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Review

Kombu cultivation in Japan for human foodstuff

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With the advance of seaweed culture technology, modern Kombu (*Laminaria*) cultivation has been expanding so rapidly compared to the traditional Kombu fishing of Japan. However, most production of cultivated Kombu is limited to the four prefectures, Hokkaido, Aomori, Iwate and Miyagi, of northern Japan. In Hokkaido, the largest Kombu production area, three representative cultivation methods are adopted, e. g. Two Year Cultivation, Cultivation by Transplanting and Forced Cultivation, using high quality species as *Laminaria japonica*, *L. ochotensis*, *L. diabolica* and *L. angustata*. The two year cultivation requires more than twenty months to produce good quality for consumption, whereas in the forced cultivation Kombu of almost the same quality is produced within eleven months by severely controlled seedling production on land and subsequent regular cultivation in the sea as based on scientific surveys and long experience. The transplanting method is widespread among fishermen, often using jointly the other cultivation methods. The annual production of cultivated Kombu in Japan jumped from 284 tons wet weight in 1970 to 44,220 tons in 1981 and this accounts for about 28% of the total Kombu production.

Key Index Words: *Cultivation districts*; *cultivation methods*; *growth*; *Kombu cultivation*; Laminaria; *productivity*.

Kombu is the common Japanese name for the edible species of *Laminaria* and some closely related genera such as *Kjellmaniella*, *Cymathaere* and *Arthrothamnus*, which all belong to the Laminariales.

Kombu has long been a part of the Japanese diet and the Japanese people have a special liking for the seaweed. According to some ancient documents, Kombu was gathered in the beginning of the eight century by the Ainu, a native people who lived on Yezo Island, the old name for Hokkaido, and in other northern districts of Japan. As the northern areas became more developed, the output of Kombu increased gradually through the efforts of many Japanese colonists. At present, Kombu harvested from natural reefs consists of fourteen species, all of which are found on the coasts of Hokkaido. Only two species, *Laminaria japonica* and *L. religiosa*, grow around the prefectures of Aomori, Iwate and Miyagi in the northern part of Honshu, the main island of Japan.

In the beginning, because the output of Kombu was small, the product was considered a delicacy and was eaten only by the privileged classes in Kyoto, the old capital of Japan. Its use expanded gradually to the *Samurai* cast and then to the general public. Thus, the custom of using Kombu spread over the entire country and has continued over a great period of time.

From early times, the Kombu plants gathered from Yezo Island were transported to Kyoto and other cities in western Japan by ships sailing the Sea of Japan along the so-called "Kombu Road". By the middle of the seventeenth century, this sea route had extended to Osaka by way of the Inland Sea. Since that time, Osaka has become the major market for Kombu in Japan. The traditional food processing industry for Kombu also developed in Osaka and in neighbouring cities of the western district. The Kombu road of the Sea of Japan no longer exists, having given way to transport by land. Osaka, however, remains the major Kombu market and processing area.

For more than two hundred years, fishermen have attempted to increase Kombu resources by means of various propagation techniques as planting stones or concrete blocks, blasting reefs and weeding out of competitors on the natural Kombu grounds (HASEGAWA 1971a 1975, KAWASHIMA 1972). In spite of these efforts, however, recent annual yields of natural Kombu in Japan have stayed at approximately 150,000 tons wet weight. The production of some species of good quality, such as *Laminaria japonica*, *L. ochotensis*, *L. diabolica* and *L. angustata*, is failing to meet consumer demand; because production is very unstable and is in fact gradually decreasing overall, the market price fluctuates greatly.

To increase the output of good quality Kombu, an artificial cultivation technique was first tested from 1955 to 1956 in Hokkaido (KAWAI and HASHIBA 1958). Four years after this, the first full-scale experiment of Kombu cultivation was started by research workers and fishermen in Hokkaido. At the beginning of Kombu cultivation in Hokkaido, the cultivation technique for Wakame (*Undaria*) was adopted. This technique had already spread widely among fishermen. However, the anticipated results were not obtained because, whereas Wakame is an annual plant, Kombu usually requires two winters to attain commercial size and quality.

Through study, the technique has been improved gradually and now Kombu cultivation is widespread among fishermen not only in Hokkaido but also in Aomori, Iwate and Miyagi Prefectures. Furthermore, there have been a few recent attempts to cultivate Kombu outside of its natural area of distribution in Tokyo Bay, the Inland Sea and Ariake Bay. Through these efforts, in recent years, the production of cultivated Kombu in Japan reached more than 40,000 tons wet weight which corresponds to about 28% of the total production of Kombu in Japan.

As representative macroalgae of the Phaeophyceae in Japan, the study of the Laminariales as pure botanical research would be interesting. However, practical research on how to protect this resource and to increase production of the commercially valuable Kombu is thought to be more important. The following description deals in general with the current artificial cultivation of Kombu mainly in Hokkaido, the chief producing district of Japan.

Cultivation Districts and Species

Although Kombu grows extensively along the coasts of northern Japan, the distribution range of each species is divided into fairly well defined areas as shown in Fig. 1. On the other hand, the cultivation of Kombu is carried out only in those areas where Kombu of the highest quality and price can be grown so that the greatest profit can be made. For this reason, both cultivation districts and species are severely limited at present. The following is a list of those districts in which Kombu cultivation occurs on a commercial scale and of the main species which are utilized.

I. Hokkaido
1. The southwestern district (Oshima Province)
   Laminaria japonica (Ma-Kombu)
   Laminaria angustata (Mitsuishi-Kombu)
2. The northern district (Soya Province)
   Laminaria ochotensis (Rishiri-Kombu)
3. The eastern district (Nemuro and Kushiro Provinces)
   Laminaria diabolica (Oni-Kombu)

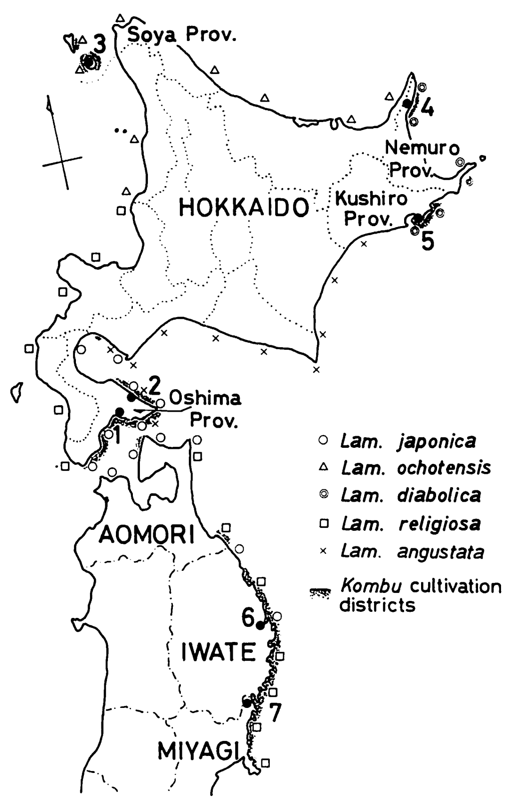

Fig. 1. Distribution of five *Laminaria* species and their cultivation districts dotted along the coast of northern Japan. The numbers 1-7 correspond to those of the locations in Fig. 2.

