マングローブ林の防災機能に関する研究 (V)
マングローブ林造成法に関する予備試験(林学科)

Studies on the Protective Functions of the Mangrove Forest against Erosion and Destruction

(V) Preliminary trials for the establishment of the mangrove forest as a coastal prevention forest*

Kazuhiro SATO**

Summary

In Malaita Island, the Solomon Islands, and Iriomote Island, Okinawa prefecture, preliminary trials had been made for the establishment of the mangrove forest of *Rhizophora stylosa* in a place where is no mangrove forest in the past.

The followings became evident after examining the observational results obtained.

1. On the raft moored in a inlet or port, the seedling transplanted in the pot fixed to the raft can grow.
2. The protection or support against the wave action is needed for the establishment of mangrove forest in a place without it under natural conditions.
3. At least in Okinawa, some kinds of seaweed that propagated and floated in the bay harm the seedlings transplanted or striked naturally their roots.
4. For the nutrient deficiency, the effect of a kind of slow-release fertilizer may regarded as significant also under the exceptional condition of the sea water.

Introduction

The various protective functions of mangrove forest under the natural conditions have been pointed out and made clear gradually.[1,5,7] For utilizing the functions still more positively, the afforestation methods have to be established under new and slightly harsh conditions. Though studies on the reforestation of mangrove in deforested area have been done by several researchers,[4] there are few reports about the afforestation under the circumstances of having no mangrove forest in the past.

I discribed here some trials for the establishment of the mangrove forest of *Rhizophora stylosa* in a place where hypocotyle could not naturally strike its root as the place was little deeper than the length of hypocotyle or was surged by the wave. I supposed that the place

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** Department of Forestry, College of Agriculture, University of the Ryukyus

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where the range of spring tide was not so wide, when it was low water of neap tide the depth was shallower than about one meter and usually high waves did not surge from the open sea. If we can develop a way for the afforestation of mangrove in such place, the area which can become the object of afforestation may be vast. And in such a place, the mangrove forest must become important as a prevention forest[5,7] and a forest for fish breeding moreover.[2,3,8]

Trials and results

I. Trials in Malatia Island

1) Trial I-No. 1

The trial of transplanting the seedlings of *R. stylosa* was done in Langa langa lagoon, on the west coast of Malaita Island in the Solomon Islands. Figure 1 shows a rough map of the surroundings of the trial places. The test place consisted of plots on the coral reef at a distance of 0.3 km or 1.1 km from the border of a mangrove forest of *R. stylosa.* Plot No. 3 was at the waterside of the small island called Rarata. Two kinds of seedling were transplanted at the beginning of November, 1980. The one was about 30 cm long within several weeks after striking its root and the other was about 1 m long within about one year. The root of seedling was put in the hole dug with an iron bar, covered with coral sand and buried with coral gravel and blocks.

