Bay of Bengal Programme

Development of Small-Scale Fisheries

EXPERIMENTAL CULTURE OF
SEAWEEDS (*Gracilaria Sp.*)
IN PENANG, MALAYSIA

BOBP/WP/52

SWEDISH INTERNATIONAL DEVELOPMENT AUTHORITY

FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS

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BAY OF BENGAL PROGRAMME BO8P/WP/52
Development of Small-Scale Fisheries GCP/RAS/040/SWE

EXPERIMENTAL CULTURE OF SEAWEEDS *(GRACILARIA Sp.)* IN PENANG, MALAYSIA

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Executing Agency:

Food and Agriculture Organizatic!-.
of the United Nations

Funding Agency:

Swedish International
Development Authority

Development of Small-Scale Fisheries in the Bay of Bengal. Madras, India, August 1987.

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This paper reports on a one-year pilot project for seaweed culture centered at the Fisheries Research Institute at Glugor (GFRI) in Penang, Malaysia. The work was undertaken during a 12-month period in 1983-84.

Following discussions between the Malaysian Department of Fisheries and the BOBP, an experimental seaweed culture project was decided on in 1982 with the following limited objectives:

- to determine whether and which species of seaweed of the genus *Grad/aria* could be cultured
- to determine the most feasible methods of culture
- to select some typical culture sites with suitable characteristics; and
- to give on-the-job training to counterpart staff.

The project's long term objective was to establish an ongoing agarophyte seaweed production industry as an alternative means of employment for inshore fishermen of Malaysia.

Implementation of the project on behalf of BOBP was entrusted to ARDP (Agronomic Research, Development and Production Inc., Honolulu, Hawii). The ARDP made available an expert consultant, Jack Fisher; while research facilities, staff and other counterpart support were extended by the Fisheries Research Institute, Glugor, Penang. (The staff included Ms. Faazas Latif, Mr. Sulkhifli Talik, Mr. Chan Seng Mei and Mr. Samad Mohamad). The small-scale fisheries project of the Bay of Bengal Programme (BOBP) provided a part of the funds, and also monitored and reviewed the projec'

This paper discusses project rationale and effort on seaweed culture sites and species. farm production technologies, the methods and materials used, the conduct of seaweed farming experiments and their results.

The small-scale fisheries project of the Bay of Bengal Programme started in 1979. During its first phase, which terminated in 1986, the project was funded by the Swedish International Development Authority (SIDA) and executed by the Food and Agriculture Organization of the United Nations (FAO). Its main goals were to develop, demonstrate and promote appropriate technologies and methodologies to improve the conditions of small-scale fishertolk in member countries — Bangladesh, Malaysia, Sri Lanka, Thailand and India.

This document is a working paper and has not been cleared either by the FAO or by the Government concerned.

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1. BACKGROUND

A 1977 study by the author (Doty) had revealed promising potential fcr seaweed farming in Malaysia. Subsequently, the Middle Bank (between Kedah and Penang) was. entified as a principal source of seaweed.

Preliminary work had identified a red algal seaweed species *(Gracilaria sp.)* from the Penang area as desirable for its very clear agar. Another species, *Grad/aria cylindrica,* is also common in the Penang area. Both species occur on the calm protected inshore waters and gently sloping sea floor between Penang Island and the adjacent Middle Bank (Fig 1.). There are about 1500 he.tares of such habitat. The,management of the wild crop and the farming of these two species app6ared feasible. They produced distinctive food grade agars with some sugar-gel reactivity. If either of the targeted species could be shown to be farmable, no greater success was desired for the year, as both produced readily marketable agars, though not of the highest quality. The attention of the Fisheries Research Institute at Glugor (GFRI) was drawn to this potential and to the expanding market for *Gracilaria* agars.

It was decided that the *Graci/aria* to be farmed should be the one that would bring maximum profit to the farmer. The species vary widely in their farmability and market value. The wholesale price of finished agars ranges from about US **$** 12.50 per kilogram for standard agar to $ 23.50 for microbiological grades and perhaps up to twice as much for the most expensive grades. The rate for seaweeds from which these are extracted runs upwards from at least US **$** 600 per tonne to perhaps $ 1600 per tonne at 18 per cent water (prices as of November 1984).

1.1 POTENTIAL CULTURE AREA

Farms are preferably situated on level ground for twO reasons. One is ease of working, which a sloped site does not offer; the other is that the environment over a level area is more likely to approach uniformity than a sloped or irregular area.

The terrain in the Penang area and the western shores of the Peninsular states of Malaysia is usually so gently sloped that it may be considered as level for our purposes. Figure 1 indicates the potential areas for *Grad/aria* farming in and around Penang Island. The Middle Bank is one such area. Since it is isolated from the island by water and not of interest to many people other than a few fishermen, this mud flat area is relatively free from site competition. All subtidal lands in Malaysia belong to the Government and while they cannot be either bought or sold, they can be obtained for farming on the same type of temporary occupation licence as that required for a kelong fish trap.

A minimum area of 1,000 hectares with farming potential may be required for an industry, but this figure will vary depending on site fertility. From hydrographic charts, aerial inspection and photographs, there seem to be at least 1485 ha of suitable area around Penang (Table 1).

The terrain in the Penang Island and Middle Bank region is characterized by very low slopes, on much of which *Gracilaria* may be grown. The values were derived from Admiralty Chart No.1366, the scale of which is 1: 60,000 (1 cm = 600 metres). The results are given in hectares.

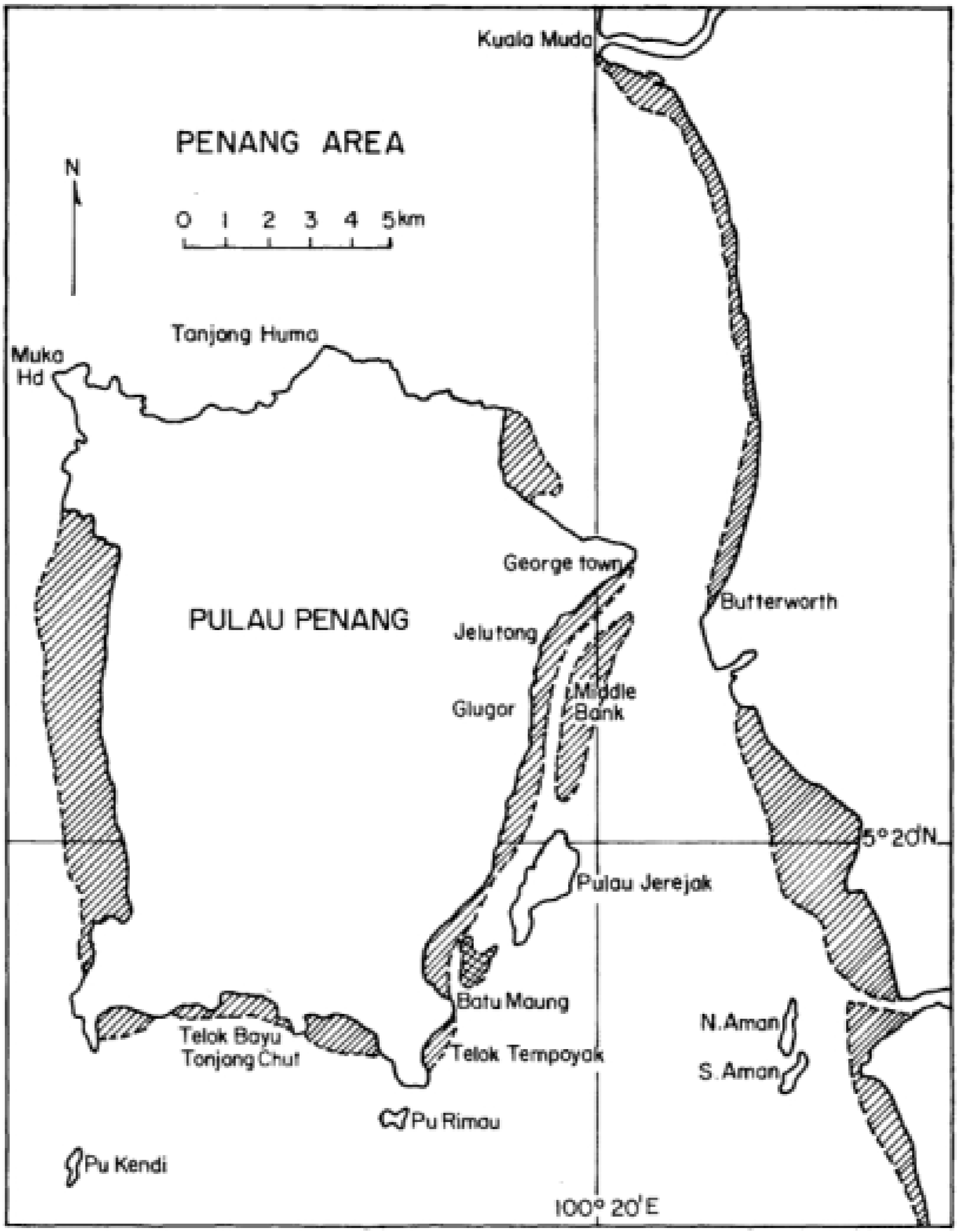


Fig. 1
Potential area, nearly 1,500 hectares, suited for mudflat Gracilaria farming around Penang island, Malaysia.

Table 1

Potential farmable area

	cm =	m =	(10000 m^2) hectares
West Penang Mud Flat (N)	10 x 1.5	6000 x 900	540
West Penang Mud Flat (S)	10 x 0.8	6000 x 480	288
GertakSunggul	2 x 0.5	1200 x 300	36
Telok Kumbar	2.5 x 0.8	1500 x 480	72
Telok Kapur	3 x 0.8	1800 x 480	86
Telok Tempoyak	3 x 0,5	1800 x 300	54
Batu Maung (N)	2 x 0.5	1200 x 300	36
Batu Maung (S)	3 x 0.8	1800 x 480	86
Tanjong Tokong (S)	3 x 1.5	1800 x 900	162
Middle Bank			125
		Total hectares	1485

There appears to be little use for these 1485 hectares of mud flats now. Most of the highly commercial cockle, *Anadara granosa* and other fin and shell fish are adjacent to the sites where the five most farmable *Gracilaria* species seem to thrive.

Although still subject to site testing, it would appear that Penang has the inshore area for a successful *Gracilaria* production industry. The outwash western shores of Peninsular Malaysia, when compared to Penang, are vastly more impressive area-wise for marine agronomy. However, they can be considered in this paper only in very preliminary way. The Kerian Bank on the shore of Perak State, (i.e. between Kuala Tangah and Tanjong Piadang), offers over 2000 hectares of potentially farmable mud rlat. Without question Malaysia has the necessary inshore area for a successful *Gradllaria* production industry or even an agar industry.

1.1.2 SITE SELECTION AND SITE CHARACTERISTICS

In Malaysia the bristle-like stipules of *Enhalus acoroides,* a sea grass, is the main substratum for *Gracilaria* aside from jetsam. In fact, the variation in the density of the wild crops of *Gracilaria* often appeared to be secondarily dependent on the density of the appropriate substratum.

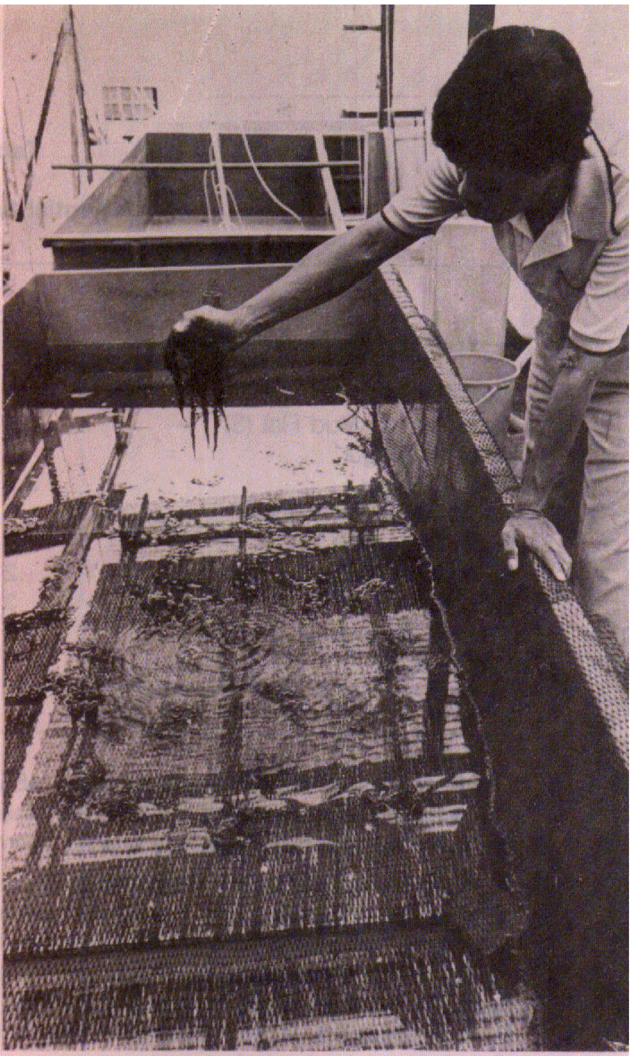
Almost any solid surface that projects at some season above bottom may ultimately have *Gracilaria* attached. However, some materials such as rubber, mangrove wood and concrete require a fairly lengthy leaching process to remove toxicity or induce other changes in their surfaces which will promote sethng of *Gracilaria,*

Two *Gracilaria* farming sites were easily accessible from Glugor. Two other sites may have yet greater potential for *Gracilaria* farming, but have not been tested, They are very large and south of Butterworth, Both these sites appear to have sizeable populations of under-employed small-scale fishermen. The four sites are described below. Of these, Middle Bank was selected as the site for the first pilot farm.

Several other site types such as ponds and rocky intertidal areas as well as other mud bottoms were considered briefly and rejected for the present and immediate future. The other areas considered and rejected were Pulau Sayak, Jelutong, Ban Merbok and Pulau Langkawi.

