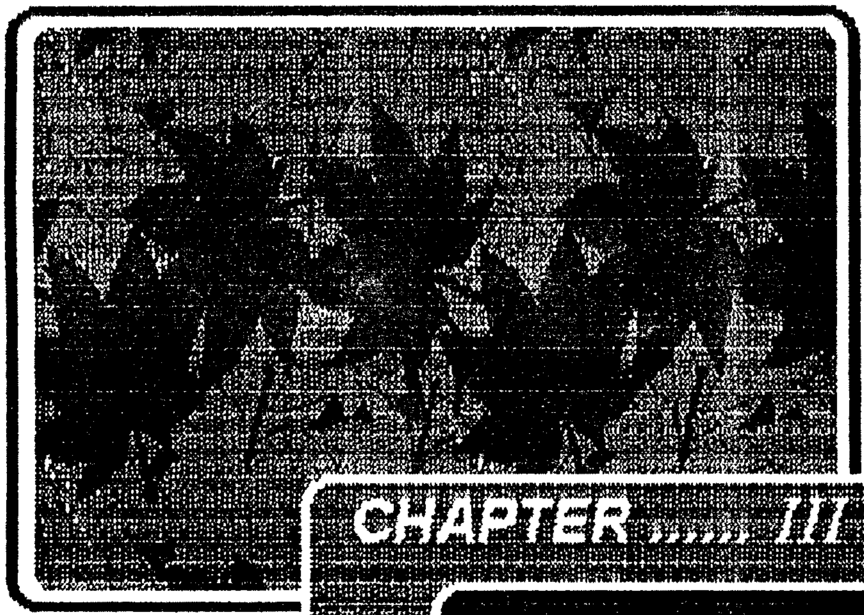


CHAPTER III

Results and Discussion.

1) Habitat analysis

Caesalpinia crista inhabits mangrove swamps at Bhatye creek, Ratnagiri. In the present study Pomendi-Someshwar part of the Bhatye creek was selected as a study site as it is rich in C.crista plants Fig. 3a. Soil at the root zone and water from the habitat were analysed for different characteristics during different seasons. These are recorded in Table 1. Soil and water are slightly alkaline during all the three seasons. Conductivity of soil and water during monsoon is too low due to heavy rains in Konkan, but it goes on increasing after monsoon and highest conductivity is observed during summer.

Amount of sodium and chloride are appreciable in soil and water during all the three seasons and salinity increases from monsoon to summer. The amounts of potassium, calcium, magnesium and phosphorus are comparatively low. The

Table No. 1

Some characteristics of soil and water collected from root zone and habitat of *Caesalpinia crista* L. respectively.

	Monsoon		Winter		Summer	
	Soil	Water	Soil	Water	Soil	Water
pH	7.45	7.65	7.4	7.1	7.43	7.3
EC*	0.216	0.247	1.47	23.0	4.57	48.58
Inorganic elements Macroelements **						
Na	0.116	0.024	0.180	5.400	0.560	11.400
Cl	0.206	0.047	0.312	10.700	0.971	22.600
K	0.024	0.0047	0.051	0.630	0.056	1.027
Ca	0.0031	0.0067	0.0019	0.151	0.0032	0.468
Mg	0.0450	0.010	0.028	0.03	0.045	0.058
P	0.0037	0.0044	0.0039	0.0009	0.0028	0.0009
K:Na	0.207	0.196	0.283	0.117	0.1	0.09
Ca:Na	0.027	0.279	0.011	0.028	0.0057	0.041
Microelements ***						
Fe	1038.00	389.00	519.00	60.00	163.00	34.00
Mn	2.26	100.00	7.12	84.00	10.32	30.00
Zn	0.10	42.00	0.08	30.00	0.04	16.00
Cu	0.12	30.00	0.90	20.00	0.82	40.00

* m mhos.cm^{-1}

** g/100g for soil and g/lit for water samples.

*** µg/g for soil and µg/lit of water samples.

relative dominance of sodium over other cations is also reflected in K:Na and Ca:Na ratios.

Iron, manganese, zinc and copper are present in microamounts, in water and soil. Amount of iron is comparatively more in water and soil, which decreases from monsoon to summer months.

Estuary is a partly enclosed body of water that is formed when river joins the sea. The salinity of soil and water in such area depends on several factors such as height, frequency and duration of tides, rainfall, ground water levels, presence of river fans and ground water flows etc. Hence there are seasonal variations in the characters of soil and water in this region. Such seasonal variations are recorded by many workers (Joshi, 1976; Ghevade, 1983). Our observations also indicate a similar trend and highlight the fact that the plants like *C.crista* growing in such environment are greatly exposed to seasonal variations in soil and water composition.

2) Germination Studies

A) Characters of Disseminules

The pods of *Caesalpinia crista* are woody, one seeded, indehiscent and float on water Fig.3b. The buoyancy is due to the space around the seed. Waisel (1972) has noted that certain tissues of most hydrohalophytes are having large intercellular air spaces which enable them to float on water for a considerable period of time. *Suriana maritima*,

Fig. 3a - Experimental site.

Fig. 3b. - Floating disseminules of *Caesalpinia crista* L.
On water under laboratory conditions in contrast
to seeds.

Fig. 6a. - Effect of soaking of <u>Caesalpinia</u> <u>crista</u> L. Pods in sea water, on seedling performance.

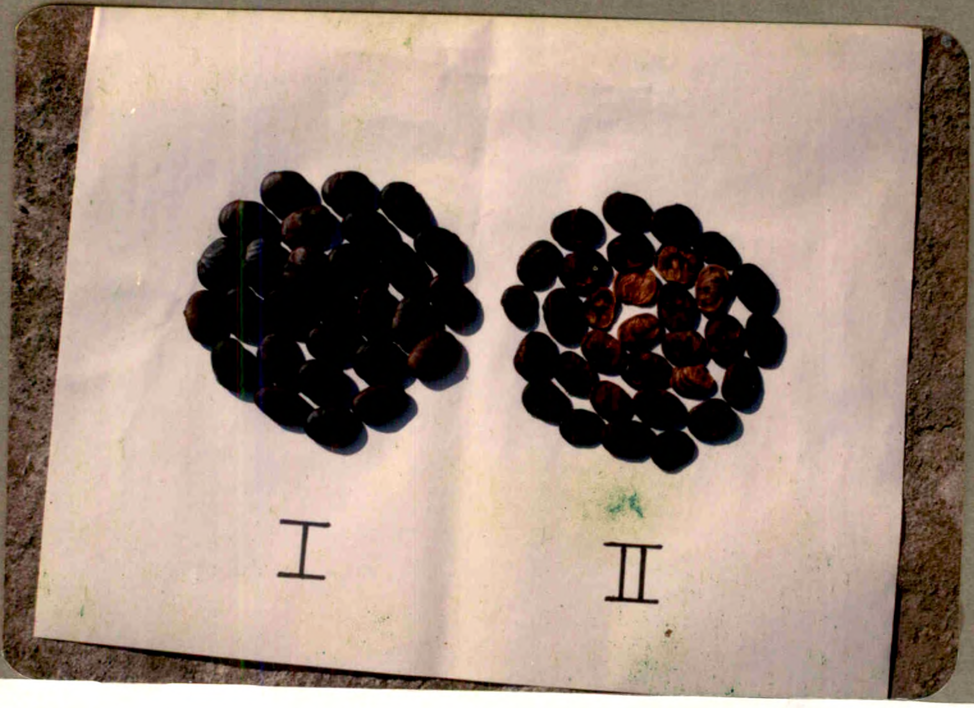


Fig. 6b. - Dimorphic seeds of <u>Caesalpinia</u> <u>crista</u>, L.
I. Large seeds II. Small seeds.

Gyrocarpus jacquinii and Entado scandens have air - filled lacunae usually between cotyledons. Canavalia obtusifolia has sponge like intercellular spaces in the cotyledons whereas Pancratium maritimum has an air-containing tissue in the seed coat.In various species of Salicornia, seeds are buoyed by air bubbles adhering the seed coat hairs. Propagules of Thespesia populnea show hollow parts between the fruit and the seed. Nakanishi (1988) recently studied fruit characteristics of some coastal species namely Wedelia biflora, Messerschmidia argentea, Scaevola frutescens, Calophyllum inophyllum, Hernandia sonora, Pongamia pinnata, Guettarda speciosa, and Terminalia catappa. Buoyancy in the first four species is due to a corky mesocarp and in the last two species a fibrous mesocarp. Pongamia pinnata has woody pods, which are indehiscent and have space around the seeds. The pod characters of P. pinnata appear very much identical with the pod characters of C. crista.

In order to have further insight in this problem, average density of the C. crista pods (dry weight/volume ratio) was determined. The values ranged from 0.574 to 0.773 g/cm3 for 100 pods. As the density is less than unity the pods are able to float on water. These values are comparable with the values recorded for some coastal halophyte species by Nakanishi (1988). The species include Wedelia biflora, Messerschmidia argentea, Scaevola frutescens, Calophyllum inophyllum, Hernandia sonora, Pongamia pinnata, Guettarda speciosa, Terminalia catappa. The estimated density of these fruits was ranging from 0.09 to 0.61g/cm^3. He also observed some maritime plants like *Canavalia maritima*, *Hibiscus tiliaceus*, *Ipomea gracillis* etc. where the seeds float on water current. The estimated density in these seeds ranged from 0.28 to 0.72g /cm^3.

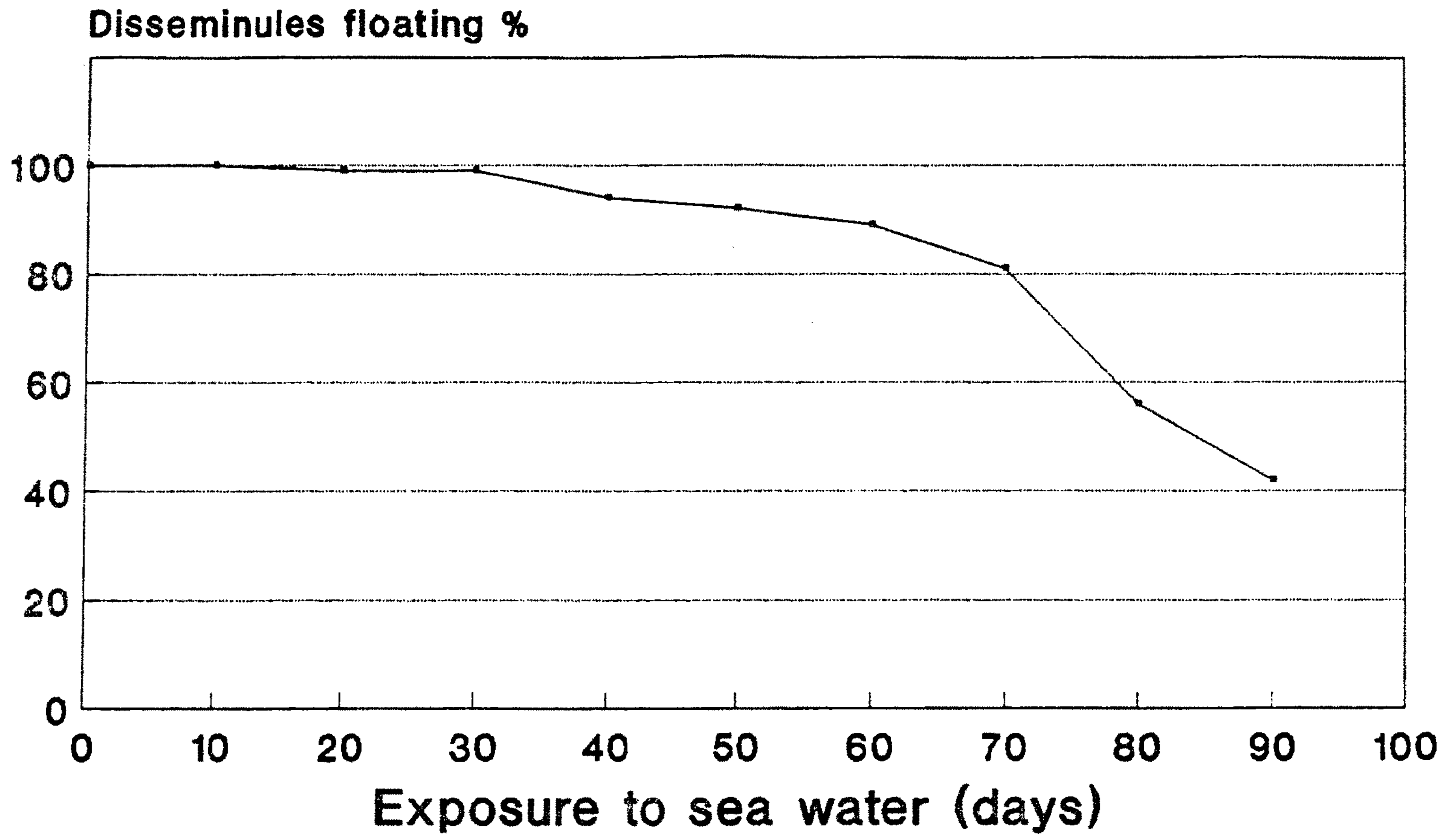
B) Buoyancy test.

The findings of the buoyancy test of *C. crista* pods are shown in fig.4. Up to 99% of the pods were able to float for a period of one month and then they started to sink slowly. At the end of second month 89% pods were found floating. After 2 months the sinking was quite appreciable and at the end of 3rd month 42% pods remained floating.

Praeger (1913) compiled a detailed list of seed buoyancy capacity of various species. Seeds of approximately 11% of the total 786 species investigated remained buoyant beyond one month most of them were marsh or coastal species. Similarly Dalby (1963) has found that the entire fruiting spike of *Salicornia pusilla*, containing 4 to 10 seeds, float on sea water. These spikes float up to three months and then seeds germinate on the spike.

A more systematic study of this aspect has been recently made by Nakanishi (1988) in several coastal species. He observed that disseminules of *Calophyllum inophyllum*, *Messerschmidia argentea*, *Scaevola frutescens*, *Terminalia catappa* and *Wedelia biflora* remained 100% floating for a

Figure : 4 Buoyancy test of disseminules of <u>Caesalpinia</u> <u>crista</u> L. in sea water .



period of three months while those of *Canavalia maritima*, *Guettarda speciosa* remained 100% floating for a period of two months. Seeds of *Ipomea prs-caprae* showed 95% floatingness for one month, 90% at the end of second month and 85% at the end of third month. 92% seeds of *I.gracillis* remained floating at the end of first month and decreased slightly up to 90% at second month stage. Seeds of *Vigna marina* showed 96% and 87% floatingness at first and second month stage respectively. 98% fruits of *Hernandia sonora* remained floating for first month while 88% fruits remained floating for second month. Seeds of *Hibiscus tiliaceus* and *Thespesia populnea* showed quite different pattern of buoyancy. 90%, 64% and 55% seeds of *H. tiliaceus* remained floating for first, second and third month respectively. In case of *T. populnea* 86% seeds were found floating for first month. Then the sinking was fast and only 52% seeds remained floating for two months while 50% seeds were found floating at the end of third month. Mericarp of *Pandanus odoratissismus* showed 100% floating capacity which decreased drastically up to 72% and 20% at second and third month respectively. Mericarp of *Clerodendron inerme* showed continuous decrease in buoyancy as the duration of floating advanced. At one month stage 55% seeds were floating while at second month stage only 22% seeds remained floating.

From the present investigation it is revealed that the buoyancy test of Caesalpinia crista gives some what identical results to that of *Vigna marina* and *Hernandia* *sonora*, which are also the coastal halophytes.

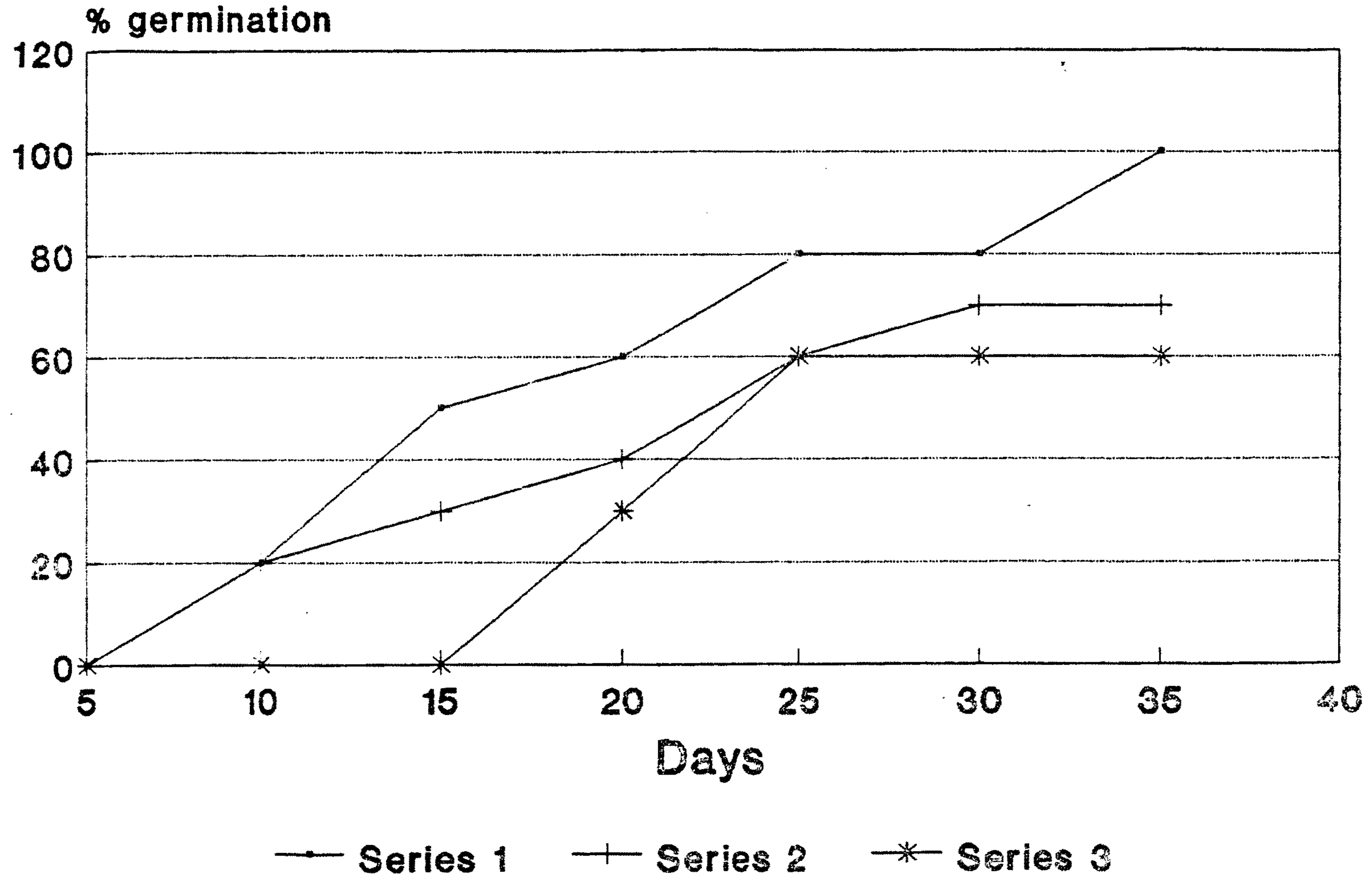
C) Germinability test.

Germination performance of *Caesalpinia crista* seed presoaked in sea water has been shown in fig .5. 100% germination was observed in case of control, while it was reduced to 70% and 60% when sown after soaking in sea water for one month and two months respectively.

At the same time, time required for seed germination is also increased considerably due to soaking in sea water for one and two months fig.5. At 15th day 50% germination was observed in control while 20% and 0% germination was observed in seeds sown after soaking in sea water for one month and two months respectivity .

Since the coastal halophytes grow in close vicinity of sea water in estuarine region, their propagules are frequently dispersed through the water current. But in this situation an additional constraint is imposed on the propagules due to saline nature of the medium.If the survival of plant species in such an environment is to be considered, then the prerequisite for such survival would be maintainance of viability of propagules even after continuous exposure to saline water. According to Ungar (1978) one of the important principal characteristic of halophyte seeds, is their ability to remain viable for long periods under extremely high salinily stress and then to germinate at a

Figure : 5 Germination performance of _Caesalpinia_ _crista_ L. seeds presoaked in sea water.



Series 1 : Control
Series 2 : One month soaking
Series 3 : Two months soaking

later time when soil water potentials are raised.

Darwin (1857) found that seeds from 87 species of plants varied in their ability to tolerate soaking in sea water. 25% of the species studied did not remain viable after a 23 day soaking period. However, seeds of Beta vulgaris were found to retain their viability after 100 days immersion in sea water.

Dalby (1963) has found that the seeds of Salicornia pusilla retain their viability and germinate directly on the spike when the entire fruiting spikes were kept floating on sea water for three months.

Lesko and Walker (1969) have demonstrated that, seeds of Scaevola taccada and Messerschmidia argentea were tolerant to long term immersion in sea water, (30 to 120 days.) without any significant loss in their ability to germinate. Germination % of seeds increased for both species after floating in sea water.

This was tested in the laboratory with several inland halophytes including Suaeda depressa, Salicornia rubra, S. europaea, Hordeum jubatum Puccinellia nuttalliana Sesuvium verrucosum and Iva annua and it was found that soaking of seeds at high salinities was not inhibitory and in some cases it appeared to stimulate germination when seeds were returned to the distilled water treatment. It has been found to be true for coastal halophytes species. Iva annua

(Ungar and Hogan, 1970), *Atriplex patula* (Ungar,1971), *Atriplex halimus* (Zid and Boukhris, 1977), *Sprobolus virginicus* (Breen *et al.* 1977), *Salicornia europaea* (Ungar 1977), *Crithmum maritimum* (Okusanya, 1977).

Laboratory results of Zid and Boukhris (1977) indicate that seeds of *Atriplex halimus* do not germinate when exposed to 4% or 5% NaCl, and germinate up to 85% to 99% after returning in distilled water. Germination of *Sporobolus virginicus* was completely inhibited by 2% NaCl. Viability of this species was not reduced even after 7 week storage period in 12% NaCl. (Breen *et al.* 1977).

In the germination test for *Ipomea gracillis*, *Vigna marina*, *Sophora tomentosa*, *Calophyllum inophyllum*, *Pongamia pinnata* and *Terminalia catappa.* Sokar and Rohlf (1981) reported that there was no significant difference between the germination of the control seeds and those exposed to sea water. These results indicate that soaking of halophytic seeds at high salinities is not permanently toxic as they recover from low water potential treatments and germinate when placed in distilled water.

Nakanishi (1988) divided some halophytic species in two groups which did show a statistically significant difference. In the first group, germination was reduced by immersion in sea water, this included *Clerodendron inerme*, *Pandanus odorastissimus* and *Scaevola fruitensens*. In the second group, germination was increased, this included

Canavalia maritima, *Ipomea pes-caprae*, *Wedelia biflora*. *Messerschmidia argentea*. *Guettard spinosa* *Hibiscus tiliaceus* and *Thespesia populnea*. However in both groups, the change in germinability was not great. It is evident from our observations that *Caesalpinia crista* belongs to first group since in this species germination is reduced due to soaking. But at the same time it was noticed that the soaking of seeds in sea water does not cause any adverse effects on the overall growth (fig.6a) of the *Caesalpinia crista* seedlings. Thus it is quite obvious that *Caesalpinia crista* very clearly shows this adaptive feature which has been advocated by Ungar (1978) to be an important survival strategy in halophytes.

D) Characters of seeds.

Seed characters of the two seed lots of *Caesalpinia crista* are shown in fig. 6b and table 2. The results clearly indicate that there is great morphological variation in the two seed lots of *C. crista*. Thus the seeds can be divided into two categories : Large and small seeds. The Large seeds have considerably higher thickness than the small seeds. The large and small seeds also differ in their weight and moisture percentage. Hundred seed weight in case of large seeds is almost double that of the small seeds. The moisture percentage of the large seeds is also considerably higher than that of small seeds.

It must be mentioned here that the pods of *C. crista* are always single seeded and the two lots of seeds

Table No.2

Seed characters of Dimorphic seeds of

Caesalpinia crista L .

Seed type	Average maximum length cm	Average maximum breadth cm	Average thickness cm	100 seed weight g	Moisture %
large	2.9418 ±0.179	2.225 ±0.162	0.742 ±0.0976	345.45	28.43
Small	2.5454 ±0.169	1.9272 ±0.099	0.448 ±0.0522	150.90	11.39

have been collected from pods from the same plant. This again indicates that there is distinct dimorphism in the seeds of this species. The pod collection during the two different seasons revealed that seed dimorphism was more prominent during December-January than during April-May period.

In view of Stebbins (1976) among the most significant factors by which natural selection can guide the direction of evolution in higher plants, are those concerned with seed size, as it affects the vigor and establishment of seedlings in new locations.

According to Harper et. al. (1970) and Harper (1977) somatic seed polymorphism is useful to plants while growing in an unpredictable fluctuating environmental conditions, as it decides the direct response of different seed morphs in changed environmental conditions. Bhat (1973) found that in two varieties of Indigofera glandulosa the emergence force is closely related with the seeds weight. Higher emergence force by virtue of heavier seeds is an asset to varieties distributed mostly in arable fields where seeds are buried due to cultivation practices as compared to other varieties distributed in grass fields.

Although variations in seed shape are classically interpreted almost wholly as adaptations, some features of shape may be imposed upon a seed by the conditions inside the ovary in which it develops. A study of the interaction between size, number and shape of Cocoa seeds suggest that the ovary sometimes restricts the shapes in which seeds develop and the shapes they attain,(Gelendinning, 1963). Much of the great variety in seed shape is obviously related to dispersal. The potential for diversity and modification of shape is greatly increased by the incorporation of extra ovular structures in the dispersal units, although testa out growths do show some diversity as plumes or the testa may be expanded to form wings. The shapes of seeds relative to predation has been reviewed by Harper *et al.* (1970). The role of morphology of seeds to minimise predation was studied by Pulliam and Brand (1975). They found that the seeds with smooth outline are difficult for ants to carry, while seeds with conspicuous awns, hairs or projections, usually require husking by sparrows, and are easily carried by them.

Besides shape and surface variation, seeds also possess different colours. Seed colours are generally adoptive in respect to visually orienting seed predators.

Beadle (1952) found that the ratio of seed morphs was variable among the Australian *Atriplex* species. The ratio of small black to large brown seeds in *A. semibaccta* was from 10:1 to 1.3:1 and in *A. inflata* the range was from 6:1 to 1:2.5 Ungar (1984) reported a ratio of 60:1 and 6:1 for *A. triangularis* seeds in less saline habitat and in hypersaline habitat respectively.

Somatic polymorphism implies the production of seeds of different morphologies or behavior on different parts of the same plant. Number of biotic and abiotic factors are responsible in the production of the different sizes of the seeds. Many species of Atriplex are known to bear polymorphic dispersal units. Becker (1913) reported that A. hortensis has four kinds of flowers, each giving rise to fruits of different colours and shape. Seeds of A. dimorphostegia also bear dispersal units of different size which vary in their germination behavior. Beadle (1952) noted that even in similar dispersal units seeds of Atriplex exhibit polymorphism and vary in germination.

Maun and Carvers (1971) correlated the weight of the seeds and the position of the flower in the inflorescence in Rumex crispus. Seeds produced on flowers that were closer to the main axis were larger than those produced on terminal portion of the branches.

