CHAPTER III

Results

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RESULTS

I. Early growth studies

1a. Changes in the early stages (ten days after germination) of growth due to exposure to salinity

Dry weight of shoot was measured in three salinity levels at the tenth day of germination. Low salinity level of EC5 m mhos/cm increased the dry weight of shoot from 1 to 12% over the control in AU1, Co43 and TKM9, whereas in other varieties the dry weight of shoot was decreased from 1 to 9% over the control. The dry weight of shoot was inhibited in all the varieties with 10 m mhos/cm salinity level. The inhibition was less in Co43, IR20 and TKM4 than the others (Table 1). Varieties AU1, Co36 and CSC1 showed 50 to 55% inhibition of shoot dry weight over the control at 15 m mhos/cm salinity level. The inhibition was more in the above three varieties when compared to others. Varieties CSC2 and IR20 were more resistant in terms of shoot dry matter production at the highest 15 m mhos/cm salinity level. From the above study the optimum concentration of 100 mM NaCl which is almost equal to EC10 m mhos/cm was selected for further studies.

Table 1 : Changes in the dry weight of shoot as affected by different levels of salinity (NaCl) on tenth day after germination.

Variety	Dry weight of shoot (mg/5 seedlings)			
	Control	Salinity level (m mhos/cm)		
		5	10	15
AU1	22.0	22.2	17.2	9.8
Co36	25.8	23.6	17.2	12.8
Co43	18.4	20.0	16.6	12.0
CSC1	20.6	19.6	15.2	10.2
CSC2	21.2	20.2	17.2	14.6
GR3	21.6	21.4	18.6	12.0
IR20	18.8	20.4	16.4	12.4
TKM4	21.2	20.4	18.6	12.8
TKM9	24.6	27.6	20.8	16.0
L.S.D. 1%		2.87		

b. Growth of shoot and root of a month old seedlings in response to salinity

Sodium chloride caused depression in the growth of shoot system in all the varieties. In the beginning, 7 days after initial salinization all the varieties appeared to be sensitive, exhibited a reduction of 65 to 78 per cent in the length of their shoot system. But after 30 days of salt treatment, the saline exposed seedlings indicated lesser degree of inhibition as compared to the early stages for example, shoot of TKM4 exhibited a maximum of 49 per cent inhibition, (Fig.1a and 2j) and Co43 showed a less degree of inhibition (about 32 per cent) in the shoot length over the control (Fig.1i and 2g). In varieties CSC2, CSC1 and TKM4 a maximum 81 to 87 per cent reduction of shoot fresh matter over the control in response to salinization was observed at the thirtieth day (Table 2 and Fig.2e, b and k). However, in Co43 and TKM9 a decrease of 72 and 81 per cent in fresh matter was documented in the initial days of salinization, but later at the thirtieth day a much lesser degree of inhibition was observed (Table 2 and Fig.2h). The depression in dry matter production of shoots at the time of final harvest were 33% in Co43, 56% in TKM9 and between 69 and 74% in CSC2, TKM4 and CSC1 over the control (Fig.1 and 2). Among all the varieties, the Co43 was less affected in dry matter production of shoot system to salt treatment (Fig 1j and 2i).

Table 2 : Effect of 100 mM NaCl on the fresh matter accumulation of shoot and root systems of rice varieties.

	Fresh weight of shoot and root system (mg)											
	7		L.S.D.	14		L.S.D.	23		L.S.D.	30		L.S.D.
	C	S	1%	C	S	1%	C	S	1%	C	S	1%
TKM4												
Shoot	35.0	5.2	1.3	40.2	7.7	1.9	50.2	8.2	2.1	64.8	8.5	2.7
Root	24.3	1.8	1.4	30.0	13.0	0.8	37.8	13.6	0.7	45.4	14.6	1.4
TKM9												
Shoot	25.8	4.8	20.9	41.5	24.4	11.9	63.3	27.9	38.9	68.3	32.9	38.9
Root	19.0	1.8	14.6	8.8	5.6	8.9	13.1	23.6	13.9	18.1	28.6	13.9
CSC1												
Shoot	40.2	5.8	1.9	46.1	7.8	1.2	59.8	9.4	1.5	74.8	10.2	2.2
Root	26.0	6.2	1.9	30.0	10.8	2.2	41.6	19.0	0.7	60.0	25.0	3.7
CSC2												
Shoot	48.0	7.8	1.9	54.8	9.8	64.6	70.0	12.6	0.9	85.0	16.0	2.2
Root	30.4	9.1	2.6	40.2	10.8	0.7	59.4	25.0	0.9	73.4	27.6	3.0
Co43												
Shoot	22.8	6.3	8.6	35.7	17.3	7.4	48.3	26.4	17.6	53.5	31.4	18.0
Root	8.4	4.4	7.5	5.9	3.4	4.1	15.0	15.4	7.5	20.0	20.4	7.5

C: Control; S: Salinized; 7,14,23 and 30: Days after initial salinization

Fig. 1a-j Effect of 100 mM NaCl on the vegetative growth of rice varieties in 7, 14, 23 and 30 days after initial salinization. The vertical lines indicate L.S.D. at 0.05 level.

○——○: Control, shoots;

●——●: Saline, shoots;

□---□: Control, roots;

■---■: Saline, roots.

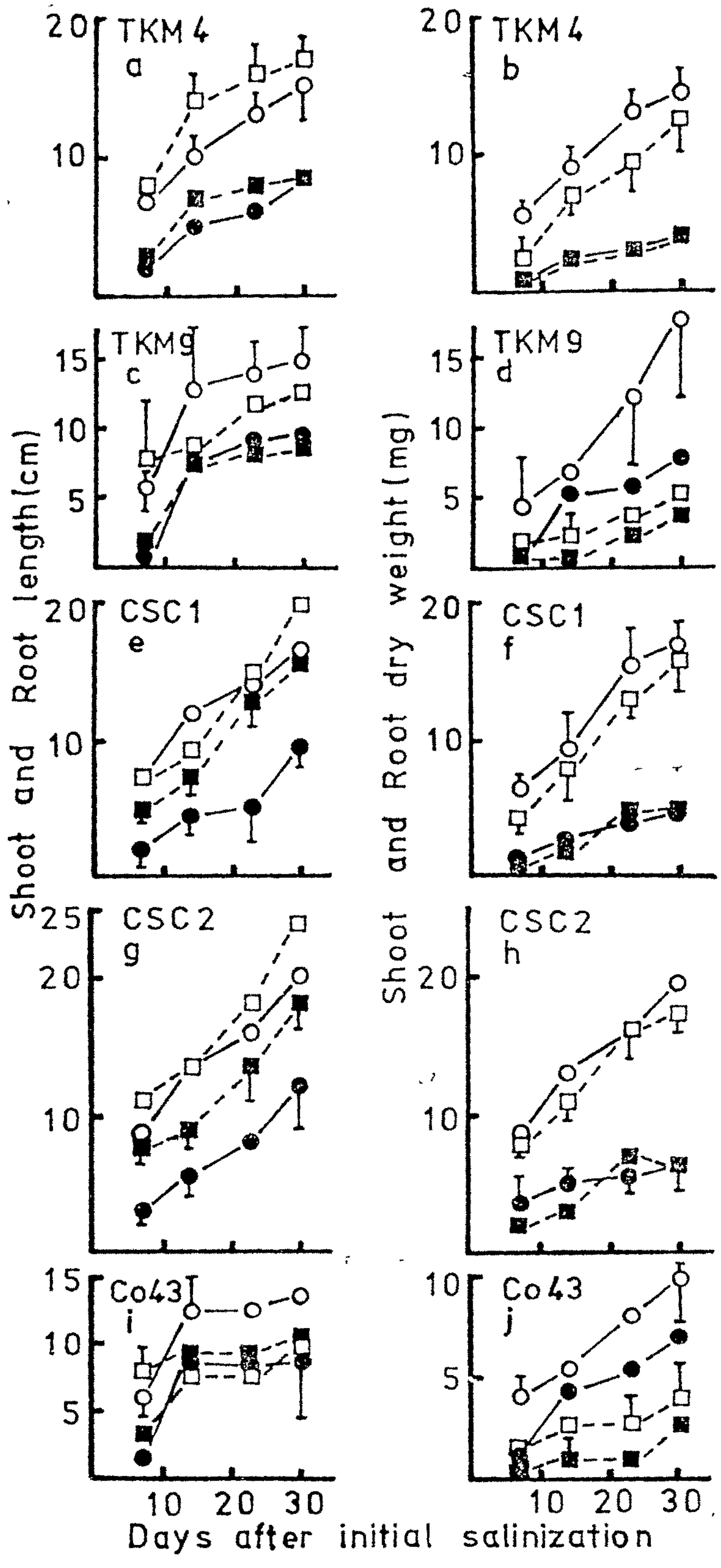
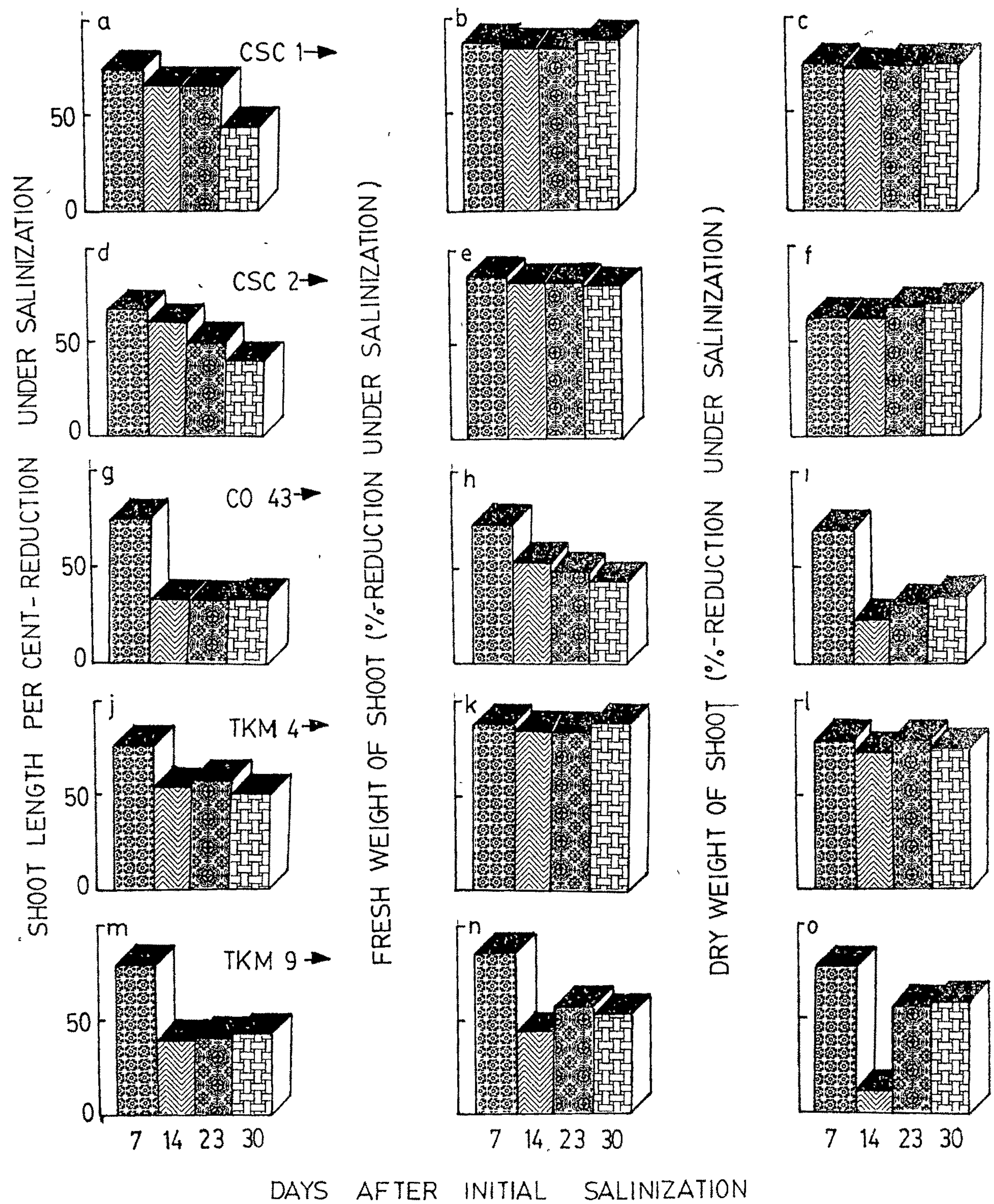

TKM 4
a
TKM 4
b
TKM9
c
TKM9
d
CSC1
e
CSC1
f
CSC2
g
CSC2
h
Co43
i
Co43
j
Shoot and Root length (cm)
Shoot and Root dry weight (mg)
Days after initial salinization

Fig. 2a-O. Changes in the shoot length, fresh and dry weight of shoot of rice varieties as affected by 100 mM NaCl. Results are expressed as percentage of reduction over the control.

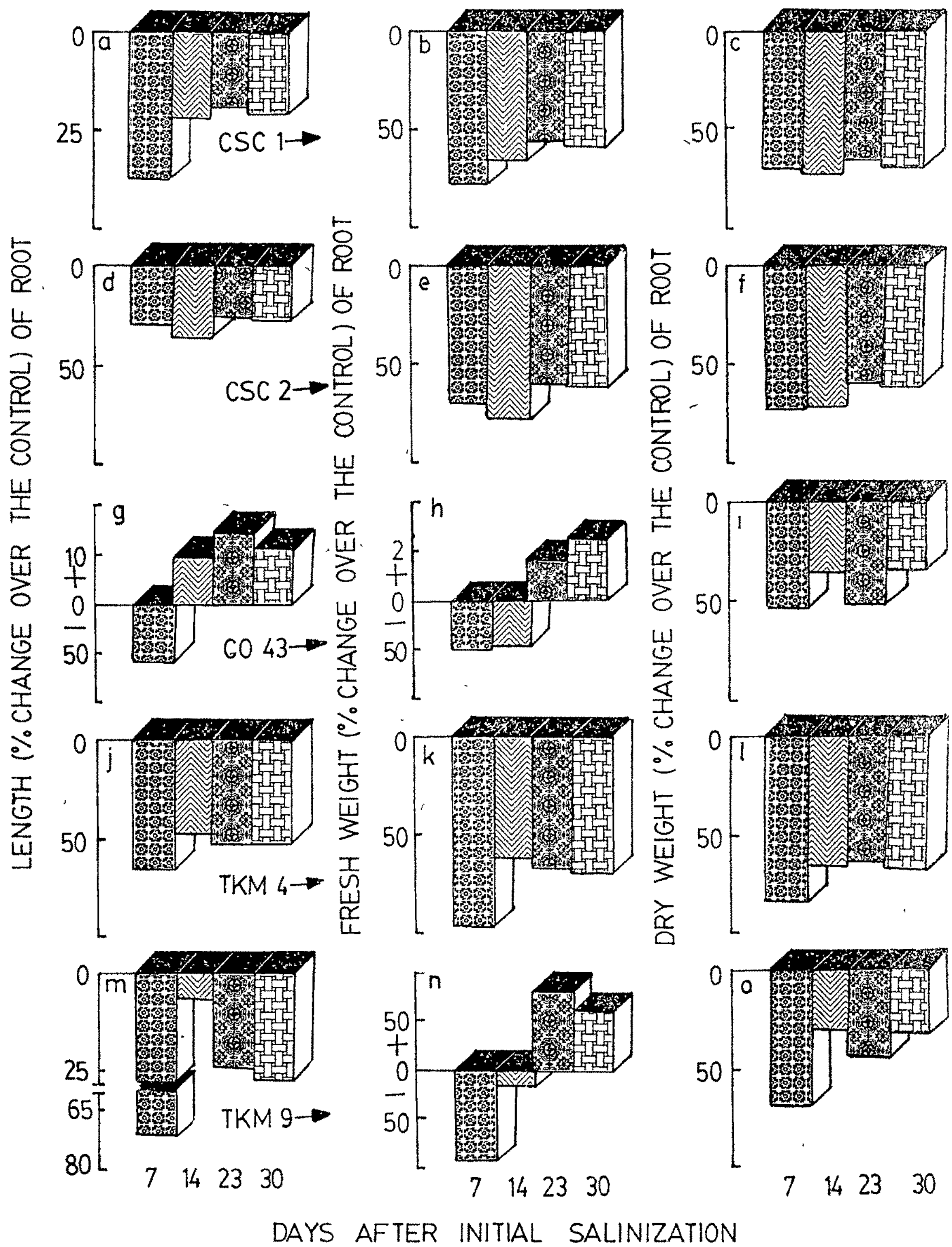

a
b
c
CSC 1
d
e
f
CSC 2
g
h
i
CO 43
j
k
l
TKM 4
m
n
o
TKM 9
50
0
SHOOT LENGTH PER CENT - REDUCTION UNDER SALINIZATION
FRESH WEIGHT OF SHOOT (%-REDUCTION UNDER SALINIZATION)
DRY WEIGHT OF SHOOT (%-REDUCTION UNDER SALINIZATION)
7 14 23 30
DAYS AFTER INITIAL SALINIZATION

The pattern of inhibition of growth observed in the shoot, was evident in the root growth too. In the initial period of salinization the per cent inhibition of root was more than the later stages. The root length of TKM4 was depressed by 52% over the control, a maximum rate that was observed at 30 days of salt treatment (Fig.1a and 3j). In the case of Co43, there was no decrease in the root length over the control (Fig.1i and 2g). Salinization for 7 days brought about lessening of fresh matter accumulation in four varieties to a great extent, but in Co43 the decrease was recorded to be 48 per cent (Table 2 and Fig.3h). Interestingly in TKM9, exposure to salinity increased the fresh matter accumulation in root system after 23 days of salt treatment and in Co43 no inhibition was noticed (Table 2 and Fig.3h and n). Great deal of reduction in root fresh weight was noticed in CSC1, CSC2 and TKM4 at the time of final harvest (Fig.3b, e and k). The Co43 and TKM9 indicated much less reduction of the dry matter content in root system in comparison with others on all the days of salinity (Fig.1d and j; Fig.3i and o). In varieties CSC1, CSC2 and TKM4, highly reduced root dry matter was recorded at 30 days after salt treatment (Fig.1 and 3).

2. Inorganic constituents

There was no marked varietal differences in the behaviour of Na^+ and Cl^- accumulation in the root and

Fig. 3a-O. Root length, fresh and dry weight of root system of rice varieties grown under saline condition (100 mM NaCl). Results are expressed as percentage of changes over the control. + : increase; - : decrease.



LENGTH (% CHANGE OVER THE CONTROL) OF ROOT
FRESH WEIGHT (% CHANGE OVER THE CONTROL) OF ROOT
DRY WEIGHT (% CHANGE OVER THE CONTROL) OF ROOT
CSC 1
CSC 2
CO 43
TKM 4
TKM 9
a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
7 14 23 30
DAYS AFTER INITIAL SALINIZATION

shoot systems of rice. All the varieties were found to accumulate Na^+ and Cl^- in their shoot and root systems. The highest Na^+ content was found in Co43 and TKM9 (Fig.4i, j, c and d; Fig.5e, f, i and j) at the 30 days of salinization. The CSC2 accumulated less sodium in the shoots and roots at the end of 30 days of salinization (Fig.5c). Generally, after 14 days of salinization all the varieties exhibited higher sodium content in the shoots than the roots. Varieties CSC2 and TKM4 accumulated a high level of chloride in their shoots than the others at the end of the growth period (Table 3 and Fig.6c and g).

Varieties TKM4, CSC1 and CSC2 showed a steady increase in the Na^+ and K^+ levels as the duration of salinization was increased, whereas the TKM9 and Co43 indicated patterns of Na^+ fluctuation in the shoots and roots during the 30 days of salinization (Fig.4). The NaCl treatment lowered the K^+ in the shoot and root systems of TKM4, TKM9, Co43 and shoots of CSC1 below the control level. Interestingly, the CSC2 maintained higher level of K^+ than the Na^+ in their shoots and roots, and CSC1 accumulated slightly higher concentration of K^+ in comparison to control (Fig.4g, h and f; Fig.7c, d and b).

Table 3: Changes in the chloride accumulation of shoot and root systems of rice varieties as affected by 100 mM NaCl

	Chloride content (m moles/g dry weight)							
	7		14		23		30	
	C	S	C	S	C	S	C	S
TKM4								
Shoot	0.18	0.64	0.28	1.19	0.31	2.01	0.35	2.75
Root	0.13	0.51	0.16	0.71	0.16	0.88	0.17	1.19
TKM9								
Shoot	0.20	0.64	0.24	0.88	0.33	1.68	0.37	2.45
Root	0.17	0.51	0.16	0.62	0.18	0.79	0.20	0.99
CSC1								
Shoot	0.17	0.31	0.18	0.44	0.22	0.64	0.24	1.01
Root	0.12	0.35	0.15	0.51	0.16	0.60	0.17	0.73
CSC2								
Shoot	0.15	0.64	0.17	1.01	0.20	1.37	0.26	2.56
Root	0.09	0.17	0.12	0.33	0.14	0.53	0.17	0.82
Co43								
Shoot	0.13	0.33	0.16	0.53	0.17	0.82	0.18	1.06
Root	0.08	0.17	0.11	0.37	0.14	0.46	0.15	0.62

C : Control; S: Salinized; 7, 14, 23 and 30 Days after initial salinization.

Fig.4a-j. Effect of 100 mM NaCl on the internal concentration of sodium and potassium in 7, 14, 23 and 30 days after initial salinization.

○——○: control, Sodium content of shoots;

●——●: Saline, Sodium content of shoots;

△——△: Control, Sodium content of roots;

▲——▲: Saline, Sodium content of roots;

□----□: Control, Potassium content of shoots and roots;

■----■: Saline, Potassium content of shoots and roots.