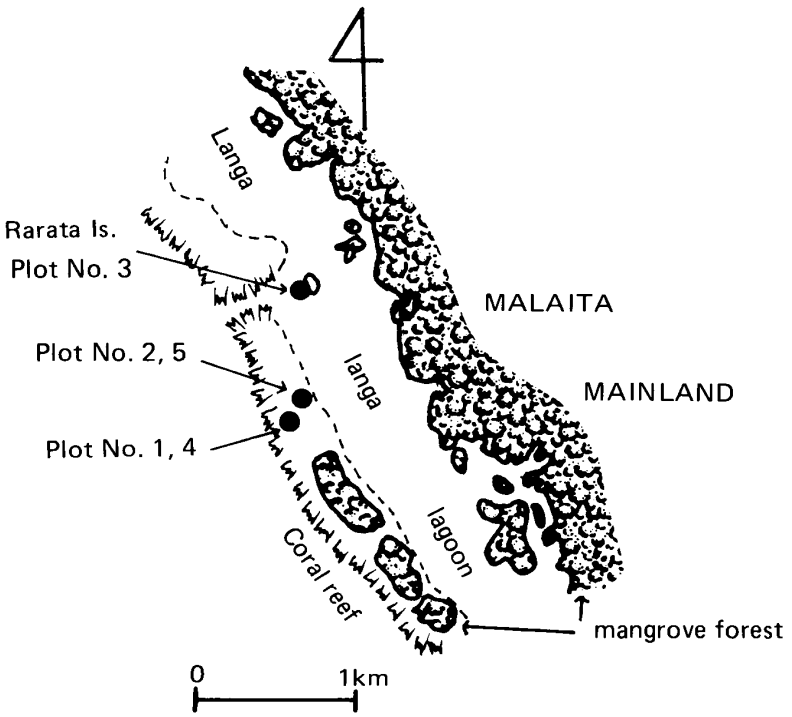

Fig. 1 Rough map of surroundings of test place in Langa langa lagoon

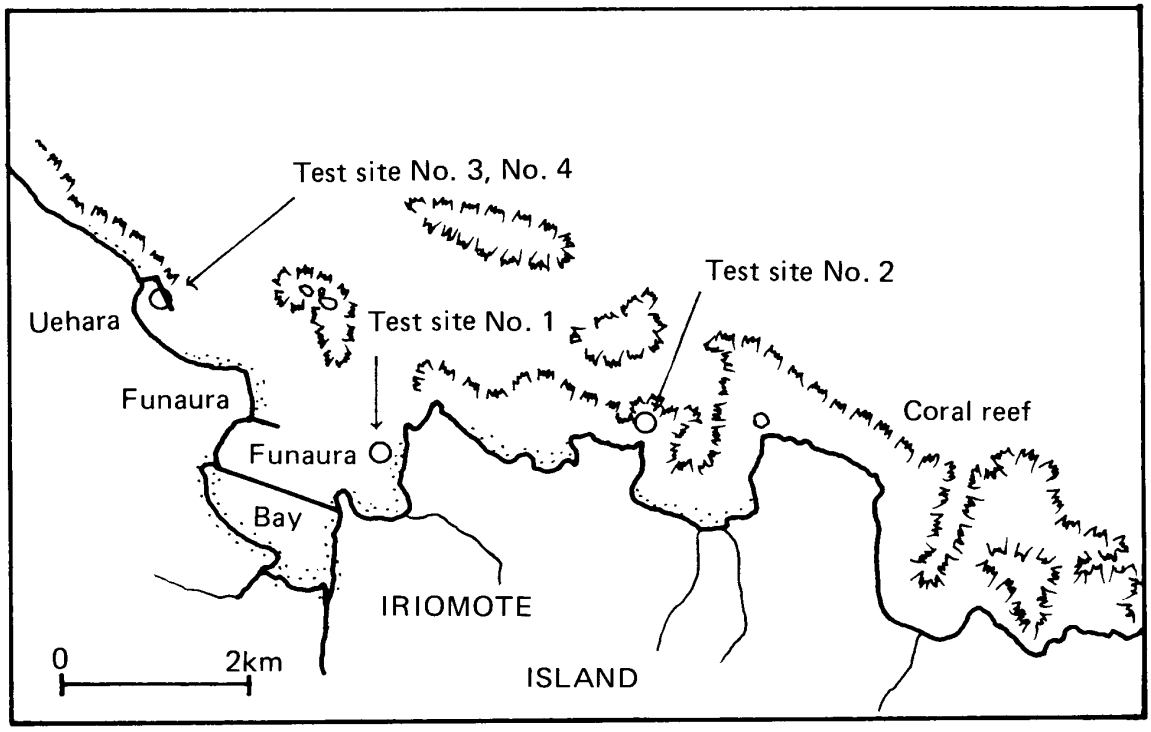

Fig. 2 Rough location map of test sites in Iriomote Island

Table 1 shows the later circumstances. Though the sea had lulled for one week after transplanting, 28% of the seedling (A) transplanted and 32% of the seedling (B) were lost in average. After six months, no one survived without exception. It is conjectured that probably all seedlings had been lost for a term not so long after the transplanting.