Ⅱ. Honshu, in the prefectures of Aomori, Iwate and Miyagi
Laminaria japonica
Laminaria religiosa (Hosome-Kombu)

Of these cultivation districts, Oshima Province in southwestern Hokkaido is Japan's leading Kombu cultivation center where 70% of the cultivated Kombu is produced. Originally, this province was recognized as the most famous natural Kombu producing district and *Laminaria japonica,* the main species gathered there, is the best in terms of quality and price. However, the annual yield of this Kombu is not as great as that of other lower ranked species such as *Laminaria longissima* which grows on the coasts of Kushiro and Nemuro Provinces. *Laminaria japonica* production is less than 15% of the total production of Kombu in Hokkaido. In order to increase this percentage, farmers and reserchers have devoted a great deal of time to the development and improvment of Kombu cultivation.

Water Temperature of the Cultivation Grounds

Figure 2 shows the seasonal change of water temperature at seven representative locations where Kombu cultivation is currently carried out. As shown in this figure, the water temperature differs about 5°C between the northern and the southern locations, and this difference in water temperature shows the specific temperature range for the species of Kombu cultured in each location. The water temperature range which is suitable for the growth of all cultivated Kombu species seems to be between 5 and 20°C. In the northern locations such as Rausu and Akkeshi where ice floes occur in winter, the temperature range is lower for such hardy species as *Laminaria diabolica.*

The Fundamental Procedure for Kombu Cultivation

Kombu has the *Laminaria* type of life history which consists of an alternation in life forms between the microscopic gametophyte (n) and macroscopic sporophyte (2n). The success of Kombu cultivation depends on the scientific control of the growth and maturation of the plant throughout its entire life cycle. Kombu cultivation is divided into two steps: artificial seedling production in special facility on land and farming on cultivation apparatus in the sea.

(1) *Seedling production*

Seedling production consists of the control of spore release and the subsequent culture of zoospore germlings on an artificial substratum. This work is carried out in a facility provided with seeding and culture room which has equipments to control water temperature, light, nutrient and other conditions.

Synthetic strings of about 3 mm in diameter are used as the substratum for seeding. These strings consist of three strands of

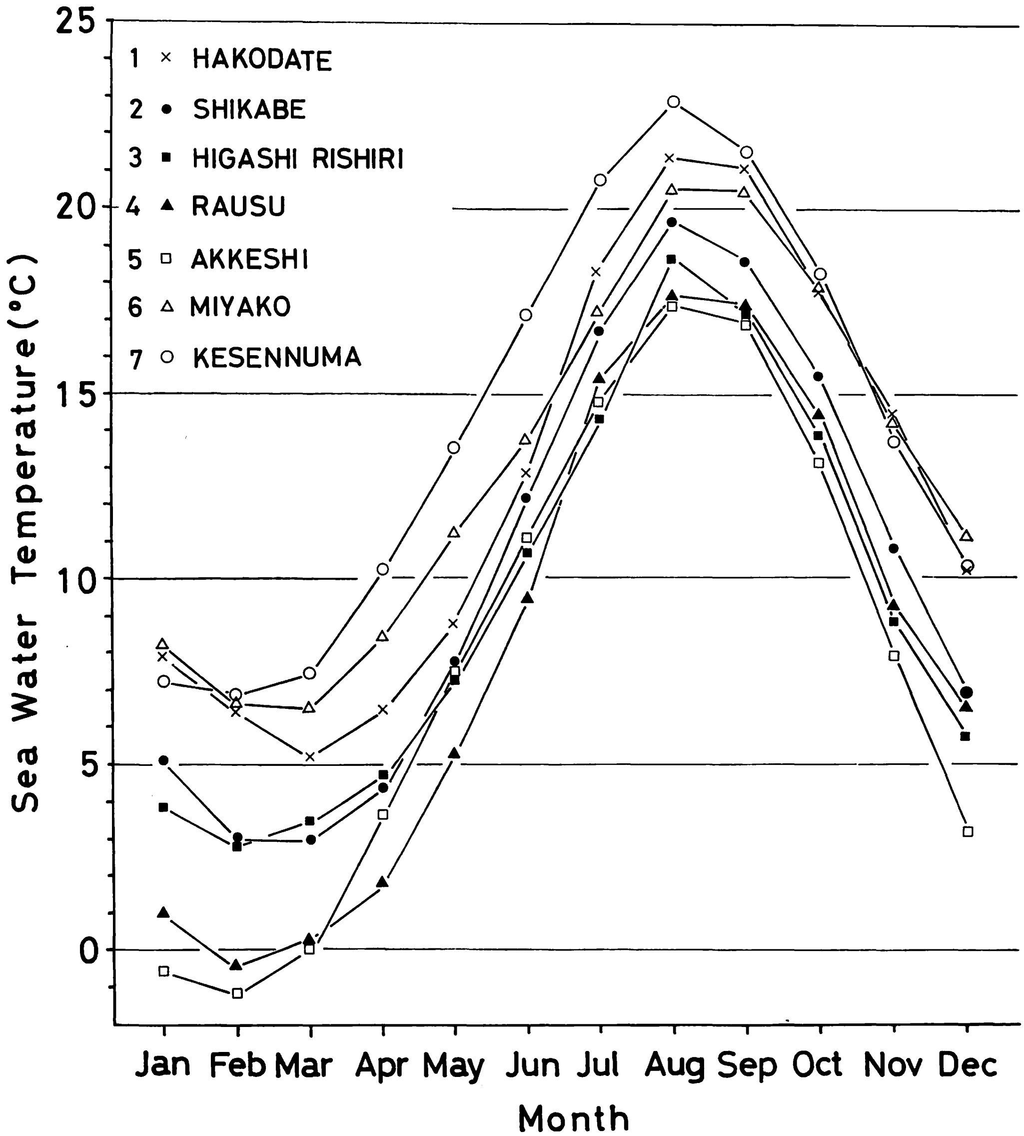

Fig. 2. Monthly changes of water temperature at seven locations where Kombu cultivation is carried out. The location numbers correspond to the numbers in Fig. 1.

different thickness which are twisted together and treated with an artificial resin to prevent unravelling. The strings are rinsed in running freshwater for several days, dried and then wound around a plastic frame to make a spore collector as shown in Fig. 3.

Before seeding occurs, a tank is filled with sterilized seawater which is maintained at about 15°C, and 1.023-1.025 in specific gravity. Well matured plants, usually collected from natural Kombu grounds the day before, are dried in a dark and cool place for about a half day. The plants are then placed into the tanks and within a half hour the zoospores are released in great numbers. This spore suspension is poured into the seeding tank filled with sterilized seawater (Fig. 4). At this point the concentration of the zoospores in the seeding tank is important in order to allow for adequate

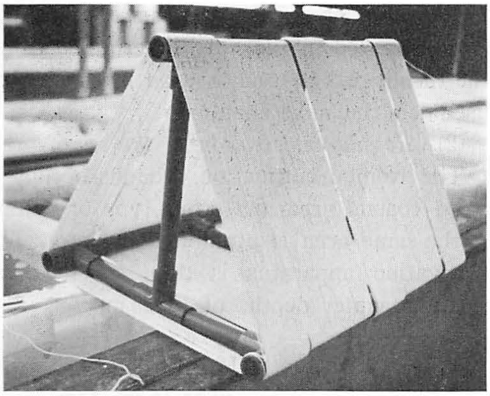

Fig. 3. Spore collector. Synthetic string used as substrate for the seeding is wound on a triangular frame made from plastic pipe. One collector contains about 300 m of string, of which 200 m is used in practice.