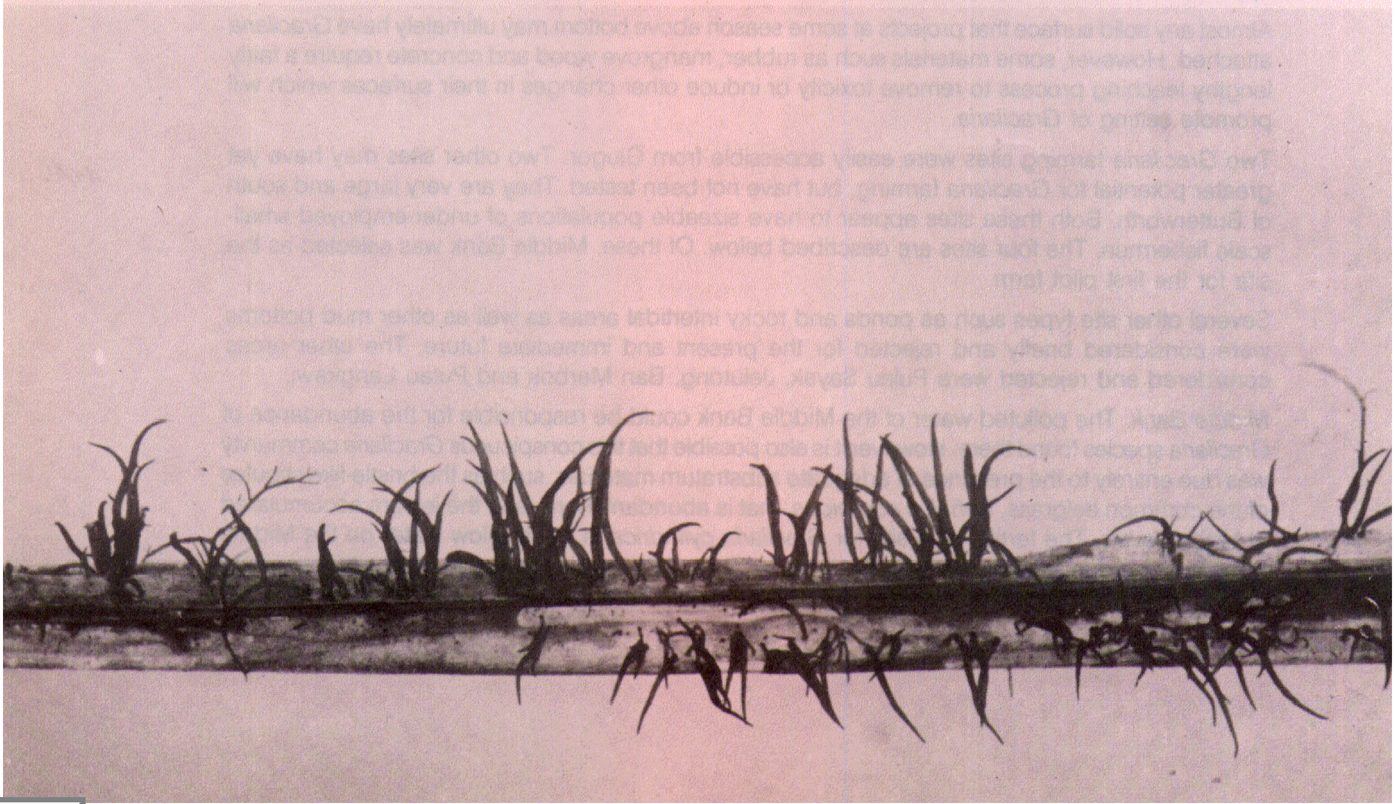
Middle Bank: The polluted water of the Middle Bank could be responsible for the abundance of *Gradilaria* species found there. However it is also possible that this conspicuous *Gracilaria* community was due entirely to the presence of adequate substratum materials, such as the bristle-like stipules of the common eelgrass, *Enhalus acoroides*, that is abundant there, and the jetsam accumulated at higher levels. The fertility of a site for *Gracilaria cyllndrica* in the shallow water on the Middle Bank may be due to the great opacity of the water as this species grows in much deeper water elsewhere in the world, The domestic pollution at Middle Bank may play a role as there were four

1. Rafia wound on frames ready for spore setting.



2. Spore setting. Tetraspore-bearing plants are placed on netting about 30 cm above frames.

3. Newly germinated spores.



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4. Pilot farm layout at Middle Bank, Penang, Malaysia.

5. Transferring q,ore-bearing rafia to pilot farm.

6. Newly transferred rafla tied to stakes at 1-meter intervals.

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7. Maintenance work in progress.

8. *Gracilaria* after four months of growth.

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9. *Profuse growth of Gracilaria*

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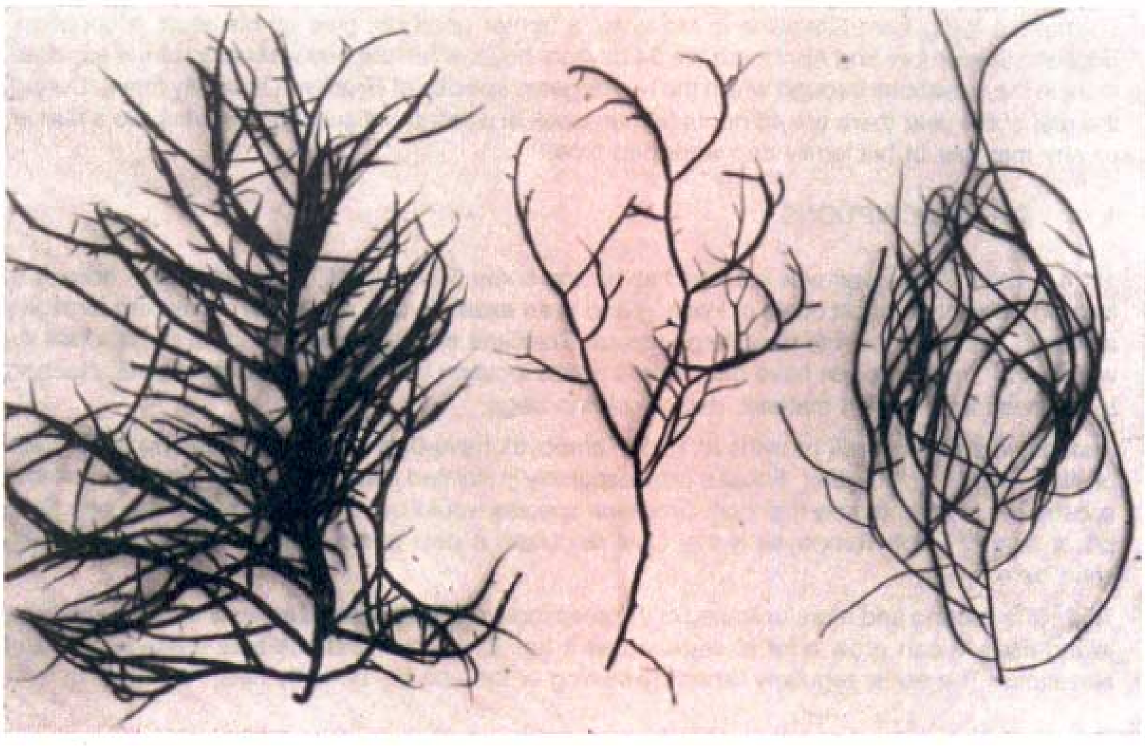
10. *Different forms of Gracilaria cylindrica.*



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species of *Gracilaria* on this site, plus one each of *Ulva* and *Hypnea.* All three genera are known to thrive in water with high nitrogen content.

1.1.3 FACTORS AFFECTING THE TARGETED SPECIES IN NATURE

To determine the nature of the aquatic elements in the environment and other factors affecting farmability, a wide variety of data was gathered. Monitoring was however cursory and dealt with the variations and qualities of the *Gracilaria* population.

Gracilaria is relatively insensitive to salinity variations of 20 to 34 per cent that occur in the Penang Straits or the site area. Some species may stand a few hours of nearly fresh water exposure such as might be found in fish ponds or in near-shore areas affected by fresh water spates during flood or storm periods.

Burial in sediment is not ordinarily disastrous for *Gracilaria* In some sites where it has a history of dominating seasonally, it is intermittently buried – at least the bases of the thalli are. Obviously burial would have to follow the arrival of the non-motile reproductory bodies which attach themselves to the bottom materials such as shell fragments or the stipules of *Enhalus.* In another project the consultants often found *Gracilaria* attached to small particles that could have been buried by the burrowing of animals or storm movement of the sediments.

The temperature records in published accounts indicate that this parameter provides no problems. However, the Ban Merbok temperatures were found to be distinctly lower than those on the mud flat near Glugor.

The fertilizing nutrients in the Penang Straits waters seem to be enough for *Gracilaria.* The uniform size and fertility as well as the dark coloured robust nature of the wild crop specimens support this hypothesis.

Secchi disk depths of 5 cm are almost a rule on Middle Bank, thus on-site work is restric d to brief periods during low tide.

The working time at sites within the elevations at which one finds wild crops of the two targeted species when the substratum or seaweed must be seen was worked out from data derived from the Malaysian Government tide tables for Penang which record levels in tenths of a metre. Over the 12-month period of 1984, the total was equivalent to 49.2 eight-hour days. This was in fragments from one to five hours long. These opportunites to work are concentrated during winter in the Northern Hemisphere. The period December through March has 50 per cent of the work opportunities and by far the greatest part of the 394 work hours for the year.

To make a living from *Gracilaria* in Malaysia, a farmer need not give up his usual occupation. Between September and April there are 34 daylight hours when the bottom substratum is exposed to air in the elevations through which the two targeted species of *Gracilaria* naturally thrive. During the rest of the year there are 45 hours (a man-week in a month) of suitably low tides. So a farmer or any member of his family can work part time.

1.1.4 SITE DESCRIPTIONS

1.1.4.1 *Telok Tempoyak* was identified as having some 50 hectares of potential farm area. It is located on the southeast coast of Penang arid is an example of a potentially rewarding farm site although it is not known to have large natural *Gracilaria* stands. However some *G.cylindrioa* as well as the "red" species have been found at this location in the past as isolated thalli attached to various forms of drift material, notably plastic bags.

Recently numerous thalli growths at Telok Tempoyak have been observed attached to *Enhalus* bristles. At this site, however, *Enhalus* grows sparsely in isolated patches. But given enough suitable substratum, it seems likely that both *Gracilaria* species would become abundant in this bay. One advantage of Telok Tempoyak is that *Ulva reticulate,* a pest at the Middle Bank, has not been seen here.

This is the second and more unlimited of the seemingly desirable sites directly attached to Penang Island itself. It can grow a lot of seaweed as it has large inter and sub-tidal areas at the right elevations. The site is regularly fished by seining or the use of 'butterfly nets" which drag over

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the bottoms. The short post and line method adopted for the first pilot farm effort could not be used here. The use of V- or J-rafia would allow such fishing to continue, yet possibly provide the ncreased substratum that would lead to harvestable crops. However, during the tenure of the one-year project only elementary testing and monitoring could be done

1.1.4.2 *Kuala Muda* might well be considered a typical example of the mud-outwash shores extending along most of the western coast of Peninsular Malaysia. The partly inter-tidal clean sand beach edging the shoreline rapidly deteriorates into a mud-substratum that extends at a gradual slope into deep sub-tidal water. According to marine charts, the width of this inter-to sub-tidal mud bottom varies considerably from point to point, For example, the area just north of Sungei Muda in Kedah is shown as extending from 0.3 km to nearly 1 km from the shoreline. At many places south of Butterworth the mud shallows extend beyond the 3 km width line before the bottom drops into deeper water.

The contours of these inter-tidal mud areas are influenced by the many rivers and streams that empty into the Penang Straits and must thus experience considerable fluctuations in the salinity of the water over them, depending on the extent of rainfall experienced inland. Fortunately *Gracilaria* is an algae that is known to tolerate salinity fluctuations within certain limits and farming this genus near such fresh water outlets as Kuala Muda (literally "the mouth of the Muda River") could therefore well be possible.

1.1.4.3 *Pulau Aman:* Little is known of this site other than the extended mud-bank shown on marine charts and the reported existence of thriving fish-cage culture systems there. If correct, this location could be ideal and provide the desired facilities for continued experimentation of fish-cage GOMPU design development, with the added advantage of being able to outplant material close to a fish-cage seedling production unit. This would facilitate monitoring the crop without the transportation problems encountered in work at the Jelutong fish cage for Middle Bank outplantings.

1.2 Species and their agar quality

To facilitate selection of additional species which might be profitable to farm, attempts were made to locate and consider as many as possible of the agarophytes in Penang's flora. Of the 10 species provisionally identified as belonging to *Gracilaria* only the following five deserved to be reported upon, although three of these may still suffer from doubtful identity. The five are comparatively more abundant than the others. Some may not truly belong to the genus *Gracilaria* but their classification will not matter to agar producers so long as they produce a good agar that can be cultured economically.

1.2.1 GRACILARIA CYLINDRICA

Gracilaria cylindrica is the most common species seen on Middle Bank, and at Telok Tempoyak is found attached to debris or the stipules of *Enhalus* on the mud flats. Santos and Doty (1983) provide a photograph of typical portions which show the gently falcate nature of many branches below where they may become rebranched – the often broadly blunt branches and the cylindrical, differently coloured, thread-like basal portions. While significantly distinct, it has often been confused with the much more slender species *G.blodgettii* by some taxonomists who may not have seen both entities.

A description of the agar of *G. cylindrica* grown on Middle Bank is already available (Doty, Santos and Ong, 1982) and there have been enquiries about the extent of its availability, its agarose content and clarity. As would be expected from its gel strength (Table 2), the agarose content of *G. cylindrica* is not remarkable. However, the agarose is sometimes very strong when taken from fresh samples (Table 3) but has been significantly weaker when isolated from older samples.

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Table 2

Examples of the qualities of the Agars extracted from two of the *Gracilaria* species common in Penang area

(CAW = Clean anhydrous weed; CAY = Clean anhydrous yield;
MT. = Melting temperature; G.T. = Gelling temperature)

Gracilaria spp Sample No.s & date collected	PH of extrac- tion	Agar yield %CAW	%CAY	1.5% gel strength g/cm²	MT. (°C)	G.T (°C)
G. cylindrica						
28421	8.0		39.71	32	85.6	29.5
(unlimed)	12.0		31.56	547	87.5	34.5
5. V. 77	13.0		31.97	605	86.5	34.2
28422	8.0		42.86	236	85.5	29.5
(limed)	12.0		29.27	779	88.5	36.0
	13.0		30.77	905	88.5	35.5
G. "red" spp						
31624	12.0	49.80	29.60	63	79.0	38.0
28. VI. 76	13.0	49.80	31.33	42	78.5	39.3
26631						
(unlimed)	12.0	60.00	34.72	97	80.0	39.2
29. X. 76	13.0	60.00	35.18	93	80.0	37.5
26632						
(limed)	12.0	58.25	31.24	93	80.5	39.2
29. X. 76	13.0	56.60	34.50	105	80.0	37.8
26635						
(unlimed)	12.0	43.55	26.29	108	79.0	37.5
24. XII. 76	13.0	43.55	28.70	126	78.0	37.5
26636						
(limed)	12.0	40.18	31.86	99	80.0	37.6
24. XII. 76	13.0	38.65	29.95	116	77.0	37.5

Table 3

Properties of agarose from Malaysian *Gracilaria cylindrica*
All the seaweed samples were treated with alkali to pI-1I3

(CAY = Clean anhydrous yield; G.S. = Gel strength; MT. = Melting temperature;
G.T. = Gelling teplperature; AG = Anhydrogalactose)

Sample	CAY % in relation to seaweed	G.S. 1.5% gel 9/cm2	MT. 1.5% soln	G.T. 1.5% gel	Ester Sulp- hate %	3, 6- AG %
28421						
(unlimed) from agar	13.90d	1220*	92.0	36.0	0.35	48.13
28422						
(limed) from agar	10.38	1220*	92.0	35.0	0.45	48.35
28422						
(limed) from seaweed	16.33	1220*	91.0	35.5	0.255	48.49

* No higher measurement could be made with the marine colloids gel tester and its 1 cm2 plunger with the particular scales being used.