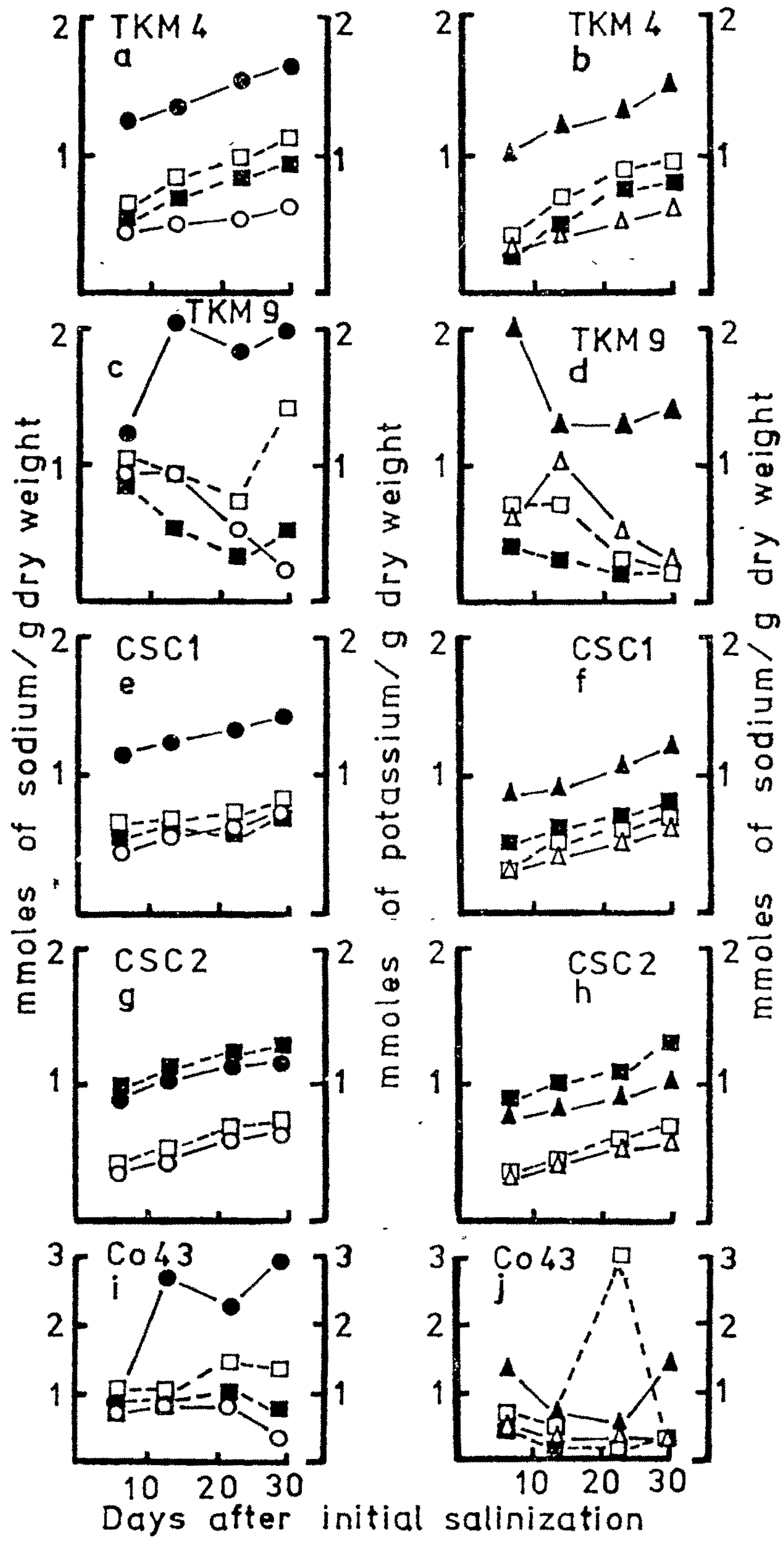

TKM 4
a
b
TKM 9
c
d
CSC1
e
f
CSC2
g
h
Co43
i
j
mmoles of sodium/g dry weight
mmoles of potassium/g dry weight
mmoles of sodium/g dry weight
10 20 30
Days after initial salinization

Fig.5a - j. Effect of 100 mM NaCl on the sodium content of shoot and root system of rice varieties in different days after initial salinization. Results are expressed as percentage of increase over the control.

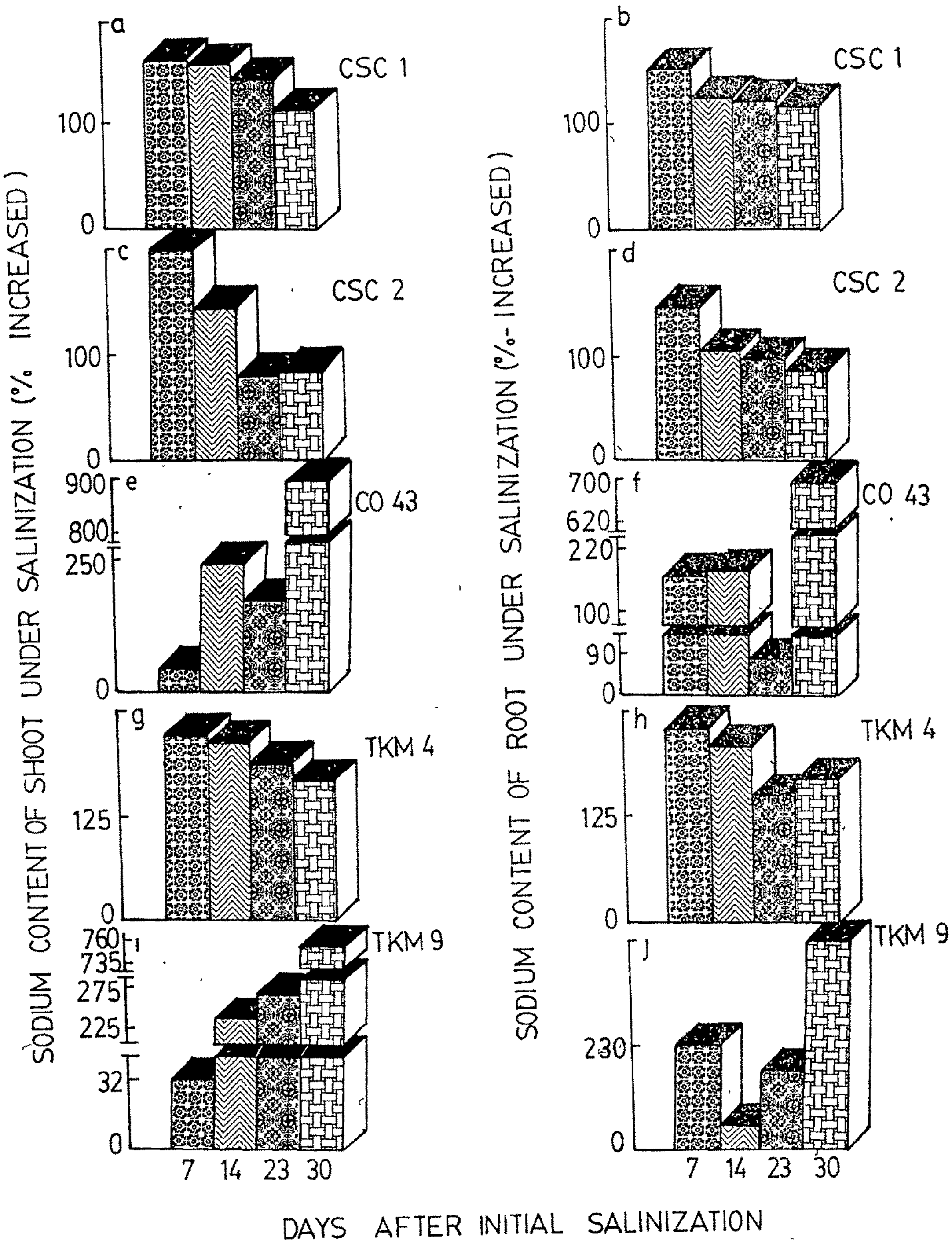
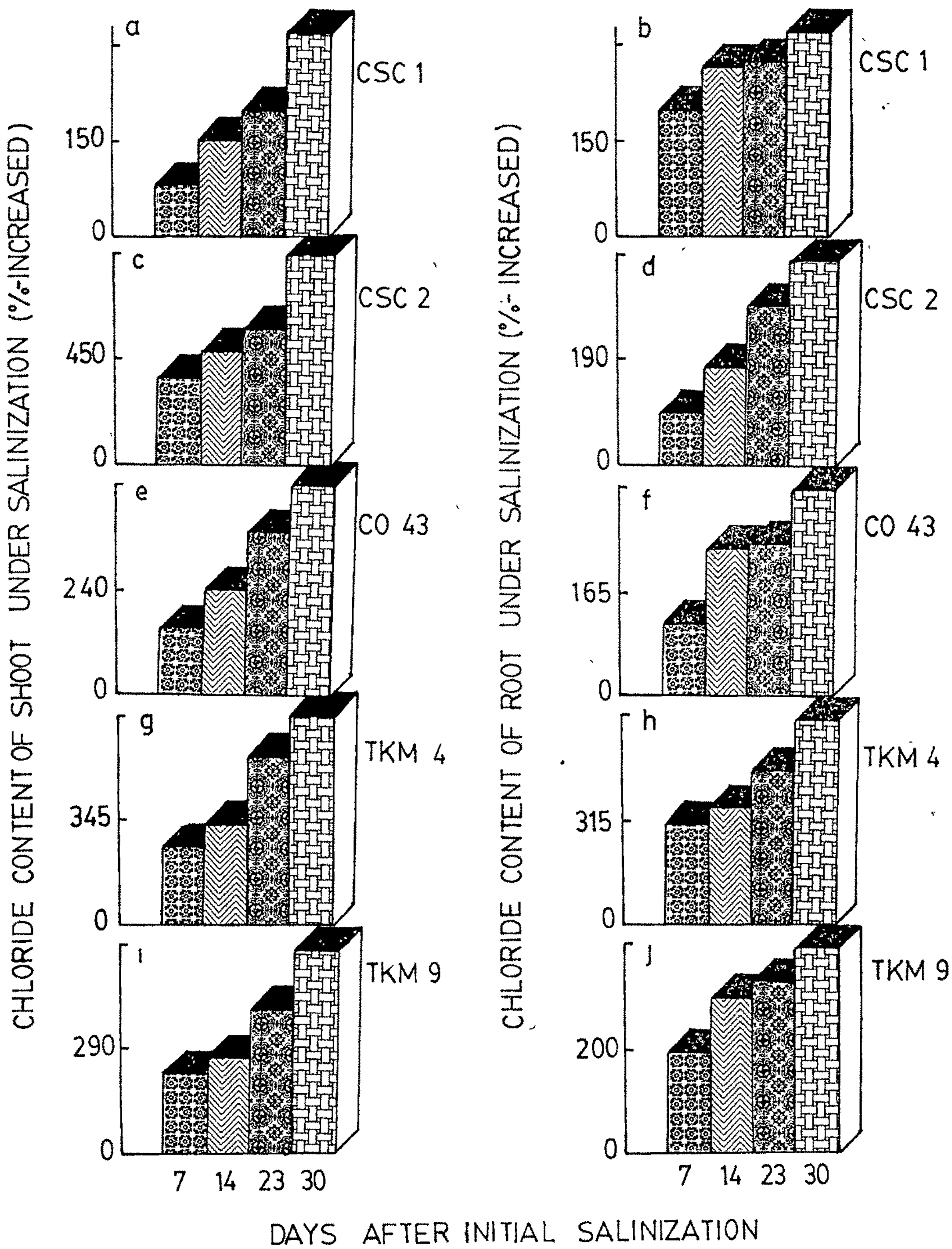

a
CSC 1
100
0
b
CSC 1
100
0
c
CSC 2
100
0
d
CSC 2
100
0
900
e
800
250
CO 43
0
700
f
620
220
100
90
0
CO 43
g
TKM 4
125
0
h
TKM 4
125
0
760
735
275
225
32
0
i
TKM 9
j
TKM 9
230
0
7 14 23 30
7 14 23 30
SODIUM CONTENT OF SHOOT UNDER SALINIZATION (% INCREASED)
SODIUM CONTENT OF ROOT UNDER SALINIZATION (%- INCREASED)
DAYS AFTER INITIAL SALINIZATION

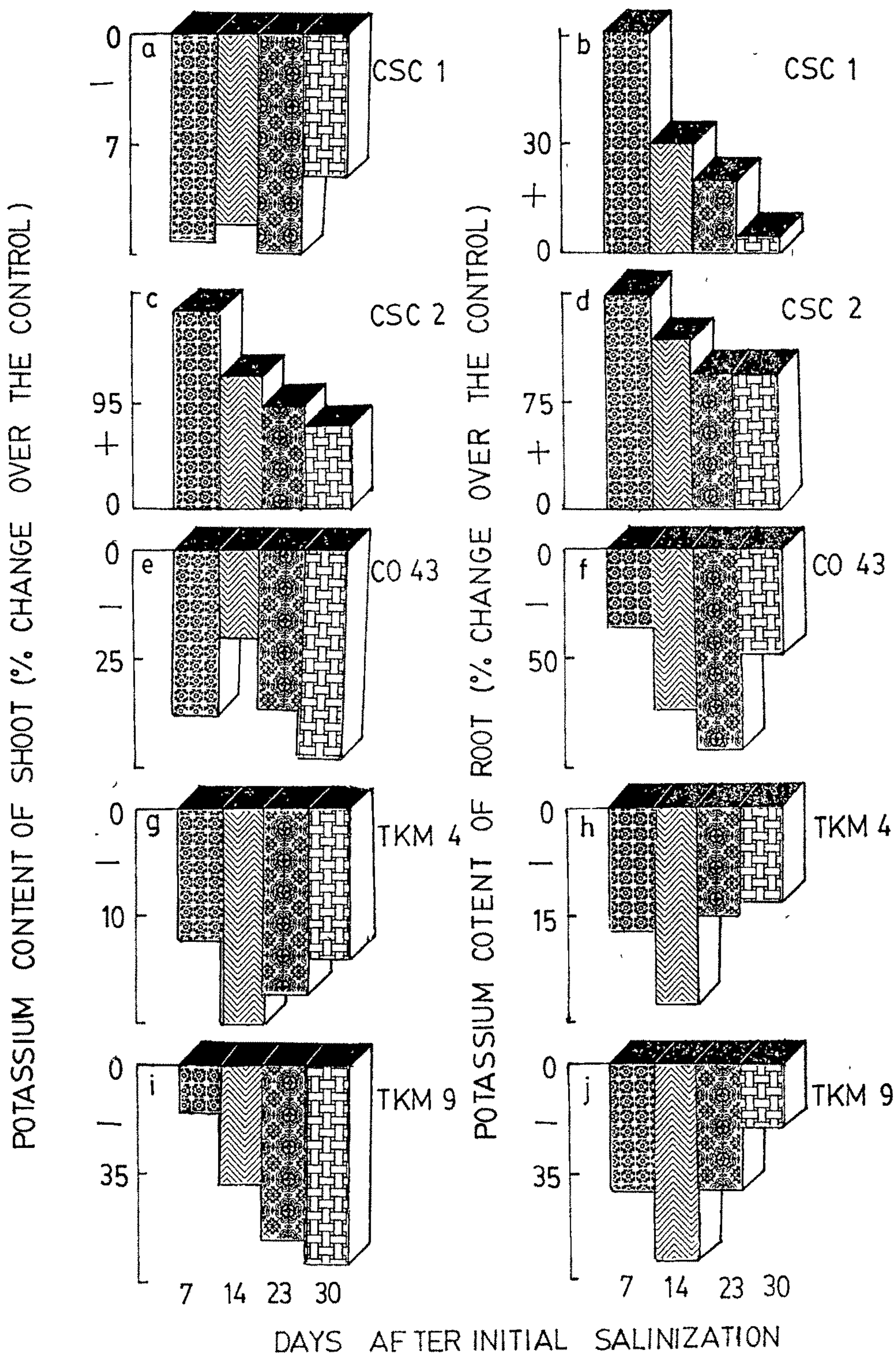
Fig.6a-j. Chloride content of shoot and root systems of rice varieties as affected by 100 mM NaCl in different days after initial salinization. Results are expressed as percentage of increase over the control.



CHLORIDE CONTENT OF SHOOT UNDER SALINIZATION (%-INCREASED)
CHLORIDE CONTENT OF ROOT UNDER SALINIZATION (%-INCREASED)
a
b
c
d
e
f
g
h
i
j
CSC 1
CSC 2
CO 43
TKM 4
TKM 9
150
450
240
345
290
190
165
315
200
0
7
14
23
30
DAYS AFTER INITIAL SALINIZATION

Fig.7a-j. Potassium content of shoot and root systems of rice varieties grown under saline condition (100 mM NaCl). Results are expressed as percentage of changes over the control.

+ : increase; – : decrease.



POTASSIUM CONTENT OF SHOOT (% CHANGE OVER THE CONTROL)
POTASSIUM COTENT OF ROOT (% CHANGE OVER THE CONTROL)
a
CSC 1
b
CSC 1
c
CSC 2
d
CSC 2
e
CO 43
f
CO 43
g
TKM 4
h
TKM 4
i
TKM 9
j
TKM 9
0
7
30
0
95
0
75
0
0
25
0
50
0
10
0
15
0
35
0
35
7 14 23 30
7 14 23 30
DAYS AFTER INITIAL SALINIZATION

3. 3. Organic constituents

a. Free amino acid level

All the rice varieties were found to increase their free amino acid pool in response to NaCl stress. The TKM4, CSC1 and CSC2 followed the similar pattern of steady state increase of free amino acids with increasing days of salinization (Fig.8a, b, e, f, g and h), but in the case of TKM9 and Co43, the accumulation pattern of free amino acids was different, marked by fluctuations (Fig.8c, d, i and j; Fig. 9i, j and f). The Co43 could accumulate the maximum level of proline upto 8.8 μ moles in the shoots during 23 days of salinity (Fig.8i). Free amino acid content in shoots always exceeded that of roots in all the varieties. Contrary to the above, the TKM4 appeared much less capable of maintaining high levels of free amino acids in response to salinity (Fig.8a and b; Fig.9g and h; Fig.10g and h). CSC1 and CSC2 behaved similarly accumulating proline as the duration of salt treatment increased (Fig.8e and g). Except for TKM9 and Co43, others always indicated an increase in the internal proline content with the increasing level of total free amino acid pool. Co43 did not accumulate the high amount of free amino acids in its root system when the days of salt treatment extended. The concentration of free amino acids were increased at the early stages and

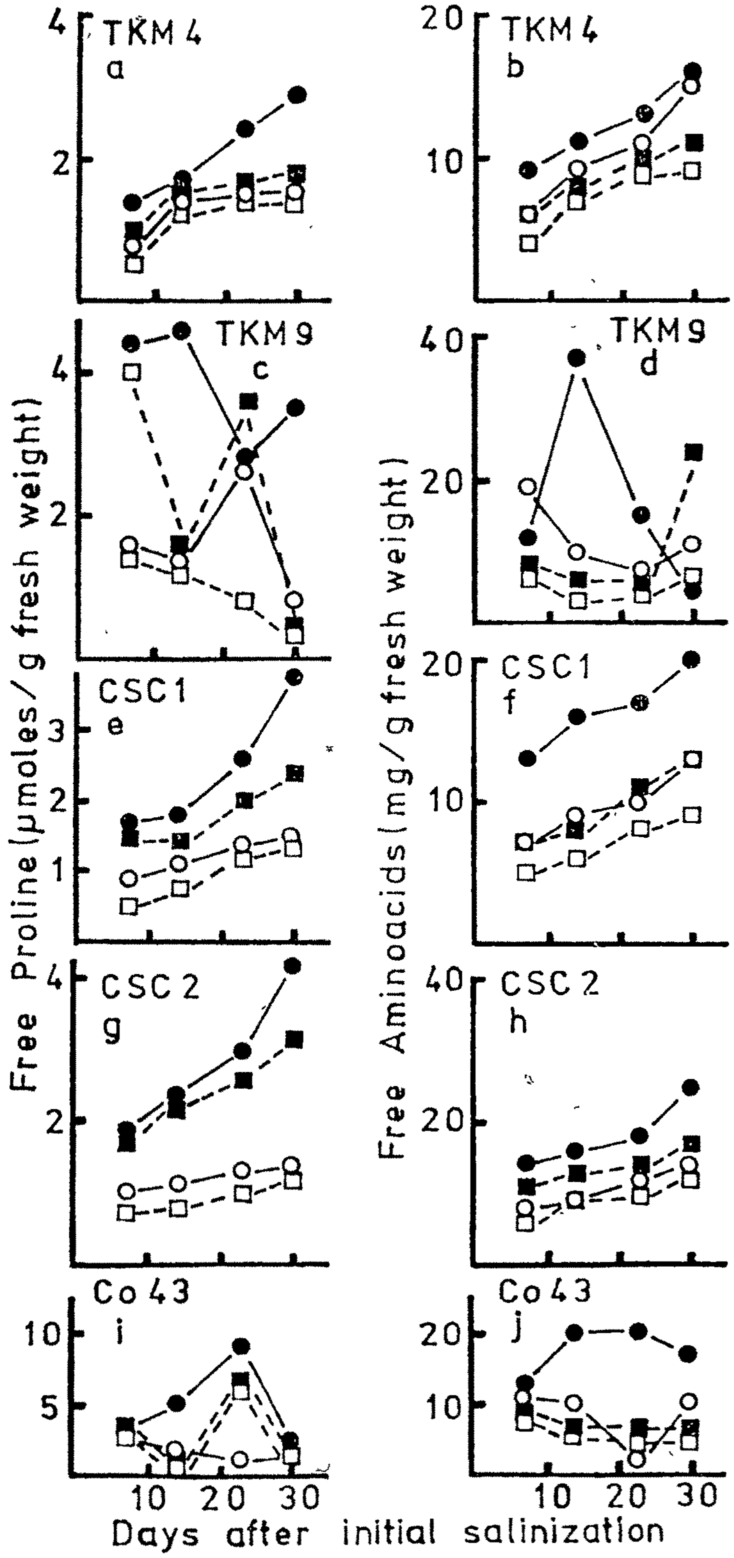
Fig. 8a-j. Effect of 100 mM NaCl on the free amino acid levels in 7, 14, 23 and 30 days after initial salinization.

