Chapter-IV
RESULTS AND DISCUSSION

1. Effect of NaCl salinity on growth and development of P. aconitifolius :

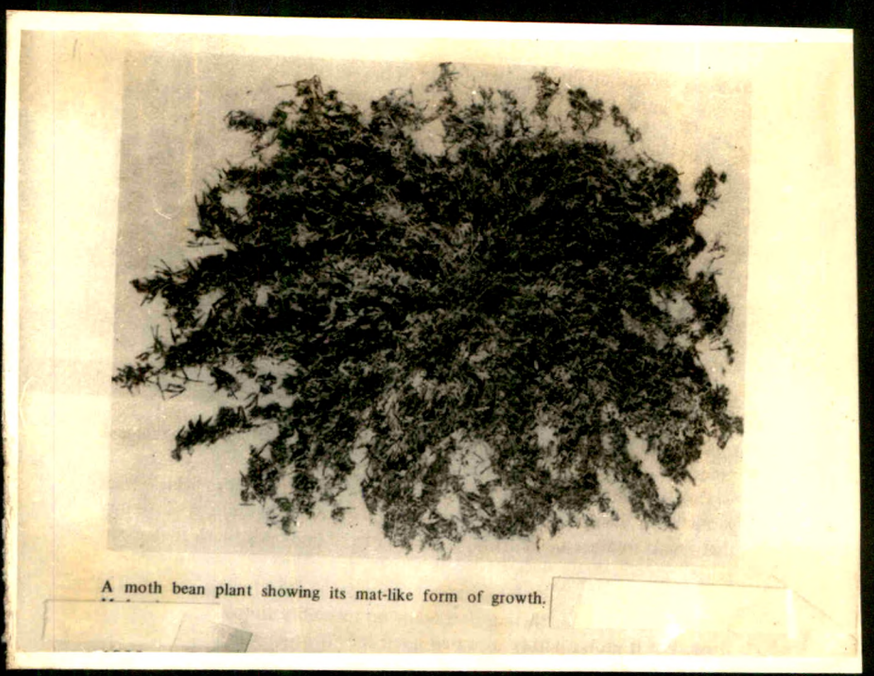
Growth analysis is an important tool for studying very complex interaction between plant organism and the environment. This interaction helps understanding the critical phases in the life cycle of a plant. Usually growth of a plant can be divided into three major phases. The early or slow growing phase referred as initial or lag phase, the second is log phase or the phase of exponential growth. Usually in this phase growth rate with respect to increase in number of leaves, increase in leaf area, increase in fresh as well as dry matter takes place. This second phase also comprises the flowering or initiation of reproductive organs. This second phase is ultimately followed by a phase of senescence where there is decline in the rate of increasing biomass production. Thus, when plotted the growth span of a plant gives a sigmoid type of curve.

Growth and development of P.aconitifolius and the effect of NaCl salinity there on have been depicted in Tables 1, 2 and 3 and Fig. 2, 3, 4, 5, 6 and 7. It can be seen that the height of the plant increases continuously till the last stage of the growth (vi) i.e. after 90 days of growth. It is also evident that after first stage (after 40 days) the increase in plant height seems to be rapid. However, the root to shoot ratio is

maximum during the IV stage of growth indicating continuation of root growth rather at the faster rate. The number of leaves produced per plant is maximum at the second stage of growth and later on it decreases down. This may be probably due to the fall of senescent leaves toward the end of the life cycle of the plant. Other data related to the leaf characteristics such as leaf area per plant and leaf area index in particular is supporting the above feature.

Fresh and dry matter production of whole plant as well as of individual plant part like leaf, stem and root is increasing continuously with advancement of period of growth. However, the rate of increase in fresh as well as dry matter production is high during the 3rd and 4th stage of development. There after it declines. This may be probably due to loss of some dry weight in the form of dried and fallen leaves.

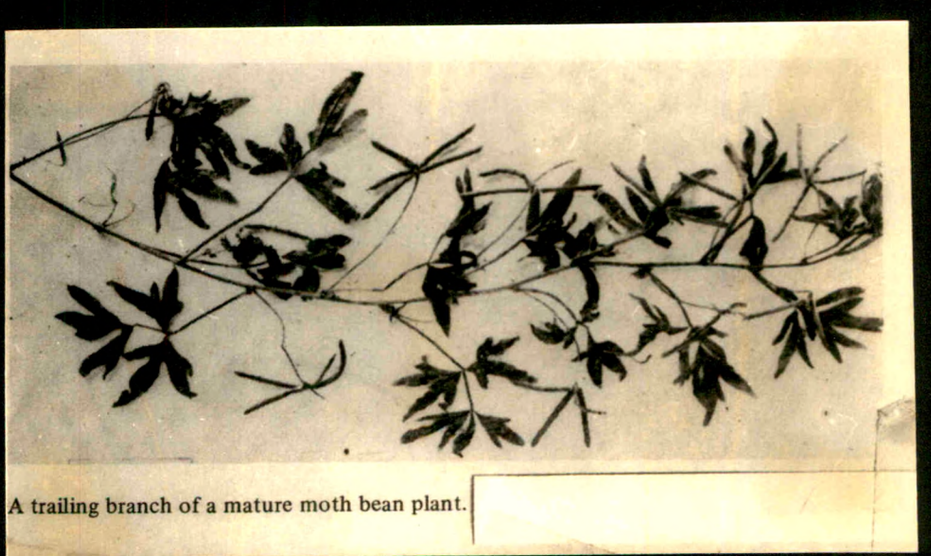
From the above basic data the RGR, NAR, LAR of whole plant and plant parts have been computed and recorded in Table 3. The effect of sodium chloride salinity on these growth parameters have also been depicted in the same Table and Fig.7. It is evident from the results that RGR is highest during the stage II. However, the RGR is usually kept high even during the later stages of growth. NAR, however, is very low during the last stage of growth. However, LAR is very high even during the last stage of growth. It appears



A moth bean plant showing its mat-like form of growth.

Fig. 1 (A)

A moth bean plant showing its mat-like form of growth.



A trailing branch of a mature moth bean plant.

Fig. 1 (B)

A trailing branch of a mature moth bean plant

Fig. 2

Effect of NaCl Salinity on growth of *Phaseolus aconitifolius* (Jacq.).

1 Control 2. 10 mM NaCl 3. 25 mM NaCl 4. 50 mM NaCl

5. 100 mM NaCl

that LAR may be the main contributing factor for the increased LAR during the later stages of growth. The RGR of pods is the highest at the last stage.

The influence of sodium chloride salinity on growth of P.aconitifolius has also been depicted in Tables 1, 2 and 3 and Fig. 2, 3, 4, 5, 6 and 7. It is evident from the observations that salt stress has caused a considerable decrease in growth in terms of average plant height, number of leaves plant^{-1}, total leaf area plant^{-1}, biomass produced plant^{-1} (dry matter), leaf dry matter, root dry matter, number of pods plant^{-1} and their dry weight only at the highest salinity level i.e. 100 mM NaCl. From the values of root to shoot ratio it is evident that root to shoot ratio is always high at all the stages of growth in P.aconitifolius plants grown in 100 mM NaCl medium. This reflects the more inhibitary effect of salt on mainly shoot growth. Low leaf area produced by the plants subjected to highest salinity level along with decreased number of leaves plant^{-1} probably causes lower number of pods developed in those plants. With increasing concentration of sodium chloride upto 50 mM concentration there is linear increase in almost all the growth parameters. Dry matter produced plant^{-1} grown in 50 mM NaCl medium is the highest recorded (1.2 g plant^{-1} at Vth stage of growth). Even dry matter of pods developed plant^{-1} grown in 50 mM NaCl concentra-

EFFECT OF NaCl SALINITY ON SHOOT & ROOT LENGTH IN *P. aconitifolius*

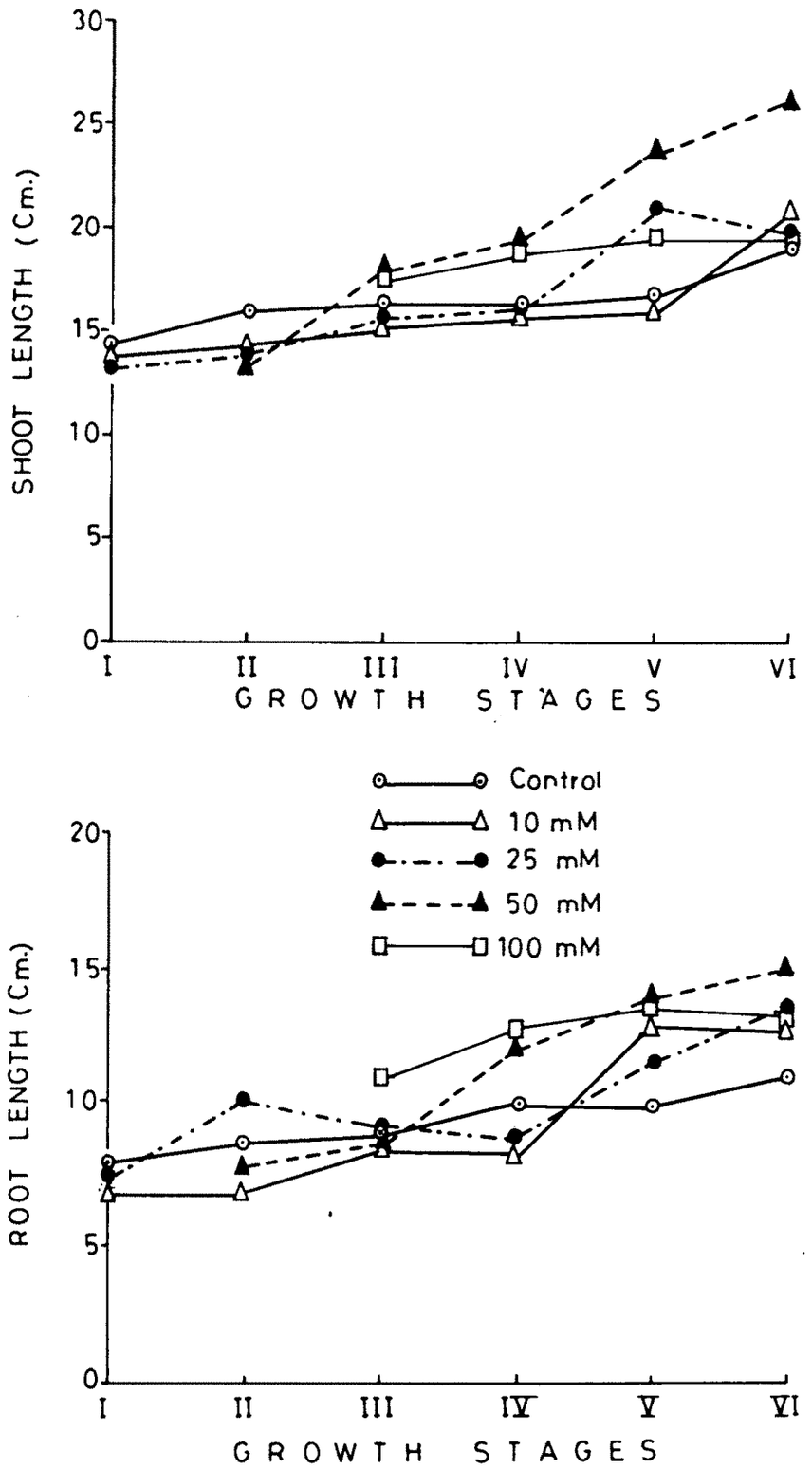


Fig. 3

tion at the later stages of growth is 0.5 and 0.6 g plant^{-1} (Vth and VIth stages of growth).

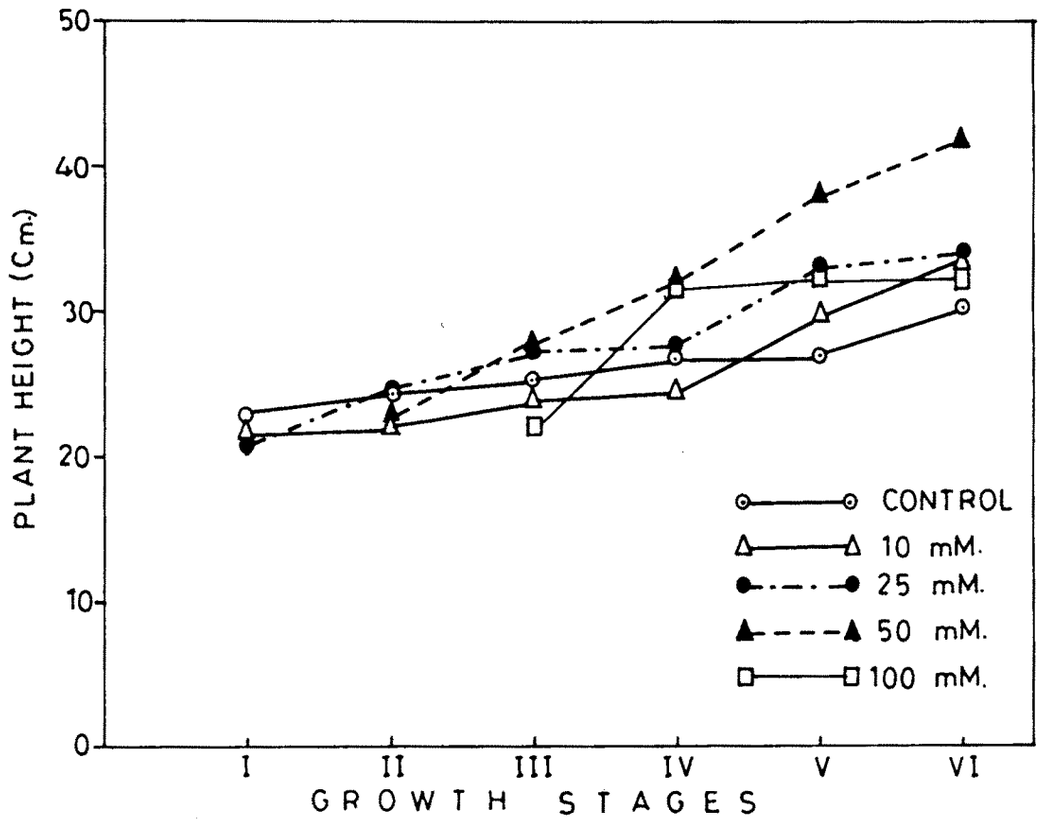
RGR when calculated on dry weight basis for whole plant as well as individual plant parts is maximum when the plants are grown in 50 mM NaCl concentration. However, the NAR and LAR are maximum in the plants grown in 25 mM NaCl medium. All these observations lead us to suggest that with increasing concentration of salt in the medium upto 50 mM concentration there is stimulation in growth (vegetative as well as reproductive) and development in P.aconitifolius.

