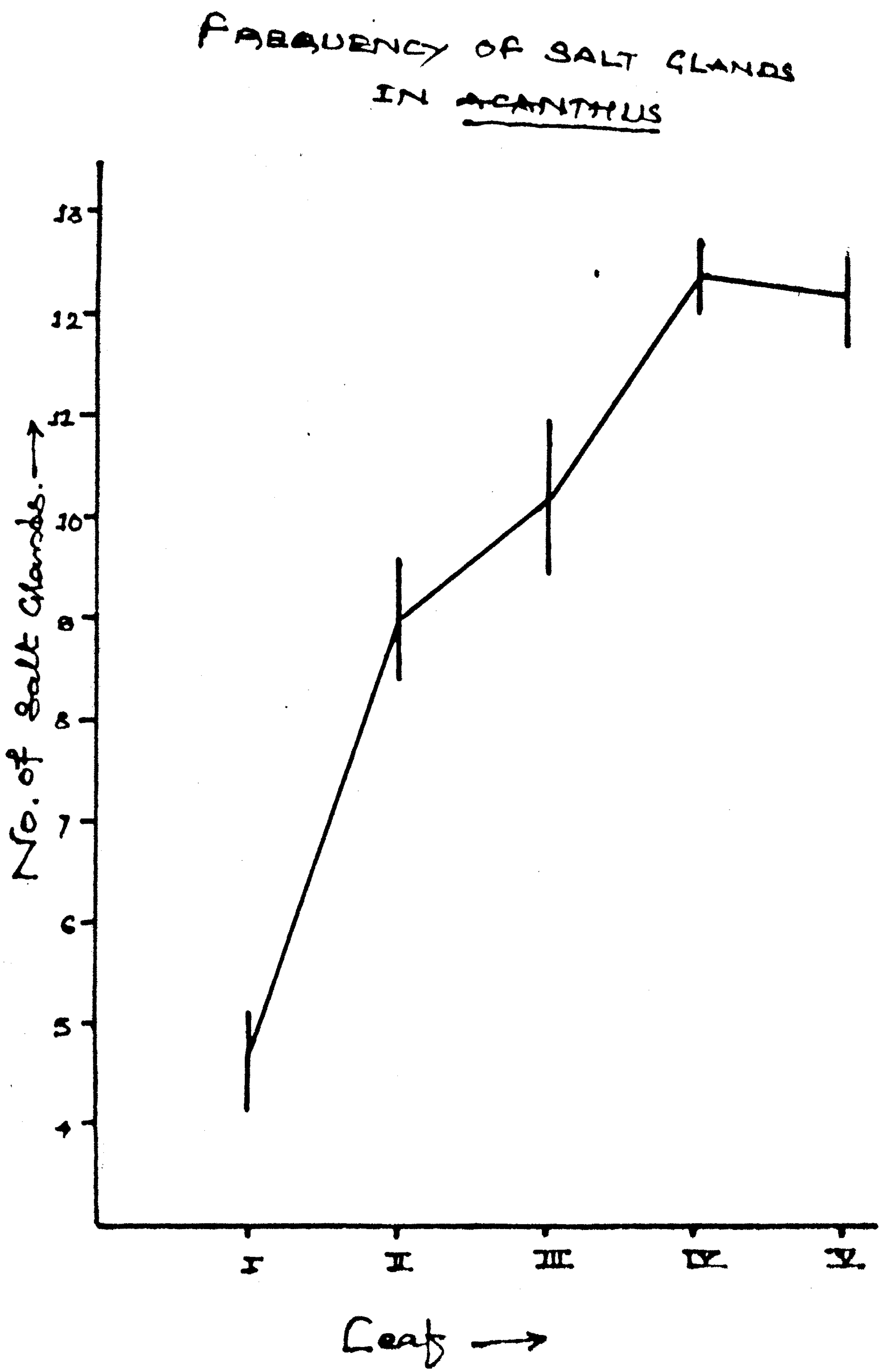
IV RESULTS AND DISCUSSION

The results of the experimental data are presented in 16 tables. *Acanthus ilicifolius* shows the presence of salt glands only on upper epidermis of leaf. The frequency of salt glands per unit area has been determined in the leaves of various age and the results are shown in Fig. 3. It is evident from fig. 3 that number of salt glands increases with developing leaf. The maximum number is reached at maturity. The 1st leaf is youngest of all, the 4th mature and 5th the old one. 4th and 5th leaf from top, both show same number of salt glands which is about 12/mm^2. Here diameter of salt gland is about 40 µ. Atkinson *et. al*. (1967) has reported 9.0 salt glands per square milimeter in case of *Aegialitis* situated in a depression of epidermis with diameter about 30 µ.

Table - 1 records inorganic constituents and water content in the leaves of *A. ilicifolius* from Ratnagiri while Table - 2 reports mineral status of *A. ilicifolius* from different localities. Tables from 3 to 15 present results from excretion studies whereas Table - 16 summarises the results of radio-isotopic studies with chloride. Some of the results are presented graphically. These results are discussed in the following pages.

FIG. 3

Frequency of salt gland
(No. of glands/mm^2) in
A. ilicifolius.



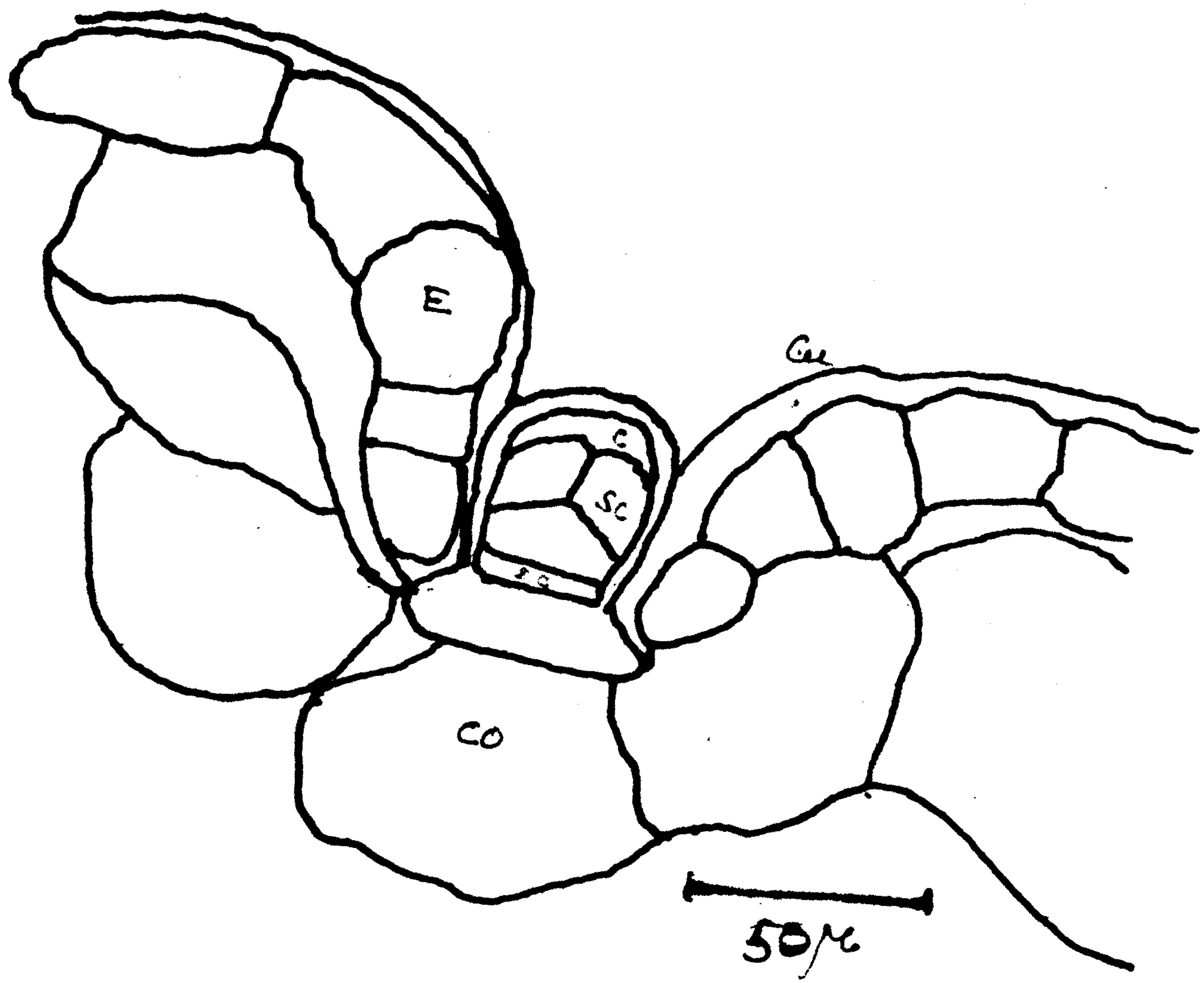
FREQUENCY OF SALT GLANDS
IN ACANTHUS
No. of Salt Glands
13
12
11
10
9
8
7
6
5
4
I
II
III
IV
V
Leaf