Ungar (1979) noted that each flower of Salicornia europaea produces a single seed and in an 'Inland North American Population' the median flower at a node produced a large seed while lateral flowers produced small seeds. The distribution of lengths of seeds from lateral and median flowers was bimodal. Seeds from the large median flowers were 1.8 ± 0.1 mm long and those from the lateral flowers were 1.1 ± 0.1 mm. Weights of air-dry seeds also fitted a bimodal distribution and could be divided into two general classes based on the flower types. The mean weight for large seeds was 0.78 ± 0.1 mg and that of small seeds was 0.24 ± 0.04

mg. These data indicated that seeds of S. europaea were dimorphic. Although the seeds of S.europaea differed in size and shape, the analysis of Austenfeld (1988) revealed that seed dimorphism in Salicornia was reflected neither by the composition nor by the concentration of the nutrient reserves. Due to the different size of the seeds, only the total amount of nutrient reserves per seed was slightly higher in the larger seeds.

In case of Pastinaca sativa the position of the flowers in the inflorescence decides the size of the seeds (Hendrix, 1984). Seeds from primary umbels were double in weight than those from tertiary umbels. It was also noted that the relation between the size of the plant and the weight of the seeds produced on them was in direct proportion.

Interspecific competition is the another biotic factor affecting seed polymorphism. Baker and O'Dowd (1982) had shown that the size of Hypochoeris glabra seeds was affected by the level of competition. Plants grown at high densities produced the unbeaked animal dispersed seeds in higher proportion than the plants grown under low densities, which produced more beaked wind dispersed achenes.

Sher Mohammed and Sen (1991) have recognized the seed polymorphism in some characteristic halophytic plants. They found that seeds of Cressa cretica, Salsola baryosma, Sesuvium sesuviodes, Suaeda fruticosa, *Trianthema triquetra*, and *Zygophyllum simplex* differed in morphological characters like seed weight, size, viability and germination behavior.

Ungar (1984) noticed that the ratio of small to large seeds on the plant was apparently controlled by environment. Small plants of *Atriplex* growing in highly saline habitats were having a lower small : large seed ratio than the larger plants growing in less saline habitat. The number of seeds produced per plant ranged from 67 seeds/plant from most saline sites to 2515 seeds/plant from less saline sites.

Our observations reveal that similar to above halophytic species, the seed dimorphism does prevail to some degree in the leguminous halophyte *Caesalpinia crista.*

The germination performance of the two seed types of *C. crista* is depicted in Table 3. It is clear that these seeds not only differ morphologically but their germinability and growth pattern also differ . Large seeds germinate early and the germination percentage is 90% which is three times more than that of small seeds. It is evident from the table 3. that the seedlings raised from the large seeds are superior to the seedlings raised from small seeds with respect to various growth parameters as well as biomass.

There are several studies which indicate that seed dimorphism also reflected in germination behavior.

Table No.3

Germination performance of dimorphic seeds of

Caesalpinia crista L .

Seed type	Seed Germination %	Seedling growth *				
		Root length cm	Shoot length cm	Number of leaves	Total number of leaflets	Biomass fresh weight g/plant
large	90	14.06	43.50	12	81	11.375
Small	30	10.83	38.83	11	75	08.660

* Average of 10 seedlings

The larger seeds produced by both S.europaea and A. triangularis are apparently dormant and germinate more rapidly than smaller seeds.

Ungar (1979) studied the effect of photoperiod and stratification requirement of dimorphic seeds. Exposure of seeds to a 12-hr photoperiod did not significantly influence the percentage of germination for large seeds, while small seeds had higher germination in light. Germination of large seeds of S. europaea was stimulated by a cold treatment. Small S. europaea seeds were also initially stimulated by stratification, but differences in the response of small seeds occurred when they were not stratified, indicating both an inhibition of germination and no reduction.

Hendrix (1984) noted that small seeds of Atriplex patula could fall and germinate more quickly than the large seeds, but it is not true during spring when the overall seed germination percentage of small seeds is low.

It is also noticed in some cases that the large and small seeds differ in the salt tolerance potential at germination stage. Ungar (1979) noted that the larger seeds of S. europaea were more salt tolerant than the small and also yield higher germination percentages at all tested salinities. Of the ungerminated large seeds originally immersed in 5% and 10% NaCl, 87% seeds germinated after immersed in distilled water for 42 days, indicating that germination inhibition due to salt stress was transitory. Khan & Ungar (1984 a, 1984 b) found that large seeds of *A. triangularis* were more salt tolerant than the small seeds produced on the same plant.

According to Ungar (1982) one advantage that plants with polymorphic seeds have in unstable environment with changing soil salinity stress could be that this morphological character is associated with physiological differences which provide for multiple germination periods. An entire population of plants might be eliminated by increased salinity stress and with only a single highly synchronized germination period, no seed reserve could be available. Both *Atriplex triangularis* and *Salicornia europaea* have prolonged germination periods under field conditions (Mc Mahon and Ungar 1978; Ungar *et al* 1979). These extended germination periods running from February to June and sometimes later into the summer, are probably related to both, the response of dimorphic seeds in these species and fluctuating soil salinity stress under field conditions, which at times may be beyond the salt tolerance of these plants.

Although growth of the seedlings raised from dimorphic seeds is worth investigating, only one report is available which indicates that *Atriplex patula* var. hastata plants arising from larger seeds has faster root and shoot growth than seedlings from small seeds which germinate at the same time (Baker, 1974).

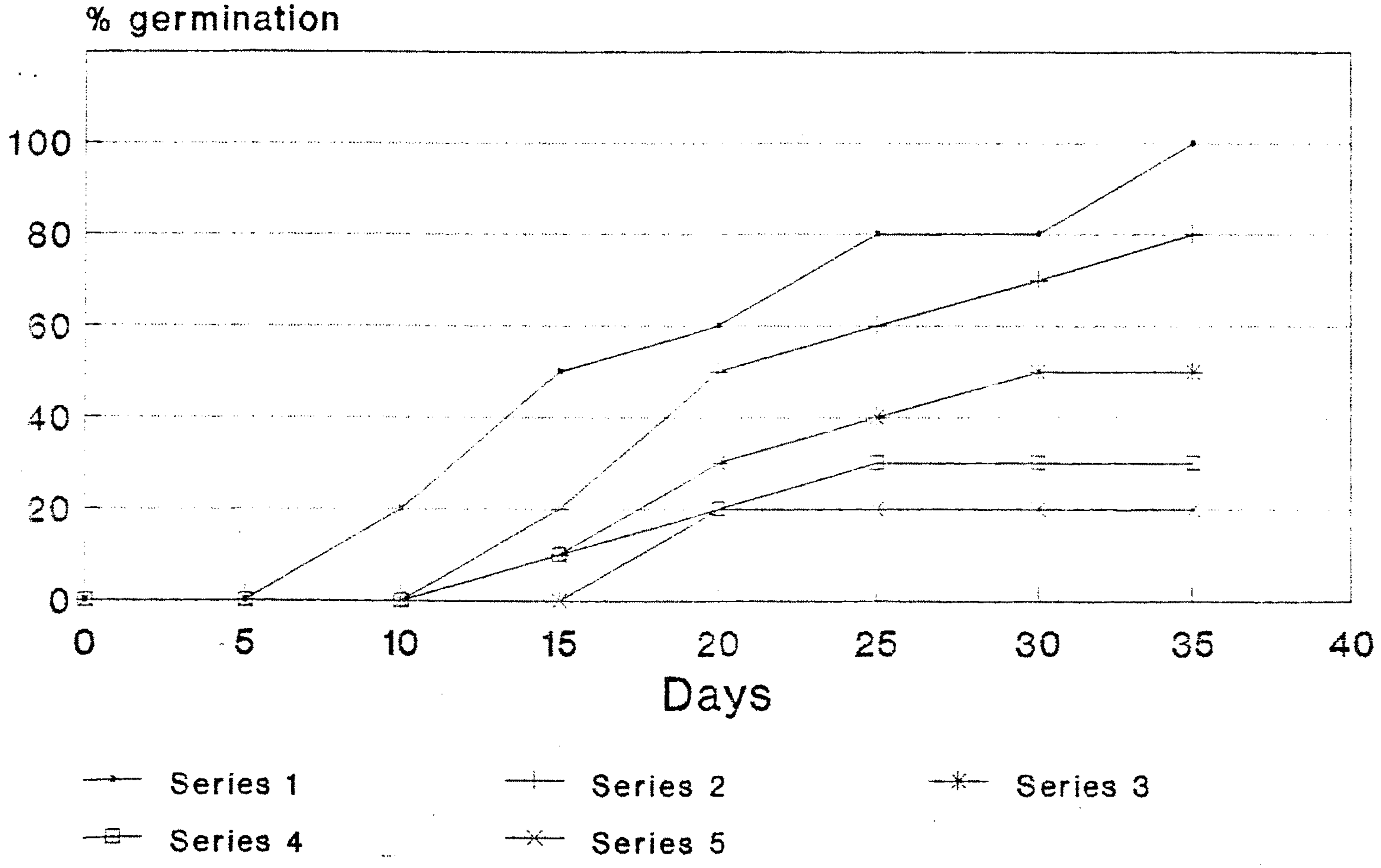
In case of Caesalpinia crista it is apparent that the germination potential of large seeds is higher and the seedlings raised from these seeds are more vigorous in growth. However the salt tolerance of the large and small seeds at germination stage has not been investigated in the present study. But at the same time it is quite probable that the seeds with higher germination capacity and better seedling vigor, would tolerate the higher salinity doses more effectively.

E) Seed Germination under Saline Conditions .

Effect of NaCl salinity on germination of Caesalpinia crista seeds is shown in fig 7. Highest germination was observed in fresh water and the germination percentage decreased as the NaCl salinity increased. In 1.00% NaCl salinity only 20% seed germination was observed and death of the seedlings occurred after few days. Seeds could not germinate above 1% NaCl salinity. Not only decrease in the germination percentage but delay in germination was also noticed. The period required for seed germination increased with improvement in the salinity level. Days required for seed germination in 1% NaCl salinity were nearly double to those required for germination in fresh water. (fig.7)

The phase of seed germination and seedling

Figure : 7 Germination performance of *Caesalpinia* *crista* L. seeds under saline conditions .



Series 1 : control
Series 3 : 0.50% NaCl
Series 5 : 1.00% NaCl

Series 2 : 0.25% NaCl
Series 4 : 0.75% NaCl

establishment is one of the most critical stages in the life cycle of halophytes. The behavior of halophytes at this stage of development is rather poorly understood (Waisel,1972). Surface soils may have salinities 2 to 100 times that of the subsoil and present much more extreme environments to seeds of halophytes than a vigorously growing plant may be exposed to, and this presents a serious problem at the germination stage which must be overcome by a species to successfully establish in a saline environment.

Since sodium chloride is a dominant salt, present in the saline habitat, various workers have investigated its effect upon the seed germination in halophytes. The results show that the great majority of halophytes germinate best under fresh water conditions, (Seneca, 1969; Onnis and Bellettato, 1972;Breen *et al*.,1977; Okusanya, 1977; Ungar,1977,1978; Zid and Boukhris, 1977; Dietert and Shontz, 1978; Partridge and Wilson, 1987.) but that some germination can be expected in up to 2% NaCl. Germination of seeds is found to be usually retarded in saline medium. The response of seeds or the degree of inhibition differs from species to species.

Waisel (1958) studied salt tolerance in germination of some halophytes at 20°c. He recorded that seeds of *Aeluropus repens* and *Mesembryanthemum nodiflorum* could tolerate 0.1% NaCl salinity while *Nitraria retusa*. and Juncus *maritimus* seeds could germinate in a medium containing up to

0.2% NaCl salinity. Suaeda monoica and Salicornia herbacea seeds germinated in 0.4% NaCl, on the other hand Halocnemum strobilaceum seeds could tolerate up to 0.6 % NaCl.

A similar correlation between the ability to germinate under saline conditions and zonation of plants in a salt marsh was also reported by Ungar (1965,1967). The halophytes Suaeda depressa and Tamarix pentandra germinated in salt solution up to 4% NaCl while semihalophytic species Hablopappus phyllocephalus and Iva annua tolerated up to 2% NaCl at the time of germination. Germination percentage of Aster tripolium and Triglochin maritime seeds were extremely low in sea water. Plantago maritime had not tolerated sea water concentration about 75% while Atriplex hastata, Beta maritima and Plantago coronopus above 50% sea water.

Ungar (1962) reported that seeds of Atriplex, Salicornia and Suaeda germinate better in 0.5% NaCl than in distilled water. Macke and Ungar (1971) noted the sharp decrease in germination in seeds of Puccinellia nuttalliana at-12 bars. He further reported that recovery in germination is possible in - 42 bars, indicating the temporary inhibition in seed germination. Ungar (1974) studied the effect of salinity on seed germination of Hordeum jubatum. He noted that seeds of H. jubatum were highly tolerant of salinities up to 1%, with little reduction in germination. Each increase in salt concentration delayed the time of germination.

Okusanya (1977) reported that in *Crithmum maritimum* seeds, the germination of seeds, was reduced and delayed with increase in sea water concentrations.

Seeds of *Atriplex halimus* did not germinate when exposed to 4% NaCl and germinated at 85 to 90% when returned to distilled water (Zid and Boukhris 1977) Germination of *Sporobolus virginious* was completely inhibited by 2% NaCl (Breen *et al.*,1977).

Joshi and Iyengar (1977) reported that seeds of *Suaeda nudiflora* germinated well up to 5,000 ppm. sea water. In higher concentrations the germination was retarded remarkably. The highest germination percentage was achieved in 1,000 ppm. sea water.

Germination of seeds of a highly salt tolerant halophyte *Salicornia europaea* remained inhibited in salinity level above 5% NaCl and germinated in following the decrease in salinity had been reported by Ungar (1977).

Waisel (1958) noticed that besides intergeneric differences, interspecific and intervarietal differences also exist with respect to salinity tolerance at germination stage. Thus the salt tolerance limits of various *Tamarix* species namely *Tamarix gallica* var. maris-mortui and *T. gallica* var. eilanthesis seeds tolerated 0.6% NaCl salinity. *T. deserti* and *T. jordanis* var. negevensis 0.7% NaCl salinity, *T. meyeri* could tolerate 0.9% NaCl salinity 1% NaCl salinity was tolerated by *T.amplexcaulis*, *T.aravensis* and *T. aphylla* at germination stage. He further pointed out that plants growing naturally in sites with a high salt content showed a higher salt resistance in germination than plants from less salty sites.

Perennials mostly reproduce vegetatively in number of species. A more detailed study of this aspect has been recently made by Partridge and Wilson (1987). These workers studied effect of NaCl salinity on 9 halophytic and 2 glycophytic species. They recorded that *Atriplex prostrata*, *Cotula coronopifolia*, *Plagianthus divaricatus*, *Plantago coronopus*, *Polypogon monspeliensis*, *Schoenus nitnes*, *Selliera radicans*, *Spergularia media*, *Triglochin striatum* germinated close to full potential in upto 0.5% NaCl Between 0.5% NaCl and 0.35% NaCl, differences in salt sensitivity were noted. All species examined had slower germination rates, the higher the salinity. Perennials like *Suaeda*, *Juncus*, *Sarcocornia schoenus*, *Triglochin.* *Selliera* etc. were more sensitive for germination than for growth. They only germinate in salinities much lower than their adult tolerance. Amongst the perennials, germination sensitivity decreases only slowly with an increase in adult tolerance. Partridge and Wilson (1987) concluded that seeds of perennial halophytic species are more sensitive to salinity at germination stage than at growth and reproductive stage. According to these workers the perennials can afford to wait for rare low salinity conditions for their occasional seedling establishment.

In the view of these workers good germination in saline environment ordinarily occurs during the spring or in a season with high precipitation, when soil salinity levels are usually reduced. In the light of these findings when we examine the germination performance of *Caesalpinia crista* under saline conditions we can notice that this species exhibits considerable salt sensitivity at germination stage and this may be possibly related to perennial nature of this species.

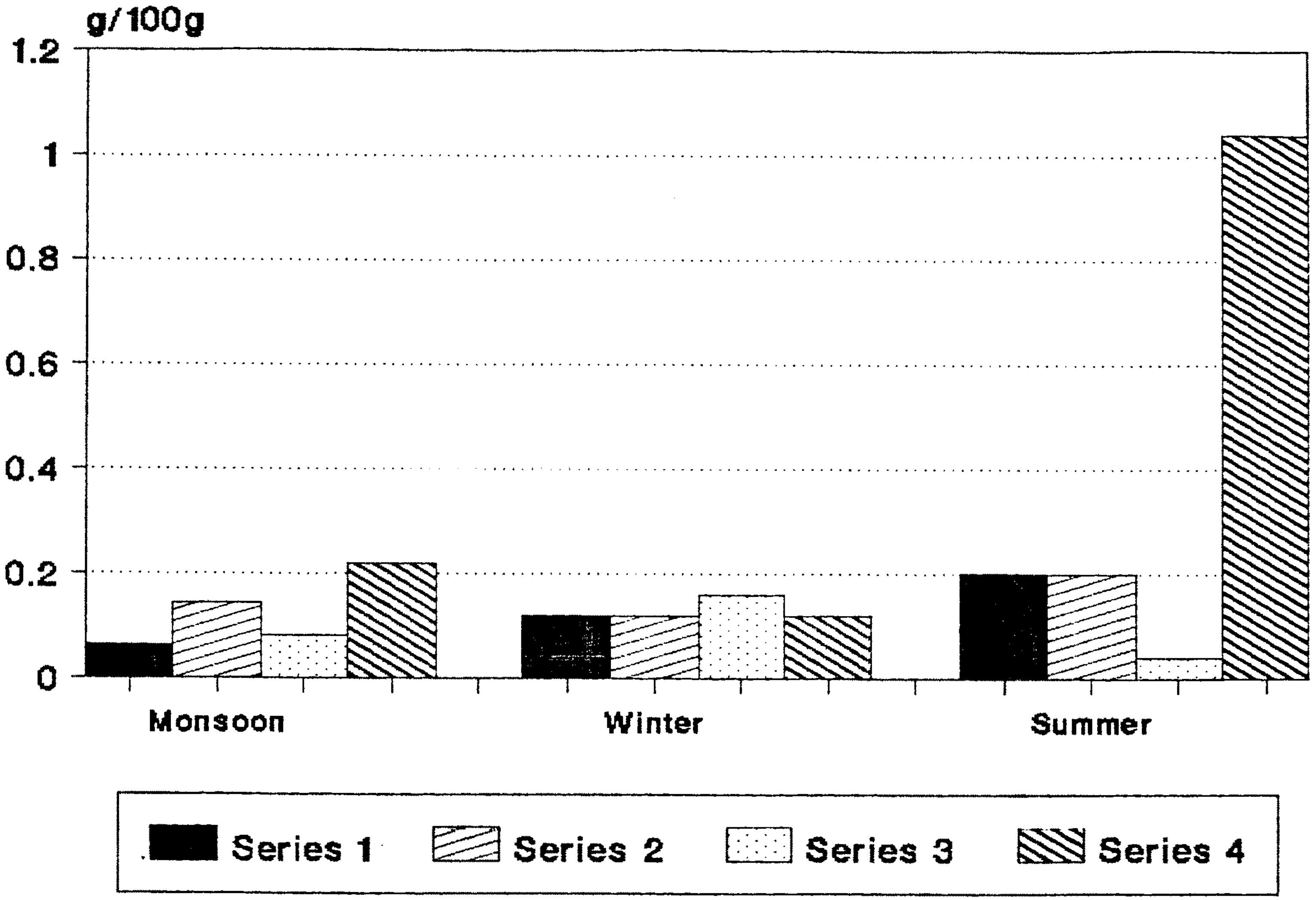
3) **Mineral nutrition**

A) Inorganic constituents in different plant parts.

a) *Sodium*

Sodium contents of different parts of *Caesalpinia crista* and their seasonal variation are shown in fig.8. An appreciable amount of Na^+ is observed in roots of *C. crista* during all the three seasons monsoon, winter and summer. Highest accumulation being observed in summer. Relatively less amount of Na^+ is noticed in the stem tissue in monsoon and summer. But in winter sodium level in the stem tissue is higher than that in other parts. In leaf and rachis Na^+ accumulation takes place nearly in equal amount during all the three seasons. It is evident from the fig.8 that as compared to other plant parts the leaf tissue contains lesser amount of sodium, although during summer season sodium level in leaf tissue is higher than that recorded for other seasons.

Figure : 8 Sodium contents in different parts of
Caesalpinia crista L.
during different seasons.
(expressed on dry wt. basis.)



S1: Leaf S2: Rachis S3: Stem S4:Root

Sodium is an essential micro-nutrient element for some species and is beneficial element (at much higher concentrations) for some others. Sodium at high levels stimulates the growth in some species mainly members of chenopodiaceae and some mangroves. Other plants like wheat, oat, barley and cotton etc. show the response to sodium in a deficiency of potassium and cotton in a deficiency of calcium. Atriplex vesicaria was the 1st plant for which sodium was shown to be essential as a micronutrient (Brownell, 1965). The growth responses to Na^+ are more related to the function of K^+ particularly osmoregulation and enzyme activation. Sodium at high levels has been shown to affect some plants qualitatively. Increase in the concentration of sugar have been recorded in sugarbeet (El-Sheikh and Ulrich, 1970) and the quality of fiber crops including flax and cotton improved by application of salt of sodium (Treggi, 1951).

Sodium has been shown to be essential for C_4 species in families, Gramineae, Cyperaceae, Amaranthaceae, Chenopodiaceae and Portulacaceae (Brownell, 1968). The Crassulacean Acid Metabolism species, Bryophyllum tubiflorum show essentiality of sodium under short-days with large diurnal temperature variation as the bulk of CO_2 assimilated gets taken up in the dark, involving the C_4 dicarboxylic system (Brownell and Crossland, 1974). It seemed likely that sodium was required for the functioning of the C_4 dicarboxylic CO_2 fixation system operating in C_4 and CAM species (under certain conditions) but was not required in C_3 species, which lack this system. The signs of sodium deficiency are similar in all species for which it is essential. Leaves become chlorotic and in severe cases margins and tips become necrotic. An early response by sodium deficient leaves of C_4 *Atriplex* to sodium was an increase in the rate of respiration as oxygen uptake or CO_2 out put. It is quite obvious that under saline conditions the problems due to sodium excess arise and not due to sodium deficiency.

In contrast to glycophytes, halophytes show appreciable levels of sodium within their tissue. But even among various halophyte species, Na^+ concentration varies substantially.

It is mentioned by Walsh (1974) that salt secreting species were having high Na^+ content [*Acanthus ilicifolius* 3%, *Aegiceras corniculata* 2.3% *Avicennia alba* 3.5%, *A. marina* 5.06%, *A. officinalis* 2.33%]. Salt non secreting species also contained Na^+, comparable with that of salt secreting type [e.g. *Bruguiera caryophylloides* 2.77%, *Ceriops candolleana* 3.66%, *Rhizophora mucronata* 2.28%]. In some salt accumulating species such as *Lumnitzera racemosa* and *Sonneratia apetala* he recorded 4.3% and 1.49% sodium respectively. At the some time relatively low levels of sodium were also noticed in some mangroves species such as *Rhizophora mangle* [1.11%], *R. brevistyla* [0.98%] and

Exoecaria agallocha [0.48%]

Joshi [1975] also recorded Na^+ levels in leaves of mangroves and associate halophytes of estuaries in Maharashtra. According to him salt secreting mangroves *Avicennia officinalis*, *A.alba*, *Aegiceras corniculata* contained high Na^+ content [5.30, 3.11 and 2.35 g/100g respectively]. Salt accumulating species like *Acanthus ilicifolius*, *Lumnitzera racemosa*, *Sonneratia alba* and *Exoecaria agallocha* contained 3.46, 5.54, 5.04 and 3.26 g/100g Na^+ respectively. Relatively lower values were recorded in salt excluding types *Rhizophora mucronata* [2.57], *Ceriops tagal* [1.57], and *Kandelia candel* [1.20]. The mangrove associates like *Salvadora persica*, *Aeluropus lagopoides*, *Thespesia populnea* and *Clerodendron inerme* also contained quite high amount of sodium.

Very little information is available about sodium nutrition in leguminous halophytes. Walsh [1974] mentioned that the leaves of *Derris uliginosa* contained 1.23% Na^+. On the other hand Mohite [1990] noticed that Na^+ contents in leaves of two *Derris* species *D. trifoliata* and *D. scandens* growing in coastal areas of Ratnagiri were 0.55% and 0.24% respectively. It is noticed in the present investigation that *Caesalpinia crista* plants grow in close contact with *D. trifoliata*. Their leaves also contain very low levels of sodium comparable with *D.scandens.*

Cassidy [1970] had opined that the ion

concentrations in plant tissue should be expressed in equi.m^{-3} plant water because this is a more meaningful basis for considering osmotic relations than the conventional dry matter basis. Storey and Wyn Jones [1977] had supported this view and added one more point that values expressed in equi.m^{-3} plant water, facilitate inter-species comparison.

Albert and Popp [1977] found that the ionic composition varies substantially among the halophytic species and many a times a specific pattern of ion content can be found within the specific taxon. They found extraordinary accumulation of sodium in the leaves of dicotyledonous halophytic plants like *Chenopodium botryodes*, *C. glaccum* , *Atriplex hastata*, *Comphorosma annua*, *Suaeda maritima*, *S. pannonica*. *Salicornia prostrata*, *Spergularia media*, *Lepidium crassifolium*, *Plantago maritima*, *Artemisia monogyna*, *Aster tripolium*, *Sonchus arvensis* ranging from 150 equi.m^{-3} {in *Sonchus arvensis*} to 869 equi.m^{-3} plant water [in *Salicornia prostrata*] In contrast very little sodium was accumulated in the leaves of halophytic monocotyledonous species like *Crypsis aculeata*, *Puccinellia distans*, *Agrostis stolonifera*, *Phragmites australis*, *Carex distans*, *Bolboschoeus maritimus* and *Juncus gerardii*. The range of Na^{+} concentration was only from 23 equi.m^{-3} fresh water content [in *Carex distans*] to 141 equi.m^{-3} [in *Bolboschoeus maritimum*]. They further concluded that the reduced salt content especially Na^{+} salts gives the impression that salt exclusion mechanism persists in these plants in contrast to the other halophytes having high salt content.

Gorham et al. [1980] studied the chemical composition of some salt marsh plants. They also noted comparatively low values of Na^+ in leaves of monocotyledonous halophytes in contrast to dicotyledonous halophytes. They found that Na^+ concentration among Cyperaceae members ranged from 17 $equi.m^{-3}$ plant water [Carex aeraria] to 167 $equi.m^{-3}$ [Eleocharis uniglumis]. In Gramineae the Na^+ concentration ranged from 48 $equi.m^{-3}$ [Agropyron pungen] to 177 $equi.m^{-3}$ [Phragmites communis]. In the family Juncaceae the Na^+ concentration ranged from 65 $equi.m^{-3}$ [Juncus inflexus] to 155 $equi.m^{-3}$ [Juncus articulatus]. Few exceptions to this trend were Spartina anglica [346], Triglochin maritima [279] and Zostera marina [608] from Gramineae Juncaginaceae and Zosteraceae respectively where Na^+ concentration was very high. They also recorded that in dicotyledonous salt marsh plants the Na^+ concentration was very high [i.e. Suaeda maritima 547 and Salicornia europaea 8200 from Chenopodiaceae, Spergularia media 615 from Caryophyllaceae, a Primulaceae member Glaux maritima 237]. At the same time very low Na^+ concentration was noted in Umbelliferae member Oenanthe lachenalii [92 $equi.m^{-3}$ plant water]. According to these workers the low values of Na^+ clearly indicate that the salt exclusion mechanism must be present in many monocotyledons and Oenanthe lachenalii from dicotyledons.

