10 to 20 times more carrageenan than the wild seaweed crop provides. Part of this need is being met by the research and development reported here on the basic production ecology and agronomy of *Eucheuma*, a carrageenan-producing tropical seaweed. Other marine algae, such as *Chondrus crispus*, the "Irish moss" of temperate regions, produce variable mixtures of the different carrageenans.

The genus, *Eucheuma*, can be divided (Table 1) into two groups of species; one produces iota carrageenan and the other, kappa carrageenan. Morphologically these two are named in commerce "spinosum" and "cottonii".

Currently, an amount perhaps between 3000 and 4000 dry tons of *Eucheuma* reaches the world market. Most of it goes to the United States, with much less going to the United Kingdom, France, and Denmark. Largely it comes from Southeast Asia, *e.g.*, the Philippines (Figure 1) and Indonesia. Wildman (1971) provides both an interesting series of photographs and a variety of information on the *Eucheuma* industry. The world price might now be $350 (U.S.) per ton if the product were clean, rewashed, dry and monospecific regardless of the species or kind of carrageenan contained. Deviations from these specifications may reduce the F.O.B. price one-half or two-thirds, but the value has nearly doubled in the past five years.

TABLE 1. THE BETTER-KNOWN CARRAGEENAN-CONTAINING *EUCHEUMA* SPECIES USED COMMERCIALLY

Sources of kappa carrageenan ("cottonii" types)	Sources of iota carrageenan ("spinosum" types)
E. cottonii (E. okamurae)[a]	*E. spinosum* (E. muricatum) (E. denticulatum)
E. striatum (E. nudum) (E. edule)	*E. isiforme* (E. acanthocladum)
E. procrusteanum	*E. uncinatum* (E. johnstonii)
E. speciosum	

[a]The scientific names in parentheses are probable synonyms of those under which they are indented insofar as they are used in the Pacific.

GROWTH CHARACTERISTICS

Iota carrageenan is the principal component of the walls of *Eucheuma* species having a dense central axis of slender cells in the center of each branch. Likewise, these iota carrageenan-bearing species have (Figure 2) regularly-spaced spine-like branchlets on the margins of their flat fronds or in whorls on cylindrical fronds (*e.g., E. spinosum*) when these are young. Later spines appear elsewhere and the primary spines may elongate into branches. The branches tend to be uniform in diameter from the base to tip or throughout any given segment. The characteristics of iota carrageenan (Stancioff & Stanley, 1969) include its being rather like a sugar solution, *i.e.*, hardly becoming really rigid as it thickens. Also it suspends quickly in cold water.

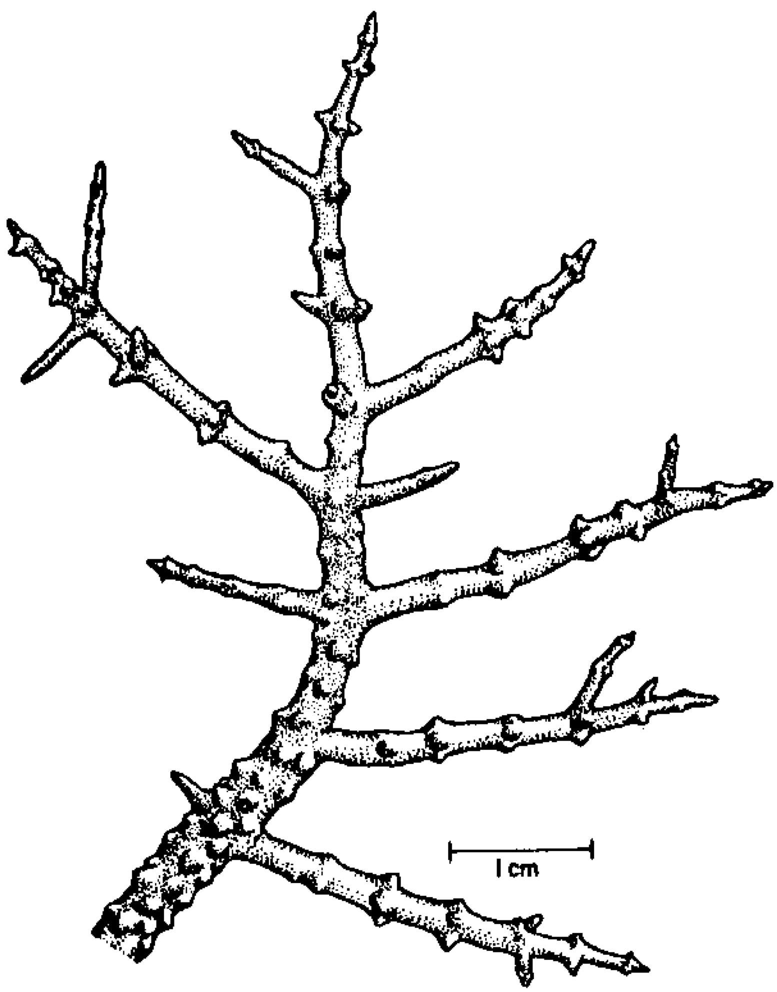


Figure 2. A common form of *Eucheuma spinosum*. The whorled, regularly spaced spines and branches are characteristic, as are the regular diameters of the main axes. The proliferations are of two sorts: primary proliferations, which are tapered spines arising in regularly predictable places near the branch tips, and secondary proliferations, which at first are hemispherical but later may become cylindrical or grow out as branches. The secondary proliferations arise neither near the tips of rapidly growing thalli nor at regularly predictable places.

