Bull. Mar. Sci. Fish., Kochi Univ.
No. 12, pp.51-65, 1992

Eucheuma and *Kappaphycus* : Taxonomy and Cultivation

Gavino C. Trono, Jr.
Marine Science Institute College of Science

University of the Philippines at Quezon City, Philippines

Abstract : The Genera *Eucheuma, Kappaphycus* and *Hypnea* are three important genera of carrageenophytes which are abundant in the Philippines and in the tropical Asia and Western Pacific. The most useful species for the source of kappa carageenan is *K. alvarezii* called *E. "cottonii"* of commerce. *E. denticulatum* called *E. "spinosum"* of commerce is also the most useful species for the sources of iota carrageenan.

The different methods of *Eucheuma* cultivation were tried in the past from very simple bottom culture to the more sophisticated types using some form of a support system, such as the raft method, the fixed off-bottom-(net) method, tubular net method and the fixed off bottom monoline method. Recently the floating method of culture are used in area where water current is weak.

At present *Encheuma* and *kappaphycus* are exported in four form, as dried raw seaweeds, as alkali-treated chip or as a semi-processed powder and as pure carrageenan.

Key words : Taxonomy, Cultivation, *Eucheuma, Kappaphycus Philippines,*

Introduction

The genera *Eucheuma, Kappaphycus* and *Hypnea* are three important genera of carrageenophytes which are abundant in the Philippines and in the tropical Asia and Western Pacific. More recently *Acanthophora spicifera* has been reported to contain *lambda* carrageenan which is not produced by either *Eucheuma, Kappaphycus* or *Hypnea.*

The most important of these carrageenophytes are *Eucheuma* and *Kappaphycus* which are at present the main base of the seaweed industry in the Philippines and Indonesia.

The development of the culture technology for these genera has boosted tremendously production in the Philippines to an estimated 60,000 MT in 1987.

Taxonomy of Philippine *Eucheuma and Kappaphycus*

The genera *Eucheuma* and *Kappaphycus* belong to the Family *Solieriaceae* of the Order Gigartinales. Of the more than two dozen species known in the world, three species of *Eucheuma* and four species of *Kappaphycus* are present in the Philippines. These are *Eucheuma denticulatum* (N.L. Burman) Collins et Hervey *(= E. spinosum) ; E. arnoldii* Weber van-Bosse ; *E. gelatinae* (Esper) J. Agardh ; *Kappaphycus alvarezii* (Doty) Doty nov. comb. *(=E. alvarezii) ; K. striatum* (Schmitz) Doty nov. comb. *(=E. striatum) ; K. procrusteanum* (Kraft) Doty nov. comb. *(=E. procrusteanum) ; K. cottonii* (Weber van-Bosse) Doty nov. comb. *(=E. cottonii). Eucheuma alvarezii* and *E. denticulatum* are the species presently produced through mariculture in the Philippines and Indonesia. *K. alvarezii* and *E. gelatinae* are also cultured in Hainan Island in China and several other Western Pacific Island countries.

The thalli of *Eucheuma* and *Kappaphycus* are very cartilaginous, may be prostrate or erect in habit and consists of cylindrical to compressed branches except in one species whose thallus is a thick and flattened blade *(K. procrusteanum).* Gametophytic and sporophytic thalli have been reported for many species. Fertile female thalli develop distinct cystocarps which appear as mammillate struc-

tures. The male thalli, however, appear to be uncommon.

Key to Philippine species of *Eucheuma* and *Kappaphycus*

1. Thalli prostrate 2
1. Thalli erect 3

2. Thalli segmented, branches compressed with marginal and ventral spines ; axiferous ..... *E. gelatinae*
2. Thalli not segmented ; branches, cylindrical, mottled, fused with each other at certain portions to form crust (erect, branches may be present) ; axiferous ..... *K. cottonii*

3. Thalli may or may not be segmented ; segment(s) of thick, flattened blades .... *K. procrusteanum*
3. Thalli consisting of generally cylindrical branches 4

4. Determinate branchlets in form of whorled simple or decompound spines 5
4. Determinate branchlets coarse, irregularly arranged spines 6

5. Determinate branchlets distinctly arranged as simple whorls of spines at the distal portions of the branches, axiferous ..... *E. denticulatum* = *(E. spinosum)*
5. Determinate branchlets arranged as compound discrete whorls of branched spines or covering the entire branch completely ; anaxiferous ..... *E. arnoldii*

6. Main axes not per-current, roughened by presence of secondary coarse determinate spinose branchlets ; branching irregular or dichotomous the former with close angular axils : branches uniform in diameter but abruptly tapred to the tip ; axiferous, medullary core of axial hyhae present in branches less than 5 mm in diameter ..... *K. striatum*
6. Main axis percurrent generally (or may be obscured) smooth and cylindrical with only indeterminate branches interrupting ; branching open with generally round axils ; branches larger at their bases (inflated) and tapering towards their apices ; axiferous, medullary core of axial hyphae persistent at least 10 cm below the tip of any indeterminate branch less than 5 mm in diameter ..... *K. alvarezii*

1. *Kappaphycus procrusteanum* (Kraft) Doty nov. comb (Fig. 1)

= *Eucheuma procrusteanum* Kraft

The description of this species is based on a single incomplete material collected by Kraft from Semirara Is., south of Mindoro Island.

