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K. candel in the centre

The mangroves are mainly tropical in nature but extend in subtropics also. Nevertheless their occurrence in a particular latitude is not uniform. Sometimes they occur on east coast but not on the west. According to Chapman (1976) this may be because of water currents as well as other physiographic conditions. Kotmire (1983) reported very interesting observation that, apart from the distribution of mangroves along the coast, the occurrence of species in a given mangrove stand is in response to conditions of substratum. He reported that Avicennia officinalis and Avicennia marina differ in their salt tolerance and also show the difference in supporting soil.

AUTECOLOGY

For the present study a place towards the south of Ratnagiri city was selected. The estuary is known as Bhatya estuary. The Ratnagiri river joins the Arabian sea and constitutes the said estuary. It is interesting to note here that this estuary is peculiar in that it supports mangrove species which are not found towards the north boundary of the Ratnagiri city along the Shirgaon estuary. There are two important species which occur only at Bhatya estuary and so far not reported from Ratnagiri and Sindhudurg districts. They are Rhizophora apiculata and Kandelia candel. That is, the distribution of these species is restricted to Bhatya estuary in Ratnagiri district.

Both these species belong to family Rhizophoraceae. In this family there are five genera out of which four, Rhizophora, Bruguiera, Ceriops and Kandelia, are mangroves, and the remaining one Carallia is a glycophyte. There are seven species of Rhizophora out of which two are reported from western coast of India. Bruguiera has six species out of which two are found along the western coast of India. Ceriops is represented by one species out of two, Kandelia being monotypic. The genus Rhizophora is characterised by following characters.

Trees, branches thick, terete, marked with leaf-scar. Leaves opposite, coriaceous, ovate or elliptic, mucronate, quite entire, glabrous, stipules large, in pairs, interpetiolar, caducous. Flowers rather large, in axillary 2-3 crotomously divided and few-flowered cymes. Calyx 4-lobed, surrounded at the base by connate bracteoles, tube short, adnate to the ovary at the base. Petals 4, entire, inserted on a fleshy disc. Stamens 8-12, anthers subsessile, multiloculate. Ovary 2-celled, $\frac{1}{2}$ -inferior, produced beyond the calyx into a fleshy cone, ovules 2 in each cell, style conical at the base, subulate, stigma bifid. Fruit coriaceous, ovoid or obconic, girt at the base with the reflexed persistent calyx teeth. Seed germinating while the fruit is still on the tree, radicle elongates, perforating the apex of the fruit and descending from the tree to the mud (Cook, 1903).

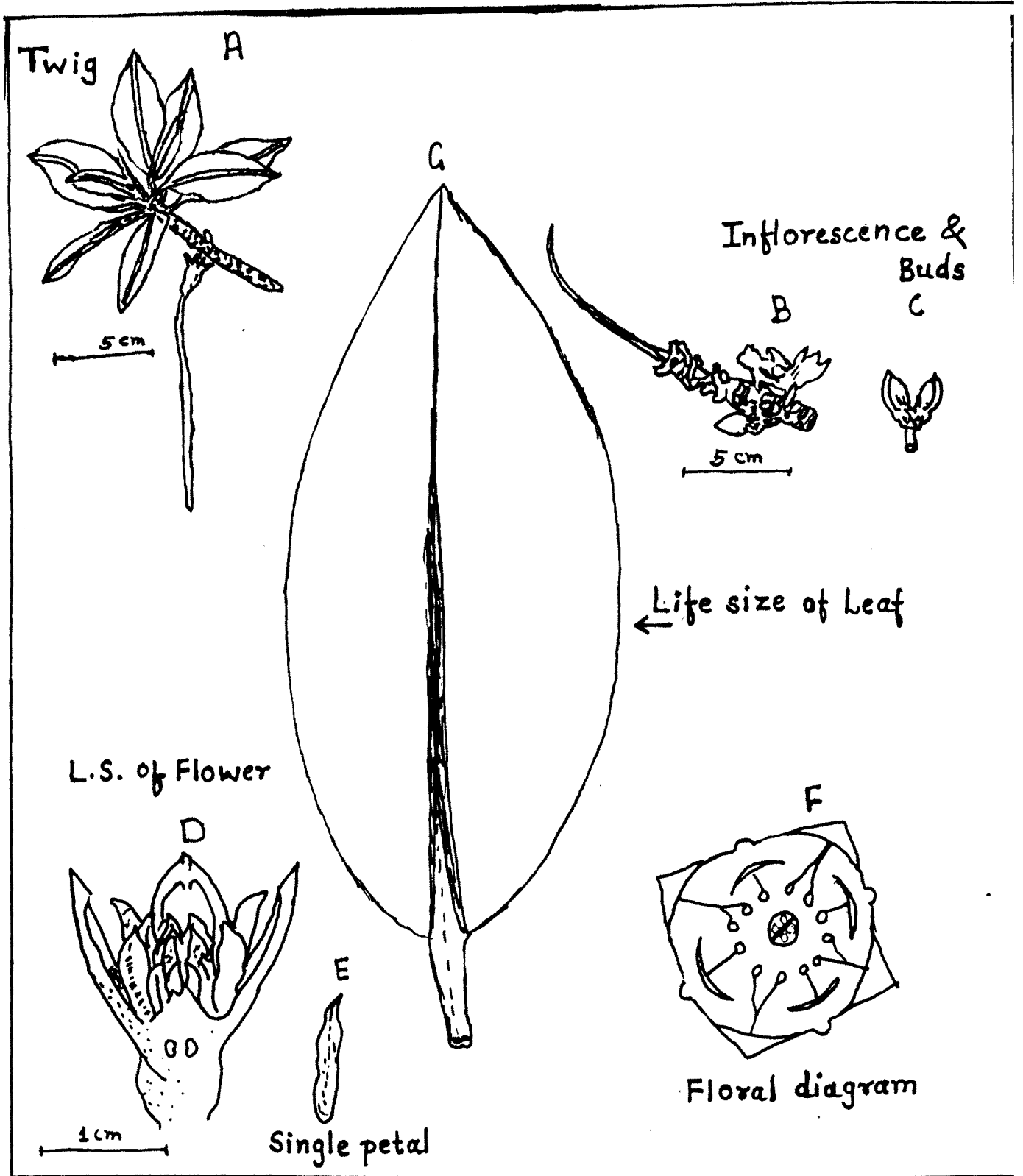


FIG. 1

The most recent studies, Ding Hou (1958, 1960), Keay (1953), Savory (1953), Stearn (1958) have indicated that there are seven recognised species, four from the Indonesian region and three from the west Africa - New World - Rhizophora mangle is the sole species of the New World group that overlaps with the Indo-Pacific group. The key for the genera of Rhizophoraceae and to the species of the genus Rhizophora has been given in the following pages.

The genus Kandelia

A small tree with terete leafy branches, leaves opposite, oblong, obtuse, entire, stipules interpetiolar, caducous. Flowers large, few, on axillary dichotomously - branched penduncles, white. Calyx 5-6 merous, surrounded at the base by connate bracteoles, tube short, adnate to the ovary, lobes linear. Petals 5-6, inserted at the base of fleshy disk, bifid, lobes capillaceo-multifid. Stamens indefinite, filaments filiform, anthers small, oblong. Ovary $\frac{1}{2}$ inferior, 1-celled, produced beyond the calyx into a fleshy cone, ovules 6, affixed in pairs to a central column, style filiform, conical at the base, stigma 3-fid. Fruit coriaceous, conical-ovoid, girt above the base by the reflexed calyx-lobes, 1-celled. Seed 1, germinating as in Rhizophora. Cotyledons confluent, protruding radicle elongates, clavate acuminate (Cook, 1903).

