Biology of *Sargassum crassifolium* J. Agardh from Lucolan Shoal, Panguil Bay (Mindanao, Philippines): I. Growth Rate

MANUEL BARQUILLA
PATRIA ROSALES-APAO

Abstract

The growth rate of cut and uncut thalli of ***Sargassum crassifolim*** *J. Agardh under natural conditions in Lucolan Shoal, Panguil Bay was studied within a thirteen - month period. Uncut thalli served as the control while some thalli had the stipe cut 1 cm from the holdfast or the lateral cut 1 cm from the stipe of the main branch. Growth rate refers to the length increase in the stipe or the regenerating laterals. The growth rate of regenerating offshoots and stipe from the three experimental set-ups varied showing a seasonal pattern.*

Longer laterals or regenerating offshoots were longer during the onset of reproductive phase of ***Sargassum crassifolium****. The cutting of the stipe increased the daily growth rate (DGR) while cutting the laterals increased the numbers of emerging or regenerating offshoots.*

It is recommended that ***Sargassum crassifolium*** *be cut or harvested with trimmers during the start of the reproductive phase when much biomass is expected.*

Introduction

In the recent years the economic uses and utilization of seaweeds have increased from the traditional use for human consumption and as a source of potash and iodine [15,8]. A number of species are used as gelling agents, emulsifiers, food stabilizers, and additives for medicines and cosmetics [7,33,22].

Among the economically important seaweeds is *Sargassum* which is widely distributed in tropical and subtropical seas. In the Philippines, extensive beds of *Sargassum* are common in rocky intertidal and subtidal

MANUEL B. BARQUILLA is a Teather III in the Science Department, Integrated Developmental School, MSU-Iligan Institute of Technology PATRIA ROSALES-APAO is with the Department of Biological Sciences, College of Science and Mathematics, MSU-Iligan Institute of Technology.

areas.

The commercial significance of this alga has gained considerable public interest in the recent years that a bulk of these are exported to Japan as important component in animal feeds and fertilizers [28]. The species is also a potential source of alginate [31,7,21,20,1], a polysaccharide which is widely used in paper, textile, food and pharmaceutical industires.

The demand for alginate and fertilizer is increasing in the world market, thus, harvesting *Sargassum* becomes an alternate source of income to the coastal populace [27]. This unregulated and indiscriminate harvesting from natural wild stocks has resulted to the destruction of *Sargassum* beds [11] and may pose a threat to the availability of *Sargassum* in the coming years.

To prevent the depletion of the natural stocks, intensive studies on the biology and physiology of *Sargassum*, such as growth rate, should therefore be conducted. Knowledge on such parameters is a prerequisite in the formulation of a sound resource management of the natural stocks.

Currently, there is no available published information on the recovery of the cropped-over *Sargassum* bed [2]. Likewise, no set of specific policies are formulated to regulate the harvesting of *Sargassum*, hence, the importance of this study. The findings of this study will provide bases in the formulation of policies to regulate the harvesting of *Sargassum* and guide the seaweed gatherers in designing proper methods or ways of harvesting Sargassum.

Although several studies on the phenology, regeneration, recruitment, community structure and seasonality of *Sargassum* had already been conducted in Luzon [4,33,34,35], no extensive studies on the growth and regeneration of the said alga in Panguil Bay, Mindanao has been done. Specifically the growth rate of *Sargassum crassifolium* J. Agardh is based on the length increase of stipes and laterals.

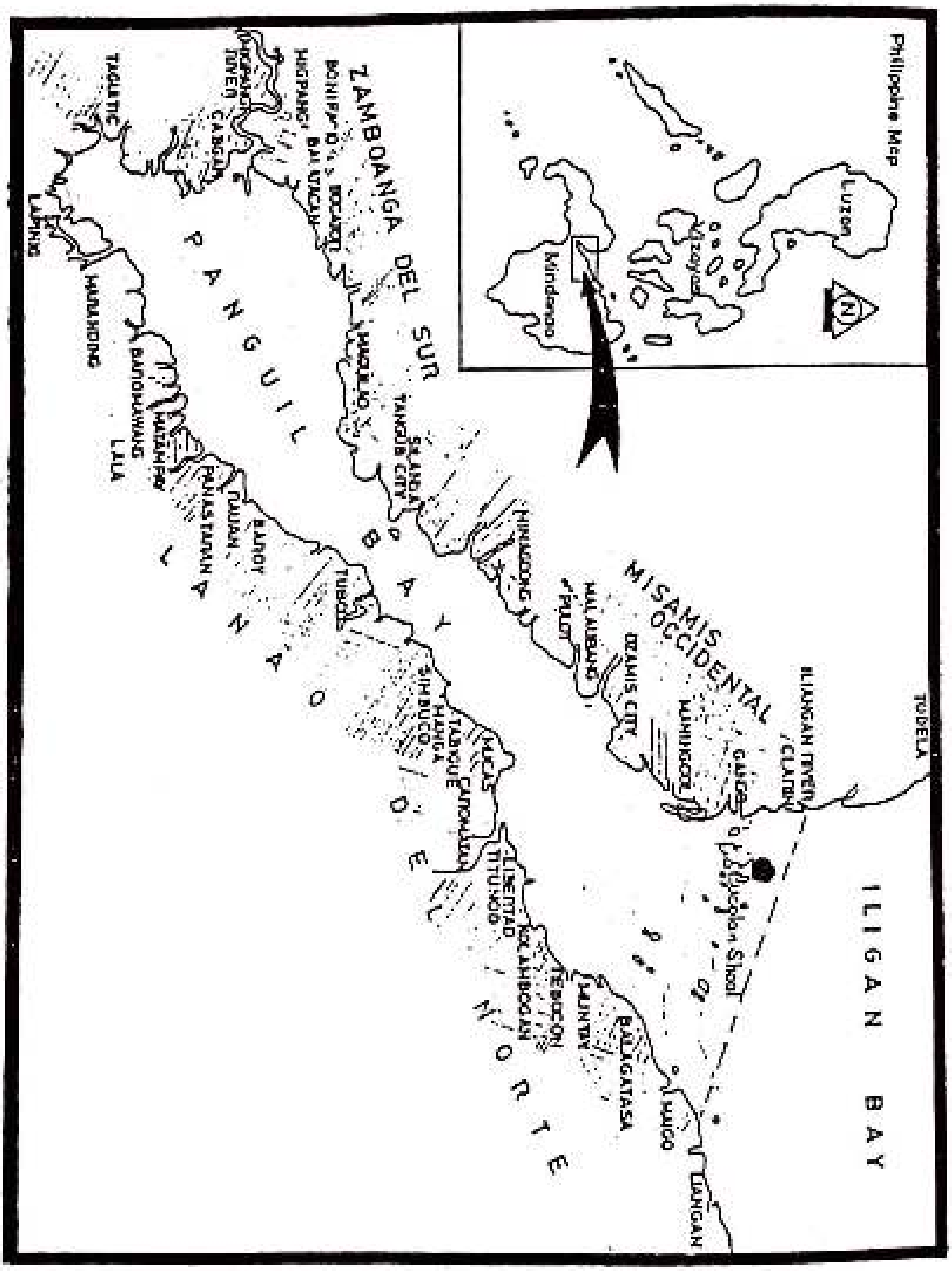
Growth rate in relation to seasonality of the species and the relationship with some of the physico-chemical parameters such as salinity, temperature pH, and dissolved oxygen are discussed.