2) Trial I-No. 2

Simultaneously with the transplanting trial on the coral reef, young trees of *R. stylosa* of about 1.7 m in tree height were transplanted in the pots fixed to rafts. The surface of the mud filled a pot was covered with coral gravel, which was covered with net. Logs of diameter about 20 cm were used to make rafts. Insufficient buoyancy was supplented with some floats for aquaculture. Two rafts attached nine pots were moored with anchors at a depth of about 5 m in a small calm inlet near Lade in Langa langa lagoon[5,6]. After some days, lower several leaves of all tree transplanted had changed their color to yellow and the whole of tree was slightly enfeebled. This may be because of the damage of root by transplanting. But, later, all trees got well again.

After six months, three pots fell off the raft as the parts attached to raft had been broken by roll of raft. But the three trees removed in shore were vigorous. All trees on the rafts also were vigorous, so no one was dead. For six months, the height growth of about 10 cm and the elongate growth of prop root apex in water were recognized. Logs used for the raft had been bored a great number of holes by sea worms. When a raft is moored for a long term, the durability against sea worms will become a serious ploblem. It was observed that many small fishes gathered below the raft.

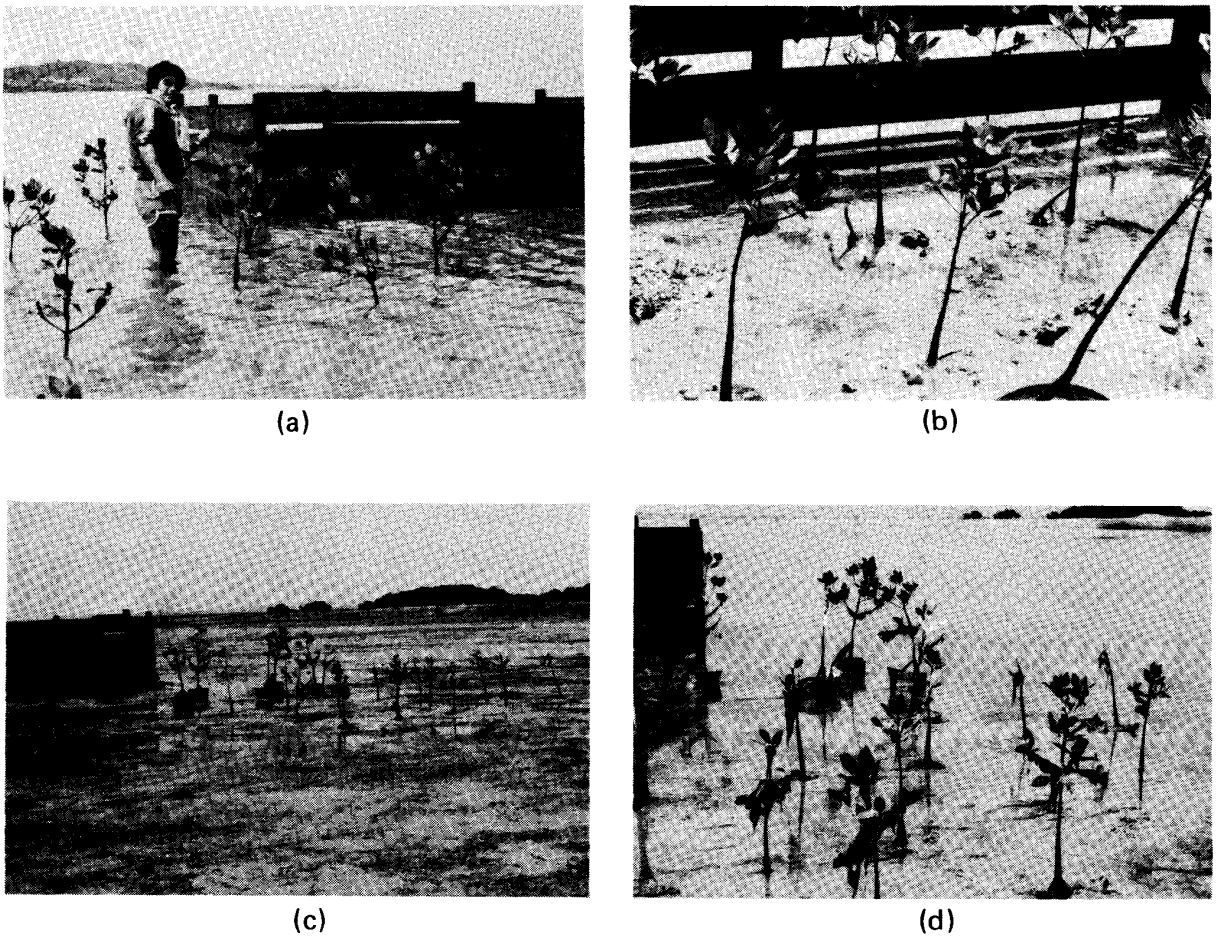

Fig. 3 Photos of trial II-No. 1, (a) apperance of wooden fence and seedlings in periphery of fence (b) inside circumstance of fence (c) circumstance in periphery of fence (d) seedlings clung by seaweeds

II. Trials in Iriomote Island

The following four trials on transplanting the seedlings of *R. stylosa* were performed in Funaura bay and neighborhood, on the northern coast of Iriomote Island in Okinawa prefecture. The purposes of these trials were divided roughly into two, the one was a comparison between the way directly transplanting the seedlings and the way striking the roots which spread out from the pot planted, and the other was an examination of the effects of a protection against the wave action. The seedlings transplanted directly were planted on 27 June, 1980. The mean seedling height was 52 cm. The seedlings were transplanted to each trial place at the beginning of March, 1983. The Yaeyama Islands was hit by Typhoon No. 10 on September, 1983. It was estimated by the record of the nearest Ishigaki observatory that the northern coast of Iriomote Island was within the typhoon area with the winds of over 25 m/sec for 24 hours and the maximum instantaneous wind speed of about 40 m/sec. The wooden fences for a protection against the wave were almost destroyed