Kandelia candel

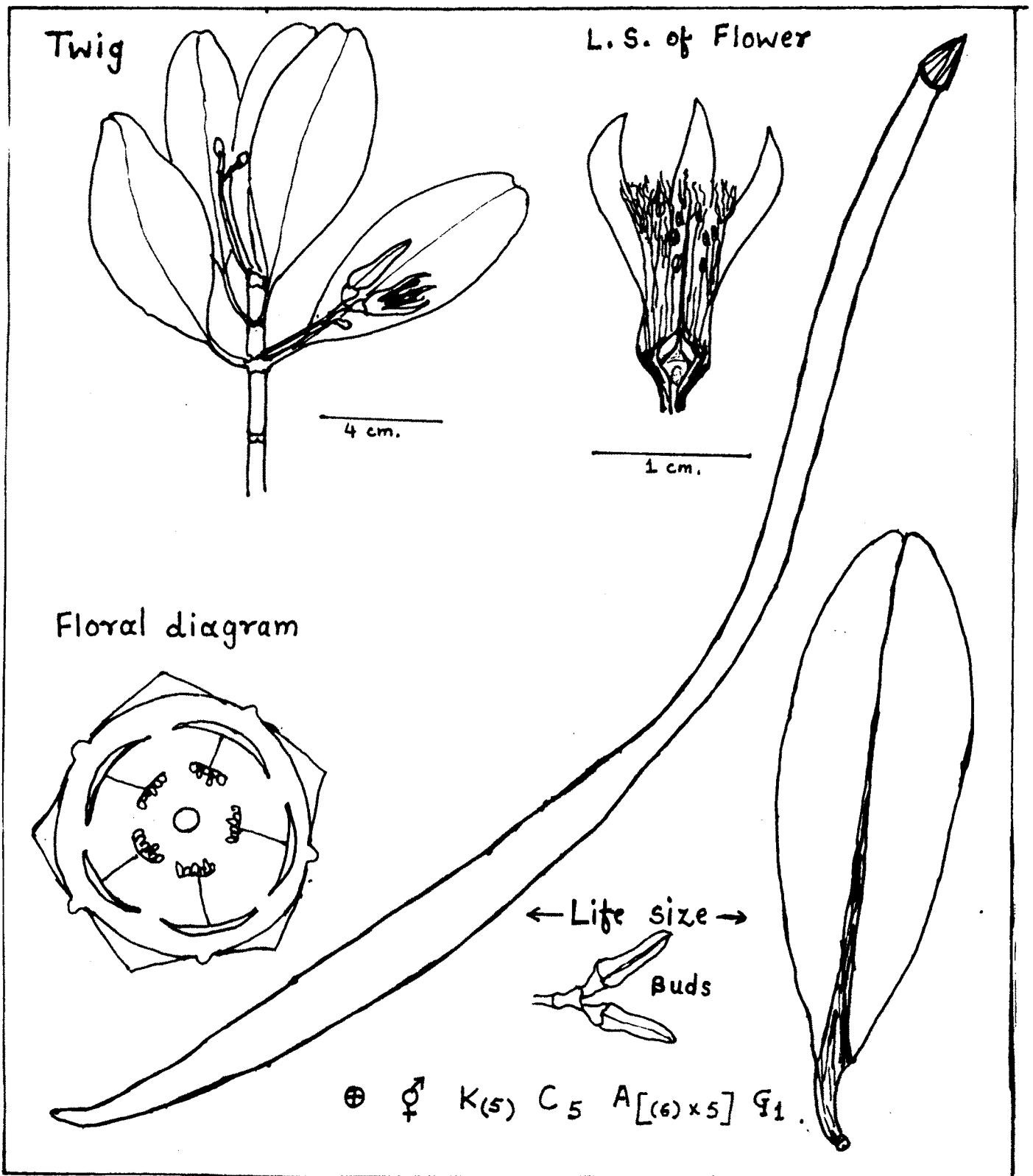


FIG. 2

Family Rhizophoraceae

Key to the genus identification (Cook, 1903)

Seeds exalbuminous, radicle large, protruding while the fruit is still on the tree.

Calyx 4-lobed, stamens 8-12, ovary 2-celled... 1 RHIZOPHORA

Calyx 5-6 lobes, stamens 10-12, ovary 3-celled..2 CERIOPS

Stamens indefinite, ovary 1-celled.....3 KANDELIA

Calyx 8-14-lobed, stamens 16-28,

ovary 2-4 celled.....4 BRUGUIERA

Key to species of Rhizophora (Chapman, 1976)

Key to Indo-Pacific species.

1. Leaf tips acute, not recurved, never rolled up, → 2, leaf tips blunt, recurved or rolled up R. mangle
 2. Petals hairy, inflorescences in leaf scar arils, → 3, petals glabrous, inflorescences in leaf scar arils R. apiculata
 3. Inflorescence 2-8 flowered, stamens mostly 8, → 4, Inflorescence 2(-4) flowered, stamens 12-15 R. lamarckii
 4. Free part of ovary emerging beyond disk in anthesis R. mucronata
- Free part of ovary by disk in anthesis R. stylosa

The genus Kandelia

This genus is monotypic. Cook (1903) has described a single species, Kandelia Rheedei however, Chapman (1976) has recognised this species as Kandelia candel. He has given the synonymes as follows :

Kandelia candel (L) Druce

Ding Hou, Kanehira, MacNae, Merr, Sloom, Wlker.

= Rhizophora candel/linn, DC

= Kandelia rheedii W and A, Arn, Backer,

Bl, Benth, Craib Guillaumin Henslow,

Hooker, Koord and Valetton, Kurr, Miq,

Ridly, Watson, Weight.

Distribution percentage

The vegetation at Bhatya estuary starts with Avicennia marina on the north bank and Sonneratia alba on the south. Rhizophora apiculata was found distributed on both the banks intermixed with other species. The experimental site was selected on the south bank of the estuary after almost a pure vegetation stand of S. alba. The dimensions of area were 100 x 200 m. At this site the percentage distribution of component species was studied. It was found that R. apiculata constitutes 45 %, K. candel 25 % and remaining 30 % was occupied by Agiceras corniculatum, Avicennia officinalis and Sonneratia alba. Kotmire (1983) reported 100 % distribution

of S. alba at Deogad estuary. This was afterwards substituted by other species, as the survey was made of upstream location. In the present investigation also S. alba was observed as pioneer species near the mouth of estuary. Then S. alba was replaced by R. apiculata and other species in the upstream areas. It will not be out of place to record here that a mature tree of R. apiculata can attain a height of 40 m and d.b.h. of 60 cm (Percival and Womersley, 1975). This report comes from Papua New Guinea, however, in present investigation the height was observed only of 6-8 m.

Flowering

Both the plants under present study possess vivipary. Their flowering period, however, differs greatly. In the present study initiation of flowering was observed in the beginning of June in R. apiculata, it continues upto October-November, Fruit is the stage onset immediately after flowering. The cycle of flowering takes almost one year till the viviparous seedling is mature and ready to shed. However in R. apiculata, the shedding of mature seedling is completed before the initiation of flowering during next season.

K. candel differs from R. apiculata in that it flowers and fruits simultaneously and one can see the mature seedling (propagules) hanging on mother plant when the plant starts flowering during the next year. Initiation of flowering in

Flowering in R. apiculata and K. candel.