Kappa carrageenan is the principal wall component of the anaxiferous *Eucheuma* species. While the principal species is *E. striatum*, in the trade the term "cottonii" is used for all kappa carrageenan producers of the genus. There is no dense central strand of slender cells; thus these species are said to be anaxiferous. The branchlets arise irregularly as protuberances near the branch tips, though sometimes they appear to be elongated longitudinally or arranged longitudinally in respect to one another. Branches are often seen that are swollen or much larger in diameter toward their apices than at their bases and callus-like collars or swellings are associated with wound healing and branch regeneration. Sometimes the thalli may be flattened (Figure 3) as is the species, *E. cottonii*, in its scientific sense. *Eucheuma procrusteanum* produces (Kraft, 1969b) erect flat blades from a branched basal cylindrical portion. Kappa carrageenan makes (Stancioff & Stanley, 1969) a rigid gel that will retain its form without support.

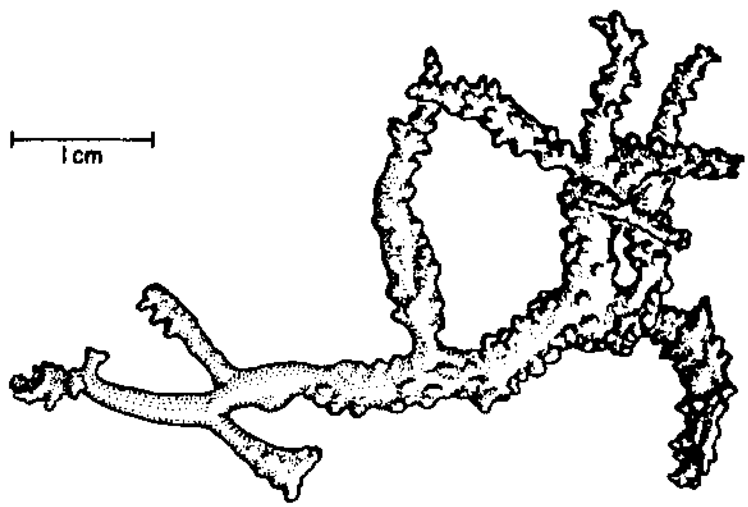


Figure 3. A common form of *Eucheuma cottonii*. The branches are irregularly branched. Their diameter is often irregular or flattened, or sometimes conspicuously swollen above. The proliferations arise as protuberances near the branch apices; they are hemispherical to cylindrical, and do not appear at regularly predictable places. They may grow out as branches; often they are conspicuously marginal on flattened thalli.

There are exceptions to the above characterizations, but these involve a very small number of the species in the genus for which there are at least 42 specific epithets. These exceptional species of *Eucheuma* are not usually found in any quantity. It could be that more than one genus should be recognized. At present *Eucheuma* is usually recognized on the basis of the anatomy of the cystocarps, the seriate tetraspores and, in addition to the form of the individual species, by being both coarse and about the only non-calcareous tropical seaweed the branches of which are so rigid when alive they will snap in two when bent back on themselves.

PRODUCTION ECOLOGY

Commercial crops of *Eucheuma* are harvested in water rarely more than a half meter deep at low tide. Some species have been found in water more than 25 fathoms deep. Some, *e.g., E. serra,* seem to be principally intertidal. Indeed, most of the Southeast Asian crop appears between the lowest level to which the tide descends and the level at which the longest single exposure to air is not much more than one hour.

Limestone-rich substrata where there is little coelenterate coral seem to favor both the sprawling *E. spinosum* and the erect *E. striatum.* The prostrate *E. "cottonii"* types are usually draped over solid limestone. However, they may be on rocks nearly buried in mud, as at Tandjung Pasir Laba, Singapore. *E. arnoldii* lives in close association with finger coral which it simulates in form and color.

Among the other observed field relationships are some concerning form or occurrence. For example, at higher intertidal levels the "cottonii" types become heads or crusts with few discrete branches. These thalli may grow to weigh a few kilograms. As deeper water is reached, the species tend to be more discretely branched, more slender, and – *e.g.,* in the case of *E. striatum* at Quiniluban in the Northern Sulu Sea – the thalli may be (Kraft, 1969a) more than a meter tall, growing on bottoms that are nearly two meters deep at low-tide level. In shallow water one thallus of *E. striatum* may bear olive green, vinaceous purple, and rather tawny branches, of similar form and size, all at the same time.

The wild crop of *Eucheuma* will vary between 50 and 1500 grams per square meter in areas attractive to wild-crop harvesting. Of course, most of the sites visited in the tropics will have no *Eucheuma* at all. In exceptional places a large outrigger canoe has been loaded with a few hundred kilograms of *Eucheuma* in "an hour" at one place. Panagatan Cay in the Northern Sulu Sea yielded about 25 dry-weight tons of *Eucheuma spinosum* from an area of much less than one square kilometer the first time it was harvested. This indicates a live weight of several kilograms per square meter in this nearly pure stand.