Popp [1984] had analysed some Australian mangroves for their inorganic ion content. She noted very high values of Na^+ content in the leaves of salt secreting mangrove species such as *Aegiatilis annulata* [540], *Aegiceras corniculata* [550] and *Avicennia marina* [500 equi. m^{-3} plant water]. These values were higher than the Na^+ contents recorded for salt non secreting species e.g. Rhizophoraceae members *Bruguiera exaristata* [475], *Ceriops tagal* [320], *Rhizophora apiculata* [360], R. *lamarckii* [350], *R. stylosa* [400]. The salt accumulating species were found to accumulate high amount of Na^+ in their leaves, as seen in *Lumnitzera racemosa* [670], *Xylocarpus granatum* [540], *X. mekongensis* [460], *Acanthus ilicifolius* [480]. Comparatively lower concentrations of Na^+ were seen in *Excoecaria agallocha* [260], *Osbornea octodenta* [360], *Scyphiphora hydrophylacea* [220], *Hibiscus tiliaceus* [50] and *Heritiera littoralis* [20]. She noticed that the lower concentrations were associated with both habit and physiological features. *Hibiscus tiliaceus* and *Heritiera littoralis* are regarded as brackish water species or mangrove associates. Brackish water contains substantial Na^+ concentration. According to Popp this is possibly similar to some monocotyledonous halophytes which are able to maintain low Na^+ concentrations in their shoots. The other three species 1. *Excoecaria agallocha* which occurred *Lumnitzera racemosa*, 2. *Osbornea octodenta* near *Ceriops tagal* and 3. *Scyphiphora hydrophylacea* found to occur in normal mixed mangrove strands, differed from their neighbouring species in their ion concentration. Hence in opinion of Popp [1984] these low Na^+ containing plants were the salt excluding type of halophytes.

In the light of above findings when leaf sodium content in *Caesalpinia crista* is expressed on the tissue water basis, the values ranged from 13.71 to 223 $equi.m^{-3}$ plant water. When these values are compared with the values recorded by other workers for various halophytic species, it is clearly evident that the plant adapts the strategy of sodium exclusion from the leaf tissue as seen in mangrove species and associates like *Excoecaria agallocha*, *Scyphiphora hydrophylacea*, *Hibiscus tiliaceus* and *Heritiera littoralis*.

Although ion regulation in halophytes has been extensively studied, most of the studies are restricted to leaf analysis and very few attempts have been made to analyse other plant parts. It is mentioned by Walsh [1974] that as compared with the leaves, the stem contained much less Na^+ content in salt secreting and salt non secreting types such as *Avicennia nitida*,*Rhizophora mangle* and *R. brevistyla*. Spain and Holt [1980] have recorded the Na^+ concentration in stem of seven mangrove species *Aegiceras corniculatum*, *Avicennia marina*, *Ceriops tagal*, *Excoecaria agallocha*, *Osbornea octodenta*, *Rhizophora stylosa*, *Xylocarpus australasicus*. Values of Na^+ were ranging from 0.16 to 0.73% in *Excoecaria agallocha* and *Avicennia marina* respectively. But in *Derris trifoliata* and *D. scandens*, Mohite [1990] recorded comparatively higher Na^+ content in stem than the leaves. Similar trend is seen in *Caesalpinia crista* during rainy and winter seasons. But in summer season leaf Na^+ content is considerably higher than the stem Na^+ content.

The legumes like *Derris* and *Caesalpinia* have got compound leaf with prominent rachis. Rachis of *D. trifoliata* and *D.scandens* was found to contain more Na^+ than the foliar tissue (Mohite 1990). Similar trend is seen in *Caesalpinia crista* during rainy season. During winter and summer the Na^+ content of leaf and rachis was almost identical. It is suggested by Karadge and Chavan [1983] that in salt tolerant legume *Sesbania aculeata*, rachis functions in accumulating sodium and lessening salt toxicity in foliar tissue and this may be considered as one of the mechanism of salt tolerance. However such situation does not prevail in *Caesalpinia crista*.

Very little information is available regarding sodium status of the root tissue. Walsh [1974] mentioned that root Na^+ content in salt secreting type [*Avicennia nitida*] and salt non-secreting type mangroves [*Rhizophora mangle*, *Conocarpus erectus*] was less than that of leaves, clearly indicating that there is no accumulation of salt in root zone but it is transported to leaves via stem. Joshi [1976] also recorded that as compared to stem and leaf of *Rhizophora mucronata* the different parts of young and old roots contain lower levels of sodium. However opposite trend was noticed in leguminous halophyte *Derris trifoliata* by Mohite [1990] who found marked accumulation of sodium in the root tissue. Similar pattern is also found in *Caesalpinia crista* and the accumulation of salt in root region is more pronounced during summer season as compared to the other seasons.

From the above discussion it is very clear that *Caesalpinia crista* has different pattern of Na^+ distribution in the plant parts than that of salt secreting, non-secreting and salt accumulating type of halophytes which are present in the vicinity of *C.crista*, but it shows salt evading tendency similar to *Prosopis farcata* [Waisel,1972]. Here the exclusion mechanism seems to occur in the retention of salt mainly within the roots, stems and rachis to some extent, so as to prevent the translocation of Na^+ to the photosynthetic organ, the leaves.

An increase in the external salt concentration usually results in salt transport to shoot at higher rate. It is well known that during salt transportations in the xylem sap water remain untouched and uptake of ions takes place out of the flowing sap by shoot cells. But some halophytic species selectively accumulate sodium out of the sap, resulting the reduction of sodium content in leaves and upper part of the shoot. Such selective accumulation has been recorded in legume *Prosopis farcata* by Eshel [1966].

It is the xylem parenchyma cells which actively and selectively absorb sodium.

Similar mechanism of salt exclusion in crop legumes like *Glycine max*, *Pisum sativum*, *Phaseolus* species, *Vicia faba*, *Arachis hypogaea*, *Cicer arietinum*, *Vigna unguiculata*, Medicago sativa, Trifolum species under saline conditions, has been recorded by Lauchli [1984].

Jacoby [1964] demonstrated that bean plants exclude Na^+ by retention in the basal part of the plants. Retention of Na^+ in the stem becomes gradually saturated with increasing salt concentration in the medium. Further he concluded that Na^+ retention in bean stems is energy dependent and due to accumulation by cells in vascular tissue.

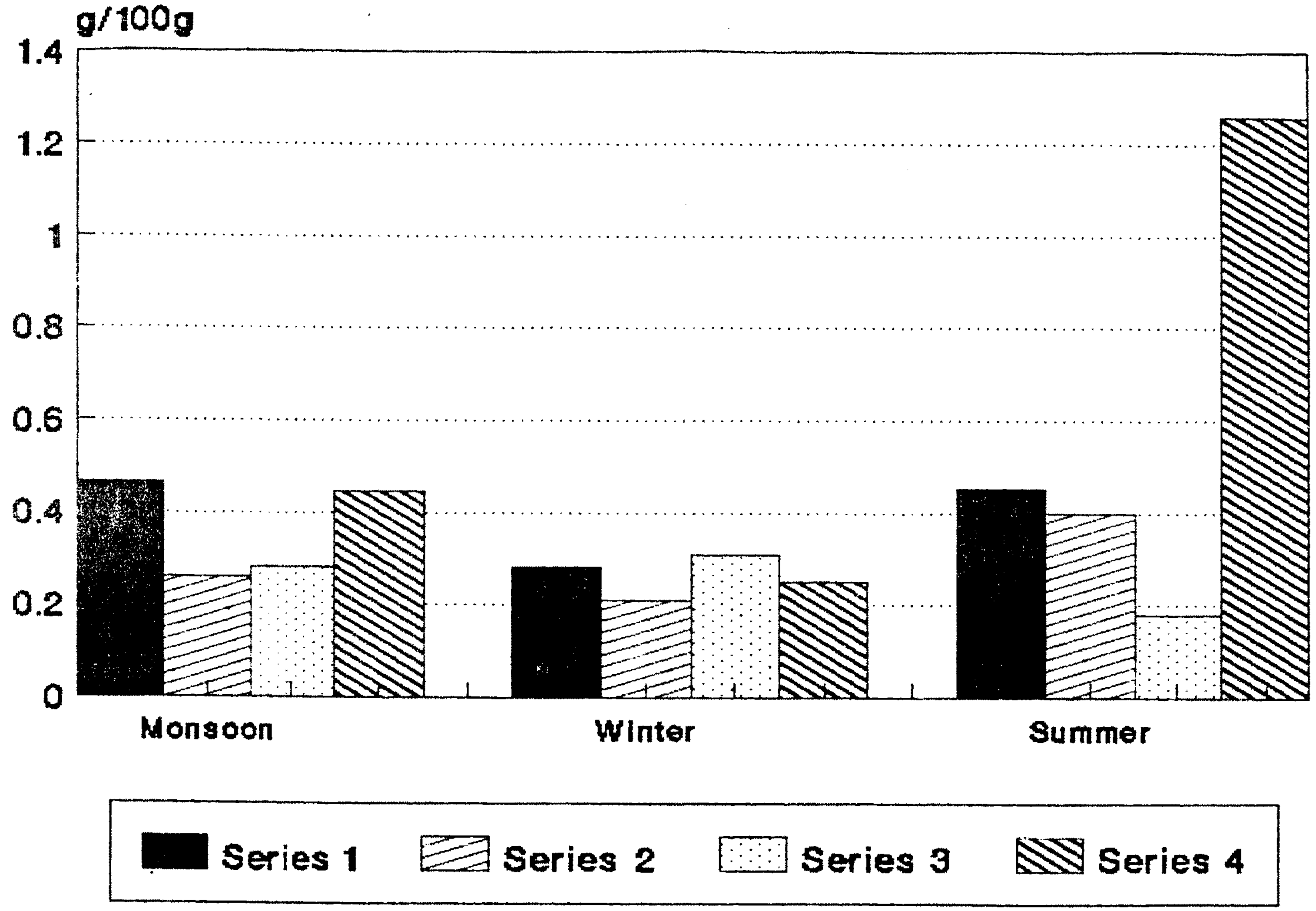
In halophytic legume *Canavalia obtusifolia* Scholander, [1968] noticed that the xylem sap tension was more than -20 atm. similar to other mangrove species and he further suggested that the xylem sap formation of the roots of mangroves and halophytes, including *Canavalia obtusifolia* involves essentially an ultra filtration of the sea water combined with an ion transport.

In legumes, Na^+ specific events in the primary vascular tissues of the proximal region of the roots and the base of the stem are of primary significance. Kramer *et al* [1977] revealed the existence of transfer cell-like xylem parenchyma cells in the proximal region of the roots of *Phaseolus coccineus*, where the Na^+ level is highest. They also demonstrated very high Na/K ratios in xylem parenchyma cells, in contrast to xylem vessels, where the Na/K ratio is near about unity. The accumulation of Na^+ in xylem parenchyma is due to Na^+ reabsorption from xylem sap in exchange for K at the plasmalemma, [Lauchli,1984] and the ultimate result is the Na^+ exclusion from the leaves. In *Caesalpinia crista* we notice a similar trend regarding sodium uptake. Thus sodium is mainly excluded from entry into the plant possibly due to ultrafiltration process and whatever sodium ions that enter in the plant are excluded from the laminar tissue through their retention in roots. It is further evident that during summer months the sodium uptake is more since the salinity of medium is higher. Such pronounced accumulation of sodium during summer season has been recorded by Jamale and Joshi [1977] in mangrove species *Sonneratia alba*, *Avicennia officinalis*, *A. alba*, *Aegiceras corniculata*, *Excoecaria agallocha*, *Rhizophora mucronata* and *Acanthus ilicifolius*. Similar trend was recorded by Smith *et al* [1989] in the halophyte *Conocarpus erectus* during dry season.

b) Chlorides.

The values of chloride content from different parts of *Caesalpinia crista* and the seasonal variations of chloride contents in these parts are shown in fig. 9. There is no tendency of chloride accumulation as seen in other

Figure : 9 Chloride contents in different parts of
Caesalpinia crista L.
during different seasons.
(expressed on dry wt. basis)



S1:leaf S2:Rachis S3:Stem S4:Root

halophytes. Chloride accumulation is seen in the root tissue in summer. Maximum chloride content in root tissue is very low. Stem accumulated chloride during winter is higher as compared with the rainy and summer season. During summer stem had the least chloride level as compared with chloride from all other parts during all the seasons. Rachis has highest chloride level during summer season which is about double the values recorded for winter and rainy season. Leaves of C. crista showed highest chloride content. It was very low during winter while in summer and rainy season the content was relatively higher.

Although chloride is a dominant element in saline soil it serves as an important micronutrient in higher plants. It is an important anion helpful for photosynthesis and stomatal regulation. During photosynthesis chloride ions are involved in the splitting of water at the oxidizing cite of photosystem II. It is assumed by Kelly and Izawa [1978] that chloride acts as a cofactor of the manganese containing O_2 evolving system.

$$H_2O \xrightarrow[Mn^{++} + Cl^-]{\nearrow O_2 \quad e^-} PS\ II \xrightarrow{e^-} PS\ I \xrightarrow{e^-}$$

The enhancing effect of chloride can be correlated with corresponding increase in photophosphorylation. The dependence of photosynthetic O_2 evolution has also been demonstrated with isolated thylakoid membrane [Ball et al.

1984]. Chloride also have stimulating effect on Asparagine synthetase in nitrogen metabolism.Aspargine synthetase uses glutamine as a substrate .

$$\text{Glutamine} \xrightarrow[\text{asparagine synthetase}]{(NH_3)} \text{Aspargine + Glutamic acid}$$

Each chloride ion enhances this transfer. The plant species in which asparagine is the major compound in long distance transport of soluble nitrogen, chloride plays an important role in nitrogen metabolism.

The normal concentration of chloride in plants is between 200 to 2000 mg/100 g which is typical of the level of macronutrient but the chloride requirement of plant for optimal growth is between 34 to 120 mg/100g dry weight which is in the range of micronutrient levels [Marschner, 1986.].

According to Waisel [1972] sodium and chloride are taken up by roots of halophytes in non-equivalent quantities and they also differ in the patterns of their distribution within plant organs.

In *Clerodendron inerme*, a borderline mangrove, chloride in the leaves was 6.24% of dry tissue [Mishra, 1967] The succulent halophyte *Sesuvium portulacastrum* has a large amount of chloride ions in leaves as 8.64% and in mangroves *Rhizophora mucronata*, *Bruguiera parviflora*, *Ceriops candolleana* the range of chlorides was 2.5% to 4.4% as reported by Chirputkar [1969]. High amount of Cl has been recorded by Joshi [1975] in the leaves of mangroves and associate halophytes of estuarine areas in Maharashtra. It ranged between 2.03% in mangrove associate Thespesia populnea to 11.73% in salt accumulating mangrove Lumnitzera racemosa.

Spain and Holt [1980] analysed seven mangrove species for their leaf chloride contents. They reported that the chloride levels in the leaves of the mangrove species they studied, ranged from 3.25% to 6.07% for Xylocarpus australasicus and Avicennia marina respectively.

Mohite [1990] has estimated the chlorides from two species of leguminous halophyte species Derris. The leaves of Derris scandens [0.3%] were not showing chloride accumulation while the leaves of D.trifoliata [2.98%] were having distinct accumulation of chlorides. It is evident from our work that the leaves of Caesalpinia crista have very low chloride content which clearly indicates the exclusion of chloride from the foliar region.

Chloride content in leaves of some monocotyledonous and dicotyledonous halophytes has been investigated by Albert and Popp [1977].According to them Cl^- concentration in dicotyledonous leaves was more than monocotyledons from 80 equi.m^{-3} [Chenopodium glaccum] to 784 equi.m^{-3} [Salicornia prostrata] while that of monocotyledons from 32 equi.m^{-3} [Carex distans] to 288 equi.m^{-3} [Bolbochoenus maritimus]. Gorham and Wyn Jones [1980] also recorded low levels of Cl^- in monocotyledonous halophytes. The range was from 48 equi.m^{-3} [*Ammophilia arenaria*] to 315 equi.m^{-3} [*Spartina anglica*]. Exceptionally high Cl$^-$ content was recorded in *Zostera marina* [731 equi m^{-3}]. Higher values were recorded in dicotyledonous halophytes ranging from 481 to 965 equi m^{-3} in *Spergularia media* and *Salicornia europaea* respectively. At the same time quite low values of chloride were recorded in two plants *Glaux maritima* [225 equi.m^{-3}] and *Oenanthe lachenalii* [94 equi.m^{-3}] by them.

Popp [1983] analysed leaves of number of mangroves and mangrove associate for Cl$^-$ contents. Most of the mangrove species were having Cl$^-$ concentration between 480 to 600 equi.m^{-3}. Only two species *Xylocarpus granatum* [680 equi.m^{-3}] and *Lumnitzera* [790 equi.m^{-3}]has exceptionally high Cl$^-$ levels. Low values of Cl$^-$ were recorded in *Excoecaria agallocha* [410], *Scyphiphora hydrophylacea* [380], *Hibiscus tiliaceus* [160] and *Heritiera littoralis* [80 equi.m^{-3}].

When the values of Cl$^-$ contents in the leaves of *C.crista* are expressed in equi.m^{-3} lower values 67.57 and 52.65 are seen during rainy and winter season. But during summer season leaf Cl$^-$ level is 326.42 equi.m^{-3} which is in the range of other mangrove species.

Very little data is available about the chloride content in the rachis of leguminous leaves. Mohite [1990] recorded that the pattern of chloride accumulation in the rachis of two species of *Derris* varies. In *D. scandens* [0.5%] there was little accumulation but in *D.trifoliata* [1.98%]

accumulation of Cl^- was appreciable.

Very few attempts have been made to analyse the stem for Cl^- levels. Waisel [1972] observed that the stem tissue of *Suaeda monoica* contained less chloride than the leaves. Joshi [1976] recorded that in *Sonneratia acida* as compared to leaves the different parts of stem contain lower levels of chloride. He also found appreciable accumulation [1.38%] in mature *Rhizophora mucronata* stem. Spain and Holt [1980] investigated chloride levels in seven mangrove species. The values recorded by them were *Aegiceras corniculatum* [1.53%], *Avicennia marina* [1.57%], *Ceriops tagal* [0.43%] *Excoecaria agallocha* [0.41%], *Osbornea octodonta* [0.78%], *Rhizophora stylosa* [1.00%], *Xylocarpus australasicus* [0.87%] Mohite [1990] recorded lower levels of chloride in the stem of *D. trifoliata* than that of leaves, while reverse was the case in *D. scandens*.

Mohite [1990] observed equal levels of chloride in roots of both the species of *Derris*, *D. trifoliata* and *D. scandens* [1.0%]. But as compared to other plant parts the same value was the smallest in *D. trifoliata* and largest in *D. scandens* than the Cl^- in other parts.

Seasonal variation in Cl^- content of different mangrove leaves has been recorded by Jamale and Joshi [1977]. In all the mangroves they recorded *Sonneratia alba*, *Avicennia officinalis*, *A. alba*, *Aegiceras corniculatum*, *Excoecaria agallocha*, *Rhizophora mucronata* and *Acanthus* *ilicifolius* least chloride contents were recorded during monsoon and highest during summer. It is in direct relation with the salinity of estuarine water.

Rajpurohit and Sen [1979] observed seasonal variation in Cl^- in the leaves of six saline parts of the Pachpadra salt basin. They recorded that the patterns of Cl^- accumulation differ with species. In *Cressa cretica* Cl^- level was highest during March [10.37%] and lowest during September [2.42%]. In *Haloxylon recurvem* [November 12.63%, March 5.53%] *Salsola baryosma* [August 12.17% and January 2.13%], *Suaeda fruticosa* [January 27.14% and June 13.33%], *Trianthema triquetra* [July 8.87%, November 4.46%], *Zygophyllum simplex* [July 36.16% and January 13.33%]

Joshi [1982] also noticed the seasonal variation in chloride contents of *Suaeda nudifera* and *Salicornia brachiata*.

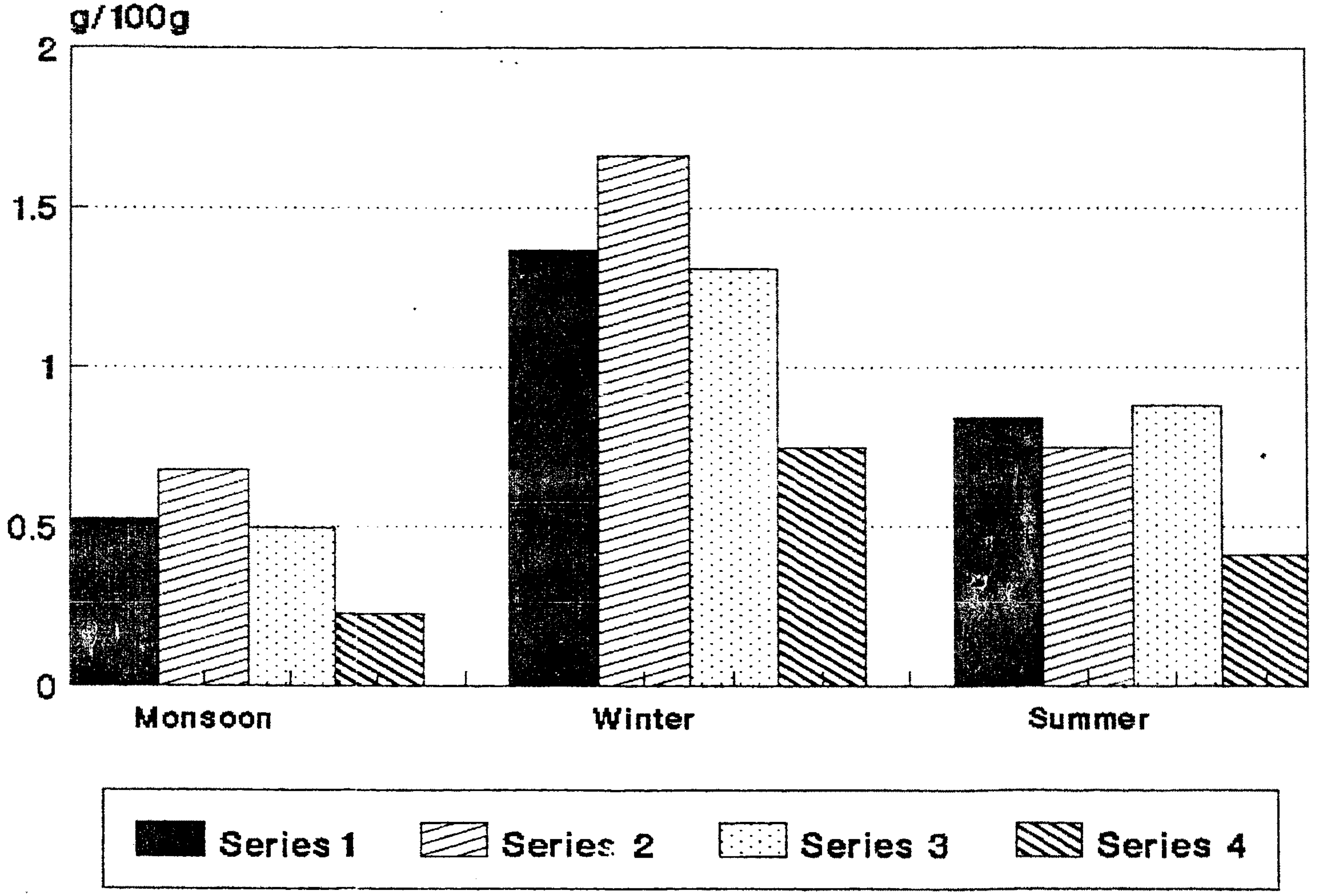
Our observations about *C.crista* indicate that there is remarkable seasonal variation in Cl content and Cl^- levels during summer season are quite high particularly in the root tissue. Although chloride levels are high in the roots tissue, the plant successfully manages to keep the important metabolic center, leaf, away from the toxic effects of this anion. It has been noticed by Lauchli [1984] that in some leguminous crops like, soybean cv.`Lee´ *Lupines angustifolia*, *Trifolium alexandrinum* the retention of chloride in root tissue can be regarded as a mechanism of ion regulation. Thus *Caesalpinia crista* adapts strategies i.e. exclusion of chloride to the considerable degree and retention of excess chloride in root tissue in summer season when the chloride content in the medium is very high.

c) Potassium.

The distribution of potassium in different plant parts of *Caesalpinia crista* and their seasonal variation is shown in figure 10. An appreciable amount of K^+ in different plant parts is seen in winter and the values are quite low in monsoon season. It is evident from the figure that as compared to root tissue the potassium level in aerial parts viz. stem, rachis and leaf are quite high in all three seasons. There is not much variation in potassium status in leaf, rachis and stem during respective seasons and there is no definite trend regarding this uptake pattern.

Potassium is regarded as most essential macronutrient and its uptake is highly selective and closely coupled with metabolic activity. It is highly mobile element in plants at all levels, within individual cells, within tissue as well as long distance transport via xylem and phloem. K^+ plays important role in activation of enzymes, protein synthesis, stomatal movement, photosynthesis and osmoregulation etc. [Marschner, 1986]. The deficiency of K^+ results in stunted growth, leaf damage, decrease in photosynthetic activity, and translocation of photosynthates.

Figure :10 Potassium contents in different parts of *Caesalpinia crista* L. during different seasons . (expressed on dry wt. basis)



S1:Leaf S2:Rachis S3:Stem S4:Root

It is indicated by Epstein [1972] that the optimal level of potassium in plants is 1% on the dry weight basis. It is evident from our observations that only during winter season the aerial parts show such optimal levels of this element while the values are low during the monsoon months. But at the same time it is very clear that these values are more than the corresponding sodium contents in aerial organs during all the three seasons.

The potassium content in leaf tissue of C.crista range from 0.52% to 1.36% . Accumulation of K^+ in the leaves of number of monocotyledonous halophytes has been recorded by many workers [Albert and Popp, 1977, Gorham and Wyn Jones,1980, Gleen and O' Leary, 1984]. This is due to an alkali ion uptake system which exsists extremely high affinity to K even at high Na^+ level.[Epstein, 1969].

This is not the case with dicotyledonous halophytes. Role of K^+ in maintaining osmotic potential of the cell sap is taken over by Na^+ under saline conditions [Gorham et al. 1980]. Hence the amount of Na^+ exceeds that of K^+. Low values of K^+ are noted by number of workers, in many salt excreting and salt accumulating halophytic leaves [Chirputkar, 1969, Joshi, 1975, Albert,1975, Jamale and Joshi, 1977, Albert and Popp, 1977, Gorham et. al.1980, Spain and Holt 1980, Popp, 1982, 1983 etc.] .