There are large differences between plant species which respond differently to the saline conditions, (Maass and Hoffman, 1977). Several workers have reported that salinity adversely affects growth and dry matter production in several plants (Taylor et al., 1975; Heikal, 1976; Frota and Tucker, 1978; Joolka and Singh, 1979; Chavan and Karadge, 1980; Morard et al., 1979; Therios and Steven, 1980; Ibrahim, 1980; Ahmad et al., 1980; Makrides and Goldthwaite, 1981; Mukherjee et al., 1982; Maftoun et al., 1982). However, Hamid and Talibudeen (1976) showed that greater sodium uptake promotes increase in dry matter yield of all parts in case of barley and sugarbeet, indicating that sodium plays a specific role in their metabolism. Matar et al., (1975) obtained differential response by spinach and lettuce. It was found

folius

Parameter	Cont:l					100 mM NaCl					
	I	II	III	V	VI	I	II	III	IV	V	VI
Fresh matter plant^{-1} (g)	.54 ±.04	0.60 ±.1	.80 ±.03	4.4 ±.5	337 ±.2	- -	- -	1.2 ±.08	.64 ±.03	1.6 ±.2	.6 ±.06
Dry matter plant^{-1}(g)	.22 ±.02	.24 ±.03	.30 ±.01	1.2 ±.2	.8 ±.13	- -	- -	.22 ±.02	.35 ±.1	.56 ±.1	.39 ±.05
Leaf dry matter plant^{-1}(g)	.11 ±.01	.14 ±.06	.18 ±.01	.34 ±.09	.06 ±.03	- -	- -	.11 ±.04	.25 ±.1	.2 ± .04	.11 ±.1
Stem dry matter plant^{-1}(g)	.08 ±.02	.08. ±.01	.10 ±.01	.34 ±.1	.07 ±.04	- -	- -	.07 ±.01	.11 ±.07	.1 ±.2	.1 ±.04
Root dry matter plant^{-1}(g)	.03 ±.02	.02 ±.01	.02 ±.01	.08 ±.04	.07 ±.03	- -	- -	.04 ±.01	.05 ±.03	.05 ±.01	.04 ± .02
Dry matter of pods plant^{-1}(g)	- -	- -	- -	.5 ±.4	.6 ±.4	- -	- -	- -	.02 ±.0	.21 ±.18	.14 ±.05

EFFECT OF NaCl SALINITY ON PLANT HEIGHT & NUMBER OF LEAVES PER PLANT IN *P. aconitifolius*



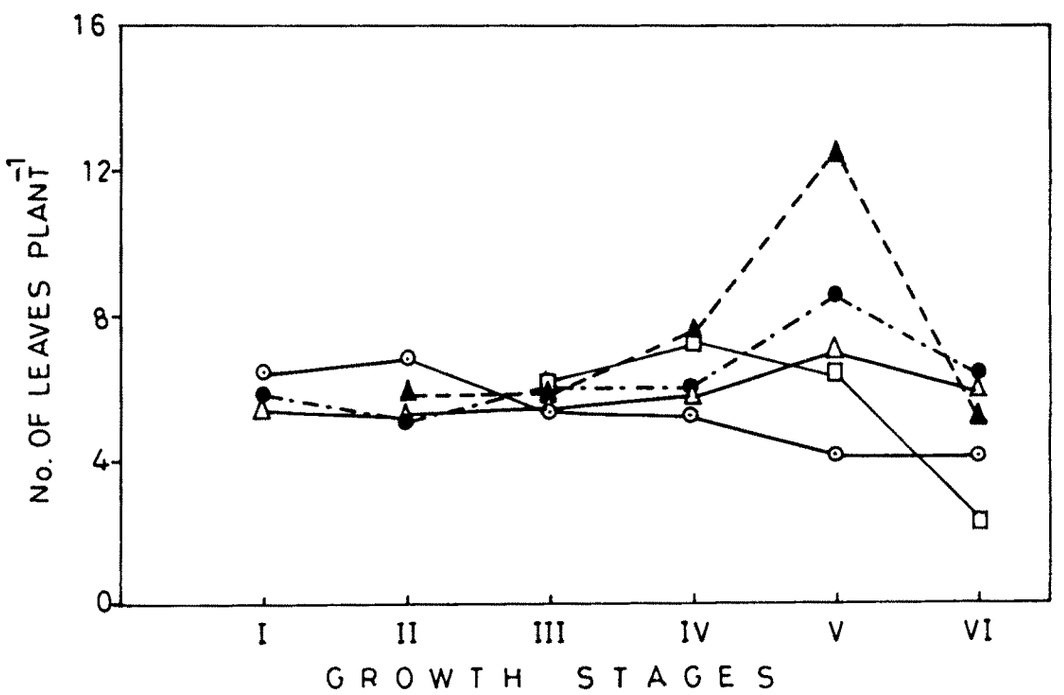


Fig. 4

that with increasing sodium supply dry matter production was decreased in lettuce while that increased in spinach. Recently Vinter and Lacuchli (1982) have compared the response of two trifolium species for their salt tolerance. It was found that T.alexandrinum survived at all salt treatments. Salt induced growth reductions of 30 and 47% accured at 50 and 100 mM Sodium chloride concentration. They considered this species as moderately salt tolerant. From the present studies it can be said that P.aconitifolius behaves like the above plants such as barley, sugarbeet, Trifolium and spinach and indicates well adaptibility to saline conditions.

Greenway and Munns (1980), while reviewing the mechanisms of salt tolerance in non-halophytes, have categorised the plants into 3 groups. The first group being that of halophytes which continued to grow rapidly at 200-500 mM NaCl, include the plants such as Suaeda maritima, Atriplex numularia, A.hastata, Spartina townsendie and sugarbeet. The second one of both halophytes and nonhalophytes which grow very slowly above 200 mM NaCl include halophytic monocotyledons, cotton, barley and tomatoes. The 3rd group comprises of very salt sensitive nonhalophytes and include fruit trees such as citrus, avocado and stone fruit. From the present results it seems that P.aconitifolius species can be included in the second group and that probably between halophytes and non-halophytes. Thus it can be suggested that

EFFECT OF NaCl SALINITY ON LEAF AREA AND NUMBER OF PODS PER PLANT IN P. aconitifolius

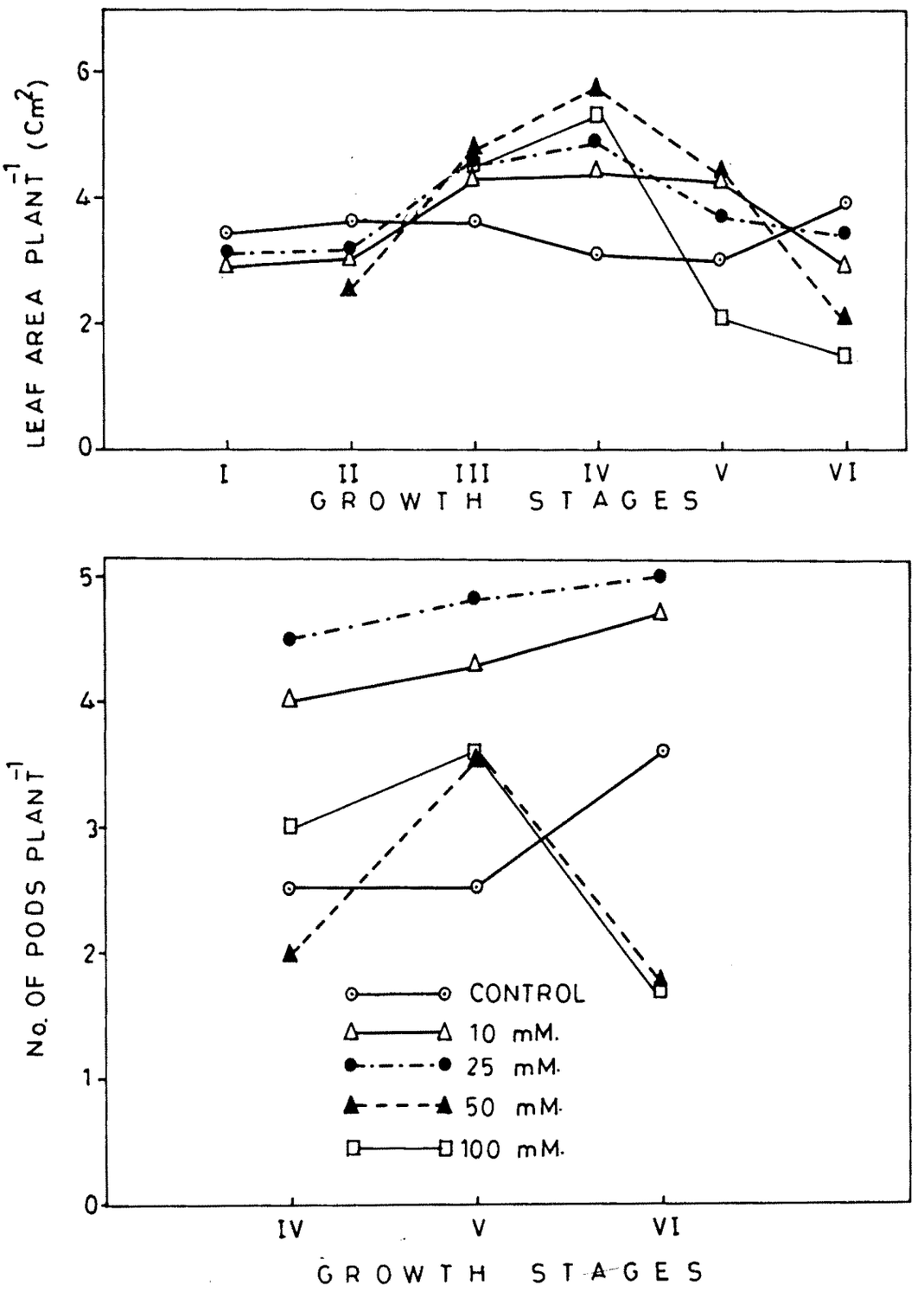


Fig. 5

ılation

Growth Parameter	Control				100 mM NaCl				
	I	II	IV	V	I	II	III	IV	V
RGR mg g^{-1} day^{-1} (Dry matter)	.29	.41	.67	-	-	-	.47	.59	-
NAR mg cm^{-2} day^{-1} (dry matter)	.29	-	-	-	-	-	.67	-	-
LAR cm^{-2} (Dry matter)	1.0	-	-	-	-	-	.7	-	-
RGR Leaf	.34	.37	.52	-	-	-	.37	.39	-
RGR Stem	-	.29	.55	-	-	-	.37	-	-
RGR Root	-	-	.37	-	-	-	.23	-	-
RGR Pods	-	-	-	.46	-	-	.52	-	-

P.aconitifolius can be taken as moderately salt tolerant crop.

2. Effect of NaCl salinity on Organic constituents and some enzymes in P.aconitifolius. :

A. Organic constituents :

The effect of salinity on some organic constituents such as titratable acidity (TAN), carbohydrates (soluble sugars and starch), polyphenol content, total nitrogen and protein contents. proline content and chlorophylls in different parts of P.aconitifolius has been investigated and the results have been recorded in Table 4 to 10 and Fig. 8 to 12.

i) TAN : It can be seen that there is decrease of titratable acidity in the leaves even at the lower salt concentrations. However, it increases considerably in the stem of P.aconitifolius till 25 mM NaCl concentration and there after decreases slowly at higher salinity levels (Table 4 and Fig.8). Strogonov (1964) has observed increase in organic acid content due to NaCl salinity in maize. Similar increase in organic acid content in leaves of salt stressed plants has been observed by many workers (Rush and Epstein, 1976; Downton and Loveys, 1978). Contrary to these observations some workers have noted decreased organic acid content due to salinity. Recently Flowers and Hall (1978) have reported that organic acid content was maximum in Suaeda maritima kept in tap water and decreased

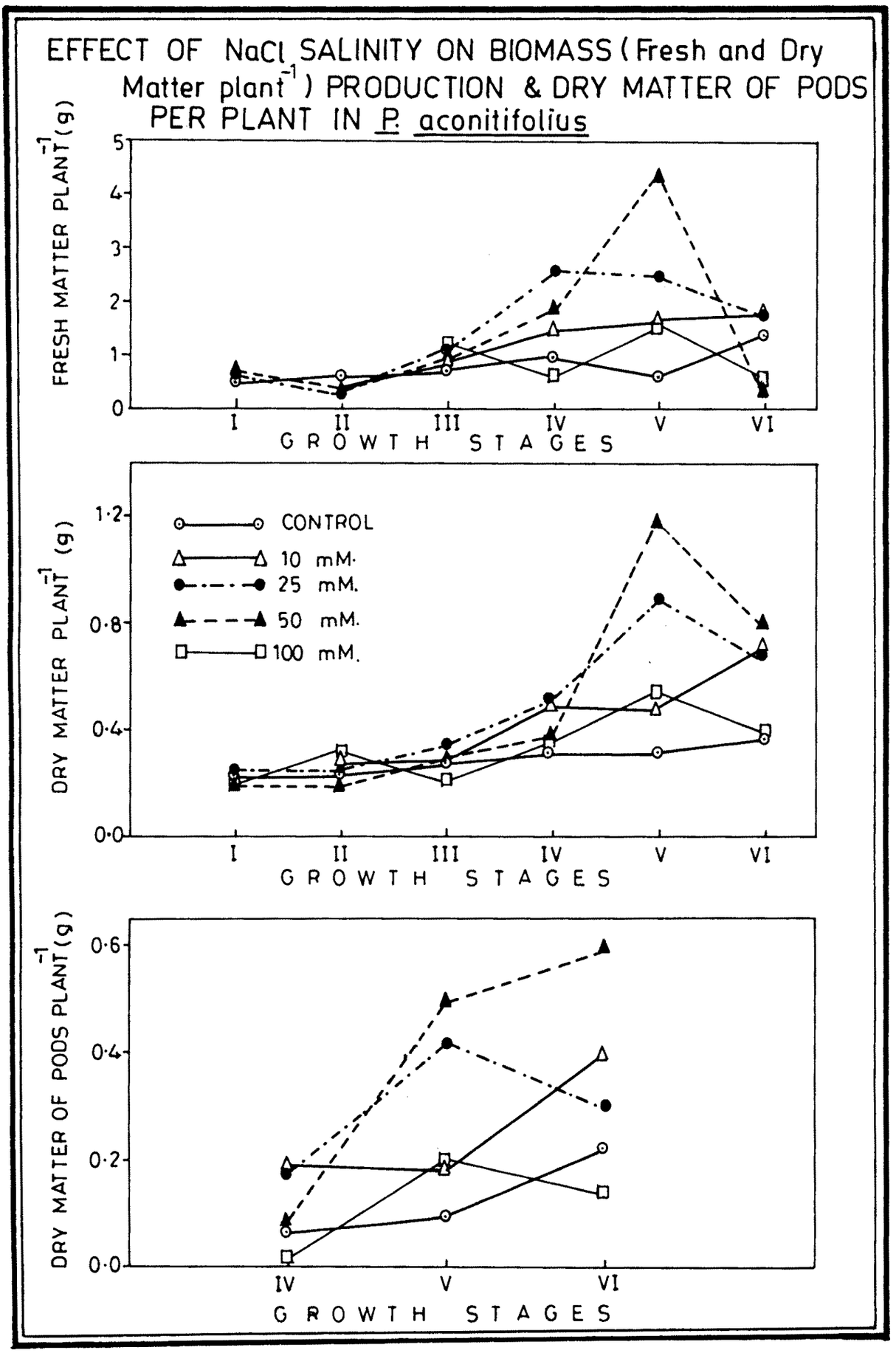
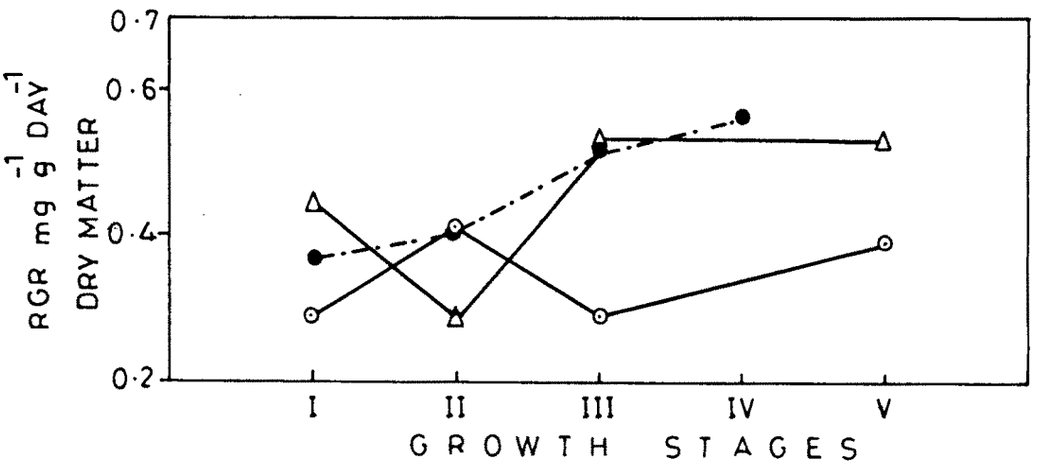
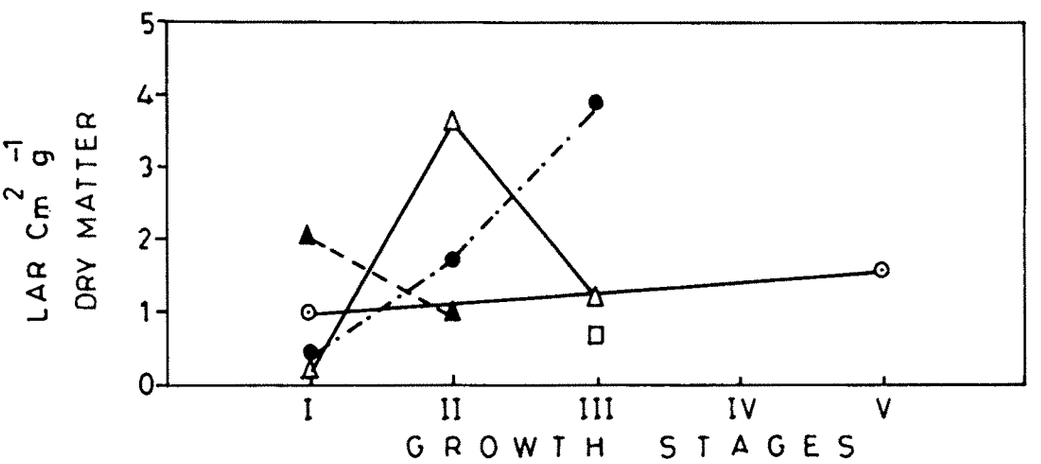

EFFECT OF NaCl SALINITY ON BIOMASS (Fresh and Dry Matter plant^{-1}) PRODUCTION & DRY MATTER OF PODS PER PLANT IN P. aconitifolius
FRESH MATTER PLANT^{-1} (g)
5
4
3
2
1
0
I
II
III
IV
V
VI
GROWTH STAGES
DRY MATTER PLANT^{-1} (g)
1·2
0·8
0·4
0·0
CONTROL
10 mM.
25 mM.
50 mM.
100 mM.
I
II
III
IV
V
VI
GROWTH STAGES
DRY MATTER OF PODS PLANT^{-1} (g)
0·6
0·4
0·2
0·0
IV
V
VI
GROWTH STAGES

Fig. 6

EFFECT OF NaCl SALINITY ON RGR, LAR & NAR IN *P. aconitifolius*





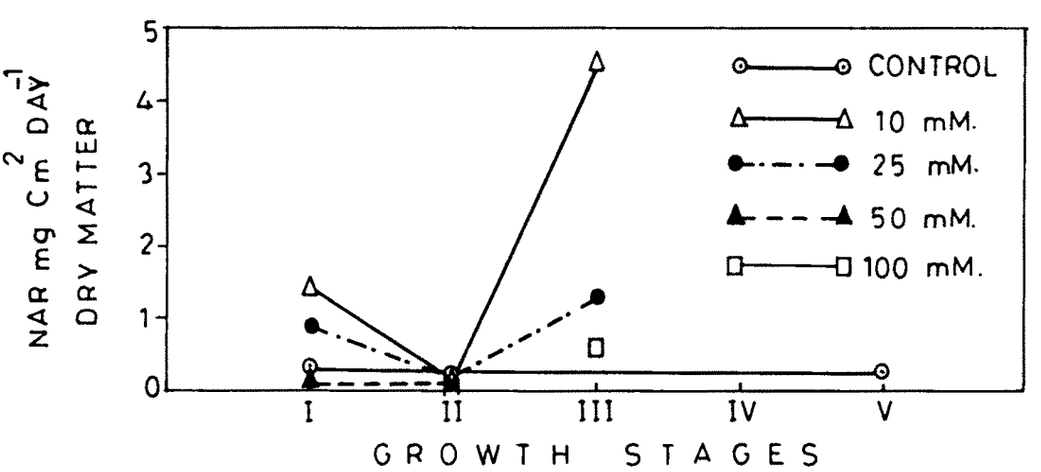


Fig. 7

TABLE NO. 4

Effect of NaCl Salinity on acidity status (TAN)* of leaf and stem pf P. aconitifolius.