FIG. 4

Camera lucida drawing of salt gland of _A_. _ilicifolius_.

Abrevations used :

C	-	Collecting compartment.
CO	-	Collecting cells.
Cu	-	Cuticle.
BC	-	Basal cell.
E	-	Epidermis.
Sc	-	Secretory cell.



E
cu
c
sc
CO
50μ

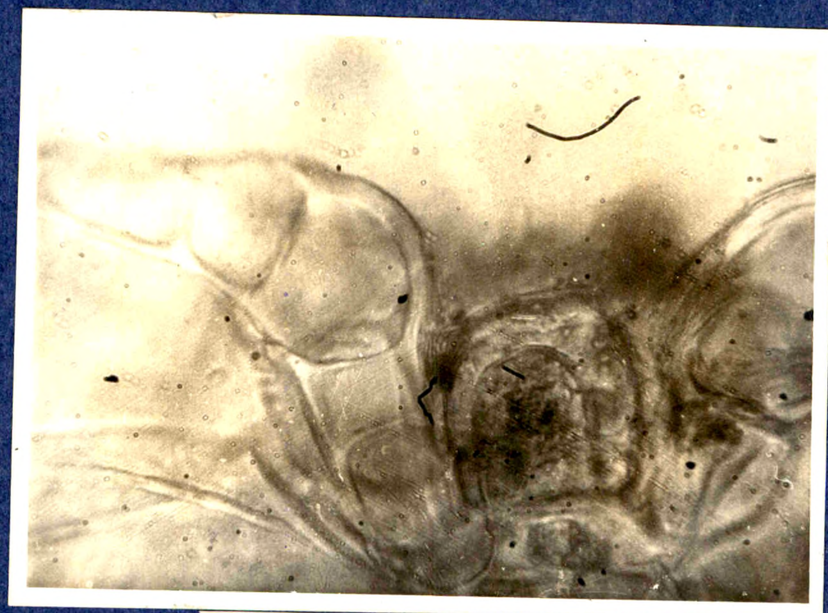


PLATE 2

[illegible]

Salt gland in T.S.

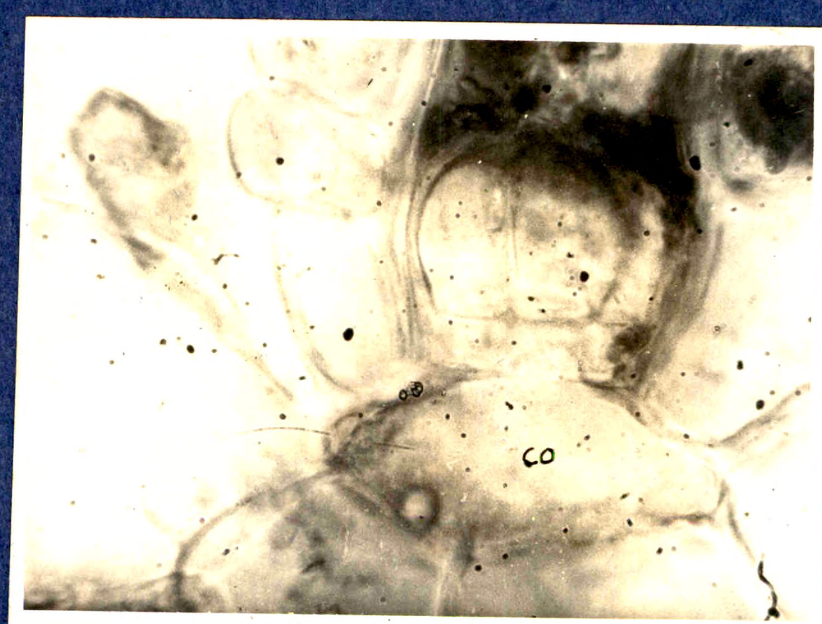


PLATE 3

Salt gland in T.S.
with collecting cell — CO.
(Higher magnification)

A. Inorganic constituents

Mangroves grow in saline soil which is rich in sodium salts. It is well-known that cells of halophytes and mangroves store large amounts of salts and still can do normal functions of life. This is the basic difference between glycophytes and halophytes or mangroves. Based on the salt tolerance mechanism, mangroves have been classified as salt excreting, salt accumulating and salt excluding (Walter, 1961; Scholander, et. al. 1962; Scholander, 1968; Jennings, 1968; Joshi, et. al., 1975). *Acanthus ilicifolius* has been classified as salt excreting mangrove. The other excreting type of mangroves are *Avicennia* and *Aegiceras*. The efficiency of salt regulation mechanism in a species determines the distribution of that species in the community. In the present piece of work *A. ilicifolius* has been analysed for its inorganic constituents as depicted by the leaves. As it is an excreting type of mangrove, the values obtained are discussed in the light of other excreting mangroves, in the following pages.

Sodium

The major cation concerned is sodium. The normal values of Na in a terrestrial glycophyte, Jatropha curcas have been shown to be 0.64 g. per 100 g. dry tissue by Torne and Joshi (1964) while Karmarkar (1965) has observed in Bryophyllum pinnatum that this value goes upto 1.28 g. per 100 g. of dry tissues. However, values for Na in saline plants range from 1.23% in Aeluropus to 9.9% in Sesuvium portulacastrum on dry weight basis (Singh, 1967). According to Warick (1960) Salicornia contains the highest percentage of sodium, that is, 10.42% in phylloclades and 5.32% in stems.

Brownell and Wood (1957) have demonstrated that Atriplex vesicaria is a Na dependent plant. Brownell (1968) has further shown that many other species of Atriplex require sodium as an essential element. Black (1960) has stated that the specilized Na uptake in Chenopodiaceae should be looked upon as osmoregulatory and not nutritional. Singh (1967) has shown that Sesuvium portulacastrum, a mud-flat halophyte can not grow in sodium-free nutrient solution. Halogeton glomeratus, a poisonous weed, requires sodium and accumulates it in the leaves (Williams, 1960).