The thallus is thick, broadly compressed or flattened, hard when dry, leathery when resoaked. It is deeply incised and divided into broad thick, blades or segments having entire to slightly dentate margins. A cross section of the thallus shows large rounded medullary cells, without rhizoids of hyphae.

Economic potential : Possible source of kappa carrageenan

2. *Eucheuma arnoldii* Weber-van Bosse (Figs. 2-3).

This *Eucheuma* mimics the habit of the hard and soft corals with which it grows closely associated. The plants form thick erect, clumps and consist of many clavate branches with slightly acute

apices. The branches are densely covered with simple or compound spinose tubercles arranged regularly into seemingly distinct "nodes" and "internodes", often forming verticils which often overlap that the verticillate arrangement is sometimes obscured, especially at the distal portion of the branches. Cross section of a branch reveals a medulla composed of large rounded cells interspersed with smaller cells. No central core of rhizoids is evident. Cortical cells are very small, ovoid or elongated.

E. arnoldii is one of the minor species of *Eucheuma* that has quite a limited distribution. This is found in shallow subtidal reef areas where the current is swift and the water free from silt. It grows on living tines of corals, lime stones or basalt substrates in close association with living hard and soft corals. This species is easily mistaken for a live coral because of its close resemblance to the coral *Acropora.*

Economic potentials : Human food ; source of iota carrageenan.

3. *Kappaphycus cottonii* (Weber-van Bosse) Doty = *E. cottonii* Weber van Bosse (Fig. 4)

Thalli form large, crust-like clumps strongly attached to solid substrates by hapters arising from the undersurface of the thallus. Plants may also consist of somewhat compressed irregular branches, attached to one another by undefined haptera forming slightly amorphous fronds. Both forms have rough warty surfaces because of numerous short, blunt and stubby spines or tubercles. Cross section of the thallus shows a medulla composed of large rounded cells without a central core of rhizoidal cells.

This species grows on rocky or solid corally substrates near the reef edge exposed to very strong wave action.

Economic potentials : Human food ; source of kappa carrageenan.

4. *Eucheuma gelatinae* (Esper) J. Agardh (Fig. 5)

Thallus is prostrate, attached to rocky substrates by well-developed haptera arising from the undersurface of the branches. The branches are compressed, branching irregular with numerous spinose processes limited to the margin and ventral surface. The medulla has thick walled rhizoidal cells, compact at the center.

Like *E. arnoldii,* this species has a limited distribution but unlike the latter, it may form a dominant component of the algal community. It grows on rocky coralline substrates a few meters from the reef edge where it is exposed to strong wave action and turbulence.

Economic potentials : human food ; source of *kappa, beta* and *gamma* carrageenan.

5. *Eucheuma denticulatum* (Burman) Collins et Hervey (Fig. 6)

= *E. spinosum* (Linnaeus) J. Agardh

= *E. "spinosum"* of commerce

Thallus consists of many terete branches, tapering to acute tips. These are usually densely covered with 1-8 mm long spinose determinate branchlets arranged in whorls, forming distinct "nodes" and "internodes" especially at the terminal portion of the branches. Cross section of a branch reveals a dense core of thick- walled and very small rhizoidal cells at the center of the medulla.

Although this species is not as widely distributed as *K. alvarezii* and *K. cottonii,* it may form a dominant component of the algal community. It thrives very well on coarse sandy-corally to rocky substrates, in areas constantly exposed to moderate to strong water currents.

This species is commercially farmed in Northern Bohol and other areas and forms a part of Philippines seaweed exports. It is the main raw material for the manufacture of iota carrageenan.

Economic potentials : human food ; source of *iota* carrageenan ; controls heavy metal pollution (Pb, Cd).

6. *Kappaphycus alvarezii* (Doty) Doty nov. comb (Fig. 7)

= *Eucheuma alvarezii* Doty
= *E. "cottonii"* of commerce

This species is variable in habit. It may be tall and loosely branched with few blunt or pointed determinate branchlets, or it may form the *"spinosum"* type where thallus may be densely branched and covered with coarse spinose branchlets. These, however, are not arranged in whorls so as to form distinct "nodes" and "internodes" as in *E. denticulatum.* In cross section, the medulla consists of large rounded cells interspersed with very small, thick-walled cells.