Methodology

Study Area and Plant Materials

This study was conducted in Lucolan Shoal, Gango, Ozamis City (Fig. 1) at the mouth of Panguil Bay (123° 38' East Longitude and 7° 57' to 12° North Latitude). The mouth of the bay extends approximately 30 kilometers from Clarin River of Barangay Iliangon, Clarin, Misamis Occidental to

Figure 1. Map of the study area and the location of the sampling station in Lucolan Shoal (*) at the mouth of Panguil Bay, Mindanao.



Maigo, Lanao del Norte.

The dominant species in the area of study was identified as *Sargassum crassifolium J.* Agardh (Fig. 2) following Trono and Ganzon-Fortes [35] and Ang [1].

Experimental Set-up

Mapping of the study area was done to mark the location and position of the experimental set-ups and test plants. The three experimental set-ups were chosen at the northeast point of the shoal approximately 80 meters from the shore.

For every set-up, two quadrats (each 0.25 m^2 with 16 grids measuring 12.5 cm x 12.5 cm.) were laid approximately at a distance of one foot. An artificial permanent marker, a concrete with nail and tag, was placed in the four corners of each quadrat. Fifteen (15) to twenty (20) *Sargassum* plants in each quadrat, based on a specific grid, was numbered using a high compact plastic tag.

Regenerating offshoots from the stipe of plants not manually cut and offshoots from the stipe which eventually became the main branch served as the control in the study. In the second treatment, thallus were cut 1 cm from the stipe or the main branch with a cutter/trimmer. Although hand cropping is the common method of harvesting among fishermen, a cutter/trimmer was used in this study to minimize variation in lengths.

Measurement of Growth

Growth was determined based on the length increase of laterals and stipe form the node or point of emergence of regenerating offshoots from experimental plants for a period of thirteen months. In the control set-up, the length of the offshoots were measured to serve as the initial length. The same procedure was used in the other treatments. Data on the emerging offshoots were clustered by batch, i.e. the offshoots which emerged at the same time were considered as one batch. Monitoring of growth increment per batch was done monthly for a period of thirteen (13) months, a period considered long enough to cover its complete cycle.

Daily Growth Rate (DGR) was computed using the simplified compound interest formula used by **Lim [24]**.

$$1)\ DGR = \frac{\text{Log } L_f / L_i)}{u} - 1 \times 100$$

where: L_f = final length of the test plants (cm)

L_i = initial length of the test plants (cm)

u = length of observation period

Percentage increase (PI) of length was computed as:

$$2)\quad PI = \frac{L_f - L_i}{n} \times 100$$

where L_f = final length
L_i = initial length
n = number of days of observation

Determination of the Physico-Chemical Parameters

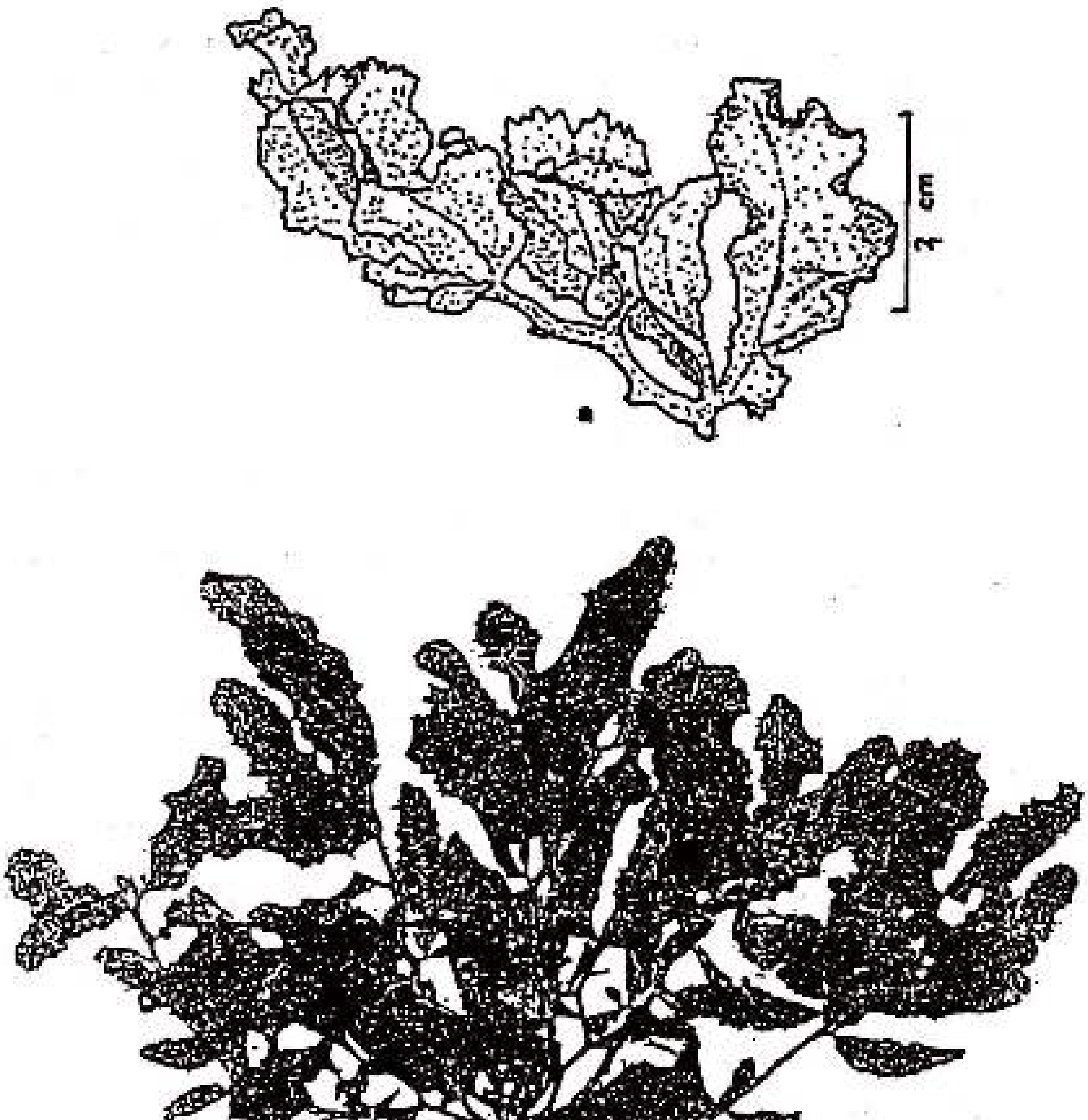
Salinity, temperature, pH, and dissolved oxygen (DO) of surface and bottom waters were determined every sampling period. Surface water salinity, temperature, and pH were measured using a refractometer, alcohol thermometer, and pH meter, respectively. DO was measured by titration using Winkler method.