Guillard (1962) has mentioned that Na and other ions may have a double role, namely, (a) the maintenance of a sufficiently high internal osmotic pressure to prevent desiccation of cells bathed by a solution of high osmotic pressure and (b) specific nutritional requirements. In many cases Na enhances K uptake and reduces Ca uptake (Ratner, 1935; Higginbotham, et. al. 1962; Joshi, et. al.,1975). The metabolic processes of halophytes have adapted for Na and it possibly serves as the cofactor for many processes. Sodium salt increase yield, improve vigour and foliar colour in many plants. In hot climates Na helps the plants to decrease wilting (Epstein, 1972).

In present investigation sodium in the leaves of *Acanthus ilicifolius* has been recorded in Table - 1. Kotmire and Bhosale (1979) have shown that values of Na for *A. ilicifolius* are 3.30 g. and 2.50 g. at Deogad and Mumbra estuaries respectively. Bhosale (1974) has recorded 3.46 g. of Na in the leaves of *A. ilicifolius* from Ganpatipule, the present value is 2.61 g. (Table-2). Na value for *Aegiceras corniculatum* is 2.5 g. (Shinde, 1981) while Na for *A. officinalis* (Bhosale, 1974) is 5.30 g. Rains and Epstein (1967) have

Table 1 : Inorganic constituents in leaves of _A_. _ilicifolius_ (gm/100 of dry wt.)

Moisture %	Na	K	Ca	Cl	P	Na/K	Na/Ca
66.9	2.61	2.09	0.80	2.18	0.13	1.57	3.26

recorded 4% of Na in A. marina. Present results (Table - 2) show that the values of Na for A. ilicifolius are very near to those obtained at Mumbra estuary by Kotmire and Bhosale (1979). Bhosale (1974) has also observed seasonal variations in the inorganic constituents of the leaves of A. ilicifolius. Highest Na for A. ilicifolius was recorded in summer which is 3.47 g. while lowest value, recorded in monsoon was 2.19 g. The present value for Na falls within this range. It can be seen from the results that the amount of Na in the leaves of a species depends much on substractum.

Potassium

Potassium is the only monovalent cation essential for all higher plants and indeed, for all living things except a few micro-organisms in which rubidium can substitute it (Epstein,1972). Though Na and K can replace each other in some cases, K can not be replaced completely by either Na or Li. It is more abundant in younger and actively growing parts. It is linked with hydration, cell organization and permeability.

As more Na is taken up by halophytes K uptake is decreased. Due to this K values decrease

Table 2 : Major inorganic constituents in leaves from different places. (g/100 gm of dry wt.)

Place	Na	K	Ca	Cl	P	Reference
Deogad	3.30	2.72	0.20	4.20	0.187	Kotmire and Bhosale, 1979.
Ganpatipule	3.46	2.81	0.83	4.27	0.180	Bhosale, 1974.
Mumbra	2.50	1.70	0.50	3.15	0.116	Kotmire and Bhosale, 1979.
Ratnagiri	2.61	2.09	0.80	2.18	0.130	Present investigation

but not so much as to replace entire K requirement by Na (Singh, 1967). Bukovac and Wittwer (1957) have shown that K can be most readily absorbed and is a highly mobile element. Burridge _et. al_. (1964) found that K is withdrawn from the leaves and supplied to the developing pods in cacco plants. A similar observation was made by Torne and Joshi (1964) in _Jatropha curcas_.

Rasmussen and Smith (1961) have shown that K affects citric acid concentration but not that of malic acid. K deficiency causes reduction in growth, internodes are shortened and leaves show inward rolling. It has also been observed that K deficiency causes a decrease in photosynthetic activity, disturbance in carbohydrate metabolism, less development of chlorophyll, an increase in respiration and an accumulation of certain other ions.

Larsen (1967) has indicated that the problem of salt tolerance is intimately linked with uptake of K. The problem of mangroves is to absorb enough K in presence of excess of sodium (Joshi, _et. al_., 1972). Joshi, _et. al_. (1975) have shown that viviparous seedlings of mangroves require more K and it is supplied by the mother plant.

The optimum values for K in terrestrial plants are 1.0% or 250 μ moles/g (Epstein,1972). Miller (1938) has analysed the entire plant of Zea mays and found the K values to be 0.92% g. However higher values have been observed in halophytes. The values of K do not exceed 3% in any of the mangroves (Bhosale, 1974). Shinde (1981) has recorded 0.73% of K in leaves of Aegiceras corniculatum. Comparatively high (2.8) percentage of K has been recorded in A.ilicifolius by Bhosale (1974). She has recorded seasonal variation, where values range from 2.17 to 2.81%. When sodium values in soil increase there is the corresponding increase in K uptake. Larsen (1967) has made the similar observation. He indicated that the problem of salt tolerance in halobacteria is solved by cuncurent more K uptake alongwith Na. Kotmire and Bhosale (1979) have recorded 2.72 g. and 1.70 g. of K for A. ilicifolius from Deogad and Mumbra estuaries respectively. Present investigation indicates 2.09 g. of K for A. ilicifolius. This value is within the range of K reported for A. ilicifolius by different investigators from different localities (Table - 2).

Black (1960) has suggested two mechanisms for uptake of K and Na in Atriplex: --

1) A sodium mechanism - where K ions can compete when Na concentrations are low, resulting in uptake of K.

2) K mechanism which is completely independent of competition with Na. Similar observations have been made by Epstein (1966).

First mechanism has a high affinity for K. The second mechanism, with low affinity for K, is the mechanism for Na absorption.

The work from our laboratory indicates that in order to overcome problem of K absorption in many mangroves, mechanism II, suggested by Rains and Epstein (1967), has evolved in the course of time. When Ca is more in external medium, it inhibits mechanism II for Na and K is absorbed, by both the mechanisms either working simultaneously or in series (Epstein, 1966). K uptake in _A. ilicifolius_ seems to be quite efficient.

Calcium

Saline soils are calcium rich. However, in halophytes Ca content is low which can be attributed to higher Na content. Osmond (1966) has shown that when Na was more in extemal medium it infered with

Ca uptake. Calcium is another element which is associated with the problem of adaptation of mangroves. It is essential to maintain the integrity of selective ion transport mechanism as well as for expression of full growth (Epstein, 1961).

Excess Na in the substratum affects calcium and magnesium uptake and this is reflected in additional uptake of Ca, and withdrawal of Mg from senescent leaves in fresh water conditions (Joshi, et. al.,1975). Over the high range of concentrations, 0.5 to 50 mM Na, a second, low affinity mechanism of Na absorption comes into play. In the presence of Ca and K this mechanism II is only one to transport Na effectively since Na absorption via mechanism I is virtually abolished under these conditions (Rains and Epstein, 1967). Bell and Biddulph (1963) have suggested that Ca moves up the stem by a process of exchange. This concept of upward translocation in the plant stem is in controversy with the classical concept of mass flow.

Optimum value for Ca in terrestrial plants is 0.5% (Epstein, 1972) on dry weight basis.

However, it has been found that in many plants values upto 3.5% exist (Ferry and Ward, 1959). Low Ca values in mangroves are recorded by Bhosale (1974) as 1.18% in *A. officinalis* and in *A. majus* 0.46%. Singh (1967) reported 0.37% Ca in *Sesuvium portulacastrum.* Beadle *et. al.* (1957) recorded 0.76% Ca in *Atriplex vesicaria.* Shinde (1981) has recorded 0.68 g. Ca for *Aegiceras corniculatum* leaves. Present results are on the similar lines for Ca. Values recorded for Ca in *A. ilicifolius* by various investigators range from 0.20 g. to 0.83% (Table - 2) which as compared to glycophytes, are low.