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In the absence of sizeable samples, the market advantages of its unusual clarity or agarose could not be explored. However, selling *G. cylindrica* on the expanding food grade market may not be a problem.

1.2.2 GRACILARIA TEXTORII

Often called the flat species, *G. textorii (Fig 1)* is found only at the Middle Bank. growing on debris at the deepest inter-tidal levels and seems to be farmable. It has been found naturally established on some of the farm lines reported upon below. Under natural conditions it grows on muddy shores at slightly lower levels than do the two species which were eventually selected for farming in this project. Its farming can be an additional crop for deeper areas adjacent to, or intermingled with, those on which the other two are being farmed.

The gel characteristics, the nature of the male structures and the general morphology of this species led the consultants to conclude that this species. classically treated as a member of the genus *Gracilaria,* should be classified otherwise.

The peculiar nature of the *G. textorii* gel and the lack of sample size have made satisfactory chemical analytic work impossible during the project year.

1.2.3 GRACILARIA ("SLENDER SPECIES")

This is the "slender" *Gracilaria* species of earlier reports. It is found on the deepest inter-tidal and possibly sub-tidal mud flat debris. The bases of the few examples collected were buried in a few centimetres of mud. Only known from the Middle Bank, this "slender species" grows at the same low inter-tidal or highest sub-tidal elevations as G *textorli* or lower than it. It was discovered too late in the year and in quantities too small for any study to be done. The form is that of some depauperate specimens seen that were named G *lemaniformis* but when alive the fronds were weak and not elastic. But this does not indicate that its agar is not desirable. There is a possibility that this species could be a slender form of G *cylindrica* arising in low light conditions from vegetative reproduction by the propagule-like branches of the G *cylindrica* thalli growing at higher elevations and higher light conditions nearby.

1.2.4 GRACILARIA ('RED SPECIES')

This is one of the two most common species of *Gracilaria* found on the intertidal mudflats at Middle Bank, Telok Tempoyak, Batu Maung and on the inter-tidal rocks at Tanjong Chut as well as Pulau Jerejak. It is predominant on fish cage rafts at Jelutong.

The cavities in which the male structures are born are compounds which, among other things, led Chang and Xia (1976) to establish the genus *Polycavernosa.* While this species is well illustrated by Chang and Xia's figures of *P. fastigiata,* the Penang material is often larger, especially on Middle Bank, and may represent a similar, but yet formally undescribed species. Since it is suspected that the differences may be environmentally induced, these forms are being taken as representing a single specific entity rather than as several genetically and taxonornically discrete specific entities.

The "red" *Gracilaria* species has been investigated only superficially with respect to the chemistry of its agar. The agar has some sugar reactivity (Table 4), though not outstanding. In the case of one sample, a 1 per cent solution was very viscous with or without any other combination of sugar and lime. As the concentration of sugar was increased the gel became clearer and, while whitish at low sugar concentrations, it became noticeably yellow, indicating a reaction between the sugar and the agar.

In the case of a limed sample, when 250 gms of sugar was used the gel was even more viscous than an unlimed sample. Otherwise it is a good food-grade agar and while this is a readily marketable grade, food-grade agar is not in great demand and therefore fetches relatively low prices.

Table 4

Sugar reactivity of agar from the Penang "red" *Gracilaria* as determined from extracts of limed and non-limed seaweed samples

Sample number	Per cent sugar in 1.0% agar					
	0	10	20	30	50	75
32255						
(unlimed) G.S. g/cm²						
Top gel	42	76	131	154	**265**	**444**
Bottom gel	25	42	72	97	168	328
32267						
(limed) G.S g/cm²						
Top gel	67	107	65	106	171	227
Bottom gel	37	82	44	102	143	137

1.2.5 GRACILARIA ("TENDRILLED SPECIES")

This is a "tendrilled" species It grows on a wide variety of substrata such as debris on the mud flats, on granite boulders or attached to other biological living materials such as large animals.

This species has some of the characteristics of a *Sebdenia* but if its gel is determined as a desirable agar, it is possibly farmable. The nature of its agar is not known.

1.3 Farmability of Penang "Gracilaria" species

Data on the handling weights of four of the above five species after different types of processing are given in the hope that future gel analysis will show the extent of the profitability of their farming (Table 5). It is suggested that the nature of the gels of all the potentially farmable Penang species be obtained along with the developing of pre-export treatments that will bring out their most desirable market qualities.

The wild crops of the two most abundant species of *Gracilaria* were sampled to get a preliminary estimate of their standing crops and predict their potential production. These two were *Gracilaria cylindrica* and *G.* (Polycavernosa) *fastigiata.* The identity of the latter is provisional and hence in this text it is often referred to as the "red" species, since under some conditions it dries red whereas *G. cylindrica* dries black. The wild crop density of these species is unknown.

Regarding the mass of the two *Gracilaria* species, 20 mature wild crop thalli of the coarser, 6. *cylindrica* had a mean wet weight of 59.7 g (rounded to 60 g). The same number of the more slender *Gracilaria* sp. (the "red" species) had a mean live weight of 40.6 g.

Preliminary calculations of possible harvests were made using the above mean thallus weights, the general growth rate figure of 3.5 per cent a day and line spacings (planting densities) equal to or lower than 150 juvenile thalli per metre which is considered as sparse growth on lines. Using such values, one metre of line was shown to have potential for producing at least 10 kg of live *Gracilaria* per crop. This would provide about 1 kg of dry *Gracilaria* for first sale. This result encouraged continuation of the work on these two species, though only one sampling of the thalli had been drawn for each species.

While not yet established, it is understood that one might expect a major difference between the gel qualities of farmed and wild crop. Pond farmed *Gracilaria* usually has less gel strength. A significant amount of the research carried on in Taiwan has been towards selecting wild strains which, when grown in fish ponds, produces gels with suitably high gel strengths. The present project could not go this far in respect to either the Ban Merbok ponds (BOBP/REP/20) or the open mud flats.

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Earlier exploratory visits on a different FAO project relating to farming a seaweed of a different kind first revealed the significant population of the *Gracilaria* species on Middle Bank. It was easily accessible and free of adverse site competition. Middle Bank also had sufficient area, low slope, water quality and currents favourable to *Gracilaria* growth. Thus in the end, *Gracilaria cylindrica* and "red" *Gracilaria* were targeted for the preliminary work that could be done in one year. The farmability of other species should also be tested. The results of such work could then be used as a guide to selecting those species for farming which produce the scarcest and the highest priced gels.

Table 5

Wild harvest handling weights of *Gracilaria* species from the Middle Bank, Penang.

Handling process and terms	*G. cyl* No. 1155(a)	*G "red"* No. 1155(b)	*G. text* No. 1183	*G. "slender"* No. 1193
Total live wt. 20 thalli (g)	1194.30	812.10	–	–
Mean live wt. (g)	59.70	40.60	–	–
Limed wet wt. (g) (Includes the lime)	621.00	383.00	870.00	510.00
Limed dry wt. (g)	51 .85	36.40	86.64	59.68
Limed dry/wet wt. (%)	8.35	9.50	9.96	11.70
Limed oven dry wt. (g)	45.92	30.46	69.32	–
Limed dry/oven dry (%)	11.44	16.04	20.00	–
No-lime wet wt. (g)	621.00	383.00	820.00	500.00
No-lime dry wt. (g)	57.51	36.93	70.10	47.82
No-lime dry/wet wt. (%)	9.26	9.64	8.55	9.56
No-lime oven dry wt. (g)	53.70	34.52	60.87	–
No-lime oven dry wt. (%)	6.62	6.52	13.17	–
Males	4	4		
Females	8	20		
Tetrasporic	21	12		

1.4 Production technologies

The selection of methods was aimed principally at evolving an industry that will provide small-scale inshore fishermen with an alternative or supplementary means of employment. At the same time alternative approaches that would preserve both environmental quality and traditional fisheries were also kept in mind.

A number of approaches to farming methods for *Gracilaria* in Malaysia were considered and discarded. For example, vegetative transplants, used successfully in respect of larger seaweeds like *Macryocystis* and *Eucheuma* and even *Gracilaria* itself. Another approach was tried with *Eucheuma;* tying loose thalli to lines and allowing them to grow. The local *Gracilaria* species appeared to be too small and fragile to be successfully cultured in this manner. The plan finally adopted and described below has two phases – hatchery/nursery and outplanting/rearing.

In nature *Gracilaria* reproduces by spores that are either diploid or haploid. While in some species vegatative reproduction does take place and it is usually easy to get cuttings to grow, this can be successful commercially only where herbivores are controllable and there is little water motion. This is the method usually used in Taiwan for pond production of *Gracilaria* In the Taiwanese method there is no hatchery stage. A different method is used historically in Japan for a wide variety of seaweeds. Basically spores of the seaweeds are held on nets or twine in a hatchery and then the sporelings are outplanted on the nets, lines or other materials for growth to harvest size. This method has not been used for *Grad/aria* other than in Hawaii for plantings to restore wild crop production.

The nursery or hatchery stage is preferred where there is water movement which will carry the spores or vegetative cuttings out of the farm area, or where there are herbivores that would consume too many of the young *Gracilaria* thalli before they reach harvestability. It was chosen in the present case and the host agency's experimental tanks were used. The approach used was to set viable spores of the *Gracilaria* on materials upon which they would grow to maturity and then outplant them to farm sites where they could be protected and nurtured further until they grew to harvestable size.

2.0 METHODS AND MATERIALS

2.1 Spore Collection. Simple routines, materials and methods were developed for *Gracilaria* Outplanting Material Production Units (GOMPU). To date all three major types of GOMPU – hatchery type, fish-cage type and field type – have been used. They differ largely in the way the lines are exposed to the spore sources. The first two were remote from the farm area, while the last was a part of the farm itself.

Each GOMPU type has its advantages and disadvantages, but the advantages of special nurturing of the most juvenile stages for *Gracilaria* outplanting material far outweigh the disadvantages. A major advantage of the remote hatchery and fish-cage GOMPU is that work can be done with them during high tide periods when on-site farming routines are severely limited or completely prevented by the very high water turbidity along Western Malaysian shores.

Otherwise, there are three main advantages of the hatching and fish-cage GOMPU5:

a) greatly improved spore survival
b) relatively uniform spore setting
c) control over what species or variety is planted in the production system.

Obtaining very high spore densities means there will be far more juvenile thalli on a given length of line than can survive as adults. When outplanted it is believed higher densities enhance the natural selection of genera suited to the outplanting site and thus give the farmer a better crop. One can expect to count 150 juvenile thalli surviving beyond the two and a half centimetre height stage on each metre of heavily spore-set rafia.

Central to standardization of the remote GOMPU operations was the use of synthetic rafia, wound the short way around 60 cm x 90 cm frames with approximately 1 cm spacing between lines to permit spores to settle on them on the underside of the frame during the spore settlement process (Fig. 2). Each frame holds about 100 metres of rafia. The frames are made of about 2.5 x 5 cm wood slats or 19 mm polyvinyl chloride pipes. The latter have holes drilled in them to admit water so that they do not float.

Experimentation in spore settlement was sought on a variety of locally available materials which might, with adaptation, be inexpensive or of no cost to the farmers. Experiments included spore settlement on *Anadara* (cockle) shells, rubber discs or squares cut from discarded tyres, rubber strips from old inner tubes, coconut shells and husks, *Nipa* fronds, mangrove branches or twigs, and plastic strips.

For the pilot phase of this project, the most useful data for comparing spore setting techniques were counts of the number of thalli attached to given lengths of the experimental and control sets of lines. These counts when obtained at intervals for the same planting were taken as measures of survival. Such comparisons of larger *Gracilaria* thalli made on the basis of differences in length at successive measurement periods were termed as "growth" or similarly on the basis of "weight change" as "production". Production in terms of mass per unit of time was the measure of "productivity". Counting can be conducted while the thalli are microscopic, long before they can be weighed without fear of damage. When the thalli are visible to the naked eye or large enough to be harvestable, it is impractical to count them or use length; so weight is used. Section 3 describes comparative results of the three spore collections method. In appraising the pilot farm results, only weights per unit of line or block (Table 10) were used.

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All the substrates tested supported *Gracilaria* spore attachment and development with the notable exceptions of “new” rubber and coconut materials. These, along with some other materials, were suspected to exude substances which either may not have stimulated the spores to attach themselves or may have poisoned them. This lack of growth was unexpected as *Gracilaria* grows on both these substrata in nature. Thus it was suspected that with considerable leaching or the addition of the right surfactant material, the spores would attach themselves and grow.

However, when placed in the field, the inadequacies of some of these loose materials with which success was noticed in the spore settling stages became apparent, especially due to burial, silt accumulation and epiphytization.

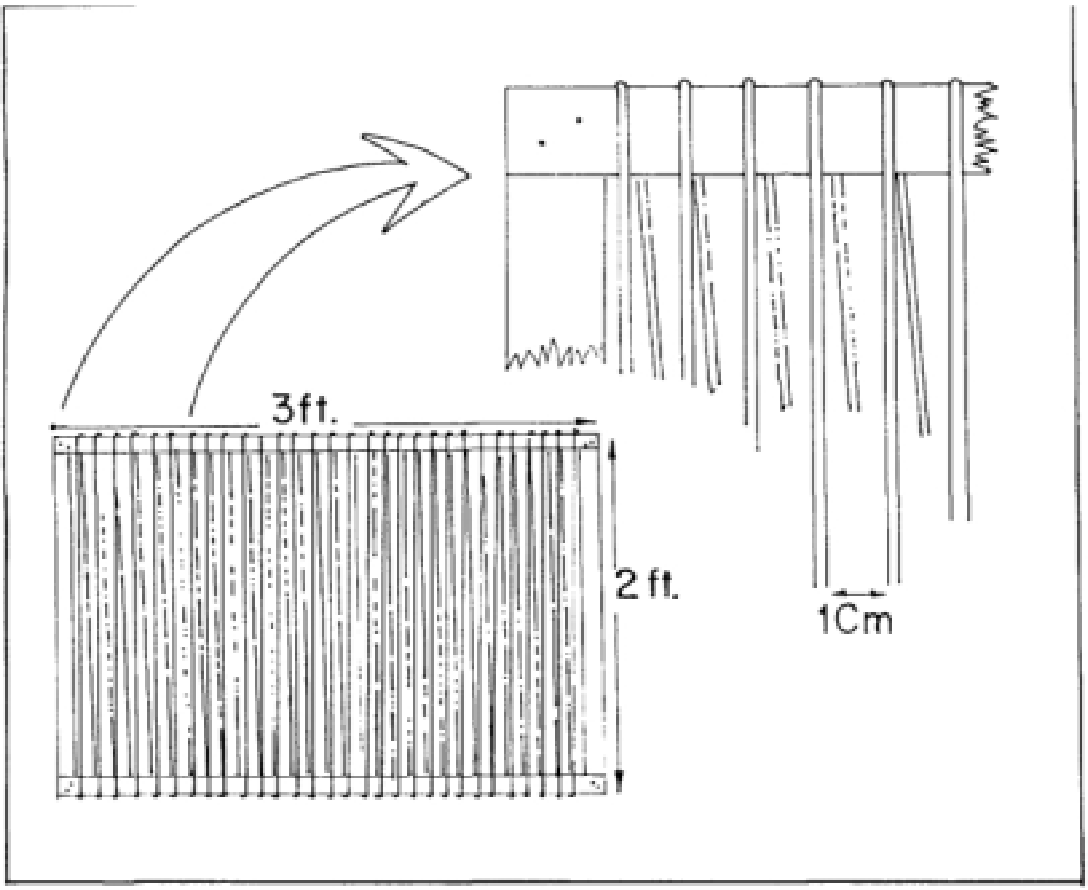

Fig. 2
Frames showing lines wound on them, as used in laboratory and fish cage Gracilaria *Outplanting Material Production Units (GOMPU).*

Since the targeted species thrive through particular depth ranges in any given habitat, consideration was given to using substratum lower than optimal, which would facilitate farming simultaneously through the optimal range of depths, that is, obtain multi-level production.