○——○: Control, total free amino acids and proline content of shoots;

●——●: Saline, total free amino acids and proline content of shoots;

□---□: Control, total free amino acids and proline content of roots;

■---■: Saline, total free amino acids and proline content of roots.



TKM 4
a
b
TKM 9
c
d
CSC 1
e
f
CSC 2
g
h
Co 43
i
j
Free Proline (μmoles / g fresh weight)
Free Aminoacids (mg / g fresh weight)
Days after initial salinization

Fig.9a-j. Percentage of changes in the free amino acid content of shoot and root systems of rice varieties as affected by 100 mM NaCl in different days after initial salinization. + : increase or - : decrease/over the control.

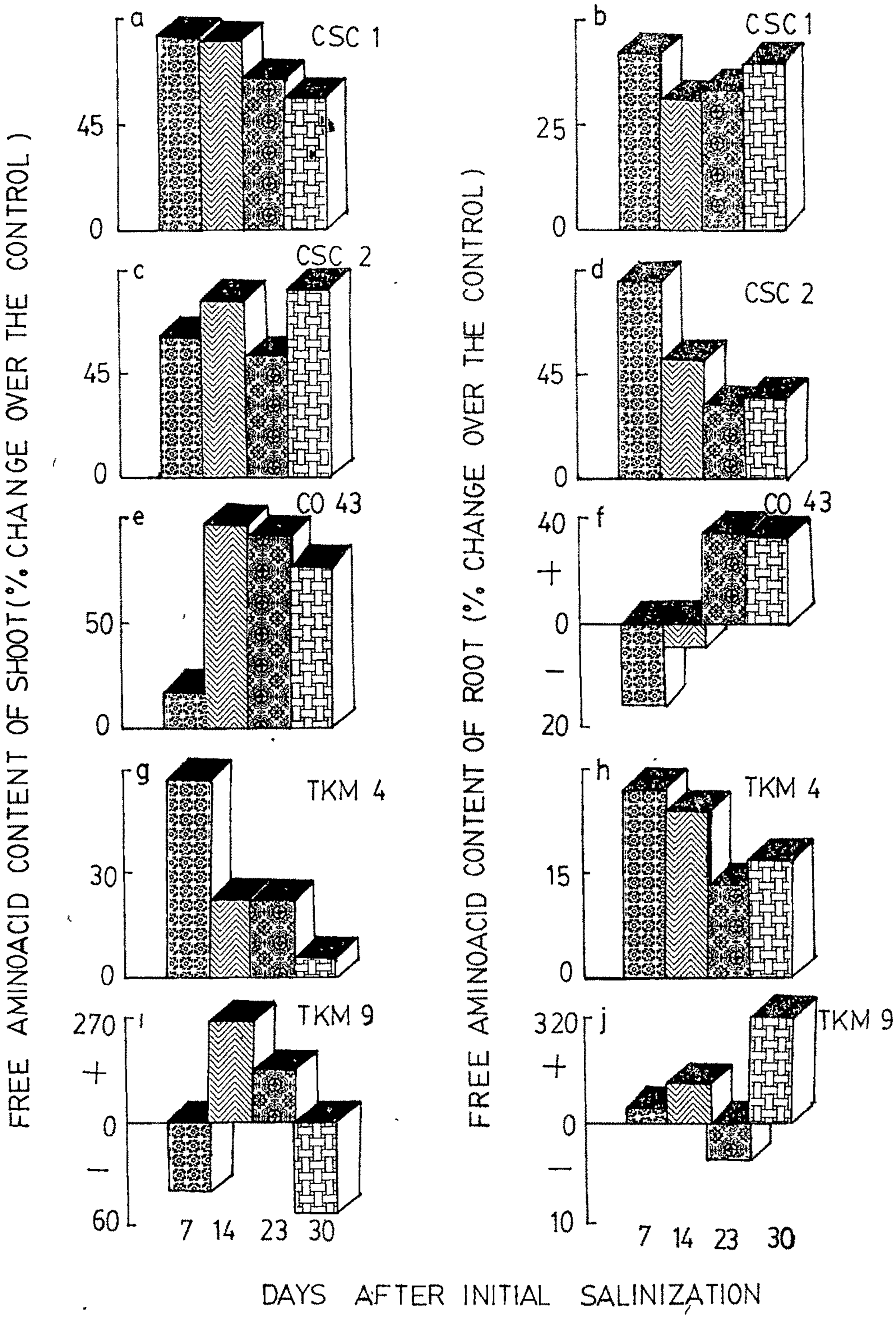
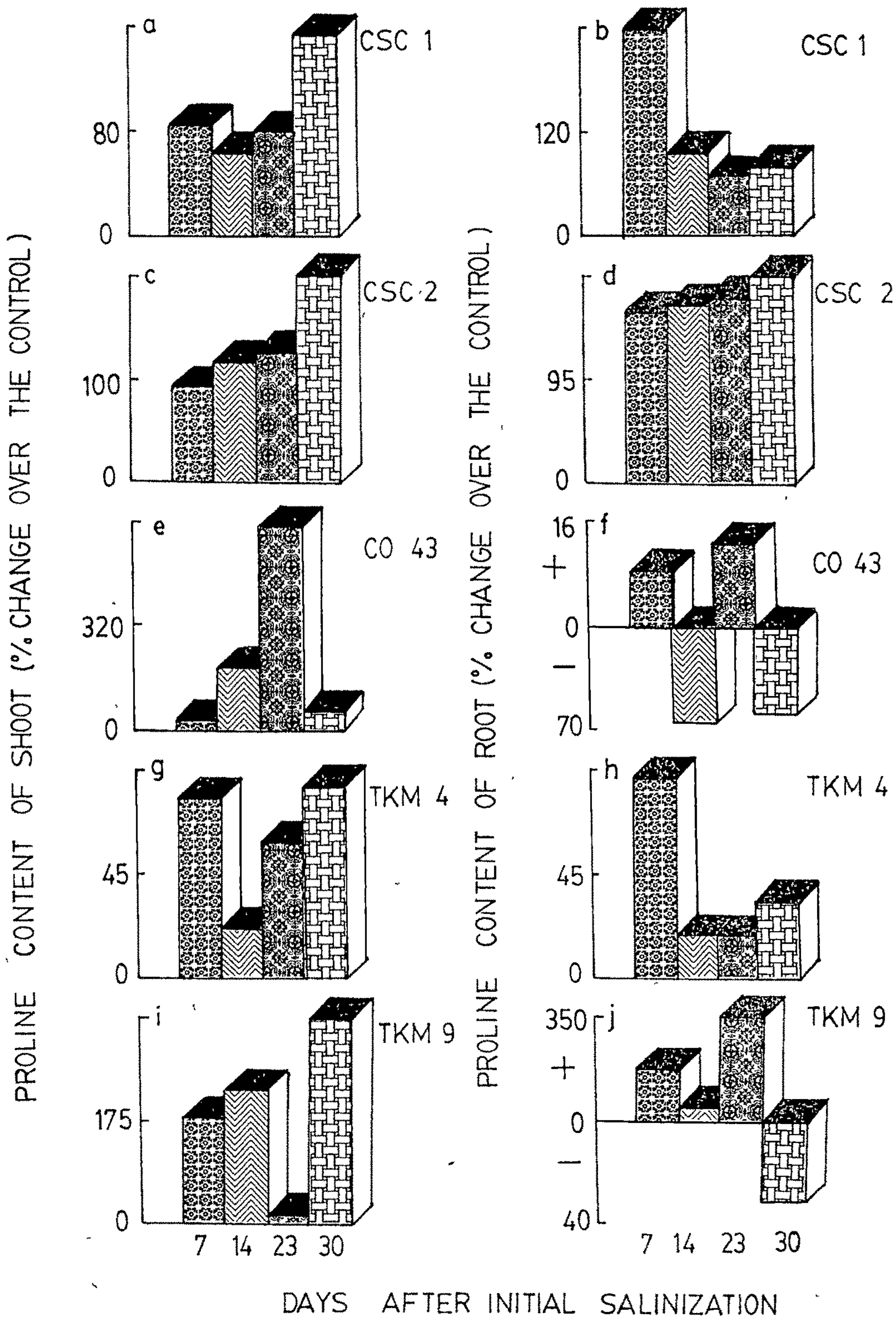

FREE AMINOACID CONTENT OF SHOOT (% CHANGE OVER THE CONTROL)
FREE AMINOACID CONTENT OF ROOT (% CHANGE OVER THE CONTROL)
a CSC 1
b CSC 1
c CSC 2
d CSC 2
e CO 43
f CO 43
g TKM 4
h TKM 4
i TKM 9
j TKM 9
7 14 23 30
DAYS AFTER INITIAL SALINIZATION

Fig. 10a-j. Proline content of shoot and root systems of rice varieties grown under saline condition (100 mM NaCl) upto 30 days after initial salinization. Results are expressed as percentage of changes over the control.

+ : increase; - : decrease.



PROLINE CONTENT OF SHOOT (% CHANGE OVER THE CONTROL)
PROLINE CONTENT OF ROOT (% CHANGE OVER THE CONTROL)
a
CSC 1
80
0
b
CSC 1
120
0
c
CSC 2
100
0
d
CSC 2
95
0
e
CO 43
320
0
f
CO 43
16
+
0
−
70
g
TKM 4
45
0
h
TKM 4
45
0
i
TKM 9
175
0
j
TKM 9
350
+
0
−
40
7 14 23 30
7 14 23 30
DAYS AFTER INITIAL SALINIZATION

decreased in the later stages of growth in shoots of TKM9 and Co43 (Fig.8c, d, i and j; Fig.9i and e; Fig.10e).

Salinity did not affect the protein-bound-proline levels in the shoots of CSC1 (Fig.11a). At the seven days of salt treatment, the protein-bound-proline content was increased in the shoots of CSC2, Co43, TKM4 and TKM9, and in roots of CSC1, CSC2 and TKM4, but subsequently, the amount of increase was less in the 30 days of salt treated plants. Invariably, the protein-bound-proline content was decreased over the control at the 14 days of salt treatment in the roots of CSC1 and TKM9 (Fig.11b and j, and Table 4).

b. Protein level

Generally salinization brought about an increase in the levels of soluble protein in both shoots and roots of all the varieties with a parallel decrease in insoluble protein as compared to the control (Table 5 and 6; Fig.12 and 13). The increase in the soluble protein content was less at the time of final harvest as compared to early days of salt treatment in all the varieties. The high level of soluble protein content was noticed in CSC1, at the seventh day in shoots and twentythird day in the roots (Fig.12a and b). The Co43 seemed to be less capable in accumulating high level of soluble protein than the others.

Table 4 : Effect of 100 mM NaCl on the protein-bound proline concentration of rice varieties

	Protein-bound proline content (μ moles/g fr.wt.)							
	7		14		23		30	
	C	S	C	S	C	S	C	S
TKM4								
Shoot	0.19	0.23	0.22	0.23	0.23	0.23	0.24	0.24
Root	0.09	0.14	0.14	0.16	0.14	0.16	0.15	0.17
TKM9								
Shoot	0.04	0.08	0.32	0.44	0.16	0.29	0.20	0.25
Root	0.04	0.04	0.21	0.16	0.07	0.09	0.43	0.43
CSC1								
Shoot	0.09	0.09	0.15	0.15	0.21	0.21	0.21	0.21
Root	0.05	0.07	0.13	0.08	0.15	0.17	0.16	0.16
CSC2								
Shoot	0.44	0.47	0.40	0.44	0.41	0.43	0.42	0.43
Root	0.31	0.34	0.34	0.36	0.33	0.36	0.32	0.34
Co43								
Shoot	0.08	0.16	0.44	0.57	0.08	0.18	0.25	0.33
Root	0.04	0.04	0.12	0.43	0.23	0.11	0.43	0.30

C : Control; S : Salinized; 7, 14, 23 and 30 Days after initial salinization.

Table 5 : Effect of salt stress (100 mM NaCl) on the Soluble protein content of shoots and roots of rice varieties.

	Soluble protein (mg/g fresh weight)							
	7		14		23		30	
	C	S	C	S	C	S	C	S
TKM4								
Shoot	0.83	1.78	3.30	7.45	6.28	8.70	8.03	8.50
Root	0.73	1.40	7.78	2.60	2.38	3.30	2.73	3.43
TKM9								
Shoot	2.35	1.20	2.95	7.10	3.50	6.00	7.70	8.85
Root	1.05	0.70	1.40	2.25	2.00	2.95	2.35	3.10
CSC1								
Shoot	0.48	1.20	2.73	2.95	7.20	8.48	5.68	5.93
Root	0.90	1.20	1.78	1.90	1.90	4.75	3.43	3.65
CSC2								
Shoot	0.83	1.78	3.55	7.68	6.50	8.80	8.28	8.70
Root	0.73	1.43	2.00	2.85	2.60	3.55	2.95	3.65
Co43								
Shoot	1.40	1.05	2.35	2.75	6.55	8.15	5.25	5.55
Root	1.30	1.20	1.40	1.55	4.00	4.40	3.10	3.30

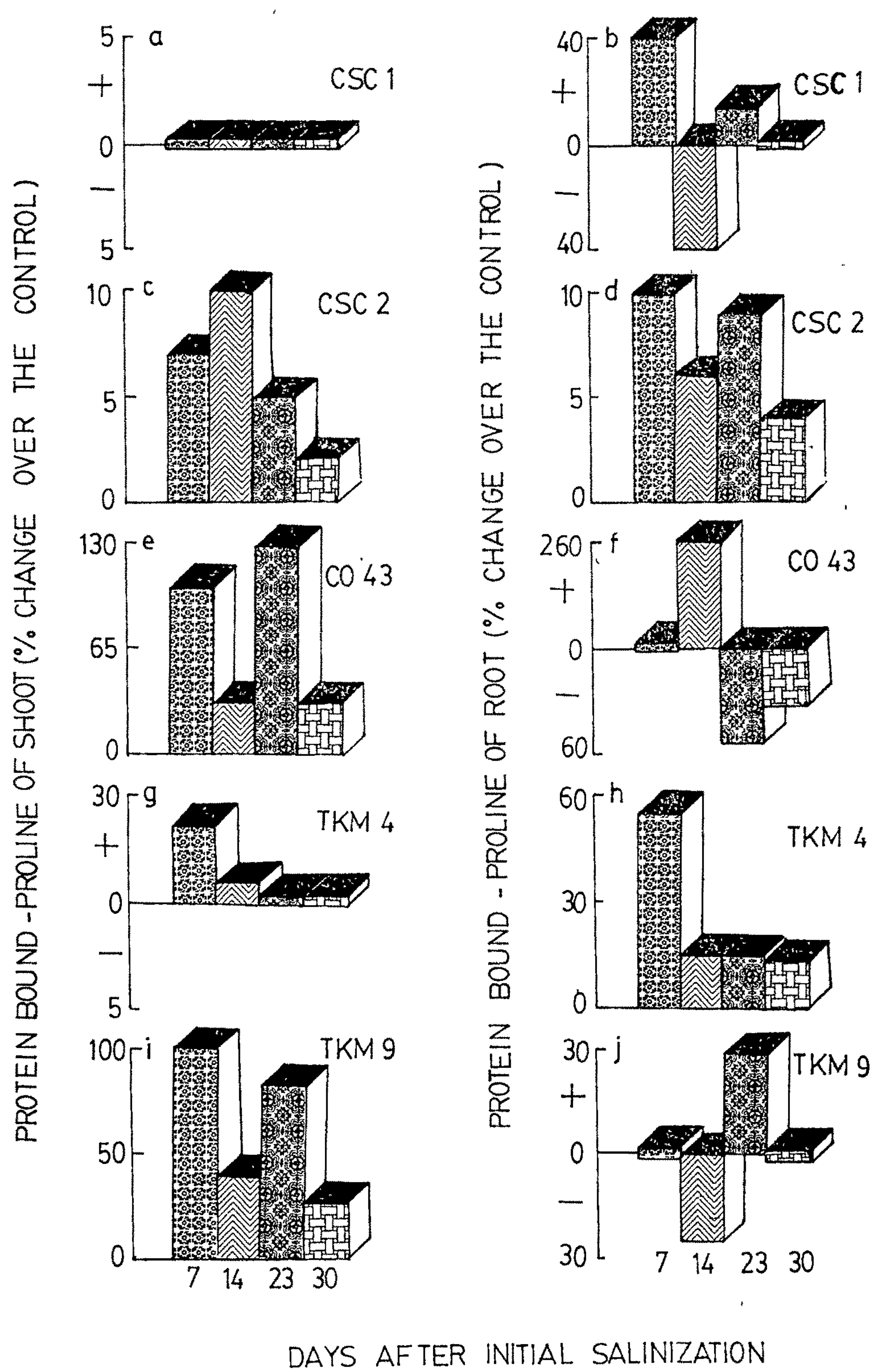
C ; Control; S ; Salinized; 7, 14, 23 and 30 Days after initial salinization.

Table 6 : Insoluble protein content of shoots and roots of rice varieties as affected by salt stress (100 mM NaCl).

	Insoluble protein (mg/g fresh weight)							
	7		14		23		30	
	C	S	C	S	C	S	C	S
TKM4								
Shoot	2.73	1.53	0.90	0.48	0.73	0.30	0.58	0.40
Root	1.40	1.08	0.95	0.70	0.58	0.35	0.93	0.23
TKM9								
Shoot	0.85	1.75	1.20	0.45	6.00	0.60	0.55	0.05
Root	0.75	1.40	0.85	0.70	0.60	0.15	0.65	0.20
CSC1								
Shoot	1.78	1.40	1.78	0.48	0.60	0.48	0.60	0.35
Root	1.65	1.53	1.53	0.58	2.95	0.25	0.73	0.60
CSC2								
Shoot	2.95	1.78	1.20	0.48	0.70	0.20	0.58	0.15
Root	1.65	1.30	0.95	0.70	0.60	0.35	0.95	0.25
Co43								
Shoot	0.50	1.20	1.20	0.35	0.90	0.75	0.60	0.40
Root	0.95	2.90	1.55	0.70	0.30	0.20	0.65	0.60

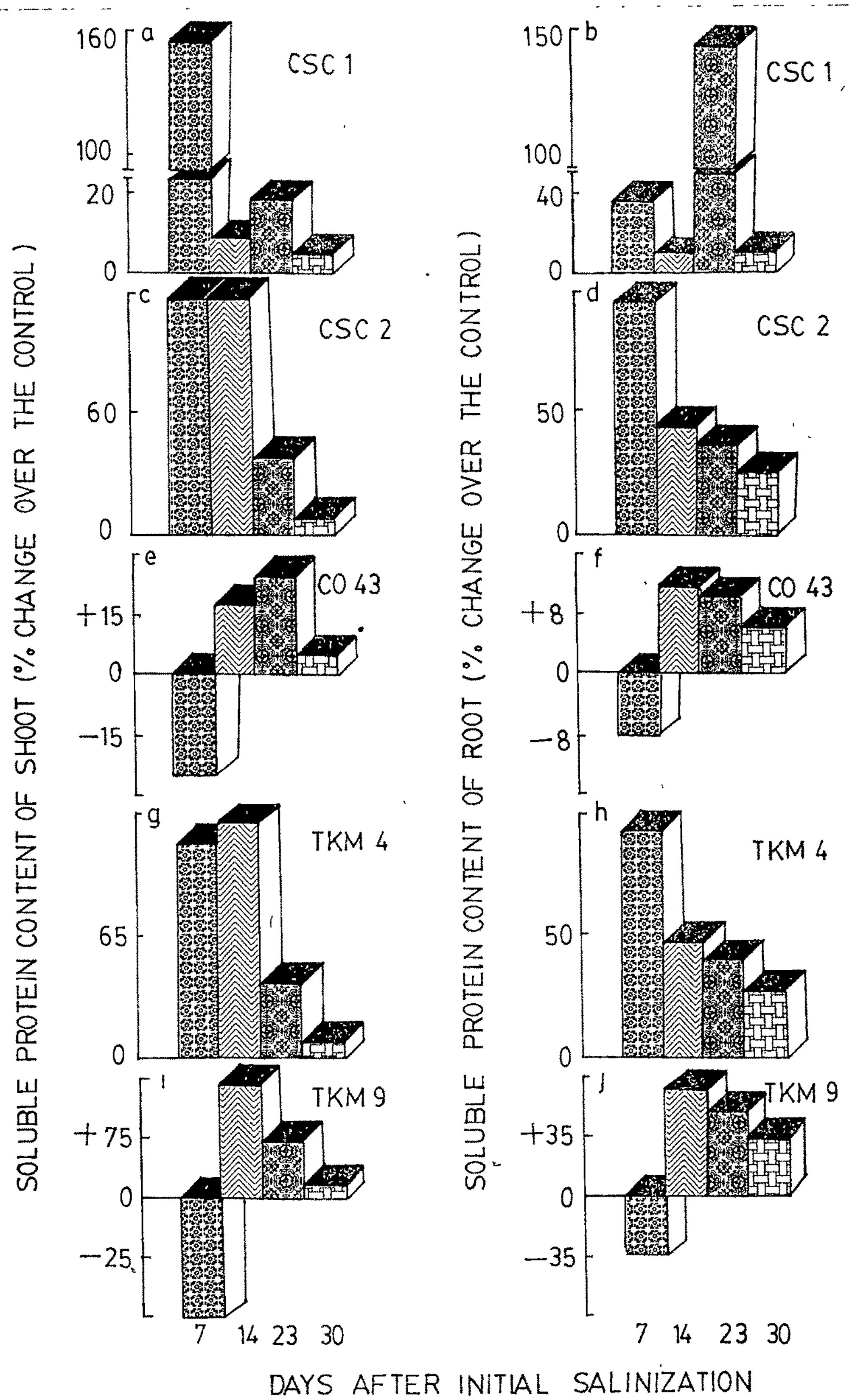
C : Control; S: Salinized; 7,14, 23 and 30 Days after initial salinization.