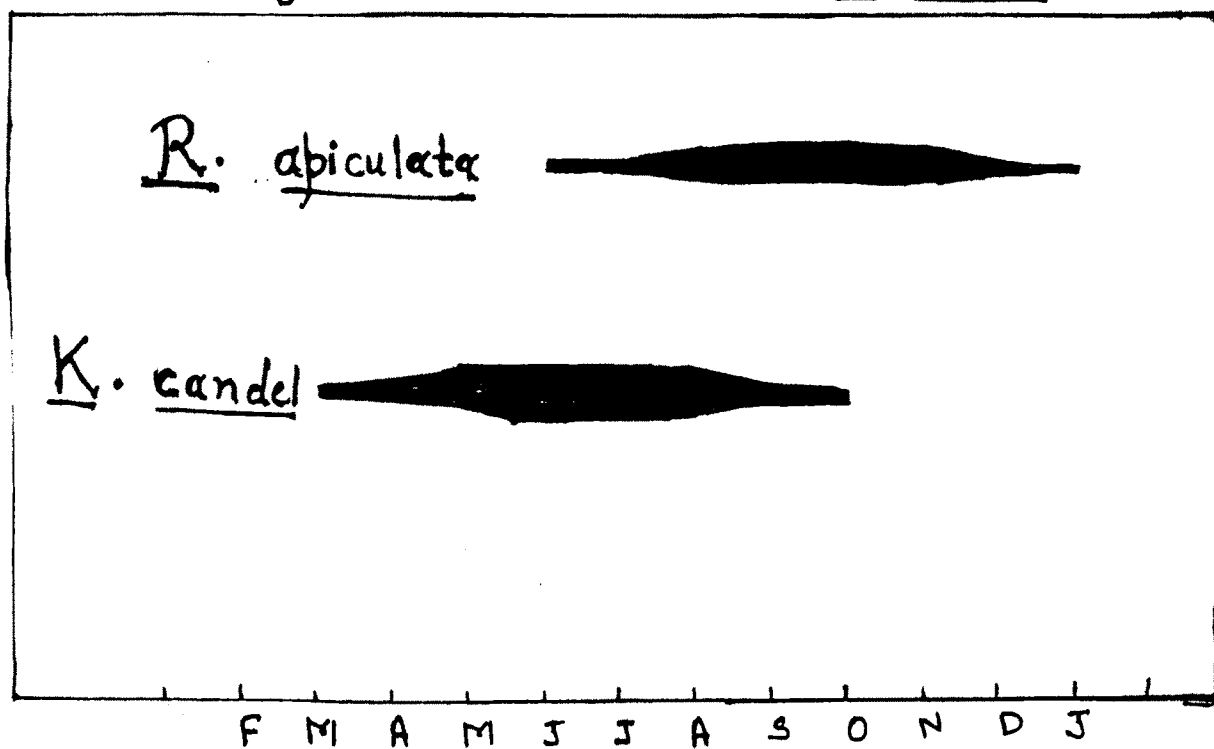
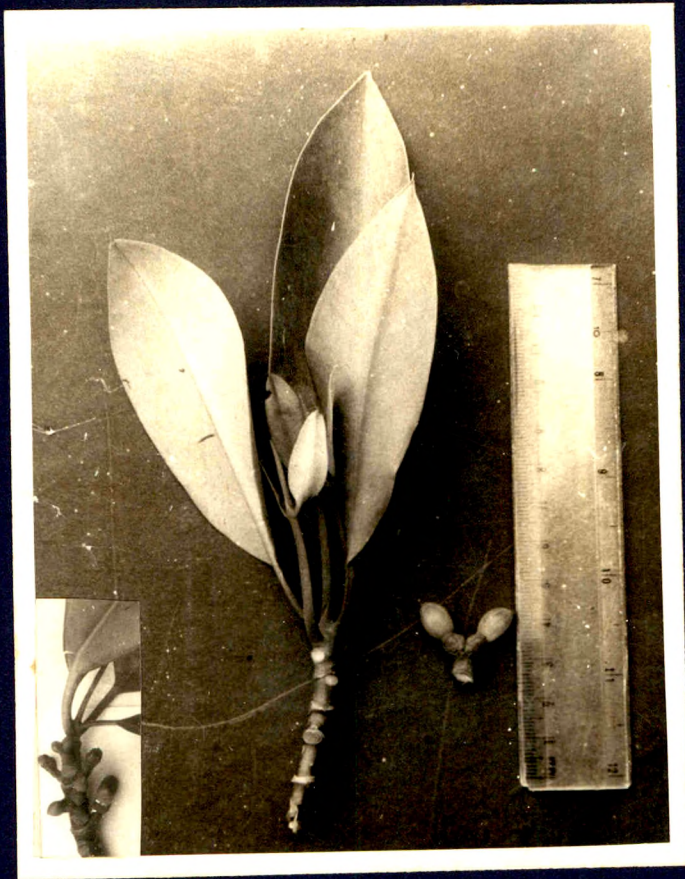


FIG. 3

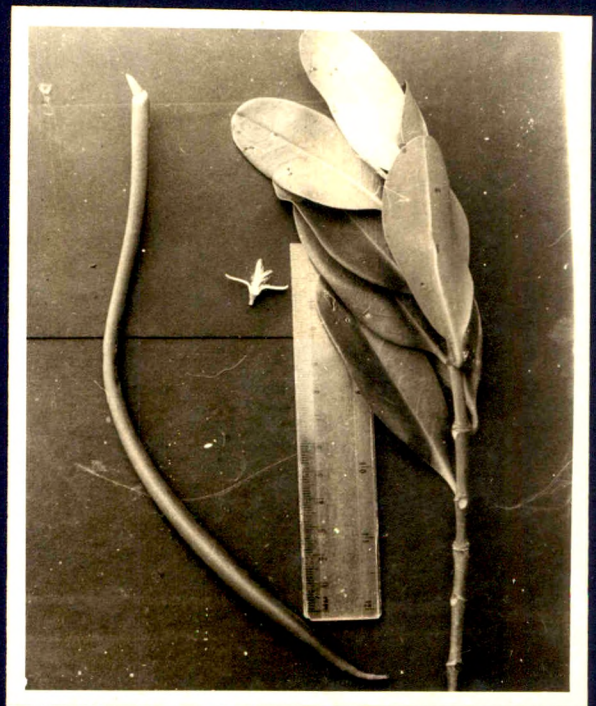
this species is seen in the month of March. Within two to three months the fruits mature and the seeds start germinating while still on the mother plant. At this stage also flowers are observed on the plant. In the month of June-July the radicle coming out of the fruit is seen, at this stage almost all mature propogules are shed (Fig. 3).

The details of flowering and fruiting in R. apiculata have been depicted in Fig. 1. The figure shows the leaf of R. apiculata sketched to its life size and twig with seedling in the axil of a leaf scar. The inflorescence and longitudinal section of a flower also have been presented in the figure. The petals are shorter than calyx, and stamens are usually twelve. The fruit is 2.5 cm long with reflexed calyx lobes. The hypocotyl of the viviparous seedling measures about 30 cm. The radicular end is blunt as against the R. mucronata, the hypocotyl of which measures sometimes 50 cm (Chirputkar, 1969).

Fig. 2 represents the life size of leaf and mature propogule (fruit part off) of K. candel. It also gives the details of flowering the mature seedling measures about 30 cm. Unlike Rhizophora the skin of the propogule of K. candel is very smooth and quite waxy. It lacks pores which are seen in Rhizophora and Ceriops. The radicular end of propogule is tapering and almost 1 cm part is very narrow and pointed. The flowering period of both the species has been given in Fig. 3. The observations are supported by photographs.



R. apiculata with buds



K. candel with a flower
and mature propagule

The Substratum

There are several attempts on substratum characterisation from mangrove ecosystem. Warick (1960) considered the soil from root zone of several mangrove species of Bombay. He reported pH variation in the soil. Earlier to Warick, Bharucha and Navalkar (1942) studied chloride salinity of sea water, soil and leaf sap of mangroves from Bombay. Navalkar and Bharucha (1948, 1949 and 1950) reported pH of soil and bathing water compared it to pH of the mangrove leaves. Recently Kotmire and Bhosale (1979 and 1980) reported texture of the soil at Deogad and Mumbra estuary as well as the soil from root zones of A. marina and A. officinalis, they considered other physicochemical characters of the soils and estuarine water.