One learns to improve his likelihood of finding new *Eucheuma* communities. However, thus far the criteria for finding *Eucheuma* crops are largely subjective feelings developed from experience. On the other hand, in watching the bottom while being towed behind a boat (a practice referred to as "trolling for sharks"), one learns that *E. striatum* is often localized on reef areas just on the deep-water side of the reef-flat coelenterate corals and in the pathways the water follows. No measurements have been made that would, *e.g.,* allow us to judge whether the causal factors here are inherent, with such an area being the pathway water takes in moving onto or off of the reef. Perhaps the sharp variability in temperature with tidal change at such sites is a factor; in such habitats 24-hour temperature variations of over four degrees Celsius have been measured.

Eucheuma spinosum, on the other hand, is characteristic of habitats where there is a constant passing of water from the sea. It would seem there is likely to be little daily temperature variation in such a habitat. The substratum is usually rich in dead finger-corals generally fragmented and often covered with prostrate algae. The most dense stands have been found in slight depressions in such substrata but usually not in water deeper than one meter at the time of the lowest tides.

Most *Eucheuma* species are attached by small basal discs a very few millimeters in diameter. These are nearly always torn from the substratum when the harvester picks the thallus. *Eucheuma speciosum* is unique for the genus in having a large disc-like or crustose base a few centimeters in diameter from which commonly as many as 25 to 50 erect branches arise. In this case at least, the natural harvesting by storm action usually removes only the erect branches. Likewise, in the case of *Chondrus crispus* and some other commercial seaweeds, new fronds spring forth from a basal crust. In these latter cases the harvesting practices often improve the beds by destroying the weed species while the crustose bases of the commercial species such as *Chondrus* may expand so as to come to form nearly a 100 per cent cover.

Early experience with an intensification of wild-crop procurement about 1966 in the Philippines indicated (Figure 4) an area may not remain productive long without effective measures to prevent its decline. The result of such destructive harvesting of *Eucheuma* in the Ryukyus and Southeast Asia has led to reduction of the harvest at some sites below the level of profitability. Given a year or two of non-harvesting, some beds have again become profitable.

Very few concessionaires or harvesters have been able to control harvesting so that their *Eucheuma* resources have continued to be profitable over the years. In Malay areas anything on the reef is free to the finder. Thus, introducing the logical practice of taking some and leaving some is ineffective as a conservation measure. The places with sustained yields (Table 2) over the years are those with some natural control of the harvests. One such is Panagatan, an atoll in the Philippines. At this site weather usually permits harvesting only during November and again in April and May. In November at this site there are a few harvesters, but the weather is too wet for drying to be feasible. In April and May and until the typhoon season, which usually begins in June, there may be a hundred harvesters and the weather is good for drying. Though the seas are calm from January until June, the early part of this period is wet. Later, until November, the water is too rough. Unfortunately most harvest sites are not so protected by seasonal weather.

TABLE 2. ESTIMATED ANNUAL HARVEST VALUES FOR PANAGATAN ATOLL IN THE NORTHERN SULU SEA

Year	Harvest, in tons dry weight	
	Estimator A	Estimator B
1966	25	25
1967	—	35
1968	97	40
1969[a]	111	90
1970	35	100
1971[b]	37	47

[a]In 1969 planting was begun.
[b]Unseasonal weather during 1971 reduced the opportunities to harvest during that year.