In the Penang area, most of the extensive bottoms are extremely soft, hence the loose substratum' idea was given up and planting was tried. Initially, the same kinds of materials used in the loose planting schemes were tied on lines and strung horizontally across the mud flats, suspended vertically from floating supports, or suspended from horizontal lines stretched between posts. Later, horizontal lines with pendant strips of various materials were also tested.

The results of this initial seeding work showed that spores of both *Gracilaria* species adhered and then juveniles developed densely on various plastic line materials such as nylon monofilament and the common, flat, very strong, linearly stressed, polyethylene material used in packing. The latter, termed 'rafia" line, was found to be the most satisfactory. However, '160 stress" nylon monofilament was also used to compare the durability of the two materials.

Even among the 'rafia lines", the narrower and more compact rafia was found to be more durable than 'loose" types. Although the latter presents a wider surface area, it tends to split longitudinally and gather more sediment and weeds.

Grades of 90-pound test strength are recommended since they stretch very little so that horizontal lines need not be tightened often. Also, this material appears to gain strength in sea water and sunlight and floats in sea water. On the other hand, nylon loses strength and within a year or so becomes brittle. Further disadvantages of nylon are that it sinks and stretches readily; this calls for tightening of the lines periodically. Furthermore, it is about three times as expensive as rafia.

2.1.1 HATCHERY TYPE GOMPU The spores are set by placing clean rafia bearing frames flat on the bottoms of tanks about 30 cm below a horizontal nylon net on which fertile *Gracilaria* is strewn. The *Gracilaria* is kept covered with clean sea water and the tanks are kept in the shade. The tanks are covered to exclude light, and during the spore setting period the water is not chE iged. The *Graci/aria* is removed late on the third day (it would be post-harvest treated for sale nder production conditions). Successful outplanting may be done on the fourth day with two nights of exposure under the spore source material. Outplanting can be delayed for some weeks provided some form of water motion is induced.

The use of such hatchery type GOMPU is the only way to control what will be planted on a farm or prepare satisfactorily large quantities of uniform outplanting material in a timely manner. A number of experiments were carried on in the GMFRI hatchery to improve the spore setting as well as survival and growth of the juveniles to the outplanting stage.

Spore density over any given area is governed largely by the distance between the spore source and the substratum which, in turn, is subject to the depth of.the container available for the spore setting procedure. Preliminary experiments indicated that fertile *Gracilaria* suspended 20 cm above the substratum produced a spore set of roughly 20 spores per mm^2, far too great a density to ensure survival of but a few. At 30 cm above the substratum the spore set averaged 10 per mm^2 which, although better distributed than the spore set at the lower elevation, is still too high to prevent ultimate loss of much of this potential farm crop. At both levels numerous extremely dense spore clusters were found on the slides as a result of carpospores settling *en masse* in the gel in which they were discharged.

In an endeavour to obtain a more even spore distribution, an experiment was conducted to assess the effect of air-induced water motion during the spore setting process. The experiment consisted of paired frames (56 cm x 117 cm outside dimensions) holding rafia in each of two tanks. The frame pairs in each tank formed a configuration where their bottom edges were in contact in the middle of the hatchery tank, as their top edges leaned against the opposite tank walls. Slides were placed in a row on the rafia at the bottom of the "V". In one tank, air was bubbled in at alternate corners, producing a significant water motion in the tank (experiment one). In the other, the water was stagnant (experiment two). Above the frames, spore-shedding *Gracilaria* was placed on horizontal nets for two days and nights. To evaluate the results, 10 counts were made on each slide and the counts per reticle area converted to spores per square centimetre.

2.1.2 FISH-CAGE TYPE GOMPU. Among the various field experiments conducted prior to the installation of the Middle Bank Pilot Farm were those connected with the privately owned fish cage farming operations on Penang's Jelutong coast. The fish-cage farms consist of a series of 7.3 x 7.3 m floating rafts lashed together with each raft divided into four individual open-topped net cages 3 m x 3 m. Floatation is provided by airtight fibreglass or plastic containers usually spaced apart on the inside borders but close together on the seaward side to act as a barrier against floating debris.

Many of these floats, especially those further from the shoreline, carry dense stands of the "red" *Gracilaria* species growing from water surface level to a depth of roughly 20 cm. Growth is restricted to this narrow band. It is obvious that the species has adapted to the constant depth and light of this environment as compared with the varying depth and light experienced at the Middle Bank and elsewere. Furthermore, this Jelutong *Gracilaria* survives in what can almost be called a wave-wash zone, as the local wave chop and the tilting of the rafts repeatedly brings the stands out of the water for brief periods, The Middle 8ank stocks on the other may be subjected to complete exposure for a few hours when the tides drop below the 0.8 metre tide datum level.

The presence of this "red" *Gracilaria* on the fish cage rafts along with an earlier successful experimental outgrowth of *G. cylindrica* in the same environment led to the belief that rapid development of juvenile *Gracilaria* thalli from spores would take place there. It was anticipated that the water would have a higher fertilizer content as a consequence of the high growth rate of the dense well fed, caged, fish population.

The special 7.3 x 7.3 m fish-cage rafts buoyed by four styrofoam blocks at the corners, were constructed so that each raft would hold a central 1.5 x 1.5 m fish cage around which eight 0.9 x 0.6 m frames were suspended. Each frame was wrapped with rafia lines bearing *Graci/aria* sporelings. The outer perimeter of each raft held a barrier of stranded nylon netting to exclude drift material. These eight frames on each raft were intended to become permanent seed-stock frames once successful outgrowth of *Gracilaria* occurred.

It was also anticipated that development of adult fertile material would take several months, but in view of the urgent need for outplanting material, 14 rafia-wrapped frames and two monofilament-wrapped frames required for the pilot farm program were also fixed in position alongside the permanent frames. These frames were the same dimensions as those used in the hatchery tanks. Fertile thalli of the two *Gracilaria* species were then placed on the net suspended in the centre of each fish – cage GOMPU to supplement the seeding of the inner permanent lines as well as to seed the 16 frames for outplanting.

The rat ia was exposed to spore population under conditions in which spores can be expected to settle evenly and densely on each metre of line. There were some problems remaining in obtaining uniform spore set and growth rate, but these did not hinder project progress.

2.1 3 FIELD - TYPE GOMPU. This approach to obtaining outplanting material consists of positioning clean rafia lines in the field where the wild populations of spores in the water will attach to them. EDOP procedures were as follows:

a) wound around standard-sized frames as used in hatchery GOMPU.
b) stretched on a special set of stakes (Fig. 3)
c) stretched on stakes parallel and in close proximity to *Gracilaria* bearing lines
d) stretched between posts set in natural beds of *Gracilaria*

Since the field-type GOMPU operation involves exposing rafia to spore populations at the chosen field site, it is by far the most simple. For economic reasons, one should be inclined to consider this method thoroughly, especially in view of the problems met to date with the above two GOMPU approaches.

Blocks 7, 8 and 9 planted on the pilot farm (Table 9) were experiments undertaken to test the placing of *Gracilaria* -free plastic materials among lines bearing *Gracilaria* as field type GOMPU. The standard method and materials of the lines in Block 3 served as the controls.

2.1.4. TRANSPLANTING OUTPLANTING MATERIALS. A critical step in the outplanting of seeded material is the actual transfer of material from the GOMPU site to the test station or farming site. The material must be kept wet at all times to avoid desiccation, anoxia and heating. Frames holding

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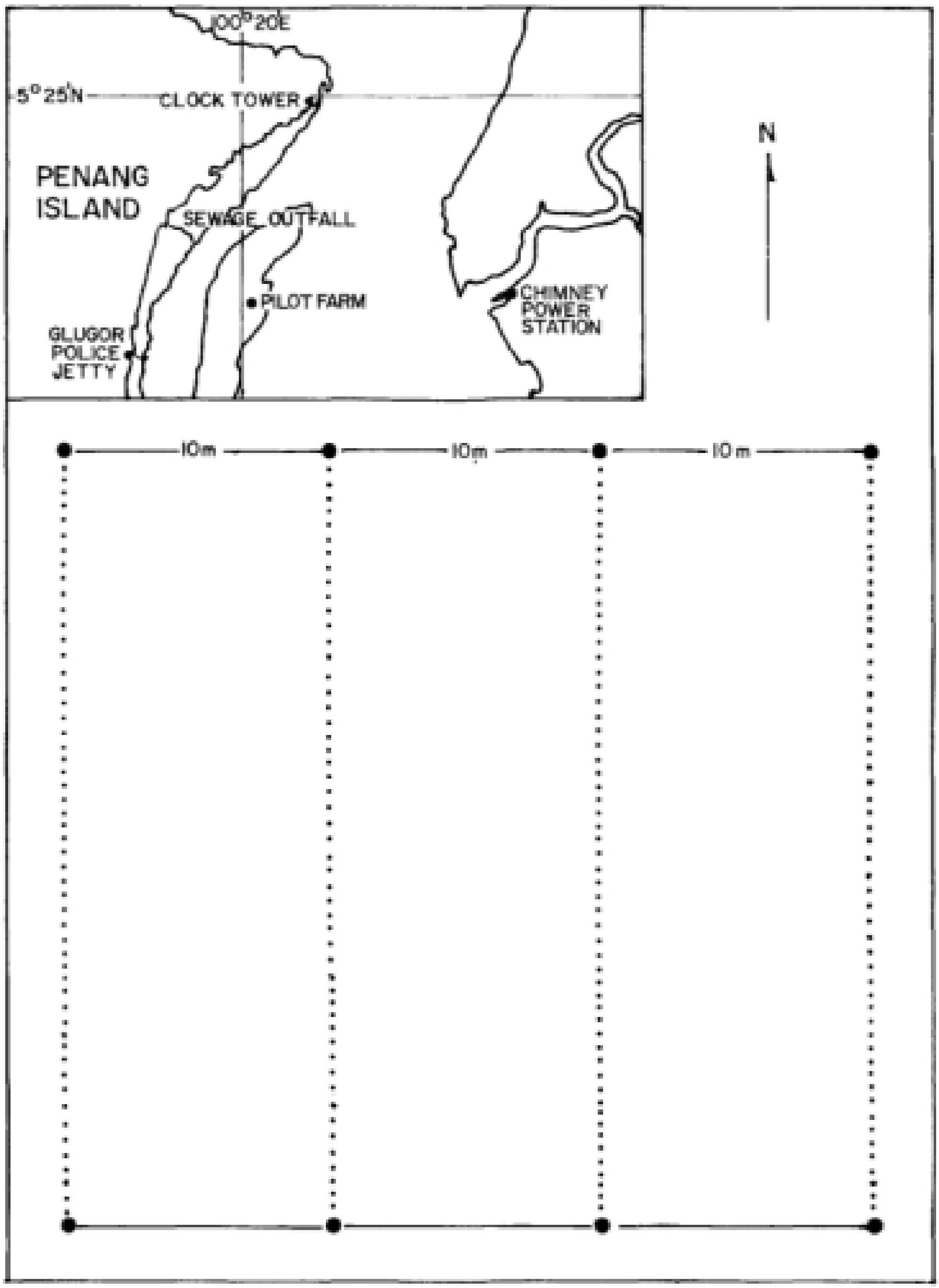

Fig. 3

Location of the experimental or pilot farm on Middle Bank, Penang. The farm diagram illustrates the placement of wooden stakes set half a metre apart in 4 parallel rows ten metres apart to hold Gracilaria *spore-bearing or other experimental lines oriented east-west, i.e. parallel to current f/ow near the low tide periods.*

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the seeded lines were wrapped in wet newsprint and kept continually dampened with fresh seawater during transportation to the outplanting site. Alternatively the frames could be inserted into wet gunny sacks, but these must also be kept damp during travel from the GOMPU to the outplanting site. In any case they should be kept wet, aerobic and cool to prevent damage to the juvenile *Gracilaria.*

2.2 Experimental farm development and testing

2.2.1 GOALS

The site for the development of line farming adapted to mud bottoms was first used as a seed-stock source. Initially, there was a strong conservationist purpose in what became pilot farming. When the project was planned, the only known strands in Malaysia of *G. cylindrica* and the "red" species were those on Middle Bank. To prevent chances of overharvesting these populations for planting material, the Middle Bank was targeted not only for special studies for its potential as the first pilot farm but also for conservation of these species. This precaution proved to be unnecessary, as both species were found to be relatively common in many places around Penang.

Other goals of the line farm development were:

a) testing the consultant's selection of a design and demonstrating that it would yield uniform results over the whole of any farm module.
b) having a site where growout from the different GOMPU methodologies could be tested and improved by EDOP methods.
c) obtaining preliminary productivity information.
d) testing the modular unit design for production farms of one hectare of more.
e) transmitting the technical knowhow through hands-on experience and demonstration.

2.2.2 FARM DESIGN

2.2.2.1 *Basic design criteria.* The need was for a farm design that would take into consideration the farmer's abilities as also his need to obtain an income of M$ 400 to M$600 per month. This goal would apparently boost three-fold the income of those coastal fishermen who, according to Malaysian public media, are now existing on incomes of about M$ 200 per month. It is felt that the farm design should anticipate an investment of about 20 per cent of one man month per month, including harvesting, and less than another five per cent in post-harvest operations and marketing. Finally, low capital investment and ready amortizability commensurate with the artisanal fishermen's business sophistication should be taken into account.

2.2.2.2 *Layout Design.* Planting *Graci/aria* in regular patterns was chosen over random patterns such as those obtained from broadcasting planting materials. Regularity facilitates maintenance and production operations and consequently the line planting method was used. Other major factors favouring the choice were the obvious flexibility in respect to planting density. as well as low labour, maintenance and capital costs.