In the present investigation attempt was made to know the texture of the soil (Table 1) from the root zone of R. apiculata and K. candel. It was observed that the major difference in the texture was due to the silt and clay components. Kotmire and Bhosale (1979) also reported that there is not major change with bigger particles^c of the soil but difference lies with the smaller particles, in case of soils from root zone of A. marina and A. officinalis. It is evident from (Table 1) that the texture of the soil at the root zone of R. apiculata was coarser than that of K. candel.

Considerable work in the field of ecology of Indian mangroves has been contributed by T. Annand, Rao and co-workers (1977).

Table 1 : Granulometry of soil from root zone of
R. apiculata and K. candel

Component	Diameter in mm	Soil component in %	
		<u>R. apiculata</u>	<u>K. candel</u>
Gravel	more than 2	45.050	45.000
Coarse sand	2 - 0.2	30.000	20.000
Fine sand	0.2 - 0.02	15.600	15.200
Silt	0.02 - 0.002	05.500	10.000
Clay	less than 0.002	03.640	09.300

Rao et al. (1963) considered distinct zonation in mangrove vegetation which was attributed to different factors like tidal effects and soil conditions. Rao and Mukharjee (1972) found that tidal effect is more pronounced in determining the zonation in mangroves. Rao et al. (1963 and 1966) studied the ecology of soil supporting different mangrove species. According to them the texture of the soil varies greatly. The soil supporting Avicennia sps. was a sandy loam, that supporting A. alba a loamy sand and that supporting A. alba and E. agallocha was a coarse sand. A mixed vegetation including Rhizophora, Avicennia, Bruguiera lumnitzera, Sonneratia etc. had a soil of loamy sand nature. Thus these ^{earlier} observations support present findings that the texture of the soil supporting R. apiculata and K. candel different ^{is} from each other.

Table 2 records different characteristic^s of estuarine water and the soil supporting R. apiculata and K. candel. It was noted that the pH of the water was almost neutral or very slightly acidic. The two soils differ in their pH by 0.5 %. The soil from the root zone of K. candel was more acidic. The electrical conductivity of water and the soil do not differ greatly. Bhosale and Kotmire (1979) however reported very high value for EC of water. This may be because of the fact that the samples were collected after the onset of rainy season. The pH range of the soils supporting different species of mangroves varied from 7.1 to 8.0 (Rao et al., 1963, 1968). Kotmire (1983) compared the soils of Deogad, Mumbra and Are estuary and reported the pH ^{range} regarding between 5.8 and 6.6.

Table 2 : Water soluble inorganic constituents, pH and electrical conductivity of water and soil samples from Bhatya estuary

	Water*	Soil at the root zone of	
		<u>R. apiculata</u>	<u>K. candel</u>
pH	6.9	6.7	6.2
EC (M mhos/cm)	1.9	2.1	1.85
Na	692.4	80 (540)@	114.6 (773)@
K	40.6	9.34 (80)@	10.0 (86)@
Cl	697.3	99	150
Na/K	17.05	8.60	11.46

Values expressed as mg/100 g air dry soil.

* Values expressed as mg/l.

@ Values in leachate with ammonium acetate.

The major inorganic constituents of estuarine water and the soil are Na and Cl. The sodium affects the potassium intake in plants, higher levels of sodium in substratum hinders the K-absorption in plants (Rains, 1972). Therefore it was thought worth ^{while} to investigate Na, K and Cl from the water as well as soil supporting R. apiculata and K. candel. It is seen from Table 2 that the flooding water consisted large amounts of sodium and chloride and very little amount of potassium and the Na/K ratio was as high as 17. Rains and Epstein (1967) reported this ratio as high as 40 in water and its reduction to 7 in plants.

In plants, the present investigation water soluble salts were estimated, as well as the values for Na and K from ammonium acetate leachate were recorded (Table 2). It was obvious that value of water soluble salts was very low. Sodium values in both the soils were second, in the descending order the chloride values being highest similar observations are due to Kotmire (1983). It was found that potassium was less in the flooding water, therefore, the values for K in the soils were also low. The important function in the soil was studied by determining Na/K ratio. The ratio was as high as 17 which dropped down to 8.6 (R. apiculata - soil) and 11.46 (K. candel - soil). Bhosale et al. (1983) presented a review on biology of mangroves where Na/K ratio was reported as 6.35 (A. officinalis) and 8.3 for (A. marina). This ratio for Deogad and Mumbra soil found to be 1.4 and 2.2 respectively. It appeared from Table 2 that K. candel soil contained more amount of sodium and chloride. The ratio of Na/K also being higher with

more acidic soil indicated more salinity. The soil study provided the ecological background for the species distribution and understanding the nature of salt tolerance of the two species under study.

PHYSIOLOGY

It has been already stated that the species under present study were found distributed only at certain locations on the western coast of India. This arose interest to know the endogenous salt levels i.e. the salt tolerance in these plants. Obviously, the determination of sodium, potassium, calcium and chloride levels, as major salt components, from the plants became the essential aspects. In addition, the overall picture of physiological status of plant can become evident by studying the organic contents like carbohydrates, chlorophylls, polyphenols and ^{ti}filtratable acidity.

I. Inorganic constituents

Walsh (1974) in his review on mangroves presented a good account of physiology including mineral constituents. Joshi and Bhosale (1982) gave inorganic constituents of several mangroves and associates. They also presented the seasonal variations in major inorganic constituents of several mangroves.

i) Sodium :

It is obvious that under saline environments, the major cation concerned is sodium (Na). In terrestrial glycophytes like Jatropha curcas (Torne and Joshi, 1964), sodium levels were

Table 3 : Major inorganic constituents of the mature leaves and different parts of seedlings of R. apiculata and K. candel

Element	Leaf Mature	<u>R. apiculata</u>			Leaf Mature free	<u>K. candel</u>		
		Leaf	stem	Root		Leaf	Stem	Root
Na	0.970	5.950	1.245	3.145	1.035	3.580	0.950	2.490
K	0.898	0.609	0.440	0.694	0.728	0.694	0.949	0.439
Ca	1.571	0.714	0.428	0.404	0.939	0.286	0.428	0.143
Cl	5.756	4.050	4.292	3.267	8.907	4.292	7.073	5.960
Na/K	1.09	9.77	2.83	4.53	1.42	5.16	1.00	5.67
Na/Ca	0.62	8.33	2.90	7.78	1.11	12.52	2.22	17.41

Values expressed as g/100 g dwt.

as low as 0.64 %. However, in saline plants the value could be as high as 9.9 % in S. portulacastrum (Singh, 1967). Warick (1960) reported 10.42 % and 5.32 % Na in the phylloclades and stems of Salicornia. However, Na was found unevenly distributed in different plants (Shinde, 1981; Joshi and Bhosale, 1982; Kulkarni, 1983). Brownell and Wood (1957) reported Atriplex vesicaria as Na-dependent plant. Brownell (1968) stated that other species of Atriplex required sodium as ^{an} essential element. Similar observation was due to Singh (1967) that S. portulacastrum can not grow in Na-free medium. Williams (1960) also reported Halogeton glomeratus, a poisonous weed, as Na-dependent.

Guillard (1962) mentioned that Na and other ions may have a double role viz. (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 requirement. In some cases Na enhances K uptake and reduces Ca (Ratner, 1935; Higginbotham et al., 1962). The metabolic processes of halophytes have adapted for Na. Sodium salt increases yield, improves vigour and foliar colour in many plants. In hot climates Na helps the plants to decrease wilting (Epstein, 1972).