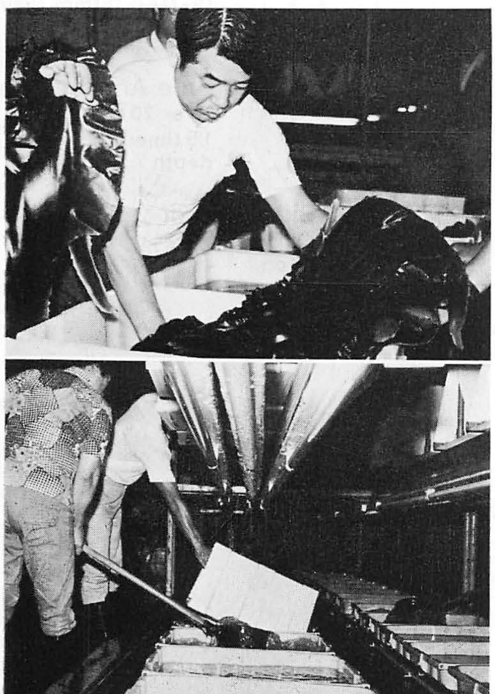

Fig. 4. Artificial seeding work on land.
The upper picture: mother blades with mature zoosporangial sorus are soaked in seawater, then, zoospores are released in great numbers in tank. The lower picture: zoospore suspension is poured into clean sea water in seeding tanks and immediately thereafter spore collector is submerged in the tank.

germling growth on the strings. This concentration should be about 5-10 zoospores in a field when one drop of the seawater is applied to a slideglass and viewed under the microscope at a magnification of 150. The spore collector is immersed into the tank immediately after adding the spores. The time required for the spores to settle on the strings varies with water temperature, but it is usually completed in about 24 hours when the water temperature is around 15°C.

After the seeding, the spores on the strings grow into gametophytes. These gametophytes in turn produce young sporophytes.

This culture of germlings is generally carried out from the end of August until the end of November. During this period the temperature of the seas around Hokkaido decreases from about 20 to 10°C. The temperature required for the gametophytes to produce young sporophytes is about 13-15°C. Therefore, in order to accelerate the seedling production, the culture water must be cooled to less than 15°C if the culture starts in summer or early autumn season. In the culture room, the culture tanks are arranged in large, shallow concrete pools ($8\times2\times0.5$ m) into which is pumped freshwater cooled at a temperature of 13-15°C by cooling device. But, in order to keep costs down, a simple cooling method, fresh spring water at a temperature of about 15°C, is used in some facilities.

White fluorescent lamps are used for the culture of germlings as the conditions vary too much according to the daily change in weather. Generally, the light intensity required is 3,000 to 6,000 lux with a light period between 12 to 16 hours.

Prior to 1970 the nutritional requirements for seedlings were poorly understood, only nitrogen and phosphorus being added to the culture seawater in accordance with the Schreiber's prescription. As a result of work by TATEWAKI (1966) PROVASOLI's ES solution with the addition of iodine was used, resulting in dramatic improvement in seedling growth. The seawater is changed every 10 or 15 days and, at the same time, nutrients are added. During the culture period light aeration is applied.

When the conditions are right, the gametophytes will mature in about 7 days after the culture started and in about 3-8 days after that, embryonic sporophytes start to grow. In about 45 days, the thalli have grown up to 5 mm in length. However, depending on the culture conditions, this period can be longer. The time when seedling production occurs and the length of the culture period in tank are determined as to the needs of the cultivation method to be used (cf. the next chapter).

(2) *Regular cultivation in the sea*

The Kombu cultivation grounds occupy a fixed coastal area and other type of fishing in the same area is prohibited by law. The cultivation apparatus is then set in these areas at water depths of 15-25 m.

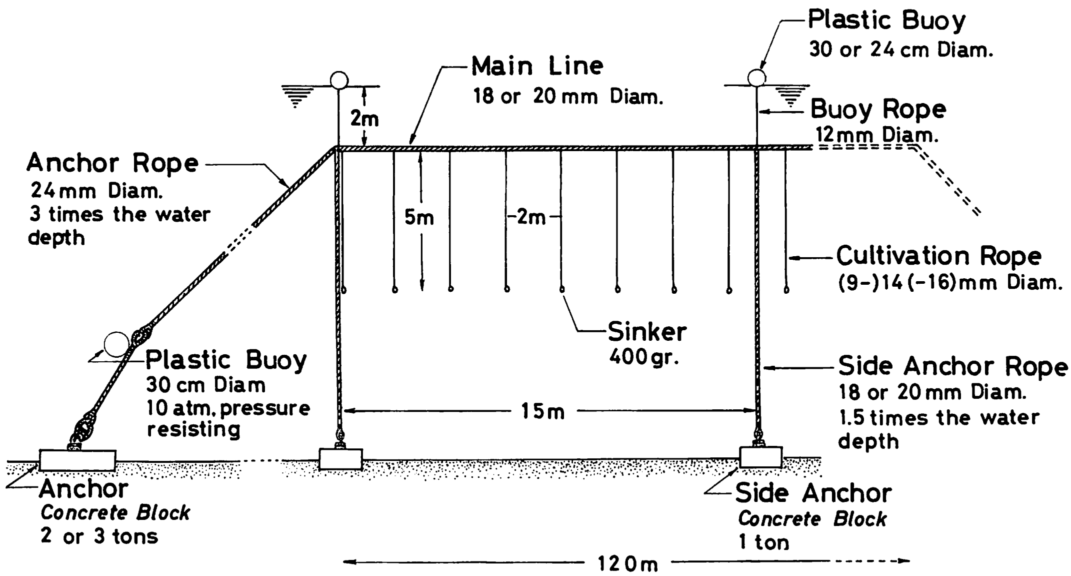

Fig. 5. Profile of a standard Kombu cultivation apparatus (*Noren Shiki*) used in southwestern Hokkaido.