2.2.2.3 *The block scheme design.* In establishing the pilot farm, the rafia-line planting materials were arranged in sub-areas referred to as blocks (Fig. 4). A total of 213 lines and/or implanted sets were located by block and number and initially each had an experimental purpose. Many were expected to provide no growth or poorer growth than the lines which were their controls. Conversely, some were expected to show growth optimal for production lines on a commercial farm.

2.2.2.4 *The modular farm design* This design leads directly to modular plantings which, in turn, facilitate planting, maintenance and operation. In this case, a 900 square metre module was anticipated as being large enough to accommodate experimental growth and pilot work (Fig. 3). There would be nine modules with 3.3 metres of space between the modules for boat access in each ideal one hectare farm. This 3.3 metre space seems much smaller when one tries to navigate a boat on a wind in shallow water when a current is running and the secchi disc depth is 5 cm, but allows the ideal of 900 square metres of planting on a one-hectare farm among other farms of similar size.

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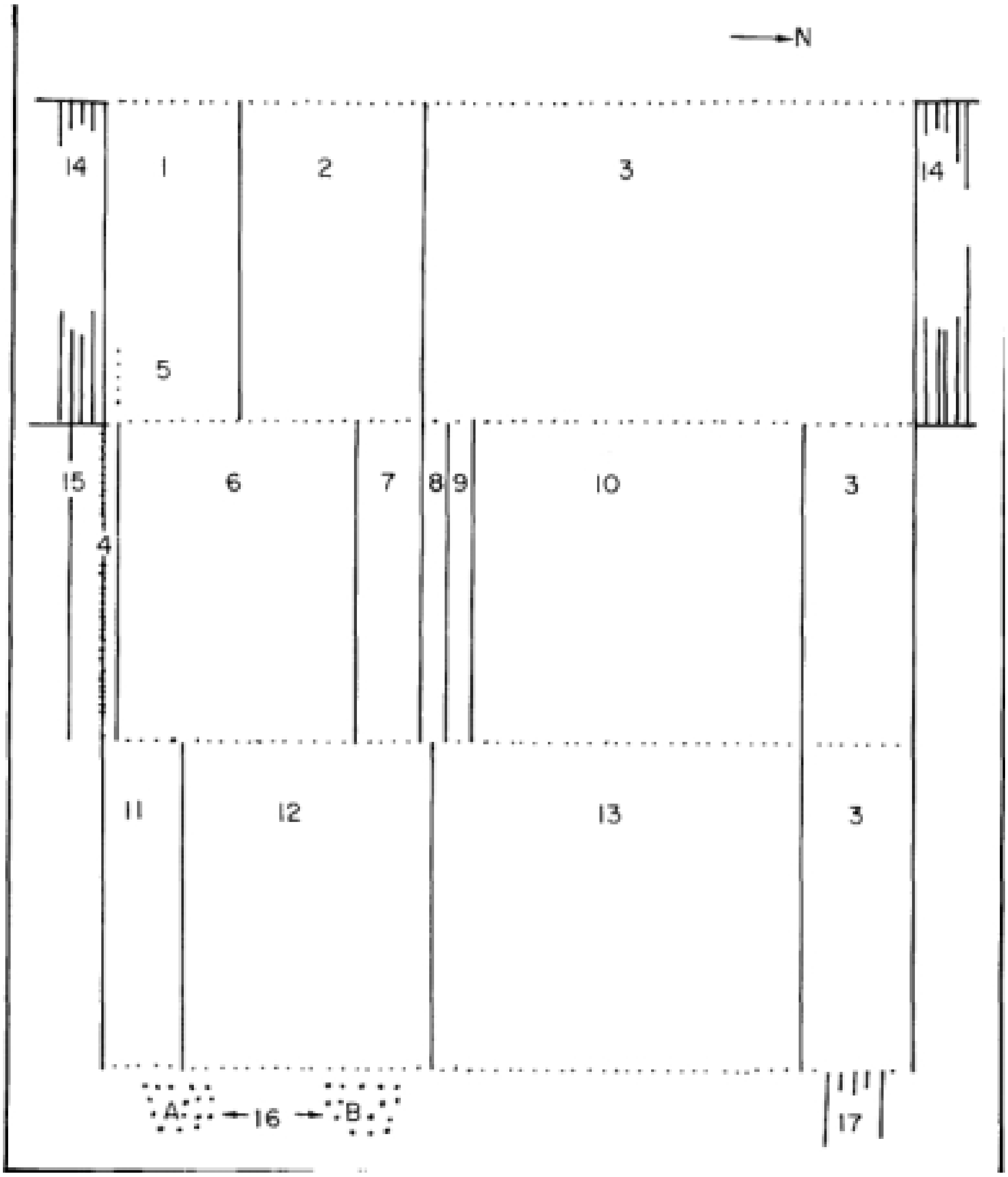

Fig. 4
The Block Planting Plan used on Middle Bank pilot farm. The lines, or other rows of planted material, were arbitrarily placed a half metre apart initially

2.2.2.5 *Line orientation design.* To optimize the uniformity of water motion, the lines were set out parallel to the principal direction of the current (Fig. 3). On Middle Bank, the north/south current is weak, being strongest at high tide. The major water exchange is tidal water flow and east/west current especially during periods of low water. To maximize water motion throughout the pilot farm, the lines were oriented parallel to the tidal flow shortly before and after low tide. This orientation of the lines also reduced damage from floating debris. Items of flotsam could float over or between the farm lines.

2.2.2.6 *Material design.* The design envisaged lines of man-made materials physically holding the growing *Gracilaria* in place or rows of objects, e.g. the V-rafia inserted in the bottom which does the same thing. The lines and V-rafia, being of man-made plastic material, are immune to fungal and bacterial degradation and are inexpensive.

The stakes or posts used for anchoring the lines in the farms were made of local materials, of which mangrove proved the best. However, some mangrove species are much more durable than others. As a rule the people living in the region know which ones rot quickly and which ones last a long time. Age of the wood (as judged by stake diameter) appears to be a major factor in durability. When made of the longer lived species, the stakes cut half a metre long and over 5 cm in diameter at the top last over a year.

2.2.2.7 *Operation design.* Havesting was designed to lead to regularizing operations and maximizing production. The particular approach to this was the use of “half harvesting” whereby approximately half of each thallus is left attached in the field.

In experiments carried on by the consultant elsewhere, it was learned that re-growth is quicker with more branches, especially with undamaged tips, left in the field. It would apparently be best to cut off only the longest branches near their bases leaving half the weight of the thallus in the field as shorter branches. This is not practical; hence half harvesting is done by cutting away the distal halves of all thalli, leaving the rest attached to re-grow the next crop.

The time required for the crop to double in size and replace the losses from all negative factors such as pests and storms would determine the number of crops per year. Growing at the common rate of 3 or more per cent per day for mature seaweed thalli, a crop would double in 21 days. Allowing nine days’ growth for replacing the losses due to negative factors, there would be a harvest every month. This of course, is the mean harvesting frequency and could be upset by seasonality.

Operations were designed keeping in mind the nearly opaque water. Operating a farm, among other things, would require ready and quick access, the farmer preferably living at the site. This would also reduce vandalism which is a problem in the early stages of farming.

2.3 Installation

2.3.1. *Posts and Lines:* The site selected was first posted with stakes to provide identification and to aid in relocation and warning other people that the area was beset with the four rows of 61 pegs. For the purposes of this initial pilot effort, the half-metre long pegs were driven 0.5 metres apart and left protruding 10-20 cm above the mud surface.

2.3.2 *Outplanting:* The lines from the GOMPU (Pic. 5) were transported to the pilot farm site while still wrapped around the GOMPU frames. Until put in place on the pilot farm, each frame was wrapped in wet newspaper and kept wet with seawater. On site, one at a time, frames were gently removed from their wrappings and the end of the lines were tied to opposite posts in the rows with a minimum of exposure to the air and sunlight. The elevation and tautness of the lines was chosen to keep them from becoming buried but otherwise as close to the bottom as feasible. The ends of the lines were tied so as to be easily released for maintenance, harvesting or other operations.

2.3.3. *The EDOP block plan:* The initial blocks of lines were attached to the pegs at various intervals between 12th of August and the 8th of November. These (Fig. 4) were, for the most part, obtained from GOMPU-initiated experiments which reached the outplanting stage at different times. This outplanting onto the farm provided the numbered blocks in addition to those added later.

The approach to testing the farm design and its materials was to use it to organize the results for interpretation along with the results of a variety of other experiments of similar design. Each of these “other” experiments was outplanted as a “block” containing the experimental or control materials. The use of blocks was a management device to obtain data from experiments and also to test the site and farm design.

The purpose of each block of lines is presented in Table 6.

Table 6
Index of pilot farm blocks

Block 1	Growout Aspects of *G. cylindrica* hatchery GOMPU lines. a) Line retention time in GOMPU versus immediate outplanting. Control = Block 3. b) Hatchery spore settlement in unaged seawater against aged seawater. Control = Block 10. c) Hatchery GOMPU lines against field GOMPU lines. Control = Block 9(a). d) Hatchery GOMPU lines against fish-cage GOMPU lines. Control = Block 6. e) Hatchery GOMPU rafia lines against monofilament with due regard for methodology and age. Control = Block 2. f) ***G. cylindrica*** versus "red" species. Control = Block 1(e), 3 and 9(a).
Block 2	Retention time secondarily in the fish-cage GOMPU. Control = Block 1(e), 3 and 9(a).
Block 3	Arbitrary initial standard hatchery GOMPU rafia line products and minimal retention time in the hatchery GOMPU. This is the general control block as it represents the routine selected for further GOMPU operational and material development via EDOP methods. Control = Blocks 1, 2, 6, 7(a) and 9(a).
Block 4	Nylon cord productivity and durability versus rafia in control in Block 7 and nylon lines in Block 9(b).
Block 5	Plastic strip planting re-growth after harvesting experiment in the form of five plastic strips held in place by having one end buried deeply in the bottom mud. Spores thought to have attached and give rise to germlings at station 4, initial site testing experimental site converted to a part of the farm area. Control, none.
Block 6	Growout on fish-cage GOMPU lines against hatchery GOMPU lines. Control = Blocks 1(d) and 3.
Block 7	Aspects of productivity and durability. a) Rafia with plastic strips versus rafia line. Control = Block 9(b). b) Rafia line versus monofilament. Control = Block 8. c) Rafia line versus nylon cord. Control = Block 4.
Block 8 Monofilament	Aspects of productivity and durability, line versus rafia. Control = Block 7(b).
Block 8 Monofilament	Aspects of productivity and durability, line versus rafia. Control = Block 7(b).
Block 9	a) Growout on field GOMPU rafia line versus hatchery GOMPU rafia lines in control Blocks 1(c) and 3, and for "red" species, Block 11(c); versus hatchery GOMPU rafia with secondary retention at fish-cage GOMPU in Block 2. b) Aspects of productivity and durability. Rafia line versus nylon line with plastic strips in Control Block 4; versus rafia line with plastic strips in Control Block 7(a).
Block 10	Growout from hatchery spore settlement in aged versus unaged seawater. Control = Block 1(b).

Block 11 Growout aspects of hatchery GOMPU lines for the "red" Gracilaria species.

a) Retention time in hatchery GOMPU against immediate outplanting. Control = Block 13(a).

b) Hatchery spore settlement in unaged versus aged seawater. Control = Block 13(b).

c) Hatchery GOMPU lines against field GOMPU lines. Control = Block 9(a).

d) Hatchery GOMPU lines against fish-cage GOMPU lines. Control = Block 12.

e) "Red" *Gracilaria* species versus C. *cylindrica* Control = Block 1(f).

Block 12 Growout of fish-cage GOMPU lines versus hatchery GOMPU lines. Control = Block 11(d) and 13(c).

Block 13 Growout aspects of "red" *Gracilaria species.*

a) Immediate outplanting versus retention time in hatchery GOMPU. Control = Block 11(a).

b) Hatchery spore settlement in aged versus unaged seawater. Control = Block 11(b).

c) Hatchery GOMPU lines against fish-cage GOMPU lines. Control = Block 12.

Block 14 Nylon header line replacing stakes in arbitrary standard farm form. Note both *6. cylindrica* and the "red" species planted in this same block.

Block 15 Growout on rafia line with short strips of rafia tied at intervals. Control = Block 16.

Block 16 Experiment in still ("A-group") and moving ("B-group") water hatchery GOMPU production. The rafia were installed as short V-rafia strips implanted in row for growout. Control = "A-group" versus "B-group" or vice versa in this same block.

Block 17 Prototype standard for GOMPU materials and procedure as rafia bearing 6. *textorii* juveniles. Control, none. Block 17 is the first attempt by anyone to seek controlled growth of this species. Thus it might become the standard for EDOP development of GOMPU operations for *G. textorii* which, though well known, has never been handled agronomically before anywhere.

Some blocks had several experimental purposes as distinguished by their appropriately different controls. For example, Block No. 3 was planted as the control for EDOP development of the hatchery GOMPU materials and methods. Thus the results from it could be expected to provide information on five different aspects of GOMPU procedures when compared with the results from Control Blocks 1(a), 2, 6, 7(a) and 9(a).

The experimental design was compromised to some degree by time constraints and the limited facilities. The least constraint was the randomness in the numbering of the blocks in respect to the experimentation, its chronology and the relationships between blocks. The last block of five lines was put out just a few days before the formal close of the project with the hope that the host institution could complete the experiment.

2.4 Growout monitoring

Frequent monitoring is essential to ensure that lines are (a) neither loose and rubbing on the bottom or entangled or broken or buried in mud, (b) kept reasonably free of sediment and (c) kept free of pest algae such as *Ulva* and *Hypnea,* as well as large animals.

Observations on the growth, environment and maintenance at the farm were monitored to recognise the causes of any unanticipated results. The crew kept a record of their activities on a time-line outline. No untoward environmental event was recorded. There was no practical monitoring other than subjective visual observations that could be readily made at the site. Between October and February, *Ulva* came to cover most of the lines. There was no more than minor physical change in the farm materials or environment: none that would have called for action on the part of the crew other than removal of the *Ulva* and uncovering the lines when covered with sediment.

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Very few maintained lines produced *Gracilaria* large enough to harvest before the formal end of the project. Those lines that were covered with sediment and pest seaweeds showed very little growth of *Gracilaria,* and the juveniles had disappeared. However, here and there a thallus of harvestable length had developed by the end of January.

The natural wild populations near the farm survived normally.

2.5 Maintenance

During the growout period, maintenance methods and schedules were developed which should be successful in the hands of those farmers/fishermen expected to engage in the farming later on. A common garden rake was the principal maintenance tool. The rakes were used to move the pest seaweeds to one end of the lines and between line spaces. From there they were removed to deeper water.

Buried lines were lifted into the water and rinsed off by gently "swishing" them back and forth. Occasionally lines were checked for tautness and distance from the bottom to keep them adjusted to a height that would prevent their being buried in the mud.