NaCl Treatment (mM)	Leaf	Stem
Control	2.21	1.38
10	1.24	2.07
25	1.52	2.45
50	- 1.76	1.66
100	2.35	1.52

Values are expressed as ml 0.1N NaOH required to neutralise the acids present in 100g fresh plant material.

in salt treated plants. It is suggested by Bernstein (1975) that organic acids can play a role in osmotic adjustment. From the present studies with P.aconitifolius it appears that accumulated organic acids at their high concentrations upto 50 mM NaCl level may be playing an important role toward osmotic adjustment and there by showing adaptive mechanism.

ii) Chlorophylls : The influence of salt stress on chlorophyll content in the young and mature leaves of P. aconitifolius is recorded in Table 5 and Fig.8. It can be seen that with increasing level of salinity in the medium there is dramatic increase in total chlorophyll content of mature leaves upto the level of 25 mM salt concentration. Due to higher concentrations eventhough there is a sharp fall in the level of chlorophylls, these are kept almost at the same level of that in control. However, there is sharp rise of total chlorophyll content in the young leaves only at the lower salinity level (10 mM). Higher concentrations, however, appear to be toxic in this respect. From the results and chlorophyll a : b ratio it is apparent that chlorophyll 'a' is degraded more in both types of leaves due to salinity.

A decrease in chlorophyll contents under saline conditions has been recorded by several workers (Weimberg, 1975; Petolino and Leone, 1980 and Grant and Somers, 1981). Such a decrease in chlorophylls has been atributed to weakening of

TABLE NO. 5

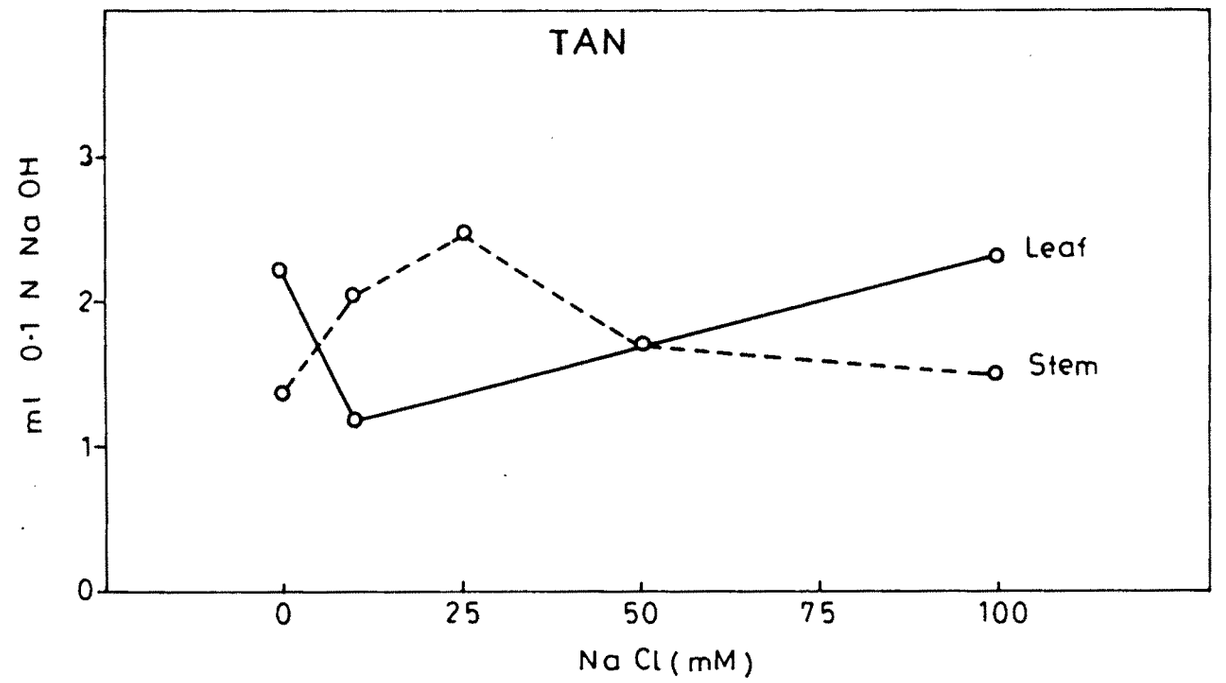
Effect of NaCl Salinity of Chlorohyll contents of young and mature leaves of P. aconitifolius.

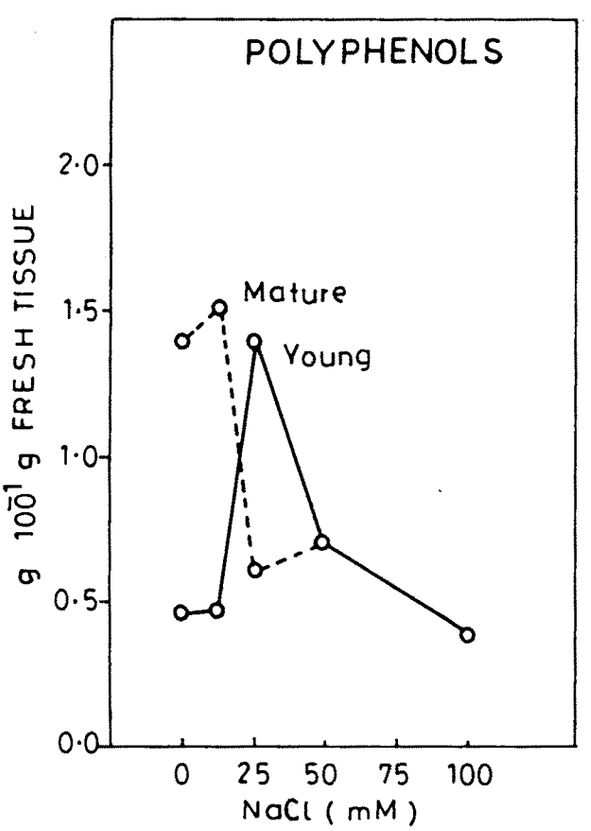
NaCl Treatment (M M)	Young leaves				Mature leaves			
	Chlorophylls (Mg 100^{-1} g fresh tissue)							
	Chl. a'	Chl. b'	Chl. a+b	Chl. a/b	Chl. a'	Chl. b'	Chl. a+b'	Chl. a/b
Control	100	60	160.0	1.7	42.1	33.0	75	1.3
10	107	75	182.0	1.42	134.0	104.0	238	1.3
25	77	51	127.2	1.52	88.0	60.0	148	1.5
50	54	37	91.0	1.5	42.0	37.2	79	1.12
100	66	42	108.0	1.6	73	43.0	116	1.7

protein-pigment-lipid complex (Strogonov, 1964) or increased chlorophyllase activity (Svitsev et al., 1973). According to Strogonov et al., (1970), the salt tolerant species retain or accumulate chlorophylls under saline conditions while salt sensitive ones loose them. Present observations with P. aconitifolius indicate that this plant can be classified as moderately salt tolerant because it has got chlorophyll retaining capacity at the intermediate levels of salinity (25 to 50 mM NaCl concentration).

iii) Polyphenols : Table 6 and Fig. 8 shows the effect of NaCl salinity on polyphenol contents of young and mature leaves of P.aconitifolius. It is evident that the level of polyphenols increases considerably in young leaves with increasing salinity stress upto 50 mM NaCl concentration in the medium. However, polyphenol content of mature leaves is slightly higher in 10 mM NaCl treated plants. It appears that the salt exerts its influence more on the mature leaves in this respect. As young leaves are the rapidly growing parts of the plant, accumulation of polyphenol in these leaves may be an adaptive feature of the plant for its further growth. Roger (1972) has observed an increase in the content of phenolic acids, chlorogenic and isochlorogenic acids due to NaCl stress in the leaves of Helianthus annus. Shetty (1971) and Jamale (1975) also recorded stimulation of polyphenol content due to salt stress in mangrooves. Karadge and Chavan

EFFECT OF NaCl SALINITY ON TAN (LEAF and STEM) IN POLYPHENOLS and CHLOROPHYLLS IN YOUNG and MATURE LEAVES OF *P. aconitifolius*





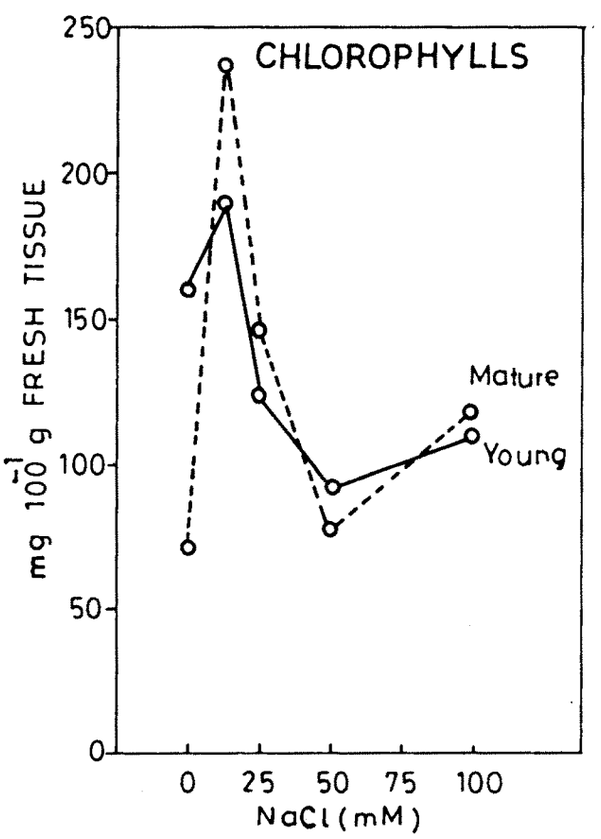


Fig. 8

TABLE NO. 6

Effect of NaCl Salinity on polyphenol contents of young and mature leaves of P. aconitifolius.

NaCl Treatment (mM)	Polyphenols (g 100^{-1} fresh tissue)	
	Young leaves	Mature leaves
Control	0.48	1.40
10	0.48	1.52
25	1.40	0.60
50	0.72	0.72
100	0.40	0.40

(1981) have also recorded increased level of polyphenol content of the leaves of groundnut var. TMV-10 due to treatment of both sodium chloride and sodium sulfate salts. Increased level of polyphenols in the leaves of P.aconitifolius indicates salinity tolerance to be present in this plant.

iv) Carbohydrates : Effect of NaCl salinity on soluble sugar and starch contents of the leaves and pods of P.aconitifolius at different developmental stages has been recorded in Table 7 and depicted in Fig. 9 and 10. It can be seen that with the advancement of developmental stage of leaves as well as pods there is continuous accumulation of both soluble sugars as well as starch. This is quite significant in the plants grown in non-saline conditions and low salinity levels. It is interesting to note that the carbohydrate level in the leaves and pods of the plants treated with NaCl salt goes down considerably at the later stages of growth. At the beginning there is contineous increase in the level of soluble sugars and starch in the leaves as well as pods with increasing salt concentration in the medium. However, when we look to the figures of soluble sugars and starch in leaves it is evident that there is decrease at the higher concentrations of salt. At the lower concentrations it appears that the synthesis or accumulation of carbohydrates in leaves as well as pods is stimulated.

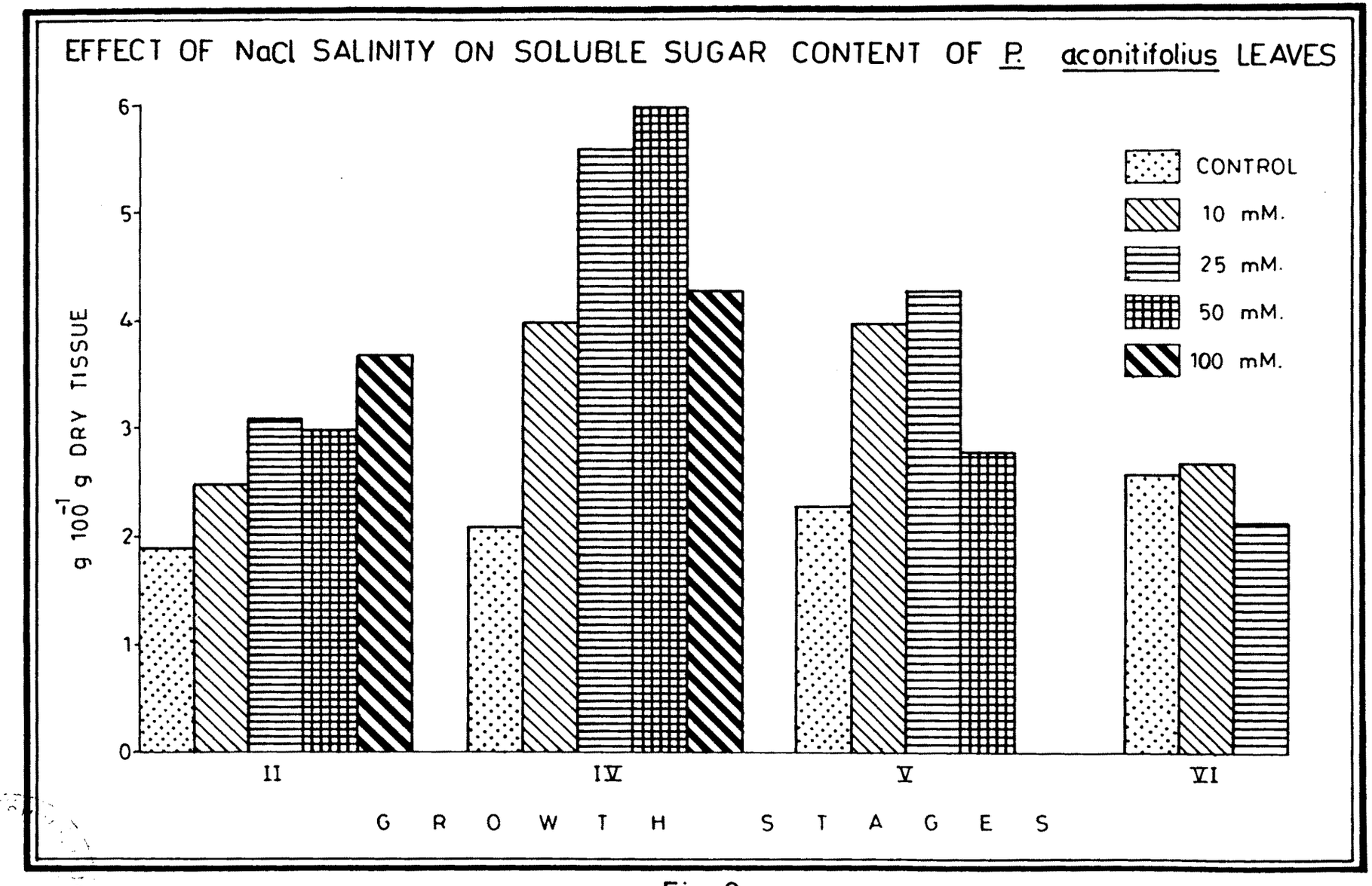

EFFECT OF NaCl SALINITY ON SOLUBLE SUGAR CONTENT OF P. aconitifolius LEAVES
g 100^{-1} g DRY TISSUE
0
1
2
3
4
5
6
CONTROL
10 mM.
25 mM.
50 mM.
100 mM.
II
III
IV
V
VI
G R O W T H S T A G E S