Results and Discussion

Elongation and Growth of Regenerating Offshoots

The length of the regenerated offshoots of S. *crassifolium* considered by batches in 25 plants for each treatment showed seasonal patterns (Fig. 3). The offshoots or primary laterals of the first five batches (R1-R5) of the control plants were shorter (12 to 28 cm) than those laterals (R6-R12; 34 to 98 cm long) emerging after dieback or degeneration of the laterals which occured in October. Maximum growth were observed form November to January or within a period of three months. Longer length of the laterals occured in January and was attributed to the presence of receptacles which signals the reproductive stage of *S. crassifolium*. Simultaneously, new laterals emerged in January and March and grew at more or less constant rate until the termination of the experiment. These new laterals may show

Figure 2. *Sargassum crassifolium* J. Agardh: line drawing (a) and pressed specimen (b).



the start of a new growth cycle.

Similar with the control, plants cut 1 cm above the stipe (treatment III) showed the same seasonal pattern of lateral elongation. However, the length of the primary laterals, i.e. the 6th up to 12th batches (3.0 to 50 cm) were shorter than the control plants (Fig. 3).

The length of laterals emerging after cutting the plants 1 cm from the holdfast (treatment II) were longer than the succeeding laterals, 24-44 cm and 9-20 cm, respectively.

Pooling the results of the length increment by different emerging laterals or batches per month showed percentage increase of 0.014-1.45 cm day $^{-1}$ for treatment II and 0.04-0.69 cm day $^{-1}$ for treatment III. Monthly increase of laterals were higher in the control than in treatments II and III.

Growth Rates of Regenerated Raterals

Growth rates of the regenerated laterals of *Sargassum* in term of percent increase per day (% d^{-1}) or length increase (cm day $^{-1}$) determined *in situ* as a function of length increment are shown in Figs. 4-8. Generating offshoots showed growth peaks during May-June, however, in comparison, the offshoots which emerged in November attained the highest daily growth rates.

The daily growth rate (% d^{-1}) by month was highest in January for all treatments: 4.12% d^{-1}, 2.94% d^{-1}, and 3.82 % d^{-1} for treatment I or control, II and III, respectively, Highest growth in January corresponds to those laterals emerging later, either after the dieback or even without dieback. In general, it could be stated that growth of offshoots were higher in the beginning of the year, even higher than those growth observed in June for all treatments. The longer laterals were observed at the time receptacles appeared or during the reproductive stage of *S. crassifolium* which occured in January. For all plants, reproductive stage was observed starting December up to February.

Length Increase and Growth of the Stipe

The total length increment, the DGR, the percentage increase of stipe of plants in the three treatments determined for a total of 367 days are shown in Fig. 9 and Table 1.

S. crassifolium cut 1 cm from the base had the highest DGR (0.10 % day $^{-1}$) of the stipes followed by the control (0.07 % day $^{-1}$) and treatment III (the laterals cut 1 cm from the stipe; 0.02 % day $^{-1}$) and treatment III (the laterals cut 1 cm from the stipe; 0.02 % day $^{-1}$). The results suggest that plants

Figure 3. Periodic length increment (9n cm) of regenerated offshoots in the three treatments (I-control (a), II-cut 1 cm from the base (b) and III-cut 1 cm above the holdfast (c) by months and batches (R1, R2, ... R15).