Pests soon began to appear on the outplanted lines. Minor grazing by siganid fishes appeared on the plantings. Later, as the farming proceeded, the seaweed genus *Ulva* became very abundant. This abundance could also have been a seasonal bloom, to be expected annually during the lower low daytime tides of the Bay of Bengal in the winter, with lower sunlight intensity and shorter days.

2.6 Harvesting

Four months after the first planting a partial harvesting was carried out to remove only the apical portions of the thalli. Work on other projects had shown that greater productivity was obtained through such partial harvesting, rather than through harvesting by cutting or pulling the thalli off from their bases.

It was planned that 50 per cent of the crop would be pruned away in any harvesting. Actually during the first harvest, the rafia line from which the *Graci/aria* was being pruned was laid on a board that had three parallel lines 5 cm apart drawn on it. The production rafia line was placed on the central line with the *Gracilaria* projecting at right angles across the other line. The projecting branches of the *Gradilaria* were then cut off at the outer lines which were 5 cm from the rafia on the centre line. Thus the stock left in the field was expected to be of the same average order or length as that harvested.

Most thalli trimmed had only one or a few leaders (long branches) extending beyond the 5 cm long base, i.e., the "half-length" to which the trimming was adjusted. By the time such a pruned crop has doubled in length (and weight), there should be many more than the few leaders of this trimming extending beyond the half length.

The first harvest took place in January and at the peak of what may have been a seasonal *Ulva* bloom. Thus, this operation required 13 minutes for one man to harvest 10 metres of test line with 70 per cent of his time being spent removing the entangled *Ulva*

Since it was to be at best only a pruning away of the longest thalli, at the close of the project it was felt better to finish the job with the one method rather than try to develop a more efficient one. The reasons for any harvest at this time were to demonstrate and test procedures as well as establish a base line for later work. Less important was either the weeding or pruning of this normally ragged light first crop to induce a more uniform second cropping.

The project was expected to discontinue after this first harvest. Thus other than for recording total wet weights for the whole farm as an initial or, as mentioned above, a time-zero value, the line values were not kept separately. Later it was found that the harvest weight from one line from Block 2 had been recorded separately, for it was both unusually uniform and heavily beset with seaweed.

The second harvest was suggested by the consultant and accomplished with the initiative of the host institution. The result was a rather careful half-harvesting of farm blocks 1, 2, 3 and 9 and a recording of the weights harvested line by line and block by block — 76 lines in all.

The third harvest was a quick sampling made about three months later by the consultant. This was undertaken largely to learn if the weight on the farm had increased beyond that shown by the second harvest and, since at that time, the data from the March harvesting was not available to the consultant, to obtain sample weights per unit of line length. Available time on-site only allowed obtaining samples of what appeared to be average standing crop. However, as the water was clearer, and the tide favourable, the consultants (having been provided with two able GFRI staff members and a helpful private boatsman) were able to remain on site longer than planned and block by block "cover" estimations were obtained.

At the time of the third harvest of a new farm, the productive lines were expected to be still increasing in density but with the *Gracilaria* yielding productivity values of those on a mature farm. Still some of the least dense lengths of line would be increasing their *Gracilaria* growth density during the next few crops beyond the third harvest.

The third sample harvest was done successfully in July with a large pair of scissors and without the board. Much faster and more economical bulk cropping methods should be developed during successive harvests and from them one or more should be adapted for commercial farming. It would take six months of further growth and possibly two more croppings in that period before even a quasi-final harvesting system is reached.

2.6.1 *The standing stock left in the field* While the intent was to conduct the harvesting in such a manner so as to leave "half" of the standing crop in the field, this could not be done in a calculated manner. Rather it was done differently during each harvest period. The use of the marked board during the earlier harvests surely left more in the field than was taken, due to the high percentage of juvenile short thalli on the lines. Leaving "half" the standing stock in the field means half-harvesting with the growth periods between harvests about equal to the time it takes for a crop to double.

2.7 Post-harvest treatment

The materials cut from the lines were gathered into baskets and various larger plastic containers either in the field or at the hatchery site. They were taken to the scales used for the particular lot and the harvest weights recorded.

There were two drying methods, depending upon the plans for use of the harvested materials. The seaweed was dried without further treatment or it was "limed", i.e., shaken in bags with enough dry slacked powdered lime to give the live, very dark coloured thalli a clearly whitish appearance.

Drying was done in the shade, protected from rain, but open to as much air as feasible and continued until in successive 24-hour periods no further measurable loss in weight took place. The means of weighing was rather inappropriate at times but it was felt that the dry weights recorded were less than the 18 per cent water content required for the dried *Graci/aria.* No tare weight for lime was taken and the dry trade weights recorded in the results below were for non-limed material. Storage was generally in bags indoors in the dry laboratory rooms of the Fisheries Research Institute.

3.0 RESULTS AND DISCUSSIONS

3.1 Hatchery spore collection and growout

Several problems were experienced with hatchery production:

a) the hatchery water supply was inconsistent (sometimes there was none);

b) ephiphytization by *Enteromorpha* and diatom blooms was often a problem if the material was kept in the tanks for prolonged periods of several weeks;

c) water movement could only be induced by air, which often has been found to be injurious to seaweed cultures;

d) the water supply at times was low in fertilizer content.

e) when planted side by side in the field, *Gracilaria* often grew more poorly when outplanted from hatchery GOMPU then when simultaneously produced by the field GOMPU method.

The pressure for outplanting material was too high and the number of the tanks too few to extend the residence time for the spore bearing rafia in the hatchery GOMPU style of operation. Thus, the advantages anticipated from extending the residence time were not realised due to the loss of the Pilot Farm growout stage.

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One encouraging result in respect of "site competition" and the line planting method was that no line or post was lost from the 208 lines put out in the Pilot Farm area. Some lines become loose at one end or broken but none was free at both ends. Some posts were loosened as were some lines. The July *Gracilaria* coverage on this 34.85 m of line was accepted as the mean value to be expected of any line on the farm if its 10 m length was so maintained as to be covered uniformly. Even the lines from which this 34.85 m sample were drawn were not entirely uniform. Thus for each block (last column of Table 10), an estimate was recorded of the percentage of line uniformly covered. This was estimated during a field inspection. The weighted means for each block (number of lines in the block times the respective sample per cent estimate) were summed for the whole farm and divided by the total number of lines on the farm (183 in this case) to obtain a factor for calculating the productivity estimated to have been harvestable from the pilot farm on this date. This, as "total mean per cent" of lines covered, is 54.9 as shown in Table 10.

In the July harvest, the maximum density was rather uniform between the many lines lifted above the water surface for inspection, sampling and photography.

In Table 7, the similarity of the harvested weights from the two blocks was a coincidence.

Table 7

July harvest data from the Middle Bank pilot farm

(obtained on 4.7. 1984)

Sample Block Number	Wt Weight (Kg) Line Number	Line Length	Total	Left on Line	% left on line	Harvested Wet (kg)	Block Sample harvested Wet (gm/rn)
	1	3.85	2.20	1.20	54.5	1.0	
2	2	4.40	2.60	1.10	42.3	1.5	311
	3	4.30	2.00	0.60	27.3	1.4	
	1	7.40	2.40	1.00	41.7	1.4	
3	2	7.70	3.00	1.50	50.0	1.5	175
	3	7.20	1.80	0.80	44.4	1.0	

During the July harvest, both the total weight of the *Gracilaria* bearing lines and their harvested wet weight were recorded (Table 7). The difference was the weight left on the lines. The rafia lines, themselves weighing about one gram per metre plus the excess of water, besides foreign matter, were included in this latter value. The foreign matter was sometimes abundant in the basal parts of the *Gracilaria* as well as on the lines. Usually some such material is included in the harvest weight sold. The values are quite variable as seen in the table, but since the sample was small and the balance was deficient are hardly worthy of statistical treatment. Nevertheless on this basis, the mean values for weights which would have been left in the field (Table 7) for the two samples are: Block No.2, 43 per cent and Block No.3, 46 per cent of the line wet weight total.

The results of this experiment (Table 8) showed that four times as many spores settled on the glass slides in still water as settled on their counterparts in the water moved by aeration.

Table 8
Air induced water motion effect on *Gracilaria* spores.
(The values are in terms of spot spores settling per square centimetre on 29. 11.83)

Experiment	Condi-tions	Slide Number	Recticle subsample counts 1	2	3	4	5	6	7	8	9	10	X
One	Water	1	7	6	16	5	7	21	13	14	19	2	11.0
	in	2	2	3	5	3	1	3	2	5	10	4	3.8
	Motion	3	2	1	1	8	3	4	4	5	5	0	3.3
		4	1	0	6	0	8	2	0	0	2	0	1.9
		5	6	0	1	0	6	0	2	11	4	3	3.3
		Mean											4.6
Two	Still	1	24	12	20	34	26	8	8	5	21	9	16.7
	Water	2	25	22	17	18	12	14	8	8	16	22	16.2
		3	29	22	41	12	33	37	21	12	19	10	23.6
		4	1	6	22	12	15	29	32	9	10	31	16.7
		5	0	6	10	17	7	10	28	9	17	11	11.5
		Mean											16.9

Table 9

***Gracilaria* Outplanting Materials Produced for pilot farm testing.**

All spore setting was done in 1983 except Block 17 in 1984. GOMPUs were at the Fisheries Research Institute hatchery (hatch), Jelutong (cage), in the field (field) or on Pilot Farm (farm).

Block No.	No & Kind of lines or rows	Gracilaria species	Spore Date	Setting GOMPU	Water detail
1	10 rafia	C. *cylind.*	26-29 Aug.	Hatch	Unaged
2	14 monofilament	*G. cylind.*	12-15 Aug.	Hatch.	Unaged
3	50 rafia	*G. cylind*	9-11 Sep.	Hatch.	Unaged
4	1 nylon and plastic strips	Lost	—	Farm	—
5	Plastic strips	—	—	Farm	—
6	18 rafia	C. *cylind.*	26 Aug.	Cage	—
7	5 rafia & plastic strips	Insufficient to harvest	—	Field	—
8	2 monofilament	Insufficient to harvest	—	Field	—
9	2 nylon and plastic strips	Insufficient to harvest	—	Field	—
10	24 rafia	*G. cylind*	24-25 Sep.	Hatch	Aged
11	5 rafia	G. “red”	26-29 Aug.	Hatch	Unaged
12	21 rafia	G. “red”	26 Aug.	Cage	—
13	28 rafia	G. “red”	24-25 Sep.	Hatch	Aged
14	22 rafia	*G. cylind* & “red”	26 Aug.	Cage	—
15	1 rafia&”V” strips	*G. cylind.*	07-08 Nov.	Hatch	Aged
16	Implanted rafia “V’	*G. cylind*	07-08 Nov.	Hatch	Aged
17	5 rafia	*G. textorii*	20-24 Oct.	Hatch	Aged

The field-type GOMPU should not be used to start a farm. In the major identified farm areas there are few seaweeds now and often (as at Telok Tempoyak) devoid of *Ulva* and *Hypnea.* The paucity of seaweeds at this most desirable site is thought to be due to the lack of the appropriate substratum required for sea weed to attach to. However, the field-type GOMPU a farm in view of the fact that potential farmers are unlikely to have the requisite facilities for hatchery operations. Excellent results were frequently obtained with this GOMPU in spite of more weeds and irregular *Gracilaria* populations when compared to hatchery GOMPU.

3.1.1. BLOCK AND LINE INTERPRETATIONS.

3.1 .1 .1 *Prefatory note.* The purposes of individual lines, blocks and the whole farm must be considered as well as their history. Otherwise very wrong impressions can be gathered. As shown in Table 9 different procedures were implemented in the production of lines for the farm. Where possible parallel spore setting of both C. *cylindrica* and the "red" species were conducted as EDOP to try and ascertain whether the two species reacted differently to the methodology used. Unfortunately the hatchery facilities were often not sufficient for implementing all the related experiments at one time. To replicate them for confidence often proved impossible if only due to the lack of the tides which were required for collecting the needed material from the field.

Smothering of the farm by sediment and pests, as well as loosening of the lines, meant that the blocks were rarely found useful for their original purposes. By the time the *Gracilaria* on them had grown to a harvestable size, using the blocks for their original purposes became impossible. The changes wrought during the six months following the first harvest were striking and offered evidence of the historical origins of the line while block purposes were blurred or eliminated entirely. The interpretations in respect to the original planned line and block outplantings are taken up first, and general interpretations regarding the farm then follow. The index of Pilot Farm Blocks (Appendix I) should be referred to for elaborations on the purposes of each block, the discussion of which follows.

3.1.1.2 *January*

Block No. 1. Growout on ratia lines which were outplanted almost immediately after spore setting in the GFRI tank (Block 3) was more than double that of the rafia lines retained at the shore base facility for about 14 days after spore setting occurred, i.e., 2.42 g/m vs 5.51 g/m, and considerably greater than the 0.18 g/m attained by spore setting in the GOMPU at Jelutong (Block 6). In this instance, the use of unaged water during the spore setting period also produced lower growout rates than the aged water seen for Block 10 (3.5 gim). Though the two nylon lines with attached plastic strips in Block 9 were not harvested in January, it was obvious that the shore-based spore setting produced faster growout than those from the field GOMPU, but this may be largely due to the coverage of the latter by *Ulva* and mud between the outplanting date and date of harvest. However, when compared with the similarly produced rafia lines for the "red" *Gracilaria* species in Block 11, a strange reversal occurred whereby growth of C. *cylindrica* produced over 70 per cent of the harvested crop where the "red" species had been anticipated as predominating. The only explanation for this anomaly is that natural spore settlement of *G. cylmndrica* occurred before the *Ulva* bloom in November and the off bottom rafia lines were not buried in mud as were the plastic strips of Block 9. The monofilament lines in Block 2 produced over 50 per cent more *Gracilaria* than the Block 1 rafia lines, probably due to the tautness and smooth nature of the former which kept them unburied and free of sediment. A factor that also bears consideration when comparing the outgrowth of C. *cylindrica* with that of the "red" species is the rigidity of the latter in comparison with the flexibility produced by constricted stems of the ***G.*** *cylindrica.* The "red" species is thus prone to losses from drift *Ulva* etc.

Block No. 2. The highest yield of the first harvest came from these monofilament lines. Taken as a whole, however, 48.6 per cent of the total harvest came from only one of the 10 lines and much of the balance from two adjacent lines with dense growths on half their lengths. This may possibly be due to the secondary retention of the GFRI spore set lines in the fish-cage GOMPU and the demise or retardation of spores and sporelings below the 10 cm growth depth at the floating GOMPU.

Nowhere is the chance effect of sedimentation a more desirable interpretation than here. The harvestable thalli were solitary or clumped on most of the lines in January, as though by chance those line segments were neither covered with sediment or *Ulva* In one strange relationship, three adjacent monofilament lines showed good growth as a whole. The oddity was that the

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central one of the three lines had growth throughout its length while one of the adjacent lines had good growth at one end and the other line at the opposite end.