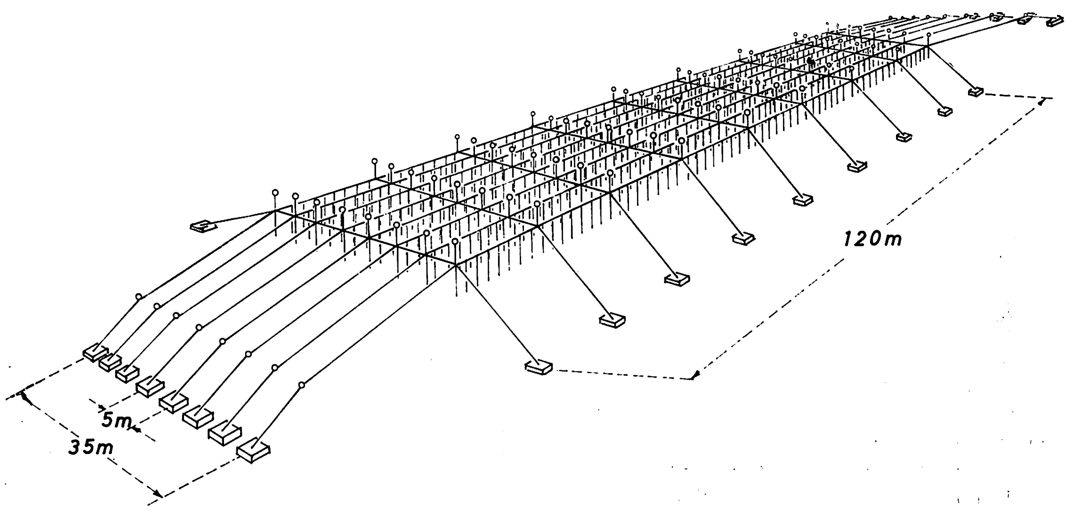

Fig. 6. An overview of the practical arrangement of the Kombu cultivation apparatus set in the cultivation ground.

Standard cultivation apparatus is a long line style of 120 m in length which is made of synthetic fiber ropes, synthetic buoys and concrete block anchors to make a large scale set. The sets are fixed firmly so as to prevent damage from large waves (Figs. 5 and 6).

The next step in the sequence of cultivation in the sea is provisional outplanting of the previously cultivated germlings (sporophyte). The seedling strings are first distributed to the fishermen, who then hang the strings in the sea under natural conditions so that healthy sporophytes will grow and adapt to these conditions (Fig.7-A). This provisional outplanting lasts 7-10 days and during this time weak sporophytes germlings will fall off naturally from the strings.

After that, the strings are cut in 5 cm lengths and are inserted into the cultivation ropes at 30 cm intervals for the regular cultivation (Figs. 5 and 7-B). Then, these ropes are hung vertically from the main line of the cultivation apparatus at 2 m intervals

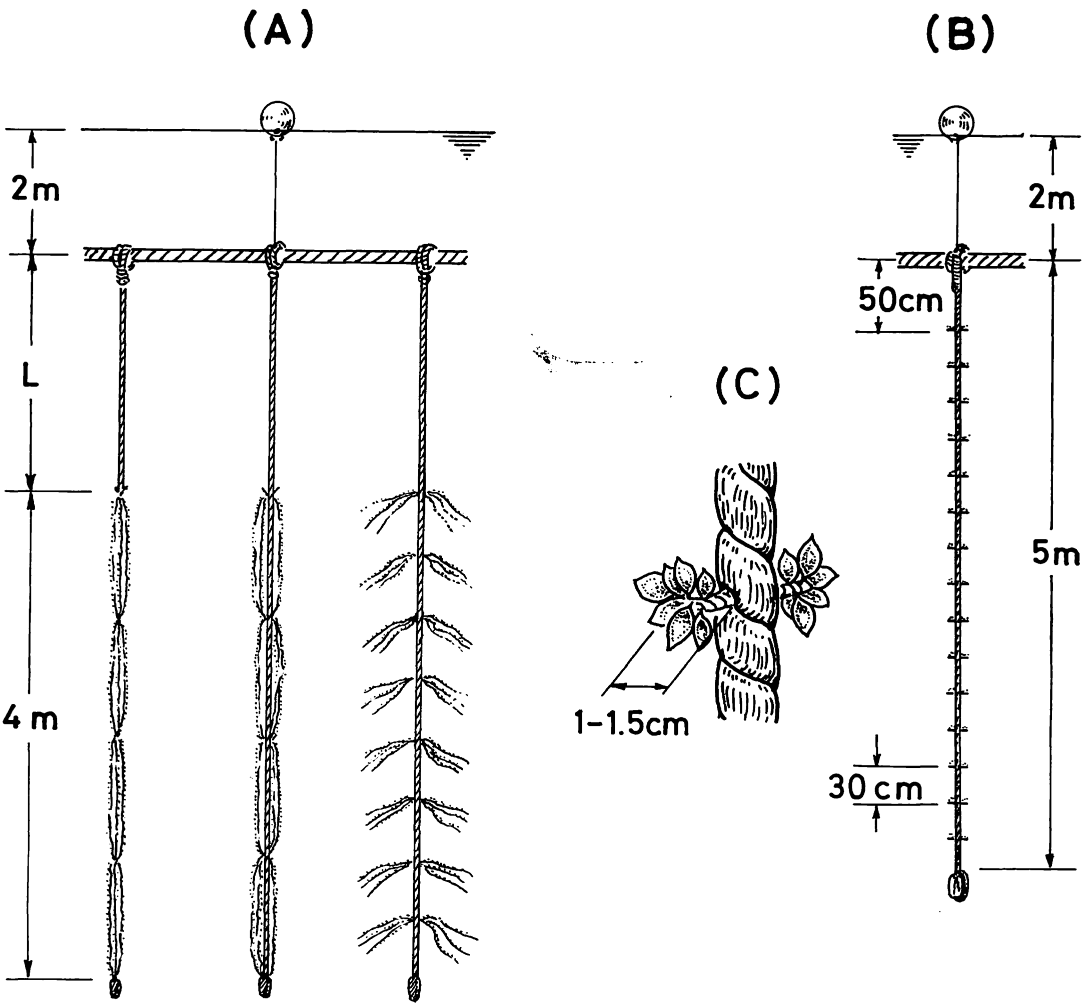

Fig. 7. Processes for the outplanting of seedlings. (A). Three examples of hanging seedling strings for provisional outplanting. L is 5-7 m at the beginning, but is gradually shortened to 1.5 m; (B). Fixation of seedling strings to cultivation rope by the insertion method for regular cultivation; (C). Detail of inserted seedling string.

(Figs. 5 and 7-B), or, alternatively, the ropes are stretched horizontally and fixed into the main line directly. The former is called *Noren Shiki* in Japanese (Vertically Hanging Method) and is used widely in the southwestern district of Hokkaido, and the latter, *Hae-nawa Shiki* (Longline Method) or *Suihei Shiki* (Horizontally Stretching Method), is used in the eastern and northern districts of Hokkaido and Honshu.

The depth at which the main lines are set varies according to such environmental conditions as transparency of water and wave action at each location. For example, in southwestern Hokkaido this depth is 2 m but in the northern and eastern districts it is about 5-7 m. However, in the eastern district where there are ice floes from January until April, the entire cultivation apparatus sinks below the ice close to the bottom which is more than 20 m in depth. This way the apparatus is protected from damage by large floes.

From spring to summer of the year of harvest, during the season when growth is good, the main lines are raised gradually until they are almost to the water surface so that the Kombu is well exposed to sunshine. In this way the quality of the plants improves due to an increase in photosynthetic production.

In addition to controlling the cultivation depth, it is very important to thin out excessive plants from the cultivation ropes to prevent overgrowth and to promote Kombu of good quality. Of the plants remaining on the ropes, those which are not firmly attached are bound lightly with soft synthetic tape to prevent them from being washed away. Daily maintenance of the cultivation apparatus including removal of all epiphytes is also important during the entire cultivation period.