This is one of the common and fast growing farmed species of *Kappaphycus.* It is found just below the 0 tide line to the upper subtidal portion of reef areas on sandy-corally to rocky substrate where water movement is slow to moderate.

This species forms the bulk (80%) of the Philippine seaweed exports. It is commercially farmed in Tawi- Tawi, Northern Bohol, Palawan and other areas in the Philippines. It is the raw material for the manufacture of kappa carrageenan.

Economic potentials : human food ; source of kappa carrageenan ; with minerals - Ca, K, Mg, Na, Cu, Fe, Mn ; controls heavy metal pollution (Pb, Cd).

7. *Kappaphycus striatum* (Schmitz) Doty nov . comb. (Fig. 8)

= *Eucheuma striatum* Schmitz

Thallus erect or decumbent ; the axis not percurrent, branches roughened by the presence of spinose processes or determinate branchlets. Two forms are present, the elkhorn type is erect and irregularly branched the branch axil acute, very variable in morphology. The second form generally form thick dense decumbent clump with typical dichotomous branching, the branches roughened by short processes. Both forms are characterized by the presence of axial hyphae in the branches not more than 5 mm in diameter.

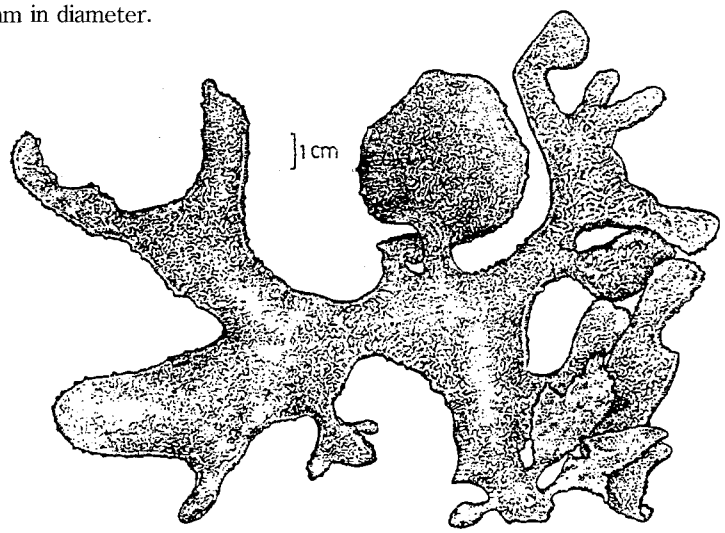


Fig. 1. *Kappaphycus procrusteanum,* habit (Trono, 1986).

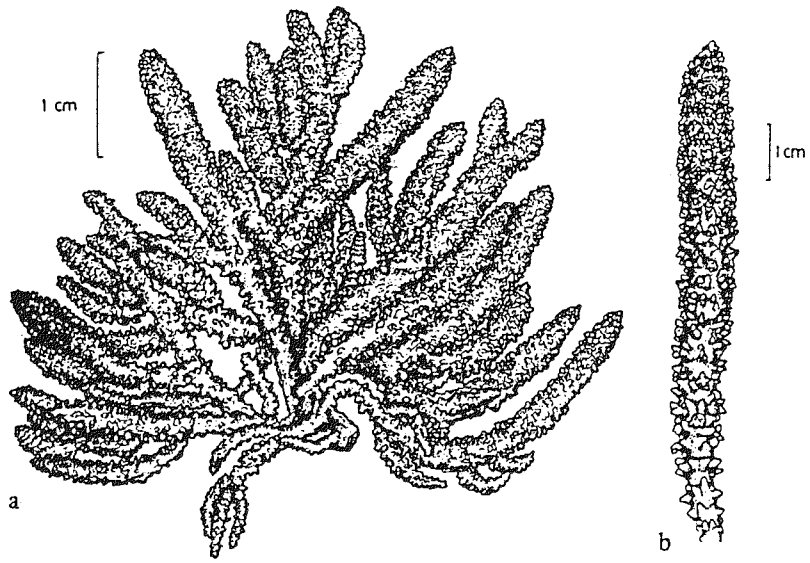


Fig. 2. *Kappaphycus arnoldii,* habitat and portion of a branch (Trono, 1986).