But salt excluder type of halophytes and border line halophytes show tendency of preferential K^+ uptake, as in monocotyledons. It has been demonstrated by Mishra [1967] in Clerodendron inerme, Siddhu [cf Walsh 1974] in Derris uliginosa and Excoocaria agallocha, by Hollister [Cf. Walsh, 1974] in Avicennia nitida, Conocarpus erectus and Rhizophora mangle, Joshi [1975] in Kandelia candel, Joshi [1976] in Excoecaria agallocha, Barth [1982] Popp [1984] in leaves of Heritiera littoralis and Hibiscus tiliaceus and Mohite [1990] in Derris scandens and D. trifoliata.

Comparatively high amount of K^+ is present in rachis of C. Crista ranging from 0.675 to 1.66%. Very little information is available regarding the K^+ content from rachis. High K^+ values are noted by Mohite [1990] in Derris trifoliata and D. scandens the leguminous halophytes.

The potassium content in the stem tissue of C. crista range from 0.495 to 1.30% which nearly equals that of leaf tissue. Accumulation of K^+ in the stem tissue of halophytes has been noticed by many workers. Hollister [cf Walsh, 1974] noted high K^+ content ranging from 0.2% to 2.78% in the stem tissue of Avicennia nitida, Conocarpus erectus, Leguncularia racemosa and Rhizophora mangle. High K^+ contents in the stem tissue of Rhizophora brevistyla [0.39%] has been noted by Golly [cf Walsh, 1974]. Spain and Holt [1980] reported the K^+ levels from branch wood of six different mangrove species ranging from 0.15% [Osbornea octodenta and Rhizophora stylosa] to 0.81% [Excoecaria agallocha]. They observed that in E. agallocha and Xylocarpus australasicus the K^+ content from branchwood tissue was higher than the leaf tissue. Mohite [1990] reported that in leguminous halophytes <u>Derris trifoliata</u> and <u>D. scandens</u> the K^+ content in the stem tissue were 1.35% and 0.75% But these values are lower than the K^+ contents from the leaf tissue of the respective plant.

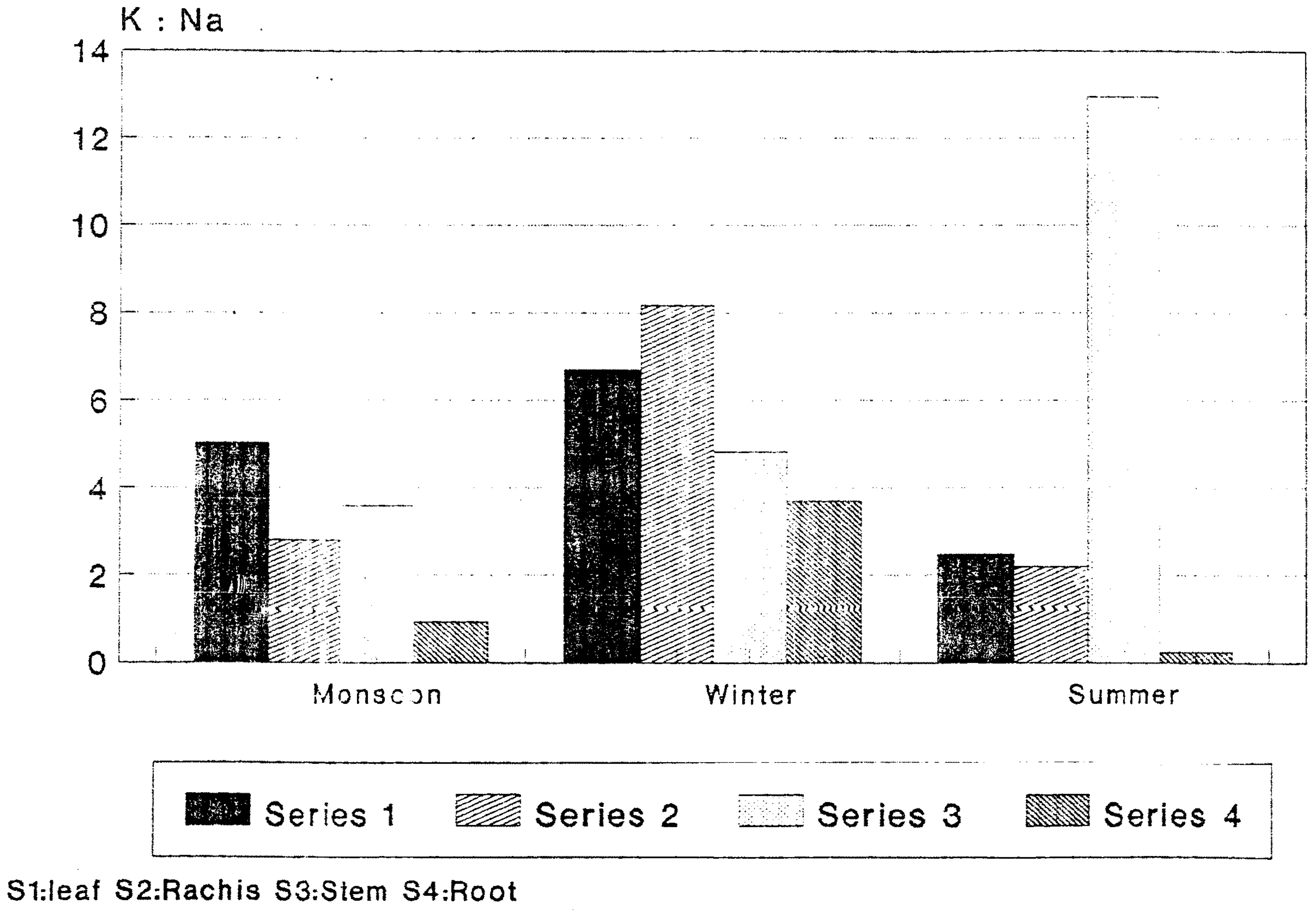
Low potassium contents are observed in root tissue of <u>C. crista</u> ranging from 0.2 % to o.74%. But Hollister [cf.Walsh, 1974] reported accumulation of K^+ in the root tissue of <u>Avicennia nitida</u> [2.9%] . Mohite [1990] found that the K^+ content in root tissue of <u>Derris trifoliata</u> and <u>D. scandens</u> was 1.25% and 0.52 % respectively.

d) <u>Potassium : Sodium ratio</u>

Instead of study of absolute concentration of monovalent and essential cation like potassium it is always desirable to study the fate of this element relative to the other dominant but nonessential monovalent cation like sodium.

K/Na ratios in different plant parts of <u>Caesalpinia crista</u> during different seasons are shown in fig. 11. These ratios are computed on the basis of K and Na^+ values expressed in equi.m^{-3} plant water basis. It is very clear from the figure that <u>C.crista</u> shows high values of K/Na ratio in all the plant parts during all the seasons except roots in monsoon and summer seasons where it is less than

Figure : 1.1 Potassium : Sodium ratio in different parts of *Caesalpinia crista* L. during different seasons. (expressed on plant water basis).



unity. During monsoon it is 0.92 but during summer season it is extremely low 0.232 and at the same time stem shows highest K/Na ratio 12.95.

Modification of the ion uptake system under saline conditions can be responsible for a high K/Na ratio within the plant due to highly selective potassium uptake even in presence of excess sodium in the substratum. This has been demonstrated by Rain and Epstein [1967] for the mangrove *Avicennia marina*.

Albert and Kinzel [1973] used the term "physiotype" for describing halophytes whose leaves have a particular type of K^+/Na^+ ratio with a particular taxonomic unit . One physiotype associated with monocotyledonous families like Gramineae, Juncaceae and Cyperaceae was characterized by high K^+/Na^+ ratio. The dicotyledonous families Chenopodiaceae and Caryophyllaceae were grouped in the second physiotype where K^+ $/Na^+$ ratio is less than unity. Albert and Popp [1977] found that the highest K^+/Na^+ ratio was 9.7 in *Carex distans* a Cyperaceae member and the lowest value recorded by them in dicot halophyte *Lepidium crass* was 0.055.

Gorham *et al.* [1980] also analysed leaves of number of monocotyledonous plants. They analysed 21 monocotyledonous plants of which 18 plants were showing high K^+/Na^+ ratio , highest being recorded in *Carex arenaria* 14.2. They also analysed 5 dicotyledonous plants from Chenopodiaceae, Caryophyllaceae and Umbelliferae and found

K^+/Na^+ ratios less than unity [except in Umbelliferae member *Oenanthe lachenalii* with K^+/Na^+ ratio 1.19]

Popp [1982] compared two halophytes one salt accumulated type, *Salicornia rubra* from Chenopodiaceae and other salt excluder type, *Puccinellia airoides* from Poaceae for their inorganic constituents. K^+/Na^+ ratio of *S. rubra* was 0.06 and that of *P. airoides* 1.7 which means that in salt excluder type of halophytes K^+/Na^+ ratio is more than unity.

Barth [1982] found that the K^+/Na^+ ratios were more than unity in brackish water species or mangrove associates *Heritiera littoralis* and *Hibiscus tiliaceus* and gave rise to the assumption that these two species have special ion uptake and transport characteristics. This is possibly similar to some monocotyledonous halophytes which are able to maintain low Na^+ concentration in their shoots.

Low K/Na values [below unity] have been recorded in mangroves which grow in the vicinity of *C.crista* by many workers [Albert and Kinzel,1973, Albert and Popp, 1977, Popp,1982, Barth,1982.] It is very clear from the above discussion that generally monocotyledonous halophytes are having K/Na ratios more than unity and dicotyledonous halophytes show K/Na ratio less than unity with few exceptions like *Oenanthe lachenalii*, *Heritiera littoralis*, *Hibiscus tiliaceus*. It must be mentioned here that all the above values have been calculated from K and Na^+ content expressed on equivalent $/m^3$ plant water basis.

In C. crista high K/Na ratios are noticed in different plant parts in contrast to habitat (Tab.1) indicating a preferential potassium uptake in C. crista with respect to sodium similar to the above mentioned halophytes.

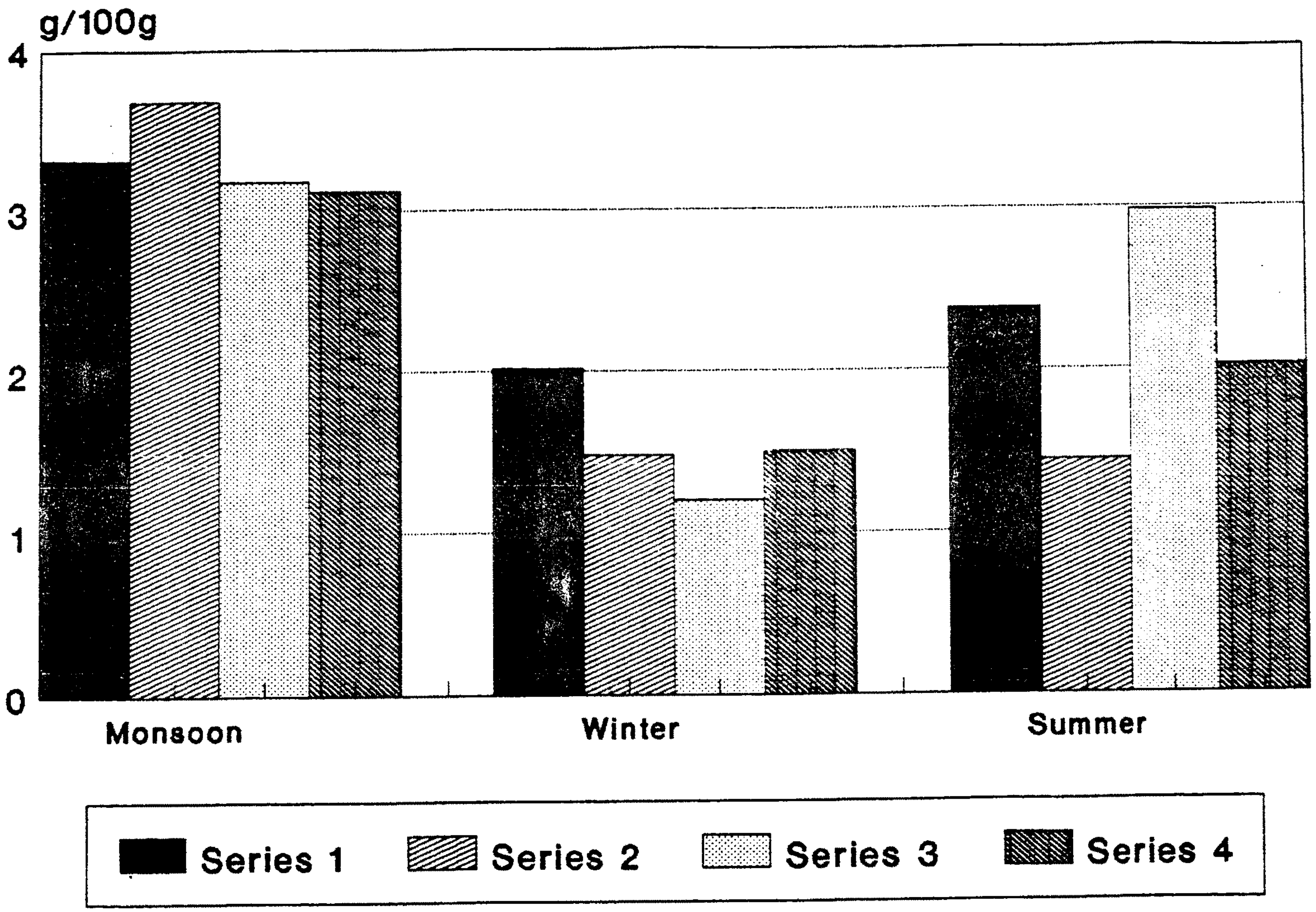
e) Calcium.

The calcium contents in different parts of Caesalpinia crista during different seasons are shown in fig.12. It is interesting to note that all the parts of C. crista show marked accumulation of calcium. Aerial parts contain relatively more calcium than the root tissue.

Calcium is relatively large divalent cation required by the plant in macroamount. It enters the apoplast and is bound to cell walls in an exchangeable form and at the exterior surface of plasma membrane. Calcium is a nontoxic mineral nutrient even in high concentration and is very effective in detoxifying high concentration of other mineral elements in plants. According to Epstein [1972] the concentration of calcium considered as adequate in higher plants is 0.05%. The calcium requirement for optimum growth is much more in dicotyledons than in monocotyledons. [Loneragan and Snowball, 1969].

Calcium plays a major role in cell wall stabilization. In contrast to other macronutrients, a high proportion of the total Ca^{2+} in plant tissue is located in the cell walls, at two distinct areas, the middle lamella in

Figure : 12 Calcium contents in different parts of *Caesalpinia crista* L. during different seasons. (expressed on dry wt. basis.)



S1: Leaf S2: Rachis S3:Stem S4: Root

which Ca^{2+} is bound with pectins and exterior surface of plasma membrane. In both areas Ca^{2+} regulates the membrane permeability and related process and strengthens the cell wall. Hence a typical system of Ca^{2+} deficiency results in the disintegration of cell walls and the collapse of the affected tissue, such as the petiole and upper part of the stem [Bussler, 1963].

Calcium is involved in cell division and extension. It appears that changes in cytosolic Ca^{2+} regulates the spindle activity [Wolniak, 1988]. Role of Ca^{2+} in cell extension is not yet clear. Calcium is also involved in pollen tube growth. It also plays a fundamental role in membrane stability and cell integrity. Calcium stabilizes cell membrane by bridging phosphate and carbonate groups of phospholipids. [Caldwell and Haug,1981] and proteins at membrane surface [Legge et al., 1982].

Calcium has recently been recognized as a transducer of normal and environmental signals to the responsive element of cell metabolism.[Hepler and Wayne, 1985].

In view of a key role of calcium in membrane activity and various developmental processes, understanding the relationship between sodium and calcium is of utmost importance in search of mechanism for salt tolerance . There are several reports which indicate that salinity severely effects Ca^{2+} uptake and transport so that shoots frequently show symptoms of calcium deficiency [Cramer et al, 1989] especially in salt sensitive genotypes. Even in some halophytes like Galenia pubescens the uptake of Ca^{2+} is hampered by salt stress [Wallace ,1982]. Rengel [1992] has discussed the effect of salt stress on calcium nutrition under such situations. According to him uptake of Na^{+} across the plasma membrane is very fast, resulting the physiological effects on extracellular as well as intracellular sites. Sodium reduces binding of Ca^{2+} to the plasma membrane, inhibits influx while increasing efflux of Ca^{2+}, and depletes the internal stores of Ca^{2+} from endomembranes. These changes in the cell Ca^{2+} homeostasis are suggested to be the primary response to salt stress that are perceived by root cells. Salt would almost instantly reduce the amount of Ca^{2+} being transferred to the leaf cell, with Ca^{2+} activity dropping and Na^{+} activity rising in the apoplasm of the leaf cells. This Ca^{2+} signal would be transported to leaves together with it not proceeding the signal of limited water supply. Hormonal signals are likely to be secondary in nature, and caused by the Na^{+} related disturbance of the root cell Ca^{2+} homeostasis.

There are several reports which indicate that supplemental Ca^{2+} supply can have ameliorative effects on the plants exposed to salt toxicity. [Bliss,et al. 1986].

Thus it is clear that the possession of efficient calcium uptake mechanism is one of the possible mechanisms of salt tolerance in higher plants. In *C. crista* if we take into consideration very low Ca/Na ratios in the supporting soil and water (Tab.1) the preferential Ca uptake mechanisum is clearly noticeable. Thus efficient calcium uptake can be regarded as a possible mechanisum of solt tolerance in this leguminous halophyte.

According to Waisel [1972] calcium content in various halophytes is low and usually does not exceed 0.5% of their dry weight. According to him the calcium content in the halophytes like *Atriplex*, *Suaeda monoica* and *Aeluropus litoralis* is not affected by the presence of NaCl in the medium. Although this is the case with the above halophytes, it has been observed in several mangroves that Ca^{2+} content varies from 0.65 to 2.48% [Walsh, 1974]. Albert and Popp [1977] noted high Ca^{2+} level in the leaf tissue of *Pragmnites australis* a halophyte from Austria. Spain and Holt [1980] noticed that the calcium levels in the leaves of mangrove species varied from 0.27 [*Aegiceras corniculatum*] to 2% [*Xylocarpus australasicus*]. High Ca^{2+} levels from 3 monocot halophytes *Carex arenaria*, *Iris pseudocorus*, *Phalaris arnndinaca* and one dicot halophyte *Oenanthe lachenalii* have been reported by Gorham *et al.* [1980]. El-Ghonemy *et al.* [1982] analysed some desert halophytes for their Ca^{2+} contents. They recorded the range of Ca^{2+} in the leaves from 0.48 % [*Juncus rigidus*] to 5.70% [*Zygophyllum album*]. According to them *Z. album* and *Tamarix nilotica* [5.20%] are performing selective uptake of Ca^{2+} while *Juncus* *rigidus* selectively exclude the uptake of Ca^{2+}. Teas [1985] reported 1.22% Ca^{2+} in the leaves of *Rhizophora*. Recently Mohite [1990] recorded low calcium levels 0.4% and 0.6% in the leaves of *Derris trifoliata* and *D. scandens*. But in contrast to the leguminous halophyte *Derris*, *Caesalpinia crista* shows considerable accumulation of Ca^{2+} in the leaf tissue.

Walsh [1974] recorded appreciable amount of Ca^{2+} in the stem tissue of *Avicennia nitida*. Spain and Holt [1980] recorded Ca^{2+} levels in stem tissue of different mangrove species ranging from 0.23% [*Osbornia octodonta*] to 1.83% [*Rhizophora stylosa*]. They also recorded higher Ca^{2+} level than the Na^{+} level, in stem tissue of *Ceriops tagal*, *R.stylosa*, *Excoecaria agallocha* and *Xylocarpus australasicus*. In the stem tissue of some desert halophytes El-Ghonemy *et al* [1982] noted the range of Ca^{2+} from 0.32% [*Juncus rigidus*] to 3.54 % [*Zygophyllum album*]. Teas [1985] recorded 1.29% Ca^{2+} from *Rhizophora* wood. In *Caesalpinia crista* stem tissue also we noticed marked accumulation of Ca^{2+} ranging from 1.2 to 2.02% and these values are considerably more than the corresponding sodium values.

Walsh [1974] recorded very high Ca^{2+} level [2.12%] in *Conocarpus erectus* roots as compared to the stem and leaf tissues. Similarly Teas [1985] recorded high root Ca^{2+} level in the aerial roots of *Rhizophora* [1.29%] but low level in surface roots [0.75%] as compared to leaf tissue Ca^{2+}

content, but Mohite [1990] recorded the low levels of Ca^{2+} in Derris trifoliata [0.32%] and D.scandens [0.42%] as compared with leaf tissue. In the present investigation it is noticed that the roots of C.crista contain appreciable amount of Ca^{2+} [ranging from 1.5 to 3.2%] although it is less than the calcium content in the aerial tissue.

Seasonal variation of leaf tissue Ca^{2+} content has been recorded by Joshi and Bhosale [1982] for different mangrove species. They found highest Ca^{2+} level during summer season in leaf tissue of Sonneretia alba, Avicennia officinalis, A. alba, Aegiceras corniculatum, Excoecaria agallocha, Rhizophora mucronata and Acanthus ilicifolius, and lowest during monsoon. Seasonal variation in Ca^{2+} levels in Suaeda nudiflora and Salicornia brachiata leaves have been studied by Joshi and Iyengar [1982]. They recorded highest Ca^{2+} during winter, while calcium contents were minimum during monsoon.

In contrast to the above observation in C.crista we observed the highest Ca^{2+} levels in all the parts during monsoon and lowest values during winter except in rachis tissue. Thus it is clear that there is no uniform trend among different halophytic species with respect to calcium uptake during different seasons and its distribution with the plant. This may be possibly due to differential requirement of this element during different climatic conditions as well as differential availability.

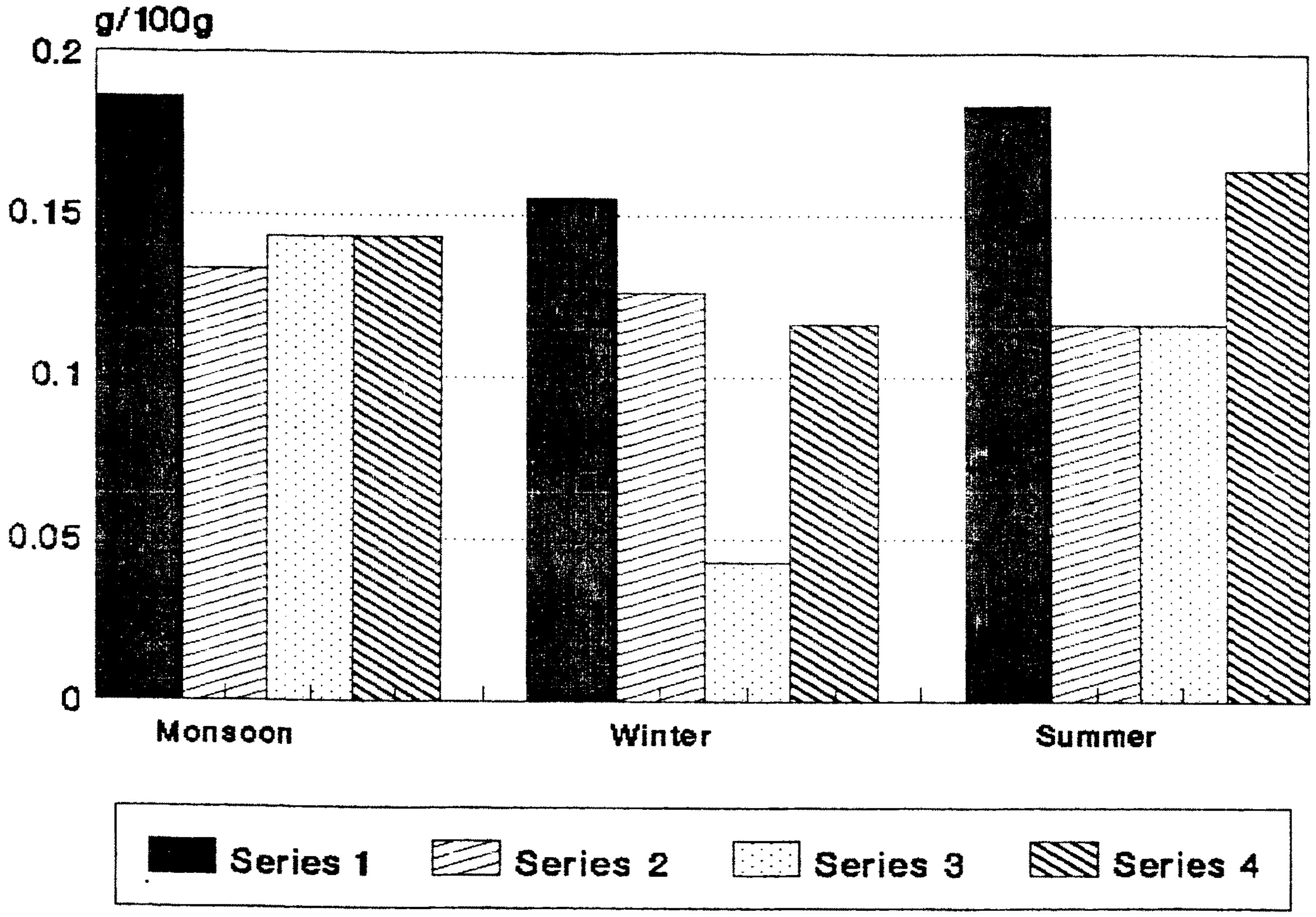
f) Magnesium.

Fig.13 shows magnesium content of different parts of *Caesalpinia crista* and their seasonal variation. Mg^{2+} level in leaf tissue is more than the other plant parts.

Magnesium is small and strongly electropositive divalent cation important in plant metabolism. The major function of Mg^{2+} is in the synthesis of chlorophyll and cellular pH control. This divalent cation forms central core of the nucleus of the chlorophyll molecule, as well as a cofactor in almost all enzymes involved in phosphorylation process. Magnesium also plays an important role in aggregation of ribosome subunits during protein synthesis. It is also essential for enzyme activation and energy transfer reactions. Thus magnesium plays key role in plant metabolism and overall plant growth [Marschner, 1986] .

Inspite of its key role in plant metabolism very little attention has been paid towards the role of Mg^{2+} in salt tolerance process. Atkinson *et al.* [1967] have speculated that this element maintains the salt balance in the leaves of *Aegialitis*, a mangrove species. Furthermore , Bernstein [1975] has postulated that the salt tolerance of a species for a particular salt, reflects the ability of the species to absorb nutritionally adequate level of Ca^{2+} and Mg^{2+} from the soil. In this respect the report of Konigshofer [1983], that non-halophytic species of *Plantago* tended to exclude sodium from leaf tissue by enhancing Mg^{2+} uptake for charge

Figure : 13 Magnesium contents in different parts of *Caesalpinia crista* L. during different seasons. (expressed on dry wt. basis.)



S1:Leaf S2:Rachis S3:Stem S4:Root

balance under saline condition, appears interesting.

Magnesium requirement of the plant for optimal growth is 0.5% of the dry weight of the vegetative parts [Epstein, 1965]. It is evident from the fig.13 that values of Mg^{2+} contents in all the parts of C.crista are much less during all the seasons. The values in the leaf tissue are ranging from 0.155% to 0.186%. When these values are compared with the values of leaf magnesium status recorded for other halophytic species it can be seen that the leaf magnesium status is really poor in C.crista.