Fig. 11a-j. Effect of 100 mM NaCl on the protein-bound-proline content of shoot and root systems of rice varieties in different days after initial salinization. Results are expressed as percentage of changes over the control. + : increase; - : decrease.



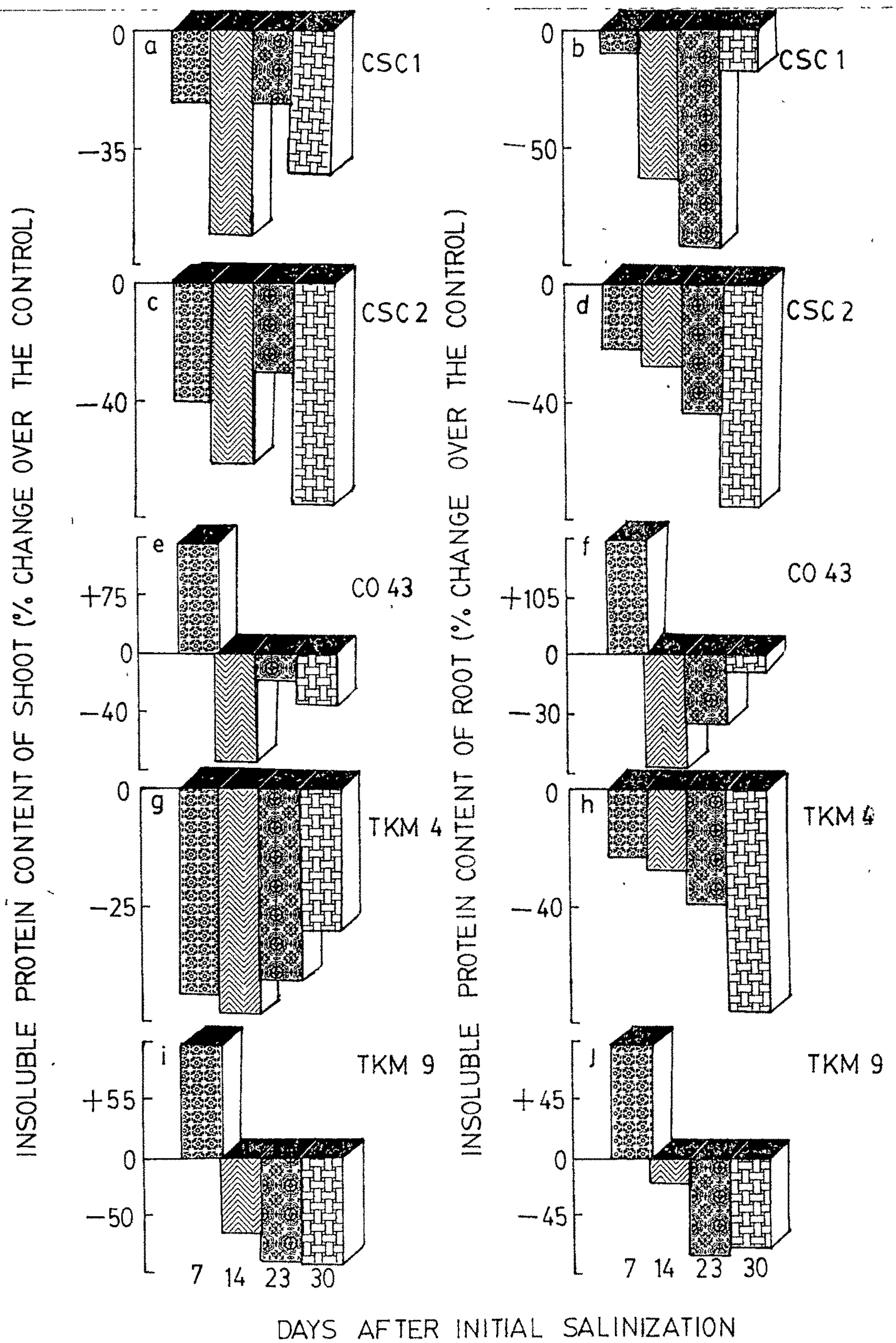
PROTEIN BOUND - PROLINE OF SHOOT (% CHANGE OVER THE CONTROL)
PROTEIN BOUND - PROLINE OF ROOT (% CHANGE OVER THE CONTROL)
a
CSC 1
b
CSC 1
c
CSC 2
d
CSC 2
e
CO 43
f
CO 43
g
TKM 4
h
TKM 4
i
TKM 9
j
TKM 9
7 14 23 30
DAYS AFTER INITIAL SALINIZATION

Fig.12a - j. Percentage of changes over the control in the soluble protein content of shoot and root systems of rice varieties as affected by sodium chloride (100 mM NaCl) in different days after initial salinization. + : increase; - : decrease.



SOLUBLE PROTEIN CONTENT OF SHOOT (% CHANGE OVER THE CONTROL)
SOLUBLE PROTEIN CONTENT OF ROOT (% CHANGE OVER THE CONTROL)
a
CSC 1
160
100
20
0
b
CSC 1
150
100
40
0
c
CSC 2
60
0
d
CSC 2
50
0
e
CO 43
+15
0
−15
f
CO 43
+8
0
−8
g
TKM 4
65
0
h
TKM 4
50
0
i
TKM 9
+75
0
−25
j
TKM 9
+35
0
−35
7 14 23 30
7 14 23 30
DAYS AFTER INITIAL SALINIZATION

Fig.13a - j. Effect of salinity (100 mM NaCl) on the insoluble protein level of shoots and roots of rice varieties in 7, 14, 23 and 30 days after initial salinization. Results are expressed as percentage of changes over the control. + : increase; - : decrease.



INSOLUBLE PROTEIN CONTENT OF SHOOT (% CHANGE OVER THE CONTROL)
INSOLUBLE PROTEIN CONTENT OF ROOT (% CHANGE OVER THE CONTROL)
a
b
c
d
e
f
g
h
i
j
CSC 1
CSC 2
CO 43
TKM 4
TKM 9
0
−35
−50
−40
+75
+105
−30
−25
+55
+45
−45
7
14
23
30
DAYS AFTER INITIAL SALINIZATION

to salt treatment (Fig.12e and f). At the seventh day of salt treatment in the Co43 and TKM9 an increas in insoluble protein over the control was observed while in others it decreased (Fig.13e, f, i and j). All the varieties showed fluctuating levels of total protein upto 14 days of salinity marked by steady increase in the subsequent days (Table 7), but however at the end of 30 days of salinity they exhibited less ability to maintain high levels of total protein (Fig.14). Varieties CSC2, TKM4 and TKM9 accumulated the maximum level of total protein than the others at the fourteenth day of salinity in their shoot system (Fig.14c, g and i). In CSC1 and Co43, on the seventh day salinization the maximum increase of 32 to 38% ever recorded in total protein was observed in the roots (Fig.14b and f).

c. Total nitrogen content

Salinization significantly increased the total nitrogen in both shoots and roots of TKM4 and TKM9, whereas it decreased the same in other varieties at all the stages of investigation (Table 8; Fig.15). There was a steady state increase of total nitrogen in both non-salinized and salinized plants of CSC1 and CSC2 (Table 8). Variety Co43 showed 50 to 55% decrease in total nitrogen at 14 and 23 days of salinity, which was high when

Table 7 : Saline stress (100 mM NaCl) and the total protein content of shoots and roots of rice varieties.

	Total protein (mg/g fresh weight)							
	7		14		23		30	
	C	S	C	S	C	S	C	S
TKM4								
Shoot	3.55	3.30	4.20	7.93	7.00	9.00	8.60	8.90
Root	2.13	2.48	2.73	3.30	2.95	3.65	3.60	3.65
TKM9								
Shoot	3.20	2.95	4.15	7.55	6.60	9.50	8.25	8.90
Root	1.80	2.10	2.35	2.95	2.60	3.10	3.00	3.30
CSC1								
Shoot	2.25	2.60	3.90	3.42	7.80	8.95	6.28	6.38
Root	2.60	3.43	3.30	2.48	4.85	5.00	4.15	4.25
CSC2								
Shoot	3.78	3.55	4.75	8.15	7.20	9.00	8.85	8.86
Root	2.38	2.73	2.95	3.55	3.20	3.90	3.80	3.90
Co43								
Shoot	1.90	2.25	3.55	3.10	7.45	8.90	5.85	5.95
Root	2.25	3.10	2.95	2.25	4.20	4.60	3.75	3.90

C : Control; S : Salinized; 7, 14, 23 and 30 Days after initial salinization.

Table 8 : Total nitrogen in shoots and roots of rice varieties grown in salinized culture medium (100 mM NaCl)

	Total nitrogen (mg/g dry weight)							
	7		14		23		30	
	C	S	C	S	C	S	C	S
TKM4								
Shoot	4.20	5.60	18.20	22.40	29.40	50.40	50.40	61.10
Root	2.40	2.80	10.80	13.60	10.80	13.60	29.40	50.40
TKM9								
Shoot	40.00	50.00	40.00	42.00	65.00	66.00	22.50	40.00
Root	25.00	30.00	21.00	29.00	24.00	28.00	15.00	17.50
CSC1								
Shoot	29.40	23.80	50.40	34.30	60.90	44.80	47.60	36.40
Root	4.90	4.20	5.90	5.60	8.00	5.90	11.90	8.40
CSC2								
Shoot	38.50	28.70	42.00	34.30	47.60	35.00	51.10	42.70
Root	6.30	4.20	9.80	6.60	11.90	8.40	16.10	10.10
Co43								
Shoot	55.00	40.00	51.00	39.00	50.00	37.50	30.00	35.00
Root	40.00	35.00	25.30	22.10	22.50	20.00	20.00	22.50

C : Control; S : Salinized; 7, 14, 23 and 30 Days after initial salinization.

Fig.14a - j. Changes as per cent over the control in the total protein content of shoots and roots of rice varieties in response to salinity (100 mM NaCl) at different days after initial salinization.

\+ : increase; - : decrease.

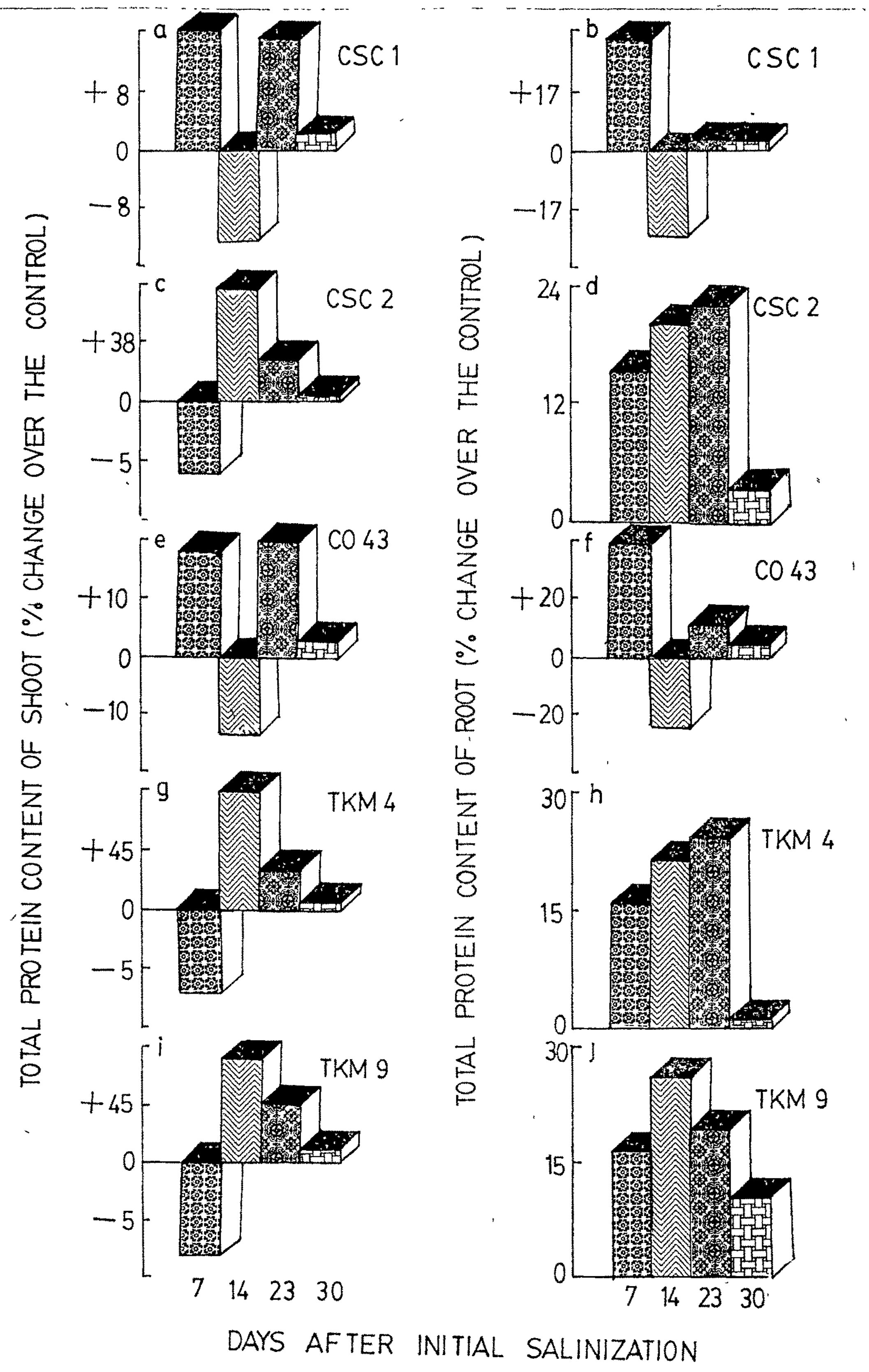
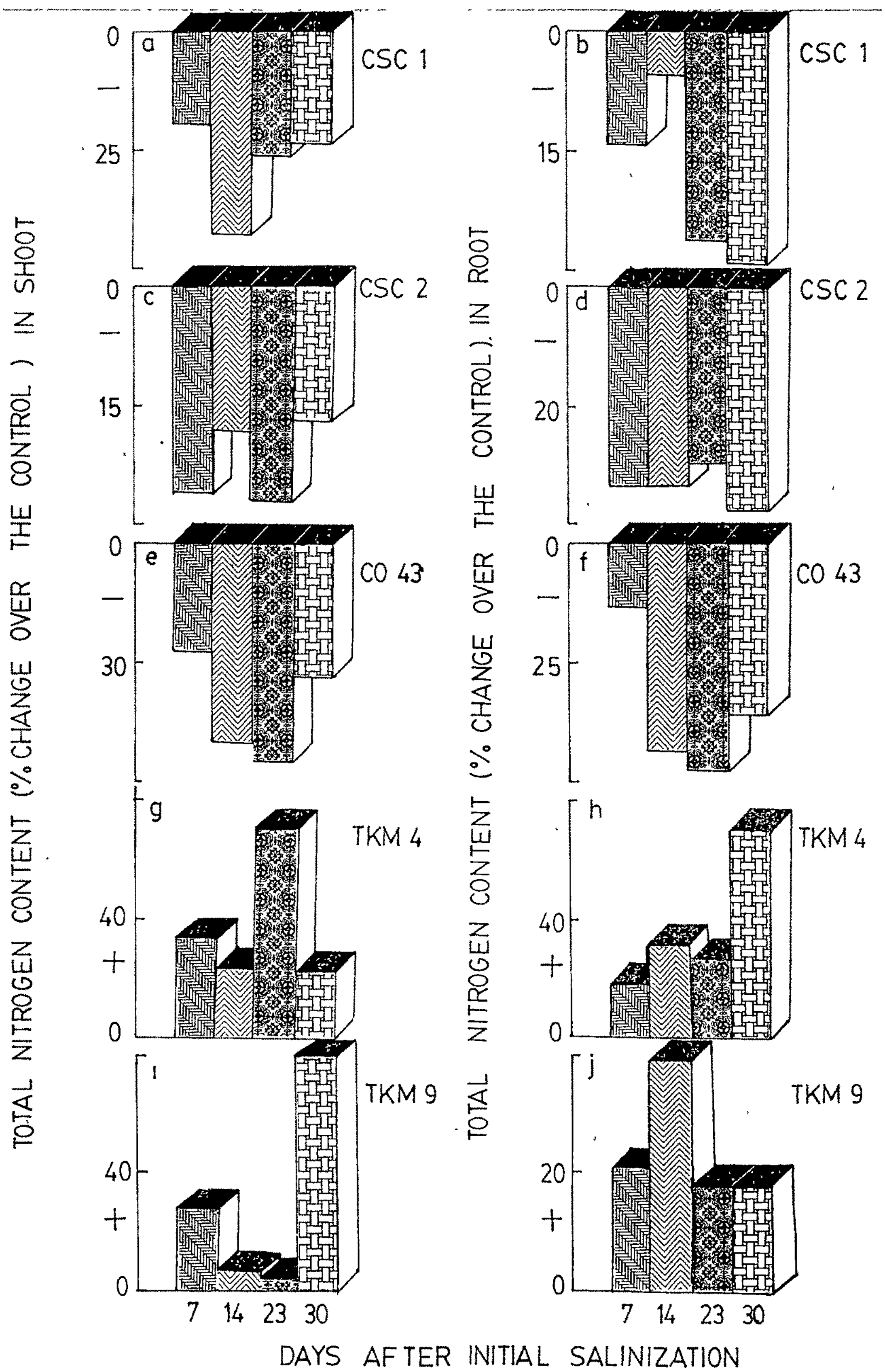

a
CSC 1
+8
0
−8
b
CSC 1
+17
0
−17
c
CSC 2
+38
0
−5
d
24
CSC 2
12
0
e
CO 43
+10
0
−10
f
CO 43
+20
0
−20
g
TKM 4
+45
0
−5
h
30
TKM 4
15
0
i
TKM 9
+45
0
−5
J
30
TKM 9
15
0
7 14 23 30
7 14 23 30
TOTAL PROTEIN CONTENT OF SHOOT (% CHANGE OVER THE CONTROL)
TOTAL PROTEIN CONTENT OF ROOT (% CHANGE OVER THE CONTROL)
DAYS AFTER INITIAL SALINIZATION

Fig.15a - j. Total nitrogen content of shoots and roots of rice varieties grown under saline stress condition (100 mM NaCl) for 30 days after initial salinization. Results are expressed as percentage of changes over the control. + : increase; - : decrease.



TOTAL NITROGEN CONTENT (% CHANGE OVER THE CONTROL) IN SHOOT
TOTAL NITROGEN CONTENT (% CHANGE OVER THE CONTROL) IN ROOT
a
b
c
d
e
f
g
h
i
j
CSC 1
CSC 2
CO 43
TKM 4
TKM 9
0
25
15
20
30
40
+
—
7
14
23
30
DAYS AFTER INITIAL SALINIZATION

compared to CSC1 and CSC2 (Fig.15e, f, a, b, c and d). At the time of final harvest it was recorded that TKM4 and TKM9 had a higher per cent increase in total nitrogen over the control in the roots than the shoots.

II. Preflowering vegetative growth studies

1. Inorganic constituents of salinized soil

At the end of seven weeks after the sodium chloride treatment the pH of the soil was observed to be 8.6 against the control value of 7.47 while the electrical conductivity (EC) of the treated soil proved to be 7.95 m mhos/cm against the untreated one having 0.94 m mhos/cm. Concurrently, the NaCl treated soil had accumulated 15.2 meq/l of sodium and 17.6 meq/l of chloride against the control having 2.04 and 2.48 meq/l respectively. The sodium absorption ratio (SAR) and exchangable sodium percentage (ESP) of the treated soil were 11.03 and 13.05 against a control level of 1.39 and 0.79 at the end of seven weeks of salt treatment (Table 9).

There was no marked differences in the other inorganic elements such as potassium, calcium, magnesium, carbonate, bicarbonate and sulphate and the ratios like potassium absorption ratio (PAR) and exchangable potassium percentage (EPP) between control and salt treated

Table 9: Changes in the pH, EC and mineral composition of the saturation extract of soil at the time of salt treatment (EC 10 m mhos/cm of NaCl)

Weeks after initial salini-zation	pH		Electrical conducctivity (m mhos/cm)		Sodium (meq/l.)		Chloride (meq/l.)		Sodium absorption ratio (SAR)		Exchangable sodium percentage (ESP)	
	C	S	C	S	C	S	C	S	C	S	C	S
0	6.30	6.30	0.60	0.60	1.60	1.60	0.55	0.55	0.87	0.87	0.03	0.03
1	6.45	6.80	0.62	1.15	1.68	8.40	0.77	1.65	0.89	4.43	0.06	5.01
2	6.66	7.20	0.69	1.85	1.80	12.00	1.07	2.75	1.01	6.71	0.22	7.95
3	6.74	7.55	0.73	2.70	1.84	15.20	1.27	4.40	1.08	8.78	0.34	10.46
4	6.95	7.94	0.78	4.05	1.96	18.40	1.54	6.60	1.19	12.20	0.50	13.24
5	7.13	8.25	0.82	5.20	1.96	18.80	1.82	9.90	1.23	12.14	0.55	14.27
6	7.28	8.45	0.86	6.80	2.04	17.20	2.15	13.75	1.33	12.48	0.70	14.64
7	7.47	8.60	0.94	7.95	2.04	15.20	2.48	17.60	1.39	11.03	0.79	13.05

C : Control ;

S : Salinized

soil (Table 10 and 11). The total cations and anions levels were found to be 19.58 and 22.1 meq/l respectively in the salinized soil as compared to the control of 7.02 and 6.83 meq/l at the end of seven weeks of salt treatment. The increased total cations and anions were caused mainly by the addition of sodium chloride.