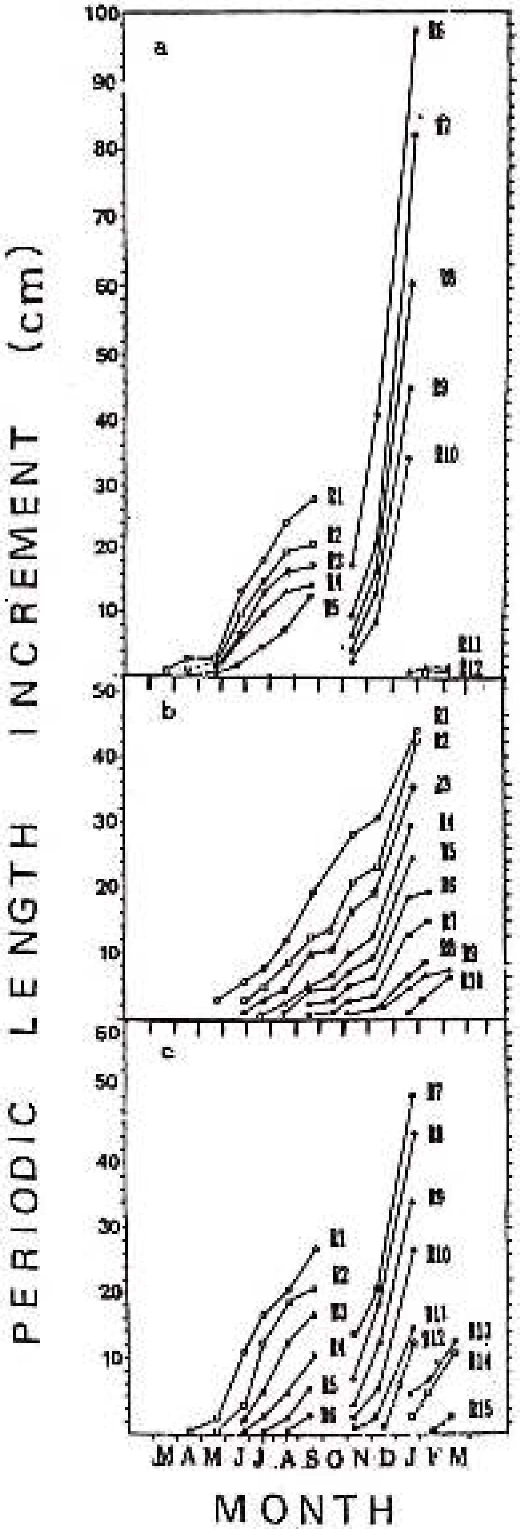


Figure 4. The daily growth rate (DGR, % d-1) of the first five regenerating offshoots (R1 . . . . R5) of the control plants per month.

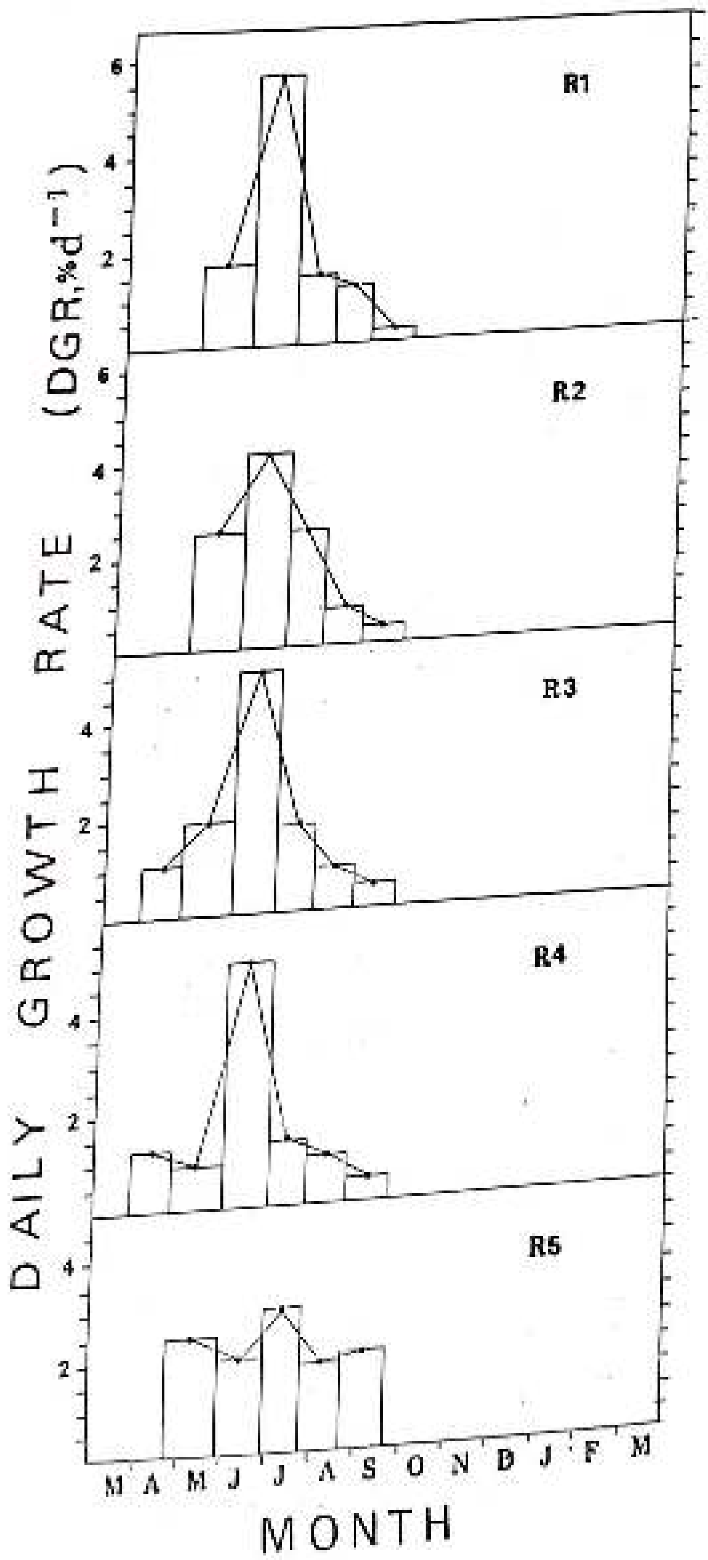


Figure 5. The daily growth rate (DGR, % d-1) of the sixth to twelfth regenerating offshoots (R6 . . . . R12) of the control plants per month.