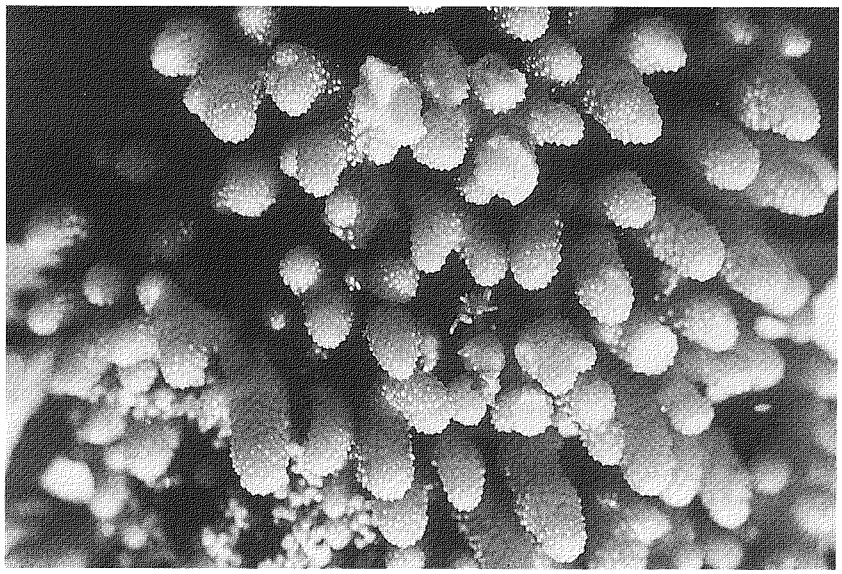


Fig. 3. *Kappaphycus arnoldii,* top view. (Trono and Ganzon-Fortes, 1988).

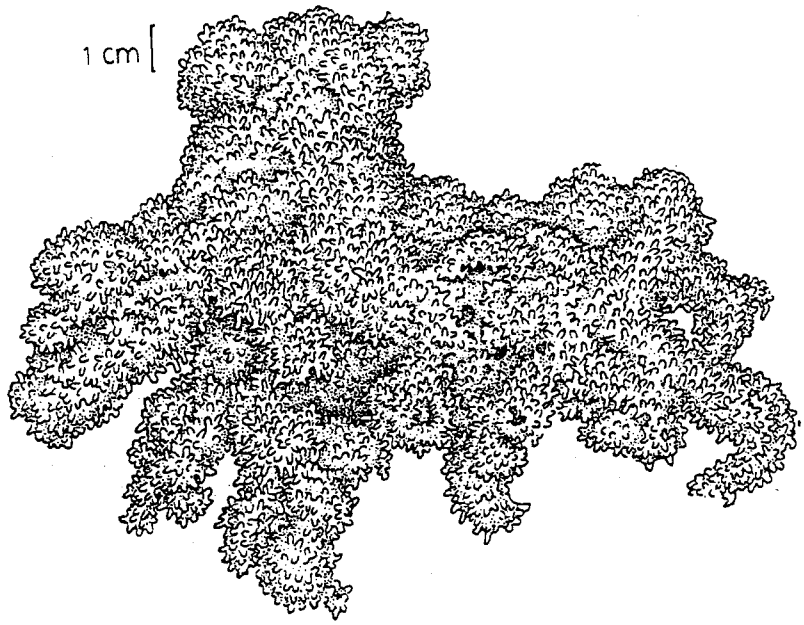


Fig. 4. *Kappaphycus cottonii,* habit of subtidal plant(Trono, 1986).

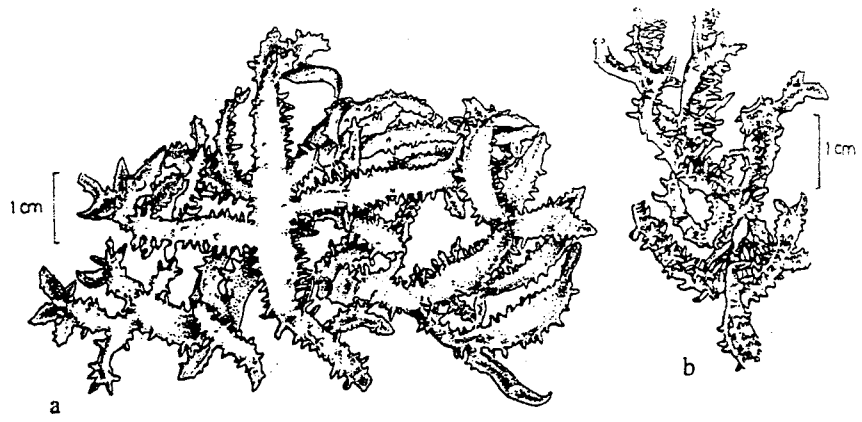


Fig. 5. *Eucheuma gelatinae,* a) habit showing dorsal surface of thallus, b) portion branch showing ventral surface of thallus (Trono, 1986).