In the present investigation Na was determined from the leaves of mature plants as well as different parts of seedlings of R. apiculata and K. candel (Table 3). It is evident from the table that mature leaves in both plants contained less amount of sodium as compared to the leaves of seedlings. The values for

Table 4 : Comparison of mineral constituents from the leaves of different mangroves

Name of the plant	Family	Life form	Na	K	Ca	Cl
<u>R. apiculata</u>	Rhizophoraceae	Tree	0.97	0.89	1.57	5.76
<u>R. mucronata</u>	"	"	3.00	0.66	0.70	3.40
<u>K. candel</u>	"	"	1.03	0.73	0.93	8.91
<u>B. gymnorhiza</u>	"	"	3.39	0.36	1.28	4.35
<u>B. parviflora</u>	"	"	4.13	1.33	1.23	3.87
<u>C. tagal</u>	"	Shrub	1.40	0.68	1.06	3.49
<u>A. marina</u>	Avicenniaceae	Tree	4.60	1.24	0.36	6.31
<u>A. afficinalis</u>	"	"	5.30	1.63	1.18	3.88
<u>S. alba</u>	Sonneratiaceae	"	2.80	0.80	1.06	6.13
<u>L. racemosa</u>	Combretaceae	Shrub	5.54	2.77	2.17	11.73
<u>E. agallocha</u>	Euphorbiaceae	Tree	1.00	1.28	0.86	5.03
<u>S. persica</u>	Salvadoraceae	"	2.75	1.96	5.88	9.29

Values expressed as g/100 g dwt.

(Data based on Chirputkar 1969, Joshi and Bhosale 1982, Kotmire 1983, and present investigation).

seedling-leaves were higher than stem or root in both plants; the stems showed intermediate levels of Na. This trend appeared to be obvious as roots, being absorbing organs, may have higher values than the conducting organ, the stem. The leaves indicated the accumulation of Na. The levels of Na in R. apiculata seedling-leaves were very high (5.950 %). Such a high level of Na was also reported for A. officinalis (5.30 %) and L. racemosa (5.54 %) by Joshi and Bhosale (1982). Many mangrove species contain high level of sodium in the leaves (Table 4). Lumnitzera racemosa is a succulent plant but Avicennia officinalis or A. marina are not. Mishra (1967) also recorded high Na (5.49 %) for Clerodendrum inerme.

Kotmire (1983) found that A. marina, C. inerme and S. alba were accumulators of Na. He presented a list of Na-accumulators in descending order as under :

- | | |
|----------------------------------|--------------------------------------|
| 1. <u>Atriplex vesicaria</u> | 5.2 % (Beadle <u>et al.</u> , 1957). |
| 2. <u>Sonneratia alba</u> | 4.4 % (Joshi, 1976). |
| 3. <u>Bruguiera parviflora</u> | 4.12 % (Chirputkar, 1969). |
| 4. <u>Avicennia marina</u> | 4.10 % (Rains and Epstein, 1967). |
| 5. <u>Acanthus ilicifolius</u> | 3.46 % (Bhosale, 1974). |
| 6. <u>Rhizophora mucronata</u> | 3.36 % (Joshi, 1976). |
| 7. <u>Salvadora persica</u> | 2.75 % (Joshi and Bhosale, 1982). |
| 8. <u>Ceriops tagal</u> | 2.64 % (Joshi, 1976). |
| 9. <u>Avicennia alba</u> | 2.40 % (Joshi, 1976). |
| 10. <u>Excoecaria agallocha</u> | 2.39 % (Sawant, 1971 unpublished). |
| 11. <u>Aegiceras coniculatum</u> | 2.35 % (Bhosale, 1974). |
| 12. <u>Aeluropus</u> spp. | 1.23 % (Warick, 1960). |

In this list R. apiculata stands 14th and K. candel 13th. However, these places of mangroves in the list can not be final. The values change as per the location (Kotmire and Bhosale, 1979) which can be seen from Table 5. Moreover, substratum plays an important role as evident from Tables 1 and 2. The soil supporting K. candel contained more Na, possibly, causing more Na in the leaves.

ii) Potassium :

Potassium is the essential monovalent cation, required by all living organisms except a few microorganisms where rubidium substitutes it (Epstein, 1972). K is linked with the processes like hydration, cell organization and permeability. In some cases K is substituted by Na but it cannot be completely replaced by Na or Li. It is needed in ^{kg/ha} more amounts by young actively growing parts. Burridge et al. (1964) and Torne and Joshi (1964) found that K was withdrawn from the leaves and supplied to developing regions in Cacao and Jatropha curcas. K deficiency causes reduction in growth, leaves show inward rolling and internodes are shortened. K is further responsible for decrease in photosynthetic activity, disturbance in carbohydrate metabolism, ^{red. CO₂} less development of chlorophylls, increase in respiration, and accumulation of certain other ions. K also affects citric acid concentration but not that of malic acid (Rasmussen and Smith, 1961).

As the environment of mangroves has higher sodium content, more Na is taken up by plants and K uptake is decreased. However,

K values do not decrease to the extent to be entirely replaced by Na (Singh, 1967). K can be readily absorbed and is a highly mobile element (Bukovac and Wittwer, 1957). In halophytes and saline plants K is responsible for the degree of salt tolerance. The problem of mangroves is to absorb enough K when Na is abundant in the surrounding medium (Joshi et al., 1972). Larsen (1967) already indicated that the problem of salt tolerance is intimately linked with K-uptake. According to Ferry and Ward (1959) average value of K in glycophytes ranges in between 0.3 and 0.6 g per 100 g dry weight. But according to Epstein (1972) the optimum value for K is 1 %. Absorption of K depends upon Na as well as other cations in the medium. It was reported by Osmond (1968) that in Atriplex leaf slices, when kept in NaCl solution, Na was taken in largely by exchanging K; the influx of Na and efflux of K were caused by low concentrations of Ca in the medium. Two mechanisms of uptake of K and Na existed in Atriplex (Black, 1960) are given below :

i) Sodium mechanism : where K ions can compete when Na concentrations were low, resulting in "luxury" uptake of K;

ii) K mechanism which is completely independent of competition with Na.

Epstein (1966) reported similar observations. First mechanism has a high affinity for K while second mechanism is for Na absorption.

The present investigation indicated less than 1 % K in R. apiculata and K. candel. It can be seen from Table 4 that K values in many mangroves are below 1 %. Apparently it seems that some of the mangroves are deficient in K. This is possibly because of ion antagonism. Joshi et al. (1975) reported an antagonism both between Na and K and Na and Ca. Looking at the Table 5, it is clear that the levels of K in the leaves of K. candel are governed by Na in the substratum. Vashisthi estuary contains almost fresh water whereas other two estuaries have saline water. Under fresh water conditions more K (1.25 %) was absorbed possibly at the cost of Na and Ca. At Terekhol estuary higher level of sodium caused lower levels of K and Ca. The K level in ^{the} present study for K. candel and R. apiculata mature leaves are higher than R. mucronata and B. remnorhiza, all species having the same life form. It is possible that the distribution of species restricted to the areas which are within the limits of Na and K tolerance and requirements, respectively, of the species.

iii) Calcium :

Saline soils are usually calcium rich, however, in halophytes and other saline plants it is low which indicates the role of Na salinity in Ca uptake. When sodium was in external medium it interfered with Ca uptake (Osmond, 1966). Excess Na in substratum affects the uptake of divalent cations, Ca as well as Mg. Bell and Biddulph (1963) have suggested that Ca moves up the stem by the process of exchange. This concept of upward trans-

location up the plant is ^{conforming to} in the controversy with the classical mass flow. The problem of Ca uptake is an important aspect concerning the physiology of mangrove vegetation, Ca functions as a structural component, as well as cofactors of certain enzymes. The optimum levels of Ca required by terrestrial plants are 0.5 % (Epstein, 1972). Ca is an essential element, according to Epstein (1961), for maintaining the integrity of the selective ion transport mechanism and essential for full growth. LaHaye and Epstein (1969 and 1971) reported that presence of appropriate concentration of Ca increased the ability of an otherwise susceptible species to be able to stand the effect of high NaCl concentration.