Chlorides

Chloride has been shown as an essential element in plant metabolism. (cf. Verner and Bonner, 1965). It is a major constituent of sea-water and constitutes almost 55% weight of dissolved material. Cl is an indicator of salinity of sea-water.

Broyer *et. al.* (1954) has mentioned that Cl is required for the growth of higher plants and has also shown the accumulation of Cl in older parts. Eventhough high concentrations of Cl are harmful to glycophytic plants and their growth, for saline plants presence of Cl ions is necessary.

Woolley et. al.(1958) have reported that Cl was translocated from older to younger leaves and from high concentrations to low ones. Hodges and Waadia (1964) have shown that Cl uptake is influenced by Cl content of root tissues. During dark fixation of 14 CO_2, Cl ions stimulate amino acid synthesis (Joshi et. al.,1962; Webb and Burley, 1965).

Walter and Steiner (1936, 1937) have determined several zones of East African mangroves depending upon their Cl tolerance. Bharucha and Navalkar (1942) have recorded high Cl percentage in the cell sap of *Avicennia alba*. Beadle et. al. (1957) have stated that among the anions Cl always dominates in salt rich plants.

Walter (1955) has suggested that in halophytes Cl ions produce an increase in succulence whereas sulphates do not produce this effect. Cl ions are present as free ions in the plants. Cl causes swelling of the plasma when present in large quantities, due to which absorption of other cations is prevented (Adriani, 1956). The extensive work on chlorides in halophytes has been carried out by number of investigators (Drabble and Hilda, 1905; Harris and Lawrence, 1917; Adriani, 1934; Chapman, 1936, 1938; Cooper and Pasha, 1935; Bharucha and Navalkar, 1942; Takada, 1954 and Warick, 1960).

In monsoon lowest values for Cl have been recorded for soil as well as for the leaves. These gradually increase in winter and reach the peak in summer (Bhosale, 1974). Rains and Epstein (1967) have recorded 7.5% Cl in _A. marina_ while Beadle _et. al._ (1957) have recorded 9.6% Cl for _Atriplex vesicaria_. Work from our laboratory indicates 11.73% Cl for _Lumnitzera racemosa_. Shinde (1981) has shown 3.05 g. Cl for _A. corniculatum_ leaves. _A. ilicifolius_ has higher Cl in the leaves as compared to _A. corniculatum_. 4.20 g. and 3.15 g. Cl has been recorded for _A. ilicifolius_ from Deogad and Mumbra estuaries respectively. (Kotmire and Bhosale, 1979). The present value is in confirmity with earlier records and differs slightly because of different habitat.

Halophytes are Na and Cl dependent plants and show poor growth in their absence (Brownell and Wood, 1957). Greenway (1968) found increased growth of halophytes at high Cl concentrations. This explains comparatively higher values of Cl in A. ilicifolius in present study.

Phosphorus

Phosphorus plays a key role in bioenergetics of metabolism and in biosynthetic reactions. It is required for ATP formation and in numerous other phosphorylated compounds. The chloroplasts of P deficient plants show abnormalities but they are not uniform in all plants (Marinos, 1963; Thomson and Weier, 1962; Vesk et. al. 1966).

Dhawalkar and Joshi (1962) have found that K accumulation is closely linked with growth metabolism in which P takes an active part. Ishizuka (1964) has stated that P and N are absorbed rapidly during growth and maximum values are obtained at the flowering stage, including the necessity of P for growing tissues. Na - dependent uptake of inorganic phosphate has been observed by Ullrich-Eberius and Simonis (1970). Bhosale (1974) has recorded seasonal variation in P uptake where highest value for P in mangroves is during monsoon. Further she observed that available P is absorbed or accumulated by the plant tissue depending upon the salinity gradient of the environment. The average value of P in glycophytes is 0.186% on dry weight basis (Epstein, 1972). In *A. ilicifolius* also equal level of P has been reported i.e. 0.187%. However, this level drops at Mumbra estuary to 0.116%. The other salt excreting mangrove species viz. *A. officinalis* and *A. marina* show 0.130% and 0.150% P respectively (Kotmire and Bhosale, 1979). For *A. corniculatum* P value is 0.83 g. (Shinde, 1981). In present study the phosphorus level is slightly low i.e. 0.130% which is possibly due to different habitat.

B. Excretion

It is generally accepted that organisms are able to survive in a changing salinity habitat or in a certain salt concentration due to their ability to perform an osmotic adjustment that maintains a constant turgor potential (Bernstein, 1961; 1963; Waisel, 1972; Steward and Lee, 1974; Hellebust, 1976; Storey and Wyn-Jones, 1977). Salt resistance mechanism only would work in a limited range of saline concentration (Pannier, 1959 and Mizrachi, 1978). However, plants like mangroves, have special mechanisms for salt regulation like salt excretion (Atkinson et. al. 1967) salt accumulation (Gessner, 1967; Jennings, 1968) and salt exclusion (Scholander, 1968). Excreting type of plants maintain low levels of salts in metabolic environment by throwing out the excess salts.

According to Thomson (1975), Fahn (1979) secreted salt solution contains K, Na, Mg, Ca, Cl, SO_4, NO_3, PO_4 and HCO_3. However Atkinson et. al. (1967) have shown that *Aegialitis* glands secrete predominatly NaCl and consequently there is a build up of divalent cations in the leaf as leaf becomes older and due to secretion K level in leaves increases.

PLATE 4

Salt excretion by young leaves of *A. ilicifolius* seedling in cultured condition.

PLATE 5

Mangrove vegetation at Ratnagiri.

a. <u>Hoagland culture</u>

A ilicifolius plants were washed and placed in Hoagland nutrient solution (N.S.). After every 24 hours leaf wash was taken and Na, K, Ca from salt excretion was studied for 6 days while Cl estimation from excreted solution was continued upto 12 days. There was one bottle with daily change of N.S. Results show that though Na and Cl are predominantly excreted, Ca is also one of the cations excreted out in higher concentration. Table - 3 shows that Na from salt excretion by *A.ilicifolius* do not show constant trend, instead fluctuations are observed in Na excretion. The Na excreted per plant varies from 9.9 to 84.6 μg. On the other hand plant with daily change of N.S. first shows increase in excreted Na value and then decreases slowly. Values of Na given out here range from 11.7 to 71.1 μg. Atkinson *et. al*.(1967) have shown Na contents of exudate from *Aegialitis annulata* to be 355 equi/ml. (8165 μg/ml).

Table - 4 shows that K in excreted solution decreases slowly and finally it becomes zero. K value ranges from 0 to 238 μg. In case of plant with daily change of N.5, the same ranges from 0 to 298 μg. Ziegler and Luttge (1967), Scholander

Table 3 : Excretion of Na (μg/plant/day) from the leaves of *A. ilicifolius*.

Plant	Dates in January, 1982.					
	12	13	14	15	16	17
1	51.30	33.3	36.9	36.9	26.1	25.2
2	46.9	23.4	36.0	36.9	23.4	21.6
3	84.6	31.5	42.3	36.0	15.3	16.2
4	59.30	30.6	40.5	36.0	21.6	18.9
5	76.5	40.5	57.6	51.3	35.1	30.6
6	28.8	13.5	29.7	29.7	9.9	12.6
With daily change.	67.5	71.1	45.0	40.5	18.9	11.7

Table 4 : Excretion of K (μg/plant/day) from the leaves of *A. ilicifolius*.