2. Vegetative growth of shoot system

The effect of salinity on growth was of varying magnitude among the varieties tried. Varieties Co43, CSC1 and CSC2 appeared to suffer less reduction in shoot height in response to six weeks of salinization (Table 12; Fig.16; plate 1a and b; plate 2a). The high reduction in the height of shoot system was noticed in GR3 and IR20 at the end of salt treatment (Fig.17 plate 3a and b). The sodium chloride treatment similarly inhibited the height of shoot system in Co36, TKM4, AU1 and TKM9 (Plate 4a and b; Plate 5a and b). 13 to 16 per cent reduction of fresh matter and 10 to 21 per cent reduction in dry matter accumulation was noticed in AU1, Co43 and CSC1 when compared to control after six weeks of salinization. This reduction was found to be less comparatively (Table 12 and 13; Fig.18, 19 and 20). Contrary to this, in the varieties TKM4, IR20 and GR3 a record reduction of 38 to 50 per cent in fresh matter accumulation was noticed at the final stage of harvesting (Fig.18h, g and f). Similarly, in these varieties maximum reduction of 54 to

Plate 1a and b. Sixty five days old plants of Co43 and CSC1 in response to sodium chloride treatment.

PLATE 1


CO 4.3
CONTROL
CO43
SALINIZED
a
CSC 1
CONTROL
CSC 1
SALINIZED
b

Plate 2a. Effect of sodium chloride on the shoot system of CSC2.

PLATE 2

Plate 3a and b. Response of GR3 and IR20 to sodium chloride treatment.

PLATE 3

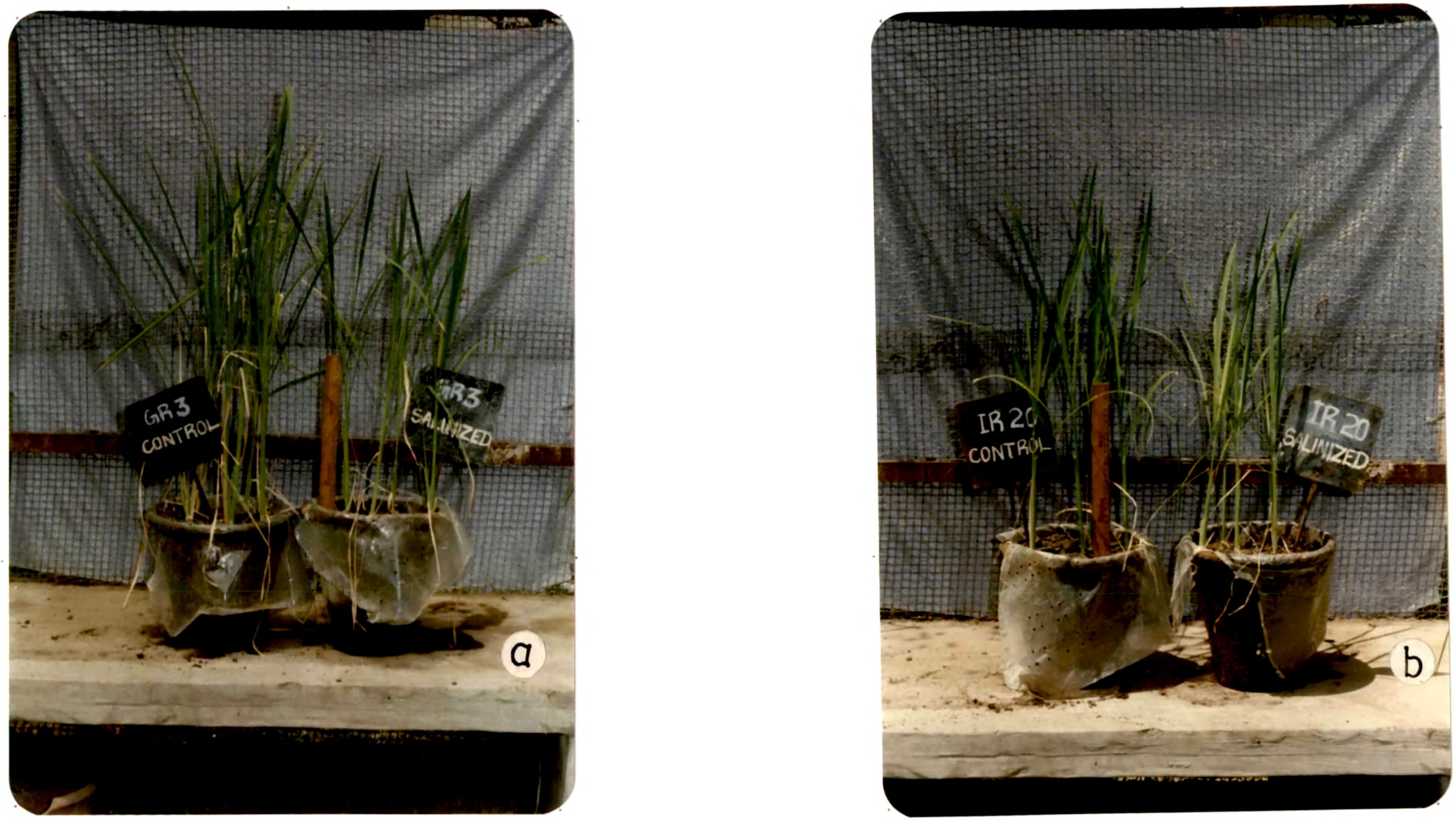


Plate 4a and b. Effect of sodium chloride on the shoot system of Co36 and TKM4.

PLATE 4

Plate 5a and b. Shoot system of AU1 and TKM9 in response to sodium chloride treatment.

PLATE 5

Table 10 : Inorganic composition of the saturation extract of soil at the time of salt treatment (EC 10 m mhos/cm of NaCl)

Weeks after initial salini-zation	Potassium (meq/l.)		Calcium (meq/l.)		Magnesium (meq/l.)		Potassium absorption ratio (PAR)		Exchangable potassium percentage (EPP)	
	C	S	C	S	C	S	C	S	C	S
0	1.08	1.08	4.0	4.0	2.7	2.7	0.59	0.59	8.93	8.93
1	1.05	1.00	4.3	4.5	2.8	2.7	0.56	0.53	8.64	8.37
2	0.95	0.88	3.8	3.9	2.6	1.5	0.53	0.49	8.41	8.06
3	0.85	0.75	3.3	3.5	2.5	2.5	0.50	0.43	8.13	7.54
4	0.73	0.60	3.1	3.0	2.3	2.4	0.44	0.37	7.64	6.92
5	0.70	0.60	2.9	2.6	2.2	2.2	0.44	0.39	7.58	7.12
6	0.70	0.58	2.8	2.1	1.9	1.7	0.46	0.42	7.75	7.43
7	0.68	0.58	2.8	2.1	1.5	1.7	0.46	0.42	7.81	7.43

C : Control;

S : Salinized

Table 11 : Salt concentration of the saturation extract of soil at the time of salt treatment (EC 10 m mhos/cm of NaCl)

Weeks after initial salinization	Carbonate (meq/l.)		Bicarbonate (meq/l.)		Sulphate (meq/l.)		Total cations (meq/l.)		Total anions (meq/l.)	
	C	S	C	S	C	S	C	S	C	S
0	0.0	0.0	2.0	2.0	1.16	1.16	9.38	9.38	3.71	3.71
1	0.0	0.0	2.10	2.10	1.20	1.20	9.83	9.83	4.07	4.95
2	0.0	0.0	2.15	2.15	1.20	1.20	9.15	19.28	4.47	6.10
3	0.0	0.0	2.25	2.25	1.40	1.35	8.49	21.95	4.92	8.00
4	0.0	0.0	2.33	2.33	1.45	1.40	8.09	24.4	5.32	10.33
5	0.0	0.0	2.40	2.40	1.60	1.55	7.76	24.2	5.82	13.85
6	0.0	0.0	2.44	2.44	1.70	1.65	7.44	21.58	6.29	17.84
7	0.0	0.0	2.50	2.70	1.85	1.80	7.02	19.58	6.83	22.1

C : Control ;

S : Salinized

Table 12 : Effect of NaCl on the vegetative growth of rice varieties.

Variety	Height of shoot system (cm)						Fresh weight of shoot system (g)					
	2		4		6		2		4		6	
	C	S	C	S	C	S	C	S	C	S	C	S
AU1	44.0	41.4	73.2	66.6	89.2	74.4	2.56	2.26	5.55	4.92	11.70	10.00
Co36	35.0	30.6	45.0	41.2	59.2	49.6	2.04	1.54	2.54	1.74	3.40	2.46
Co43	37.6	32.6	68.0	60.0	80.2	75.0	2.18	1.93	3.75	3.34	5.76	4.86
CSC1	37.2	35.4	67.6	63.8	75.8	69.6	2.14	1.90	4.03	3.22	10.00	8.66
CSC2	36.0	33.2	64.8	58.0	74.8	69.4	1.92	1.63	3.76	2.82	9.96	7.56
GR3	34.0	30.0	61.6	47.6	74.6	58.0	1.62	1.28	4.32	1.63	5.34	2.54
IR20	20.2	16.8	39.6	29.6	48.0	37.2	0.99	0.86	1.45	0.95	2.68	1.42
TKM4	39.6	35.4	69.6	62.4	94.4	79.4	1.36	0.82	2.22	1.12	3.92	2.44
TKM9	29.2	25.8	48.6	45.8	67.6	59.0	1.21	0.83	1.28	1.24	5.10	4.62
Mean	34.8	31.2	59.8	52.8	73.8	63.5	1.78	1.63	3.83	2.33	6.43	4.95
C.D. 5%	1.21		1.11		1.66		0.12		0.29		0.43	

C: Control; S: Salinized; 2,4 and 6 : Weeks after initial salinization.

Table 13 : Effect of NaCl on the vegetative growth of rice varieties

Variety	Dry weight of shoot system (g)						Height of tiller (cm)		Fr.Wt.of tiller/plant (g)		Dr.Wt.of tiller/plant (g)	
	2		4		6		6		6		6	
	C	S	C	S	C	S	C	S	C	S	C	S
AU1	1.26	1.04	2.56	1.98	4.46	4.02	73.3	70.1	8.54	6.20	2.50	2.13
Co36	0.58	0.33	0.70	0.41	1.40	0.83	41.2	23.6	1.98	0.30	0.53	0.03
Co43	0.97	0.63	1.42	1.22	2.03	1.60	58.7	50.4	3.10	1.66	1.17	0.58
CSC1	0.94	0.80	1.61	1.04	3.78	3.14	61.5	54.1	5.08	3.00	1.53	1.09
CSC2	0.49	0.36	1.13	0.87	2.95	2.18	58.04	54.1	4.04	2.70	1.35	0.89
GR3	0.66	0.41	1.07	0.62	2.09	0.90	62.4	33.8	3.52	0.87	1.37	0.22
IR20	0.41	0.26	0.53	0.33	0.91	0.42	27.1	7.4	0.74	0.05	0.15	0.01
TKM4	0.40	0.25	0.62	0.37	1.26	0.51	45.2	9.8	2.14	0.14	0.57	0.02
TKM9	0.45	0.34	0.80	0.61	1.72	1.09	55.9	44.1	2.67	1.44	1.02	0.50
Mean	0.68	0.49	1.16	0.83	2.29	1.98	53.7	39.4	3.53	1.98	1.13	0.61
C.D. 5%	0.09		0.10		0.05		7.26		8.81		0.35	

C : Control; S : Salinized; 2, 4 and 6 : Weeks after initial salinization.

Fig.16. Changes in the depression of height of shoot system of rice varieties as affected by NaCl at six weeks after initial salinization.

EFFECT OF NaCl ON THE HEIGHT OF SHOOT SYSTEM OF RICE CULTIVARS

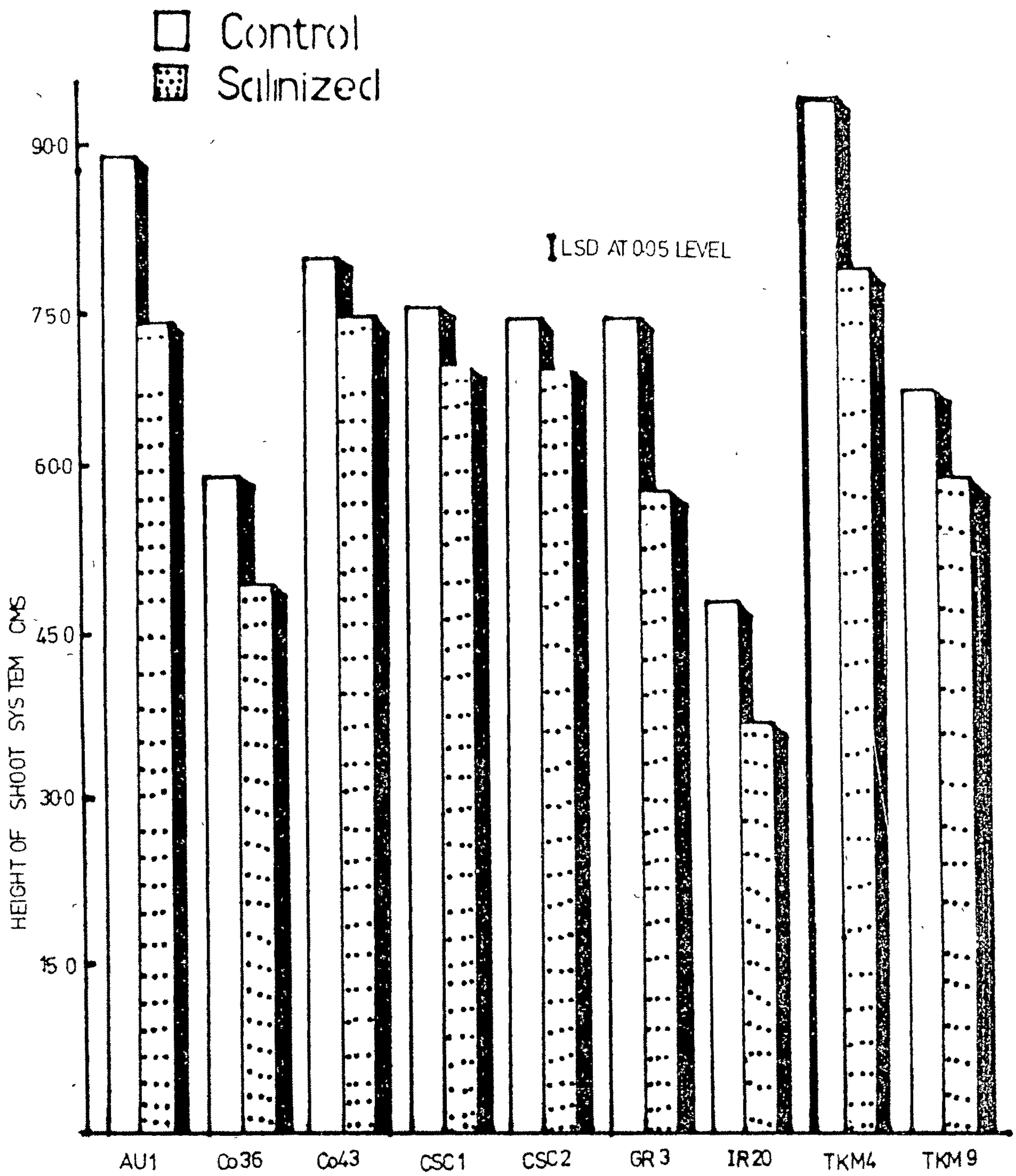
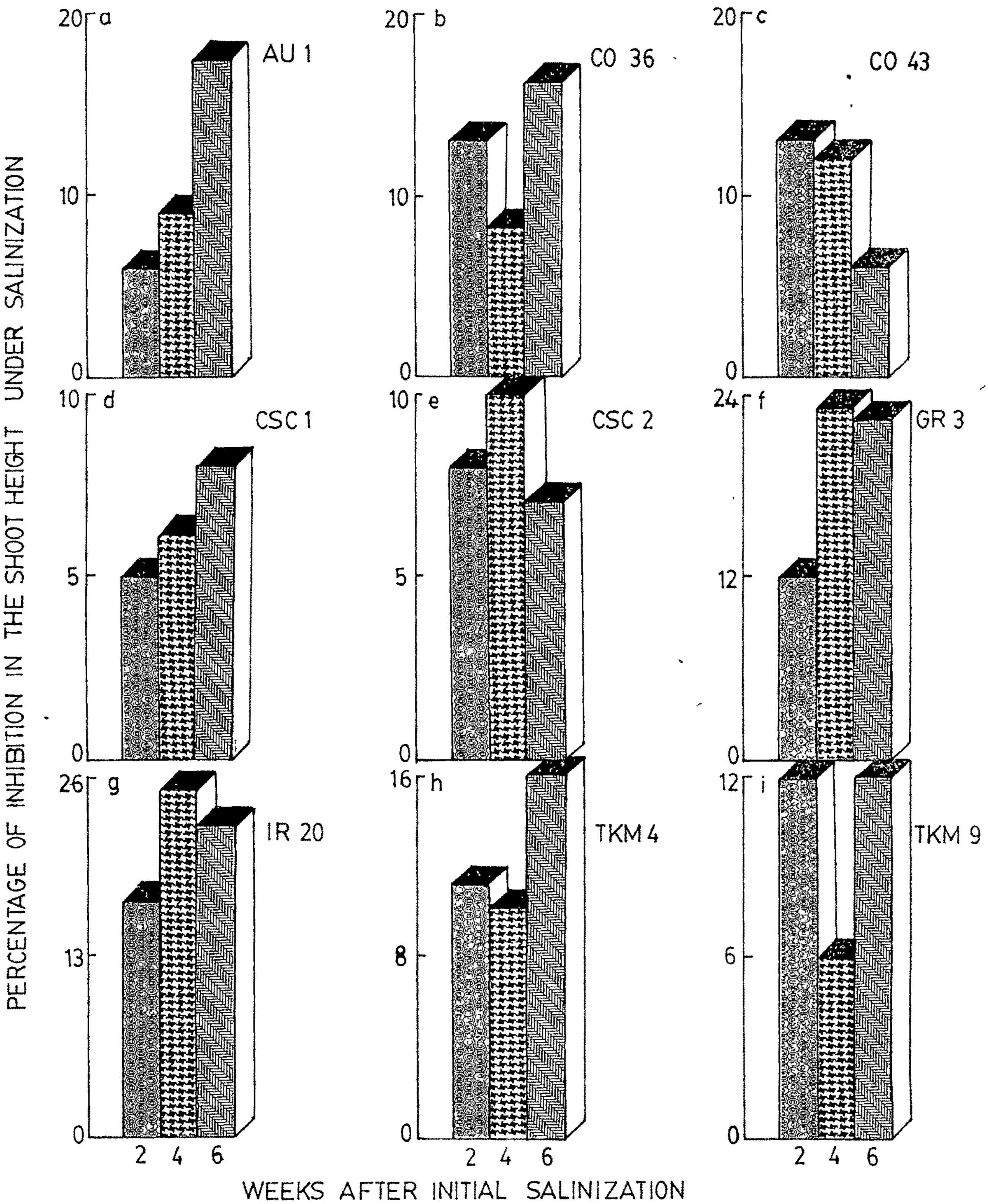
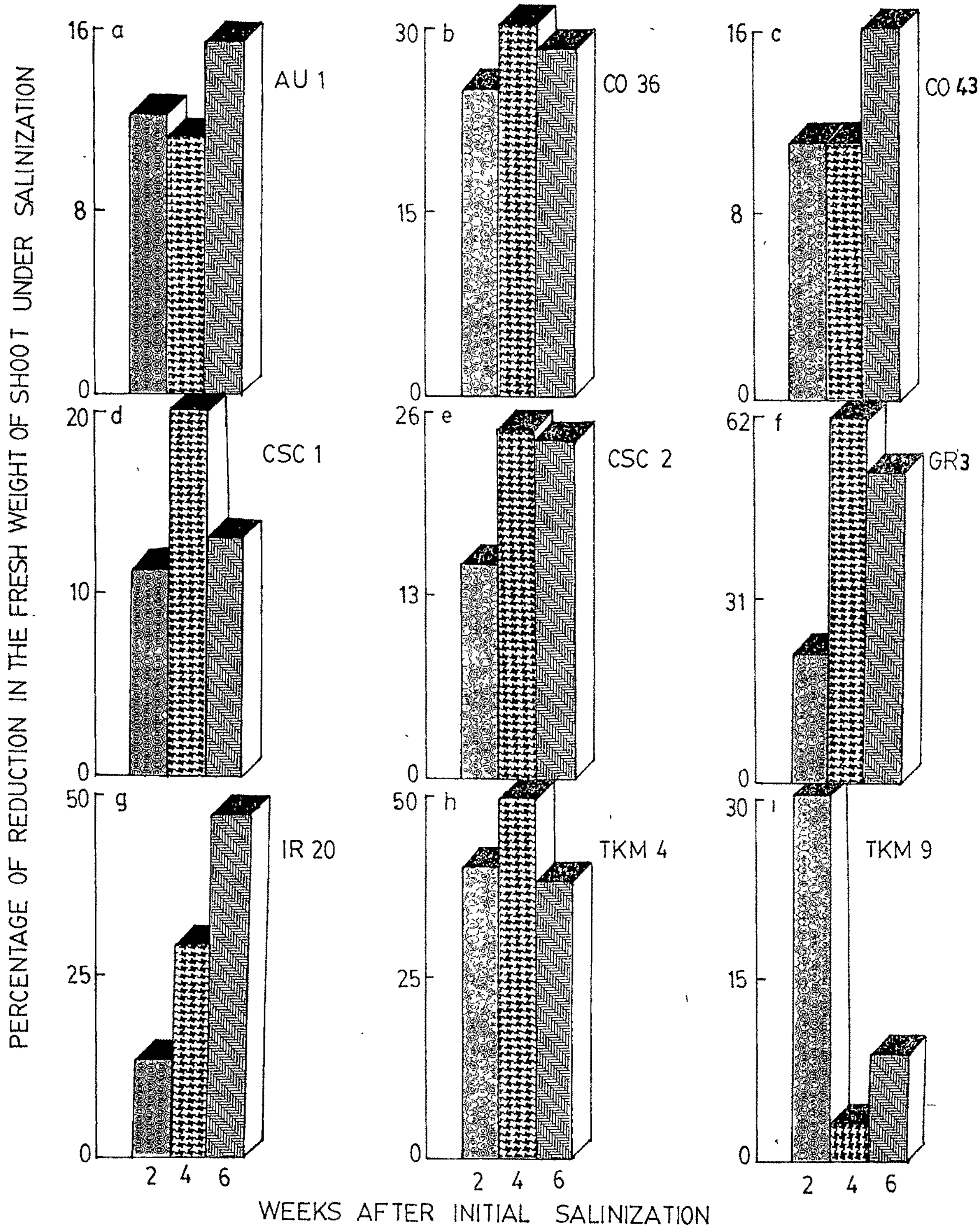


Fig.17a-i : Effect of Sodium chloride on the height of shoot of rice varieties in 2, 4 and 6 weeks after initial salinization. Results are expressed as percentage of decrease over the control.



a
AU 1
b
CO 36
c
CO 43
d
CSC 1
e
CSC 2
f
GR 3
g
IR 20
h
TKM 4
i
TKM 9
20
10
0
5
24
12
26
13
16
8
6
2 4 6
PERCENTAGE OF INHIBITION IN THE SHOOT HEIGHT UNDER SALINIZATION
WEEKS AFTER INITIAL SALINIZATION

Fig.18a-i : Fresh matter accumulation of shoot system of rice varieties grown under NaCl saline condition. Results are expressed as percentage of decrease over the control.