Walsh [1974] mentioned that Mg^{2+} content in different mangrove leaves were ranging from 0.23% to 1.45% in Avicennia nitida and Rhizophora mucronata respectively. Mg^{2+} contents in the leaves of different mangroves and associate halophytes of estuaries in Maharashtra have been recorded by Joshi [1975]. The Mg^{2+} content was in the range 0.04% [Clerodendrum inerme] to 1.64% [Aeluropus lagopoides]. Spain and Holt [1980] also determined the Mg^{2+} levels in the foliage of seven different mangrove species such as Aegiceras corniculatum, Avicennia marina, Ceriops tagal, Excoecaria agallocha, Osbornia octodonta, Rhizophora stylosa and Xylocarpus australasicus. They recorded the range from 0.39% [Xylocarpus australasicus] to 0.94% [Ceriops tagal]

It is evident from our observation that C.Crista is having considerably low magnesium uptake potential when compared with other halophytes. Magnesium and calcium are divalent cations and it is indicated in many studies that there is a strong competition between Ca^{2+} and Mg^{2+}. This is because of low affinity of the highly hydrated Mg^{2+} for binding sites at the root plasma membrane [Marschner, 1986]. As we have seen earlier the calcium levels in various parts of *Caesalpinia crista* are quite high and this may be one of the reasons for lower levels of magnesium in *C. crista*.

Very little information is available regarding the Mg^{2+} levels in stem zone. Walsh [1974] mentioned relatively low levels of Mg^{2+} contents in stem of *Avicennia nitida* [0.308 to 0.365%], *Conocarpus erectus* [0.24 to 0.34%], *Laguncularia racemosa* [0.12 to 0.18%] *Lumnitizera recemosa* [0.34], *Rhizophora brevistyla* [0.1 to 0.29%] and that in *R. mangle* [0.28%]. Spain and Holt [1980] recorded the Mg^{2+} of stems of different mangrove species. They mentioned the range of Mg^{2+} content from 0.08%[*Ceriops tagal* and *Xylocarpus australasicus*] to 0.22% [*Aegiceras corniculatum*] which are considerably lower than those in the foliage of corresponding species. Recently Mohite [1990] observed the same trend in *Derris* species stem tissues, which were having very low levels of Mg^{2+} as compared to root and leaf tissue. Our observation with *Caesalpinia crista* also reveal the same trend of Mg^{2+} content in the stem tissue.

Mg^{2+} levels in the roots have been mentioned by Walsh [1974]. He noted that Mg^{2+} contents in roots of *Avicennia nitida* and *Conocarpus erectus* were 0.37% and 0.716%

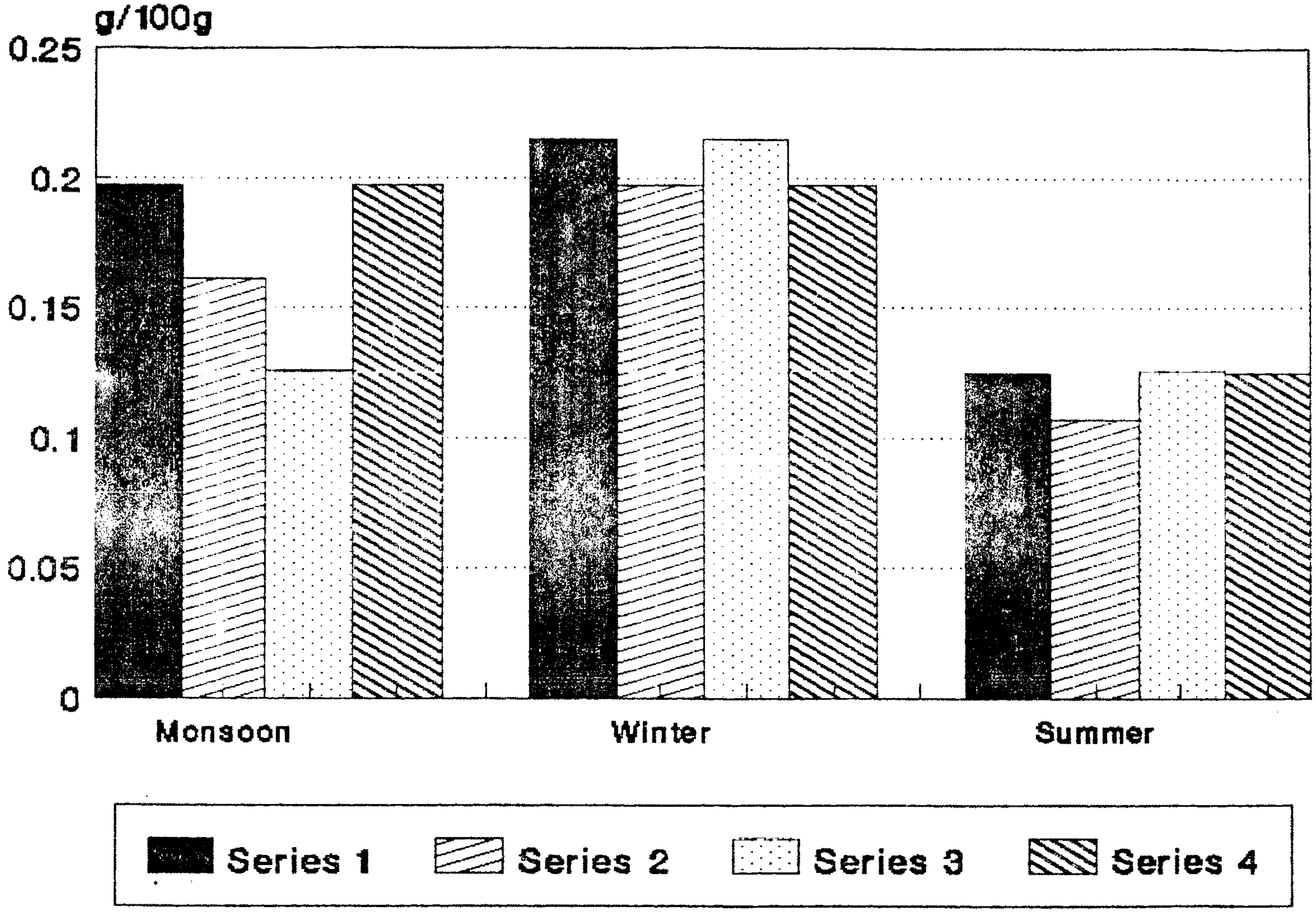
respectively. About 0.3% Mg^{2+} content was recorded by Mohite [1990] in the roots of the leguminous halophytes *Derris trifoliata* and *D. scandens*. As compared to the above values the Mg^{2+} content in root tissue of *C. crista* is relatively low.

Seasonal variation of Mg^{2+} content was studied by Joshi and Iyengar (1982). They reported a peak of Mg^{2+} in the leaves of *Suaeda nudiflora* during winter and in the leaves of *Salicornia brachiata* during monsoon while least during summer in both the plants. Joshi (1975) also reported seasonal variation from *Aegiceras majus*, *Acanthus ilicifolius* and *Avicennia officinalis* leaves He noted that there is not a common trend in seasonal variation of Mg^{2+} level in these three plants. It varied with the species. Smith et al. (1989) reported a decrease in Mg^{2+} level in the old leaves of *Avicennia germinans* and *Conocarpus erectus* from rainy to dry seasons. Our observations about *Caesalpinia crista* leaves indicate a peak during monsoon and least during winter season. The other plant parts also show seasonal variations but the trend varies.

g) Phosphorus.

The phosphorus contents of different parts of *Caesalpinia crista* and their seasonal variation have been shown in fig.14. There is not much variation in the phosphorus contents of different plant parts. Leaves and roots contain nearly equal amount of phosphorus except in

Figure : 14 Phosphorus contents in different parts of *Caesalpinia crista* L. during different seasons. (expressed on dry wt. basis)



S1:Leaf S2:Rachis S3:Stem S4:Root

winter where leaf phosphorus level is slightly higher than the root phosphorus level.

Phosphorus is an important macronutrient of plant. It is a structural constituent of most prominent nucleic acids DNA and RNA. It plays major role in energy transfer during plant metabolism like glycolysis, respiration, photosynthesis in the form of ATP,NADP and also in cell division and expansion. In inorganic forms of RuBP, PEP, phosphorus controls photosynthesis and carbohydrate metabolism. Inorganic phosphates in the form of phytate plays significant role during seed germination and early stages of seedling growth. Phosphorus is involved in the formation of cell membrane lipid, which plays a vital role in ionic regulation [Bieleski and Ferguson, 1983].

The phosphorus requirement of plant for optimal growth is 0.2g/100g of plant dry weight during the vegetative growth [Epstein,1972]. Waisel and Ehel [1974] analysed _Suaeda_ _monoica_ leaves using X-ray microanalyzer. They have localized negligible amount of phosphorus inside the vacuole of the leaf cell and high concentration in the cytoplasm. Though there is very low phosphorus concentration in the soil solution, an additional mechanism i.e. an unexploited growth of roots for the absorbtion of phosphorus is present. At the same time he noted the stimulative effect of light on the uptake of phosphorus in the leaves of submerged marine angiosperm _Zostera_ _marina_. Golley [cf Walsh, 1974] recorded the similar type of light induced phosphorus accumulation in *Rhizophora brevistyla*. He recorded 0.9g/100g phosphorus in the leaves directly exposed to light and 0.8g/100g phosphorus in understory.

Siddhu and Hollister [cf. Walsh, 1974] recorded phosphorus levels from different mangrove leaves ranging from 0.14 to 0.41g/100g in *Rhizophora mangle* and *Excoecaria agallocha* respectively. *Derris heterophylla* plants growing in Mumbra and Deogad creeks were analysed by Kotmire and Bhosale [1979] for their leaf phosphorus levels and found to have 0.05 to 0.11g/100g phosphorus respectively. Data presented by Spain and Holt [1980] also gives the range of phosphorus from 0.09 [*Ceriops tagal*] to 0.21g/100g [*Excoecaria agallocha*] when they analysed seven mangrove species for leaf phosphorus content. The phosphorus contents of the leaves of different desert halophytes have been investigated by El-Ghonemy *et al*. [1982]. They found that the element content varied from 0.069 % [*Salsola tetrandra*] to 0.44% [*Zygophyllum album*]. In *Rhizophora* leaves Teas [1985] recorded high phosphorus level 0.9 g/100g. In *Derris trifoliata* Mohite [1990] recorded relatively high phosphorus level than *D. scandens* [0.46 and 0.22 g/100g respectively. Our observations indicate that *C. crista* leaves contain 0.125 to 0.215 g/100g phosphorus which vary seasonally.

Mohite [1990] observed relatively low phosphorus in rachis tissue than leaflet tissue in D.trifoliata and D.scandens. In C.crista rachis tissue also, similar pattern of phosphorus content during all the three seasons is noticeable. This is quite understandable if we consider the significant metabolic role of the laminar tissue.

The branchwood phosphorus levels have been recorded by Spain and Holt [1980]. The values ranged from 0.01 to 0.11 g/100g [Ceriops tagal and Excoecaria agallocha] respectively, where each value was less than the values recorded for their respective leaf tissue. Stem tissue phosphorus levels recorded by El-Ghonemy et al. [1982] from different desert halophytes ranged from 0.05 to 0.8% in Salsola tetragona and Nitraria retusa respectively. But Teas [1985] recorded 0.9 g/100g phosphorus in stem tissue of Rhizophora which was equal to the leaf tissue phosphorus. Mohite [1990] recorded relatively low phosphorus content in the stem tissue of D.trifoliata and D. scandens than that of respective leaf tissue. In the present investigation we have observed phosphorus content in stem tissue ranging from 0.12 to 0.21 g/100g. dry tissue.

There are only few reports of phosphorus analysis from root tissue of halophytes. Teas [1985] reported 0.7 g/100g phosphorus from Rhizophora surface roots. Mohite [1990] reported phosphorus content in root tissue of D.trifoliata as 0.24 g/100g and D.scandens 0.2 g/100g.

Not much data is available about influence of different seasons on phosphorus status in halophytes.

Seasonal variation of phosphorus content in different plant parts in *Avicennia marina* and *Rhizophora mucronata* has been investigated by Subramanian and Venugopalan [1983]. In *A. marina*leaf tissue they recorded peak in August [0.12g/100g] and minimum in June [0.045g/100g]. Similar trend was observed in *R. mucronata* but values ranged from 0.015 to 0.065 g/100g. The stem tissue phosphorus content in *A. marina* showed peak in April and minimum in October. No significant variation has been noticed in phosphorus level of *A. mucronata* stem tissue except a peak during April. Root tissue of *A. marina* shows a peak in August and minimum in November while *R. mucronata* root tissue showed not much seasonal variation except a peak in March.

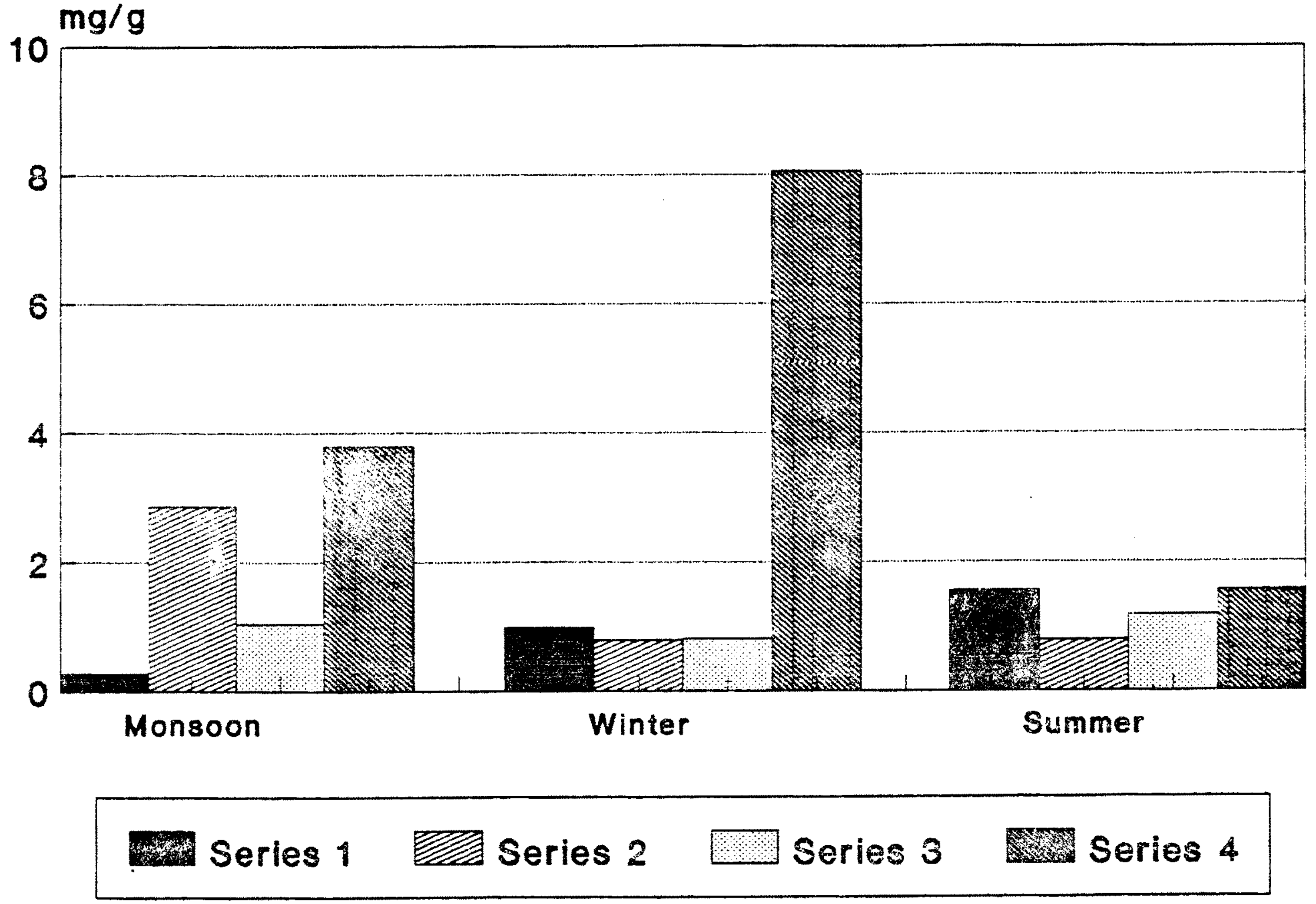
Phosphorus content in different parts of *C. crista* during different seasons do show great variation. Thus during summer season phosphorus content in the leaf, rachis and root is quite low as compared to winter phosphorus status. These observations indicate a possible negative influence of salinity on phosphorus nutrition in *Caesalpinia crista* plants since during summer months the salinity of the medium is maximum. Only an elaborate sandculture experiment will throw more light on this aspect.

h) Iron

The iron contents in different parts of *Caesalpinia crista* and their seasonal variations are shown in fig. 15. Roots contain high amount of iron during all the three seasons, extensive accumulation being observed in winter. All the aerial parts i.e. leaf, petiole and stem contain relatively low amount of iron.

Iron is one of the important micronutrients required in plant metabolism. The formation of chelates and its reversible oxidation- reduction action constitute the major metabolic function. There are two major iron containing proteins hemoprotein and iron sulphur proteins. [Sandmann and Boger, 1983]. Cytochromes are hemoproteins containing heme-iron porphyrin complex as a prosthetic group, hence plays a major role of electron transport in respiration. Iron also plays major role in the biosynthesis of chlorophyll. In green leaves 80% of the iron is localized in the chloroplasts. In iron sulphur proteins most prominent is ferrodoxin, which occurs in chloroplast and acts as an electron transmitter. In respiratory electron transport process also several iron sulphur proteins are involved. Other heme enzymes are catalase and peroxidases. In iron deficient roots decrease in peroxidase activity is much greater than catalase. As a consequence cell formation and lignification are impaired, phenolics accumulate in the rhizodermis [Romheld and Marschner, 1981]. The iron containing enzymes are xanthin oxidase, aconitase in TCA

Figure : 15 Iron contents in different parts of *Caesalpinia crista* L. during different seasons. (expressed on dry wt. basis.)



S1: Leaf S2: Rachis S3: Stem S4: Root

cycle and coporphyrinogen oxidase. The possible role of iron in protein metabolism has been suspected from the findings of number of authors who have observed that in iron deficient plant the protein fraction decreases simultaneously with an increase in the level of soluble organic nitrogen compounds [Perur *et al*, 1961]. The short term experiments with alga *Euglena gracillis* indicate that iron is directly implicated in nucleic acid metabolism [Price *et al*. 1972]. According to Mengel and Kirkby [1982] the iron content of green plant tissue is low as compared to macronutrient content and is generally in the order of about 100 ppm in dry matter.

According Waisel [1972], unless precipitated as sulphides,iron is maintained in marshes in their reduced and more soluble divalent form, which suggests a possibility of higher content of iron in salt marsh plants. However Gorham and Gorham [1955] recorded that some salt marsh plants like *Silene maritima*, *Limonium binervosum*, *L. vulgarae*, *L. humile*, *Aster tripolium*, *Salicornia perennis* and *S. stricta* have very low iron concentration than in woodland or in freshwater swamp plant. It may be due to a high NaCl content of the medium which antagonizes uptake and reduces assimilation of iron by such plants. According to Waisel [1972] some plants like *Arthocnemum glaucum* and *Salicornia herbacea* may require low amount of iron, and thus avoid the problem. But it is not true for all marsh plants. Plants like *Spartima alterniflora* require a high amount of iron and they can grow under reducing conditions. Oxygen diffusion out of plant roots oxidizes some of the precipitated iron sulphides to ferrous sulphate and makes it available again to plants. Wallace et al [1982] studied the effect of NaCl salinity on the Fe levels of different parts of some desert *Atriplex* species. They recorded increase in Fe level in *A. polycarpa* with increase in NaCl salinity in soil culture. Thus there are two groups of halophytes 1] having low iron requirement, 2] having high iron requirement.

There are only few reports regarding the iron content from different parts of halophytes. Morton [1965] found that the iron content from the leaf tissue of *Rhizophora mangle* was 0.15 µg/g where as Golley and Hollister [F. Walsh, 1974] observed the difference in iron content depending on their position on the plant. They noted the highest range from 0.08 to 0.69 µg/g in *Rhizophora brevistyla* overstory and understory respectively. The halophytes from Deogad and Mumbra creeks were analysed for their leaf tissue iron content by Kotmire and Bhosale [1979] and have recorded the iron content from *Derris heterophylla* ranged from 0.26 to 0.52 µg/g El-Ghonemy et al. [1982] analysed leaves of seven desert halophytes for mineral contents. They recorded Fe levels ranging from 0.35 µg/g to 1.52 µg/g in *Salsola tetragona* and *Halocmemon strobilaceum* respectively. In *Rhizophora* species Teas [1985] recorded 0.07 µg/g iron in leaf tissue. In two species of leguminous halophyte *Derris*, iron content was 0.24 µg/g in *D.trifoliata* and 0.2 µg/g in *D. scandens* [Mohite, 1990]. In comparison to this legume the leaf iron content in *Caesalpinia crista* is quite high in all the three seasons.

In rachis tissue Mohite [1990] recorded iron level 0.32 µg/g in *D.trifoliata* and 0.36 µg/g in *D. scandens*. In the present investigation we have recorded quite high levels of Fe in rachis tissue.

Golley, Hollister [cf.Walsh, 1974] noted the difference in iron content of overstory and understory stem from different halophytic plants. The maximum range they noted in *R. brevistyla* was 0.036 to 1.00 µg/g. Stem tissue Fe levels noted by El-Ghonemy *et al*. [1982] from different desert halophytes ranged from 0.36 [*Tamarix nilotica*] to 0.97 µg/g [*Salsola tetrandra*] Wallace et al. [1982] recorded much lower Fe levels in stem tissue of *Atriplex polycarpa* and *A. canescens* in soil culture and Soufi and Wallace [1982] recorded in *A. hymenelytra* in solution culture than their respective leaf iron levels, but there was no correlation between stem iron level and salinity. Teas [1985] noted that stem tissue iron level of *Rhizophora* species was 0.042 µg/g Mohite [1990] noted iron contents from the stem of *D. trifoliata* [0.84 µg/g] and *D. scandens* [0.2 µg/g]. *Caesalpinia crista* stem tissue is relatively richer in iron.

Root tissue iron contents were found to be 0.465 µg/g in *Avicennia nitida* and 0.979 µg/g in *Conocarpus* *erectus*. [Golley, Hollister, cf. Walsh, 1974]. Soufi and Wallace [1982] recorded higher accumulation of iron in root tissue of plants grown in solution culture with various NaCl concentrations than the control. At the same time they recorded decrease in Fe levels with increase in salinity ranging from 2.08 µg/g to 1.365 µg/g. Teas [1985] recorded high iron content [1.0 µg/g] from surface roots of *Rhizophora*. Roots of *Derris trifoliata* and *D.scandens* also showed higher iron contents 0.98 and 0.7 µg/g respectively.[Mohite ,1990]. Our observations regarding *Caesalpinia crista* also indicate accumulation of iron in the root tissue. It has been suggested by Untawale *et al*. [1980] that this is probably related to less efficient ultrafiltration mechanism.

Seasonal variation of iron in the leaves of seven mangrove species was recorded by Untawale *et al*. [1980]. They recorded pre-monsoon peaks in *Bruguiera gymnorhiza*, *B. parviflora* and *Rhizophora mucronata* and monsoon peaks in *Derris trifoliata*, *Acanthus ilicifolius*, *Sonneretia alba* and *Avicennia officinalis*. During winter season Fe levels were low in all plants. They recorded the range of Fe from Nil [*A. ilicifolius*, *D. trifoliata*, *B. parviflora* and *R. mucronata*] to 22.0 µg/g in *B.gymnorhiza*. Subramanian and Venugopalan [1983] also noticed seasonal variation of Fe in *Avicennia marina* and *Rhizophora mucronata* leaves. Leaf tissue of *A. marina* showed peaks during winter and summer season and least Fe during pre-summer [0.45 and 0.175 µg/g] *R.mucronata* leaf tissue showed peak during summer and least level during winter [0.375 and 0.050 µg/g]. In the present investigation we have observed the seasonal variation of leaf tissue iron status in _Caesalpinia crista_ with a significant peak in summer [1.55 µg/g]

The rachis tissue of _C. Crista_ also shows seasonal variation . In monsoon highest iron level [2.85 µg/g]is seen.

Subramanian and Venugopalan [1983] observed that in stem tissue Fe accumulation showed two peaks during winter and monsoon and least amount was observed during pre-winter season [0.26 and 1.05 µg/g] in _A. marina_. In _R. mucronata_ stem, peak of iron level was recorded during summer and least value was recorded during monsoon [0.29 and 0.02 µg/g] In both the plants stem tissue Fe content was less than the leaf tissue iron. In _C. crista_ stem tissue iron contents are relatively low during winter.

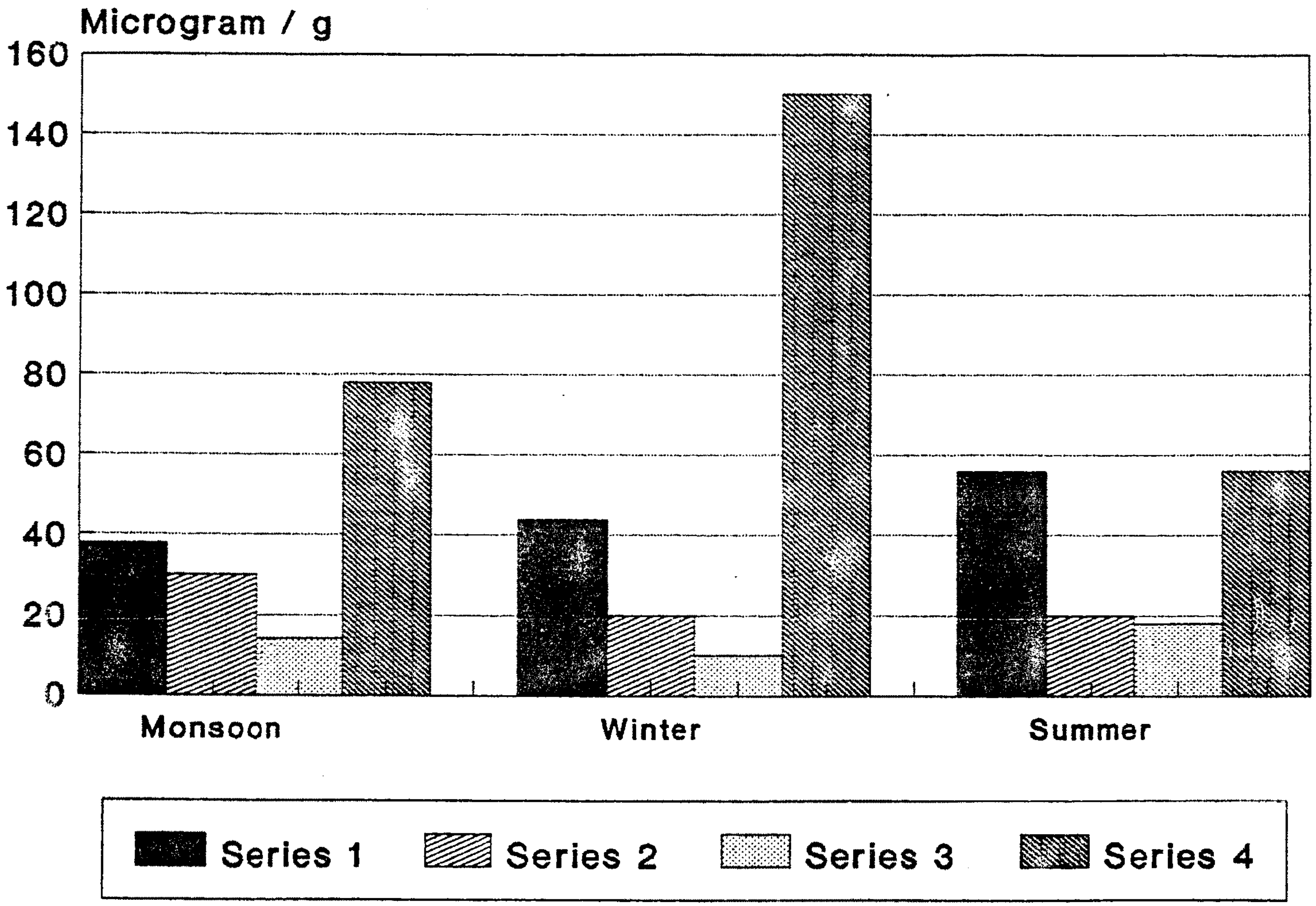
Subramanian and Venugopalan [1983] found high levels of iron in root tissue of _A. marina_ and _R. mucronata_. They further noticed maximum accumulation of iron in root tissue during winter season. In case of _C.crista_ also similar trend is seen. The iron levels in all plant parts are relatively higher. One possible reason for such heavy accumulation of iron may be the fact that the plant grows under water-logged conditions for some period and this leads to greater availability of reduced iron in the medium. The other possible reason might be a greater iron requirement of this halophyte for its growth and metabolism.

i) Manganese

The manganese contents in different parts of *Caesalpinia crista* during different seasons are shown in fig. 16. It is clear from the figure that the manganese levels in the root tissue during all the seasons are relatively higher than the leaf, rachis and stem tissue. The stem tissue shows minimum manganese contents during all the seasons.