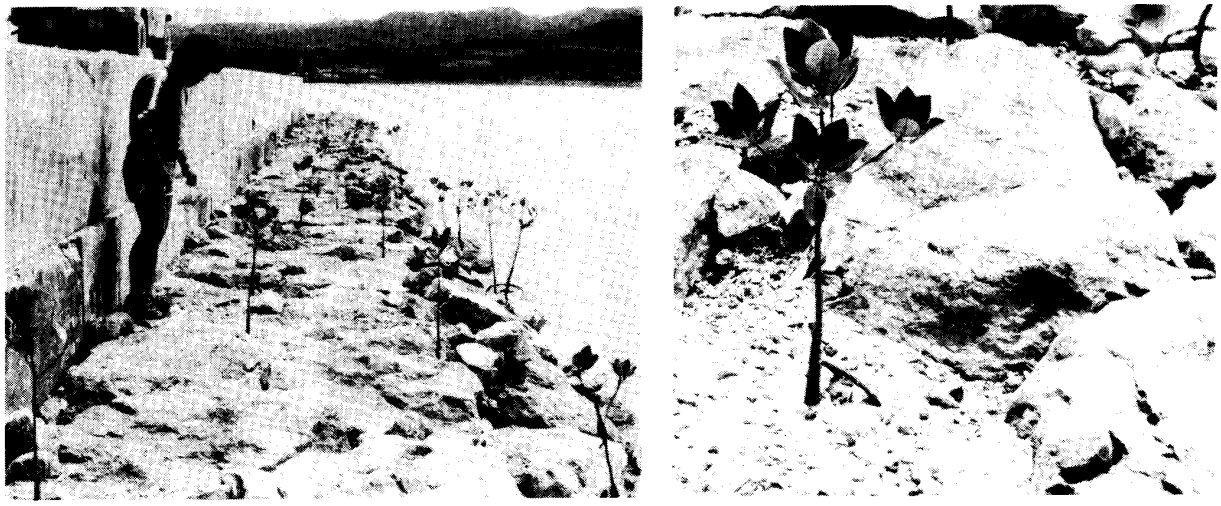

Fig. 4 Photos of trial II-No. 3, seedlings transplanted on riprap

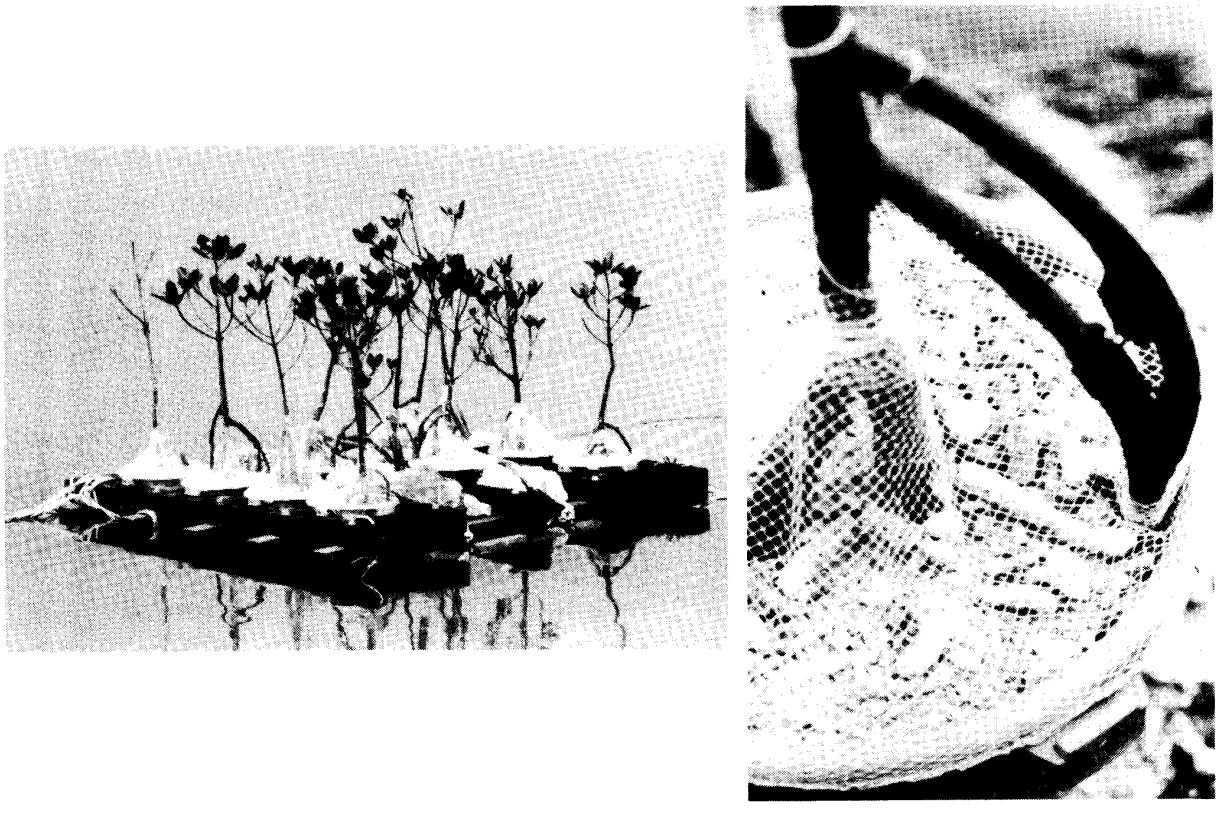

Fig. 5 Photos of trial II-No. 4, seedlings on raft and covering net

and washed away, but on the raft a float was only chipped a little. Table 2 shows the change of state of seedlings after the transplanting to each trial place.