Block No. 3. Central to all spore-setting methodologies was the standard operational GOMPU procedure at the hatchery. Block 3 was an outplanting of them as a control for the others. Nearly every one of its 50 lines carried *G. cylindrica* sporelings at the time of harvesting but only four of them carried populations dense enough to support the hypothesis that this spore-setting technique was the best of the various GOMPU methods. Perhaps this may be due to the fact that these four lines were accorded some degree of maintenance by removal of *Ulva* and *Hypnea* just once, in mid-December. The other lines in this block could have been expected to have produced more encouraging results had they been given similar treatment.

Block No. 4. This is one of four blocks containing between one and five lines, each aimed purely at determining natural spore-setting phenomena on different substrata, nylon monofilament in this case. Burial of the lines of this block appears to have resulted in loss of nearly all of the *Gracilaria* population, though it did appear that due to high cost, nyion can be discarded as a potential farming material. On the Pilot Farm, growth was heavier on ralia and monofilament than on standard nylon. Sufficient outgrowth occurred on the plastic strips in this block to justify harvesting them in January. However, it was observed that outgrowth was concentrated along the edges of the plastic strips rather than over the entire flat surfaces, considerably reducing the value of this "larger-surface-area" farming methodology when comparing the actual harvesting process with that of a simple line of no significant width and also the obvious necessity of increasing the elevation of off-bottom outplantings to prevent burial of the plastic strips (or the lines).

Block No. 5. This block contained 5 plastic strips transferred from the original Test Station No.4 to continue their observations under farm conditions in an endeavour to establish regrowth rates after harvesting at their original sites.

Block No. 6. Very poor outgrowth of only 0.18 glm occurred on these fish-cage GOMPU lines when compared with lines produced in the GFRI spore setting tanks (Block 1). This is possibly due to the random spore discharges which may have occurred, the comparatively swift currents at the Jeiutong site which could have prevented spore attachment and, of course, the depth limitations at the Jelutong site.

Block No. 7. Same as Block 4. Outgrowth insufficient to harvest. Natural spore settlement experiment.

Block No. 8. Same as Block 4. Outgrowth insufficient to harvest. Natural spore settlement experiment.

Block No, 9. Same as Block 4. Natural spore settlement experiment. Outgrowth insufficient to harvest.

Blocks No. 10 and 11. (See Block No. 1). The absence of conclusive data resulting from the burial of lines by *Ulva* and/or mud between September outplantings and January's harvest does little to support the contention that the use of aged seawater in the spore-setting procedure would be more beneficial than unaged seawater. In both species, i.e., *G. cylindrica* Block 1 vs Block 10 and the "red" *Gracilaria* Block 11 vs Block 13, growout on lines produced in unaged seawater was greater than that produced in aged seawater. However, observations carried out in September and October indicated that the opposite was occurring, as sporelings on the lines set in aged seawater were much more dense than those on the lines set in unaged water. There is little doubt that faster spore development increases the chances of thallus survival in the field, particularly if lines are outplanted within four days of spore settlement.

Block No. 12. As in Block 6, very poor outgrowth occurred on these fish-cage GOMPU produced lines for the "red" *Gracilaria* species.

It was hoped that *Gracilaria* growth at the pilot farm would enable comparison and selection among the different spore setting techniques. Regrettably this did not occur, as the *Ulva* and mud burial of the lines, and the subsequent demise of spores and sporelings between November and January, produced results in January inconsistent with observations made in early November. As an example, the total January harvest of the 21 lines of Block 12 produced only 35.5 g of the "red" *Gracilaria*

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(Table 8) whereas in early November most, though not all, of these lines carried good healthy populations of sporelings which alone would have weighed much more.

Block No. 13 See Block 11 above. However, it should be noted that most of this particular block occupied an area of the Pilot Farm with a much softer substratum than that of the Block rows to the west. With lines laid taut close to the bottom, the central lengths of the majority of the lines soon became buried in mud as the rafia stretched or the pegs yielded.

Block No. 14, The 22 lines in this block are the remainder of fish-cage GOMPU lines and were used to test the hypothesis that a greatly reduced number of stakes could be used in a farming program if lines were attached to a rope or cord linking stakes 5 m apart rather than tied to individual stakes. Block 14 is in fact 2 blocks of 11 lines each outplanted on the south and north sides of the pilot farm respectively and outside the 90 m^2 pilot farm. These were not harvested in January. but it would appear that this technique would be impractical as the loose nature of the outplantings following stretching of both the nylon cord header lines and the rafia lines themselves did little to keep the farm line from burial in mud.

Block No.15. This represents a 10 m length of rat a with a series of rafia V-strips tied at 20cm intervals and used in an experiment aimed at avoiding the use of stakes completely. It was felt that this method would be practical in areas where protruding stakes would hinder inshore net fishing.

The idea being tested here is that the 10 m length of line would be pegged flat on the bottom or even buried so that only a row of rafia strips would project above substratum and that these strips would in effect replace *Enhalus* bristles as a substratum for *Gracilaria* After a short period, however, the rafia became too limp to remain upright and the protruding tips were soon buried in the mud. A similar technique using much stiffer monofilament v-lengths was planned for later experimentation but could not be implemented within the project period.

Block No. 16. A no-stake" farming technique similar to that for Block 15, except that the rafia V-strips were individually implanted rather than tied to a length of 10 m line. The designation of 'A" and "B" to separate groups of Block 16 outplanting refer to spore-setting techniques whereby those in Block 16 A had no water motion during the tank GOMPU spore-setting stage whereas those in Block 16 B had water motion induced by air bubbling (Table 9). The V-strips were again found to be partially or completely buried in January. Thus only ragged results for comparison of the growout could be expected, and perhaps no comparison yielding the 4 6 to 16,9 spotting ratio for the two spore-setting procedures of Table 9 could be obtained.

Block No. 17. The farmability of *Gracilaria textoni,* the species used to plant this block, has probably never been investigated. Thus th.e opportunity was taken to set out lines on which spores of this species has been set in the laboratory GOMPU system. The five rafia lines had been outplanted earlier in January and so no results were available for this measurement period.

3.1.1.3 *March*

During the period March 19-22, 1984, the GFAI staff harvested 3½ blocks, i.e., 76 lines of the Middle Pilot farm. Details of these line and block harvests were made available to the consultants.

As anticipated, a substantial increase in *Gracilaria* density on lines occurred during the 2½ months between the first ragged cropping in January 1984 and this second harvest. What was equally rewarding was that the targeted species, G. *cylindrica,* clearly dominated the lines on which their spores had been set to such an extent that many of the lines apparently carried none of the red" *Gracdara* species at all.

Block 1. The highest individual 10 m line weight recorded was 660 grams or 66 gfm while the 10 line block as a whore averaged 29.6 g/m. It appears that only 3 of the 10 lines carried any of the 'red" *Gracilaria,* the largest volume of which represented 24.6 per cent of the total harvested from the particular line.

Block 2.This block of 14 monofilament lines again produced the highest mean growth per metre of line; i.e., 46.8 glm, of all the blocks harvested. As mentioned in the interpretations for the January "84 harvest, one line yielded afar greater volume than most of the others (117 g/m) but two adjacent lines also carried relatively dense stands, 106.7 g/m and 97.6 g/m respectively. Although G. *cylindrica* forms the bulk of this harvest, the "red" species occurred on 11 of the lines though in seven instances, the volume was virtually negligible when compared with the total Gracilaria harvested for the lines concerned. The “red” species represented only between 1 .5 per cent and 4,8 per cent of the whole.

Block 3. Only 11 individual line weights were provided for the 51 lines in this block. The harvests of the remaining 40 lines were combined in lots of 2 or 3 lines thus providing a total of 29 weights for the block. Expressing these weights as grams per metre, an erratic outgrowth pattern emerges for the spore set species, *G. cylindrica,* which is difficult to interpret without knowing what actually happened at the site between January and March. Sixteen lines apparently produced less than 20 g/m, 25 lines between 20 and 40 g/m, 8 lines between 40 and 60 g/m and 2 lines above 60 g/m. The anomaly is that the lines carrying the densest crops were located between lines of relatively low density. The lines adjacent to the line producing 73.5 g/m for example, yielded 25.7 g/m and 14.4 g/m respectively, while the second highest volume line (62.7 g/m) lay between lines yielding only 16.0 g/m and 17.0 g/m. Assuming that the figures provided by GFRI are in line harvest sequence, it is apparent that very inconsistent outgrowth occurred in Block 3 as in a few cases two adjacent lines produced comparable harvest of respectable proportions, the harvests generally followed a distinctive high yield - low yield sequential pattern.

Block 9.This represents one of the blocks where clean lines were installed to investigate natural spore settlement as a means of line production once a farm is in operation, i.e., Field GOMPU. In this instance consideration was also given to increasing production by attaching 90 plastic strips (roughly 30 m long and 4 cm wide) at approximately 10 cm intervals to the 10 m line and also to the possible use of standard nylon cord in lieu of rafia monofilament. It had earlier been observed that nylon cord showed little promise in view of cost, but the outgrowth on the added plastic strips in March appeared to open the door to a style of multi-level farming provided it is conducted in subtidal areas where the line can be tied about 20 cm above the substratum. Because of periodical exposure during low tides, the test lines on the Middle Bank Pilot farm were placed almost on the bottom. Despite this, as well as burial by mud and *Ulva* burial of the plastic strip line yielded 61 .8 g/m *Gracilaria,* 82 per cent of which was *G. cylindrica.* This percentage compares with the 91 .6 per cent *G. cylindrica* crops for the total March harvest.

3.1.1.4 *July*

The tide height and the turbidity of the water prevented identification of the blocks sampled. Inspection showed remarkably uniform development on all lines that were neither buried nor broken. (See Table 7).

3.1 .1 .5 *General Interpretations of the farming results*

In taking an overall view of the first pruning or January harvest, one is naturally inclined to view further discussion with some prejudice in as much as the total weight harvested from the 1830 metres of line was only 5065.6 grams of wet material or 2.76 g/m. However, as Table 10 shows, the March and July harvest paint a vastly different picture.

Firstly, the *Gracilaria* on the lines could not by any definition be considered to be adult size as the longest thalli had only attained a length of about 10 cm in January and 30 cm in July whereas natural strands on the Middle Bank have been known to measure over 40 cm in length. The 10 cm length is illusory as young thalli appear to have but one major branch or leader with many lateral branches below the 5 cm pruning length. More mature thalli would have branches reaching beyond the 5 cm and even up to 10 cm length.

Secondly, the experimental nature of the spore-setting routines was not expected to produce lines bearing uniform weights of *Gracilaria* for their origins were different time, site and treatment. Detected in January, these differences were observed by March. By July no differences due tu origin or spore species could be detected.

3.1.1.6 *Yields*

The harvest weight data are presented in Table 10 for all three harvests. Very often the weighing of the harvests from the farm was done on inappropriate apparatus, especially for the third harvest period.

In the first harvest there was too little to weigh or harvest and the strands of *Gracilaria* on the lines were very irregular. The consultants made this harvest an exercise in technology transfer and to provide a baseline for any possible future GFRI work. The second harvest was done by the GFRI staff and the results were made available to the consultant in late September.

Having heard in late spring from the GFRI staff that there was a lot of *Gracilaria* re-growth on the farm somewhat over a month after the second harvest, and being in the area, the consultant’s operations managers made a brief visit to the farm and obtained the data of the third harvest done in July.

Table 10
Middle Bank pilot farm harvest results.

(The harvest values for January. March and July are given in grams wet weight. Other calculations are based on the 183 lines Blocks 1 - 13. For Block 9 the weights from one line were doubled to be able to enter a weight for the two lines. In July, tides and turbidity prevented block determination).

Bock Number	Lines outpianted in number and nature	Date outpianted	Harvest in Gross Wet Weight January G cyl	January "Red"	March G. cyl.	March "Red"	Juiy G cyl.	Juiy "Red"	July % cover
1	10 rafía	1009.83	1620	805	2822.9	135.5	—	—	**75**
2	14 monofiiament	100983	7262	262.3	5724.7	832.9	—	—	**65**
3	51 rafia	12.09.83	21499	606.5	133828	975.9	—	—	**60**
4	1 nylon and piastic strips	10.09 83	52 0	23 0	—	—	—	—	**60**
5	Piastic strips	—		—	—		—	—	
6	19 rafia	1209.83	70	250	—	—	—	—	70
7	5 ratio and plastic strips	26 09.83		—					
8	2 monofilament	26 09 83	—			—	—	—	1
9	2 nylon and piastic strips	26.0983	—	--	1013.2	223.4	—	—	**73**
10	24 ratia	26.09.83	85 (1	—	—	—	—	—	70
11	5 rafia	10.09 83	1250	51.0		—	—	—	**5**
12	21 rafia	12.0983	61.7	35.5	—	—	—	—	10
13	29 rafia	26.0983	91.0	274.0	—	—	—	—	50
14	22 rafia	08.1083	--						
15	1 rafia and V strips	10 11 83	—	—	—	—	—		—
16	Impianted rafia V strips	10 11 .83	—	—	—		—	—	
17	5 rafia	01 02.84	—	—	—	—	—	—	—
Total harvested & totai X per cent of hnes covered			36228	14428	22943.6	21677	—	—	**54.9**
Totai wet grams harvested/no. 10 m - hnes			5065 6/1 74		251 11.3,i77		7800/3.485		

The per cent cover (Table 10. last column) was estimated by the consultant team with the assistance of the very helpful technical crew provided by GFRI as were the wet weights for July in the same table.

Arrangements were made for obtaining the dry weights and these were provided by mid-October (1984) for the bulk of the harvests. The dry material was sorted into species (in Honolulu) and the species ratio information obtained is incorporated in Table 11.

Table 11
Percentages of G. *cylindrica* and the *Gracilaria* "red" species from successive harvests of the Middle Bank pilot farm during 1984.

(Values in dry weight. per cent)

Species Harvested	January	March	July
G *cylindrica*	71.5	91.5	5.2
"Red"	28.5	8.8	94.8

3.2 In-field spore-setting and growout

In-field spore-setting on clean lines and growout of a mixed species crop has been demonstrated at the Middle Bank site. Although this field-type GOMPU success has not yet been achieved in an actual farming situation, there is no reason to believe that similar results will not occur in a farm situation. Outgrowth on this type of lines at the Pilot Farm site already has produced fertile material of all three genders in the *Gracilaria* life cycle. The native population there contains G. *cylindrica,* the "red" species and G. *textorii;* thus the field GOMPU lines were initially exposed to a mixed spore population of these three species. If a polyspecific product is acceptable, in practice the farmers could tie clean lines alongside those carrying semi-adult *Gracilaria* say a month or so before harvesting. During the harvesting process either the newly seeded or the original lines could be relocated to increase the farm area. Likewise complete harvesting of the old lines could be done then, a process eventually necessary to reduce pests.

If *G. cylindrica* and the red species are seeded on separate clean lines in hatchery GOMPU, the likelihood of getting mixed populations on them is remote. Mono-specific farming possibly could be continuous if the hatchery GOMPU approach is used. Seeding clean lines would become essential for farm expansion programs and/or to replace original lines in mono-specific farming whenever the desired species is lost.