Representative Methods of Kombu Cultivation

The three representative methods of Kombu cultivation which are actively used in Hokkaido are diagramed in Fig. 8.

(1) *Two Year Cultivation*

All the cultivated Kombu in Hokkaido are biennial plants. The two year cultivation is a very orthodox method to reproduce faithfully the life cycle of the natural biennial Kombu. It was the first cultivation method attemped in Hokkaido and is even now widely used as a basic cultivation method in the eastern and northern districts as well as in a part of southwestern district of Hokkaido.

In this method, seedling production starts from October. After that, plants are left to grow through two winter seasons and harvested in July and August after three calender years. Consequently, this method produces two year Kombu which is almost of the same quality as the natural plant. However, the biggest problem with this method is that it takes more than twenty months from seeding to harvest and it results in a comparatively high price of the products.

(2) *Cultivation by Transplanting*

Kombu is able to attach not only to rocks but also to ropes, wooden posts, piles and other substrata in the sea. This ability is most pronounced from winter to spring when the activity of the meristem increases and new holdfasts are formed. During this time the fishermen can successfully thin out the excess fronds completely with holdfast from the cultivation ropes and transplant by fastening them onto a new rope with thin, soft tape.

In about ten to fifteen days new haptera grow and fix the frond firmly to the new cultivation rope. Natural Kombu which has been washed up on land by storms is also used sometimes.

The advantage of this method is that it conserves manpower and materials. It is often combined with the other cultivation methods in order to increase production as shown in Fig. 8.

(3) *Forced Cultivation*

Because the two year cultivation method takes over twenty months to complete, there can be only one harvest every two years at one fishing ground. To try to solve this

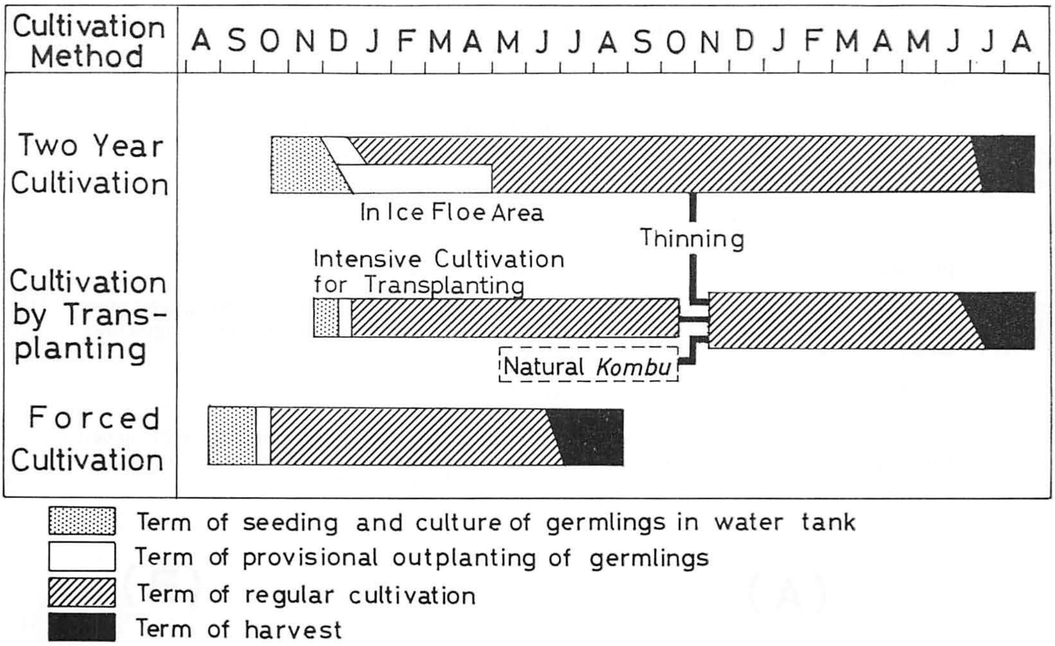

Fig. 8. Diagramatic flow chart of three representative Kombu cultivation methods in Hokkaido.

problem, HASEGAWA (1971b 1975) and his coworkers worked from 1966 to 1970 to create a method that would cut the production time in half, but yet would produce plants of the same quality as the two year Kombu at Minamikayabe, the most famous Ma-Kombu producing district in Oshima Province, Hokkaido. The epochmaking new cultivation technique that resulted from this research is called "Forced Cultivation". This method has since spread widely to southwestern Hokkaido and now the production by this method accounts for 92% of the total cultivated Kombu produced in this district.

There are four basic technological features concerning the forced cultivation method.

Firstly, seedling production is done as early as possible. Usually, in southwestern Hokkaido, the seeding is carried out from the end of August to the middle of September. This seeding period is about 30-45 days earlier than that of two year cultivation. The subsequent culture of zoospore germlings in tanks is continued for about 45 days under the conditions as shown in Table 1 (Fig. 9).

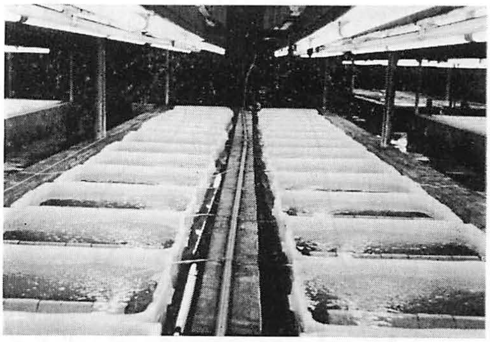

Fig. 9. The seedling production facility for forced cultivation. Seedlings are cultured in tanks under severely controlled conditions of water and light.

Secondly, regular cultivation in the sea begins immediately after the water temperature of fishing ground reaches 18°C or less. This is around the middle of October in southwestern Hokkaido.

Thirdly, the Kombu must be grown as quickly as possible when the water temperature is lowest. This is in winter up to the end of February when the water temperature is 3-5°C. Because the Kombu grows quickly and densely on the

Table 1. Culture conditions of seedlings in the forced cultivation of Ma-Kombu (*Laminaria japonica*)

Water temperature	13-15°C
Light intensity	For the first week: 2,000 lux For the second week: 4,000 lux Thereafter: 6,000 lux (With white fluorescent lighting)
Photoperiod	12(-16) hours light
Changing of culture water	All the medium is changed first two weeks after cultur bigins, thereafter the half is changed once a week.
Aeration	Aerate slowly
Nutrients	ESI medium (Provasoli's ES medium with added iodine of 1 mg per *l*) is added (2%) to each renewed culture water.