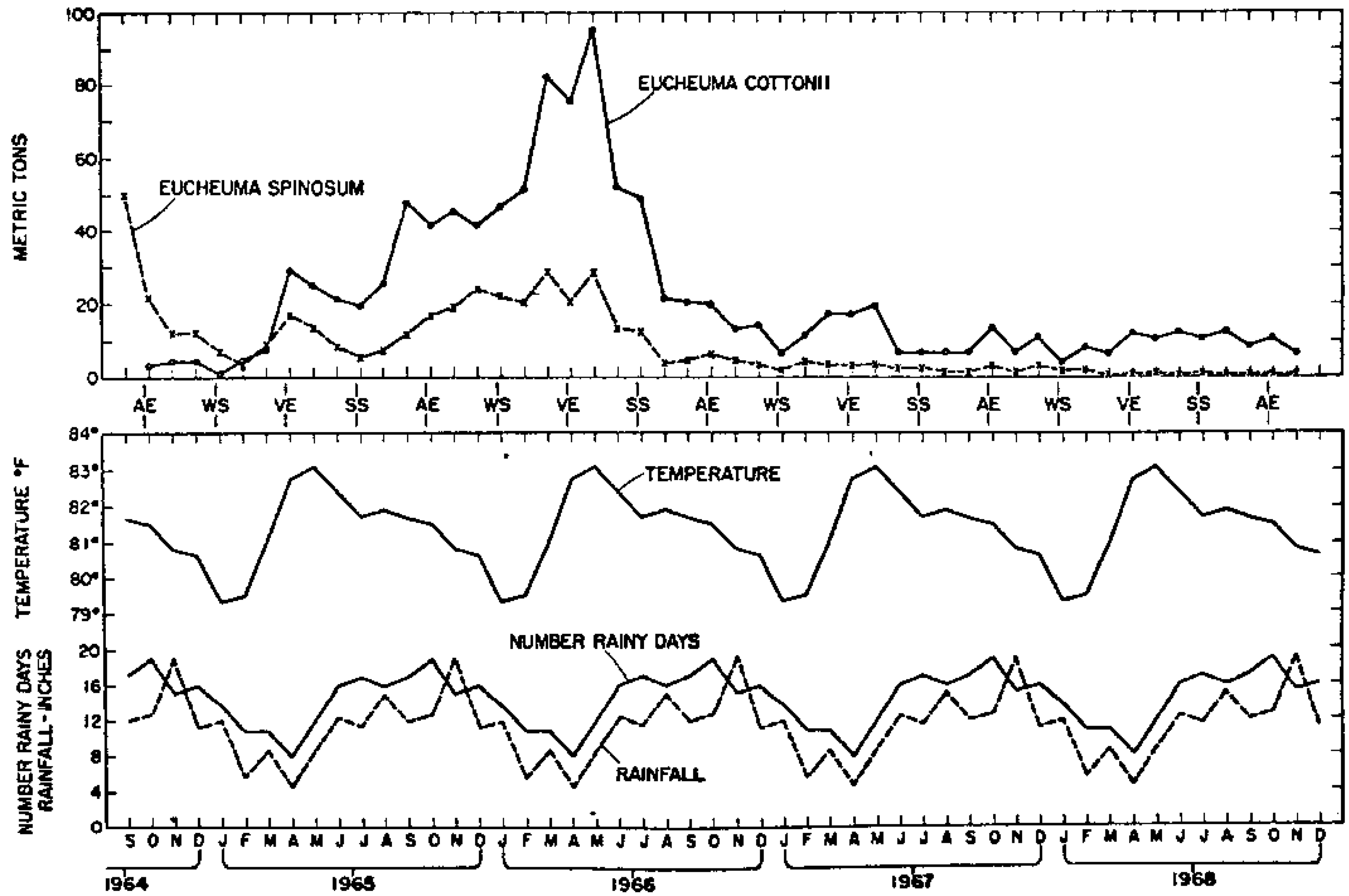


Figure 4. The shipments of dried *Eucheuma* from one company in the Visayan area of the Philippines (upper portion) and related climatic data (lower portion). It is thought that these amounts were over 90% of the *Eucheuma* exported from the Philippines during the 1964-1966 period. The values have been serially averaged in groups of three. The sun's position in reference to the winter (WS) and summer (SS) solstices and vernal (VE) and autumnal (AE) equinoxes is given between the separated crop and climatic plots.

The exporting of production from the harvesting of wild crops is (Figure 5) certainly seasonal. Searches for causes of such seasonality (Figures 4 & 5) have been fruitless when sought objectively in the field. Random sampling of 16 sites in the most southern Philippines over a period of 36 months has failed to reveal seasonality of the crop in its natural communities. No seasonal changes in growth rate were found when wild thalli were brought in at monthly intervals and reared by a uniform method at a field laboratory.