PERCENTAGE OF REDUCTION IN THE FRESH WEIGHT OF SHOOT UNDER SALINIZATION
a
AU 1
16
8
0
b
CO 36
30
15
0
c
CO 43
16
8
0
d
CSC 1
20
10
0
e
CSC 2
26
13
0
f
GR 3
62
31
0
g
IR 20
50
25
0
h
TKM 4
50
25
0
i
TKM 9
30
15
0
2 4 6
2 4 6
2 4 6
WEEKS AFTER INITIAL SALINIZATION

Fig. 19. Effect of NaCl on the dry matter content of shoot system of rice varieties at six weeks after initial salinization.

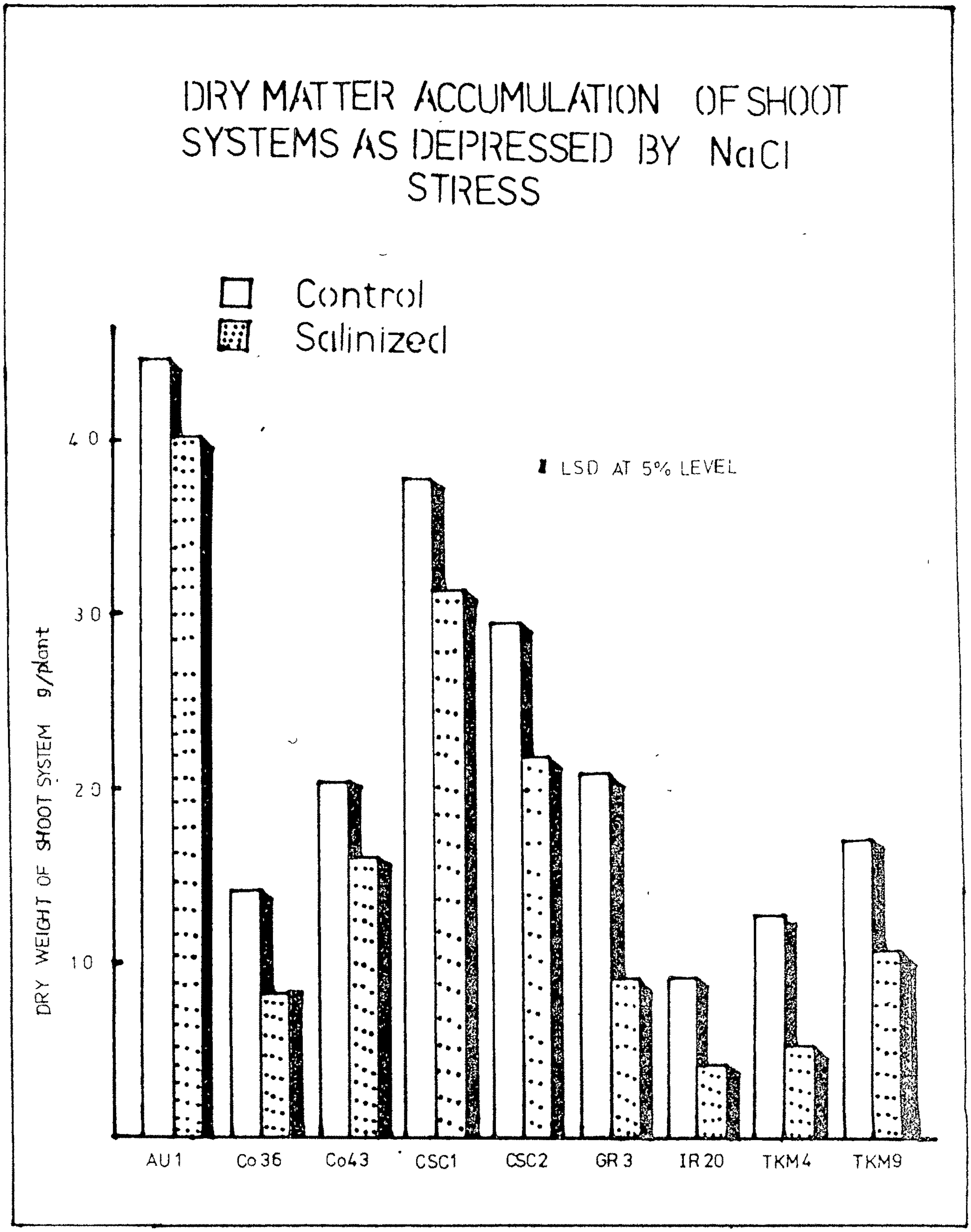
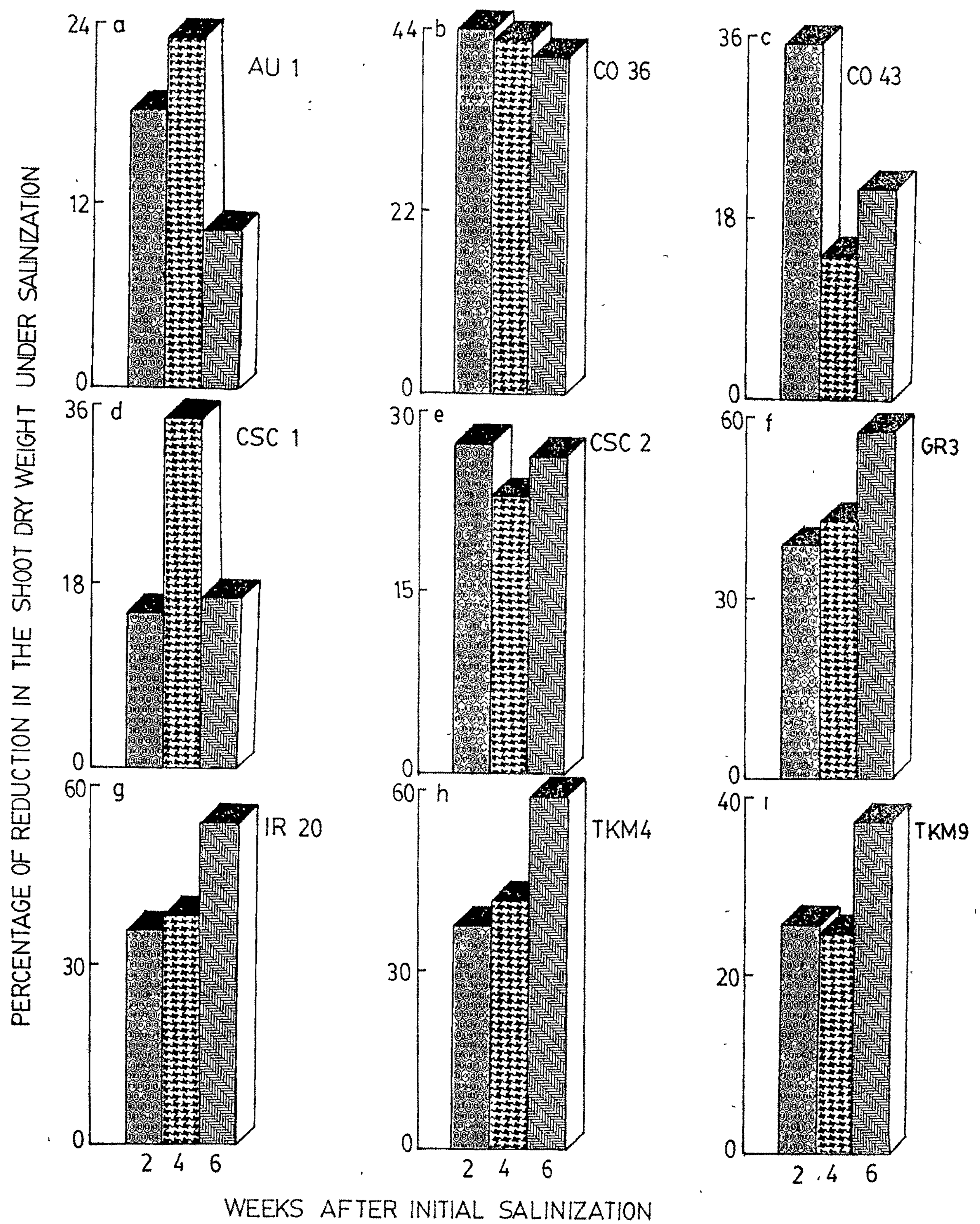

DRY MATTER ACCUMULATION OF SHOOT SYSTEMS AS DEPRESSED BY NaCl STRESS
Control
Salinized
LSD AT 5% LEVEL
DRY WEIGHT OF SHOOT SYSTEM g/plant
4 0
3 0
2 0
1 0
AU 1
Co 36
Co43
CSC1
CSC2
GR 3
IR 20
TKM4
TKM9

Fig. 20a-i: Changes in the dry matter accumulation of shoot system of rice varieties as affected by sodium chloride in 2, 4 and 6 weeks after initial salinization. Results are expressed as per centage decrease over the control.



PERCENTAGE OF REDUCTION IN THE SHOOT DRY WEIGHT UNDER SALINIZATION
a
AU 1
24
12
0
b
CO 36
44
22
0
c
CO 43
36
18
0
d
CSC 1
36
18
0
e
CSC 2
30
15
0
f
GR3
60
30
0
g
IR 20
60
30
0
h
TKM4
60
30
0
i
TKM9
40
20
0
2 4 6
2 4 6
2 4 6
WEEKS AFTER INITIAL SALINIZATION

59 per cent shoot dry matter accumulation was evident at the sixth week of salinization (Fig.20g, f and h).

Varieties AU1, TKM9 and Co43 had experienced a less reduction in tiller number per plant (20 to 39%) when compared to their respective control (Fig.21 and 22a). The tiller production was highly (83 to 85 per cent) inhibited by salinity in IR20 and TKM4 (Fig.22a). The height of tillers was not much affected in the AU1, Co43, CSC1 and CSC2 (Table 13; Fig.22b) but it was highly inhibited (73 to 78%) in IR20 and TKM4 (Fig.22b). Fresh weight of tillers recorded a reduction of 75 and 93% over the control in GR3, Co36 and IR20. AU1, Co43, CSC1, CSC2 and TKM4 proved to be more resistant in the production of fresh matter in their tillers to salinity (Table 13; Fig.22c). Varieties IR20, Co36 and TKM4 had maximum decreased dry matter content of the tillers (by 93 to 96%) over the control (Table 13; Fig.22d) whereas varieties AU1 and CSC1 were much less affected.

Varieties GR3, TKM4, IR20 and Co36 appeared to be highly sensitive in their total leaf area production and showed 55 to 67% inhibition over the control (Fig.22e and 23). The AU1, Co43, CSC1 and CSC2 exhibited lesser degree of inhibition in the total leaf area to salinity treatment. After six weeks of salinization 87 to 93 per cent of plants survived in AU1, CSC1 and Co43 and seemed to be more

Fig. 21. Changes in the tiller number of rice varieties as affected by NaCl at six weeks after initial salinization.

EFFECT OF NaCl ON THE NUMBER OF TILLERS OF DIFFERENT RICE CULTIVARS

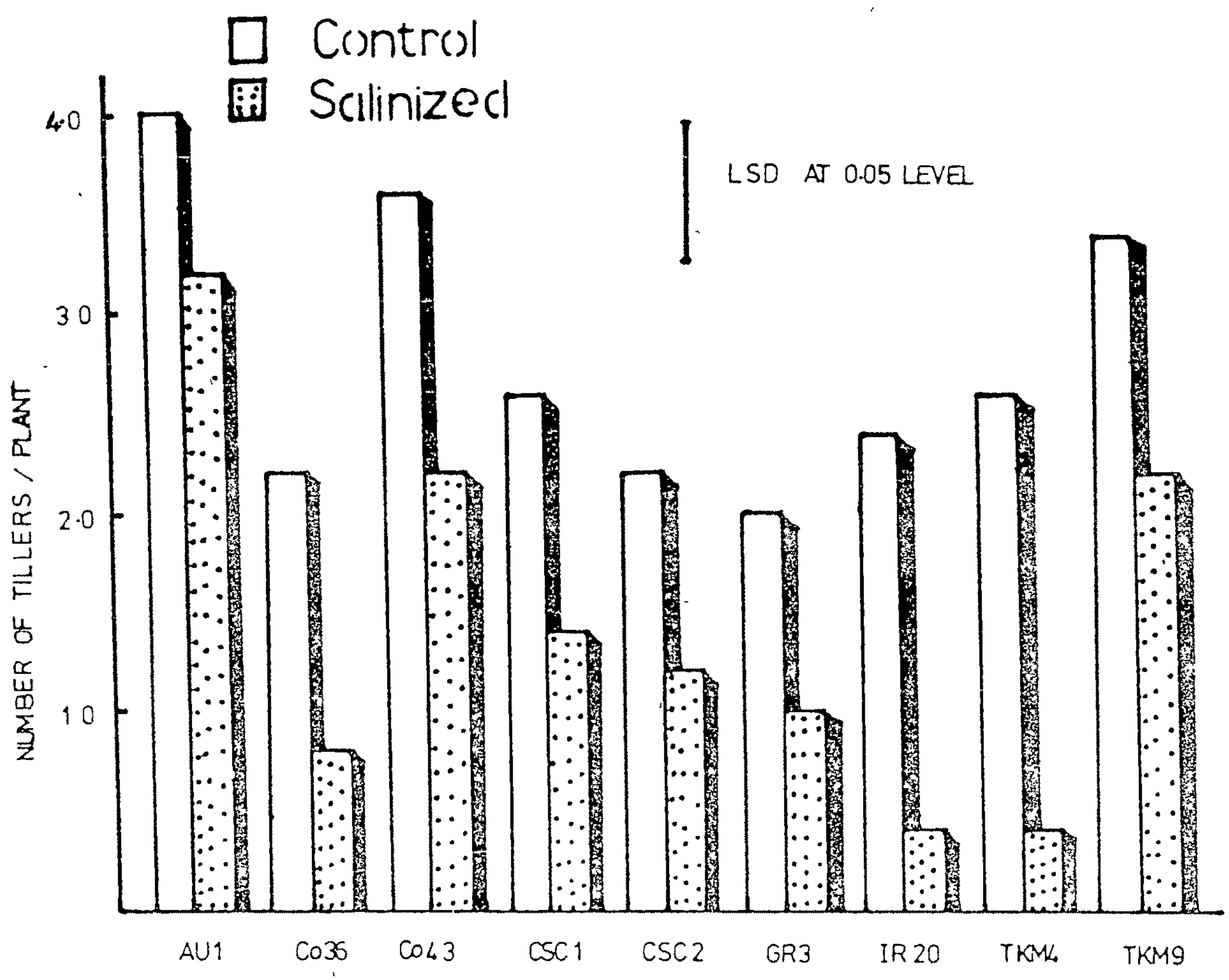
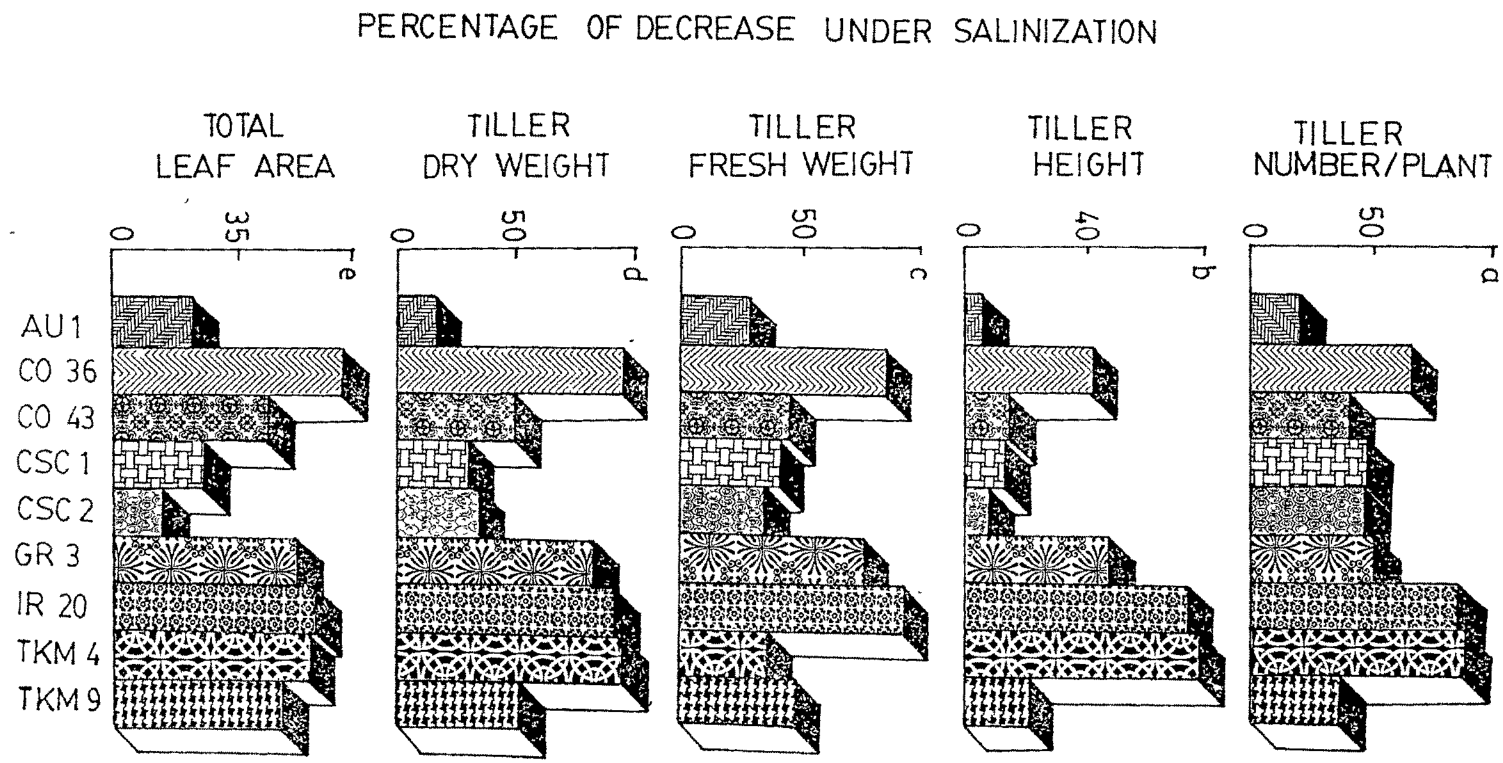
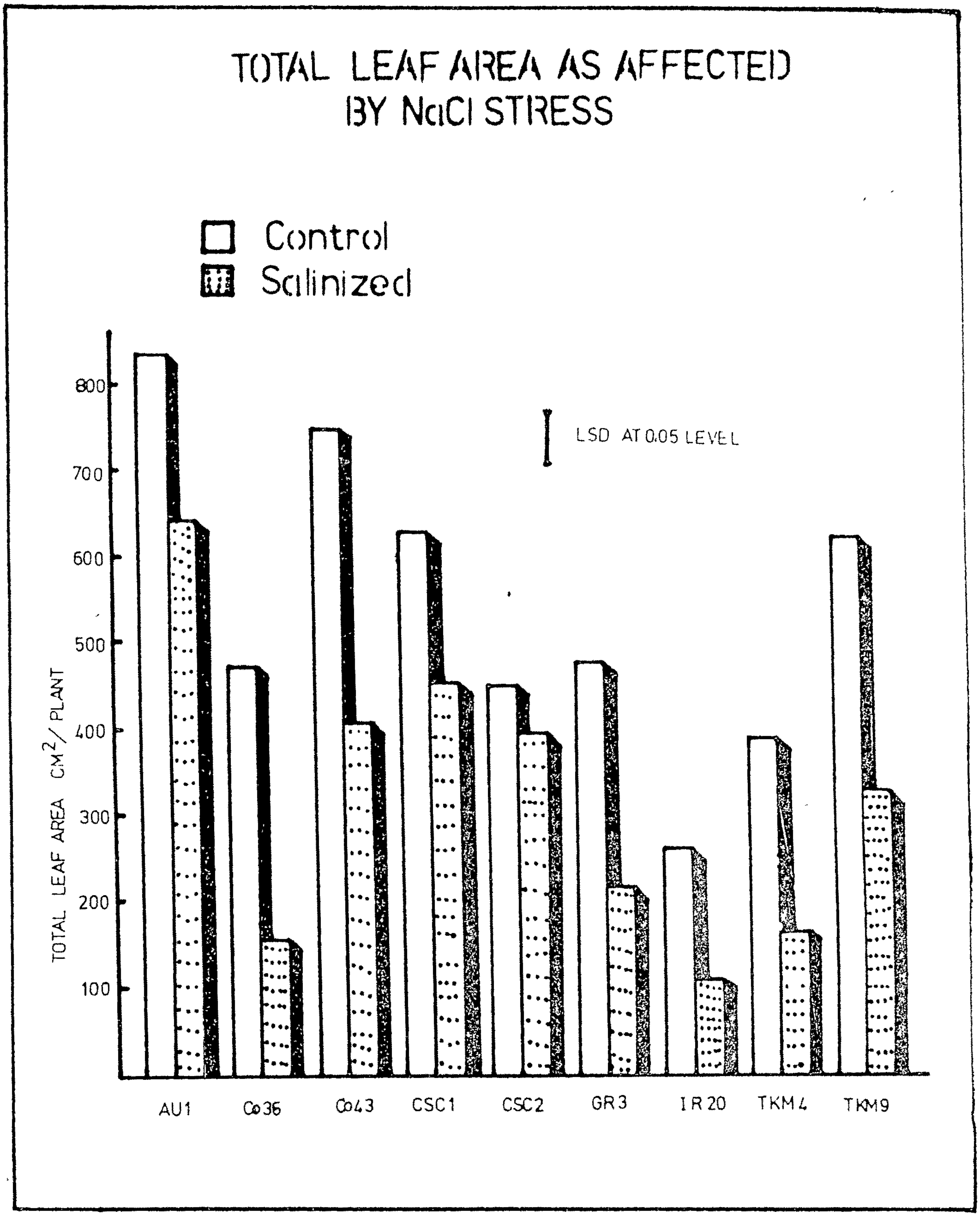