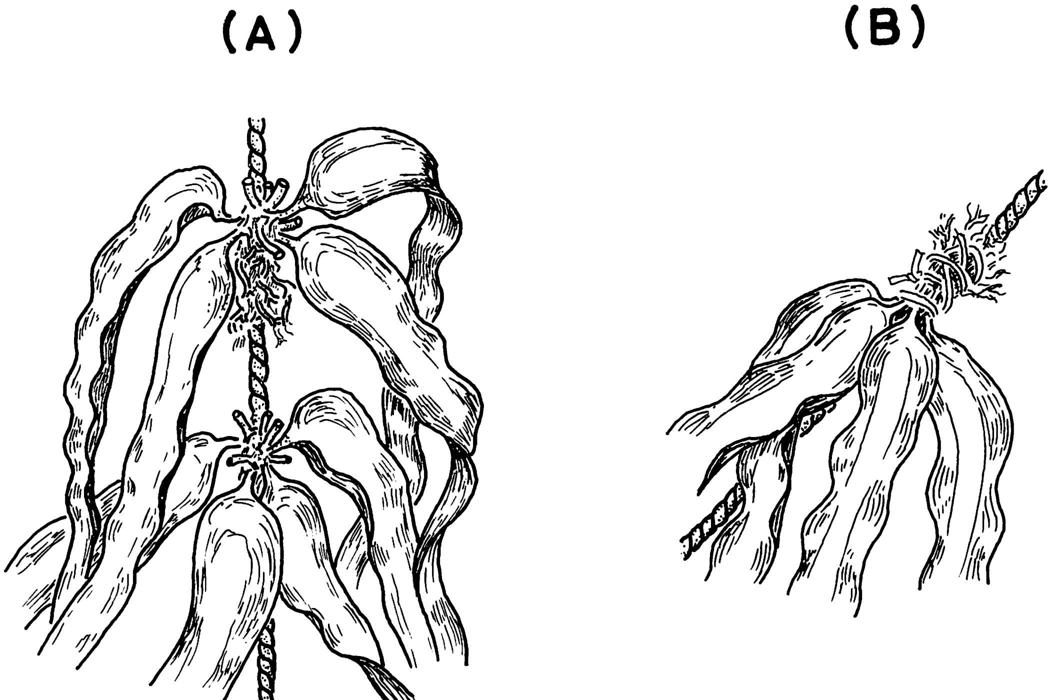

Fig. 10. Treatment to accelerate growth and prevent loss of plants. (A). Thinning of excessive plants; (B). Binding of unstable holdfats with tape.

cultivation ropes, the fishermen must drastically thin them out during midwinter, from the end of December to the beginning of March. Finally 4-5 plants remain where each piece of seedling string was originally inserted in the cultivation rope (Fig. 10-A). This corresponds to 12-15 plants per meter of cultivation rope. At the same time, since the sea is very rough during winter, it is important to secure weak haptera to the ropes with thin, soft synthetic tape in order to prevent the plants from being washed away (Fig. 10-B). At present, the forced cultivation method does not adapt well to the fishing grounds in northern and eastern Hokkaido because such exacting work as thinning and fastening the plants is very difficult to do under the much harsher winter conditions found in those areas.

Fourthly, it is to insured that the Kombu receives proper exposure to the light. Beginning from March the weight and length of the blade increase with increasing photosynthetic activity. To increase light exposure, the vertically hanging cultivation rope is raised gradually to within 2 meters of the water surface. At this point the rope is secured horizontally with its lower end attached to the neighbouring main line. This should be completed by the end of May and, as a result, all the plants should be exposed to uniform light conditions. In the last stage of regular cultivation, the horizontally secured ropes are raised further to within half a meter of the water surface (Fig. 11).

Up to the present, the theoretical basis of forced cultivation has not yet been solved satisfactorily from the physiological point of view ; but a great deal of interest is taken in ecological phenomena by practical cultivation experiments. The force cultivated biennial plant grows very rapidly for four months around March when the water temperature is at its lowest. On those plants which grow especially rapidly, distinct zoosporangia begin to form near the upper end of the blade around February. After this, as the blade continues to grow, its apical portion withers and is washed away. Then, in late summer when the plant has attained a sufficient size and weight, the blade produces zoosporangia for the second time on the basal portion. This process of producing zoosporangia two different times is in common with typical biennial Kombu which produces zoosporangia once on the first year blade and then again on the second year one. Namely, it can be seen that the force cultivated Kombu com-

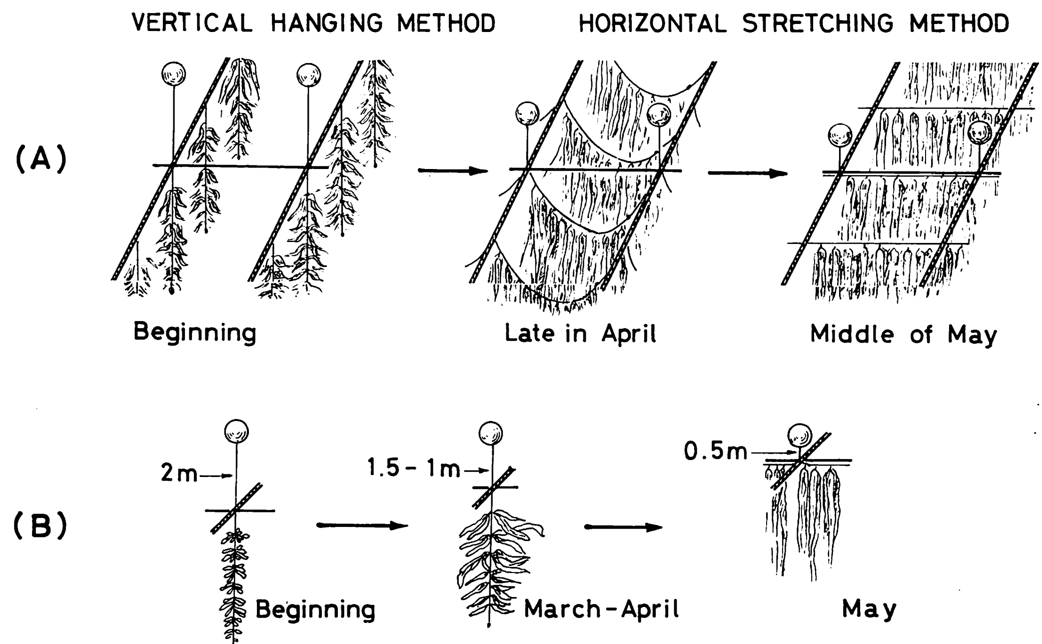

Fig. 11. Methods for growing high quality Kombu. (A). Alteration from vertical hanging method to horizontal stretching method; (B). Raising the cultivation ropes to increase light exposure.

pressed the life span of the natural biennial Kombu into only one year and is quite different from natural annual Kombu which produces zoosporangia only once in a lifetime (Fig. 12).

Growth and Quality of Force Cultivated Kombu

(1) *Growth*

An investigation into the forced cultivation techniques using *Laminaria japonica*, Ma-Kombu, was carried out by FUNANO and ISHIKAWA (1974) from November 1972 to August, 1973. Fig. 13 shows the seasonal changes of blade length, width and wet weight, as well as the substantiality value which is the ratio of blade weight to area. Fig. 14 shows the seasonal changes in apparent daily increase for the same parameters. There are four distinctive features which can be seen in these figures as follows:

(i) As determined from an average of forty-five plants taken at harvest time, the blade length is 500 cm, the blade width is 18 cm and the blade wet weight is 1,250 g.