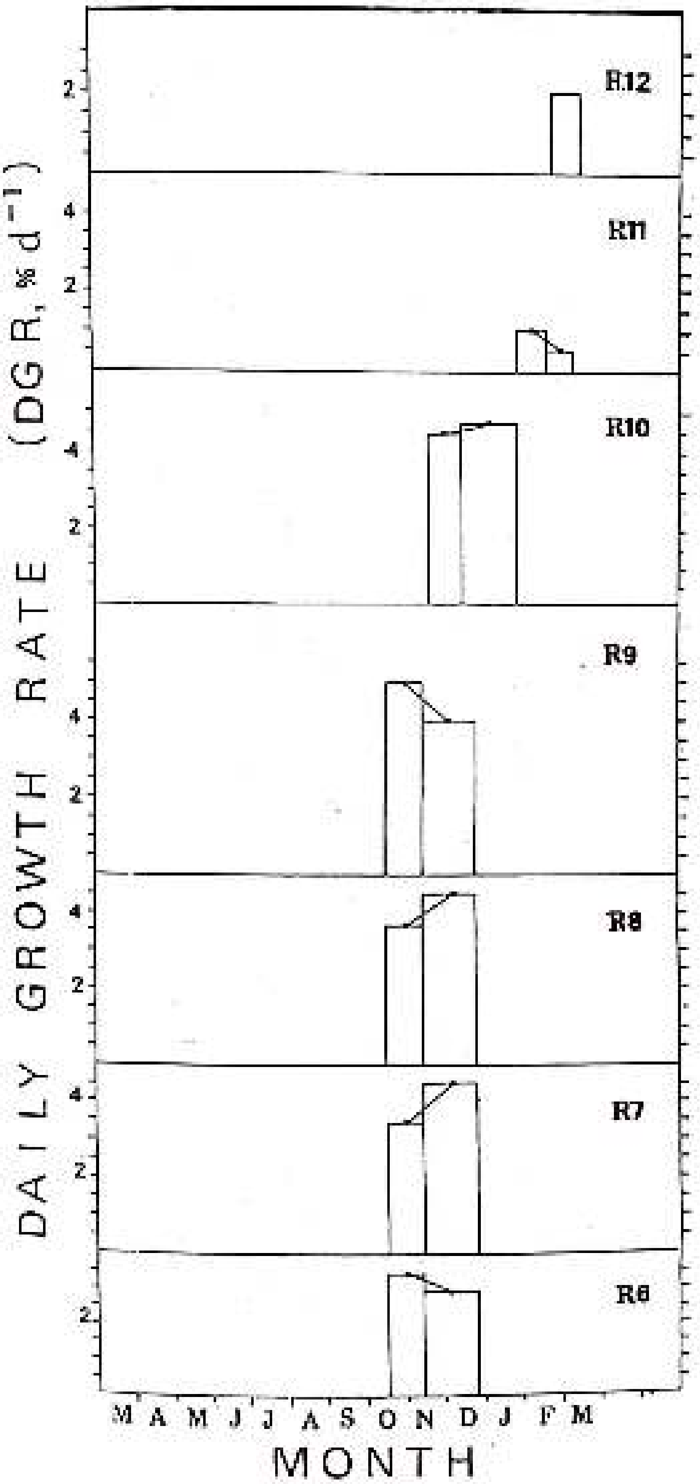


Figure 6. The daily growth rate (DGR, % d-1) of batches first to tenth of regenerating offshoots (R1 . . . R10) of *Sargassum* in treatment II per month.

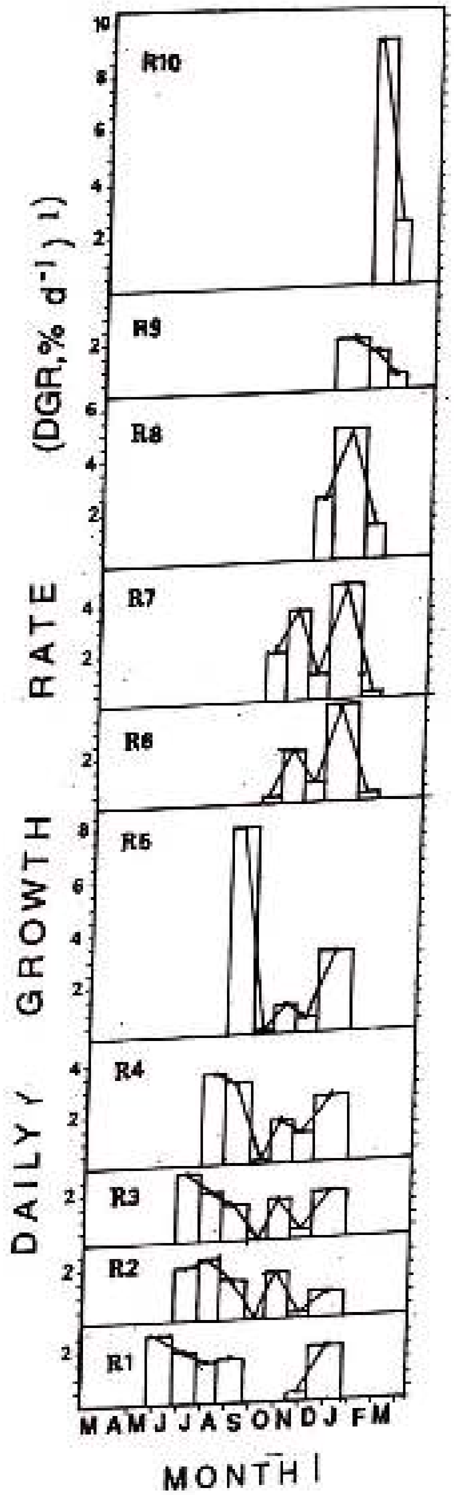


Figure 7. The daily growth rates (DGR, % d-1) of first six regenerating offshoots (R1 . . . R6) of *Sargassum* in treatment III per month.