E. denticulatum (green)

E. denticulatum (brown)

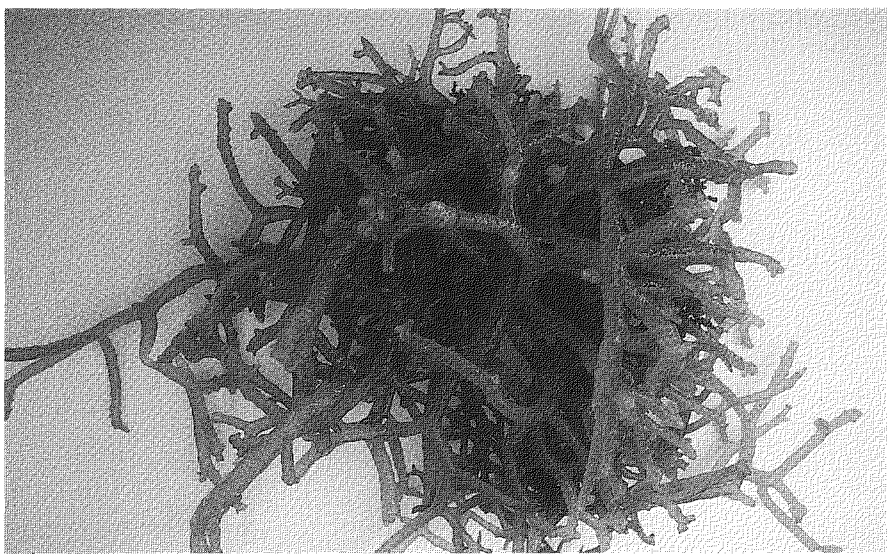
Fig. 6. *Eucheuma denticulatum,* habit of the green and brown forms.

K. alvarezii (brown)

K. alvarezii (green)

Fig. 7. *Kappaphycus alvarezii,* habits of the brown and green forms.

K. striatum (erect form.)



K. striatum (decumbent form)

Fig. 8. *Kappaphycus striatum,* habits of erect and decumbent forms.

CULTIVATION OF *EUCHEUMA* AND *KAPPAPHYCUS*

Methods of Cultivation

The farming of *Eucheuma* and *Kappaphycus* had undergone changes in two major areas, that is in culture techniques and in its organization and management. Different methods of cultivation were tried in the past from the very simple **bottom culture** to the more sophisticated types using some form of a support system, such as the **raft method**, the **fixed off-bottom (net) method,** the **tubular net method** and the **fixed off bottom monoline method.** The change in the organization and management was a shift from the highly organized **"hacienda-type"** or company farms to individual family farms and/or cooperatives.

In the bottom culture cuttings of *Eucheuma* are attached to pieces of corals and arranged on the bottom into plots of uniform sizes. While this method is easy and cheap to use, it is not very productive. The plants are easily attacked by benthic grazers or are easily dislodged or washed out when the area is affected by waves.

In the original **raft method,** a pair of 2.5 by 5 m monofilament nets with mesh size of approximately 30 cm are attached and stretched to a 6 x 6 m bamboo raft. Cuttings of 50 to 100 g are tied to the intersections of the meshes. The rafts are anchored to the bottom. Approximately 250 to 300 plants can be planted on such a raft.

In the **tubular net method** the planting material is placed on a strip of monofilament netting (2 cm mesh, 12-15 cm wide and one to two meters long) mounted on a seeding board. The edges of the netting are laced with a nylon braided string to form a tube with the cuttings inside and the ends of the tube are closed by tying these with the nylon string which also serve as a support line. The seeded tubes are then attached either to a raft or to wooden stakes. Harvesting is done by pruning the branches of the plants outside the net tubing. This method has also high material and maintenance costs and is not very productive. It was not adapted in the commercial production.

In the **fixed off-bottom (net) culture method** the monofilament nets (as described above) are stretched horizontally above the bottom and their corners are tied to wooden bipods or tripods which serve as support. Four modules consisting of two hundred nets each form a hectare where approximately 102,000 cuttings can be planted. This method is an intensive type of farming but was later replaced by the fixed-off bottom monoline method presently used in both small family and large company farms. Although productivity of the fixed monofilament nets is relatively high, costs of materials, maintenance and the difficulty in planting and harvesting were the factors which caused the farmers to shift to the simpler, cheaper and easy to maintain monoline method.

1. Site Selection

Any attempt to open new areas for farming should be preceded by careful site selection unless farming of *Eucheuma* / *Kappaphycus* is already being done in the vicinity. Reconnaissance survey of reef areas should be made and potentially good portions of the reef should be identified and subjected to intensive in situ growth rate studies. The following general guidelines are used in the preliminary evaluation of sites. Reefs far from freshwater sources are preferred because *Eucheuma* is a stenohaline marine alga and salinities below 30 ppt may have adverse effects on it. The area should be protected from the destructive effects of wave actions. thus the presence of buffer zones is necessary to minimize these effects.