Fig. 22a-e. Effect of sodium chloride on the number of tiller per plant, height of tiller, fresh weight of tiller per plant, dry weight of tiller per plant and total leaf area per plant of rice varieties at six weeks after initial salinization. Results are expressed as per cent decrease over the control.



PERCENTAGE OF DECREASE UNDER SALINIZATION
TOTAL LEAF AREA
TILLER DRY WEIGHT
TILLER FRESH WEIGHT
TILLER HEIGHT
TILLER NUMBER/PLANT
0
35
50
40
a
b
c
d
e
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9

Fig. 23. Changes in the depression of total leaf area of rice varieties as affected by sodium chloride at six weeks after intial salinization.


TOTAL LEAF AREA AS AFFECTED BY NaCl STRESS
Control
Salinized
LSD AT 0.05 LEVEL
TOTAL LEAF AREA CM2/ PLANT
800
700
600
500
400
300
200
100
AU1
Co36
Co43
CSC1
CSC2
GR3
IR20
TKM4
TKM9

resistant to sodium chloride treatment. But the CSC2 and TKM4 were more susceptible to salinity, and only 33 to 47% of plants survived at the end of salt treatment (Fig.26).

3. Inorganic constituents of shoot system

Varieties Co36 and CSC2 could accumulate a high level of sodium than the others after four weeks of salinization. AU1 was always less able to maintain high level of sodium in the shoot system (Fig.24, 25 and 26). There was also high level of chloride content in the shoot system of varieties Co36, CSC2 and IR20 when the duration of salinization was extended (Fig.26 and 27e and g). The sodium chloride treatment increased the potassium, calcium and magnesium in AU1, Co43 and CSC1 while it decreased the above ions in others at 4 and 6 weeks after initial salinization (Table 14 and 15; Fig.28, 29 and 30).

4. Enzymes activity from the third leaves after six weeks of salinization

There was two fold increase in peroxidase activity in the leaves of CSC2 and IR20 after salt treatment while it was recorded to be four fold in TKM9. Varieties AU1, CSC1 and GR3 registered less degree of increase in peroxidase activity in response to salinity (Table 16; Fig.31). There was 2 to 5 fold increase of polyphenolase activity in the IR20 and CSC2 to salinity, and other

Table 15 : Changes in the magnesium level of the shoot system of rice varieties as affected by NaCl.

Variety	Magnesium (m moles/g dry weight)					
	2		4		6	
	C	S	C	S	C	S
AU1	1.32	0.80	0.80	1.12	0.60	0.96
Co36	0.16	0.08	0.80	0.76	0.72	0.68
Co43	0.68	0.80	0.68	0.92	0.76	0.84
CSC1	1.42	0.52	0.84	1.04	0.88	1.12
CSC2	0.80	0.84	1.28	1.20	1.32	1.00
GR3	1.12	0.56	0.60	0.20	0.56	0.28
IR20	0.40	0.48	0.96	0.76	0.92	0.80
TKM4	1.40	1.36	1.08	0.88	1.40	0.88
TKM9	0.76	1.04	0.84	0.60	0.84	0.64

C : Control;

S : Salinized;

3, 4 and 6 : Weeks after initial salinization.

Table 16 : Effect of NaCl on the activity of different enzymes from the third leaf of rice six weeks after initial salinization

Cultivars	Peroxidase		Ascorbic acid oxidase		Polyphenolase		Amylase		Invertase		Phosphatase	
	C	S	C	S	C	S	C	S	C	S	C	S
AU1	197	275	77.0	118.8	24	30	23.2	43.1	3.4	4.2	4.5	7.1
Co36	36	72	41.8	118.8	12	26	92.1	214.9	3.4	6.5	2.7	5.0
Co43	32	87	29.6	125.4	14	33	54.2	74.0	18.8	45.6	1.6	3.5
CSC1	83	120	57.2	195.8	16	38	56.3	76.2	3.6	8.7	3.6	4.4
CSC2	26	95	8.8	41.8	5	32	58.9	114.0	8.2	10.3	3.1	4.7
GR3	96	125	35.2	92.4	7	18	67.1	113.1	3.9	7.0	1.9	5.8
IR20	38	141	51.6	125.4	10	37	87.1	198.0	3.2	5.4	1.1	2.2
TKM4	25	36	77.0	132.0	12	20	23.2	64.1	17.4	39.6	2.9	7.0
TKM9	38	192	57.2	118.8	12	27	44.4	92.1	4.2	22.6	4.4	8.1

C : Control
S : Salinized

Peroxidase : Units increased/minute/mg protein
Ascorbic acid oxidase : µmoles of ascorbic acid oxidised/hour/g ft.wt.
Polyphenolase : Units increased/minute/mg protein
Amylase : µ moles of matlose released/10 min./mg protein.
Invertase: µ moles of reducing sugar produced/hour/mg protein.
Phosphatase: µ moles of p-nitrophenol released/30 min./mg protein

Fog. 24. Accumulation of sodium in the shoot system of rice varieties grown under saline (NaCl) condition at six weeks after initial salinization.

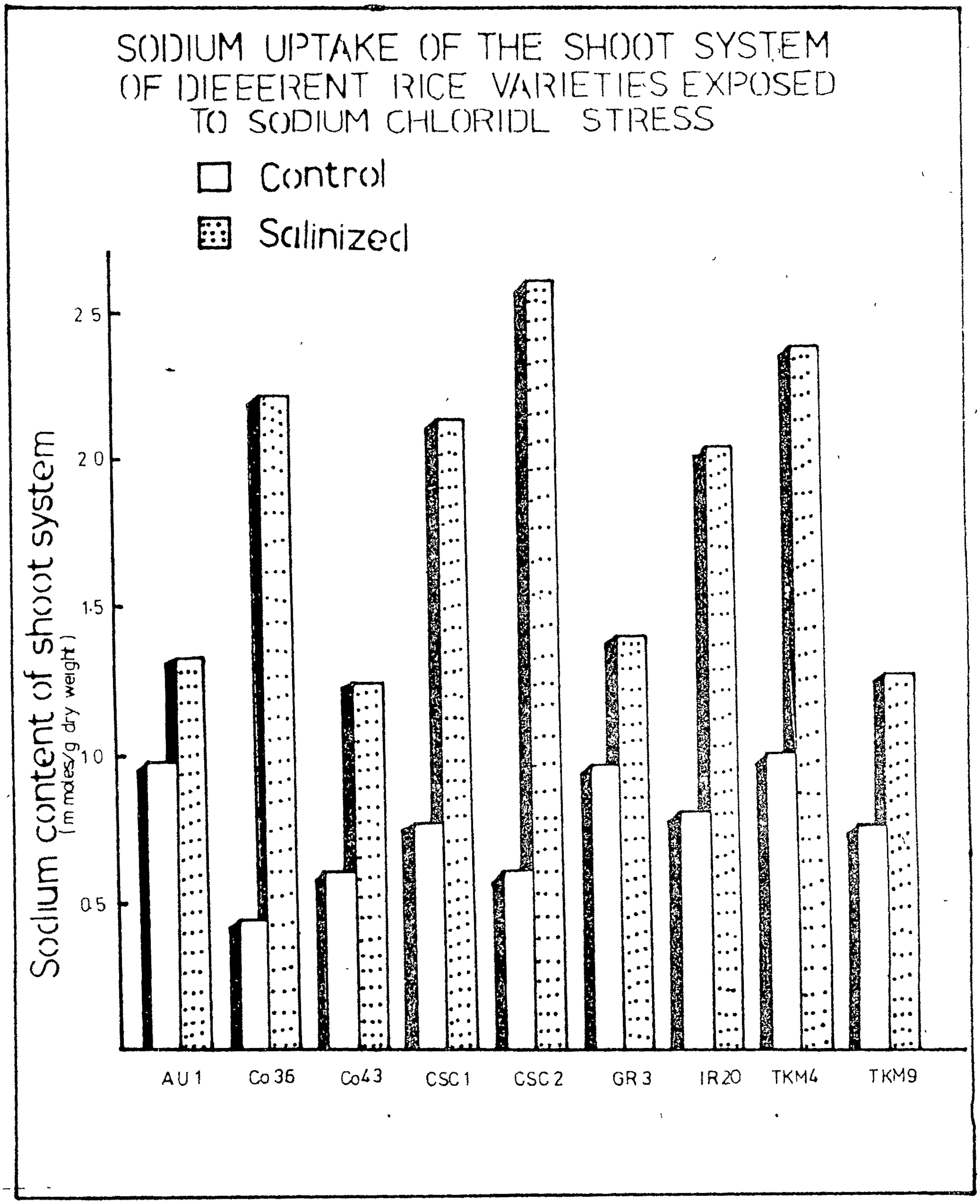
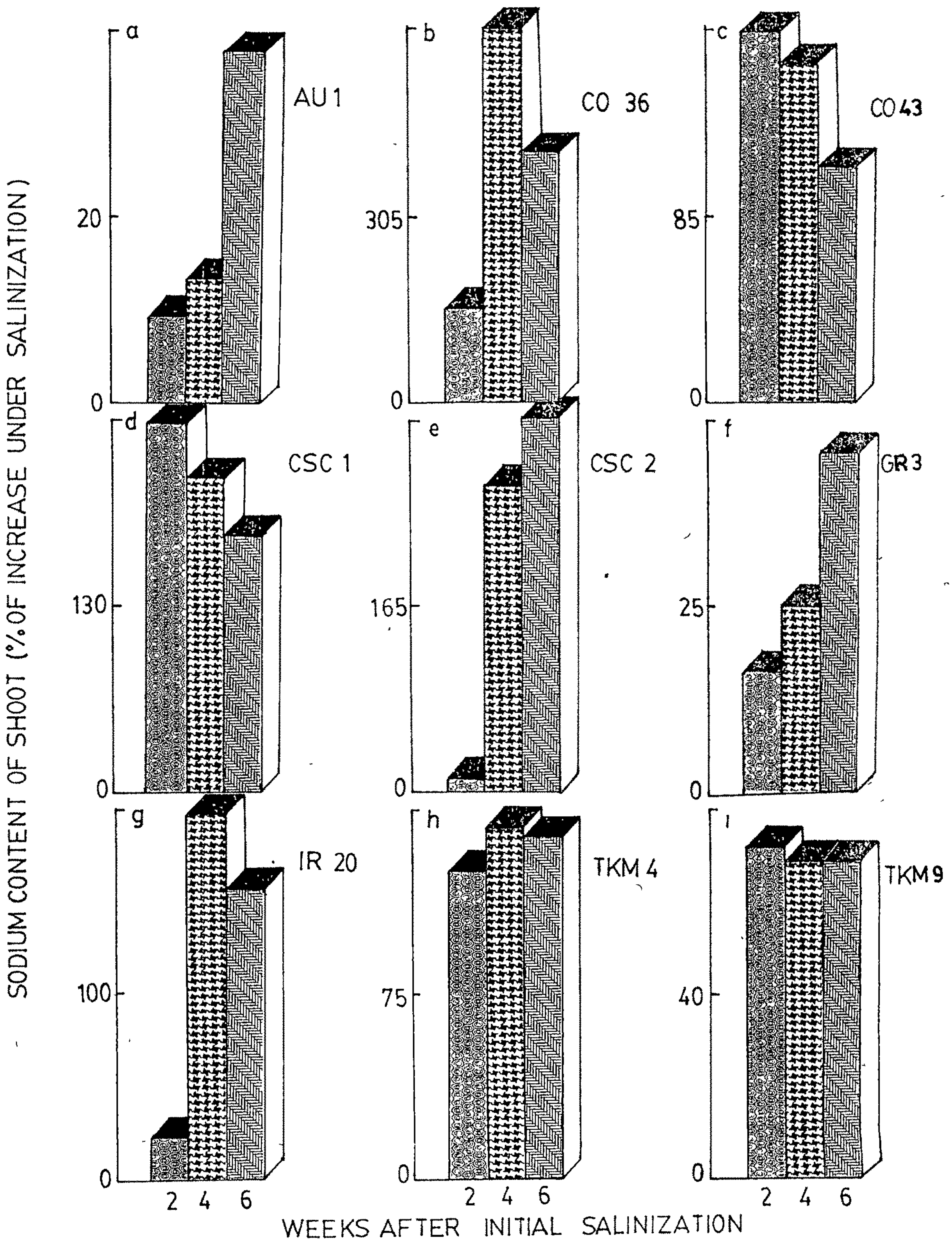

SODIUM UPTAKE OF THE SHOOT SYSTEM OF DIEEERENT RICE VARIETIES EXPOSED TO SODIUM CHLORIDL STRESS
Control
Salinized
Sodium content of shoot system
(m moles/g dry weight)
2.5
2.0
1.5
1.0
0.5
AU 1
Co 36
Co43
CSC 1
CSC 2
GR 3
IR 20
TKM4
TKM9

Fig. 25a-i. Effect of sodium chloride on the sodium content of shoot system of rice varieties at different weeks after initial salinization. Results are expressed as percentage of increase over the control.



SODIUM CONTENT OF SHOOT (% OF INCREASE UNDER SALINIZATION)
a
AU 1
20
0
b
CO 36
305
0
c
CO 43
85
0
d
CSC 1
130
0
e
CSC 2
165
0
f
GR 3
25
0
g
IR 20
100
0
h
TKM 4
75
0
i
TKM 9
40
0
2 4 6
2 4 6
2 4 6
WEEKS AFTER INITIAL SALINIZATION

Fig. 26. Internal level of sodium and chloride ions of shoot system in 2, 4 and 6 weeks after initial salinization and percentage of plants survived in 6 weeks after initial salinization.

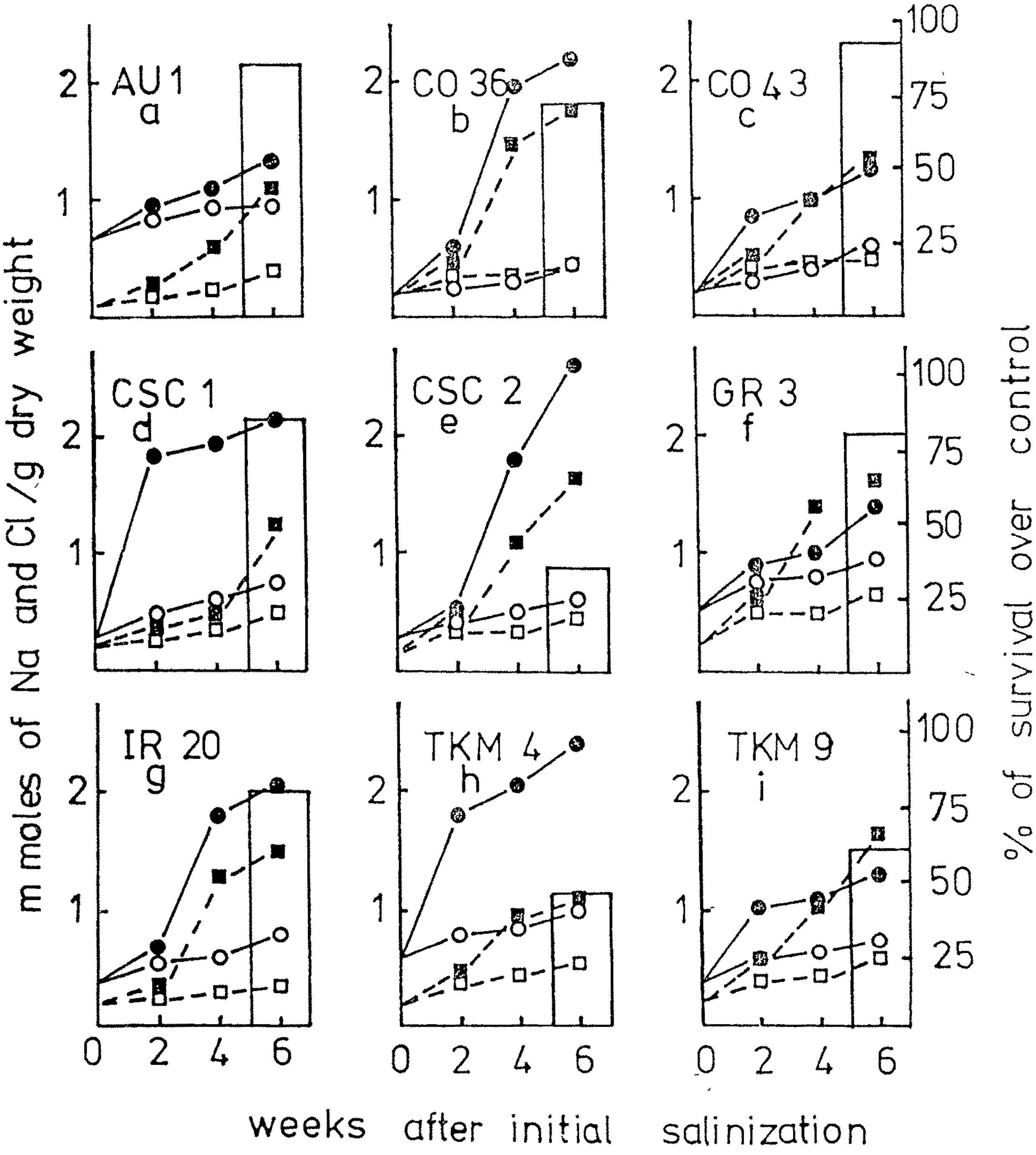
○——○: Control, sodium content of shoots;

●——●: Salinized, sodium content of shoots;

□---□: Control, chloride content of shoots;

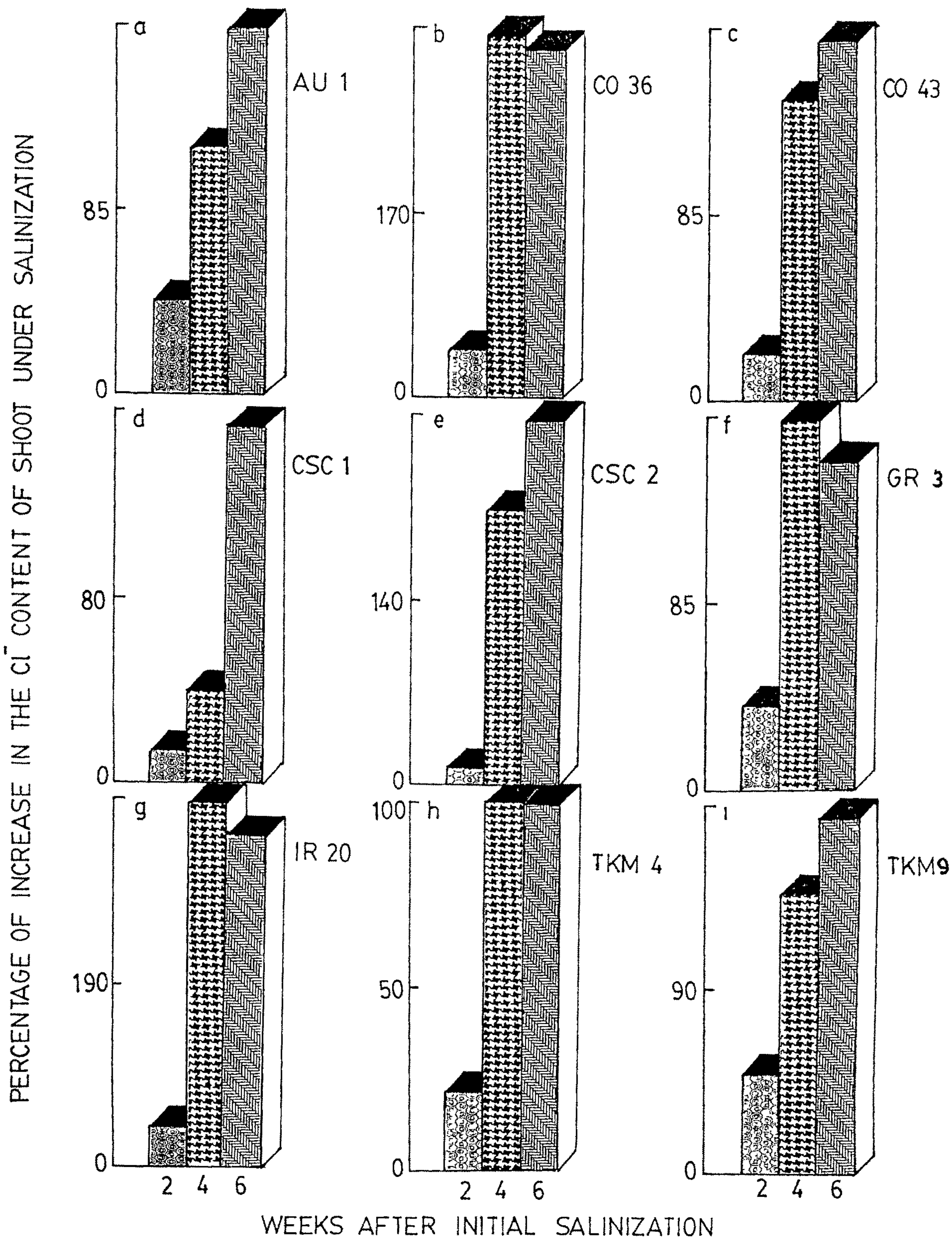
■---■: Salinized, chloride content of shoots;

□ : Percentage of plants survived.