Manganese is absorbed mainly as Mn^{2+} and is translocated as free divalent cation in the xylem from the roots to the shoots.[Graham, 1979]. As a micronutrient, manganese plays very important role in plant metabolism. Mn^{2+} is mainly involved in the photosynthetic O_2 evolution, as a component of enzyme which catalyzes the reaction of O_2 evolution in PSII [Edwards and Walker, 1983]. Manganese is essential for the activities of other enzymes like super oxide dismutase, acid phosphatase, decarboxylase and dehydrogenases of TCA cycle. An increase in peroxidase activity is a typical feature of manganese deficient tissue. Manganese deficient leaves exhibit exponentially high IAA oxidase activity [Morgan *et al*. 1976] which might lead to enhanced auxin [IAA] degradation in the tissue. Mn^{2+} can replace Ca^{2+} in its role as a bridge between ATP and enzyme complexes phosphokinase and phosphotransferase. It also plays an important role in the synthesis of proteins, carbohydrates

Figure:16 Manganese contents in different parts of *Caesalpinia crista* L.
during different seasons.
(expressed on dry wt. basis.)



S1: Leaf S2: Rachis S3 : Stem S4: Root

and lipids. Its presence is highly essential during cell division and expansion. According to Cramer and Novak [1992] manganese deficiency reduces photosynthetic electron transport capacity, photosynthesis, net assimilation rate and finally relative growth rate.

According to Epstein [1965] the average level of manganese sufficient for adequate growth of plants is 50 µg/g. There are only few reports regarding the manganese nutrition of halophytes. In *Rhizophora mangle* Morton [1965] noted 30 µg/g Mn^{2+} in the leaf tissue. Golley and Hollister [f. Walsh, 1974] observed that the manganese content in the leaves of halophytes varies from 50 µg/g [*Conocarpus erectus*] to 387 µg/g [*Rhizophora brevistyla*]. Bhosale [1979] reported minimum Mn^{2+} in the leaf tissue of Aegiceras corniculatum 25.8 µg/g] and maximum in *Avicennia officinalis* [158.7 µg/g], among nine coastal halo phytes they have studied. In *Derris heterophylla* a leguminous halophyte, the manganese content in the leaves varied from 14 to 20 µg/g. Spain and Holt [1980] analysed 7 different mangroves for their leaf Mn^{2+} status. They recorded the range from 16.8 µg/g to 318 µg/g in *Osbornia octodonta* and *Rhizophora stylosa* respectively. Joshi and Bhosale [1982] reported that manganese content in the leaves of mangroves varied from 2.5 to 15.8 µg/g. Mn^{2+} levels from seven desert halophytes were investigated by El. Ghonemy *et el*. [1982]. Leaf tissue showed range of Mn^{2+} content from 28 to 187 µg/g in *Zygophyllum album* and *Salsola tetrandra* respectively, exceptionally high

Mn^{2+} level 745 µg/g in *Halocmemon strobilaceum* leaf tissue was recorded. Wallace *et al* [1982] recorded increase in leaf Mn^{2+} level with increase in salinity in *Atriplex polycarpa* grown in soil culture but Soufi and Wallace [1982] recorded decrease in Mn^{2+} level with increase in salinity in *A. hymenelytra* grown in solution culture. In *Rhizophora* species Teas [1985] reported very high manganese level [740 µg/g] Mohite [1990] reported quite opposite trend in manganese levels in two species of *Derris*. *D. trifoliata* leaf tissue contained minimum manganese [3.8µg/g amongst all other parts, while *D. scandens* contained highest manganese [280 µg/g] . Our observations regarding the leaf tissue manganese contents of *Caesalpinia crista* match with the observations made by other workers for leaves of different halophytes. The leaf tissue Mn^{2+} level is much less than the root tissue Mn^{2+} level, but is higher than stem and rachis tissue.

Very little information is available regarding the Mn^{2+} content from rachis tissue. Mohite [1990] recorded that Mn^{2+} levels in *D. trifoliata* and *D. scandens* rachis were 4 and 180 µg/g respectively.

Stem tissue manganese levels have been reported by a few workers only. Spain and Holt [1080] recorded lower Mn^{2+} levels in the stem tissue of different mangroves than in their respective leaf tissue. According to them the values of Mn^{2+} contents in stem tissue ranged from 4.5 to 278 µg/g [*Osborina octodonta* and *Rhizophora stylosa* respectively].

Stem tissue Mn^{2+} levels from desert halophytes were investigated by El-Ghonemy et al. [1982]. They found that the Mn^{2+} contents ranged from 28 µg/g [Juncus rigidis] to 124 µg/g [Salsola tetrandra].Wallace et al. [1982] recorded an increase in Mn^{2+} content with increase in salinity of soil culture medium in Atriplex polycarpa and A. canescens stem tissue. But Soufi and Wallace [1982] recorded decrease in Mn^{2+} content with increase in salinity of A. hymenelytra grown in solution culture. Teas [1985] reported that Mn^{2+} level from Rhizophora species stem tissue was 165 µg/g Derris trifoliata and D. scandens stem tissue Mn^{2+} levels 3.8 µg/g and 27.5 µg/g respectively have been recorded by Mohite [1990]. Our observations with Caesalpinia crista reveal that as compared to leaf tissue the stem tissue is quite low in manganese content.

Root tissue of Atriplex hymenelytra showed decrease in Mn^{2+} content with increase in salinity of solution culture medium. This has been recorded by Soufi and Wallace [1982]. Mn^{2+} level in surface roots of Rhizophora has been analysed by Teas [1985] and was found to be 95 µg/g which was less than the corresponding Mn^{2+} level in aerial plant parts. Mohite [1990] showed comparatively higher absorption and accumulation of Mn^{2+} in root tissue than the aerial parts in Derris trifoliata. Our findings regarding the Mn^{2+} levels in the root tissue also indicate the higher absorption and accumulation of Mn^{2+} than the aerial parts particularly in winter. The reason for heavy accumulation of manganese in root zone are obscure. Thus during seasonal variation there are changes in salinity of medium which can definitely influence the Mn uptake and distribution in plants.

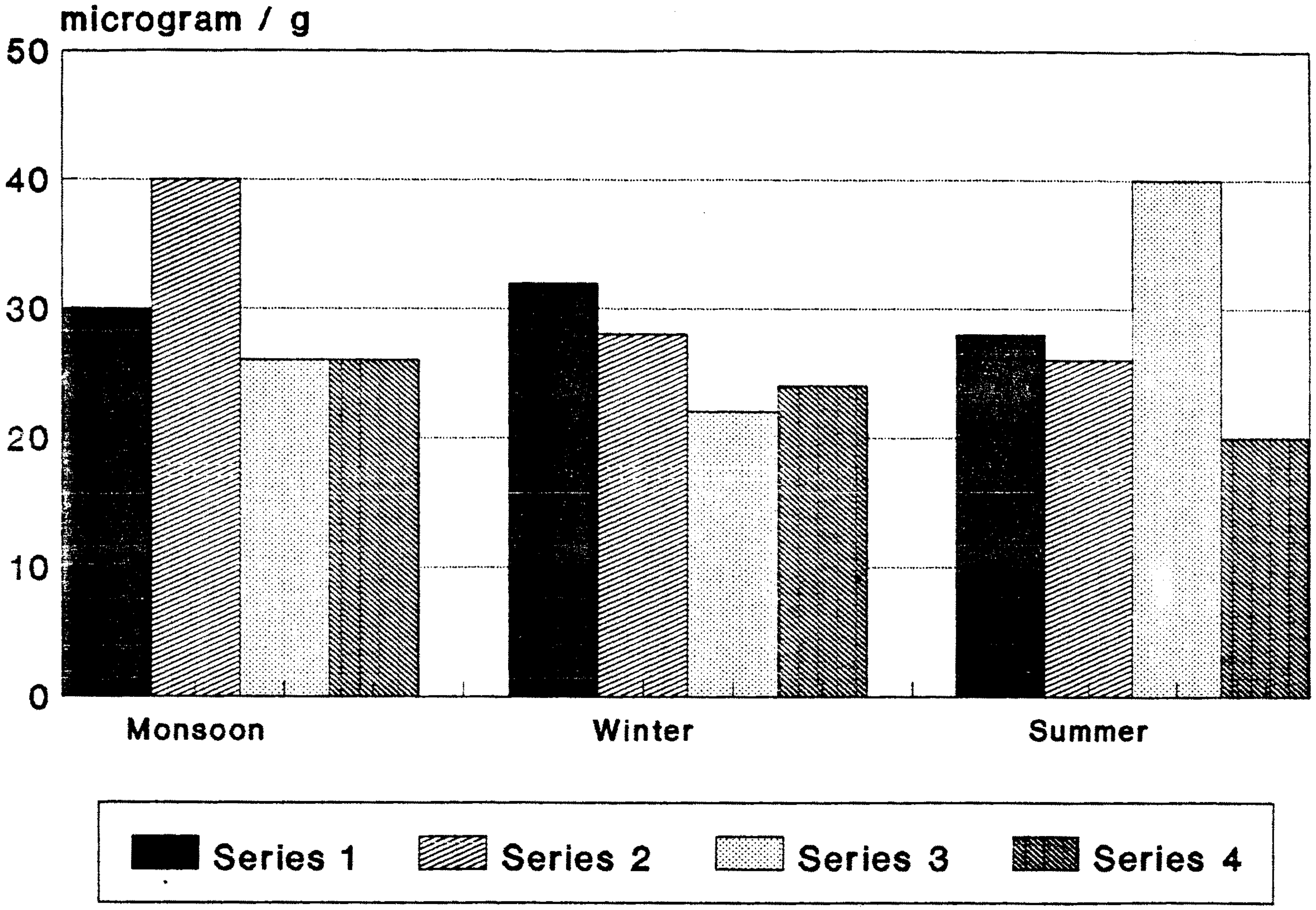
Seasonal variation of Mn contents from different mangrove leaves was recorded by Untawale *et al.* [1980]. In *Derris trifoliata* they recorded highest concentration 4320 µg/g during September and least during February [3637 µg/g]. In *Bruguiera gymnorhiza* maximum Mn level [318 µg/g] in February and minimum [36 µg/g] in July. In *B. parviflora* manganese values ranged from 428 ug/g in December to 3184 ug/g in February. Manganese from *Acanthus ilicifolius* did not show seasonal variation except a peak in October [2657 µg/g]. In *Sonneretia alba* manganese showed the highest concentration 4432 µg/g in February and lowest [80 µg/g] in May. Mn^{2+} from *Avicennia officinalis* showed peak in November [6600 µg/g and sudden decrease to 499 µg/g in April. Mn^{2+} showed very low values during monsoon and peak in winter ranging from 500 to 7000 µg/g in *Rhizophora mucronata*. Thus it clear that there is no definite pattern of seasonal variation in manganese contents of leaf tissue in different mangrove species. Our observations indicate that during summer months leaves have highest manganese content among the three plant parts. On the other hand root tissue accumulates considerably larger amount of manganese during rainy season and winter. Thus even during summer season when the salinity is high, the leaves of *C. crista* do not suffer from a manganese deficient condition.

j) Zinc

Zinc contents in different parts of C.crista and their seasonal variation are shown in fig.17. It is clearly evident from the figure that leaf tissue contains slightly higher amount of zinc than the root tissue. Highest amount of zinc is accumulated in rachis during monsoon and in stem tissue during summer.

Zinc is taken up predominantly as a divalent cation and at high pH as a monovalent cation. High concentration of Ca^{2+} inhibits the uptake of Zn^{2+} to some extent. According to Clarkson and Hanson (1980) zinc is not oxidized or reduced and it's functions are based on its properties as a divalent cation with a strong tendency to form tetrahedral complexes. Zinc acts in different ways as a metal component of enzymes, as a functional, structural or regulatory cofactor of a large number of enzymes. Alcohol dehydrogenase, Cu-Zn superoxide dismutase (SOD), Carbonic anhydrase (CA) and RNA polymerase are the enzymes containing bound zinc. The activity of SOD is much lower under zinc deficient condition which can be restored by addition of zinc to the assay medium (Vaughan et al. 1982). CA is localized in cytoplasm and in chloroplast. The function of chloroplast CA, in photosynthetic CO_2 assimilation, is not yet clear. According to Edwards and Walker (1983), CA has an effect on CO_2 equilibria in green cells.

Figure :17 Zinc contents in different parts of *Caesalpinia crista* L. during different seasons. (expressed on dry wt. basis.)



S1: Leaf S2: Rachis S3: Stem S4: Root

$$CO_2 \overset{CA}{\rightleftharpoons} HCO_3^- + H^+$$

But substrate for RUBP carboxylase is CO_2 and not the HCO_2. Hence there is no direct relationship between CA activity and photosynthetic CO_2 assimilation, but still CO_2 assimilation per unit leaf area is affected by very low CA activity.

Zinc is required for the activity of various types of enzymes, such as dehdrogenases, aldolases, isomerases, transphosphorylases and RNA and DNA polymerases. Hence zinc plays an important role in carbohydrate metabolism protein synthesis and also in sexual fertilization and the development of reproductive parts. Zinc is required for the synthesis of amino acid,tryptophan, a precursor of IAA. Hence zinc deficiency shows stunted growth and little leaf which are related to disturbances in the metabolism of auxins, IAA in particular.

According to Epstein (1965) average zinc concentration required for adequate growth of plant is 20 µg/g. There are few reports about the zinc contents from different parts of halophytes. Morton (1965) reported 43 µg/g Zn^{2+} from the leaf tissue of Rhizophora mangle while Hollister (cf Walsh, 1974) reported 146 µg/g Zn^{2+} from the same species. Golley, Siddhu, Hollister (cf walsh, 1974) reported leaf tissue Zn^{2+} content from different mangroves ranging from 11 µg/g (Rhizophora brevistyla) to 176 µg/g

(*Lumnitzera racemosa*). They also reported the difference in Zn^{2+} content of overstory and understory leaves. Zn^{2+} is more in overstory leaves. According to Bhosale (1979) leaf tissue Zn^{2+} content from 9 different mangrove species ranged from 8.3 to 36.5µg/g in *Aegiceras corniculatum* and *Clerodendron inerme* while she recorded exceptionally high Zn^{2+} content in *Aeluropus lagopoides* leaves (107.1 µg/g) Spain and Holt (1980) analysed Zn^{2+} from 7 different mangrove species and they found that it varied from 5.5 µg/g (*Rhizophora stylosa*) to 47.0 µg/g (*Excoecaria agallocha*). In leaves of two species of Leguminous halophytes *Derris trifoliata* and *D.scandens* Mohite(1990) recorded equal and high Zn^{2+} levels (70 µg/g.) In the present investigation we have recorded moderate Zn^{2+} levels in leaf tissue of *C.crista* ranging between 28 to 32 µg/g during different seasons.

Mohite (1990) has noted the higher accumulation of Zn^{2+} in rachis tissue of *D. scandens*. Similarly, accumulation of Zn^{2+} in rachis tissue of *C. crista* is noticed during monsoon only.

In *Avicennia nitida* and *Conocarpus erectus* Hollister (cf Walsh, 1974) recorded the accumulation of Zn^{2+} in stem tissue (227 and 180 µg/g respectively) while in *Laguncularia recemosa* and *Rhizophora mangle* he recorded intermediate accumulation(89 and 120 µg/g respectively) and least in *R.brevistyla* and *Lumnitizera racemosa* (11 and 25 µg/g). Spain and Holt (1980) recorded very low levels of Zn^{2+}

in stem tissue of seven different mangroves in the range of 1.4µg/g (*Ceriops tagal*) to 18.9 µg/g (*Excoecaria agallocha*). In *Rhizophora* stem tissue also Teas (1985) recorded low Zn^{2+} content (9.0 µg/g).But Mohite (1990) recorded high Zn^{2+} levels in stem tissue of *D.trifoliata* (135 µg/g) and low in *D. scandens* (7.5 µg/g).Our observations regarding *C.crista* do not indicate any definite pattern in this respect because Zn^{2+} levels in stem tissue are seen in monsoon and winter while in summer zinc accumulation in noticed in stem region.

High level of Zn^{2+} in the root tissue have been recorded by Hollister (cf Walsh, 1974) in *Avicennia nitida* (121 µg/g) and in *Conocarpus erectus* (162 µg/g). Teas (1985) also recorded high Zn^{2+} contents from *Rhizophora* surface roots. Mohite (1990) recorded the high Zn^{2+} levels in *Derris trifoliata* and *D.scandens* (135 and 200 ug/g respectively). But our data regarding the *C.crista* root tissue indicate lower levels of zinc which suggest that the plant has the capacity to rapidly translocate zinc from root to aerial parts.

Gaykar (1991) studied the seasonal variation of Zn^{2+} contents from the leaves of six different mangroves. He observed that the young and mature leaves of *Sonneretia alba*, *Rhizophora apiculata*, *R.mucronata*, *Avicennia officinalis* and *Ceriops tagal* showed a peak of zinc content during summer and lowest Zn values during monsoon. Our observations about Zn status in different parts of *C.crista* do not show much variations, although in summer months a slight reduction in zinc contents in leaf, rachis and roots is noticeable.

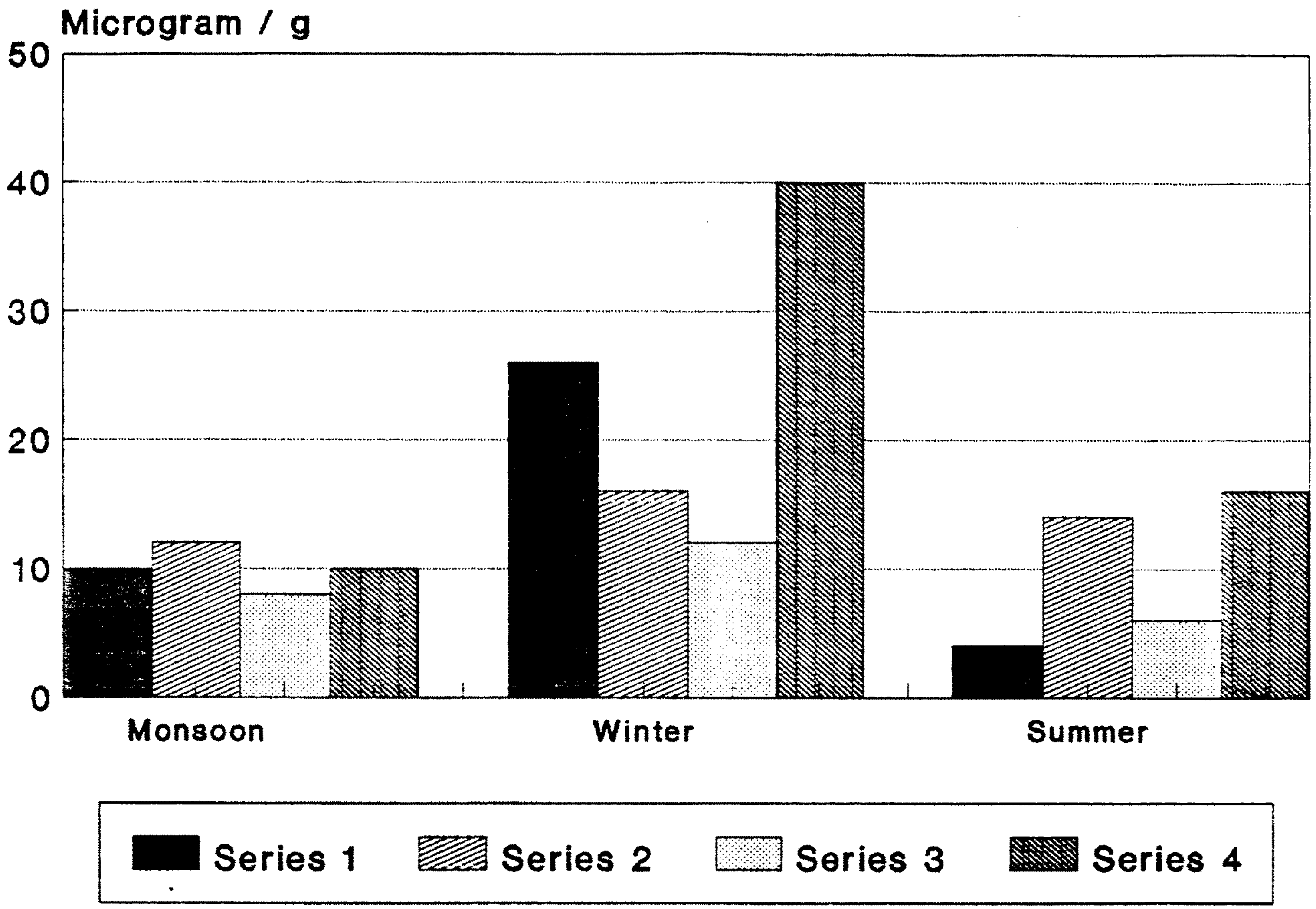
k) Copper

The copper contents in different parts of *C. crista* during different seasons are shown in fig.18. Copper content in roots is relatively higher than aerial parts during winter and summer season while in monsoon all the plant parts contain nearly equal amount of Cu^{2+}.

Copper is an unstable divalent micronutrient and mainly takes part in enzymatic redox reactions. It is present as a main component of the enzymes; cytochrome oxidase, super oxide dismutase, ascorbate oxidase, phenolase, laccase, amine oxidase etc. More than 50 % of Cu^{2+} localized in chloroplast is bound with plastocyanin which is the component of PSI Cu is also required for the synthesis of quinones. Cu plays important role in carbohydrate and nitrogen metabolism. Legumes receiving a low copper supply are depressed in nodulation and N_2 fixation (Hallsworth *et al* 1964). Copper plays a major role in pollen formation and fertilization, hence Cu deficiency affects the grain, seed and fruit formation, much more than the vegetative growth (Rahimi, 1970). The copper content in most plants is between 2 to 20 ppm in dry tissue as given by Tiffin (1972)

There are a few reports about the Cu^{2+} contents in different parts of halophytes. Bhosale(1979) has analysed

Figure : 18 Copper contents in different parts of *Caesalpinia crista* L. during different seasons. (expressed on dry wt. basis.)



S1: Leaf S2: Rachis S3: Stem S4: Root

Cu^{2+} contents from the leaf tissue of nine different mangroves and mangrove associates with minimum Cu^{2+} content in Rhizophora mucronata and Lumnitzera racemosa (4.1 µg/g) and maximum in Clerodendron inerme (10.8 µg/g). Slightly higher range of Cu^{2+} 5.8 to 20.1 µg/g in Aegiceras corniculatum and Avicennia marina has been reported from seven different mangrove species by Spain and Holt (1980). Cu content from leaf tissue of different desert halophytes were investigated by El-Ghonemy et al. (1982) They recorded the range from 9µg/g (Salsola tetrandra) to 55 µg/g (Juncus rigidus). Teas (1985) recorded 5.9 µg/g Cu^{2+} in the leaf tissue of Rhizophora. Values of Cu^{2+} content in the leaf tissue reported by Mohite (1990) from two species of a leguminous halophyte Derris showed very much difference. D.trifoliata 1.8 µg/g and D.scandens 34.5 µg/g. Our results of Cu^{2+} contents from the leaf tissue range within the observations from other halophytes.

Substantial amount of Cu^{2+} in the rachis tissue in D. trifoliata (1.4 µg/g) and D. scandens (26.5 µg/g) has been noted by Mohite (1990). The values of rachis tissue Cu^{2+} content in the present study are also prominent.

Golley and Hollister (cf Walsh 1974) reported comparatively low values of Cu^{2+} from stem tissue of different halophytes ranging from 7 to 15 µg/g in Rhizophora brevistyla and Conocarpus erectus respectively. Spain and Holt (1980) also reported low stem tissue Cu^{2+} contents with respect to their respective leaf tissue Cu^{2+} content, from seven different mangroves ranging from 3.5ug/g in Ceriops tagal and Osbornia octodonta and 9.4 µg/g in Avicennia marina. El-Ghonemy et al. (1982) recorded slightly higher values of Cu^{2+} in the stem tissue ranging from 17 to 160µg/g in Nitraria retusa and Salsola tetrandra respectively. According to Teas (1985) the Rhizophora stem tissue contains lower Cu^{2+} than their leaf tissue. Derris scandens showed similar trend but in D. trifoliata stem tissue showed same or slightly higher Cu^{2+} levels (Mohite 1990) Similar trend has been observed by us in C. crista stem tissue except in summer.

In tomato plants receiving a large supply of Cu^{2+} from the medium, the copper content of roots rises proportionally to the concentration of Cu^{2+} in the external medium, where as transport to shoot remains restricted (Rahimi and Bussler 1974). Teas (1985) also reported higher Cu^{2+} content in the surface roots of Rhizophora 47.0 µg/g. Mohite (1990) also reported high Cu^{2+} level in roots of D. trifoliata but not in D. scandens. Our observations about C. crista shows this trend especially in winterseason.