Areas which are about two to three feet deep with coarse sand to coralline substrate and subject to a moderate water current have been found to support good *Eucheuma* farms. Water movement in general favors the growth of *Eucheuma* by facilitating rapid nutrient absorption. It also prevents extreme fluctuations in other ecological factors (temperature, salinity, pH, dissolved gases, etc.),

which can adversely affect the growth of plants. The firm substrate is essential for the support system and also reflects the existence of good water movement in the area. Portions of the reef characterized by soft substrates, such as fine sand or silt, are generally not good for *Eucheuma* farming. Water depth at low tides is also an important factor because it affects the cost of farming. Areas with a depth of two to three feet at low tide are ideal. Deeper areas are hard to cultivate as the construction of the support system, the planting and harvesting in deeper water will entail higher costs in labor and materials. Reef areas supporting natural stocks of *Eucheuma* are good potential sites.

After a site has been identified, test planting of the desired species is recommended. Test plots consisting of a few monolines planted with 50 to 100 g test plants each are constructed at different strategic locations in the area. The size of the seedlings and the culture method of the test plots follows the farming practices except for the small size of the plots, which is about 2 by 5 meters. The growth of the test plants is monitored at weekly intervals and their daily growth rates determined. Areas supporting daily growth rates of 2 to 5% or higher are potentially good sites. Although two to three month long monitoring of the growth rate may be enough to start a small family farm, it is advisable that the development of a commercial size farm should be based on a whole year- round monitoring, considering the possibility of problems associated with the seasonality in the growth of *Eucheuma*. This precautionary step should be strictly observed if the site is in a newly opened area. However, if adjacent areas are already being farmed, short-term growth monitoring will suffice. In general, areas where the test plants double their size within 15 to 30 days or less, are productive areas.

2. Construction of the Support System

2.1 Fixed off-bottom monoline method

The development of the farm starts with the clearing of the site of seagrasses, seaweeds, large rocks and corals. The area is then divided to smaller sections of 1/4 of a hectare or smaller. The following is a brief description of the fixed off bottom monoline method (Fig. 9) presently used by farmers. Simple farm implements and materials (Fig. 10) are used in the farming of *Eucheuma* and *Kappaphycus*.

Construction of the support system starts with drilling of holes on the substratum with the use of a pointed iron bar (2 inch in diameter) and a heavy bull hammer. Then pointed mangrove stakes, about one to two inches in diameter and 60 to 80 cm long, are firmly driven into the holes using the bull hammer. The wooden stakes are arranged in rows at one meter intervals and the distance between the rows is 10 m. A loop is made at one end of the monofilament line (180-200 lbs test nylon) and it is attached to a stake. The line is then strongly stretched and its other end is firmly attached to the opposite stake in the next row. The distance of the monofilament line from the ground is approximately 0.3 to 0.5 m depending on the depth of the water during low tides. The monolines may be positioned parallel or perpendicular to the direction of the current, depending on the strength of the current. In areas where the current is relatively strong, the monolines are arranged parallel to the current and an extra stake is placed midway between the original rows of stakes to provide extra support for the monoline. Adjustments in the construction of the support system may be made to adapt to the needs of a specific area. 1010 m long monolines will make a hectare of farm.

2.2 Floating methods of culture

Recently the floating methods (**raft** and **long lines**) of culture are used in areas where water current is weak and in protected areas where water movement is mainly due to wave-action generated

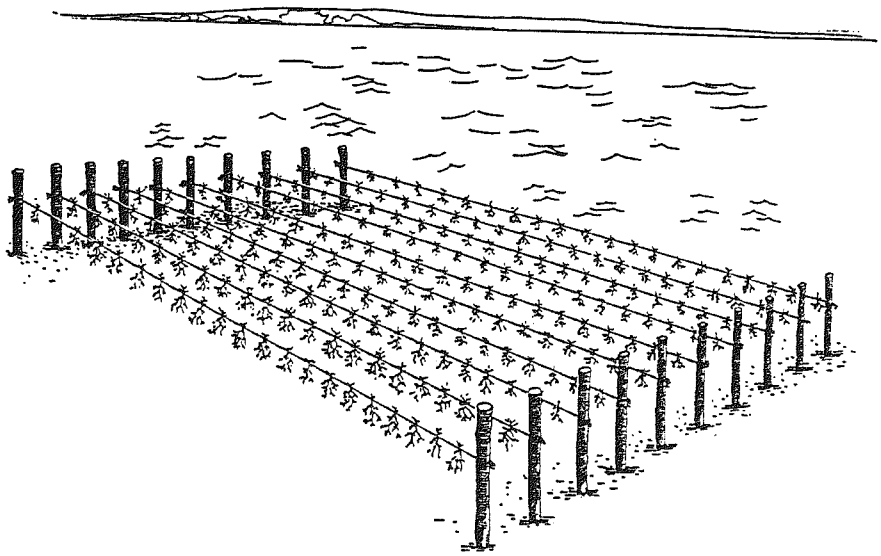


Fig. 9. Fixed off-bottom monoline method.