1) Trial II-No. 1

The fence of four meter square for protection against the wave was made at about 140 m away from the shore. This trial place was on the east coast of Funaura bay and calm relatively. The bed materials were tidal mud deposit of sandy mud mixed with coral fragment. In the fence, the seven pots placed with seedlings of about 1 m tree height were buried half and fifteen seedlings were transplanted directly, and also seven pots were set and fifteen seedlings were transplanted in the periphery of the fence. Just after the beginning of this trial, leaves were injured by the antiseptic coating the boards and pillars of the fence. In the fence the degree of damage was more serious than in the periphery of it, and especially the damage of the seedlings planted in pots was the most serious, therefore, many leaves of these seedlings fell. The cause of the above difference was considered to the exposure above the surface of the water for a relatively longer. All seedlings were clung severely by green laver and some kinds of seaweed that propagated and floated in the shallows and mud flat in the bay early summer. These seaweeds clung and drew down the seedling sometimes as they resisted against the flow and wave like a sea anchor. The leaves clung and covered with the seaweeds were withered, because the seaweeds on the leaves got dry and formed a hard mass at fine and low tide. The fence was destroyed and washed away completely by Typhoon No. 10 in 1983.

2) Trial II-No. 2

The fence similar to the trial II-No. 1 was made on the coral reef at about 160 m away from the shore. The base of a pillar was set with concrete on the coral reef. There was scarcely any sediment, however, coral sand, gravel and fragment gathered only in the small hollow and narrow drain on the coral reef. Though the number of the seedlings or pots in the fence was same with the trial II-No. 1, ten seedlings were transplanted and no pot-planted seedling was placed in the periphery of the fence. The damage by an antiseptic was slight as the boards and pillars had been soaked in the sea water for one night on the day before making the fence. Although the seaweeds injured seedlings, the damage was not so serious. The sediment couldn't strongly hold down the root of seedlings because of the shallowness of the sediment in the small hollow and narrow drain and the coarseness of coral-sand containing less silt and clay. Thus, many seedlings were slanted or pushed down by the flow and wave in a short term after transplanting. In July of 1983, the nutrient deficiency was observed on the survival seedlings. The boards of the fence were all washed away by the typhoon but pillars remained.

3) Trial II-No. 3

Twenty seedlings were transplanted in the gaps of the riprap for the inside foundation of the waterbreak of Uehara fishing port. Before the transplanting, the gap of the riprap was filled with small cobble stones, gravel, coarse sand and fine sand, in order of size. For the prevention of scouring out the sand filled at the root in the gap, the bag of fishing net, packed with coral fragment, was placed on the gap like a gabion. Though all seedlings were vigorous after four months, only a few lower leaves of each seedling yellowed slightly. The seedlings planted in pot also yellowed their lower leaves. Therefore a kind of slow-release fertilizer was supplied for each seedling. Later, the leaves of each seedling changed its color to lively deep green and all seedlings became more vigorous. Under Typhoon

No. 10, thirteen seedlings transplanted directly on the riprap and three pots were washed away. Sand was supplied in the gaps for the remaining seven seedlings as the sand at the root was scoured out. In March of 1984, the remained one seedling transplanted directly and another one planted in pot were vigorous.

4) Trial II-No. 4

Twelve pots transplanted a wild seedling of about 1 m in height were fixed on the raft moored at Uehara fishing port. The first purpose of this trial was to confirm that the seedling of *R. stylosa* could grow in Okinawa under the similar conditions with the trial I-No. 2 in the Solomon Islands. The second was the establishment of tending manner on raft. As the nutrient deficiency was observed also in this trial, a kind of slow-release fertilizer was supplied. It was the largest cause for withering in this trial that the root was exposed as sand was washed away through the holes made to side and bottom of pot for water movement. The damage by typhoon was most slight.