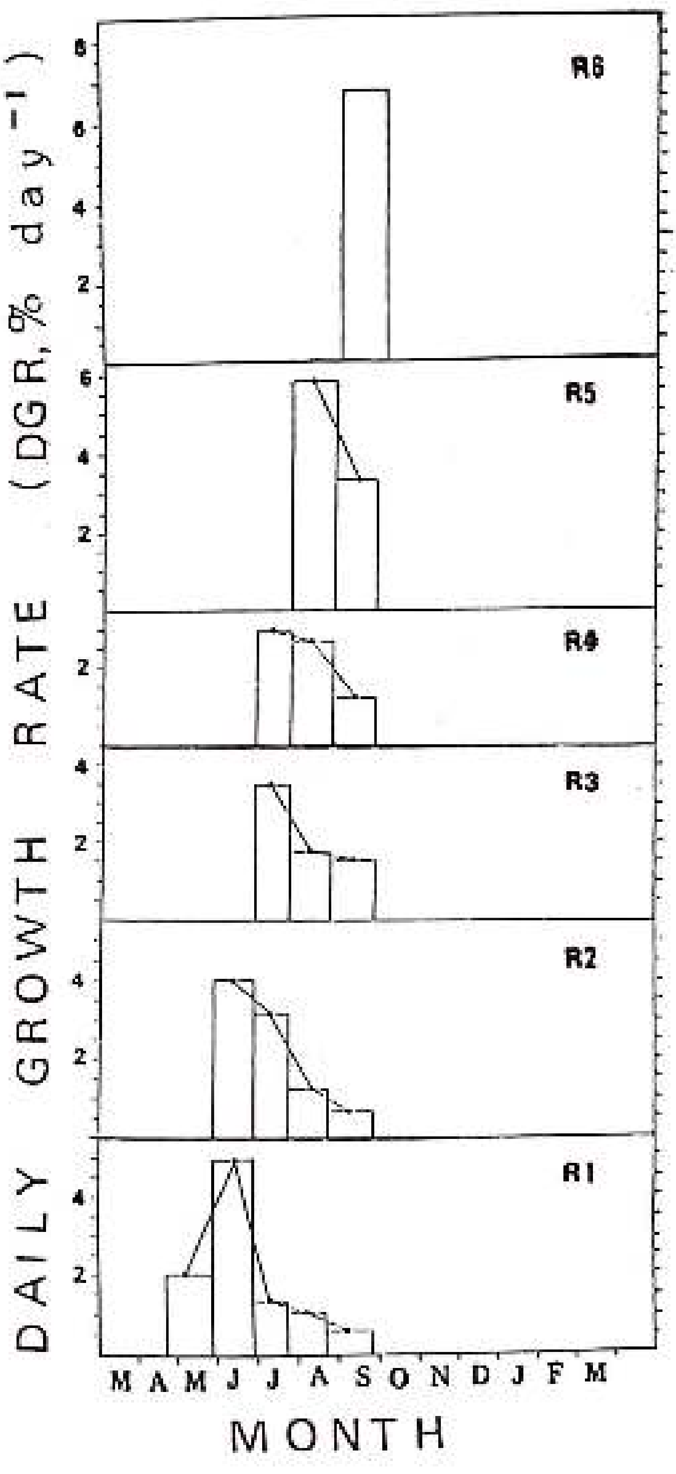


Figure 8. The daily growth rate (DGR, % d-1) of seventh to fifteenth regenerating offshoots (R7 . . . . R15) of *Sargassum* in treatment III per month.

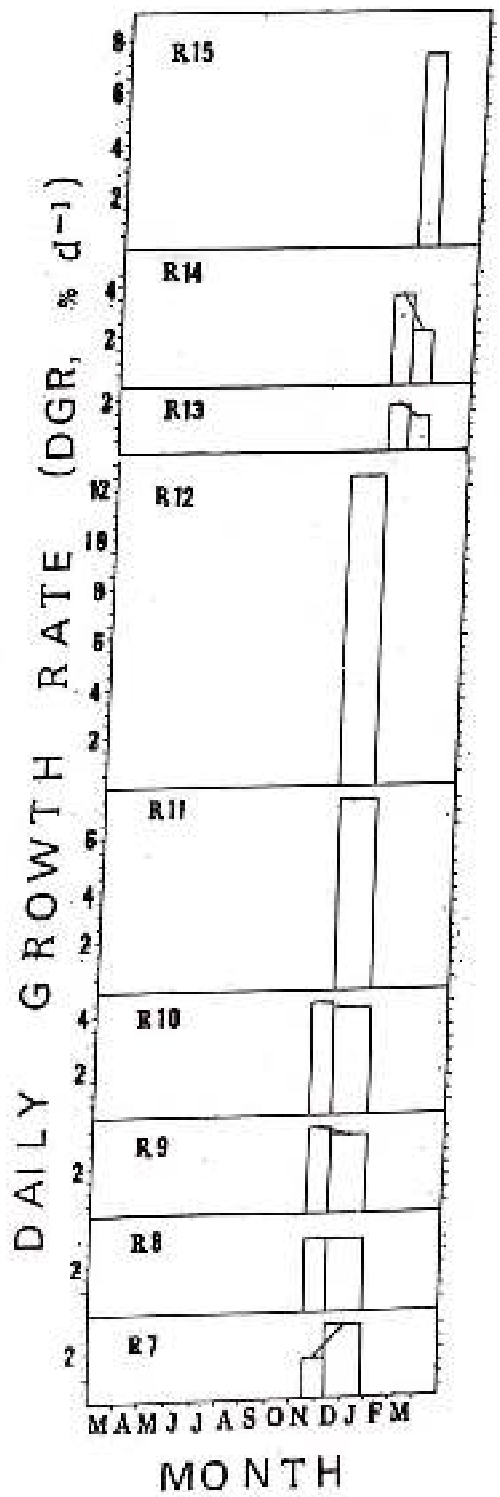


Figure 9. The total length increment (LI) attained in 367 days (cm), the daily growth rates (DGR, % day -1) percentage increase per month (% in), and the daily increase (DI, mm.day) of the stipe of *Sargassum crassifolium* in the three treatments during the whole sampling period.