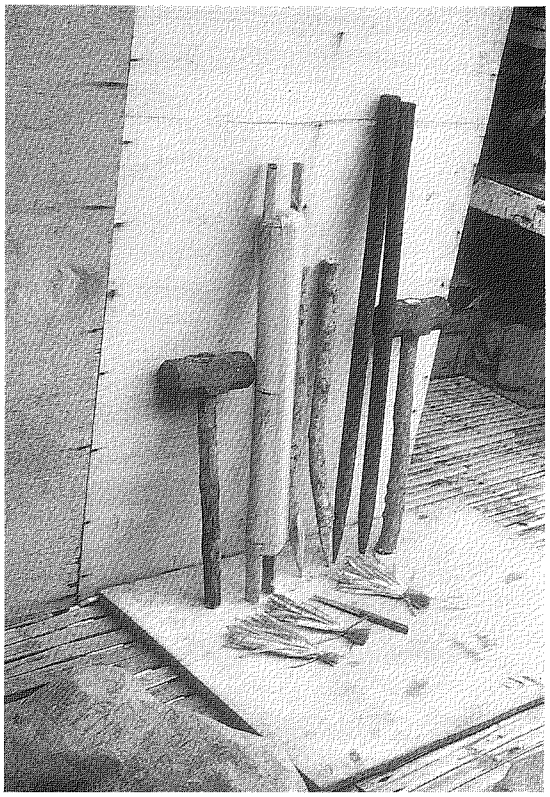


Fig. 10. Some implements used in the farming of *Eucheuma* and *Kappaphycus* (Bull hammer wooden stakes, iron bar with pointed tip, stainless steel knife, and tie-ties)

by wind. These are also adapted in places where the water is deeper and the bottom topography is very irregular.

The same principle applied to the fixed-off bottom monoline method is used except that in the raft method the monolines are attached to a wooden frame (3 x 4 m) using bamboo as a flotation device. Fifteen (15) 4.5 m long monolines spaced at 20 cm apart are attached to the wooden frame. Three hundred to 400 cuttings can be planted on one raft. Five rafts are joined together as a unit and anchored to the bottom (substrate) at the end corners of each unit using wooden stakes. Additional anchors may be used as necessary. One hundred fully planted rafts are equivalent to one hectare farm using the fixed off-bottom monoline method.

In the long line floating method (Fig. 11) six nylon monofilament lines (10 meters long or longer) are attached to bamboos (2 m long) which are distanced at 5 meters apart. The monolines are attached to the bamboos at 30 cm intervals. Each long line unit can be planted to 400 cuttings. The plants are attached/tied to the monolines at 15 cm interval. The four corner ends of the unit are anchored to wooden stakes. One hundred long line units are equivalent to one hectare farm using the fixed bottom monoline method.

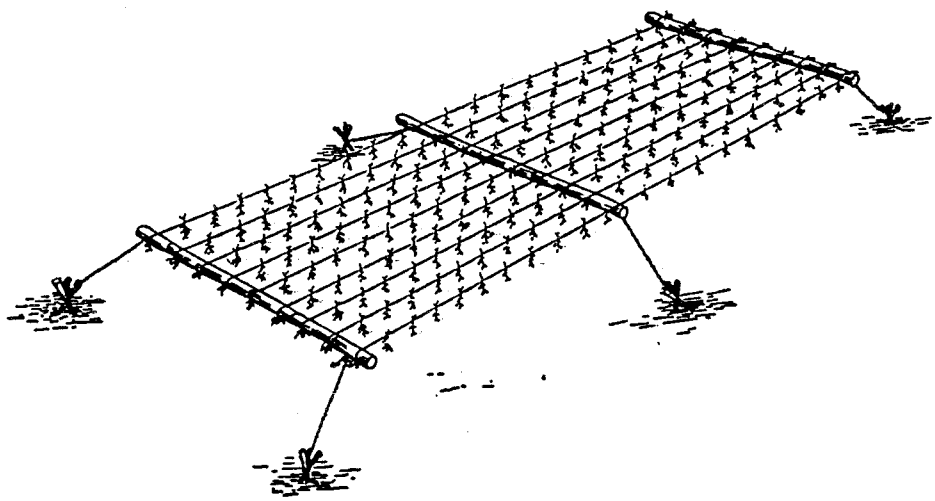


Fig. 11. Floating long line method.

2.3 Preparation of Seedlings

Seedlings of the selected species or variety are acquired from the nearest source. These are transported to the farm site in the shortest possible time and protected from exposure to sun, rain and wind. If the seedlings are in transit for longer periods, they should be occasionally soaked in clean seawater. Experience has shown that for long distance transport of seedlings the use of styrofoam boxes, with quarter-size holes at their upper sides to facilitate aeration, is the most efficient method. The seedlings should be drained of excess seawater before being placed in the box and covered. They must immediately be placed in seawater upon arrival at the farm site.