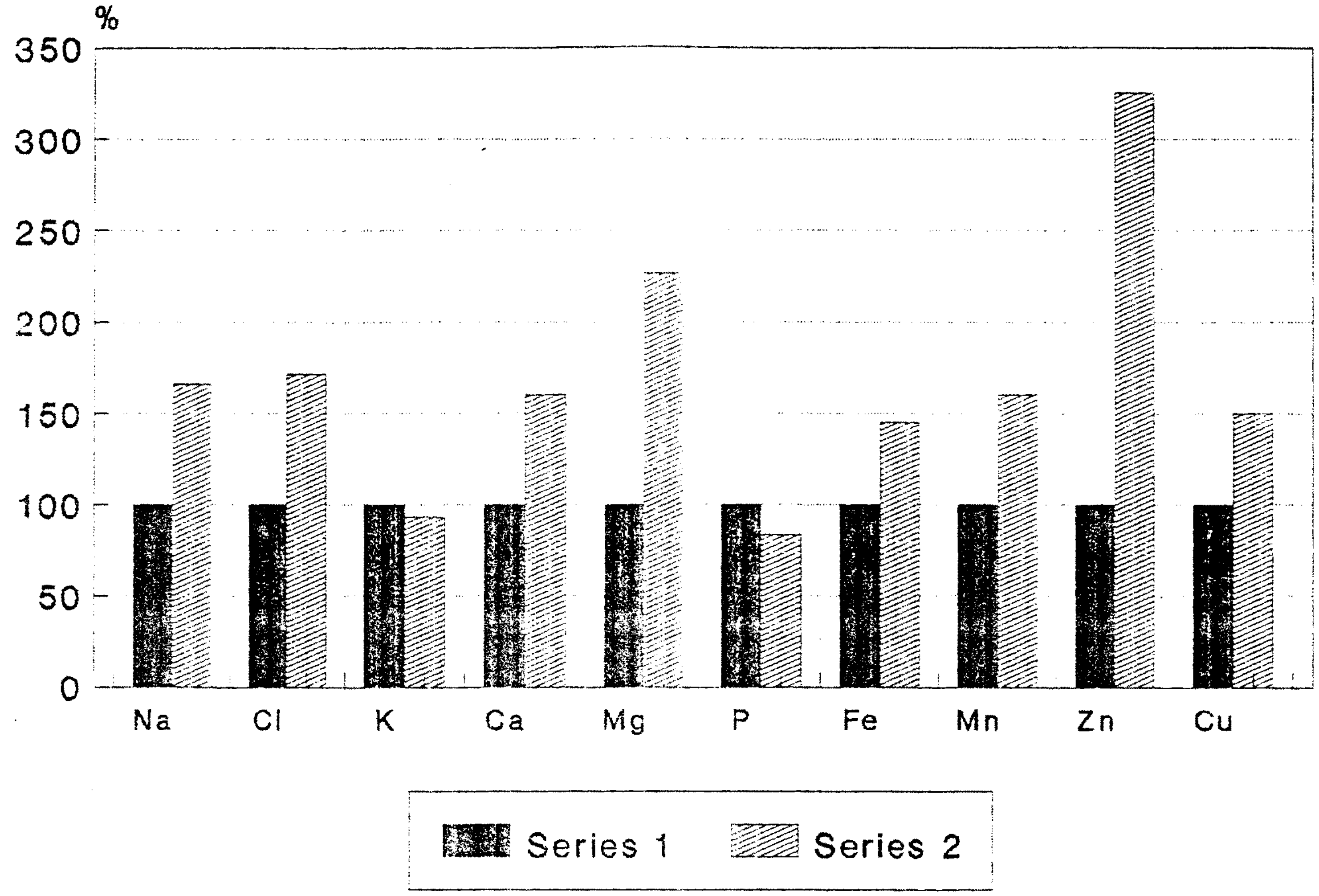
Seasonal variation of Cu^{2+} in the leaves of different mangroves has been recorded by Untawale et al. (1980). In Derris trifoliata Cu^{2+} content was maximum during February (84.65 µg/g) and minimum (18.40µg/g) during March. Seasonal fluctuation of Cu^{2+} in Bruguiera gymnorhiza was negligible while in *B. parviflora* maximum Cu^{2+} content was recorded in April (85 ug/g) and minimum in November (10ug/g). Cu^{2+} level in *Acanthus ilicifolius* leaves ranged from 27.82 ug/g in October to 77.04 ug/g in August. Typically cyclic pattern of Cu^{2+} accumulation was noted in *Sonneretia alba* with lowest value of 11.98 µg/g in May. Maximum Cu^{2+} concentration in *Avicennia officinalis* observed during monsoon was 119.41 ug/g and minimum was 36.81 µg/g in April. *Rhizophora mucronata* differed from all other species in not having a monsoon peak of copper but instead shifted to post monsoon.

In *Caesalpinia crista* amount of Cu^{2+} in different parts of plant differs seasonally. In monsoon the amount of Cu^{2+} is nearly same in all the plant parts. In winter there is high accumulation in roots with comparatively less accumulation in stem and rachis. But in summer there is comparatively low uptake of copper and as a result low level of copper, nearly equal amounts are found in different plant parts.

B) Effect of leaf age on ionic contents in *Caesalpinia crista* leaves.

Changes in inorganic constituents (% over green leaves) during senescence of *Caesalpinia crista* leaves (fig.19) are shown in fig.20. Due to senescence there is accumulation of sodium, chloride, calcium, magnesium, iron, manganese, zinc and copper. The increase in zinc content %

Figure: 20 Changes in inorganic constituents % over green leaves during senescence of *Caesalpinia crista* L. leaves.



S1:Green S2:Senescent

over green leaves in highest (325%) followed by magnesium (226%) while that of other elements ranged between 145% (iron) and 171% (chloride). The decrease in potassium and phosphorus content during aging of leaves is considerable.

It has been argued by Albert (1975) that shedding of salt saturated old leaves is one of the mechanisms of salt tolerance in some halophytic species. Karmarkar (1982) noted that several changes during senescence which are useful as an effective mean for regulation of salt in the plant tissue. There are some reports about the redistribution of mineral elements during senescence from halophytic plants. Joshi and Mishra (1970) have reported that there is accumulation of sodium, chloride and calcium content and withdrawal of Potassium in Clerodendrum inerme leaves due to senescence. Similarly leaves of mangrove species Sonneretia acida, Excoecaria agallocha and Lumnitzera racemosa accumulate sodium and calcium and loose potassium and phosphorus during aging (Jamale and Joshi, 1976). Increase in sodium, chloride and calcium content with decrease in potassium, magnesium and phosphorus in leaves during senescence has been reported by Amonkar (1977) in Salvadora persica and by Lokhande (1983) in Pentatropis cynanchoides. Kotmire and Bhosale (1985) in Thespesia populnea are noted the increase in sodium, chloride, calcium and magnesium content during senescence with decrease in potassium and phosphorus content. Smith et al. (1989) also recorded the increase in chloride, calcium and mangnesium content due to senescence of Conocarpus *erectus* leaves.

It has been observed by some workers that in the senescent leaves there is alteration in the micronutrient status also. Waughman and Bellamy (1981) reported changes in micronutrients such as Zn, B, Mo, Cu, etc. during senescence.

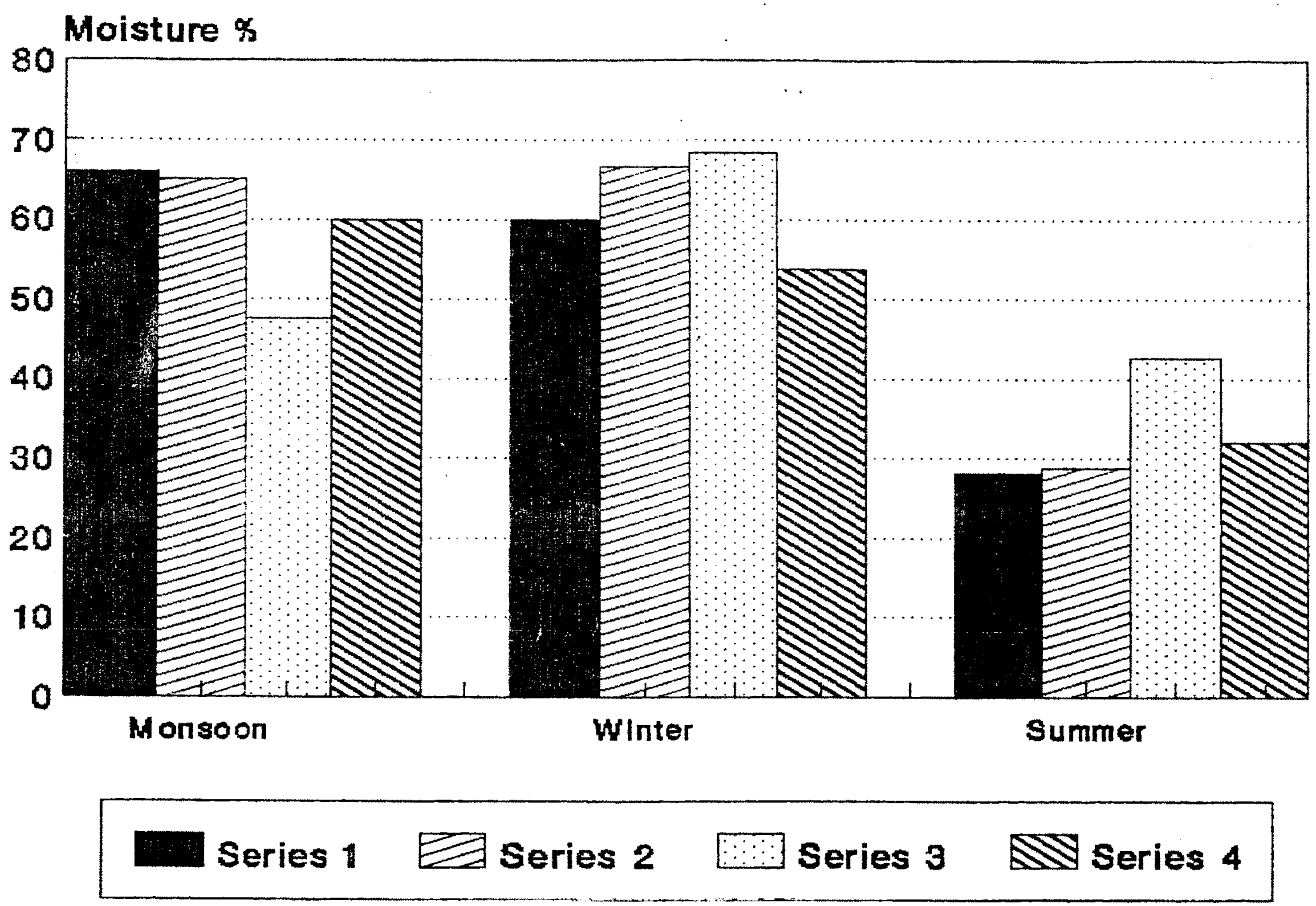
Our observations also indicate that there is an appreciable increase in both sodium and chloride in senescent leaves. Hence the strategy indicated by Albert (1975) and Karmarkar (1982) does operate to some degree in *C.crista*. At the same time it must be mentioned here that the proportion of senescent leaves in this plant during different seasons was found to be very low. Marked overall senescence was never noticed throughout the year. Hence even though there is accumulation of salt to some extent in senescent leaves, the plant being salt evader does not follow the strategy of overall shedding of salt saturated leaves.

4) Organic Constituents.

A) Moisture percentage

The moisture percentage in different parts of *Caesalpinia crista* during different seasons is shown in fig.2 1. It is evident from the figure that during summer moisture percentage in all the plant parts is low. During monsoon leaf and root tissue contain peak of moisture % and stem and rachis show a peak during winter.

Figure : 21 Moisture % in different parts of *Caesalpinia crista* L. during different seasons. (expressed on dry wt. basis.)



S1: Leaf S2: Rachis S3: Stem S4: Root

The water status of most of the plants is governed by the extent of water availability and the rate of water loss during transpiration. According to Albert (1975) increase in the water content to dilute the salt accumulated in the cell sap to minimise their toxic effect is one of the adaptive features of some halophytes such as *Suaeda*, *Sesuvium*.

The shoot of vascular halophytes is reported to increase succulence and salt content as a response of saline environment (Flower *et al.*, 1977). But in *C. crista* the values of moisture percentage during different seasons indicate that there is no such succulence development. On the other hand with the increase in the salinity of medium, the amount of water absorbed and stored in the plant tissue decreased during summer. This may be due to increase in water absorbed and stored in the plant tissue decreased during summer. This may be due to increase in waterloss from plant surface as a result of high temperature and greater light intensity during summer.

B) Chlorophylls.

The analysis of chlorophylls in the leaves of *Caesalpinia crista* revealed that it contains high amount of chlorophylls. The level of chlorophyll a(110.89 mg/100g) was found to be more than of chlorophyll b(48.142 mg/100g) and chlorophyll a/b ratio was 2.303

In higher plants chlorophylls are important because they play a key role in the process of photosythesis on which the survival of plants depends. Since chlorophylls takes part in the conversion of solar energy into chemical energy, their level in the leaf tissue is one of the important feature governing photosynthetic efficiency of plants. Chlorophyll content in the leaves is dependent on endogeneous factors like rate of pigment synthesis, rate of pigment degradation, stage of leaf development etc. and some environmental factors like shade, light, temperature, drought, waterlogging, soil salinity etc. Waisel (1972) reported that leaves of Salicornia plants turn light green when plants are grown in high salt concentrations due to decrease in chlorophyll content. Bhosale (1974) and Bhosale et al. (1983) stated that chloride salinity reduces total chlorophylls. It is further shown that NaCl salinity affects the chlorophyll b to greater extent. There are few reports which indicate that salt stress promotes the activity of enzyme chlorophyllase. Svistev et al (1973) noticed that in the salt sensitive plant chlorophyll degradation is more rapid because of the fact that degradative enzyme chlorophyllase is found to be stimulated by salt. Such a stimulation of chlorophyllase under saline conditions has been confirmed by Sudyina and Fomishyna (1974) and Gururaja Rao and Rajeswara Rao (1981). Joshi and Bhosale (1982) reported seasonal variation in chlorophylls from different mangroves. The chlorophyll contents were higher during the winter and lower during summer and monsoon. In summer there is bright light and high temperature while in monsoon the light is poor and temperature is high. In summer salinity of sea water is high. These factors may inhibit chlorophyll synthesis while moderate light and temperature might promote chlorophyll synthesis.

The chlorophyll contents in the members of coastal ecosystem have been analysed by some workers. Jamale (1975) observed that chlorophyll contents in mangrove leaves varied from 23.26 mg/100g (*Sonneretia apetala*) to 190.26 mg/100g (*Excoecaria agallocha*). Kathireson and Kannan (1985) observed variation in chlorophyll contents among the three *Rhizophora* species with value ranging from 47 mg/100g to 95mg/100g fresh weight of *R. mucronata* and *R. lamarckii* respectively. Mohite (1990) found that chlorophyll contents in two species of *Derris* growing in same habitat differed. (*D. trifoliata* 23mg/100g, *D. scandens* 22.2mg/100g). It is shown by Mishra (1967) that in *Clerodendrum inerme* chlorophyll content was reduced to half under saline conditions as compared with the garden plants. Similar observations were recorded by Kotmire (1983) in *Thespesia populnea* under saline and non- saline conditions.

The high values of chlorophylls in *C. crista* recorded in the present investigation may be due to the low chloride salinity in the leaves of *C. crista* in contrast to other halophytes. The high levels of chlorophylls may lead to higher photosynthetic efficiency in this halophyte.

C) Organic Acids

Titratable Acid Number (TAN) of leaves of C.crista is 159.57 which is high as compared with the TAN value of other plants.

Absorption of cations by plants is balanced by simultaneous absorption of inorganic anions and partly by endogeneous synthesis of organic anions. During growth process when nitrate and sulfate are assimilated or when cations are absorbed in excess of anions, organic acids balance the cations. Organic acids are produced as intermediates of a central metabolic pathway, TCA cycle. According to Strogonov et al. (1970) organic acids are helpful in binding of excess of ions in the plant cell regulating the ionic balance of plants, maintaining the electrical neutrality of the cell and finally neutralizing basic compounds. An organic acid balance of excess cations, principally of oxalate, was found in many halophytic species (Waisel, 1972). Besides conventional TCA cycle intermediates, sometimes the organic acids like malonate, oxalate, glycolate and tartarate accumulated to a high degree in some plant species. Albert and Popp (1977) analysed some halophytes for their chemical composition. They recorded malate and citrate in case of chenopodiaceae members and oxalate in caryophyllaceae members. These organic acids are of quantitative importance, among the organic anions. The total organic acid content varies substantially among plants, most conspicuously in oxalate plants, 7.3% to 65.0 % of total anions in *Suaeda pannonica* and *Comphorosma annua* respectively. Malonate, fumarate, succinate and tartarate are detected to be ubiquitously distributed among plant species, in small concentration.

TAN values give a general idea about the organic acid level in the plant tissue. The titratable acidity status of leaves of various mangrove species has been determined in our laboratory. Joshi *et al*. (1962) found that salinity inhibits organic acid metabolism. Joshi and Mishra (1970) observed that the TAN of *Clerodendrum inerme* leaves was 48.21. Jamale (1975) found that TAN values of *Sonneretia acida* and *Lumnitzera racemosa* were 88.12 and 69.52 respectively. Kotmire and Bhosale (1978) recorded TAN values of *Thespesia populnea* from saline and nonsaline habitat where they noted low TAN in plants from saline area having more salt in their metabolic environment in contrast with the plants growing in non saline area having low salt in their metabolic environment and high TAN value. Higher TAN value in *Avicennia officinalis* as compared with *A. marina* was recorded by Kotmire (1983) where *A. marina* was shown to have more salt in their metabolic environment. Similarly Karkar and Bhosale (1985) based on the results of inorganic constituents of mature leaves of *Rhizophora apiculata* and *Kandelia candel* noted that lower TAN value of *K.candel* is due to more salt content in the metabolic environment in contrast with *R.apiculata*.

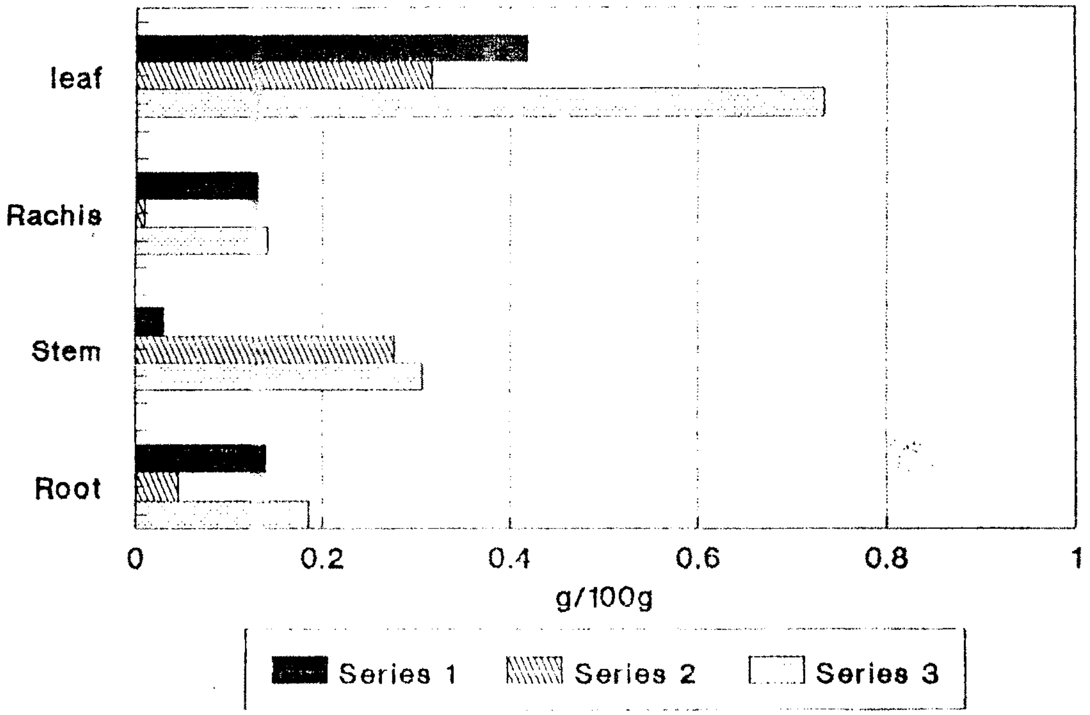
In case of C.crista it is seen that the organic acid level (as indicated by TAN values) in the leaf tissue is quite high as compared to the leaves of other mangrove species. As we have already seen, leaf tissue is relatively low in sodium. Hence heavy accumulation of organic acids in C.crista leaves is not a consequence of salt accumulation but probably the organic acids are playing an osmoregulatory role.

D) Carbohydrates

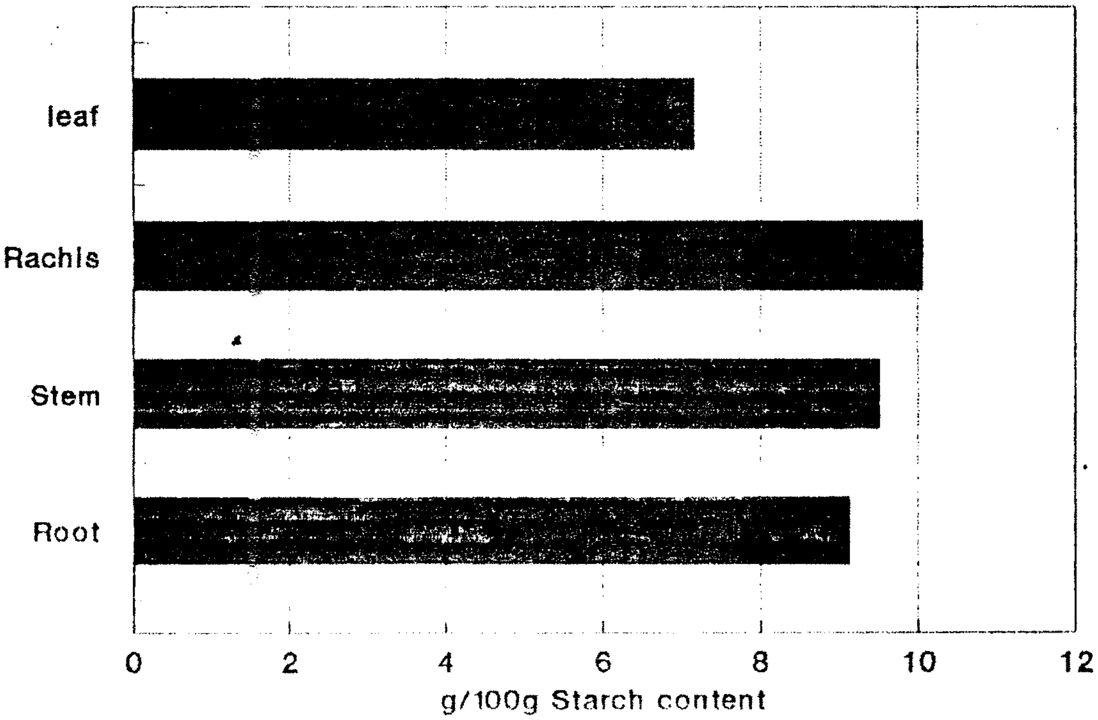
The level of various carbohydrate fractions (reducing sugars, nonreducing sugars, and starch) in different parts of Caesalpinia crista are recorded in fig.22 It is well evident from the figure that the amount of reducing sugars in leaf, rachis and root tissue is more than the non-reducing sugars, but in stem tissue the amount of reducing sugars is very low as compared to the non-educing sugars. Starch content in all the plant parts is quite high ranging from 7.163% (in leaf tissue) to 10.055% (in rachis tissue.)

Carbohydrates are of vital importance as they are the ultimate product of photosynthesis and the precursors for respiration. When stored they act as the main source of energy for growth and development of plants. Soluble carbohydrates play important role in osmotic adjustment of plant growing under saline conditions (Flowers, 1977). Albert and Popp (1977) demonstrated a higher content of soluble

Figure: 2.2
Carbohydrate fractions in different parts of *Caesalpinia crista* L.
(expressed in g/100g on dry weight basis)



Series 1 : reducing sugars
Series 2 : nonreducing sugars
Series 3 : Total sugars.



carbohydrates in the monocotyledons than in the dicotyledonous halophytes. Briens and Larher (1982) showed the accumulation of specifically sucrose, fructose and glucose in higher levels in some plants like *Plantago maritima*, (a sorbitol accumulator), and *Juncus maritimus*, *Phragmites communis* and *Scirpus maritimus*. These sugars equalize the relative water potentials of cytoplasm and vacuole and lower the internal potential. In glycophytes also amongst various sugars present in plants, glucose and sucrose have been considered osmotically active under stress conditions. Popp (1984) analysed 22 mangroves for low molecular weight carbohydrates (LMWC) and he noted that those mangroves which adapt osmotically by accumulation of LMWC, accumulate primarily sucrose, glucose and fructose. There was only one mangrove *Xylocarpus granatum* which derived its LMWC concentration by storing these three sugars and all other mangroves which extensively accumulated sugars were comparatively low in total LMWC concentration. Polyol and cyclitol occurred in limited mangroves. Popp *et al* (1985) noted that in most of the mangrove species, mannitol or pinitol are the dominating compounds in the LMWC fractions. Gorham *et al*. (1980) extensively studied the chemical composition of some salt marsh plants and found that halophytes contain high level of glucose and fructose more than the glycophytes. They are of the opinion that it is possible that the hexoses, rather than sucrose, may be involved in osmoregulation in the most halophytic species.

Our findings with *C.crista* also indicate a similar trend since reducing sugars (probably glucose and fructose) dominate over nonreducing sugars (probably sucrose).

There are some reports about the analysis of reducing sugars, total sugars and starch content mainly from leaves of different mangroves. Shetty (1971) reported more starch in *Acrosticum aurem* growing in saline area than in the plants growing in non saline area. Starch content from different mangrove leaf tissue has been recorded by Jamale (1975). He noted the starch content ranging from 1.88% (*S.acida*) to 2.76% (*E. agallocha*). In the leaves of *Avicennia officinalis* and *A.marina* Kotmire (1983) observed 3.16% and 5.04% starch respectively. From leguminous halophytes *Derris scandens* a *D.trifoliata* Mohite (1990) recorded the starch contents 7% and 8% respectively. Our observations about *C.crista* leaf tissue show considerable accumulation of starch as compared with the starch contents from leaf tissue of other halophytes.

High starch content in the root tissue than in the leaf tissue in *D.trifoliata* and *D.scandens* has been recorded by Mohite (1990). But stem tissue shows quite different patterns of starch accumulation when compared with leaf tissue. Stem tissue of *D.trifoliata* contain slightly lower and *D. scandens* contain higher starch than the leaf tissue. Our observations about *C.crista* shows high starch content in rachis, stem and root tissue than the leaf tissue. Thus it is very clear that the perennial climbing habit of the plant leads to accumulation of starch in plant organs other than leaf. Since leaf is metabolically a more active center, more rapid turn over of starch might be occurring in this organ in contrast to other plant parts.

Total sugars from leaves of different mangroves has been recorded by Jamale (1975) and noted the range from 0.54% (Sonneretia acida) to 0.78% (Excoecaria agallocha). In the leaves of Avicennia officinalis and A. marina Kotmire (1983) observed 1.13% and 0.59% total sugars respectively. Sugars from three different species of Rhizophora were analysed by Kathireson and Kannan (1985). The amount of total sugars ranged from 0.85% (R.apiculata) to 0.338% dry weight (R.mucronata) since sugars are the major photosynthetic products, the amount of total sugars can be correlated with the photosynthetic productivity of the leaf tissue.