Fig. 9

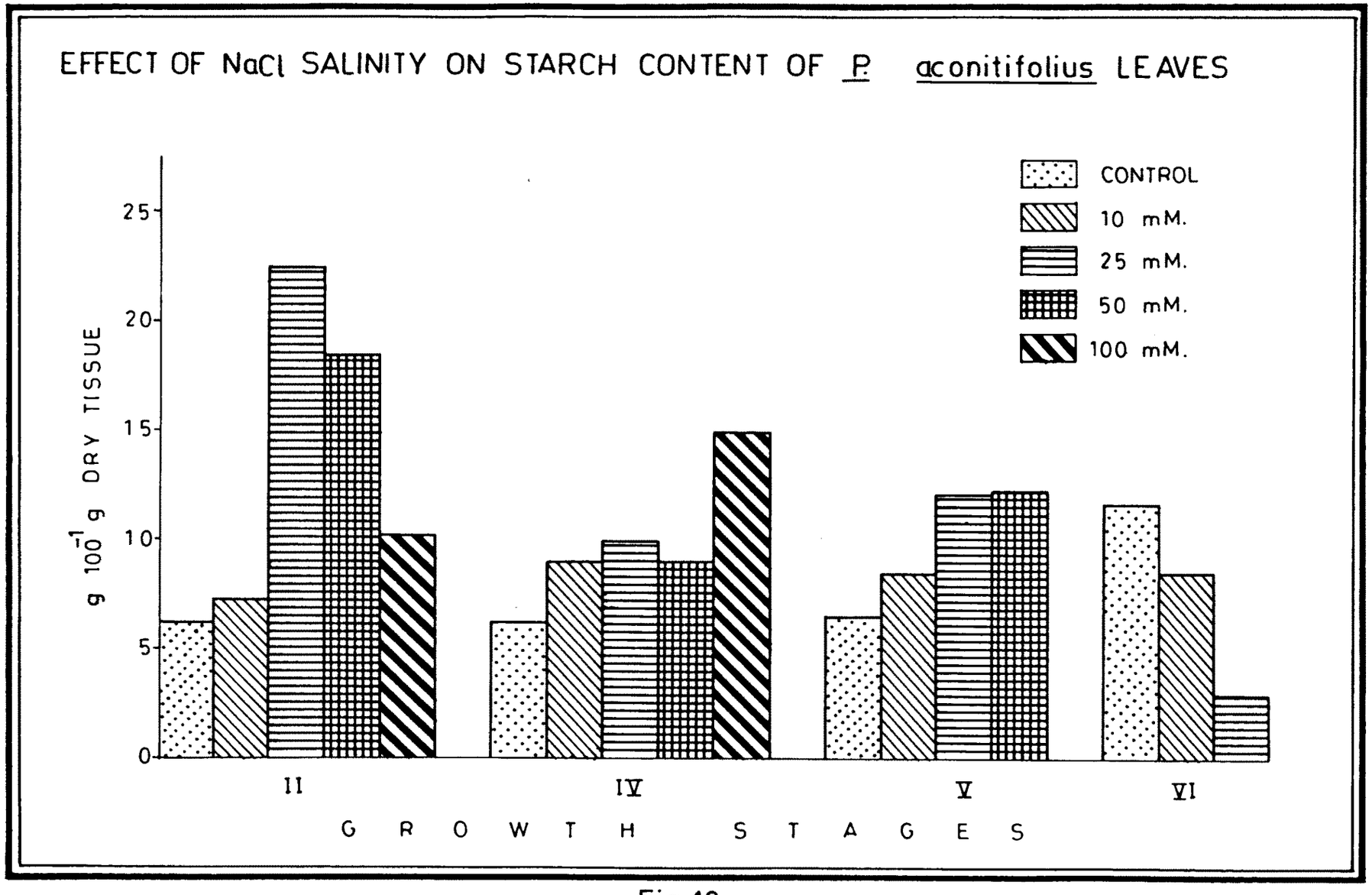

EFFECT OF NaCl SALINITY ON STARCH CONTENT OF P. aconitifolius LEAVES
CONTROL
10 mM.
25 mM.
50 mM.
100 mM.
g 100^{-1} g DRY TISSUE
0
5
10
15
20
25
II
IV
V
VI
G R O W T H S T A G E S

Fig.10

TABLE NO. 7

Effect of NaCl Salinity on carbohydrate contents * of leaf and pods of P. aconitifolius.

NaCl Treatment	Leaf								Pods			
	Developmental stages.											
	II	IV	V	VI	II	IV	V	VI	V	VI	V	VI
mM	Soluble sugars				Starch				Soluble sugars.		Starch	
Control	1.90	2.1	2.3	2.60	5.9	6.2	6.4	11.64	3.90	4.31	24.04	42.24
10	2.5	3.4	3.96	2.70	7.2	8.8	8.62	8.62	5.100	6.03	49.99	44.82
25	3.10	5.6	4.31	2.16	22.41	9.91	12.10	3.10	7.10	5.43	37.50	43.10
50	3.02	6.03	2.80	-	18.50	9.10	12.10	-	5.95	5.52	43.10	38.20
100	3.70	4.31	-	-	10.34	15.10	-	-	4.31	-	37.93	-

* Values are expressed as g 100^{-1}g dry tissue.

It is suggested by Matar et al., (1975) that even a small increase in sodium content can cause a considerable changes in carbohydrate metabolism and this action is indicated through the influence of sodium on both synthesis and translocation of carbohydrates. Steiner (1935) and Flowers et al., (1977) have expressed a serious doubt about the role of sugars in osmotic adjustment under saline conditions. Contrary to the above statements Strogonov et al., (1970) and Maas and Nieman (1978) have suggested that increased level of soluble sugars in all parts of plants grown under saline conditions may add to the osmotic balance. Ahmad and Abdullah (1979) observed that total sugar content of potato tuber increased with increasing concentration of salts in most of the varieties which were claimed as salt tolerant ones on the basis of their yields. While investigating osmometabolic adjustment in flax, cotton and wheat under salinity stress, El Sharkawa (1977) suggested that increased synthesis of sugars and probably nitrogen metabolites are the means of adjustment to salinity. In relatively more salt resistant tomatoes under maximum salinization (0.5 % for chloride), the starch content considerably increases as compared with the control (Kabuzenko and Ponomareva, 1980). From the present investigation it appears that the soluble sugars seem to play some role in the early stages of growth under saline conditions. Negligible effect of salt stress on starch content of pods indicates no adverse effect of salinity on pod development process.

v) Nitrogen and Protein : It can be seen from Table 8 and 9 and Fig. 11 that the leaves and stem show maximum amount of total nitrogen and protein content at the IInd i.e. vegetative stage and VIth or maturity stage. Contrary to this the roots of P.aconitifolius accumulate high amount of nitrogen and protein at the IVth stage i.e. during initiation of pods. It appears that the leaves and the stem are the sink of nitrogen at the vegetative stage of growth. During flowering and pod formation stage probably the leaves become the source of nitrogen and proteins. Hence, nitrogen or proteins translocated from the leaves and stem to the developing pods. It is also evident from Table 8 and 9 and Fig.11 that with increasing salinity there is slight decrease in the level of total nitrogen and protein content in the leaves and roots during the vegetative phase (IInd stage). However during flowering and pod development stage there is increase in the level of total nitrogen in the leaf as well as stem while it is decreasing continuously in the roots. At the final stage i.e. at the maturity there is no definate pattern of nitrogen content of leaf, stem, roots and even pods. The nitrogen content of the pods at maturity is slightly influenced at the lower concentrations of salt while there is dramatic increase in the total nitrogen content of the mature pods. It appears that due to salinity there is stimulation of translocation of nitrogen compounds from roots to the developing parts through

TABIE NO. 8

Effect of NaCl Salinity of total nitrogen content * of leaves, stem, root and pods of P. aconitifolius.

NaCl Treatment (mM)	Developmental stage											
	II	IV Leaf	VI	II	IV Stem	VI	II	IV Root	VI	II	IV Pod	VI
Control	2.70	1.10	3.20	1.6	1.1	1.2	1.75	4.8	0.8	-	2.0	1.3
10	2.70	1.70	3.99	1.7	1.2	3.2	1.7	4.4	1.1	-	2.1	1.2
25	2.02	2.13	1.0	1.9	4.8	2.61	-	4.3	1.7	-	5.9	1.6
50	2.13	4.30	4.30	2.93	2.7	1.0	-	3.99	1.0	-	-	3.14
100	-	2.93	3.20	-	7.98	3.62	-	2.13	1.0	-	-	3.15

* Values are expressed as g 100^{-1} g dry tissue.

EFFECT OF NaCl SALINITY ON TOTAL NITROGEN CONTENT OF LEAF, STEM, ROOT & PODS OF P. aconitifolius

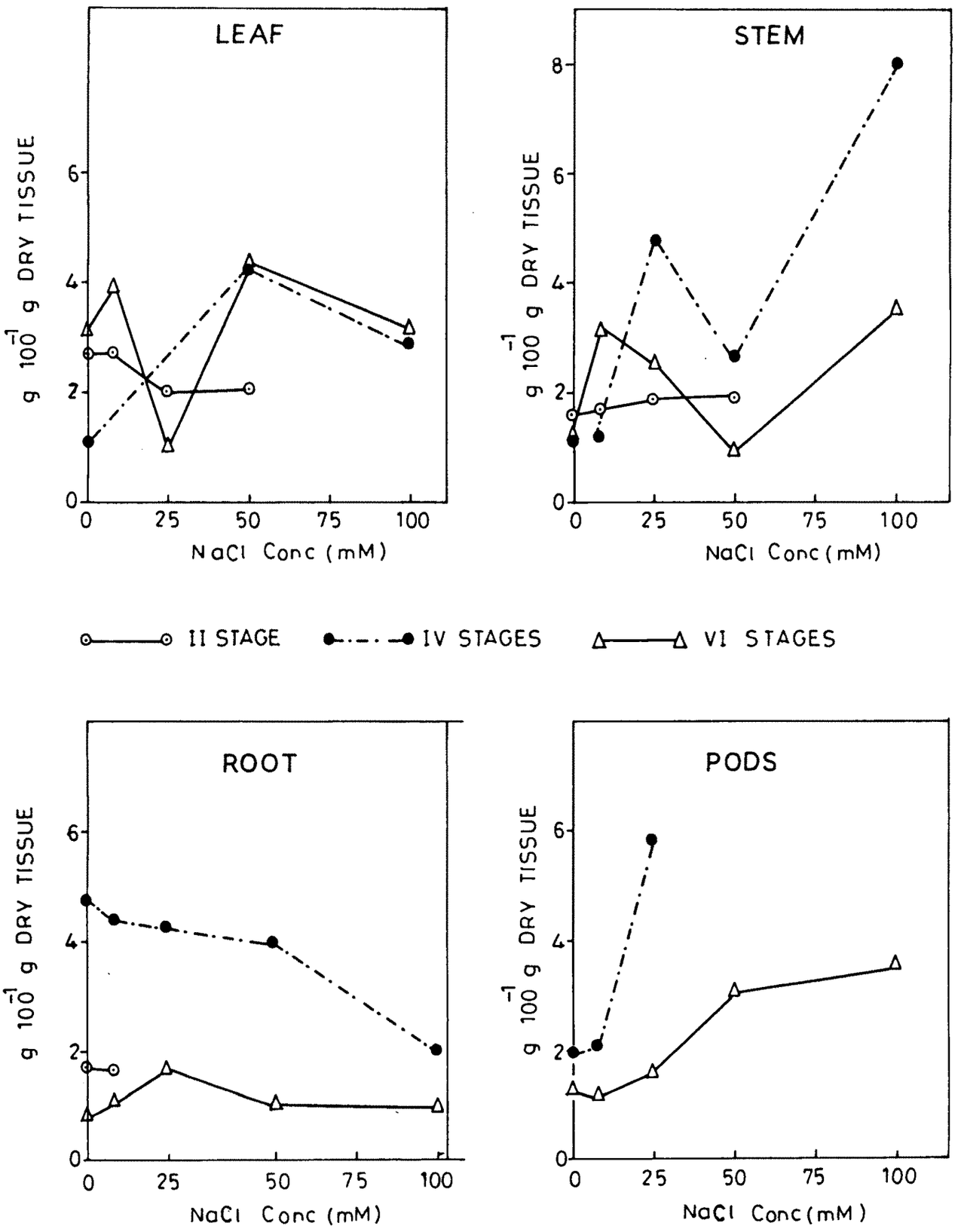


Fig. 11

both stem as well as leaf. Thus it appears that the overall nitrogen uptake and its translocation is slightly stimulated by salt stress.

Strogonov (1964) has pointed out that nitrogen metabolism is the main source of salt injury in plants and he observed increase in total nitrogen content in maize, roots and leaf saps. Ravikovitch and Yoles (1971) have noticed that the nitrogen content rises along with an increase in salinity in the growth medium of Setaria italica. Rahman et al., (1972) also observed accumulation of total nitrogen in some desert fodder plants. Ashour et al., (1977) in their detailed study reported that chloride salinity increased the concentration of protein and total nitrogen in wheat shoots. Chavan (1980) from our laboratory found that total nitrogen content of leaves increases considerably in the leaves of Eleusine coracana due to NaCl salinity. Recently Karadge and Chavan (1983) have also reported increased uptake and accumulation of N in root and leaves of Sesbania aculeata when grown in NaCl salinized media.

Contrary to above reports many workers have reported that salts were either without any effect or caused decrease in total nitrogen content. (Matal et al., 1975; Syed and Swaify, 1973; Guggenheim and Waisal, 1977; Cerda et al., 1977).

TABLE NO. 9

Effect of NaCl Salinity on total protein content * of leaf, stem, root and pods of *P. aconitifolius*.

NaCl Treatment (mM)	Developmental stage											
	II	IV	VI	II	IV	VI	II	IV	VI	II	IV	VI
	Leaf			Stem			Root			Pods		
Control	15.4	6.3	18.3	9.1	6.3	6.8	11.0	27.4	4.6	-	11.4	7.4
10	15.4	9.7	22.7	9.7	6.8	18.2	9.7	25.1	6.3	-	11.9	6.8
25	11.5	12.1	5.7	10.8	27.4	14.9	-	24.5	9.7	-	33.6	9.1
50	12.1	24.5	24.5	16.7	15.4	5.7	-	22.7	5.7	-	-	17.9
100	-	16.7	18.2	-	45.5	20.6	-	12.1	5.7	-	-	19.9

* Values are expressed as g 100^{-1} g dry tissue.

vi) Proline : The level of free proline is higher in the leaves of P.aconitifolius when grown under non-saline conditions (Table 10 and Fig. 12). The highest amount of proline is found to be at the flowering and pod developing stage (187 mg 100^{-1} g). When plants are grown under saline conditions there is slight increase in the level of proline in the leaves during the vegetative stage. However, there is decline in it in the stem however, during the later stages of growth and development. The stem appears to be themain sink or main sight for accumulation or synthesis of proline which is stimulated further by salt stress. This is quite significant during flowering and pod formation stage. The pattern of effect of salt salinity on root proline content is indefinate. It appears that accumulation of proline in stem may be one of the mechanisms of salt tolerance nature of P.aconitifolius.

It is known that proline content of glycophytes are normally negligible, however, this was increased markedly in plants subjected to salinity (Chu et al., 1976; Wyn Jones and Storey, 1978; Huber, 1979). A correlation between proline content and salt tolerance in Aster tripolium has been proposed by Goas (1968). Dreier (1983) has studied the content of proline and the salt resistance of some of the crop plants and found that application of sodium chloride in the culture medium leads to an increase in their endogenous content of

TABLE NO. 10

Effect of NaCl Salinity on proline content of leaf, stem and roots of P. aconitifolius.

NaCl Treatment (m M)	Leaf			Stem			Root		
	II	IV	VI	II	IV	VI	II	IV	VI
Control	32	187	93	45	47	44	-	-	31
10	55	179	45	-	46	71	-	41	44
25	59	20	71	38	177	102	-	43	75
50	63	199	154	41	147	179	-	47	6
100	61	161	93	33	187	62	-	-	-

* Values are expressed as mg 100^{-1}g dry tissue.