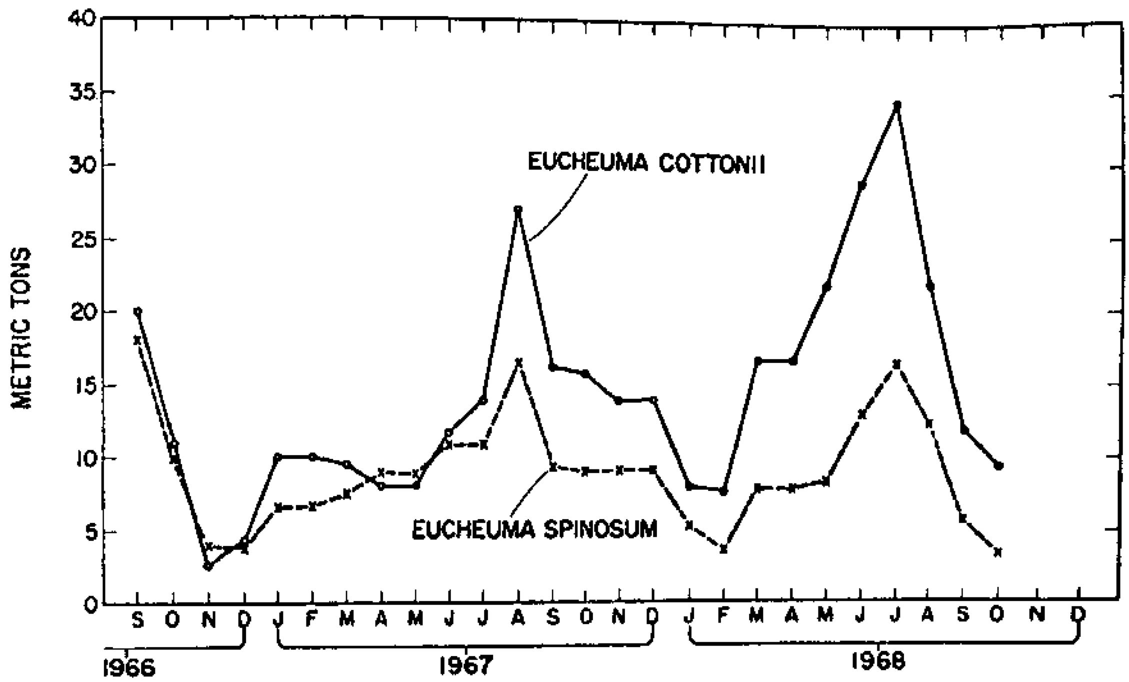


Figure 5. The shipments of dried *Eucheuma* from one company in the Northern Philippines, representing about 80 per cent of the nation's exports of this product for the period shown. The values have been serially averaged in groups of three.

However, the reported seasonality remains to be explained. The live seaweed is presumed to be harvested at least two months before being shipped. It has been shown (Doty, 1971a) that environmental factors at least one or two months before a harvest are influential in determining the size of other tropical seaweed crops. Figure 4 includes climatic data for the Visayan and Sulu areas, from which most of the Philippine crop comes. The warmest period is in April and May immediately following the clearest skies (fewest rainy days and least rain) and the brightening of sunlight due to the higher noon sun angles of spring. This occurs three months before the shipping peak, and could represent the time when there is a maximum combination of harvesting and crop available. The minimum in crop shipped appears in the northern winter months, following in the same way the minima in the same climatic events. There are other seasonal events that play a role, such as rice planting and harvesting and religious periods. While unappraised, their effects would appear to have some significance.

Figure 6. Typical *Eucheuma* Farming Scenes

A. An atoll whose reef and lagoon are largely open to the sea. Such sites are considered to be potentially good for *Eucheuma spinosum* farms.

B. Three thalli of *Eucheuma spinosum* growing in nature. The whorled spines at regular intervals show particularly well in the center of this illustration. The water is less than a meter deep at low tide. (Photo courtesy of Mr. William Anderson, of Marine Colloids, Inc.)

C. A family's one-day collection of *Eucheuma spinosum* being dried at the roadside along the southernmost shore of Celebes (Sulawesi), Indonesia. About three kg dry weight is involved here, and 25 kg wet weight.

D. Part of a *Eucheuma* farm in a lagoon. The stakes, 5 meters apart, support the wires to which net units, showing in the foreground, are attached. Each net unit is 2.5 meters wide and 5 meters long.

E. An atoll in the Sulu Archipelago displaying the proper depth and a configuration that provides protection from storms, yet the water movement is ample for a *Eucheuma striatum* farm in the near part. Note the considerable body of water beyond the narrow place in the lagoon which would ensure considerable water movement over the near part with each tidal exchange.

F. The natural habitat of *Eucheuma striatum* on the lagoonward edge of a reef in the Philippines. A greenish thallus shows to the left and a brownish thallus shows to the right near the borders of the illustration. The largest *Eucheuma* branches are about 1 cm in diameter. The two *Eucheuma* thalli have been pulled up from their natural places in small depressions and dropped back at the same site so they can be seen. Note that *Enhalus acoroides* (Linnaeus *f.*) Royle and *Sargassum polycystum* C. Agardh often occur in just slightly deeper water, as shown.

G. Recently planted *Eucheuma striatum* showing the polyethylene ties that secure the "seed" to the net units. Each seed thallus shown weighs, probably, between 50 and 100 grams.

H. *Eucheuma striatum* about 1.5 months old and the net units on which it is suspended. The farm foreman, Mr. Baltapa Anjail, is at the left. The thalli being held up probably weigh between 200 and 400 grams.

RESEARCH AND DEVELOPMENT

Since a concession system exists for marine products on reef areas in the Philippines, developing farming of *Eucheuma* on concessions has seemed the efficient way to offset seasonality and the effects of harvesting. The benefits of farming would include production of a crop of predictable size; within limits, this is at least as important as producing a less expensive crop. Research and development toward this end were thus begun as a cooperative effort between the University of Hawaii, Marine Colloids (Philippines) Inc., and the Philippine Fisheries Commission. A laboratory was provided by the Commission at Zamboanga, along with several technicians. Others were employed as needed. Mr. Ernest Loveland served from 1967 to 1970 as superintendent of the operations at Zamboanga. The principal financial support initially was provided with U.S. Atomic Energy Commission seed money and by Marine Colloids, Inc., Rockland, Maine, and later by the U.S. Sea Grant Program.

Experiments were carried out at Zamboanga using *Eucheuma striatum* and *E. spinosum* to develop information of agronomic value. These involved measuring the growth rates of *Eucheuma* thalli as a function of the variation of different environmental variables. At the same time, different possible physical methodologies were evaluated for possible use in farming practice.

Experiments revealed that the brighter the light, the faster *Eucheuma* grows. Any desiccation appears detrimental. The variations in salinity and seasonal temperature normally anticipated in fully marine Philippine situations seem not to be significant. *Eucheuma* survives well out of water if kept wet, shaded, and at or near sea temperature. Thus it can be moved from place to place. For experimental purposes, 5-kilogram lots have been taken to Hawaii successfully from as far south in the Philippines as the Sulu Archipelago.