Discussion

From the results of the trial I-No. 1 shown in Table 1, the followings are evident. After three days and one week, the survival percentage of plot 1 is slightly smaller than plot 2 and similarly that of plot 4 is also smaller than plot 5. This matter shows that the power of the wave is slightly larger as plot 1 and plot 4 are nearer to the sea side fringe of coral reef. There is a difference of about 10% on comparing the seedling A with the seedling B on the survival percentage except plot 3 in Rarata Island. It is considered that this matter is attributed to a difference of resistibility to the wave according to the variation of seedling height and number of leaf and branch. All of the seedlings transplanted had been washed away completely after six months, so the difference of survival percentages due to the plot was not recognized. It is supposed that the manner of being washed away was different due to the difference of the wave power and the resistibility of seedlings to the wave. The results of this trial suggest that the protection or support against the wave action is needed for the establishment of mangrove forest in the place without it under natural conditions.

The result of the trial I-No. 2 shows clearly that *R. stylosa* can grow in the exceptional

Table 1. Number of the seedlings remained in three periods after transplanting (Trial I-No. 1)

	Plot No.	n	Period after transplanting		
			3 days	1 week	6 months
Seedling A	1	50	41	34	0
	2	50	44	38	0
Seedling B	3	10	10	10	0
	4	25	18	14	0
	5	25	19	17	0

Seedling A: within several weeks after striking its root
B: within one year after striking

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Table 2 -(a). Change of state of seedlings after transplanting to each trial place

Trail II-No. 1	10 March, '83	23 July, '83	6 March, '84
in the fence			
direct planting			
A: vigorous	15	13	3
B: be weakened	0	1	1
C: be withered	0	1	11
D: be washed away	0	0	0
E: survival percentage %	100	93	27
Pot planted			
A	7	2	0
B	0	0	0
C	0	5	1
D	0	0	6
E	100	29	0
out the fence			
directplanting			
A	15	8	2
B	0	3	0
C	0	4	9
D	0	0	4
E	100	73	13
pot planted			
A	7	5	0
B	0	0	0
C	0	2	0
D	0	0	7
E	100	71	0

condition of the pot fixed on raft, apart from the question whether the growth is good or bad. If we can establish the way of cultivating mangrove on a raft, it may be applied to the field of not only forestry, fishery but also marine development.

At the beginning of these trials in Iriomote Island, the causes of the fact that there is no mangrove forest on the coral reef or shallows off shore in Okinawa are expected as the following two, (1) the destruction of seedling by the strong wave generated by typhoon or winter seasonal wind and (2) the injury by the salinity of pure sea water in winter. The cause of (1) was sufficientry confirmed, however, the possibility of taking countermeasure against (1) is not denied. Though the detailed physiological examination is remained, it is considered that the results of four trials in Iriomote Island back up removing (2) from the above causes. The harm by some kinds of seaweed must be added to the above causes, at least in Okinawa. As this clinging leads to the destruction by the wave, finally, the causes of the fact that there is no mangrove forest on the coral reef or shallows off shore in Okinawa is attributed wholly to the physical destruction of young seedling striking its root but not to the physiological injury. Therefore the countermeasure must be taken from this aspect.

Table 2-(b). Change of state of seedlings after transplanting to each trial place

Trial II-No. 2	11 March, '83	23 July, '83	6 March, '84
in the fence			
direct planting			
A: vigorous	15	2	0
B: be weakened	0	1	0
C: be withered	0	11	3
D: be washed away	0	1	12
E: survival percentage %	100	13	0
pot planted			
A	7	7	0
B	0	0	0
C	0	0	0
D	0	0	7
E	100	100	0
out the fence			
direct planting			
A	10	0	0
B	0	3	0
C	0	6	6
D	0	1	4
E	100	30	0