EFFECT OF NaCl SALINITY ON PROLINE OF LEAF, STEM AND ROOT OF P. aconitifolius

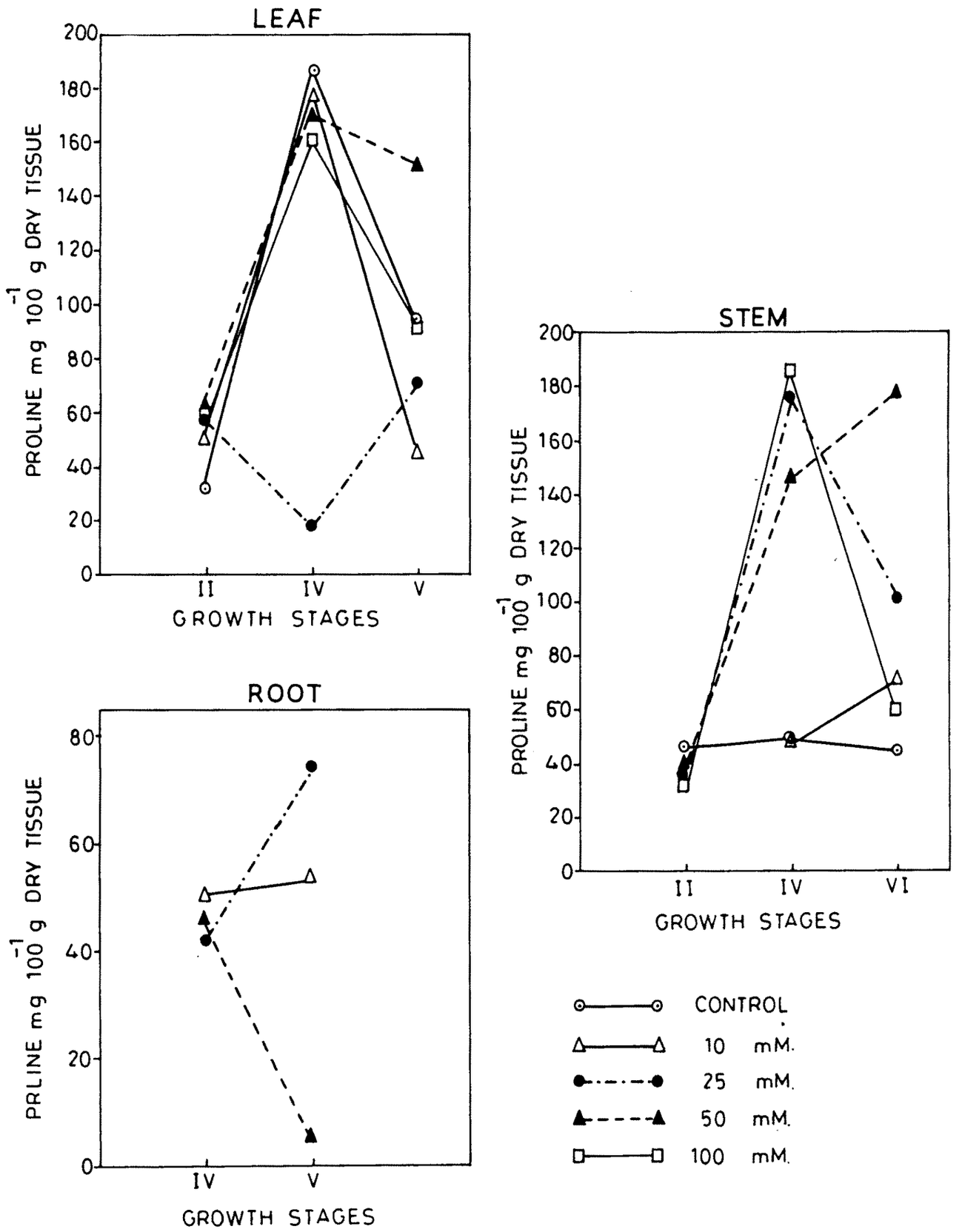


Fig. 12

free proline. There is a certain concentration of NaCl above which the proline content of the plant strongly rises (critical point). In salt sensitive plants like wheat the critical point lies below that of salt tolerant plants like barley. From the present investigation it appears that 25 or 50 mM NaCl concentration is the probable critical point above which there is strong rise in the proline level particularly of stem and leaves. This critical level is comparatively higher than that for many salt sensitive species. Based on this phenomenon the plant can be included in the species moderately salt tolerant.

The exact role of proline in the mechanism of salt tolerance is not clear. It is suggested that proline causes to increase considerably amount of bound water in the leaves (Palfi et al., 1974). It is suggested by Stewart and Lee (1974) that proline may be functioning as a source of soluble or intracellular osmotic adjustment.under saline conditions. According to Goering and Bui (1978) and Weimberg et al., (1982) if the proline accumulates in the cytoplasm it can play a key role on osmotic adjustment.

vii) Enzymes : The influence of NaCl salinity on the activity of some important enzyme systems such as peroxidase, catalase, acid phosphatase and nitrate reductase in leaves and roots of P.aconitifolius has been recorded in to Table 11.

a) Hydroxiperoxidases :

(a1) Peroxidase : Activity of peroxidase of leaf is markedly inhibited only at the highest salinity level (100 mM NaCl). However, the lowest salinity level (10 mM NaCl) is stimulatory for this enzyme system in roots. The higher concentrations, however, are strong inhibitors. Present observations agree with the findings of Flowers (1972) who observed a significant inhibition of Peroxidase in salt tolerant Suaeda maritima. Strogonov (1964), Weimberg (1970), Aleshin et al., (1971) and Molokov et al., (1973) have reported intensification of peroxidase activity due to salinity. Peroxidase can also function as IAA oxidase and it can regulate IAA level thereby influencing plant growth. Present findings with P.aconitifolius indicate that the slight increase in the activity of peroxidase in the leaves upto 50 mM NaCl concentration may be influencing the regulation of growth. Decreased activity of this enzyme at the highest NaCl concentration indicate probability of imbalance in hormone level affecting growth of plants.

(a2) Catalase : It can be seen from Table 11 that activity of catalase in roots is definately decreased with increasing salinity level. However, the effect of salinity on leaf catalase is not definate. It can be seen that at the 10 mM NaCl concentration the activity falls down remarkably

TABLE NO.11

Effect of NaCl Salinity on the activity of *Peroxidase, **Catalase, +Acid phosphatase and ++Nitrate reductase in the leaves and roots of P. aconitifolius.

NaCl	Peroxidase		Acid phosphatase		Catalase		NR	
Treatment (mM)	Leaf	Root	Leaf	Root	Leaf	Root	Leaf	Root
Control	36	43	3.0	10.5	1.8	0.9	0.33	0.82
10	38	75	4.0	12.0	0.6	0.2	0.12	1.15
25	40	10	2.6	6.5	3.7	0.2	0.28	0.90
50	32	-	5.0	-	1.2	-	0.16	0.25
100	24	17	4.0	8.5	0.6	0.2	0.41	0.33

* O. D. min^{-1} g^{-1} fresh tissue.

** mg H_2O_2 broken min^{-1} g^{-1} fresh tissue.

\+ O. D. hi^{-1} g^{-1} fresh tissue.

++ ug NO_2 liberated hr^{-1} g^{-1} fresh tissue.

while due to 25 mM concentration it rises dramatically and falls down again significantly due to higher salinity levels. Similar type of observations are made by Karadge and Chavan (1980) in groundnut var. TMV-10.

According to Tregubenko et al., (1973) the activity of this oxidative enzyme is linked with respiration rate. Catalase has also been found to play an important role in photorespiratory glycolate pathway. Present study suggest that probably there is decrease in the rate of root respiration due to salt stress. However, it is difficult to conclude regarding the leaves.

b) Acid Phosphatase :

Effect of salinity on the activity of enzyme acid phosphatase is also recorded in Table 11. It can be seen that there is increase in the activity of this enzyme even at the low salinity level. However, at the higher concentrations it is still further increased. On the other hand activity of this enzyme in the roots of P.aconitifolius is more only at the lower salinity level (10 mM NaCl concentration). The higher NaCl concentrations, however, seem to be toxic for this enzyme. Stimulation of phosphatases in plants under saline conditions has been reported by Ahmad and Huq (1974). In E.coli Fernley and Walker (1968) observed a two fold activation of alkaline phosphatase by NaCl treatment. Weimberg (1970),

however, found no significant effect of NaCl and other salts on phosphatase system in Pea seedlings. The increase in phosphatase activity in the leaves of P.aconitifolius subjected to salt stress clearly reflects an increase in metabolic activities which may indicate rapid turnover of phosphorus in shoot parts of the plant. Eventhough there is inhibition of this enzyme in roots which may not be sufficient to bring about any disturbances in phosphorus metabolism of plants.

c) Nitrate reductase :

Nitrate Reductase is the key enzyme in nitrogen metabolism of plants. This enzyme is responsible for the nitrate metabolism in particular. It is present almost in all parts of a plant. However, usually it is higher in roots which are directly exposed to the nitrate nutrients in the soil. The effect of sodium chloride salinity on the activity of this enzyme has been shown in Table 11. It is clear that with increasing soil salinity there is inhibition of this enzyme in the leaves even at the low soil concentration. However, it is slightly stimulated in the roots upto 25 mM NaCl concentration. Higher concentrations however are strong inhibitors for this enzyme both in leaves as well as in roots. An inhibition of nitrate reductase by salinity in glycophytic species has been recorded by few workers (Weimer, 1973; Plaut, 1974; Dwivedi et al., 1982). Karadge and Joshi (1983) have recorded

TABLE NO. 12

Effect of NaCl Salinity on inorganic constituents * of the leaves of P. aconitifolius.

(Soil culture)

	Control			10 mM NaCl			25 mM NaCl			50 mM NaCl			100 mM NaCl		
	II	IV	VI	II	IV	VI	II	IV	VI	II	IV	VI	II	IV	VI
Na	0.24	0.22	0.19	0.28	0.41	0.39	0.37	0.20	0.21	0.73	0.92	1.70	-	1.34	1.50
K	1.60	1.70	1.40	1.54	1.63	1.50	1.40	1.23	1.13	1.73	1.20	0.95	-	1.41	1.21
K : Na	6.70	7.70	7.40	5.50	3.97	3.90	3.80	6.20	5.40	2.40	1.30	0.60	-	1.10	0.81
Cl	1.60	0.32	2.90	1.60	4.10	4.10	1.60	6.60	0.32	-	1.30	0.96	-	7.30	4.80
Na : Cl	0.15	0.69	0.07	0.18	0.10	0.09	0.23	0.03	0.66	-	0.71	1.80	-	0.18	0.31
Ca	6.10	6.60	6.80	6.60	6.20	7.04	5.70	7.30	5.90	6.4	7.00	5.50	-	7.70	5.70
P	0.36	0.19	0.16	0.73	0.22	0.22	0.18	0.36	0.18	0.20	0.38	0.27	-	0.22	0.20
Mg	0.72	0.64	0.67	0.68	0.45	0.62	0.56	0.66	0.57	0.62	0.78	0.46	-	0.72	0.62
Fe	0.27	0.30	0.15	0.38	0.41	0.21	0.13	0.15	0.21	0.22	0.07	0.14	-	0.09	0.65
Mn	0.15	0.25	0.04	0.03	0.35	0.15	0.11	0.02	0.02	0.09	0.05	0.03	-	0.05	0.32

* Values are expressed as g 100^{-1} g dry tissue.

overall decrease in the activity of this enzyme in Portulaca oleracea grown under saline conditions. They have suggested that decreased activity of NR affects the nitrogen content of the leaves producing nitrogen deficiency symptoms. We have already seen that uptake and distribution of nitrogen in P.aconitifolius is slightly affected producing low level of nitrogen in plants. Thus, this can be attributed to lowered NR activity under saline conditions.

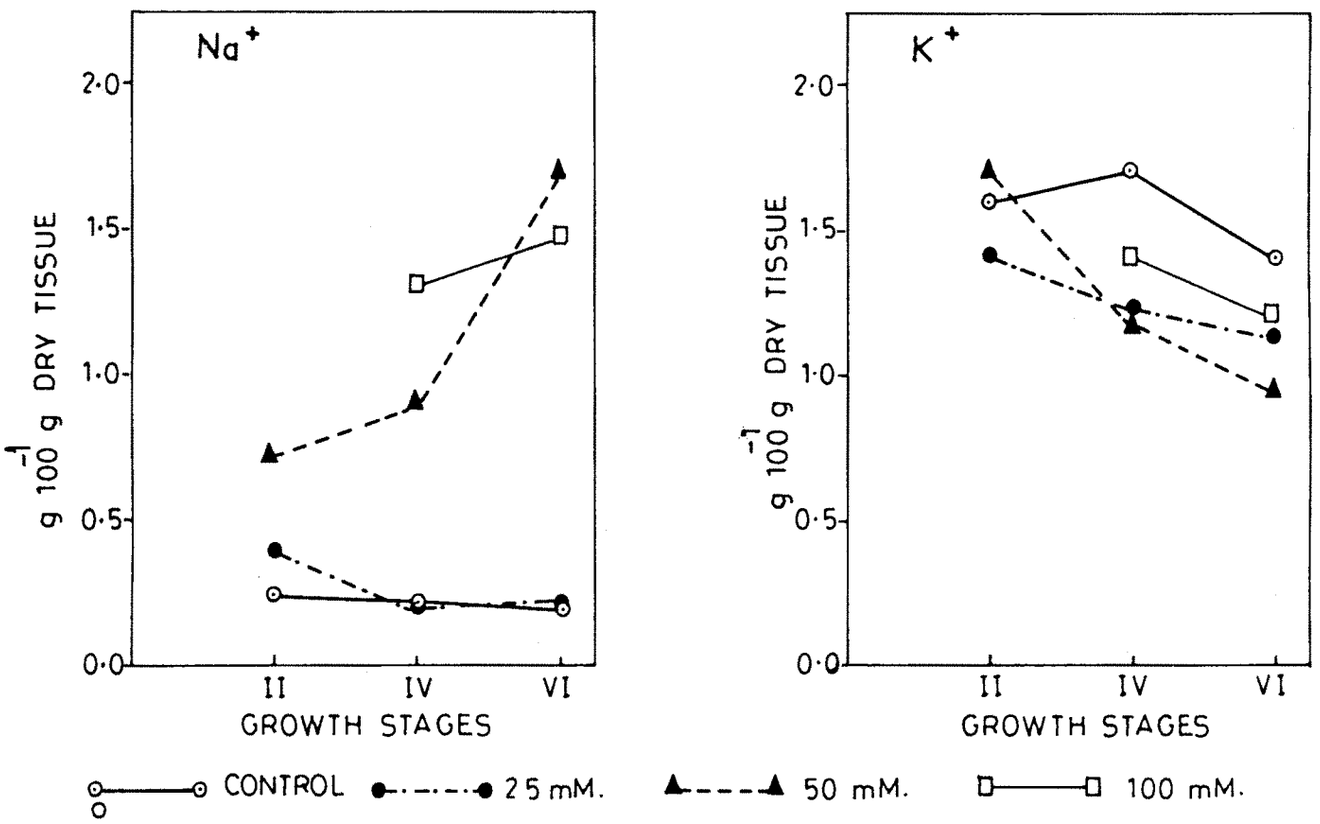
3. Effect of NaCl salinity on mineral Nutrition :

A. Soil Culture :

Uptake and distribution of different mineral constituents in different parts of P.aconitifolius plants at different stages of growth and the influence of NaCl salinity there on have been depicted in Tables 12 to 14 and Fig. 13 to 18. It is evident that both stages of growth and the salinity influence the mineral nutrition of this plant considerably.

i) Na^+ and Cl^- uptake : It is clear from the results that both these nutrients are equally distributed in leaf, stem and root parts of the plant. With the advancement of growth the Na^+ gets slightly accumulated in roots and to some extent in the stem. However, the Na^+ content of leaves decreases with growth of the plant. On the other hand Cl^- seems to be accumulated in all plant parts towards maturity. With the

EFFECT OF NaCl SALINITY ON Na^+, K^+ AND Cl^- CONTENTS AND $K^+ : Na^+$ RATIO IN LEAVES OF *P. aconitifolius*