The *Eucheuma* planting material, or "seed", consists of pieces of thalli. Variously the seed has been broadcast on bottoms that appeared to be favorable; lashed to stones on the bottom; semi-confined in open baskets; tied to stakes, nets, and lines at different constant distances from the bottom; or suspended a constant distance below the surface on floating systems. These last two methods are referred to, respectively, as **constant-level** and **constant-depth** plantings or farms.

Most plantings on bottoms have failed ultimately due to grazing, largely by sea urchins and siganid fishes. Likewise, other types of planting are often completely destroyed by grazing. In Palau this would seem to be an overriding problem. Failures otherwise have largely been due to storm damage or socio-political problems.

Successful *Eucheuma* farming has resulted from the Philippine pilot experiences. It embodies methods designed to achieve optimal long-term growth and mass-production efficiencies, and to remain within the material as well as the manipulatory and managerial skill levels available. Through installation of a series of demonstration units in the Philippines and Micronesia, largely by Mr. Robert DeWreede, the introduction of this farming method was sought. However, it was soon realized that the socio-political characteristics of Southeast Asia and the Central Pacific would prevent rapid development of indigenous farm production. Thus, pilot farms for *Eucheuma striatum* were established on a wholly owned basis in the Northern Sulu Sea and in the Sulu Archipelago. In the Sulu Archipelago (see Figure 6) where there are rarely storms, these farms have produced well.

Growth rates of *Eucheuma*, especially on the near-surface constant-depth pilot farms, are (Doty, 1971b) usually slow the first week. Then they hit a maximum for two or three weeks, followed by a steady decline for six to ten weeks, until a plateau is reached or death overcomes the thalli. The organic-nitrogen content of thalli grown just under the surface declines in a parallel fashion. The seed materials coming from natural beds on the sea bottom have developed in less-bright light than that to which they are exposed just under the surface. The change in dry-weight-to-nitrogen ratio obtaining in such surface-grown thalli may be similar to that leading to flowering and death of annual plants when forced by bright light. To maintain high growth rates indefinitely, we assume a balance is necessary between light intensity, water quality, and water motion.

In practice now, constant-level plantings are used. They are positioned just below low-tide level. This level has been chosen as a compromise on light intensity and because it is the level at which one often finds the highest standing crops of *Eucheuma spinosum* and *E. striatum* in nature. Experiments have shown that where such plantings are at least a half meter above the bottom, they survive the surface chop of local storms, and much of the grazing that often destroys bottom plantings is avoided. In the southern Philippines the principal grazer on such off-the-bottom plantings is a small *Trypneustes*-like sea urchin which can be readily removed.

The constant level is attained by lashing the seed *Eucheuma* at the mesh intersections of special nets. The nets are held in place on support wires extending between braced mangrove posts. This adaptation of the common Japanese system for production of the seaweed *Porphyra* was first tried by Mr. William Anderson (Marine Colloids Inc., Rockland, Maine) in the Northern Sulu Sea. Such a support system, using nylon monofilament for the nets and 14-gauge galvanized wire, is expected to last up to three years with maintenance.

The nets and net-support system now conform to a set of specifications developed to enable the farmer to contract or pay for their construction on a piece-work basis. Each net is constructed of nylon monofilament, 80-pound-test for the meshwork, 110-pound for the border. The meshwork used at present is square, 25 centimeters on a side, and runs diagonally within the 2.5-by-5-meter outline. Thus, there are 127 planting sites per net. Except for the dimensions and the monofilament, they are not unlike hibi – the nets used for cultivating *Porphyra*. In fact, hibi have been used for *Eucheuma* experimentally.

Using fist-sized 50- to 150-gram seed pieces, about 10 kilos of *Eucheuma* is required to plant one net. In practice, the seed is lashed to a net by tying a 1-cm by 30-cm strap of soft polyethylene material around it, so the weed can neither fall out nor move from its position at an intersection of the monofilament meshwork. These "ties" are loose enough that there is little restriction of water movement around the seed segments. All sorts of algae grow on these ties, so they are accepted as being nontoxic.

The support system now in use is developed in modules to hold 800 nets. The support wires run parallel to one another, 5 meters apart; it is recommended that they follow reef contours at right angles to tidal current flow, rather than being grouped more efficiently in respect to space and material in a square 50 meters on a side. Four such 2500-square-meter modules make a one-hectare farm. This size and arrangement have been developed in the light of their being manageable by one enterprising farm family. The plan also would seem to lend itself to economical plantation management.

COSTS AND RETURNS

The initial cost figures for installing and maintaining a constant-level one-hectare farm in the Northern Sulu Sea region (Table 3) have been only roughly developed thus far. The initial U.S. $1505 cost has been calculated to be amortizable with allowances for 6 per cent interest and depreciation to $526 per year. There has been no opportunity for one person to gather all the cost figures nor has there been, as yet, an opportunity either to repeat observations at one place or to determine the reliability of the estimated depreciation rates.