Plant Sr.No.	Dates in January, 1982.					
	12	13	14	15	16	17
1	96	50	28	22	6	0
2	78	40	26	26	4	0
3	154	40	26	22	4	0
4	102	36	24	24	4	0
5	238	86	72	60	54	28
6	70	32	18	14	4	0
With daily change.	298	80	32	28	6	0

et. al. (1962) and Atkinson et. al. (1967) have indicated that secretion of salt is a very active process and selects Na in favour of K.
A. ilicifolius leaves show increase in Na/K ratio in daily excreted solution (Table - 5). Na/K value in excreted solution ranges from 0.321 to 5.849 and on 6th day K has not been detected in excreted solution which shows that the ratio is The plant with daily change of N.S. shows that Na/K value ranges from 0.227 to 3.150.

So far as calcium is concerned, A. ilicifolius shows constant rate of Ca excretion in the begining. It increases on 4th day except plants 3 and 4 and then falls abruptly. But plant with daily change of N.S. shows constant amount of Ca in excreted solution. This Ca value decreases, on 3rd day and again increases next day and then falls abruptly. The Table - 6 indicates that Ca value in excreted solution ranges from 0 (trace) to 220 μg. In case of plant with daily change of N.S. the same ranges from 20 to 180 μg.

Chlorides from salt excretion of A. ilicifolius have been determined for 12 days (Table - 7). It was observed that the amount Cl from salt excretion decreases first but afterwards

Table 5 : Na/K ratio of the excretion from the leaves of *A. ilicifolius*.

Plant Sr.No.	Dates in January, 1982.					
	12	13	14	15	16	17
1	0.534	0.666	1.320	1.677	4.349	-
2	0.601	0.585	1.385	1.419	5.849	-
3	0.549	0.787	1.627	1.636	3.750	-
4	0.581	0.850	1.688	1.500	5.400	-
5	0.321	0.471	0.800	0.854	0.650	1.092
6	0.411	0.422	1.650	2.120	2.475	-
With daily change.	0.227	0.889	1.406	1.446	3.150	-

Table 6 : Excretion of Ca (µg/plant/day) from the leaves of *A. ilicifolius*.

Plant Sr.No.	Dates in January, 1982.					
	12	13	14	15	16	17
1	140	140	140	180	40	20
2	140	140	140	160	40	20
3	140	140	140	140	20	20
4	140	140	140	140	20	20
5	160	160	140	220	40	20
6	100	100	100	140	20	0 (trace)
With daily change.	180	180	160	180	40	20

Table 7 : Excretion of Cl (μg/plant/day) from the leaves of <u>A.ilicifolius</u>.

Plant Sr.No.	Dates in January, 1982.											
	6	7	8	9	10	11	12	13	14	15	16	17
1	1677	3550	312	312	312	312	312	234	234	234	234	234
2	4093	702	468	468	390	390	429	273	273	273	273	273
3	3783	1131	702	624	546	468	390	273	273	273	273	273
4	8619	819	936	702	546	468	351	273	273	273	273	273
5	8697	1176	1519	1638	1170	702	468	390	390	390	390	390
6	4407	585	507	429	429	429	429	273	273	234	234	234
With daily change.	--	1365	1560	5121	975	819	234	234	234	234	234	234

it remained constant. The same pattern has been observed in the plant with daily change of N.S. Cl from salt excretion ranges from 234 to 8697 μg. In plant with daily change of N.S. Cl ranges from 234 to 1365 μ g. (Table - 7). Atkinson et. al. (1967) have shown that in Aegialitis input of chloride to a mature leaf is about 100 equiv per day and this input is balanced by secretion (mainly of sodium chloride) from the salt glands. Secretion collected under oil contains chloride 450 — equiv/ml., sodium 355 — equiv/ml. and potassium 27 — equiv/ml. Scholander et. al. (1962) found that Aegiceras corniculatum secretes Cl at a similar rate to Aegialitis annulata.

Hansen et. al. (1976) have also shown that salt gland of Distichlis spicata which is two celled, actively secretes excess Na, K and Cl. In Diplachne fusca excretion of Na is higher as compared to other cations including potassium (Joshi et. al., in press). An order of preference of cation excretion per week in D. fusca was found to be Na > K > Ca > Mg similar to that of Aeluropus litoralis (Pollak and Waisel, 1970). In present study order of preference of excretion in A. ilicifolius depends upon the day of excretion. On the first day of study it is Ca > K > Na except plant No. 3 and 5. However K excretion decreases during subsequent day which changes this preference.

As values of Na, K, Ca and Cl in N.S. are not similar to that of soil, from where seedlings have been collected, plants may show presence of Ca and K rather in more amounts in excreted solution of A. ilicifolius.

It was interesting to observe excess Na in the nutrient solution. Little amount of Na has been detected initially in N.S. due to tap water, however after 6 days increase in Na in nutrient medium has been observed. This shows loss of Na from plant body. This loss ranges from 347.5 to 730.5 μg per bottle i.e. 500 ml. N.S. (Table - 8). Maximum Na detection in N.S. means less retaintion of Na in plant body. When these plants are compaired for Na given out by the plant and K, Ca retained in plant (Table - 9 and 10), it has been observed that as amount of Na retained in plant is higher, there is also more amount of calcium and potassium absorbed by the plant. Table - 11 shows that to overcome harmful effect of Na, plant absorbs more Ca and K (Table - 11). Although K in two plants (No. 1 and 3) appears to be less in

Table 8 : Na lost by the plants. (µg/Bottle).

Plants Sr. No.	Na in Hoagland 12-1-82	Na in Hoagland 18-1-82	Difference in Na/week	Na excreted by plant µg	Na lost by plant µg
1	1102.0	1188.0	86.0	209.7	295.7
2	1368.0	1386.0	18.0	188.2	206.2
3	855.0	1075.0	220.0	225.9	445.9
4	1108.0	1300.0	192.0	206.9	398.9
5	1149.5	1314.0	164.5	291.6	456.1
6	1776.5	1848.0	71.5	124.2	195.7

Table 9 : K retained by the plants (μg) as determined from the difference in uptake from N.S. and excretion by leaves.

Plants Sr.No.	K in Hoagland 12.1.82	Ka in Hoagland 18.1.82	Difference in K	K excreted	K retained
1	1798.0	486	1312.0	202	1110.0
2	2232.0	594	1638.0	174	1464.0
3	1395.0	387	1008.0	246	762.0
4	1798.0	468	1330.0	190	1140.0
5	1875.5	504	1371.5	538	833.5
6	2898.5	792	2106.5	138	1968.5

Table 10 : Ca retained by the plants (μg) as determined from the difference in uptake from N.S. and excretion by leaves.

Plants Sr.No.	Ca in Hoagland 12.1.82	Ca in Hoagland 18.1.82	Difference in Ca/week	Ca excreted	Ca retained.
1	8120	4320	3800	660	3140
2	10080	5280	4800	640	4160
3	6100	3440	2860	600	2260
4	8120	4680	3440	600	2840
5	8470	6160	2310	740	1570
6	13090	7920	5170	460	4710

Table 11 : Na is given out from the plant and added to N.S. K and Ca are taken up from N.S. and some amount is excreted. By considering total K uptake and and Ca uptake and their respective excretion, amount of their elements retained by the plant are determined.

Comparison of Na lost by the plants with K and Ca retained in the plants.