To attain a one-hectare farm from a 900 m^2 module starting size, increasing it tenfold will probably take six to twelve months before the first harvest of the whole farm can begin on a regular basis. This is based on the assumption that five clean lines are successfully set with spores between each line on an initial module having lines one metre apart. There seems to be no reason why this cannot be done. Surely the spore-set lines would have to be spread out to the full-sized farm while the thalli were in the early germling stages.

Placing five clean lines alongside each original line, for example, would produce planting material for one hectare in less than 10 months and possibly, by repeating the process, total harvest capability in less than 16 months. Complete harvesting of the crop is *not* recommended, By judicious cropping, a farmer could stagger the harvesting to meet the manpower limitations, i.e., by harvesting half the crop on selected blocks of lines before or after appropriate growth periods. However, since growth is logarithmic and expected to be at such a rate that the crop will double in a month's time, maintaining the highest standing crop feasible in the field and partial harvesting, e.g., by reducing the crop when it appears to be near its asymottic maximum to one-half size through judicious pruning is recommended. This half-harvesting will bring far higher yields than complete harvesting. Half-harvesting is a practical approach to farming for it allows management of a farm for harvesting alternate halves at successive spring tide periods after each has had a month's growth.

In the farming of another red algal seaweed, *Eucheuma,* it has been found (unpublished data of the consultant) that the closer thalli are grown together the faster the growth and the heavier the crop becomes per square metre of farm. In the present case of *Gracilaria,* since the initial inter-thallar spacing of 150 thalli per metre on the lines half a metre apart seems to yield normal growth (3.5%/day) and satisfactory size, much closer spacing of the lines themselves is expected to be successful. At least 20 cm spacing between lines seems indicated and probably at least six lines per metre will be successful.

Optimally dense plantings are likely to suppress macroherbivores, for they require a varied diet as provided by the diversity in their habitat. Such dense planting would result in a monocrop situation probably by shading out the juvenile stages of other primary producers. Much of the farm area was occupied by a large mud-dwelling anemone which the consultant sought unsuccessfully to have removed. It has a dense zooxanthellid population in its uppermost tissues and so, if these anemones depend on the primary production of their zuoxanthellae, the shading by dense *Gracilaria* plantings would probably favour farming by causing their demise.

Repeatedly in the consultant's conferences with FAO and Malaysian Fisheries officials and in the various reports submitted during the course of the year, the statement was made that the first few harvests from the present pilot farm operation *cannot* be expected to indicate much in the way of future productivity. The reason for this precaution is that the results through July are from the ragged initial growth to be expected from the yet non-domesticated seedstock. The three harvests' anticipated regrowth to the same length would take perhaps three months but possibly reharvesting could have been done once a month after the July 1985 harvest.

In almost all cases of lower than average standing crop on the large sample of lines especially examined in the field for the purpose, the cause of the lower crop appeared to fall in one or the other of a few categories. Most frequently the line had become loose so that it apparently had dragged across other lines or dragged back and forth across the bottom sediment or had a free end and such free ends were generally barren as a result of erosion. Earlier in the winter months, *Ulva* tended to cover the lines. Being mostly unattached it often slid to the ends of the lines and accumulated near their posts Perhaps the barren ends on some of the lines resulted from this phenomenon

3,2,1 *Seasonal changes in species composition* This pilot farm area may show a seasonal alteration in crop growth of the two test species. Both are present all the year around. At no level of confidence could the harvest weights of *Gracilaria cylindrica* and the "red" species (Table 10) be so interpreted by themselves. Little evidence was seen of seasonality in gel content or quality (Doty. Santos and Ong. 1983) in a related study. It may be that these species predominate at different seasons (Table 11) with no significant variation being seen in their combined standing crops Whether seasonality or succession is implied by the Table 11 data is likewise unknown. However, experiments such as pilot farming are obviously appropriate.

It is to be noted that the dry weight content of *Gracilaria* on the pilot farm became a larger percentage ot the live weight as the crop aged from January into the summer. This is normal and is a factor in determining the age at which the crop can be most economically harvested. One of the characteristics of one-year projects is that data for such appraisals cannot be gathered. However in this case, a trend exists in the three sets of data.

3.3 The "best value" approach

In a group of samples one of them is sure to be the 'best" from the point of view of the experimenter In the case of growth experiments on lines. the sample showing the most growth is probably showing growth at the maximum. In a random set of samples this one best value must be recognized either as due to chance or as revealing potential. In the case of lines from the present pilot effort, the best line is not entirely due to chance for the lines were produced, outplanted and nurtured differently The end of the project was January: subsequently the weights of the best lines being used were obtained in March and July with no maintenance in between. Yet further work would surely lead to the know-how of producing farms bearing crops on each line equal to the crops on the best lines found in the different harvests. On this basis, use of the best samples from Table 10 for predicting what appears to be feasible in the way of maximum production is justified when premature statements must be provided regarding farm production.

On Fig 5 the best values from the three harvests used appear to project a curvilinear line that would, on such a log-linear pilot, be expected to become asymptotic at about 1000 g/m. After July, it was reported that the farm was beginning to deteriorate. Thus the data from some lines harvested in September after this report on the project was essentially completed, have not been incorporated However. though the September harvest yielded an average crop weight per metre a little below the expectations of the above figure. there was at least one line (according to the Fisheries Research Institute staff) that had 1 kg of *Gracilaria* per metre on it.

4.0 SUMMARY

The site for the experimental farm was iocated along the central, more northern, part of the eastern side of Middle Bank, the mud bank between Georgetown arid Butterworth in Penang State (Fig. 1). This sandy-silty back-mud flat is isolated from Penang Island to the west and to the east, toward the mainland, by deeper water. !ts surface is rather horizontal at a tidal height of about 0.5 feet.

The experimental farm was established n September/October. 1983, by outplanting lines (Pic. 4), that had had *Graclaria* spores set on them elsewhere, largely at the Glugor Fisheries Research Institute. Spore setting was done in many ways but usually on nylon or linearly stressed polyethylene rafia. These lines (Pic. 6) were attached at their ends to stakes. The stakes were driven at half-metre intervals in the mud in four parallel rows, the rows being 10 metres apart. Such 30-by-30 metre squares for the present purposes are referred to as modules. By design, nine such modules established 3.3 metres apart (to provide access by boat) formed a one-hectare farm.

The first harvest was done in January 1984 after about 4 months of outplanting and subsequent harvests were in March, July and September. Although the project came to an end by January 1984 records were obtained from GFRI and are indicated below:

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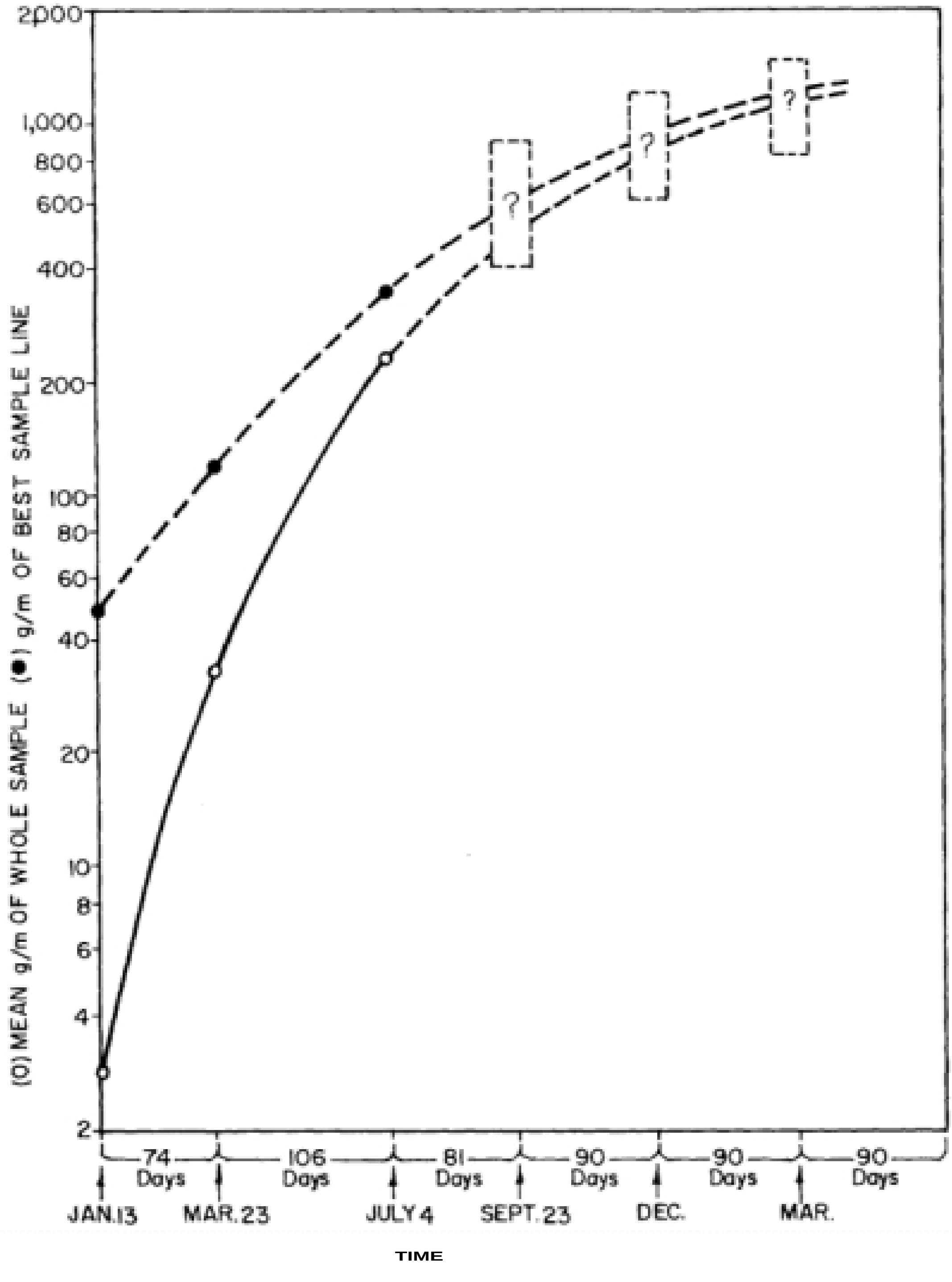

Fig. 5
Returns based on early pilot farm production. The sources of the data are the values in Table 10 for the three sample harvest measurement periods.

	Duration (Months)	Wet weight of harvest (gm/m) Best value	Mean value
1	4	48	3
2	6	110	33
3	9.5	350	224
4	12	> 1000	Not available

On such a farm, the resultant crop densities of this genus can produce (Pic.9) more than one live kilogram of *Gracilaria* per metre if properly maintained, e.g., with the lines being kept taut so as not to become buried and if kept free of the seaweed species *Ulva,* the principal pest. Obtaining such maintenance was a major problem. Had adequate manpower been provided the crop would have become much larger, grown more quickly and the opportunity for gathering data to test numerous hypotheses about the hatchery phase of the farming would not have been lost.

Replanting or frequent line replacement and related phenomena affect productivity. However, the methodology devised and implemented appeared to be so favourable for *Gracilaria* that bi-modal approach to growing a crop, and even replanting, may not be necessary. Even after a year in the field, no individual line had been lost, nor was any molestation or other loss of farming materials experienced. When a line is replaced its crop may take six months or more to reach maturity.

The experiments showed that up to ten or more kilograms of wet *Gracilaria* per harvest per square metre of farm can be expected by merely increasing the number of lines outplanted per module. Elsewhere, yields of five dry tons/ha (Taiwan), 10 dry kg/rn2 (wild crop in California) and 40 dry kg/m2 in Chile have been reported as compared to one kg dry weight in the experimental farm. The Middle Bank pilot farm site may support similarly high yields since the environment appears to have water that is no less fertile than the above three non-Malaysian sites.

Thousands of spores per linear metre of line are attached in the spore-setting process and 150 juveniles have been counted per metre of line some time after being outplanted in the field. At the harvest stage, the thalli were so large and close together (Pic. 9) that no count was attempted.

Successive harvests show a shift in the relative dominance of the two *Gracilaria* species on the outplanted lines as the seasons advanced from winter to summer. From other observations this may indicate that one species ('red' species) will dominate the farms in summer and the other *(Gracilaria cylindrica)* in winter, with or without a significant variation in standing crop. It could also result in a winter seasonal dominance of *Ulva* with less of *Gracilaria* Such a feature would naturally induce development of a mono-specific crop which may be much more valuable than a variable mixture of two species. So, with diligent and appropriate maintenance and timing of harvests, an economic mono-specific crop may be achieved.

Another observation is that there may be more variation in agar quality as a function of post-harvest treatment than as a function of seasonality. The consultant did not have time to explore this and many other such pertinent phenomena mentioned in this report.

The purpose of the lines put on the experimental farm was either to test the farm design or to test hypotheses regarding the production of outplanting material. The lines were placed half a metre apart and in the numbered planting blocks shown in Table 1. However, this density was for experimental purposes only.

Determining the planting density is critical to the development of *Gracilaria* farming by line or any other method. Until this is determined, projection of farm yield would be questionable. Since one line can come to bear a standing crop (Fig. 5) of one kilogram per metre as projected by several lines of evidence, to obtain a given number of kilograms per square metre, one would have to outplant an equal number of lines across each square metre of farm. One can imagine a farm having ten or fewer lines for they would be, respectively, ten centimetres to one metre apart. Lines half a metre apart gave good results in the present work,

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5.0 RECOMMENDATIONS

Farming *Gracilaria* in the Penang area should use rafia in *Gracilaria* Outplanting Material Production Units (GOMPU) that can be operated during periods of high tide. This will enable the farmers to operate larger farms for they can work more hours per month by doing this part of the job during high tide periods when they see the submerged farm materials due to turbid water.

More experiments would have to be made to project productivity and cash returns before production on a commercial scale is attempted. Further experimentation on pilot farms should consider factors such as the optimal metres of line per unit of area, the effects of reasonable maintenance, species seasonality and optimal elevation in the tidal system as well as the distance from the bottom for positioning the lines so that reliable estimates of productivity and cash returns can be made.

The results obtained during the experimental phase appear to indicate that although there may be good scope for developing this industry, much more work has to be done before commercial viability is established.

There are no data from which one can calculate farming returns of *Gracilaria* in the tropics. To obtain such data would mean operating a pilot farm for at least another year. Fig. 5 shows that it may take six to eight months from the outplanting date for the pilot farm plantings to be sufficiently mature for that year's seasonal monitoring to begin, Pilot projects which may have to be stopped half way should be avoided, for without data it will not be possible to evaluate the returns from farming.

The line density should be greater and harvesting more frequent. The plantings were suitably productive at half a metre apart on the experimental farm area and it is thought that at least each of five parallel lines per metre would be similarly productive.

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Published by the Bay of Bengal Programme, FAO, 91, St. Mary's Road, Madras 600 018. India,
and printed by TT. Maps & Publications Private Ltd., Madras 600 044.

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