"Seeds" for planting are prepared by tying 50 to 100 g pieces of cuttings with soft plastic tying materials commonly called as "tie-tie". The cuttings are then tied at 20 to 25 cm intervals to the

monolines already set in the sea. Maintenance and management of the farm are facilitated by planting on a unit area basis, that is a farm unit (e.g., 0.25 or 0.125 ha.) should be fully planted before proceeding to the next one. The plants are ready to be harvested when they are about one kilogram in size or bigger. The time required to grow *Eucheuma* / *Kappaphycus* to harvestable size vary depending on the growth rates of the plants as affected by the ecological conditions. In good farming areas, the crops can be harvested in 6 to 8 weeks. Seasonality in growth is a common phenomenon in some areas of the Philippines.

2.4 Maintenance of the Farm

The maintenance of the farm consists of weeding, repairing the support system, replacing lost plants and removal of benthic grazers and weeds. Other species of seaweeds grow in close association with *Eucheuma* / *Kappaphycus* as epiphytes or on the monofilament lines and stakes. These compete with *Eucheuma* / *Kappaphycus* for nutrients, light and space. They also add to the "drag" on the line in areas with a strong current which result in breakages and losses of plants. Grazers, such as siganids, sea urchins and starfishes, have been demonstrated to consume significant amounts of seaweed resulting in significant losses of biomass. Maintenance is a necessary component of farming which significantly influences production. In areas characterized by strong currents, a retaining fence made of nylon nets with approximately 10 cm mesh size should be constructed at the leeward side of the farm to catch thalli washed out by the current. In Northern Bohol about a fourth or a third of the daily harvest consists of these washed-out materials.

2.5 Harvesting

The present practice of farmers is to harvest the whole plants and to replant the farm with new cuttings. The best plants from the harvest are used as seedling material for the next crop. This practice has replaced the pruning method formerly used by farmers in which the plants during harvest were pruned down to a 100 gram bunch or so to serve as the "seed" for the next crop. The objective was to save on planting cost as well as on tying material. This old practice, however, was found to be inefficient because the bunches left behind were old portions of the thalli which grow slowly, thus it takes a longer period to produce the same amount of biomass after the first harvest. In addition the tie- ties last only for one growing season. But, most importantly, the built-in mechanism of "seed improvement" by selection which is a big advantage of the present practice is not possible with the pruning method of harvesting.

2.6 Drying of the Product

Drying is an important post-harvest activity which affects the quality of the product. The harvested crop is spread on drying platforms usually made of bamboo slots, cleaned of foreign materials, such as old tie- ties, weeds, marine animals, nylon lines, etc., and spread uniformly under the sun to dry. This drying method has been slightly modified recently to minimize the loss of materials and facilitate drying. The platform (Fig. 12) is now first lined with fine mesh braided nylon net and the crop is spread on top of it. The plants are regularly turned over to facilitate complete sun-drying. The drying crop should be protected from rains. Before the onset of rain the crop is first piled up into a heap by just pulling the lining net to one part of the platform and then covered by a water-proof sheet. The product is dried in two to three days during a hot, sunny weather. The dried product should not contain more than 40% moisture. The dried material is tightly packed in plastic sacks and stored in dry areas before shipment to buying centers.

At present *Eucheuma* and *Kappaphycus* are exported in four forms, as dried, raw seaweed, as alkali-treated chips or as a semi-processed powder (Philippine Natural Grade, PNG) and as pure carrageenan. Export of the last two forms appears to be the trend among the big exporters. This re-

flects the preference for these semi- processed products by big processors of pure carrageenan and by the pet food and canning industry. By importing semi-processed products, such as alkali-treated chips, the processors of carrageenan are receiving good quality raw materials and they can avoid pollution problems associated with the disposal of processing wastes. The semi-processed powder form is directly utilized in pet foods and by some canning industries as well as additive (food grade) in food products a cheap substitute to the pure carrageenan.

Fig. 12. Sun-drying of *Eucheuma* and *Kappaphycus*.

References

TRONO, G.C. Jr. and E.T. GANZON-FORTES, 1988. *Philippine seaweeds*. National Book Store Inc. Metro Manila, Philippines, 327 pp., 156 figs.

TRONO, G.C. Jr. and E.T. GANZON-FORTES, 1989. *Ang Paglinag ng Eucheuma (Eucheuma Farming)*. Seaveed Information Center, Marine Science Institute, University of the Philippines at Quezon City, Philippines, 57pp, 30 figs.

TRONO, G.C. JR, 1987. *Seaweed culture in the Asia Pacific region*. RAPA Publ. 1987/8. FAO Regional Office for Asia and the Pacific. Bangkok, Thailand. 41 pp., 6 text figs. and 6 pictures.

(Received 27 Januury, 1992 ; Accepted 26 March, 1992)