Plants Sr.No.	Loss of Na from plant	K retained by plant	Ca retained by plant
1	295.7	1110.0	3140
2	206.2	1464.0	4160
3	445.9	762.0	2260
4	398.9	1140.0	2840
5	456.1	833.5	1570
6	195.7	1968.5	4710

amount as compared to other plants, the total of K and Ca is quite comparable with more or less Na in the plant.

b. Soil culture

Acanthus ilicifolius and Avicennia marina were grown in garden soil. After stabilization of plants, they were treated with different concentrations of NaCl (0.0, 0.05, 0.1, 0.2, 0.3, 0.5 M). Table - 12 shows that in case of A. ilicifolius as salt concentration in soil increases amount of Na, K, Ca in excretion also increases. The highest Na has been secreted when plants were treated with 0.1 M NaCl solution. Further increase in NaCl concentration in soil, shows partly decrease and partly increase in Na secretion. Thus it seems possible that there exists no control over the function of secretion at higher concentration of salt. Fluctuations in Na secretion have been observed. The same pattern is observed for potassium. Greenway (1962) has shown that in Hordeum sp. when high NaCl treatment is given, it results in reduction of K. Possibly this is why there is increase in K excretion also. Higginbotham et. al. (1962), Rains (1967) have shown that excess Na in soil suppresses the absorption of K. In present investigation, Na and

Table 12 : Excretion from the leaves of *A. ilicifolius* after three treatments in the first week.

Treatment NaCl in M	Na (µg/plant)	Ca (µg/plant)	K (µg/plant)	Cl (µg/plant)	Na/K	Na/Ca
0.00	221.0	270.0	4.003	690.12	55.21	0.819
0.05	371.3	381.3	8.26	421.74	44.94	0.974
0.10	762.6	1092.0	17.363	3156.66	43.93	0.695
0.20	542.6	546.0	7.24	536.76	74.96	0.994
0.30	617.3	1150.0	15.46	1102.27	39.93	0.537
0.50	481.6	416.0	5.97	941.46	80.65	1.157

K, both in excretion, increase as NaCl concentration in soil increases. This indicates 0.2 M of NaCl is toxic range and also loss of control over functioning of salt excretion process.

In case of _Avicennia_ _marina_ also Na, K and Ca concentration in excretion solution increases as NaCl concentration in soil increases (Table - 13). Here highest concentration of Na in excretion has been observed when plants were treated with 0.3 M NaCl solution. As NaCl concentration in soil increases, parallel increase in Na, in secreted salt has been observed upto 0.3 M NaCl. This value falls abruptly when 0.5 M NaCl treatment is given to the plants. In _A_. _marina_, K in secreted solution also increases as salt concentration in soil increases upto 0.2 M NaCl. Further, at 0.3 M and 0.5 M NaCl concentration in soil, it falls slowly indicating the toxic range.

Both _Acanthus_ and _Avicennia_ show more Ca excretion at 0.3 M NaCl treatment. In _A_. _ilicifolius_ fluctuations have been observed while in case of _A_. _marina_, Ca concentration in salt excreted increases slowly upto 0.3 M NaCl and it falls at 0.5 M NaCl treatment. The reason for fluctuating Ca excretion remains unclear.

Na/K ratio in _A_. _ilicifolius_ shows decreased value as salt concentration increases; that is more K is excreted out upto 0.1 M NaCl treatment. At 0.2 M NaCl instead of K, more Na is excreted out by plants. Thus fluctuations have been observed in Na/K ratio in case of A. ilicifolius. Na/K ratio in A. marina shows that more Na is excreted at 0.05 M NaCl concentration while more K is given out at 0.2 M NaCl concentration. Acanthus also shows fluctuations for Na/Ca ratio. It shows that plants excrete out more Ca than Na. Least amount of Ca is excreted out at 0.5 M NaCl concentration. Here more Na is excreted out than Ca. In A. marina, at all concentrations, plants excrete out more Na than Ca. Na/Ca ratio remains more or less constant in A. marina which ranges from 6.46 to 6.60. In A. ilicifolius it ranges from 0.537 to 1.157.

Ca plays important role in salt tolerance. Pollack and Waisel (1970), Thomson (1975), Joshi et. al.(in press) have shown that Ca is not a major cation in the excreted solution. However, in the present study more Ca is found in the excreted salts. This shows that A. ilicifolius, under cultural conditions does not have efficient salt tolerance mechanism. On the contrary, A. marina is more efficient and hence shows a trend different

Table 13 : Excretion from the leaves of _A. marina_ after three treatments in the first week.

Treatment NaCl in M	Na (µg/plant)	Ca (µg/plant)	K (µg/plant)	Cl (µg/plant)	Na/K	Na/Ca
0.00	252.0	38.2	2.25	152.90	112.0	6.597
0.05	262.0	39.4	2.32	188.96	112.9	6.649
0.10	263.3	40.0	3.44	287.55	76.54	6.583
0.20	327.2	49.7	4.28	476.51	76.45	6.583
0.30	328.4	50.8	2.98	162.48	110.3	6.465
0.50	327.2	49.7	2.92	436.80	112.0	6.583

than *Acanthus* in composition of salt excreted through the leaves.

For chlorides, *Acanthus* does not show constant trend. From Tables 12 and 13 it is clear that plants excrete out more Cl when NaCl concentration is 0.1 M. but *Avicennia* excretes out more chlorides when NaCl concentration is 0.2 M. In *Avicennia* Cl concentration in excreted salt increases as salt concentration in soil increases, that is, it shows constant trend as against that of *A. ilicifolius*. This also explains the ecological distribution of these two plants. Even though both are excreting type of mangroves, *A. marina* is found as pioneer plant at many places where as *A. ilicifolius* is found little away from the low tide water levels. This is confirmed by the estimation of Cl in the excretion fluid.

For same plants of *A. ilicifolius* and *A. marina* fourth salt treatment was given. Salt excretion by these plants has been studied three days after this 4th treatment. More Na, K and Cl are excreted out when *Acanthus* plants have been treated with 0.1 M NaCl solution. Sodium like previous experiment shows fluctuations (Table - 14). Na, K and Cl in excreted salt increase as NaCl concentration in soil increases. More Ca is

Table 14 : *Acanthus ilicifolius* - Excretion study - 3 days after additional one treatment. (excretion after 4th treatment).

Treatment NaCl in M	Na (µg/plant)	Ca (µg/plant)	K (µg/plant)	Cl (µg/plant)	Na/K	Na/Ca
0.00	12.000	253.3	2.60	340.80	4.615	0.0474
0.05	19.403	247.0	9.50	364.23	2.042	0.0785
0.1	61.403	476.6	28.16	1107.60	2.181	0.1288
0.2	24.570	702.0	6.50	664.56	3.774	0.0349
0.3	30.030	713.0	4.60	661.36	6.527	0.0421
0.5	48.360	433.3	10.40	830.70	4.647	0.1115

excreted out at 0.3 M NaCl. It also shows increase in secreted salt as NaCl concentration in soil is increased. Na/K ratio shows fluctuations. Table - 14 indicates that at 0.3 M NaCl concentration more Na is excreted out by leaves. While more K is excreted out when plants are treated with 0.05 M NaCl solution. Na/Ca ratio is also not constant here. More Ca is excreted out than Na. Maximum Ca is excreted out when treatment of 0.2 M NaCl solution is given to _Acanthus_ plants. Maximum Na is excreted out when plants are treated with 0.1 M NaCl solution.

In case of _A. marina_, as salt concentration in soil increases, Na, K, Ca and Cl in excreted salt increase. Maximum amount of Na, K, Ca and Cl are excreted out when plants are treated with 0.2 M NaCl solution. From Table - 15 it is clear that Na/K ratio also shows fluctuation. More Na is excreted out than K. Maximum Na and K are excreted out when treatment of 0.5 M NaCl and 0.3 M NaCl solution respectively given to plants. Na/Ca ratio, more or less remains constant upto 0.2 M NaCl. At 0.3 M NaCl it falls abruptly and further it increases. Table - 15 indicates that plants excrete out less Na than Ca. Maximum Ca is excreted out at 0.3 M NaCl while maximum Na is excreted out when treatment of 0.5 M NaCl solution is given to plants. Na/Ca ratio ranges from 0.15 to 0.31.