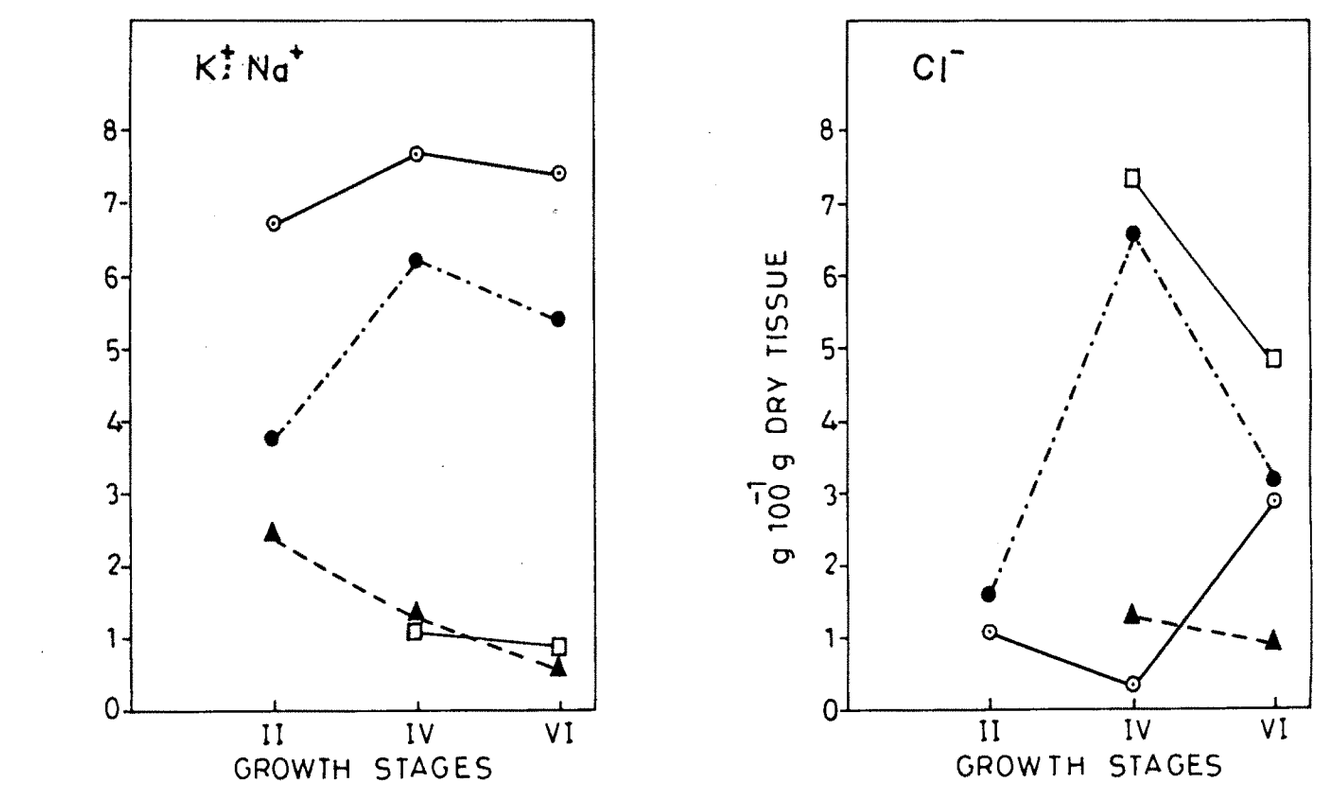


Fig. 13

increasing concentration of NaCl salinity in the medium there is accumulation of both the elements in all parts of the plant. Na^+ accumulated more in the later stages of growth. It can be seen that the leaves of plants grown in non-saline condition show the Na^+ value ranging from 0.19 to 0.24 g 100 g^{-1} dry tissue which is elevated to 1.50 g 100 g^{-1} dry tissue in the plants treated with 100 mM NaCl salinity. The maximum amount of this element recorded for stem is also the same, however, it is in plants treated with 50 mM NaCl salinity. The corresponding value for roots is still higher (1.60 g 100 g^{-1} dry tissue in 100 mM NaCl treatment). The highest amount of Cl^- is accumulated in the stem at 100 mM NaCl level followed by leaves at the same salinity level. It appears that both these elements are very easily translocated to the shoot parts of the plant where they get accumulated under saline conditions. From the Na:Cl ratios it is evident that as this ratio increases from 0.07 to 1.80 in control and 50 mM NaCl salinity respectively, there is relatively more accumulation of Na^+ than Cl^-. However, it appears that uptake and accumulation of Cl^- in the leaves is more at the highest salinity level. When we look to this ratio in stem and roots, it indicates that Na^+ is tremendously accumulated in these plant parts, particularly in stem, under saline conditions. It can be, therefore, said that Na^+ uptake is relatively more in this plant under saline conditions. However, it seems that the leaves, the most active parts of the

TABLE NO. 13

Effect of NaCl Salinity on inorganic constituents* of the stem of *P. aconitifolius*.

(Soil culture)

	Control			10 mM NaCl			25 mM NaCl			50 mM NaCl			100 mM NaCl		
	II	IV	VI	II	IV	VI	II	IV	VI	II	IV	VI	II	IV	VI
Na	0.23	0.24	0.18	0.39	0.28	0.58	0.46	0.48	0.48	0.56	0.59	1.50	-	0.57	0.99
K	3.50	1.60	1.80	3.96	1.50	1.80	3.10	1.20	1.96	2.20	2.10	1.63	-	1.60	0.48
K : Na	15.20	6.7	10.00	10.20	5.40	3.10	6.70	2.50	4.10	3.90	3.60	1.10	-	2.80	0.49
Cl	11.60	2.90	0.96	0.32	2.90	3.50	0.96	4.10	4.10	-	3.90	4.80	-	8.60	3.50
Na : Cl	0.14	0.08	0.19	1.20	0.96	0.17	0.48	0.12	0.12	-	0.20	0.31	-	0.07	0.28
Ca	4.10	3.30	3.10	3.74	2.53	3.10	3.74	5.94	2.90	4.60	4.40	2.20	-	2.97	1.32
P	0.54	0.32	0.27	0.54	0.11	1.60	0.34	0.27	0.09	0.09	0.54	0.43	-	0.18	0.34
Mg	0.62	0.31	0.46	0.62	0.54	0.31	0.42	0.97	0.43	0.55	0.77	0.45	-	0.64	0.37
Fe	0.07	0.10	0.05	0.11	0.06	0.07	0.08	0.07	0.02	0.06	0.01	0.04	-	0.11	0.94
Mn	0.04	0.02	0.02	0.07	0.04	0.06	0.05	0.02	0.09	0.02	0.04	0.02	-	0.03	0.56

* Values are expressed as g 100^{-1}g dry tissue.

plant, are kept away from the toxic accumulation of this element. Thus the selective absorption of these elements in P.aconitifolius seem to be an adaptive feature for its moderate salt tolerance nature (Karadge and Chavan, 1983).

Increased accumulation of Na^+ has been reported by many workers (Downton, 1978; Ansari et al., 1978; Laszlo and Kuiper, 1980; Karadge and Chavan, 1979; Chavan and Karadge, 1980). Storey and Win Jones (1978) have correlated the greater salt sensitivity of Arinur cultivar of barley with a poor ability of plant to regulate Na^+ and Cl^- accumulation in shoots. Present observation, however, suggest that P.aconitifolius possesses a good capacity for vegetation of sodium uptake upto the 50 mM NaCl concentration. Sodium has been shown to be relatively more harmful component of salinity (Gates et al., 1970; Wienke and Lauchli, 1980) and possibly by checking its translocation to leaves the plant can adapt to saline conditions. At the highest salinity level (100 mM NaCl) as both the ions are accumulated equally and more in all parts of the plant, probably the higher concentration NaCl and not individual ions may be toxic to the plant metabolism, retarding the growth and development.

ii) K^+ Uptake : Experiments by Rozema (1976) with Juncus species revealed the important contribution of K^+ to the total osmotic potential. It is worth noting that K^+ fluxes

EFFECT OF NaCl SALINITY ON Ca^{2+}, P^{5+}, Mg^{2+} and Fe^{3+} CONTENTS OF THE LEAVS OF *P. aconitifolius*

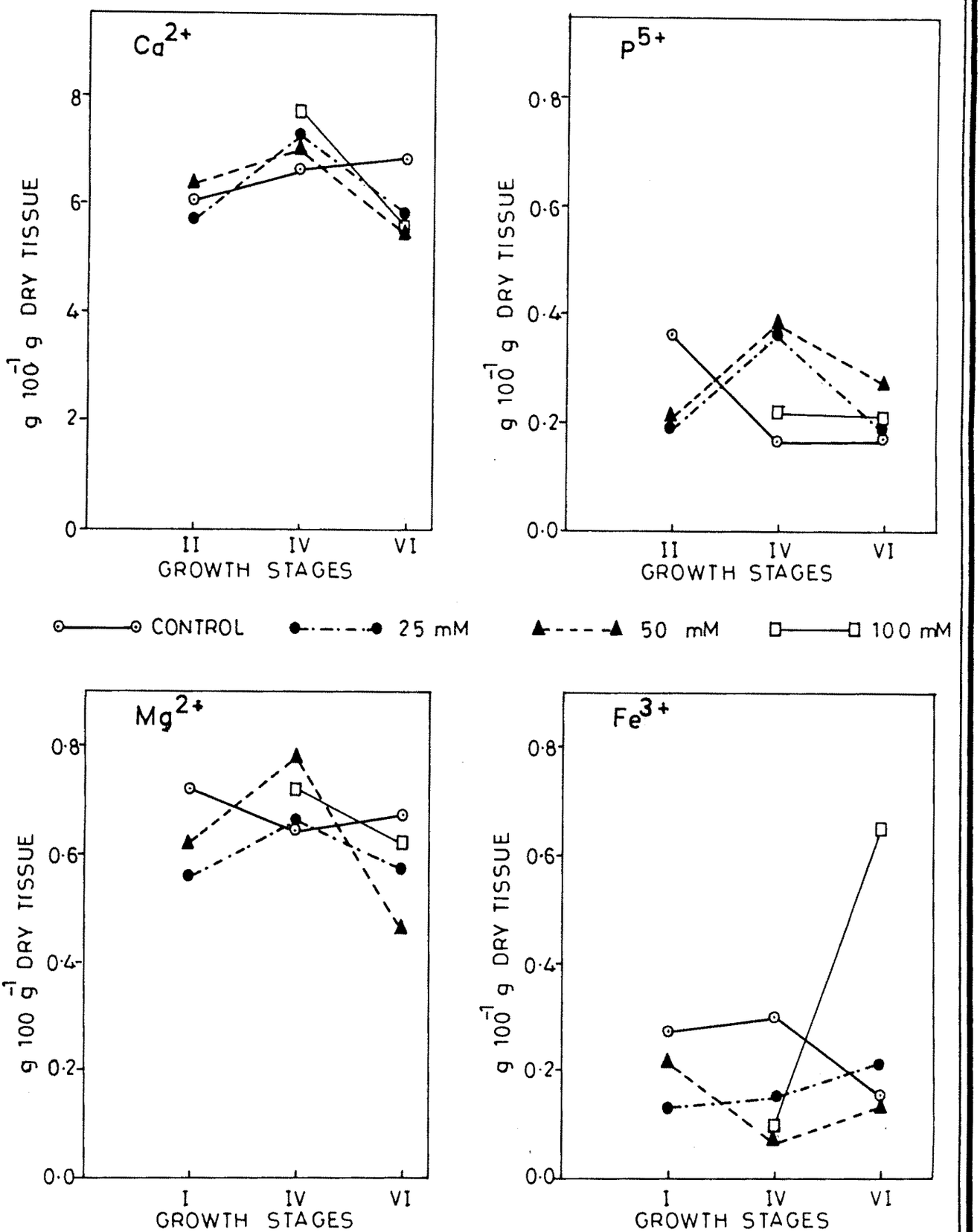


Fig.14

are not only important to salinity but they are integral to a wide range of turgor mediated responses in plants including stomatal and leaf movements (Maas and Nieman, 1978).

It is clear from the observations that usually the K^+ content of all parts of P.aconitifolius is relatively high during the vegetative (II) and the pod formation stage (IV), and falls down at the maturity stage. This is indication of an important role of this element in the rapidly growing parts of the plant during the early phases of growth. Towards maturity, when the leaves mature and senesce, probably this important nutrient is translocated to the developing pods.

It is also evident that with increasing salinity level particularly above 25 mM NaCl concentration in the medium there is less uptake of this cation. However, the uptake and distribution of K^+ is markedly affected due to the highest salinity level (100 mM NaCl) where growth retardation is observed. This is evident from the values for K^+ recorded in different parts of the plant (K^+ : Na^+ ratio, however, is decreased due to stress at all salinity regimes (Table 12 to 14 and Fig. 13, 15 and 17) in all parts of the plant. It is interesting to note here that K^+ content in control plants is quite high when we compare it with the optimum value, 1% suggested by Epstein (1972) and it can be seen that at all salinity levels K value is maintained above this optimum such

TABLE NO. 14

Effect of NaCl Salinity on inorganic constituents* of the root of P. aconitifolius.

(Soil culture)

	Control			10 mM NaCl			25 mM NaCl			50 mM NaCl			100 mM NaCl		
	II	IV	VI	II	IV	VI	II	IV	VI	II	IV	VI	II	IV	IV
Na	0.23	0.28	0.25	0.24	0.24	0.32	0.42	0.21	0.55	0.31	0.31	0.96	-	0.35	1.60
K	1.32	1.60	1.20	1.60	1.20	0.73	1.50	1.14	1.40	1.30	1.20	1.43	-	1.10	1.70
K : Na	5.73	5.71	4.80	6.70	5.00	2.30	3.60	5.40	2.60	4.20	3.90	1.50	-	3.10	1.10
Cl	-	-	2.90	-	2.90	0.96	-	4.80	1.00	-	-	0.96	-	0.32	1.59
Na :Cl	-	-	0.09	-	0.08	0.33	-	0.04	0.55	-	-	1.00	-	1.10	1.10
Ca	2.53	1.54	1.80	2.53	1.21	1.10	2.20	2.20	1.80	2.80	2.31	1.21	-	1.43	2.80
P	0.70	0.04	0.20	0.52	0.13	1.40	0.35	0.32	0.20	0.18	0.36	0.19	-	0.14	0.41
Mg	0.41	0.44	0.28	0.56	0.38	0.31	0.41	0.46	0.47	0.51	0.35	0.37	-	0.31	0.72
Fe	0.36	0.37	0.72	0.27	0.43	0.34	0.73	0.24	0.41	0.06	0.31	0.68	-	0.33	0.09
Mn	0.24	0.35	0.04	0.29	0.19	0.06	0.39	0.12	0.07	0.03	0.05	0.40	-	0.01	0.09

* Values are expressed as g 100^{-1} g dry tissue.

high levels of K^+ (5-10% dry wt.) have been reported for halophytes and in particular the Chenopodiaceae members (Flowers et al., 1977).

The work of Sutcliff (1962) has clearly indicated that marine plants have developed efficient mechanism of K^+ uptake. Rains and Epstein (1967) have also shown the preferential absorption of K^+ in mangroves. A preferential absorption of K^+ under saline conditions by many mangroves has been demonstrated by Joshi (1976). From these reports it is quite clear that K^+ plays an important role in halophytes towards salt tolerance. However, this preferential K^+ uptake mechanism in presence of salt is lacking in most of the glycophytes (Guillen et al., 1978; Laszlo and Kuiper, 1979; Chen et al., 1980; Karadge and Chavan, 1979, Chavan and Karadge, 1980). From the present studies it appears that P.aconitifolius is rather moderately salt tolerant as the values of K^+ recorded for different parts are not comparable to those for mangroves but are intermediate and the K^+ content does not fall below the optimum even under saline conditions.

iii) Ca^{2+} uptake : Uptake and distribution of Ca by P.aconitifolius plants during their growth the effect of soil salinity there on have been recorded in Tables 12 to 14 and Fig. 14, 16 and 18. It is clear that Ca content of the leaves increases linearly with the advancement of the growth stage.