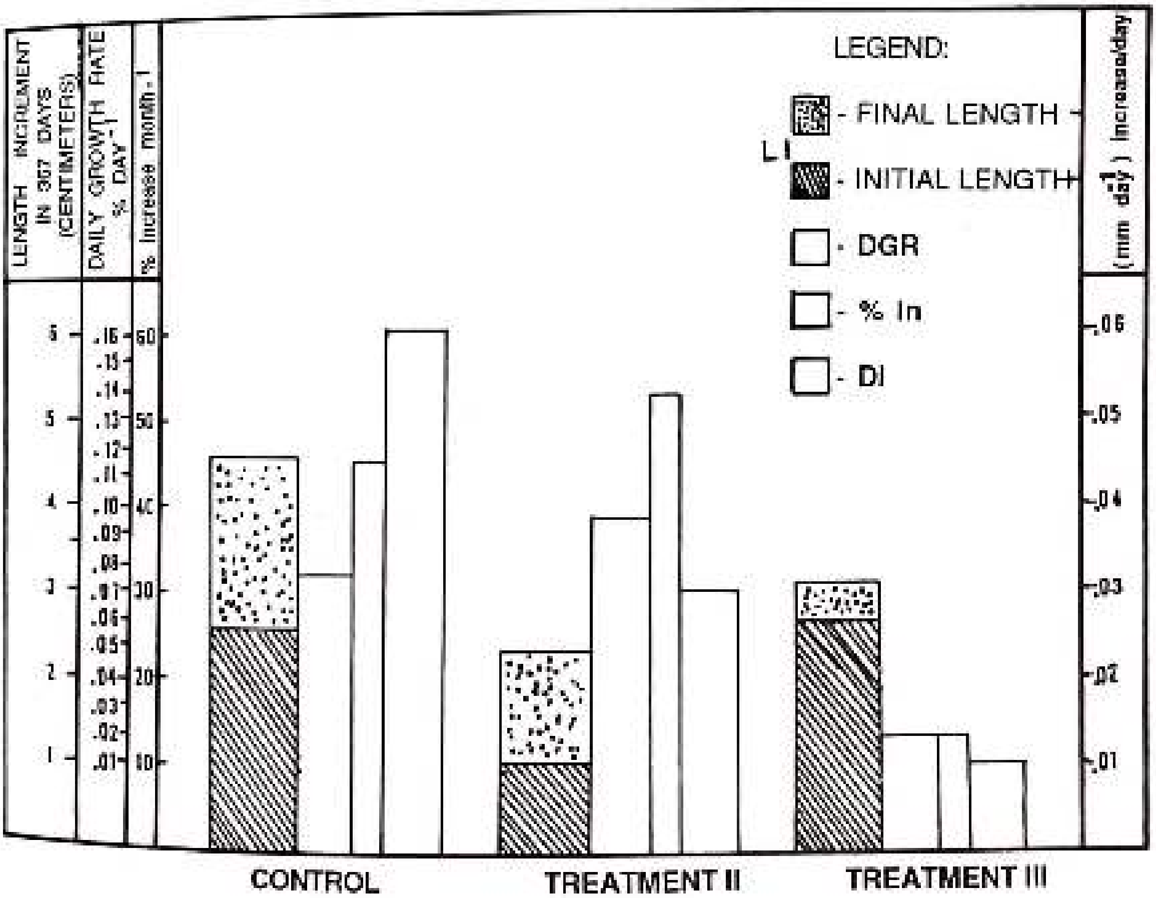


Table 1. The increase in length of the stipe and growth rates of *Sargassum crassifolium* in three treatments (I - control, II-1 cm cut above the holdfast, III-cut 1 cm above the stipe) as determined for a total of 367 days.

CRITERIA	TREATMENTS		
	I-(Control)	II	III
Initial length (cm)mean+-SD	2.57+-0.00	1.00+-0.00	2.6+-0.00
Final length (cm) mean+-SD	4.78+-063	2.+-0.38	3.05+-0.31
Daily Growth Rate (DGR) %/day	.07	.10	.02
Percentage Increase Per Month	46.2	54.95	14.67
Daily Increase (mm/day)	0.06	0.03	0.01

+- sd : Standard Deviation

cut of its laterals 1 cm from the stipe retards the growth rate of the stipe.

ANOVA and DMRT showed significant differences among the height of the stipe (F test, $p < .05$), where the control is significantly different from treatment III and is significantly larger than treatment II (i.e. control > treatment III > treatment II).

In *Sargassum* although the stipe is considered to have a determinate growth, the primary laterals were indeterminate and were capable of extreme length increase. Determinate and indeterminate growth of thalli as suggested by Cole and Sheath [24] in red algae may also be observed in brown algae.

The cutting off of a portion of the stipe or primary laterals reduces the length of the emerging laterals of the plant. Most probably, growth as a function of several interrelating factors is focused both on the repair of damaged tissue and on shoot formation rather than on the increase in length of the laterals.

On the other hand, control plants under natural conditions showed emergences of receptacles despite environmental disturbance such as occurrences of storm and infestations of epiphytes. In comparison, *S. crassifolium* cut at the laterals without disturbing the stipe had similar offshoots elongation with that of the control, however, the former was of shorter length. This must be attributed to the phenomenon of apical dominance whereby cutting the stipe resulted to acceleration of growth and length increment of the emerging offshoots and laterals.

Studies in red algae have shown that the decapitation of the main axis appears to induce the formation of indeterminate axis from the basal cells of determinate branches . Therefore, cutting off of determinate axis resulted to emergence of primary laterals while cutting off the apices of the primary laterals retards the formation of secondary or tertiary branches (L-Hardy-Halos 1971 b, 1975 as cited in Cole and Sheath [10]).

The same principle may be applied to the brown algae such as *Sargassum*. Apical dominance among laterals of *Sargassum* had been suggested by Jephson and Gray [16] and Chamberlain et al. [6] in S. muticum.

Growth of *Sargassum* in Relation to Physico-Chemical Parameters

The results of the physico-chemical determination for bottom and surface waters where water depths for every sampling ranged from ca. 0.5 to 1.5 m for a thirteen-month period are shown in and Fig. 10. The temperature, pH and salinity range observed were typical of the bays in the country. Nutrients did not show any pattern throughout the period similar to those observed by Rosales-Apao & Schramm in Iligan Bay (31).

The longer laterals observed in the month of January when the receptacles appeared may have been influenced by the low temperature coinciding with the wet season. This may indicate that the growth of *S. crassifolium* is favored by cold season. However, statistically the monthly growth rate of *Sargassum* under different treatment was not correlated to any of the physico-chemical parameters considered (Table 2). In contrast the growth and reproduction of *S. siliquosum* and *S. paniculatum* in Balibago, Philippines were positively correlated with the different environmental parameters like temperature, daylength, tide and total reactive phosphate. Likewise, growth rates of several species of algae were reported to be high during cold months or at the onset of spring time.

The seasonality of growth has been observed not only in the field but also under laboratory conditions. Under laboratory condition, for examples, *S. muticum* shows seasonal growth pattern, i.e. during vegetative phase in July the average growth rate is 40 mm day $^{-1}$ which drops to 4 mm day $^{-1}$ during summer.