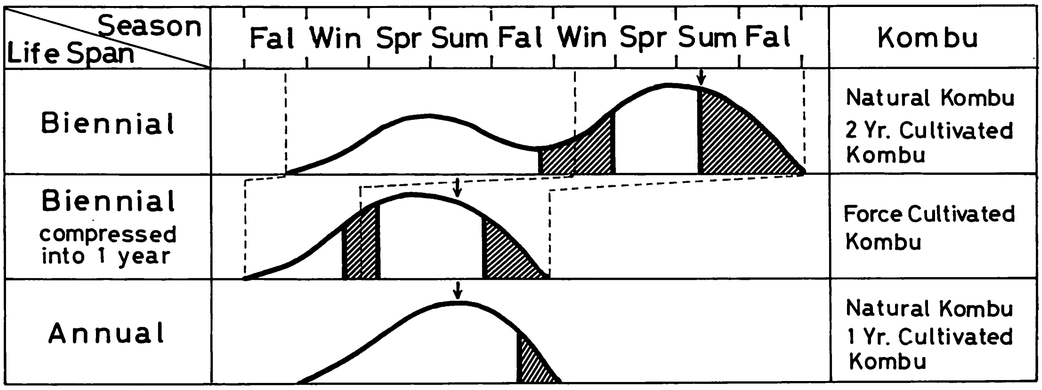

Fig. 12. Diagramatic representation of the life history of Kombu having three different life spans (sporophyte stage). The ordinate approximately indicates the relative rate of sporophyte length. The shaded portion denotes the reproductive season and the arrow the beginning of harvest season.

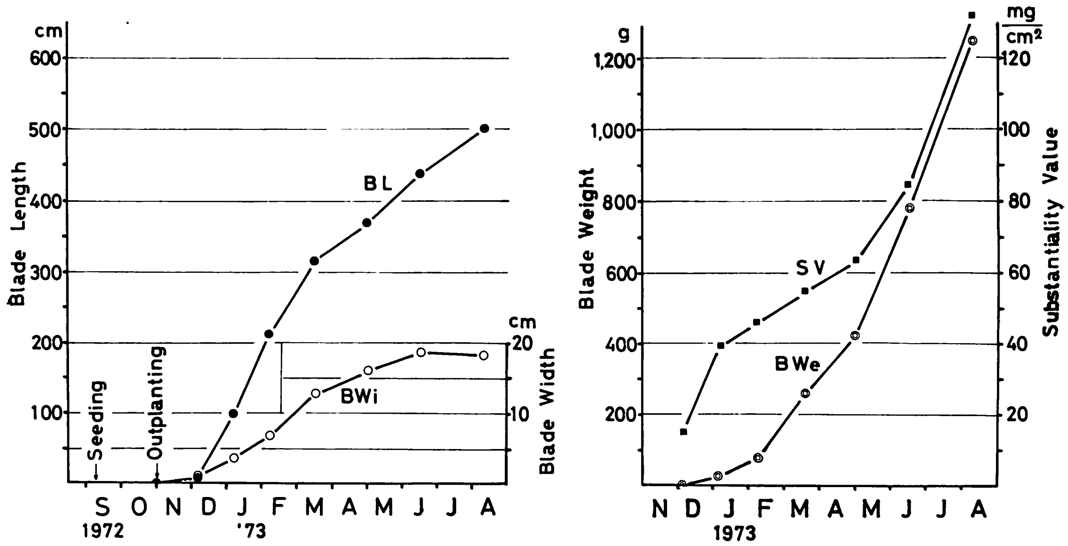

Fig. 13. Monthly changes in the average blade length, width, wet weight and substantiality value of *Laminaria japonica* during forced cultivation. Redrawn from FUNANO and ISHIKAWA (1974).

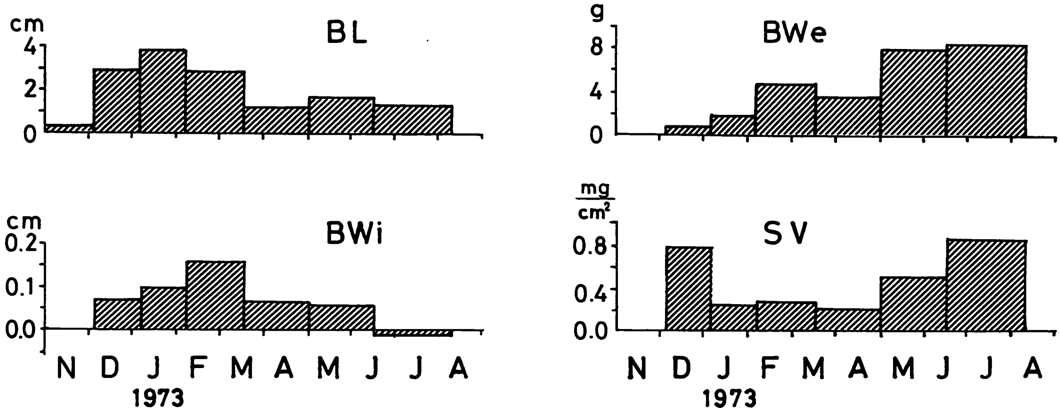

Fig. 14. Monthly changes in the daily apparent increase in blade length, width, wet weight and substantiality value of *Laminaria japonica* during forced cultivation. Redrawn from FUNANO and ISHIKAWA (1974).

(ii) The blade length increases rapidly during the winter season from December to March. After March, from spring to summer, growth slows down. The peak of apparent daily growth is from the beginning of January until the beginning of February and is about 3.6 cm per day.

(iii) The increase in blade width follows the increase in blade length. The peak of daily growth in blade width is from the beginning of February until the middle of March and is about 0.16 cm per day. However, from the middle of June, there is a slight decrease in blade width.

(iv) Whereas the increase in blade length begins to slow in March, the blade wet weight increases rapidly, producing Kombu of high quality. The apparent daily increase in wet weight peaks at 8 to 8.5 grams per day during this period.

(2) *Quality*

To determine instantly whether the Kombu is high enough in quality for consumption before harvesting, a method which utilizes blade length and width in centimeters, and blade wet weight in grams is used. Using these three factors in a formula of weight times 1,000 divided by length times width, gives the substantiality value in a unit of milligram per square centimeter as shown below (KAWASHIMA 1972):

$$\frac{\text{Weight (g)} \times 1{,}000}{\text{Length (cm)} \times \text{Width (cm)}}$$

$$= \text{Substantiality Value (mg/sq·cm)}.$$

It is known from long experience that at the start of the harvest at about the end of July the substantiality value of natural Kombu is usually about 100–120. As the season progresses, the value further increases to 150 or more. As the graph in Fig. 13 shows, the value for force cultivated Kombu is 137 at harvest time which is of a sufficiently high quality (Fig. 15).

Studies on the chemical components of the force cultivated Ma-Kombu have been conducted by OHISHI and KUNISAKI (1970) and FUNAOKA *et al.* (1974). In force cultivated Kombu, glutamic and aspartic acids, proline and alanine changed most remarkably through the culture period. The content of glutamic acid increased considerably from April to July and proline and alanine increased in May and June, but then decreased in July. Consequently, in summer, the free amino acid composition of force cultivated Ma-Kombu becomes similar to that of natural two year Kombu (OHISHI and KUNISAKI 1970). On the other hand, the former plant contains more amino-nitrogen, total reducing sugar and crude fat than the latter (FUNAOKA *et al.* 1974).