Bower and Wadleigh (1948) and Osmond (1966) observed that when Na was more in external medium, it interfered with Ca uptake. Chirputkar (1969) recorded 1.06 % to 1.28 % Ca in mangroves. Walsh (1974) gave the range of Ca for several mangroves from 0.65 % to 2.48 %. The present investigation recorded high amount of Ca for R. apiculata leaves (1.51 %, Table 3).

In case of K. candel - mature leaves, the value is 0.93. At the seedling stage Ca absorption is low. From Table 4, Ca appears not to be at deficient level except in A. marina. It is clear from Table 5 that sodium levels affected Ca absorption. The highest Ca value was reported for Salvadora persica and associate mangroves as 5.88 % by Bhosale and Joshi (1982).

Table 5 : Inorganic constituents from the leaves of
K. candell from different localities

	Estuary		
	Bhatya	Terekhol*	Vashishti*
Na	1.03	2.00	0.72
K	0.72	0.84	1.24
Ca	0.92	0.68	0.85
Cl	8.90	2.84	2.27
Na/K	1.42	2.40	0.60
Na/Ca	1.11	2.94	0.85

Values expressed as g/100 g dwt.

* Joshi and Bhosale (1982).

Table 3 represents Na/K ratio from mature leaves and different parts of seedlings. It was found that Na/K ratio and Na/Ca ratio are good indicators of Na, K and Ca relations in the plants. The Na/K ratio was found to be 40 in the water bathing mangroves which was reduced to 7 in plants (Rains and Epstein, 1967). Na/K ratio in the present investigation is as high as 9.77 in the leaves of seedling of R. apiculata and as low as 1.0 in the stem of K. candel. In both the plants, this ratio is higher in the leaves of seedlings and next to that is in the roots and the stem. Na/Ca ratio is surprisingly less in the mature leaves of R. apiculata which is less than 1. This ratio goes as high as 17.41 in the roots of the K. candel. This ratio parallels with Na/K ratio. The Na/Ca ratio under fresh water conditions was only 0.85 which could raise to 2.94 under higher sodium salinity (Table 5). This shows the relation of Na with Ca and K.

iv) Chlorides :

Chloride is an essential elements for higher plants (cf. Bonner and Verner, 1976). It is major constituents of sea water and constitutes almost 55 % of dissolved material by weight. It is taken as the indicator of salinity of water. Broyer et al. (1954) mentioned Cl as required for growth of higher plants. They further showed accumulation of chlorides in older parts. Woolley et al. (1958) reported that Cl was transported from older to younger leaves and from high concentration to low

concentration. Walter and Steiner (1936 and 1937) determined different zones of mangroves of east Africa depending upon chloride tolerance. Walter (1955) distinguished halophytes as chloride succulent and sulphate succulent halophytes.

He suggested that Cl ions induce succulence whereas sulphate ones do not produce this effects. Cl causes swelling of plasma due to which absorption of other cations is prevented (Adriani, 1956). According to Walter (1961) Cl ions are stored in vacuoles of leaf cells. Steiner (1939) noted that halophytes absorb more chlorides even from nonsaline soil than nonhalophytes from the same soil. Rains and Epstein (1975) recorded 7.5 % Cl in A. marina. Beedle et al. (1957) has recorded 9.6 % A. vesicaria.

In the present investigation very high Cl values were observed in all parts of the plants. This was so especially with K. candel. A comparison has been made with chloride value of different mangroves in Table 4. L. racemosa showed as high as 11.7 % Cl. The leaves of this shrub are succulent, the non-succulent leaves of A. marina contained 6.1 % Cl. In this comparison the values of chlorides in R. apiculata appeared to be within range, however, Cl levels in K. candel, without succulent leaves, are surprisingly very high. Singh (1967) found 8.64 % Cl in Sesuvium portulacastrum. Van Eijk (1939) noted 18 % chlorides in Salicornia herbaceae growing on 3 % NaCl solution. When the same species was grown on 4.1 % NaCl solution showed 26 % chlorides. Keller (1925) and Brownell and Wood (1957)

reported that halophytes are Na and Ca dependent plants and show poor growth in their absence.

Nissen (1973) showed the uptake of cations and chlorides by a single multiphasic mechanism which may be fundamentally same in a variety of plant tissues. Wagner (1974) showed that photosystem II is responsible for light dependent increase of chloride uptake but K uptake requires additional energy from photosystem I. Kylin (1972) suggested that halophytes have evolved various intercellular salt regulatory mechanisms simultaneously. This can be either unequal storing of ions within different well compartments by pump mechanism to keep the salt sensitive sites salt-free or synthesis of a surplus of enzymes to bypass the inhibitory effects of salt (Osmond and Greenway, 1972).

High levels of chlorides in the present study appeared to be in response to chloride in the substratum. Under low salinity lower values of chlorides were reported in K. candel. Bhosale and Joshi (1982) have presented a list of mangroves classified into different groups depending upon mechanism of salt regulation. They reported K. candel as salt excluding species. However present results of chloride did not indicate salt excluding nature of K. candel. Joshi et al. (1975) have reviewed different mechanisms of salt resistance given by Walter (1961), Jennings (1968) and Scholander (1968). Almost all Rhizophoraceae members were included under the type salt excluding. The other two types being 'salt excreting' and 'salt accumulating'. It is difficult to categorise

K. candel which does not show either salt glands or succulence, as salt excreting or salt accumulating type. Nevertheless, it can not be proved at this stage that K. candel and R. apiculata excluded or avoided the salt in the substratum by any mechanism. Therefore, the salt regulation in these plants remains unclear.

II. Vivipary

Vivipary is to give birth to young ones. In the plant kingdom also vivipary is observed where seed germinates on the mother plant itself. In this process the development of embryo is continued immediately after fertilization of ovule; due to this there is no resting period of seed and thus seed germination takes place, when the fruit is still attached to the mother plant. Mahabale (1961) observed the viviparous germinationⁱⁿ gymnosperms which is rather unusual. Vivipary in mangroves is an adaptive feature, however, all the mangroves do not show presence of vivipary but it is restricted to the family Rhizophoraceae. The first report of vivipary in mangroves was as early as 17th century when Ray observed this (Devis, 1940).

It was Treub (1883) who undertook the study of development of seedlings in A. officinalis. It was an embryological study. Later on Haberlandt (1895) examined the method of nutrition of viviparous embryos and seedlings in Bruguiera eriopetala, Rhizophora mucronata and Aegiceras majus. Carey and Fraser (1932) presented a detail^{ed} account of embryology, seedling development in A. majus. Joshi (1932) reported vivipary in Atriplex crassifolia and Suaeda fruticosa. Bharucha and Shirke (1947) studied the germination in A. officinalis.

Walter and Steiner (1936) and Kipp-Goller (1940) studied vivipary in mangroves and indicated that the water and other nutritional compounds necessary for the development of seedlings

would be supplied against the normal osmotic gradient and they stated the possibility of the presence of glandular tissue. The glandular tissue was confirmed by Pannier (1962) in case of R. mangle. He tried to correlate anatomy and morphology of vivipary with changes in physiology of a seedling. He tried to locate the exact position of the glandular tissue in the viviparous seedling with the help of acid phosphatase reactions. The presence was shown in between the cotyledonary body and the involving integument of the seedling.

Walter (1969) showed that the viviparous seedling of mangroves hanging on the parent plant contains a small amount of chlorides and their osmotic pressure is lower than that of soil solution and cell-sap of the mother plant. Therefore the seedlings do not get water by usual osmotic phenomenon but by a glandular activity of placental cell. It was shown by several workers that the germination of seed in land halophytes is optimum in fresh water. Poma (1922) reported that the germination of halophyte seeds is prevented by NaCl in the substratum which causes no damage to ungerminated seeds. According to Henckel (1950) the mangroves adapt themselves to high salinity directly on mother plant. They get salt and other nutrients partly from mother plants and partly they fulfil the requirements by photosynthesis. Thus gradually they adapt to high salt concentration.