Table 15 : *Avicennia marina* - Excretion study - 3 days after additional one treatment. (excretion after 4th treatment).

Treatment NaCl in M	Na (µg/plant)	Ca (µg/plant)	K (µg/plant)	Cl (µg/plant)	Na/K	Na/Ca
0.00	14.354	66.00	1.10	210.87	13.04	0.2174
0.05	16.122	75.14	1.18	277.50	13.67	0.2146
0.1	17.536	79.70	1.77	354.60	9.90	0.2200
0.2	25.110	103.30	2.06	363.16	12.52	0.2431
0.3	10.028	66.80	1.11	178.01	9.04	0.1502
0.5	31.750	100.80	1.44	506.08	22.06	0.3152

PLATE 6

A. ilicifolius seedling cultured in Hoagland nutrient solution.

C. Excretion of radioactive - chloride

After establishment of *A. ilicifolius* plants in Hoagland nutrient solution, equilibrated ^{36}Cl was supplied (3 ml) to the seedlings through nutrient solution. Plant showed salt accumulation on leaves after 48 hours. Then radio-activity was tested with the help of PCS.

From Table - 16, it is obvious that plant roots show more chlorides than leaves and stems. As compared to leaves, stem has very less chlorides. The results show that the two plants studied show difference only in one respect; in plant No. 1, ^{36}Cl is more in excretion than in the leaves whereas in plant No. 2, the case is reverse. Except this the trend is similar in both the plants. This difference shows that it is very likely that the second plant may accumulate Cl upto a certain level and then excrete efficiently. This is clear from the values recorded in Table - 16. From these results it is clear that chlorides are readily transported to leaves from roots. Chlorides do not remain with the conducting system.

Osmond *et. al.* (1969) studied absorption of ions in *Atriplex* leaf tissue and secretion of ions to epidermal bladders with ^{36}Cl. They have

Table 16 : Cl in terms of mg.
(uptake and excretion)

Plant	1	2
Root	11.57	5.969
Leaf	9.508	5.012
Stem	2.045	1.332
Excretion	12.57	2.429

concluded that chlorides are secreted from the solution or the lamina to the bladders against a concentration gradient. Uptake of chloride into the bladders is an active process. Osmond _et. al_. (1969) have also shown that radio-activity in case of _Atriplex_ bladder was concentrated in the stalk cell and peripheral cytoplasm of the large vacuolated bladder cell. Young leaves appear to secrete chloride to the bladder more readily than old leaves, and young leaves are the first to sustain obvious damage under extremely saline conditions. With some evidences Osmond _et. al_. (1969) have proved that chloride is actively transferred to the vacuole of bladders from the solution bathing mesophyll cells. Similar criteria have been used to describe the active secretion of salt from _Limonium_ leaves (Arisz _et. al_. 1955 and Hill 1967a, 1967b).

Ziegler and Luttge (1967) studied salt glands of _Limonium vulgare_ and the localization of chloride. Using a combination of micro-radiographic detection of chloride and an electron microscopic localization of silver precipitation they tried to elaborate the intracellular distribution of chloride and pathway of this ion in the leaf. They concluded that :

1) chloride occurs in the chloroplasts and

probably also in the nuclei;

2) presence of an apoplastic and symplastic transport of the chloride;

3) no rise of the chloride concentration between the parenchyma and the gland cells.

The salt secretion mechanism of Aegialitis is one of the most active salt-secreting systems described in plants (Atkinson et. al. 1967). They observed the secretion of chloride at 90 p-equiv. cm^{-2} sec^{-1} from Aegialitis leaves at noon corresponds to a chloride flux of about 5 n-equiv. cm^{-2} sec^{-1} over the total cross section of the glands and about 25 n-equiv cm^{-2} sec^{-1} if all section is through the junction of the sub-basal cell and annular space surrounding the gland.

In the present investigation, amount of chloride excreted is found out in terms of mg. It shows, when Acanthus excretes chloride efficiently, the rate is 6.285 mg/day. It can be as low as 1.215 mg/day. This study clearly demonstrates efficient machinery for overcoming toxic effect of salt in this species.

D. Productivity

The productivity of an ecosystem is the fixation of solar energy in terms of organic matter by the vegetation of an ecosystem. The energy is generally measured in terms of units of energy (calories), produced in a unit area (usually one square metre) per unit time (usually one year). The productivity is variable in different ecosystems. Productivity which is thus equal to the rate of photosynthesis is called as gross productivity.

Net primary photosynthetic productivity (NPP) :

Rate of photosynthesis - Rate of respiration.

The net primary photosynthetic productivity of mangroves is represented by the photosynthetically fixed carbon that is accumulated in leaves,branches, trunks etc. Mangrove NPP has been determined by enclosing portions of plants in plastic bags for measurement of carbon fixation. NPP measurements by gas exchange have been carried out in Puerto Rico (Golley et. al., 1962) and in South Florida (Miller, 1972; Hicks and Burns, 1975; Lugo and Snedaker, 1974). Productivity is also expressed as mg of CO_2 absorbed per unit area per unit time. Photosynthesis shows that productivity of mangroves is less when compared to other glycophytes (Bhosale and Karadge, 1975). The plants without stomata in the leaf epidermis, have productivity negligible while glycophytes with stomata in leaf epidermis show 4 to 14 mg CO_2 dm^{-2} hr^{-1} as has been stated by Holmgren et. al. (1965).

According to Zelitch (1971) the leaves of woody plants often have rates between 7 and 10 mg CO_2 dm^{-2} hr^{-1}. In glycophytes like sugarcane and Maize, rate of CO_2 fixation is 42 - 49 mg CO_2 dm^{-2} hr^{-1} and 46 - 60 mg CO_2 dm^{-2} hr^{-1}. Plants with low rate of photorespiration exhibit rates of CO_2 uptake from 40 - 60 mg CO_2 dm^{-2} hr^{-1}. Wolf (1969) recorded this rate in 77 species ranging from 20 to 40 or more mg CO_2 dm^{-2} hr^{-1}. In case of tall mangrove plants with fine canopy rate is 10 - 11 mg CO_2 dm^{-2} hr^{-1}. According to Bhosale and Karadge (1975) in *Rhizophora* productivity is 3.5 mg CO_2 dm^{-2} hr^{-1}. They have also reported productivity in *Sonneratia*, *Aegiceras* and *Acanthus* which is 5.2, 3.3 and 3.2 mg CO_2 dm^{-2} hr^{-1} respectively. Productivity in mangroves ranges from 2-6 mg CO_2 dm^{-2} hr^{-1}. In present study plants of *Acanthus ilicifolius* show 12 mg increase in weight per plant per day in Hoagland. In soil it is 24 mg per plant per day.