EFFECT OF NaCl SALINITY ON Na^+, K^+ and Cl^- CONTENTS and K:Na RATIO IN THE STEM OF *P. aconitifolius*

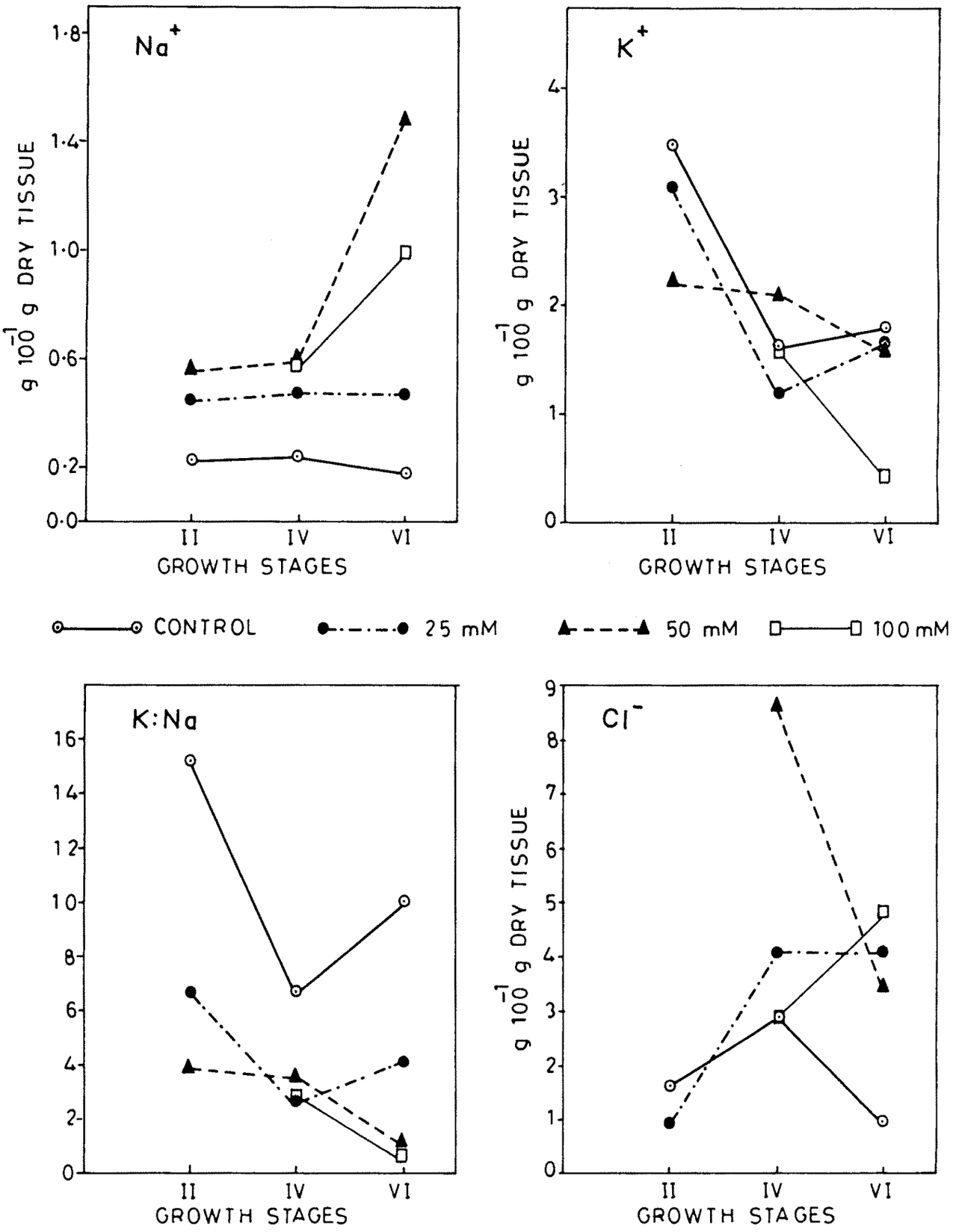


Fig. 15

However, it is on decrease in stem and roots. This is suggestive of the phenomenon that once Ca is absorbed it is deposited in the leaves. Accumulation of Ca in mature and senescent leaves of plants is well known. With increasing soil salinity there is more uptake of this divalent cation and it gets accumulated in the leaves in particular. The Ca level in stem is rather low due to salinity. However, there is no definate pattern regarding accumulation of this elements in roots. It appears that even under saline conditions the uptake and translocation of Ca is not affected.

A great importance has been attributed to Ca in salt tolerance (Elzam and Epstein, 1969; La-Haye and Epstein, 1969). Recovery from the damage due to salt stress by application of calcium sulfate in the medium was reported by Chimiklis and Karlander (1973). Epstein (1971) suggested an antagonism between sodium and calcium. A reduction in calcium uptake under saline conditions in salt sensitive plants is observed by several workers (Matar et al., 1975; Guggenheim and Waisel, 1977; Laszlo and Kuiper, 1979; Chavan and Karadge, 1980; Starck and Kozinska, 1980; Divate and Pandey, 1981). At the same time there are reports of increase in Ca contents in some plant species under saline conditions (Joolka et al., 1977; Ayoub, 1977). According to Bernstein and Hayward (1958) a degree of physiological balance between Na^+ and Ca^{2+} must be present if toxicity due to high concentration of Na alone is to be avoided.

The requirement of Ca^{2+} in maintaining membrane integrity and selective transport of other ion is well documented by Wyn Jones and Lunt (1967). Ca has been shown to regulate membrane properties and it is proposed that Ca and Na probably complete for common uptake sites (Lessani and Marschner, 1978). It appears that in P.aconitifolius Ca supresses Na uptake and probably contributes to ionic balance with chloride ions. Thus, Ca may add to the mechanism of salt tolerance in this plant.

iv) P^{5+} : Importance of P accumulation in the resistance to secondary salt induced stress has been reported by Wilson et al., (1970). Accumulation of this ion indifferent parts of salt tolerant as well as sensitive plants grown under saline conditions has been reported by many workers (Narayanan, 1975; Chavan and Karadge, 1980). Contrary to the above observations there are several reports were reduced P uptake due to salt stress has been observed (Pleinkopf et al., 1975; Dahiya and Singh, 1976; Tindal et al., 1979; Starach and Kozinska, 1980, Karadge and Chavan, 1983).

Uptake and distribution of P in P.aconitifolius during its growth and salinity effect there on have been recorded in Tables 12 to 14 and Fig. 14, 16 and 18. It is evident that the level of P falls down with the advancement of growth both in leaves and stem. This is quite significant during IVth and VIth stages of growth. This is probably due to translocation

EFFECT OF NaCl SALINITY ON Ca^{2+} P^{2+} Mg^{2+} and Fe^{3+} CONTENTS OF THE STEM OF P. aconitifolius

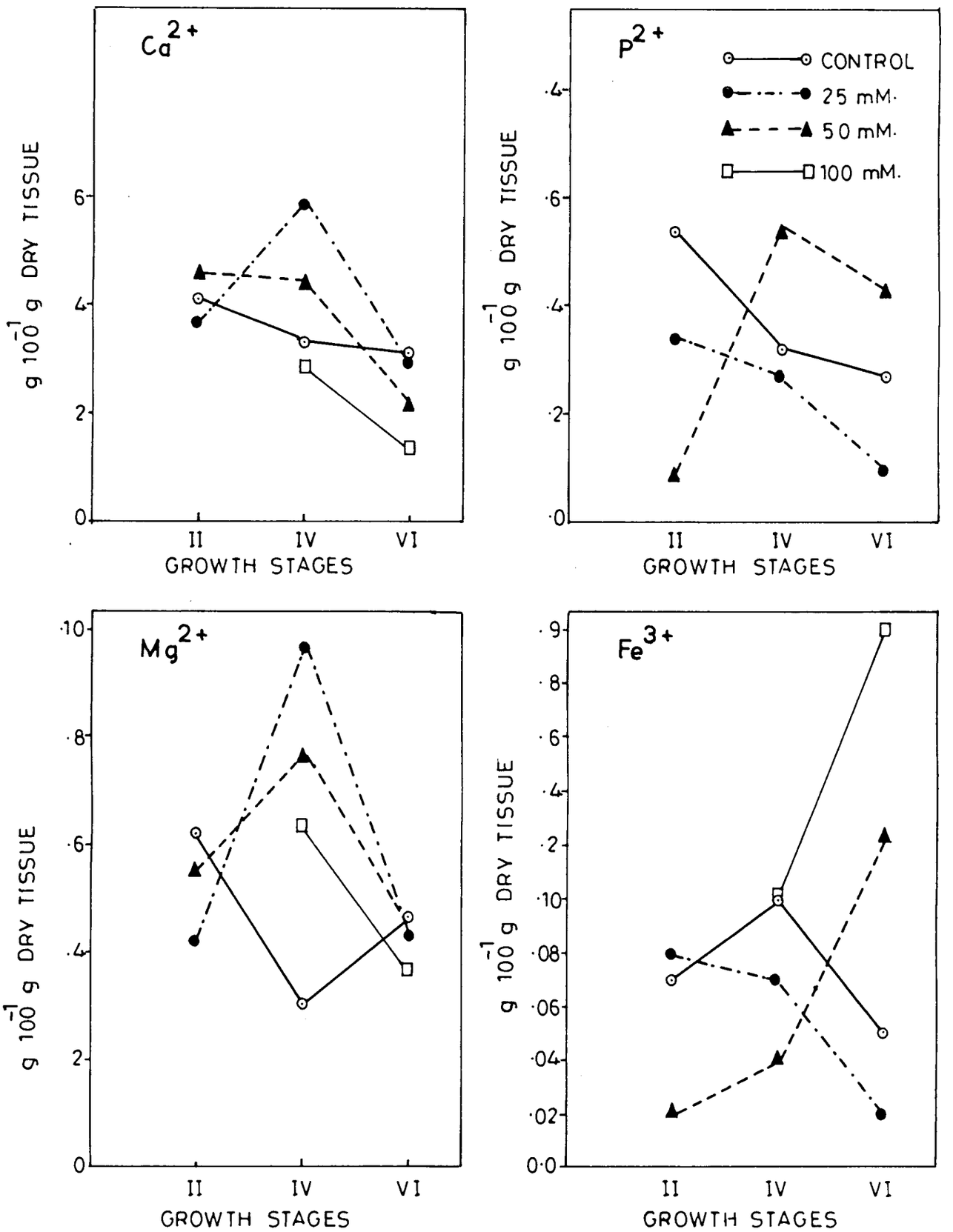


Fig. 16

of this nutrient through the developing pods. With increasing soil salinity there is accumulation of P in the leaves. However, there is no definate pattern of P content of the stem as influenced by NaCl salinity. It is also observed that P content is comparatively high in the roots. From the present studies it appears that the uptake and distribution of P is slightly affected due to salinity in P.aconitifolius.

v) Mg^{2+} : Very little work has been done regarding the role of Mg in salt tolerance. Atkinson et al., (1967) have stated that Mg maintains the salt balance in the leaves of Aegialitis, a mangrove species. Bernstein (1975) has claimed that the tolerance of species for particular salt reflects the ability of species to absorb nutritionally adequate levels of Ca and Mg from the soil. Increase in Mg content due to salinity has been reported by many workers (Syed and Swaify, 1973; Guillen et al., 1978). Contrary to the above report some workers have reported decreased Mg uptake due to salinity (Kleinkopf et al., 1975; Ackerson and Youngner, 1975; Guggenheim and Waisel, 1977; Laszlo and Kuiper, 1979). Thus from these evidence it is not definate whether Mg plays a role in salt tolerance of plants or not.

Leaves of P.aconitifolius show the presence of maximum amount of Mg, that least being in roots. Mg content of all plant parts is not changing during different stages of growth.

Uptake and distribution of this element (Tables 12 to 14 and Fig.14, 16 and 18) is less affected due to salinity. It is evident that during IVth stage of growth the Mg content of leaves increases even under saline conditions. However, in the later stages there is continuous decrease in it. Probably this may be due to stimulation of early maturity and senescence of leaves due to salinity which may result the withdrawl of this essential element and its translocation to developing as well as maturing pods. With the present investigation, therefore, it can be suggested that an increment of Mg particularly in the leaves under saline conditions is certainly beneficial in view of essentiality of this element in various biochemical processes.

vi) Fe^{3+} and Mn^{2+} : Uptake and distribution of Fe and Mn in P.aconitifolius during its growth under non-saline and saline conditions have been depicted in Tables 12 to 14 and Fig. 14, 16 and 18. It is evident that iron is accumulating more in the roots and it gets on accumulating with the advancement of growth stage. The values for this element in the stem are very low while those for leaves are intermediate. Same is also true for another micronutrient Mn. Due to NaCl salinity there is decrease in the amount of Fe and Mn in the roots while they are accumulated in stem and leaves. This is quite significant in the plants grown in the toxic salt medium (100 mM NaCl).

EFFECT OF NaCl SALINITY ON Na^+, K^+ and Cl^- CONTENTS and $K^+:Na^+$ RATIO IN THE ROOTS OF *P. aconitifolius*

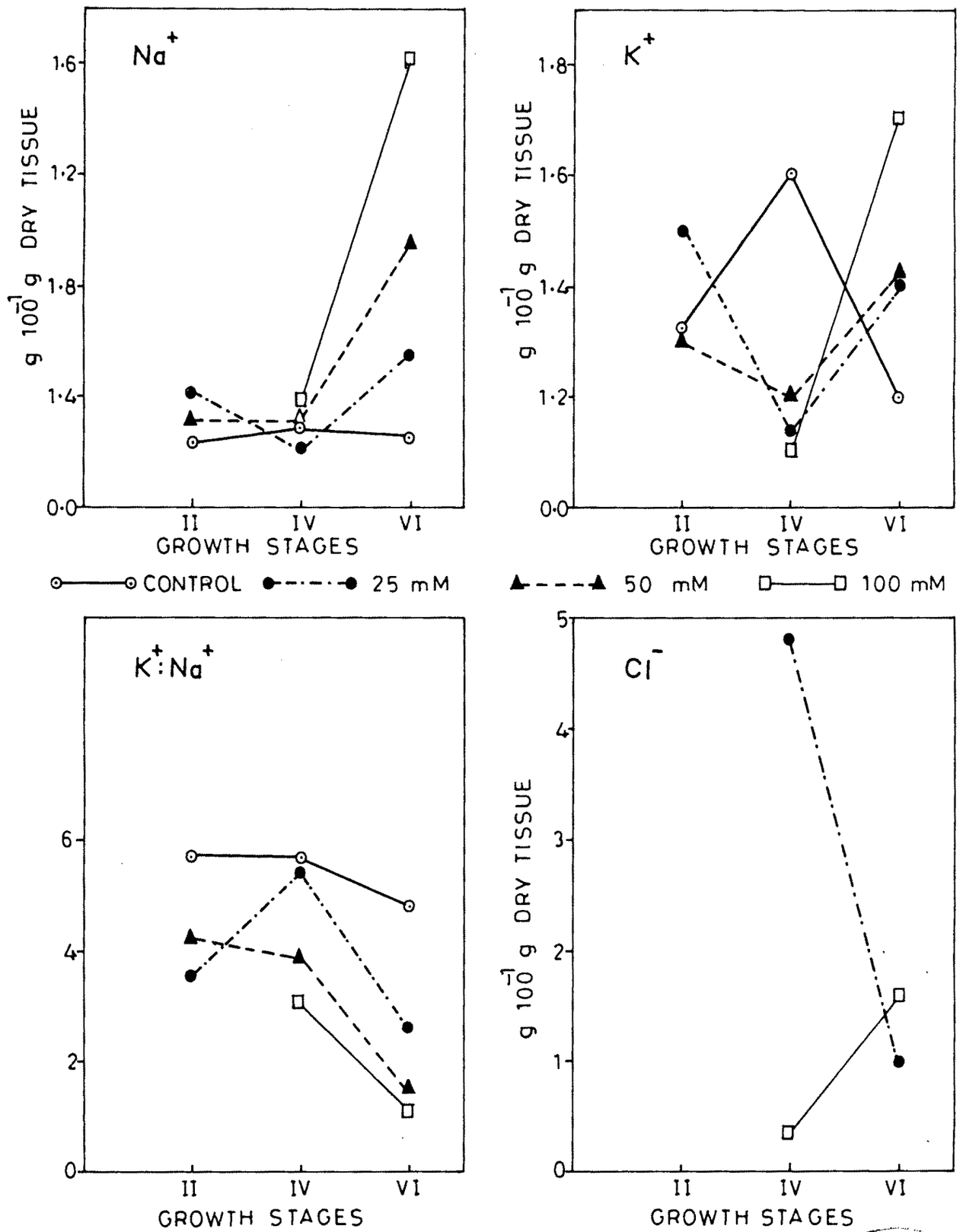


Fig.17

It appears that due to salinity the translocation of both the micronutrients is stimulated resulting in accumulation of these elements in the leaves. If the accumulation is high enough as it is observed in case of 100 mM NaCl treatment, it becomes toxic.

There are very few attempts which describe effect of salinity on Fe and Mn metabolism. Dahiya and Singh (1976) have recorded an increment of Fe content in different parts of Peas due to salinity. Shimose (1972) observed that species differ in respect of Fe uptake in salt rich environment. According to Maas et al., (1972) increase in Fe content may be due to the restricted growth of the tops or due to abrupt changes of membrane permeability. Karadge and Chavan (1983) have observed stimulation of Fe absorption due to salinity in Sesbania species. They found that iron remains to be accumulated in roots and thus the leaflets are kept away from the accumulation of this ion. In P.aconitifolius it appears that the translocation of iorn and its accumulation in leaves is notably high only in plants grown at 100 mM NaCl level. This iron concentration may be toxic and hence there is retardation of growth only at this salinity level.