TABLE 3. MATERIAL LIST FOR A ONE-HECTARE FARM AND ITS COSTS AT ILIN, MINDORO OCCIDENTALE, PHILIPPINES

Item	Cost, in pesos			
	Initial Cost	Depreciation	Interest	Fixed Cost[a]
Module support system	₱ 947.00	₱ 947.00	₱ 22.41	₱ 975.41
Laborers' quarters	1000.00	200.00	30.00	230.00
Farm manager's quarters	700.00	140.00	21.00	161.00
Drying house	446.50	89.30	13.40	102.00
Boat	2000.00	400.00	60.00	460.00
Net units	3664.00	916.00	109.92	1025.92
Miscellaneous equipment	271.92	195.92	8.14	203.60
Totals	₱ 9029.42[b]	₱ 2888.22	₱ 264.87	₱ 3157.93[c]

[a] "Fixed costs" are adjusted to a "per year" basis and are those estimated or experienced in pesos at a time when the U.S. dollar was worth 6 pesos. Maintenance is included in these figures as needed to achieve the predicted life expectancies, but not that in Table 4 required to keep the farm operating.

[b] U.S. $1505.00

[c] U.S. $526.00

The operating or variable costs per year (Table 4) run to $2600 in U.S. dollars. Such items as "seed" costs are very unpredictable and those at some sites, *e.g.*, Sibaton and Tapaan Islands, are nil. Shipping costs are also extremely variable, but fixed for a given location – in this case, Ilin in the

Northern Sulu Sea. Labor itself is highly variable. In the Philippines the minimum wage, by law, for industrial workers is 6 pesos and for agricultural laborers 2 pesos per day. However, the degree to which subsistence is provided, the way time at work is calculated, and local customs prevent any hard figure being obtained.

TABLE 4. THE OPERATING COSTS[a] OF A ONE-HECTARE FARM FOR ONE YEAR

Item	Cost, in pesos	Man-hours
Labor:		
Selecting & obtaining seed	₱ 1574.80	b
Planting	1016.00	2,032
Weeding & module maintenance	6240.00	16,640
Harvesting	1900.00	760
Drying, washing, & redrying	320.80	128
Packaging & baling	532.80	240
Shipping	2930.40	
Materials:		
Plastic ties (tie-ties)	1056.64	
Totals	₱ 15,571.44[c]	19,800

[a]These values are only partially as experienced at Ilin, Mindoro Occidentale, Philippines. In part they have had to be estimated from operations elsewhere.

[b]Varies wildly.

[c]U.S. $2600.00.

The overhead costs of $3284 (Table 5) seem excessively high. At the most advanced farm, at Tapaan in the Sulu Archipelago, these costs have been far lower for several reasons. First the manager, Mr. Baltapa Anjail, served as the foreman on the job initially, with little outside supervision. Also, the methods have been more stable during operation of this farm and less travel, per diem, and communication have been needed.

TABLE 5. OVERHEAD COSTS[a] FOR A ONE-HECTARE FARM FOR ONE YEAR

Item	Cost, in pesos
Farm manager's salary	₱ 3600.00
Farm foreman's salary	2160.00
Miscellaneous boat rentals	480.00
Plane fares, transportation	2591.88
Per diem, allowances	6900.00
Communications	1216.80
Freight, air cargo, handling charges	840.00
Representation expenses	462.00
General repairs to boat	131.00
General repairs to nipa houses	77.38
Fuel and oil for boat	1245.00
Totals	₱ 19,704.06[b]

[a]The values given were projected from the totals paid out for these items during a four-month period.

[b]U.S. $3284.00.

Returns from the farms are as yet poorly known. They have been in operation for only about one year. Farms put into operation earlier, *e.g.*, in Micronesia and, in the Philippines, at Cucarayan Inlet, Sibaton, Caluya, and Punta Arena, were abandoned for one reason or another; thus not much in the way of a crop was recorded from them. Most often the crop on the abandoned modules was grazed away, stolen, lost to storms, or used as seed for another type of planting elsewhere, and no final measurements of its quantity were made.

Growth rates on the farms have averaged 1.5 to 5.5 per cent per day. In the case of the most advanced farm at Tapaan, such persisted through the first harvest period and an average of 2.3 per cent was maintained through the second. The first partial harvest of one module at Tapaan weighed some 5891 kilograms; assuming it dried 8 to 1, this is equivalent to 736 kilograms of shipable dry weed. About 50 grams of the live weight of each thallus harvested was left as seed. A second harvest of one module produced 7921 and another, 10,800 kilograms, with perhaps 100 grams being left as seed in each case.

It is calculated that the first harvest of one module could have yielded between one and two metric tons of dry weed per hectare more, had the harvesting procedure been different. The second harvest yielded an average of about 6 tons of dry (unwashed) weed per hectare. Operating procedures have been revised; hopefully, such a harvest can be achieved every two months. If six such harvests can be made per year, possibly 36 tons per hectare per year will be produced. For this uniform, high-class, clean *Eucheuma* a price of over $250[1] per ton F.O.B. Manila seems reasonable. On this basis, even with the excessive current overhead, or two-thirds the realized production rate, the list of costs and returns in Table 6 indicates profitability.