Fig. 15. The harvest of force cultivated Ma-Kombu (*Laminaria japonica*) at Minamikayabe, Hokkaido.

In practical terms, force cultivated Kombu tends to deteriorate in quality more than natural Kombu even if they are handled in the same way. According to HASEGAWA (1978), this deterioration is probably due to changes in the quantities of intercellular substances during forced growth. At present, however, the quality of the Kombu has been improved by improving cultivation and processing techniques.

Productivity of Cultivated Kombu

In Japan, average annual yield of natural Kombu in 1970–1981 has been about 133,000 tons wet weight although the yield varies greatly each year according to the change in natural conditions (Fig. 16). In Hokkado, it has reached about 119,700 tons during the same period and account for about 90% of all the natural production in Japan.

On the other hand, full scale Kombu cultivation has been carried out since 1970 and the productivity has increased rapidly with the passing years, jumping from a total of 284 tons wet weight in 1970 to 44,220 tons in 1981, which accounts for about 28% of the total production of both natural and cultivated Kombu in Japan (Fig. 16). Hokkaido produced 73% of the total of cultivated Kombu from 1977 to 1981, while Iwate Prefecture was the second with 23% and Aomori and Miyagi Prefectures produced only 4% in total.

The objective of the Kombu industry in Japan has been traditionally to produce good quality Kombu for human foodstuff. The expectations of the Japanese people for cultivated Kombu are that it should be of the same quality as natural Kombu. Kombu is enjoyed by the Japanese but it is not a part of the staple diet. Instead it is used as an accompanying dish to meals and as a health food. Therefore, excessive production would lead to chaos in the market.

Until today, most of the processed foods

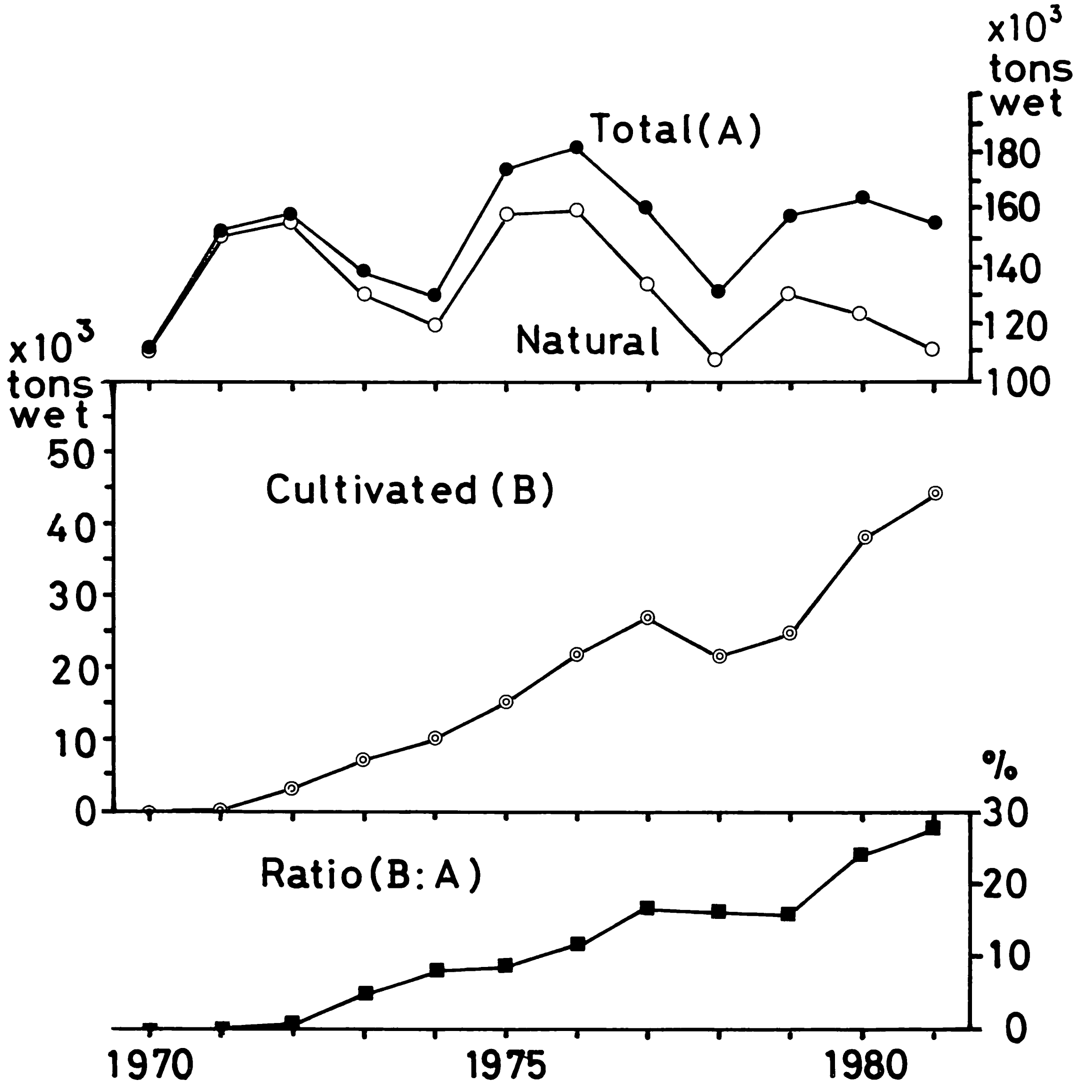

Fig. 16. Changes of Kombu production in Japan from 1970 to 1981, showing the total amount (A), natural, and cultivated Kombu (B), and the ratio of B to A. Data from Annual Report of Catch Statistics on Fishery and Aquaculture, 1970-1981 (Ministry of Agriculture, Forestry and Fishery, Japanese Government).

which contain Kombu have been manufactured entirely from dried Kombu. However, with recent improvements in processing techniques the changing tastes, new processed foods made from raw or salted Kombu have been developed and are highly favored. If new uses for Kombu as food develop, the productivity of cultivated Kombu could be still more raised in future.

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川嶋昭二：日本における食用コンブの養殖

日本人の嗜好的副食品や健康食品として広く親しまれているコンブは古くから天然資源に依存してきたが，近年技術の発達に伴って北海道，青森，岩手，宮城各県で養殖生産が盛んになってきた。主産地北海道ではマコンブ，リシリコンブ，オニコンブ，ミツイシコンブを用い，2年養殖，移植養殖，促成養殖が行われる。生産の主体である促成養殖は北海道南西部のマコンブ地帯に広く普及し，科学的に管理された人工種苗生産と長年の調査，経験に基づく本養成管理により約11か月で良品質のコンブを生産する。日本の養殖生産は1970年の284トン（生重）から1981年には44,220トンへと飛躍的に増加し，乾燥品の利用のほか，生鮮，塩蔵品の利用も進んできた。
(042 函館市湯川町1丁目，北海道立函館水産試験場)