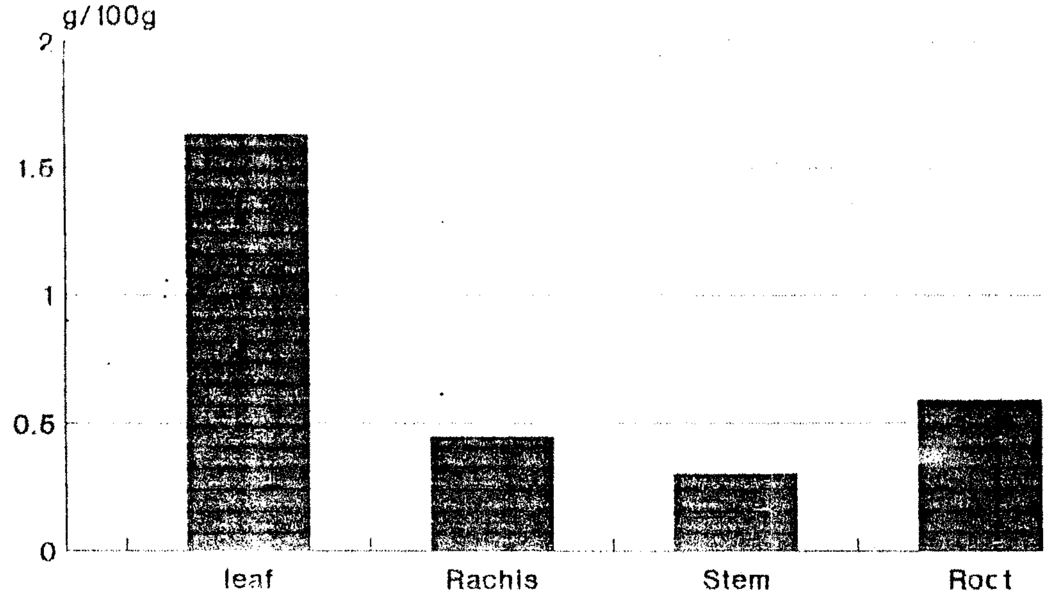
Briens and Larher (1982) recorded total soluble carbohydrates from different halophytic plants. They recorded some plants like Salicornia europaea, Suaeda macrocarpa, Atriplex hastata, Beta maritima, Halimione portulacoides etc. having high amount of total soluble carbohydrates in the stem and root tissue than the leaf tissue. But the plants like Festuca rubra, Phragmites communis and Puccinellia maritima were having low amount of total soluble carbohydrates in the stem and root tissue than the leaf tissue. Mohite (1990) recorded relatively lower total sugar content in stem and root tissue of *D.scandens* than the leaf tissue. Our observations about the *C.crista* shows lower total sugar content from rachis, stem and root tissue than the leaf tissue and this situation is similar to one noticed in *Festuca rubra*, *Phragmites communis*, *Puccinellia maritima* and *Derris scandens*.

E) Total Nitrogen

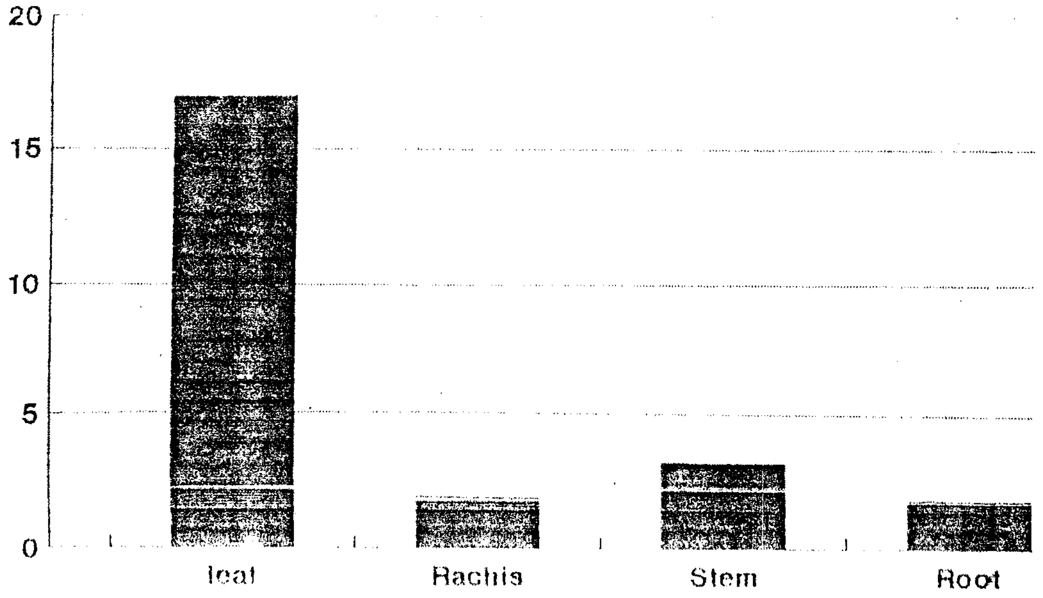
The total nitrogen content from different parts of *Caesalpinia crista* are shown in fig. 23. The leaves of *C.crista* contain highest nitrogen followed by roots, rachis and stem.

Nitrogen is a gaseous element which cannot be directly utilized by the plants but it gets fixed by number of bacteria forming nitrate and ammonium ions. These ions are the major sources of inorganic nitrogen taken up by the roots of higher plants. Most of the ammonium gets incorporated into organic compounds in the roots where as nitrate is motile in the xylem and can also be stored in the vacuoles of roots, shoots and other storage organs. Leguminous plants contain nodules on their roots in which symbiotic nitrogen fixing bacteria rhizobium are present. Hence in general such plants are rich in nitrogen contents. But *C.crista* plant do not have root nodules, so one can not expect any special accumulation of nitrogen in plant parts of this species.

Figure: 23
Total nitrogen and free proline content in different parts of *Caesalpinia crista* L.
(expressed on dry weight basis)



Total Nitrogen



Free Proline

equi/m^3 plant water

Nitrogen plays very important role as a structural and chemical component in the plant. Nitrogen is an essential building block of protein which is the basis of chemical reactions in the plant metabolism. Hence without nitrogen all the life processes are impossible. Proteins are also necessary as the structural and functional component of plasmamembrane. Nitrogen occurs in different forms in the plant cell such as nitrate, nitrite,amino acids, nucleic acids, pigments, alkaloids, quaternary ammonium compounds etc. Under different environmental stresses some nitrogenous compounds like free proline and other amino acids, quaternary ammonium compounds like glycine betaine etc. play the protective role.

Depending on the plant species, developmental stage and organ, the nitrogen content required for optimal growth varies between 2 to 5 % of the plant dry weight. Joshi and Bhosale (1982) recorded seasonal variation of nitrogen in mangroves and recorded low N contents in summer when light intensity, temperature and salinity are high in contrast to high nitrogen content in monsoon. It appears that salinity and temperature control nitrogen metabolism in the estuarire plants.

There are several reports about the nitrogen analysis from leaves of the halophytic plants. Spain and Holt (1980) reported the total nitrogen content from different mangrove leaves varied from 0.78 % (Rhizophora stylosa) to

1.85% (*Xylocarpus australasicus*). Leaves of 7 desert halophytes were analysed by El-Ghonemy *et al.* (1982) and their data shows the range of N% from 0.60 (*Zygophyllum album* and *Halocmemon strobilaceum*) to 1.36 (*Salsola tetragona*). Total nitrogen content of the leaves of some mangrove ranged from 0.96% (*Sesuvium portulacastrum*) to 3.00% (*Avicennia marina*) (Bhosale, 1985).

Popp *et al.*(1984) carried out exhaustive work on nitrogenous compounds of 22 mangrove species from Australia. They observed the total nitrogen content varied from 0.62% (*Excoecaria agallocha*) to 2.53% (*Avicennia marina*) and (*Hibiscus tiliaceus*). They also noted that in general young leaves contain more N than the old leaves with few exceptions of *Aegialitis annulata, Lumnitzera littorea, L. racemosa, Scyphiphora hydrophylacea*, and *Heritiera littoralis.* In the leaves of two species of a nitrogen fixing leguminous halophyte *Derris scandens* and *D.trifoliata* Mohite (1990) recorded the range of N% from 1.5 to 2.55% and he further noted that young leaves contain more N% than mature leaves. Our observation about *C.crista* leaves indicates that leaf tissue has moderate nitrogen content (1.63%) as compared to other halophytic species.

There are few records about the total nitrogen analysis from the other plant parts. Spain and Holt (1980) recorded relatively low values of N content from the stem tissue ranging from 0.12 % to 0.41 % in *Rhizophora stylosa* and *Excoecaria agallocha* respectively, than the leaf tissue. Similarly from desert halophytes El-Ghonemy *et al.* (1982) recorded low levels of N with only exception of *Halocmemon strobilaceum* where they recorded slightly higher N% in stem than leaves. The range was 0.5% (*Zygophyllum album*) to 0.97% (*Salsola tetrandra*). Relatively low N content in the stem tissue than the leaf tissue has also been recorded by Mohite (1990) in *Derris trifoliata* and *D. scandens*. In the present investigation also very low levels of stem tissue N in comparison to the leaf tissue are clearly noticeable. This is certainly because of the key role of leaf in the overall plant metabolism in contrast to stem tissue.

Zahran and Wahid (1982) observed that root tissue of *Kochia indica* had low nitrogen as compared to the shoot tissue. But Mohite (1990) observed nearly equal amount of N in *Derris trifoliata* and higher amount in *D. scandens* with respect to aerial parts. It may be possibly due to the presence of root nodules on *Derris* species. In contrast N% in root tissue of *C. crista* is only 1/3 rd of the N% of the leaf tissue. Since the plant does not have any nitrogen fixing capacity due to lack of nodules on its root system the relatively lower level of nitrogen in the root tissue is quite understandable.

F) Free Proline

The free proline contents of the different parts of *C.crista* are shown in fig. 23 . It is very clear from the figure that highest accumulation of proline is in leaves. Stem, rachis and roots show comparatively low proline accumulation.

Many biochemical reactions in plants get altered under saline environment, as a result of which many intermediate products such as amino acids, polyols, betaines etc. are formed. Free amino acids include mainly free proline, aspartic acid, glutamic acid, alanine, glycine, serine etc. According to Strogonov (1973) survival of plants in saline environments depend upon the altered biochemical reactions and on the quantitative ratio between toxic and protective compounds. According to him proline is one of the protective substances. He noted proline accumulation between 20% to 83% of the total amino acids from different halophytes.

Effect of seawater salinity on free amino acids in Suaeda nudiflora has been studied by Joshi and Iyengar (1987) and pointed out that there is increase in proline content with increase in salinity. Voetbery and Steward (1984) noted that in nonhalophytic excised barely leaves there is direct relation between the amount of proline accumulation and the amount of sodium taken up by the plant.

Heavy accumulation of free proline takes place not only due to salinity but also because of the other environmental stresses such as drought, high temperature, low temperature, mineral deficiencies, pathogenesis etc. Proline plays several important roles under salt stress conditions. Proline has been proposed as a cytoplasmic osmoticum in a number of halophytes by Steward and Lee (1974). It also acts as a protector of the cellular enzymes and membrane proteins against dehydration and conformational changes and thus maintaining their activity (Paleg *et al.* 1981). Proline also serves as a source of carbon and nitrogen for biosynthesis of variety of compounds during a post stress recovery.

There are several reports about proline accumulation in halophytes. Treichel (1975) found proline accumulation due to salinity stress in *Salicornia fruticosa*, *Aster tripolium* and *Mesembryanthemum nodiflorum*. High proline levels were noted by Gorham *et al*. (1981) only in four species *Puccinellia maritima* (56.0 equi.m^{-3} plant water), *Spergularia media* (32.9) *Zostera marina* (21.2) and *Triglochin maritima* (17.5) out of 27 species they have studied. They further noted that the accumulation of proline may be characteristic of certain genera, if not of whole families. Popp and Albert (1980) analysed 19 species of halophytes mainly Chenopodiaceae and Poaceae members for their free amino acids. All the plants except *Phragmites* contained proline, but high amount of proline which can serve as cytoplasmic osmoticum was detected only from *Lepidium Crassifolium* (37.47 equi.m^{-3}), *Artemisia monogyna* (21.06) and *Triglochin maritimum* (12.00) Osmoregulation in 16 higher halophytic plants was studied by Briens and Larher (1982). They observed high leaf proline levels in *Triglochin maritima*

(116 equi.m^{-3} plant water), Puccinellia maritima (88.5), Agropyron pungens (36.5) and Limonium vulgarae (46.0), Phragmites communis (15.0) and Juncus maritimum (14.5). Popp (1984) analysed the chemical composition of number of Australian mangroves. They noted high concentration of proline in two Xylocarpus species X.granatum (75.95 equi.m^{-3} plant water) and X. mekongensis (56.74) and Aegialitis annulata (28.49). High levels of proline in Spergularia media, Frankenia panciflora, Samolus rapens, Excocarpus aphylla, Nitraria billardierei and Puccinellia stricta growing in saline habitat were noted by Poljakoff - Maber et al. (1987). Although storage of proline is very abundant in many halophytes, it is less frequent in mangroves (Popp et al, 1985). According to them only 2 species of Xylocarpus out of 23 mangrove species studied stored proline in a concentration high enough for functioning as a compatible solute in cytoplasm.

The free proline content in Caesalpinia crista leaves is 16.88 equi.m^{-3} plant water which indicates that there is substantial amount of proline in the leaf tissues of this species as Xylocarpus species as noticed by Popp et al. (1984).

Rudulier et al.(1982) have analysed amino acids in different parts of legumes growing in coastal environments. In leaves of Anthyllis vulneriaria, proline was not detectable. On the other hand in leaves of Medicago sativa the proline reached the level of 41 µmole/g dry tissues. The proline level recorded in leaves of other legumes namely *Medicago lupulina*, *Meliotus officinalis*, *Lotus corniculatus*, *Ononis rapens* and *Vicia sativa* were 16, 40, 10, 21, 11 and 3 µmole/g dry tissue respectively. If on the above basis the proline content of *Caesalpinia crista* is expressed it is 18 µ mole /g dry tissue and this indicates a appreciable proline accumulating capacity in leaf tissue of this legume.

It was further reported by Rudulier *et al.* (1982) that in *Anthyllis vulneriana* in contrast to leaf, stem tissue showed quite high levels of proline (21 µ mole /g dry tissue) These workers further noticed that stem of *Meliotus officinalis* and *Ononis repens* also contained appreciable amount of proline (31 and 15 µ mole /g dry tissue) on the other hand rhizome tissue of *Lotus corniculatus* was quite low in proline content (5 µ mole /g dry tissue). The stem tissue of *Caesalpinia crista* also contain very low amount of proline (4 µ mole /g dry tissue).

Briens and Larher (1982) reported that stem and root tissue of some halophytes were having high proline level as compared with the leaf proline and some were having lower proline content in stem and root than the leaf proline. In case of *Caesalpinia crista* stem and root tissue contain less proline than the leaf proline and this situation is similar to the one reported in case of *Agropyron pungens*, *Juncus maritimus*, *Pragmita communis*, *Puccinellia maritima*, *Salicornia europaea, Scirpus maritima, Suaeda macrocarpa* and *Triglochin maritima* by Briens and Larher (1982). The glutamic acid is generally a major precursor of proline biosynthetic path way and the synthesis involves expenditure of ATP as well as reducing equivalents like NADH and NADPH. In the leaf tissue the photosynthetic process can provide these compounds for proline biosynthesis. Hence substantial accumulation of free proline in the major metabolic center leaf rather than stem and root is quite understandable.

G) Polyphenols

The total level of polyphenols in the leaf tissue of *Caesalpinia crista* is 3.86 g/100g.

The polyphenols are the aromatic compounds of secondary metabolism. The plant phenolics are widespread and extremely diverse and include the flavonoides, hydroquinone, coumarine and cinnamic acid. Less common are catechol, phloroglucinol and pyrogallor. Tannins are also derived from phenolics. The secondary metabolites in plats are important in repelling and discouraging predators and pathogens. Phenolic compounds have been implicated a role in plant growth regulation process (Gallstone, 1969). The tannins are also commercially important for their use in leather industry and ink industry.

The mangroves are rich in polyphenols. Hence they are regarded as valuable source of tannin which are mainly extracted from their bark. Most of the studies on mangrove polyphenols were restricted to the samples of bark. The polyphenols were also analysed from fruits and leaves which are good storage houses of polyphenols.

Humpries (1967) has reported that the polyphenol contents up to 35% and stated that the mangroves in spite of more salt concentration, contain large amount of water soluble tannins. The extensive work of Jamale (1975) indicated that the polyphenol content in the mangrove leaves varied from 0.96% to 9.3% of fresh tissue of Avicennia alba and Rhizophora mucronata and there were seasonal variations in the polyphenol levels. His work indicated that the average level of total polyphenols in mangroves is about 3.013% of fresh tissue. Kotmire (1983) recorded as high as 22% polyphenols in the leaves of Avicennia officinalis on dry weigh basis. Karkar and Bhosale (1985) also reported more polyphenols in the leaves of Rhizophora apiculata and Kandelia candel (3.52% and 1.74% of fresh tissue respectively.)

According to Strogonov (1964) salinity causes number of metabolic changes in plants and the prominent among these changes is stimulation of secondary metabolism. This is very well reflected in case of mangroves since their leaves are rich in polyphenols. It is evident from our observations that Caesalpinia crista which grows in close company of mangroves is also not an exception to this trend.

5) Seed Analysis

A) Organic constituents.

The levels of various organic constituents of the seeds of Caesalpinia crista are shown in Table 4. The moisture percentage of C.crista seeds is quite high, as compared to the moisture percentage from other halophytic seeds. The seeds of Pongamia pinnata contain 19% moisture (Wealth of India.) and that of Kochia seeds is 10.86% (Zahran and Wahid, 1982).

Starch is the major carbohydrate in C.crista seeds. Similar observations are recorded by Austenfeld (1986) for Salicornia europaea seeds, Mulik (1987) for Acanthus ilicifolius seeds and by Mohite (1990) for seeds of two Derris species - D. trifoliata and D. scandens. On the other hand quite low starch content is recorded from Pongamia pinnata seeds 6.6% (Wealth of India). The total carbohydrates from Kochia indica seeds recorded by Zahran and Wahid (1982) are also quite low (5.167%). Amount of reducing sugars and non-reducing sugars in the seeds of C.crista are nearly equal. In Salicornia europaea Austenfeld (1986) observed high amount of non reducing sugar sucrose as compared to that of reducing sugars. In D.trifoliata non-reducing sugars are dominant while in D.scandens reducing sugars are dominant in seeds (Mohite,1990).

The amount of total nitrogen and crude protein in C.crista seeds is quite appreciable. Earl and Janes (1962)

Table No.4

Organic constituents in seeds of *Caesalpinia crista* L.
(on dry weight basis).

Moisture %	28.430
Starch	11.500 %
Reducing sugars	0.108 %
Nonreducing sugars	0.109 %
Total sugars	0.217 %
Total Nitrogen	2.372 %
Crude protein	15.420 %
Total lipids	17.100 %

reported that protein content in halophytic seeds varied from 5.4% (*Atriplex canescens*) to 31.2% (*Mesembryanthemum crystalium*). The protein content from *Pongamia pinnata* seeds is 17.4% (Wealth of India,). In the seeds of *Kochia canescens* Zahran and Wahid (1982) recorded 21% crude protein. O'Leary *et al.* (1985) recorded 28.6% protein in the seeds of *Cakile edentula* while Mohite (1990) recorded in *derris trifoliata* and *D.scandens* 22.63% and 26% crude protein respectively. Under sea water irrigation seeds of the terrestrial halophytes *Salicornia bigelovii* were found to contain 30-33% protein (Glenn *et at.* 1991). It is very clear from the above observations that *C.crista* seeds contain intermediate amount of crude protein.

The amount of total lipids in *C.crista* seeds is quite high (17.1%). Data of Earl and Jones (1962) and Jones and Earl (1966) represented that the subfamily caesalpinoideae contain on an average 6.4% oil and specifically in tribe eucaesalpinieae the oil content ranged from 3% to 13%. The oil contents *Caesalpinia bonduc* kernel, *Derris scandens* seeds and *Pongamia pinnata* seeds were 20-24%, 10% and 27.5% respectively (Wealth of India). But Mohite (1990) recorded quite low levels of total lipids from seeds of *D.trifoliata* (106%). In terrestrial halophytes *Salicornia bigelovii* seeds Glenn *et al.* (1991) recorded the oil content ranging from 26 to 33% when plants were irrigated with sea water. These findings indicate that the halophyte *C.crista* can be considered as a possible oil yielding species.

However only a detailed study of oil characteristics will show the ways in which the oil can be utilized.

The seeds of C.crista contain relatively less total polyphenols when compared with the leaf tissue. At the same time these values are slightly more than the values (0.6%) recorded for seeds of another halophytic legume Derris trifoliata by Mohite (1990).

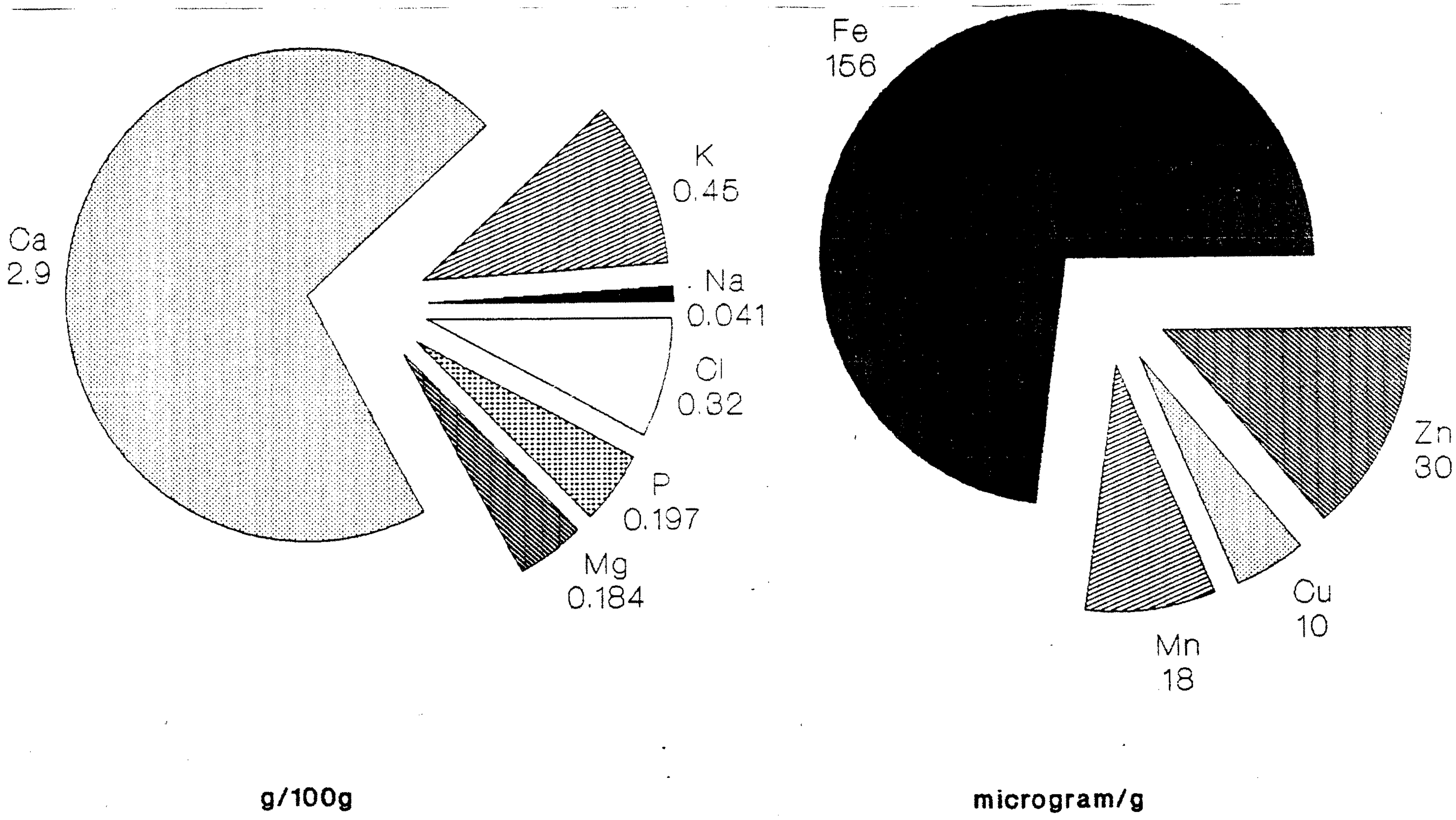
B) **Inorganic Constituents**

The inorganic constituents of the seeds of Caesalpinia crista are shown in figure 24. It is very clear from the figure that among the macronutrients calcium is the major cation in the seeds. Calcium is followed by potassium and magnesium in dominance, while sodium level in the seeds is least. Amount of chloride in the seeds is substantial and considerably higher than that of sodium.

There are some reports about the inorganic constituents of different halophytic seeds. In Lumnitzera racemosa seeds Anjal and Bhosale (1985) reported accumulation of calcium in the seeds, in spite of low level of calcium in the substratum. They further noted that, calcium is followed by potassium and sodium being the least. Though sodium level is low, they have reported quite high level of chloride similar to our observation. In contrast to above trend in Sonneretia alba they recorded accumulation of potassium followed by sodium and least amount of calcium. They also

Figure:24 Mineral contents of seeds of *Caesalpinia crista* L.

(expressed on dry wt. basis)



recorded the presence of chloride in substantial level considerably more than that of sodium. Similarly Mulik and Bhosale (1985) analysed inorganic constituents in seeds of *Acanthus ilicifolius* from different localities and noted the accumulation of potassium followed by calcium and sodium; chloride was found to be present in appreciable amount. In all the above three plants the trend of mineral accumulation in seeds is quite different than the leaves where accumulation of sodium and chloride was seen. But in *Caesalpinia crista* we observed the same pattern of mineral distribution in the leaves and seeds having calcium as a dominant inorganic constituent.

Accumulation of potassium and very low levels of sodium in seeds are also noticed by Yeo (1981) in *Suaeda maritima*, Austenfeld (1986) in *Salicornia europaea* and Mohite (1990) in *Derris trifoliata* and *D.scandens*. It is clear from the above observations that the plants are growing in highly saline areas the amount of Na and Cl is minimum in seeds. It may be because of the restricted translocation of these elements from vegetative parts to reproductive parts.

It is evident from fig.24 that *Caesalpinia crista* seeds contain high amount of phosphorus (196.7 mg/100 g), it may be due to higher requirement of active participation of phosphorus in various metabolic processes during future phase of seed germination.Mohite (1990) has recorded phosphorus levels quite low is halophytic legumes *Derris trifoliata* and *D. scandens* 41.4 and 45.9 mg/100g respectively.

The analysis of micronutrients in *C. crista* seeds is also represented in figure 24. The seeds are rich in iron followed by zinc, manganese and copper. Not much is known about micronutrient status of halophytic seeds. Mohite (1990) from our laboratory recorded that *Derris trifoliata* seeds are rich in iron, similar to *C. crista* seeds.