The countermeasures divided roughly into two seem to appeare. The one is transplanting possibly the large seedlings having large physical intencity and less influence by seaweed and the other is the establishment of the protection and support usefull for one or two years of the duration necessary for striking root themselves. It is important that the above matters are executed side by side. The manner that the large wild seedling transplanted in a pot and, after rooting in the pot, transfered and fixed to the place to serve our purpose was examined in the trial II-No. 1 and II-No. 2. This manner was expected that in a short term the prop root elongated and striked its tip into the sediment around the pot. As the brim of the pot was revealed above the deposit in the trial II-No. 1 or II-No. 2, sand in and around the pots was scoured out and all pots fell down. The material of the pot is required to satisfy several conditions of a certain measure of durable, handy and perishable in a short term after burying into the bottom at the place to surve our purpose. Using a support must make sure of the establishment of seedlings.

It became clear that the wooden fence for the protection couldn't be a reliable proof against the wave in typhoon. The shifting protection method which consists of ferroconcrete blocks may be the most desirable. To provide the support of each seedling may be a more easy way. For the prevention of scouring out the sand filled at the root, the bag of fishing net, packed with the coral fragment, was effective. But it must be improved on the shape, size and fixing way.

The nutrient deficiency was indicated by the slight yellowing of the lower leaves. From the observation made in the trial II-No. 3 and II-No. 4, the effect of a slow-release fertilizer may be regarded as significant. The effective manuring practice under the condition of the sea water must be established by the fertilizer tests on the shape, size and com-

Table 2 -(c). Change of state of seedlings after transplanting to each trial place

Trial II-No. 3	9 March, '83	24 July, '83	6 March, '84
direct planting			
A: vigorous	20	20	1
B: be weakened	0	0	0
C: be withered	0	0	3
D: be washed away	0	0	16
E: survival percentage %	100	100	5
pot planted			
A	5	4	1
B	0	1	0
C	0	0	1
D	0	0	3
E	100	100	20
Trial II-No. 4			
pot planted			
A	12	10	5
B	0	1	2
C	0	1	3
D: be fallen off	0	0	2
E	100	92	58 (70)*

*: Percentage to ten seadlings without two fallen off.

ponent of fertilizer and the method of application. The leading way must be developed by taking account of the following facts that the mangrove forest supply the organic matter of fallen leaves and branches and imporve the component of sediment at the root and, after a certain fertilizing period, can grow without fertilization.

The survival percentage on the raft was the highest. It is considered to be the reason that the effect of the wave action against the floatage is smaller. The manner fixing a pot to a raft must be improved for the prevention of falling off. The improvement of the pot must be made on the size and number of hole for water movement.

The survival percentage of the trials in Iriomote Island after one year was small. But a few survivals existed under these severe conditions. This seems to suggest that a posibility in increasing the survival percentage is enlarged by the improvement of the protection, support and fertilizer application.

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マングローブ林の防災機能に関する研究(V)
マングローブ林造成法に関する予備試験

佐　藤　一　紘

要　　約

ソロモン諸島のマライタ島と，沖縄県の西表島で，従来マングローブ林が成立していない立地への移植試験を行った。根系の形から防災上の利用価値が高く，かつ耐塩性も高いと考えられるヤエヤマヒルギ（*Rhizophora stylosa*）について行った。

筏上に固定したポットでの試験では，マライタ島，西表島ともに，高い生存率を得た。筏へのポットの固定法，筏の繋留法，施肥法等を改善すれば，筏上で充分生育する事が明らかになった。また，この事から，沖縄でもヤエヤマヒルギは，河川の流入のない海水のみの立地で，生育できる事が明らかになった。

サンゴ礁や浅瀬への移植には，次の点に留意すれば，定着できる可能性があると考えられる。

1. 波に対する強度と，浮遊する海草にからみ付かれる事による影響の少ない，ある程度大きな苗木を移植する。
2. 波や流れに対し，ある期間適当な支持，防護措置を講ずる。
3. 立地によっては，施肥を行う。