From the work of Rakitin (1955) and Strogonov et al. (1956) it appears that vivipary in mangroves is a result of the

Na, K, Ca, Cl and ash percentage in the subtending leaf and the propagule of K. candel.

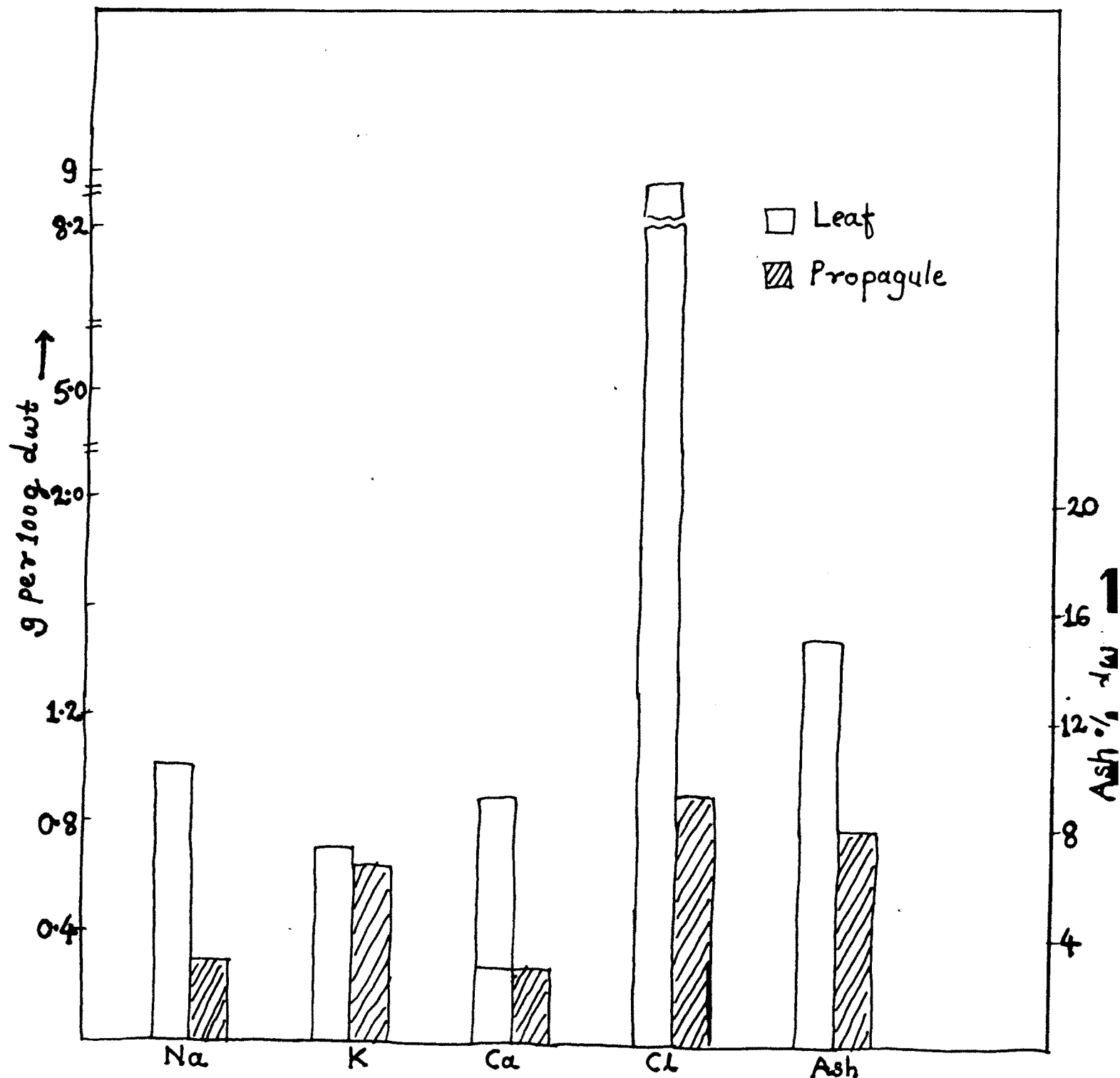


FIG. 4

Table 6 : Inorganic constituents in the leaves and hypocotyls of different mangroves

Element	R. mucronata		B. parviflora		C. candolleana		K. candel	
	Leaf	Hypocotyl	Leaf	Hypocotyl	Leaf	Hypocotyl	Leaf	Hypocotyl
Na	2.57	0.70	4.12	0.94	1.56	0.80	1.03	0.57
K	1.26	0.48	1.33	0.46	1.22	0.82	0.73	0.660
Ca	1.28	0.05	1.23	0.13	1.06	0.12	0.93	0.29
Cl	4.47	1.37	3.86	1.08	2.56	1.19	8.91	0.93
Na/K	2.04	1.34	3.09	2.03	1.28	0.98	1.41	0.87

Values expressed as g/100 g dwt.

delaying effects of chlorine ions on the fruit cast. ^e Hanckel (1963) stated that the resistance to drought is developed in the process of ontogenesis and is based on the preceding phylogeny of the plant. It is general assumption that all terrestrial halophytes are secondary halophytes and have originated from glycophytes. Obviously, the seeds formed at the onset of new ontogenesis are nonresistant^e to salinity. The halophytes acquire the property of adaptations to salinity during their individual development.

With this background, the present study was undertaken. The vivipary in K. candel was studied with respect to the salinity tolerance, therefore the study was restricted to the inorganic constituents of propogule. For the analysis, the fruit portion was removed and the remaining portion was denoted as hypocotyl. The results presented in Fig. 4 and compared (Table 6) with data by Joshi et al. (1972). It was found that the leaf subtending the viviparous seedling (propogule) contained 1.03 % sodium but such a high quantity was not translocated to the seedling in the axil of the leaf. Similarly, chloride percentage of the leaf was as high as 8.9 % and the same in seedlings was 0.93 %. This shows that there occurs selective translocation of cations and anions from the leaves to the seedling. The significance of vivipary has been investigated by several workers (Lotschert and Liemann, 1967; Chirputkar, 1969; Joshi et al., 1972; Bhosale, 1974 and Bhosale and Shinde, 1984).

It was observed (Table 6) that the sodium values in the leaves of different mangroves remain very high but its percentage in hypocotyls is less than 1. The values of Na, K and Ca in the present investigation are comparable with earlier reports by Joshi et al. (1972). It was observed in K. candel that the sodium in the leaves was more than K, therefore, Na/K ratio was more than 1, however, in seedlings Na levels dropped down and Na/K ratio becomes less than 1. This clearly signifies the role of K in viviparous seedlings of mangroves. The results presented in the Fig. 4 on ash percentage, were in conformity of inorganic constituents of leaves as well as the prop^ogule.



III. Organic constituents

i) TAN

The titratable acid number gives the acidic status of the plant tissues. Bennet-Clark (1933) has observed that the succulent hydrophytes do not exhibit diurnal variation in their acid content. Millburn et al. (1968) reported TAN from several Crassulacean Acid Metabolism plants and showed variation in acid contents in plants during day and night. Warick (1960) reported that though Sesuvium is a succulent halophyte there was no fluctuation in the TAN value. This was confirmed by Shinde (1981). Thimman and Bonner (1960) stated that organic acids are directly concerned with the active growth and metabolism of the plants. Seshagiri and Sastri (1952, 1953) noted non-succulent plants with high acidity due to tartaric and oxalic acids but no CAM.