TABLE 6. ANNUAL PER–HECTARE ILIN AND TAPAAN COSTS AND RETURNS[a]

Budget Item	Costs and Returns, in U.S. $		
	Ilin Cost	Tapaan Cost	Returns
Farm installation	$ 526	$1047	
Farm operation	2600	1648	
Overhead	3484	1874	
Crop value			$9000
Total	$6610	$4569	$9000

[a]Conservatively projected at 30 tons for one year.

The management plan effected appears (*fide* Mr. Henry Parker of Marine Colloids, Inc.) to be producing but little over 10 tons of dry weed per hectare at Tapaan, instead of the 30-odd tons that seem feasible. Elsewhere in the Philippines at least one private farm is producing at about the 30-ton level. The importance of continuous operation and intense maintenance, as in truck gardening, would seem to be critical and thus industry, initiative, and management on the part of the farm operator are critical.

Growing *Eucheuma* would be very profitable for people who would do it with no supervision from outside. This would reduce the costs by one-half. It should be noted that the foreman's wage is also included at Tapaan, but he serves as a working foreman there. Ideally the foreman would be the farmer himself and as such, his wages should perhaps not be subtracted from his profit.

From the industrialist's point of view the ability to obtain a higher quality crop that is free of foreign matter doubles the value of the weed. Likewise it is desirable that the unpredictable (Figure 4) and seasonal (Figure 5) variation in the crop, and the small crops of "bad years" be offset. Farming would be justified if these ends were met, although the cost might not compete alone, or might be the same as for wild weed.

---

[1]As much as $300, and even $400 was paid for small lots of wild harvest *Eucheuma* in the 1970-71 period.

Control of the crop will lead to improved varieties. For example, it has been observed that under farm conditions, some thalli grow twice as fast as others. According to Mr. Vicente Alvarez, under farm conditions thalli have been measured (*e.g.*, Figure 7) as growing from 50 grams to near 5 kilograms in three months. Thus, as soon as operations become stable, the use of these as seed is expected to double the yield.

Figure 7. A thallus of *Eucheuma striatum* weighing over 5 kilograms. It was grown on a farm in three months from an initial "seed" that weighed 50 grams.

Some slower growth observed in the centers of modules may be offset by fertilizer. In fact, it is possible that with the right fertilizer concentrations, productivity can be enhanced by elevating the crop to brighter light conditions or, on the other hand, success can be had under conditions of lower water motion. In this latter situation less maintenance would be needed on the supporting structures and storm loss would be less. Finally, with complete control of growth and the growing areas, genetic improvement and capital-intensive methods can be expected to produce still more carrageenan, more cheaply.

In conclusion, let us consider the probable useful dry matter and monetary returns from a *Eucheuma* farm in comparison with other productivities. The 30-odd tons of dry *Eucheuma* that can probably be produced per hectare per year is (Westlake, 1963) in line with other estimates of dry-matter productivity in tropical shallow marine waters. Such *Eucheuma* will be worth significantly more than $250 per ton. In Mauritius, sugar is profitable at 3.5 tons per hectare per year. In

Hawaii, the mean productivity[2] during 1970 was 11.23 tons of sugar per hectare per year. After all the care and processing required, it is only worth[3] $187 per ton. Yet, to tropical agriculturists, sugar is considered an attractive crop. It requires good soil and must compete with many other possible uses for the land. *Eucheuma* is a crop of tropical reef flats which are of little use in today's economics, and it provides an income to a group of people not otherwise aided by the current development programs. On a given area, *Eucheuma* farming can provide more than three times the dollar return that sugar brings.

---

[2]Value from Hawaii Sugar Planter's Association Experiment Station.

[3]U.S. average price for sugar in 1971 was $187.44 and the world price was $99.44 per ton.

LITERATURE CITED

Doty, Maxwell S. 1971a. Antecedent event influence on benthic marine algal standing crops in Hawaii. *J. Exp. Mar. Biol. Ecol.* 6: 161-166.

Doty, Maxwell S. 1971b. Physical factors in the production of tropical benthic marine algae. Pp. 99-121 *in* John D. Costlow (editor), *Fertility of the Sea*, Vol. 1, pages xi + 308. Gordon and Breach Science Publishers, New York.

Hitchens, A. P., and M. C. Leikind. 1939. The introduction of agar-agar into bacteriology. *J. Bacteriology* 37: 485-493.

Kraft, G. T. 1969a. The red algal genus *Eucheuma* in the Philippines. 358 pp. (Master's thesis deposited in University of Hawaii library.)

Kraft, G. T. 1969b. *Eucheuma procrusteanum*, a new red algal species from the Philippines. *Phycologia* 8: 215-219.

Stancioff, Dimitri J., and Norman F. Stanley. 1969. Infrafed and chemical studies on algal polysaccharides. *Proc. Intl. Seaweed Symp.* 6: 595-609.

Westlake, D. R. 1963. Comparisons of plant productivity. *Biological Reviews* 38: 385-425.

Wildman, Robert D. 1971. Those versatile weeds from the sea. *NOAA, the Quarterly Magazine of the Department of Commerce's National Oceanic and Atmospheric Administration* 1(4): 13-17.