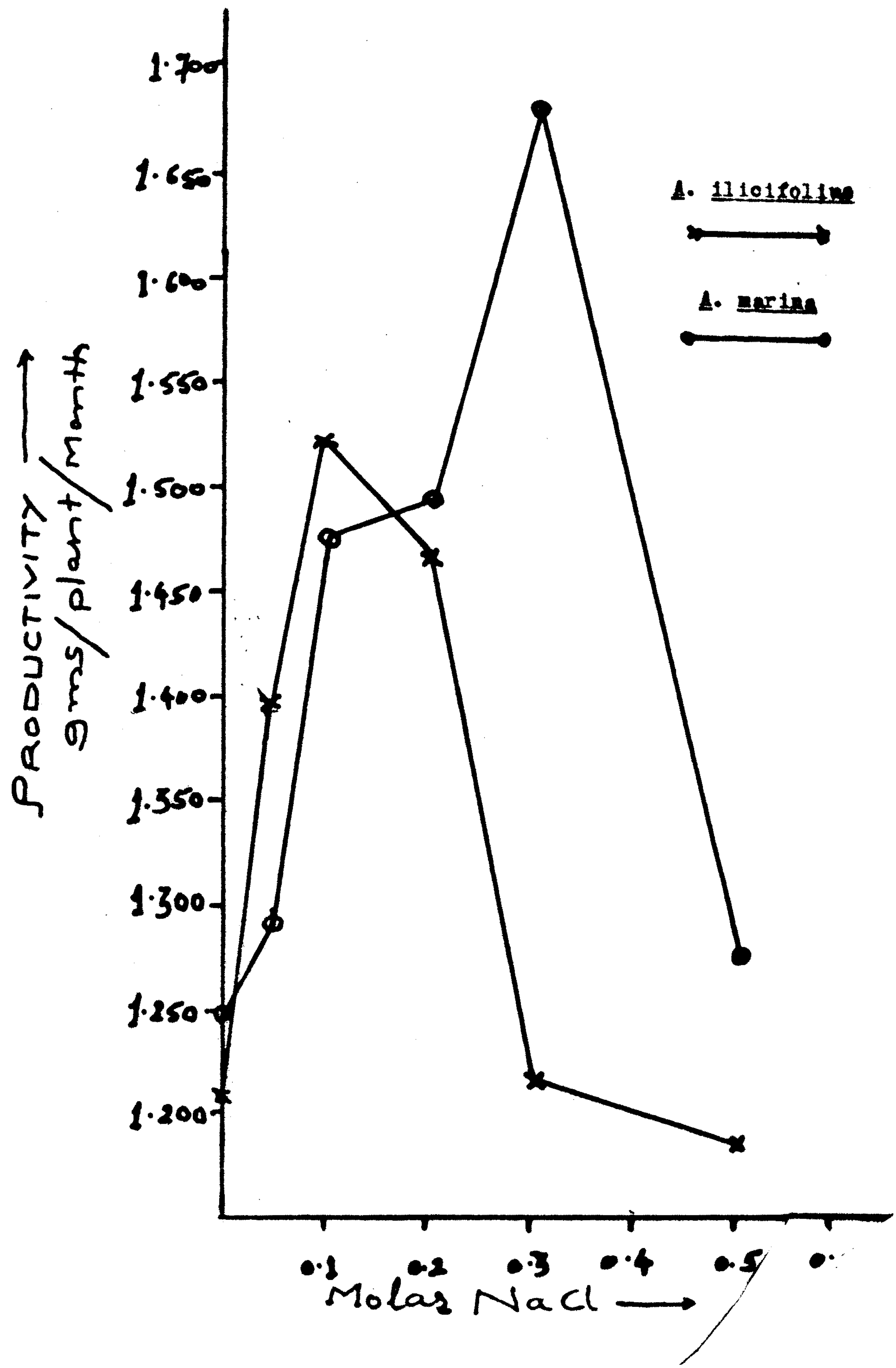
Information on the growth of mangrove forest is very megre. The annual girth increment for *Avicennia* has been reported to be ¾ inch in Penniar mangrove forest. (Untawale, 1979). Curtis (1933) has observed that *Heritiera* sp. takes approximately 12 years for one inch increase in the girth while *Ceriops roxburghaiana* takes 4 years to increase its girth by about 0.25 inches.

Bruguiera trees from Andaman alone can provide 20,000 tonnes of bark and 80,000 tonnes of wood (per acre). Untawale *et. al*. (1977) have reported the density of mangrove trees in Coondapur mangroves in Karnataka as *R. mucronata* - 16, *S. acida* - 25, *R. apiculata* - 11, alongwith the seedlings and associated plants in a unit of 6 m x 6 m.

NPP of mangrove forests can also be estimated indirectly from litter collection or leaf biomass data if litter component relationships are known and assumptions are made about the ratio of litter or a litter component to NPP. For example, it is possible to make rapid estimates of NPP for mangrove forests by measuring leaf area index LAI or by measuring light transmission of the forest canopy, if calibration data on the relationship of LAI to litter, or light transmission to litter, are available for the forest type.

Productivity is also determined in terms of dry matter production. Teas (1976) has reported NPP in the five community types which ranges from 1.2 to 10.7 tons dry matter/ha/yr for the Red Mangrove - dominated 'Sparse Scrub' and 'Coastal Band' communities. The Black Mangrove community averaged 2.85 tons/ha/yr and the White and Mixed community averaged 4.2 tons/ha/yr. Golley and Lieth (1972) estimated the average NPP for tropical forests to be 25.3 tons/ha/yr; thus, mangrove forests are not highly productive in comparison with other tropical forests. In present investigation dry matter production indicates that productivity of *Acanthus* is 1.207 gm/plant/month while in *Avicennia* productivity is 1.250 gm/plant/month. However this productivity is measured at seedling stage. This will change with maturity of the plant.

When *A. ilicifolius* and *A. marina* plants are subjected to different salinity levels, productivity increases upto certain concentration then it decreases. Maximum productivity is observed at 0.1 M NaCl in _A. ilicifolius_ and at 0.3 M NaCl in _A. marina_ which is 1.525 gm/plant/month and 1.681 gm/plant/month respectively. Blumenthal - Goldschmidt and Poljakoff - Mayber (1968) have shown that the growth of _Atriplex halimus_ was much better in presence of NaCl than in its absence but excess NaCl inhibited the growth. _Atriplex halimus_ tolerates higher salt concentrations but concentrations above 14 atm. retard growth. Present results are also on the same line. Yeo and Flowers (1981) studied effect of salinity upon growth of _Suaeda maritima_, a coastal halophyte. Plants grown in highly saline conditions (340mol m^{-3} NaCl) had larger fresh and dry weights than plants grown in a standard culture medium (13 mol. m^{-3}). William (1960) has reported that Na greatly increases the growth of halophyte, _Haloseton glomeratus_ which is known to accumulate oxalie acid. According to Haines and Dunn (1976) in case of _Spartina alterniflora_ plant height, total dry weight, rhizome length, rhizome weight, and root weight were significantly affected by NH_4-N and by NaCl but not by Fe concentrations.



1·700
1·650
1·600
1·550
1·500
1·450
1·400
1·350
1·300
1·250
1·200
PRODUCTIVITY
gms/plant/Month
A. ilicifolius
A. marina
0·1
0·2
0·3
0·4
0·5
Molar NaCl

An increase of medium NaCl concentration induces *Dunaliella* cells to evolve O_2 photosynthetically even in the absence of CO_2. This NaCl induced O_2 evolution may reflect the induced conversion of reserve carbohydrate to glycerol (Kaplan, *et. al.* 1980).

It is evident in the present study that for optimum growth and productivity, *Acanthus* needs sodium chloride. However, higher concentrations are responsible for decrease in productivity (Fig. 5). When compared with *Avicennia*, *Acanthus* is less tolerent. Productivity in case of *Avicennia marina* seedlings goes on increasing upto 0.3 M NaCl and then drops abruptly. This throws light upon the zonation met with the natural community, where *Avicennia* is found towards the low water level mark and *Acanthus* away from it.