In the present investigation (Table 7) TAN from the leaves of R. apiculata and K. candel was studied. R. apiculata showed higher value (40.51) than K. candel (30.47). Based on the earlier results on inorganic constituents of mature leaves of these two plants it appears that lower TAN value was due to more salt contents in the metabolic environment. Joshi et al. (1962) found that salinity inhibits organic acid metabolism. The earlier reports by Kotmire (1983) are also similar. He reported higher TAN in A. officinalis as compared to A. marina, where A. marina was shown to be more salt tolerance with higher levels of salts in the metabolic environment.

Table 7 : TAN, chlorophylls and polyphenols from the mature leaves of R. apiculata and K. candel

Parameter	<u>R. apiculata</u>	<u>K. candel</u>
TAN	40.51	30.47
Chlorophylls (mg/100 g fwt)		
chl a	33.18	26.82
chl b	19.06	16.34
chl (a+b)	52.24	43.16
chl (a/b)	01.74	01.64
Polyphenols (g/100 g fwt)	03.52	01.74

TAN values expressed as ml of decinormal NaOH required to neutralize the acid in the extracts of 100 g fresh weight.

Eventhough the mangroves do not show diurnal fluctuations in TAN (Bharucha and Ranganekar, 1957; Warick, 1960; Bhosale, 1974; Shinde, 1981 and Kotmire, 1983) there occurred seasonal variation in TAN. A. corniculatum showed lowest value for TAN in monsoon and highest in summer (Shinde, 1981). Such a type of seasonal variation was also recorded for Ipomea (Dhawalkar and Joshi, 1960). Cram (1976) discussed the importance of organic acid in osmotic adjustment. Ackerson and Younger (1975) suggested that salinity tolerance may be due to increased organic acids in bermuda grass. This may explain the seasonal variations in TAN of A. corniculatum, however, in the present study it appeared that higher salt levels in the tissues altered organic acid metabolism, as was shown by some of the earlier workers like Joshi et al. (1962) and Kotmire (1983). Thus the difference in TAN in the present species can be explained in the light of salt tolerance of the species.

ii) Chlorophylls

The important plant pigments, the chlorophylls, depend upon the environmental conditions, according to Bhosale et al. (1983). Under saline conditions the chlorophyll levels are low. There occurs seasonal variation in chlorophyll contents of mangroves. The lowest values of chlorophylls were recorded in winter by Bhosale (1974). This may be in response to different environmental conditions including light. The highest values were obtained in monsoon. Mishra (1967) also recorded the effect of

salinity on chlorophyll contents. Shinde (1981) reported lower values of chlorophylls in summer for Aegiceras and Sesuvium.

In the present investigation chlorophyll a and chlorophyll b were estimated from mature leaves of R. apiculata and K. candel. The lower values were recorded for K. candel. This may be due to the higher chloride salinity in K. candel leaves. It was shown by Mishra (1967) that in Clerodendrum inerme amount of chlorophylls was reduced to half under saline conditions as compared to garden plants. Bhosale (1974) and Bhosale et al. (1983) stated that chloride salinity reduces total chlorophylls, but sulphate salinity increases the same. It was further shown that NaCl salinity affects the chlorophyll b to greater extent. Similar observations were due to Kotmire (1981) for Thespesia populnea under saline and nonsaline conditions. Holden (1973) studied the pigments in C₃ and C₄ plant species and reported the range of the ratio of chlorophyll a to chlorophyll b as 3.1 to 5.6 for C₄ dicotyledonous plants. This ratio ranged from 2.5 to 3.7 for C₃ dicotyledonous plants. However, mangroves show still lower ratio, mostly ranging in between 1 and 2 (Shinde, 1981; Kotmire, 1983; Dongare, 1982).

From the range of ratio it appears that in C₄ plants chlorophyll b is less. The range given by Holden can not be applied as such to all the dicotyledonous plants especially to mangroves. In the present investigation the ratio of chlorophyll a to chlorophyll b in R. apiculata is 1.74 and K. candel 1.64. This

falls within the range of earlier reports on mangroves even though the values of total chlorophylls appear to be less, mangroves can not be said^{to} inefficient in photosynthesis.

iii) Polyphenols :

It is well known that the mangroves are rich in polyphenols. Therefore, they were used, and at some places are still used, to extract the tannin. Most of the studies on mangroves polyphenols were restricted to the samples of bark (Trimble, 1982; Anon, 1904; Drabble, 1908; Brown and Fisher, 1918; Beckley, 1929; etc.). The polyphenols were also recorded from fruits and leaves which are good store houses of polyphenols (Swain, 1965). Humpries (1967) has reported the polyphenol content upto 35 % and stated that the mangroves, inspite of more salt concentration, contain large amounts of water soluble tannins. Shetty (1971) noted enhancement of polyphenols at lower concentration of NaCl in a brakish water fern, Acrosticum aureum. Bhosale (1974) recorded seasonal variations in polyphenols of mangrove leaves where the highest quantity was reported in monsoon. Jamale (1975) found enhancement of polyphenol synthesis by lower concentration of NaCl in Avicennia seedlings. Jamale and Joshi (1978) showed that the amount of polyphenols in the leaves of mangroves is dependent upon the age of the leaves and the polyphenol degradating enzymes.

It was observed in the present investigation that R. apiculata leaves have more polyphenols than the leaves of K. candel (Table 7). It has been already stated that the endogenous levels of salt in K. candel are higher than R. apiculata. Similar observation was reported by Kotmire (1983) where A. officinalis showed more polyphenols than A. marina leaves, A. marina being more salt tolerant. This indicates that though the mangrove leaves contain higher quantity of polyphenols, the level of salinity in the cellular environment affects the polyphenol contents.

iv) Carbohydrates :

Iljin (1932) observed low levels of sugars in the cell sap of leaves of halophytes ranging from 0.54 % to 0.9 %. Mishra (1967) reported in C. inermis, 3.89 % carbohydrates on saline soil and 6.46 % under garden conditions. Dongre (1982) was of the opinion that total carbohydrates in C. inermis decreased with increasing concentration of NaCl treatment. On the contrary Hayward and Long (1947) and Gouch and Eaton (1942) reported that salinity in the substratum increases the percentage of starch in plants. Strogonov (1964) observed increase in glucose and fructose in maize due to salinity. Chirputkar (1969) noted vigorous carbohydrate metabolism in R. mucronata, but in the Bruguiera parviflora and C. tagal it was sluggish. Joshi et al. (1972) reported higher starch content in the leaves of mangroves. According to Bhosale (1974) carbohydrate mechanism

Table 8 : Carbohydrates from the mature leaves of
R. apiculata and K. candel

Carbohydrates (g/100 g fwt)	<u>R. apiculata</u>	<u>K. candel</u>
Reducing sugars	0.026	0.111
Total sugars	0.076	0.192
Starch	6.260	2.287
Total carbohydrates (starch + sugars)	6.362	2.590

in mangroves can be correlated with the method of germination in these plants. Carbohydrate storage is one of the three mechanisms proposed by Ackerson and Younger (1975) for salinity tolerance of the plants. Shinde (1981) reported that most of the saline plants contain high levels of starch.

In the present study percentage of starch is higher than the reducing sugars or total sugars. The leaves of K. candel show lower values of 2.59 % for total carbohydrates as compared to the leaves of R. apiculata (Table 8). In the light of earlier discussion, it seems that the higher salinity in K. candel leaves inhibited carbohydrate metabolism. Nevertheless, Kotmire (1983) reported higher carbohydrates in A. marina which has more salt in the leaves as compared to A. officinalis. From these and similar investigations, it seems possible that the response of carbohydrate metabolism to salinity differs with the species in the saline environment. It may also depend upon other adaptive features that the species possess^{es} to overcome harmful levels of salt in the plant.