Hasson et al., (1970), have shown a positive correlation between soil salinity and Mn content of the plant. Maas et al., (1972) found that Mn content increase in tomato and soybean

EFFECT OF NaCl SALINITY ON Ca^{2+}, P^{5+}, Mg^{2+} and Fe^{3+} CONTENTS OF THE ROOT OF *P. aconitifolius*

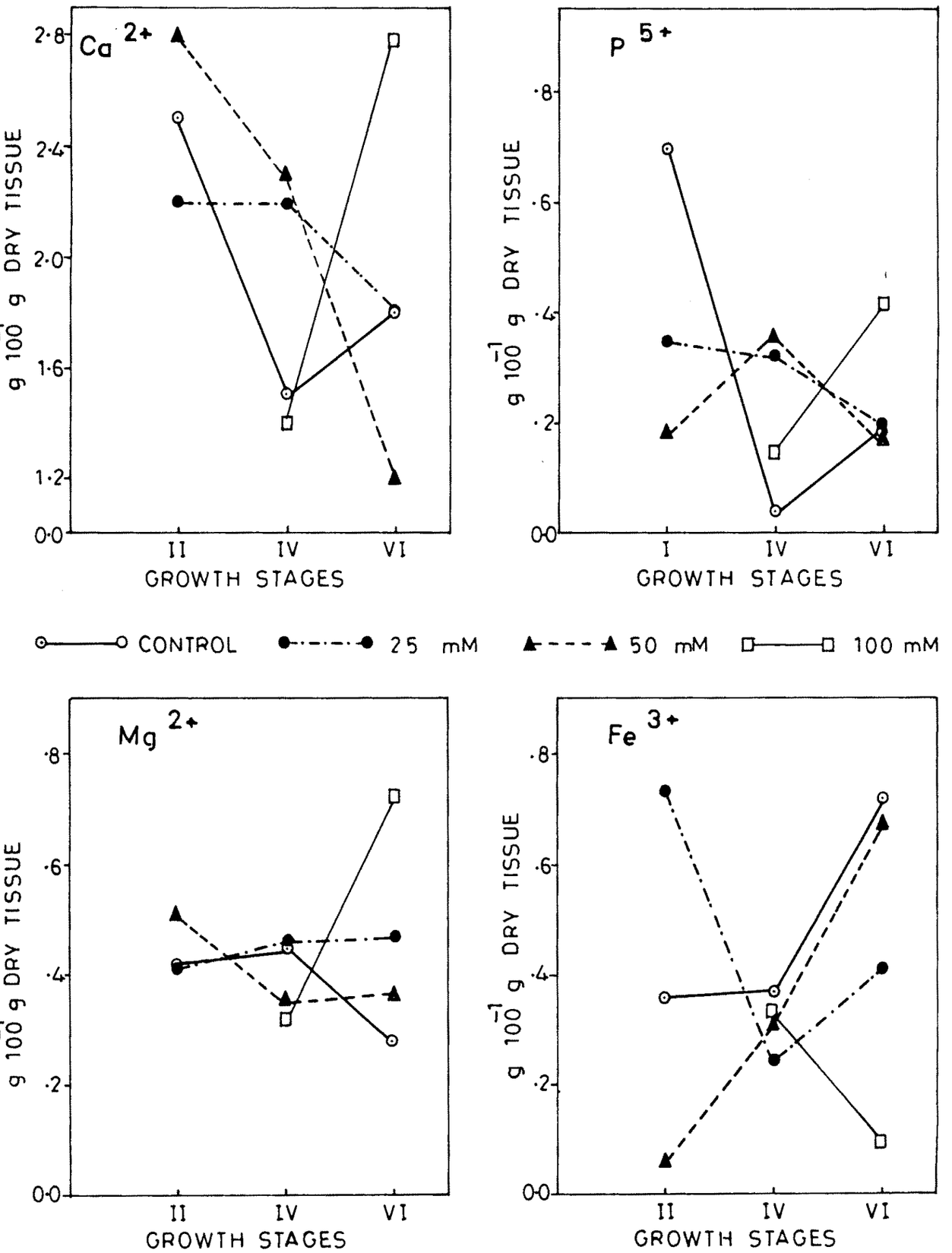


Fig. 18

TABLE NO. 15

Effect of NaCl and NaCl + $CaCl_2$ Salinity (slow and shock treatments) on the inorganic constituents* of the young leaves of P. aconitifolius. (Sand culture)

Treatment (mM)	Na^+	K^+	K^+; Na^+	Ca^{2+}	P^{5+}	Mg^{2+}	Fe^{3+}	Mn^{2+}
Control	0.43	2.72	6.33	1.6	0.18	0.160	0.065	0.010
25 NaCl (shock)	3.52	1.70	0.48	1.2	0.18	0.090	0.033	0.027
100 NaCl (shock)	2.64	1.36	0.52	1.0	0.07	0.040	0.032	0.019
25 NaCl (slow)	3.52	3.48	1.00	1.3	0.09	0.060	0.059	0.032
100 NaCl (slow)	4.40	2.72	0.62	0.8	0.19	0.050	0.038	0.010
12.5 NaCl + 12.5 $CaCl_2$ (shock)	1.76	3.40		2.1	0.18	0.064	0.035	0.019
25 NaCl + 25 $CaCl_2$ (shock)	2.90	3.06	1.06	2.8	0.22	0.030	0.033	0.025
50 NaCl + 50 $CaCl_2$ (shock)	0.89	2.04	2.29	2.6	0.09	0.056	0.034	0.037
100 NaCl + 100 $CaCl_2$ (shock)	0.79	1.36	1.72	2.6	0.43	0.008	0.021	0.019

* Values are expressed as g 100^{-1} g dry tissue.

tops but decreased in squash. Accumulation of Mn in P. aconitifolius plant parts under saline conditions particularly at lower concentrations of salt, may be beneficial for its growth and development.

From the foregoing discussions it can be suggested that P.aconitifolius has got well developed selective ion absorption property with respect to uptake of K, Ca, P and Mg. It has an ability towards regulation of Na uptake. These properties are more pronouncing at the lower salinity levels. This clearly indicates the moderately salt tolerant nature of this plant.

B) Sand Culture :

To study the effect of salinity as slow and shock treatments and the role of Ca^{2+} in the salinity tolerance the P.aconitifolius plants were raised in acid free silica sand. The treatments were commenced after about one month when the plantlets were well established. The slow treatments were continued till the highest salinity level treatment is just completed. However, the shock treatments were given i.e. the plants in different pods were treated with different concentrations of NaCl added in the Hoagland nutrient medium. It has been found that in the saline soils usually Ca^{2+} in the soil is unavailable to the plants growing in and hence the

plants show the symptoms well contributing to calcium deficiency. Hence while evaluating the salinity experiments, as suggested by U.S. Salinity Laboratory, $CaCl_2$ should be supplied externally to compensate the unavailable Ca^{2+}. Usually NaCl and $CaCl_2$ are suggested to be mixed in the proportion of 1:1. In the present study therefore, the effect of salinity developed in this way on the growth and uptake and distribution of mineral nutrients has been investigated. The results obtained are recorded in Table 15 to 18.

It was found that when $CaCl_2$ was mixed along with NaCl in the medium (100 mM NaCl + 100 mM $CaCl_2$) and the plants treated for 2-3 consecutive treatments alternating with watering the plants, the plant leaves started showing burning symptoms and at the end of 3rd and 4th treatment almost all parts of the plant were dried and decayed. The plants treated by NaCl salinity as shock treatment showed the salinity affected symptoms immediately after 2-3 treatments. Therefore, in the experiment to study the effect of NaCl salinity in the presence of sufficient amount of $CaCl_2$ the plants were harvested after only three treatments. Plants from the slow and shock treatments were analysed one or two treatments later. The results have been recorded in Table 15 to 18.

It is evident that Na^+, K^+ and P^{5+}, uptake is more in the plants grown in sand culture while Ca^{2+}, Mg^{2+}, Fe^{3+} and

TABLE NO. 16

Effect of NaCl and NaCl + $CaCl_2$ Salinity (slow and shock treatments) on the inorganic constituents* of the mature leaves of P. aconitifolius. (Sand culture)

Treatment (mM)	Na^+	K^+	K^+; Na^+	Ca^{2+}	P^{5+}	Mg^{2+}	Fe^{3+}	Mn^{2+}
Control	0.35	2.72	7.77	2.6	0.12	0.260	0.066	0.037
25 NaCl (shock)	2.20	1.36	0.62	3.2	0.07	0.170	0.065	0.047
100 NaCl (shock)	3.52	1.36	0.39	2.4	0.18	0.180	0.044	0.010
25 NaCl (slow)	0.80	3.06	3.83	0.7	0.28	0.059	0.055	0.025
100 NaCl (slow)	3.96	2.38	0.60	1.4	0.43	0.150	0.055	0.037
12.5 NaCl + 12.5 $CaCl_2$	0.79	4.08	5.16	2.8	0.22	0.038	0.024	0.010
25 NaCl + 25 $CaCl_2$	3.30	2.72	0.82	3.3	0.18	0.033	0.076	0.037
50 NaCl + 50 $CaCl_2$	0.67	2.72	4.06	3.5	0.04	0.020	0.016	0.025
100 NaCl + 100 $CaCl_2$	0.88	2.04	2.32	3.6	0.12	0.100	0.044	0.035

* Values are expressed as g 100^{-1}g dry tissue.

Mn^{2+} are absorbed less. Thus, it appears that the method of culture has a profound influence on the ion uptake and other processes.

It is clear that Na^{+} gets accumulated more in the leaves of plants grown at both 25 mM and 100 mM NaCl levels in the slow salt treatments. However, the uptake of Na^{+} is definately affected due to presence of Ca^{2+} at all salinity levels. The same is also true for stem and roots. It can be seen that at low salinity level (25 mM NaCl, shock) Na is remaining accumulated in the roots. It can be suggested that presence of sufficient amount of Ca^{2+} in the medium checks the uptake and translocation of Na^{+}. Thus it appears that presence of Ca^{2+} in the medium affects the absorption and translocation of Na^{+}. The burning symptoms observed thus appear to be due not to the ionic effect but may be due to osmotic effect.

It is evident that the K uptake and its distribution in different parts of the plants is variously influenced by different methods of salt application. When NaCl was applied alone and as a shock treatment there is inhibition of K uptake. This is evident from the values for K in all plant parts. However, when salt is applied alone but with slow treatment the K uptake and distribution seems to be normal and even it is include at lower salinity level (25 mM). This indicates that probably the plant gets adapted to the saline environment due

S - TABLE NO. 17

Effect of NaCl and NaCl + $CaCl_2$ Salinity (slow and shock treatments) on the inorganic constituents* of the stem of P. aconitifolius. (Sand culture)

Treatment (mM)	Na^+	K^+	K^+; Na^+	Ca^{2+}	P^{5+}	Mg^{2+}	Fe^{3+}	Mn^{2+}
Control	0.13	2.38	18.30	1100	0.09	0.099	0.098	0.025
25 NaCl (shock)	0.32	2.72	8.50	1.0	0.12	0.076	0.043	0.010
100 NaCl (shock)	3.96	2.72	0.67	1.1	0.18	0.150	0.043	0.032
25 NaCl (slow)	0.55	4.42	8.04	0.9	0.09	0.130	0.033	0.010
100 NaCl (slow)	0.94	2.72	2.89	0.7	0.19	0.038	0.044	0.019
12.5 NaCl + 12.5 $CaCl_2$	0.78	3.40	4.36	3.7	0.52	0.089	0.027	0.019
25 NaCl + 25 $CaCl_2$	0.55	3.74	6.80	2.8	0.22	0.082	0.098	0.025
50 NaCl + 50 $CaCl_2$	0.69	3.54	5.13	3.1	0.12	0.130	0.022	0.010
100 NaCl + 100 $CaCl_2$	0.88	2.72	3.09	3.1	0.43	0.051	0.087	0.052

* Values are expressed as g 100^{-1}g dry tissue.

to slow treatment. Addition of $CaCl_2$ with NaCl salt upto 50 mM concentrations stimulates the K uptake and distribution. The K content of young and mature leaves as well as stem is always higher than that of control. When we look to the K : Na ratio it is severely affected due to shock treatments when salt was applied alone. However, when salt was applied as slow treatment there is little improvement in this ratio. The ratio is still further increased in Ca treated salt growing plants. This is true for all plant parts. Same pattern has been observed regarding uptake and distribution of Ca. The efficiency of Ca in enhancing the tolerance of beans to sodium salinization is studied by Ayoub (1974). He found that increased yields of dry matter, roots, nodules and pods are positively correlated with increased Ca application and negatively correlated with the Na contents of irrigation water and plant tissue. Further, he observed that the Na levels both in roots and tops declined significantly as increased amounts of Ca were added. He suggests that Ca in the range of 2-8 m mol litre^{-1} causes competative inhibition of Na uptake and translocation. However, he noted that high rates of Ca application results in a higher death rate. Our observations with P.aconitifolius are also exactly on the similar lines. Wieneke and Laeuchli (1980) reported that increasing the level of salinity in the root solution substantially reduces the Ca uptake of Soyabean varieties differing in salt tolerance. However, in an experiment with

R - TABLE NO. 18

Effect of NaCl and NaCl + $CaCl_2$ Salinity (slow and shock treatments) on the inorganic constituents* of the roots of P. aconitifolius (Sand culture)

Treatment (mM)	Na^+	K^+	K^+ ; Na^+	Ca^{2+}	P^{5+}	Mg^{2+}	Fe^{3+}	Mn^{2+}
Control	0.09	2.72	30.2	0.3	0.12	0.18	0.053	0.025
25 NaCl (shock)	0.094	1.36	14.5	0.2	0.18	0.17	0.087	0.025
100 NaCl (shock)	0.44	1.36	3.09	0.3	0.18	0.14	0.055	0.025
25 NaCl (slow)	0.28	2.04	7.29	0.2	0.22	0.089	0.056	0.019
100 NaCl (slow)	0.32	2.38	7.44	0.1	0.19	0.051	0.055	0.010
12.5 NaCl + 12.5 $CaCl_2$ (shock)	0.12	1.70	14.2	0.4	0.12	0.13	0.024	0.025
25 NaCl + 25 $CaCl_2$ (shock)	0.17	2.18	12.8	0.6	0.12	0.17	0.046	0.010
50 NaCl + 50 $CaCl_2$ (shock)	0.36	2.04	5.7	0.8	0.12	0.15	0.022	0.025
100 NaCl + 100 $CaCl_2$	0.48	2.04	4.3	1.2	0.12	0.13	0.049	0.025

* Values are expressed as g 100^{-1}g dry tissue.

the salt sensitive variety under constant salinity but increasing Ca concentration inthe medium they observed that the plants show a reduction in Na uptake and translocation to stem and leaves.and an enhanced Ca uptake and translocation to the shoots. Bassett (1980) also found that the Na content of Bromus mollis plants was reduced by raising the soil Ca levels. However, he did not find any beneficial effect on growth of this plant.

Contrary to the above reports some workers have observed very slight or almost no effect of added Ca salts on plant growth. Ibragimov (1979) found that the application of Ca salts to salinized soils and the pre-sowing seed retting in a $Ca(NO_3)_2$ solution do not increase the salt tolerance of cotton. Nukaya et al., (1981) report that salt tolerance of green soybeans in sand culture is not enhanced by the application of $CaSO_4$ indicating that the role of Ca to salt tolerance may differ with crops. Sury and Flueckiger (1983) studied the effect of different mixtures of NaCl and $CaCl_2$ on the silver fir. They found that at both concentration levels used growth inhibition and needle necrosis were more pronounced in test conditions rich in $CaCl_2$, a fact which is probably due to chloride toxicity. We have also noted strong inhibition of growth and drying up of leaves in P.aconitifolius plants when treated with mixture of equal amounts of 100 mM NaCl and 100 mM $CaCl_2$. This effect appears to be probably due to high osmotic potential of the medium and high level of chlorides. Nassery

(1979) reported that the preventive effect of various concentrations of $CaCl_2$ and $MgCl_2$ on salt induced K loss indicates that the protective effect of Ca is specific. He has suggested that the measurement of salt induced K loss appears to be a quick and reliable method of estimating the degree of salt resistance in plants.

The P uptake and distribution in P.aconitifolius is also influenced variously by different methods of salt treatment. It is evident that the P content of young and mature leaves is affected where mostly there is increase in it at higher salinity levels. At higher concentrations the accumulation of P almost in all parts of the plant is probably the indication of P induced secondary salt tolerance mechanism. This mechanism seems to be more pronounced when the salt is applied as alone with slow treatment and mixed with $CaCl_2$.

There is no significant change in the uptake and distribution pattern in case of Mg. Usually the uptake and translocation is affected due to the salinity. However, Fe uptake and its translocation is at the higher level due to the presence of $CaCl_2$ in the medium. The Mg metabolism is also on the same line.

From the foregoing discussions it appears that P.aconitifolius responds differently to the different methods of salt application. However, it has got the ability to overcome the salt injury to certain extent. It is suggested, therefore, that P.aconitifolius is moderately salt tolerant plant.

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