In this study longer laterals were observed in the months of January when the receptacles appeared. Low temperature coinciding with the wet season probably triggers the initiation of the reproductive phase. This finding conforms with the results of De Wreedeee and McCourt [25] showing that the reproductive phase of *Sargassum* occured during colder months but in contrast with Prince and O'Neal [29], Raju and Venugopal [30], Tsuda [38, 39, 40], Cordero [11], Chenubhotla et al. [9] and Ang [3] who reported that *Sargassum* attained their maximum growth in warmer months and shortest during the cooler months.

In summary, the present study indicates that cutting the stipe 1 cm from the base or cutting the primary laterals 1 cm from the stipe changed the growth rates of the stipe and the regenerating shoots. The laterals regenerating from the *Sargassum* stipe are the major source of biomass and potential for large scale utilization, hence, sound management of algal beds which includes proper harvesting should be done. Hand cropping and complete harvesting of the thalli which includes the holdfast is a destructive harvest method, thus, should not be practised. The use of knife or cutter facilitates cutting in either the stipe or the laterals and is instead recommended.

It is suggested that harvesting of *S. crassifolium* should be done in the months of October and November before the dieback stage when laterals are long and in May when its growth is high. Thus, harvesting can be done twice a year.

Figure 10. Monthly variation of the physico-chemical parameters of the seawater in Locilan Shoal, Gango, Ozamis City (Panguil, Bay).

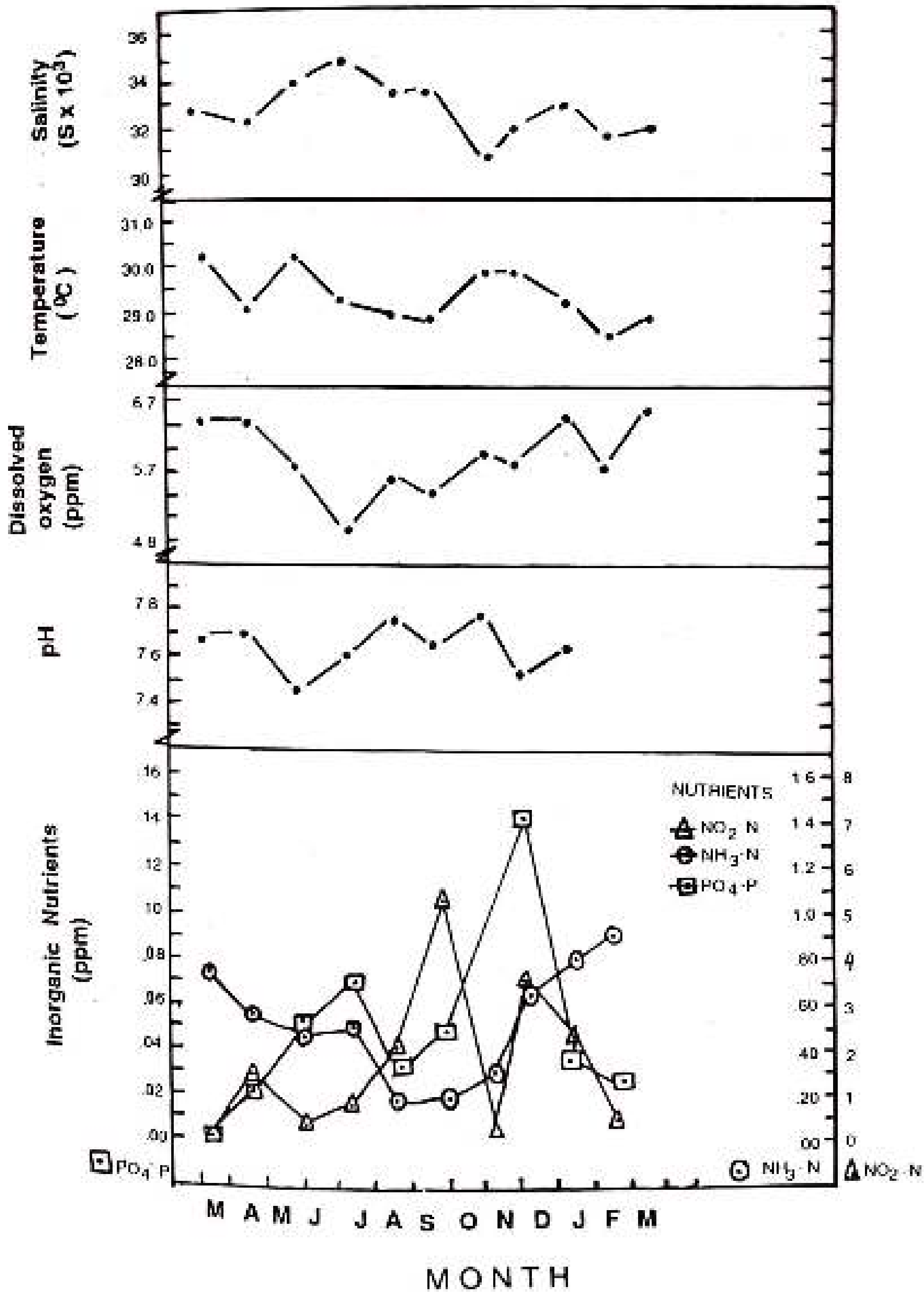


Table 2. Correlation between growth rate of test plants in three treatments (I - control, II - thallus cut 1 cm from the base and III - thallus cut 1 cm from the stipe) and the physico - chemical parameters taken at the surface and bottom seawater and the mean (x) values within a thirteen-month period.

PARAMETERS	Correlation to growth of the three set-ups		
	(Control) 1 r*	II r*	III r*
Salinity (x)	0.20	0.11	0.14
Surface	0.20	0.11	0.15
Bottom	0.18	0.09	0.13
Temperature (x)	-0.39	-0.39	-0.41
Surface	-0.31	-0.39	-0.41
Bottom	-0.32	-0.39	-0.41
Dissolved Oxygen (x)	0.12	0.01	0.17
Surface	0.12	0.01	0.17
Bottom	0.11	0.01	0.01
pH (x)	-0.31	-0.38	-0.40
Surface	-0.31	-0.37	-0.40
Bottom	-0.30	-0.37	-0.40

critical value : +/- .49 at p. 05
*MICROSTAT Program (Ecosoft, 1984)