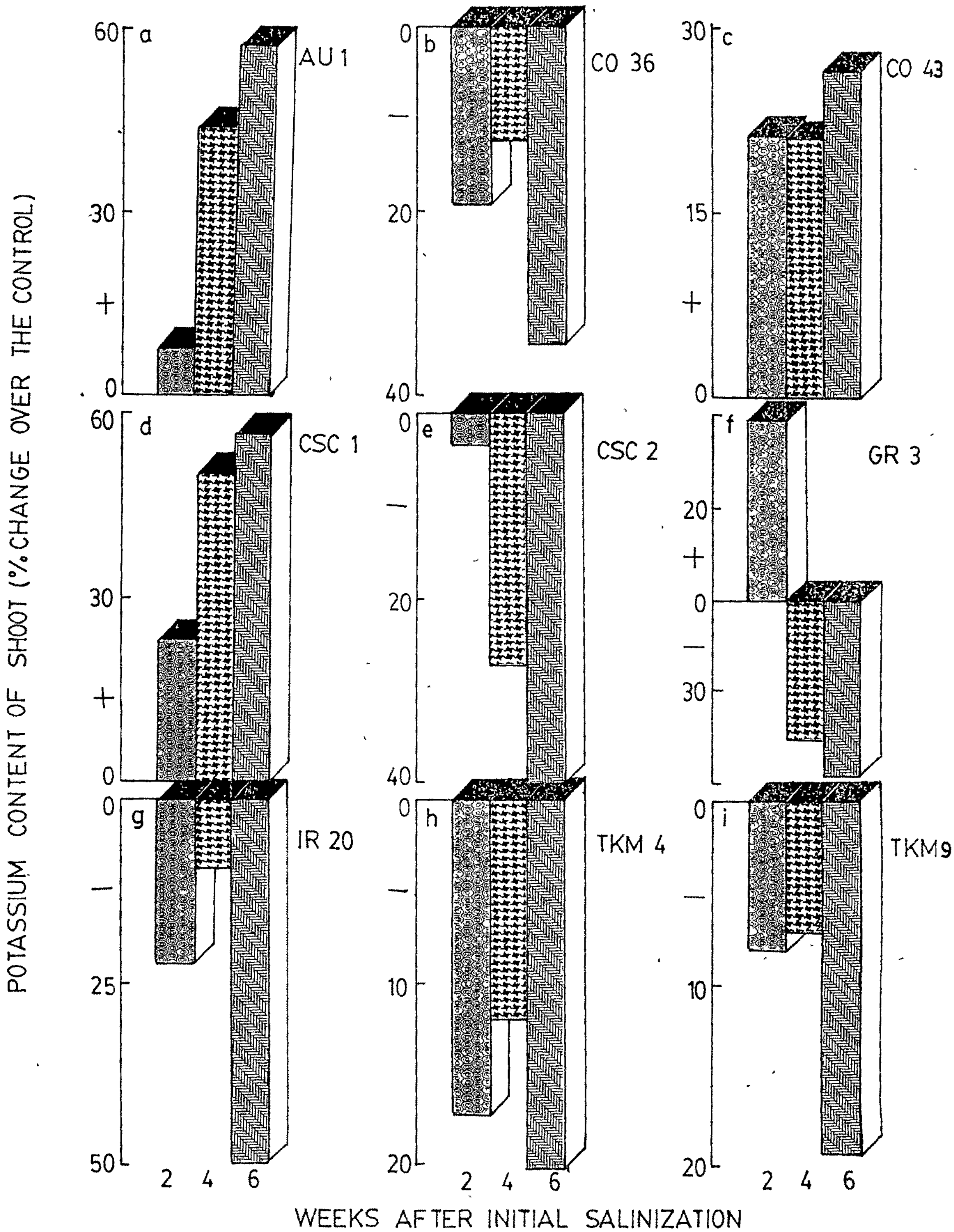
AU 1
a
CO 36
b
CO 43
c
CSC 1
d
CSC 2
e
GR 3
f
IR 20
g
TKM 4
h
TKM 9
i
m moles of Na and Cl /g dry weight
% of survival over control
weeks after initial salinization
0
1
2
25
50
75
100
0 2 4 6

Fig. 27a-i. Chloride accumulation in the shoot system of rice varieties in response to NaCl stress at different weeks after initial salinization. Results are expressed as percentage of increase over the control.



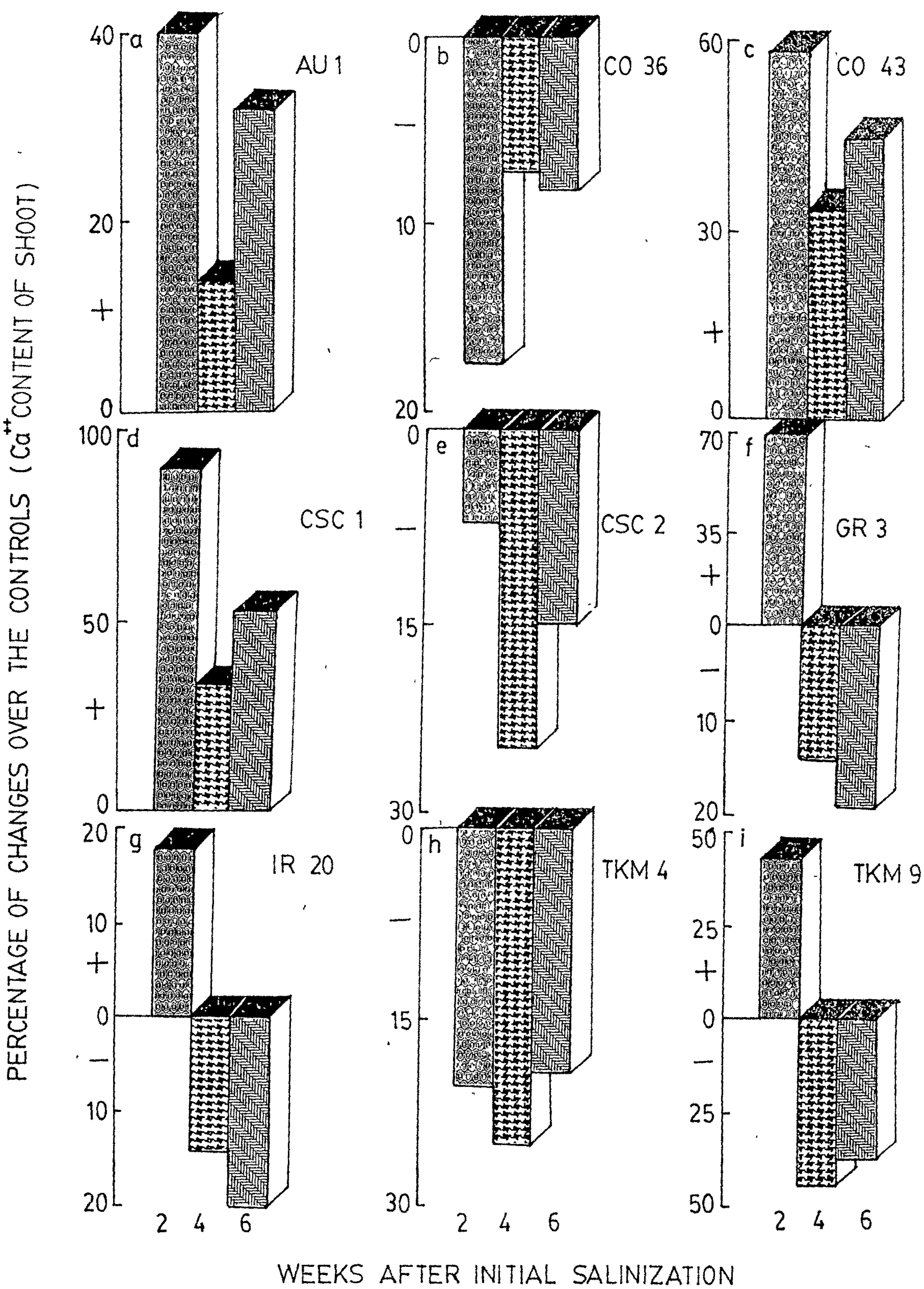
PERCENTAGE OF INCREASE IN THE Cl⁻ CONTENT OF SHOOT UNDER SALINIZATION
a
AU 1
85
0
b
CO 36
170
0
c
CO 43
85
0
d
CSC 1
80
0
e
CSC 2
140
0
f
GR 3
85
0
g
IR 20
190
0
h
TKM 4
100
50
0
i
TKM9
90
0
2 4 6
2 4 6
2 4 6
WEEKS AFTER INITIAL SALINIZATION

Fig. 28a-i. Potassium content of shoot system of rice varieties grown under saline (NaCl) stress condition. Results are expressed as percentage of changes over the control. + : increase; - : decrease.



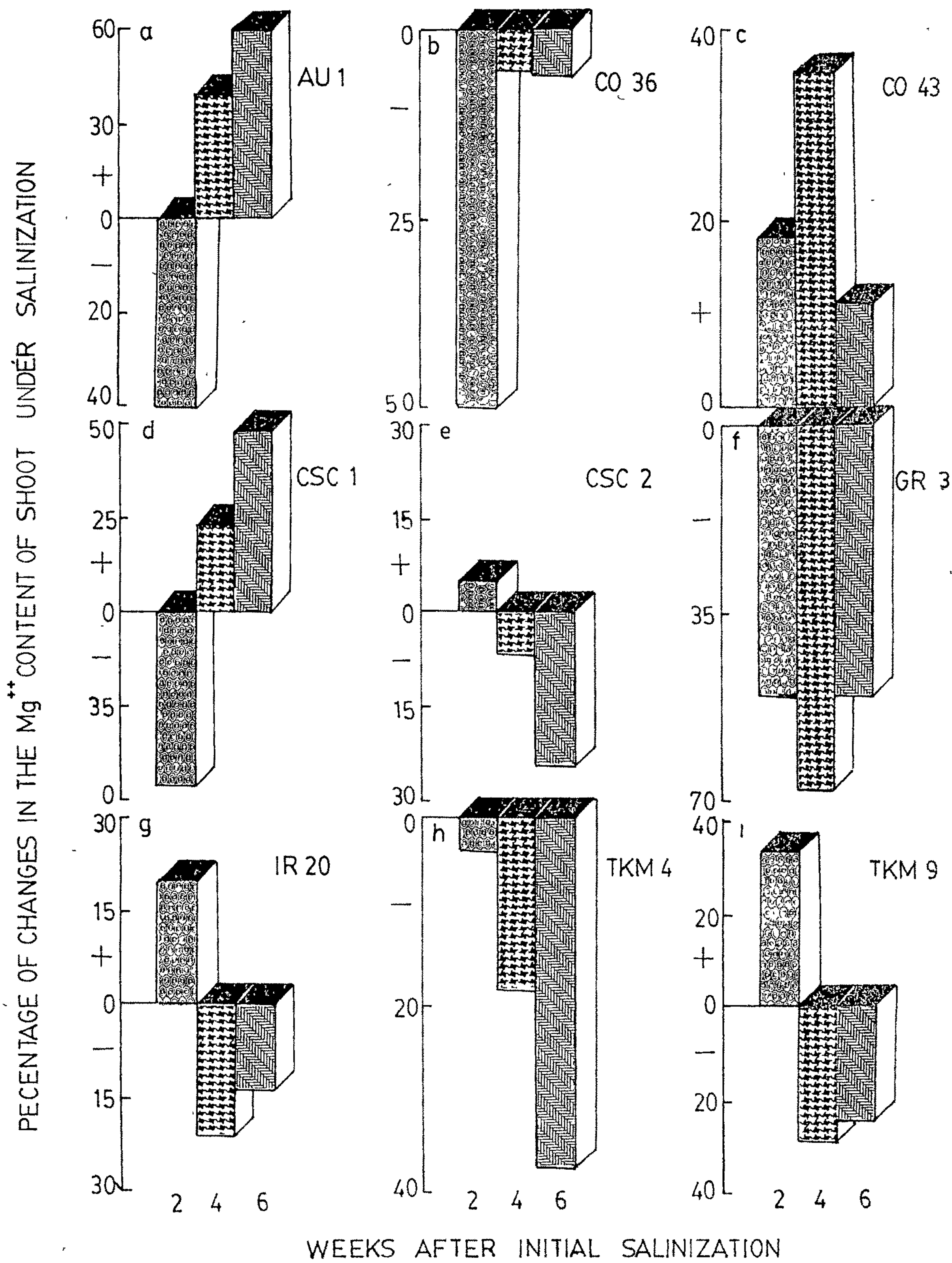
POTASSIUM CONTENT OF SHOOT (% CHANGE OVER THE CONTROL)
a AU 1
b CO 36
c CO 43
d CSC 1
e CSC 2
f GR 3
g IR 20
h TKM 4
i TKM9
2 4 6
WEEKS AFTER INITIAL SALINIZATION

Fig. 29a-i. Effect of sodium chloride on the calcium content of shoot system of rice varieties in different weeks after initial salinization. Results are expressed as percentage of changes over the control. + : increase - : decrease.



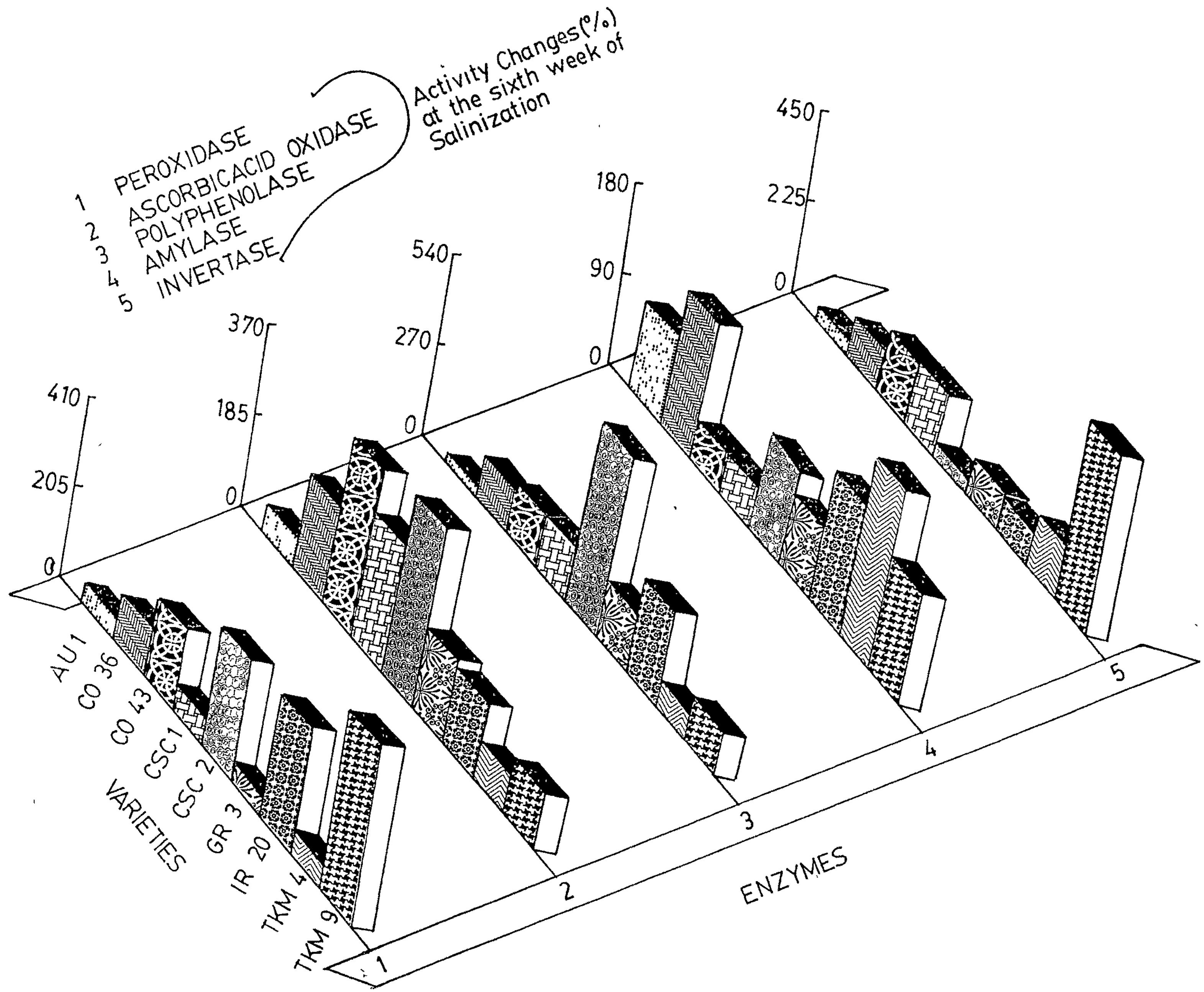
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
PERCENTAGE OF CHANGES OVER THE CONTROLS (Ca^{++} CONTENT OF SHOOT)
WEEKS AFTER INITIAL SALINIZATION

Fig. 30a-i. Changes in the magnesium content of shoot system of rice varieties as affected by sodium chloride stress at 2, 4 and 6 weeks after initial salinization. Results are expressed as percentage of changes over the control. + : increase; - : decrease.



a
AU 1
b
CO 36
c
CO 43
d
CSC 1
e
CSC 2
f
GR 3
g
IR 20
h
TKM 4
i
TKM 9
PECENTAGE OF CHANGES IN THE Mg++ CONTENT OF SHOOT UNDER SALINIZATION
WEEKS AFTER INITIAL SALINIZATION
2 4 6

Fig. 31. Effect of sodium chloride on the peroxidase, ascorbic acid oxidase, polyphenolase, amylase and invertase enzymes activity from the third leaf of rice varieties at six weeks after initial salinization. Results are expressed as percentage of increase over the control.



1 PEROXIDASE
2 ASCORBICACID OXIDASE
3 POLYPHENOLASE
4 AMYLASE
5 INVERTASE
Activity Changes(%) at the sixth week of Salinization
410
205
0
370
185
0
540
270
0
180
90
0
450
225
0
AU1
CO 36
CO 43
CSC1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES
1
2
3
4
5
ENZYMES

varieties recorded less increase. The polyphenolase activity was less pronounced in varieties AU1, Co36 and TKM4 grown in salinity (Table 16; Fig.31). Ascorbic acid oxidase was maredly increased by 2 to 3 fold in CSC1, CSC2 and Co43 while its increase over the control was less in AU1 and TKM4 (Table 16; Fig.31). Amylase activity was less increased by 36 to 89 per cent over the control in CSC1, Co43 and AU1 (Fig.31) and it was highly stimulated by salinity in Co36, IR20, TKM4 and TKM9, whereas it was one fold in Co43, CSC1 and TKM4 to salt treatment (Table 16; Fig.31). The activity of invertase was not much affected in AU1 and CSC2 to salinity. AU1, CSC1 and CSC2 exhibited slight increase in the activity of acid phosphatase over the control whereas in GR3 and TKM4 there was 1 to 2 fold increase in the acid phosphatase activity in plants exposed to salinity (Table 16; Fig.32).

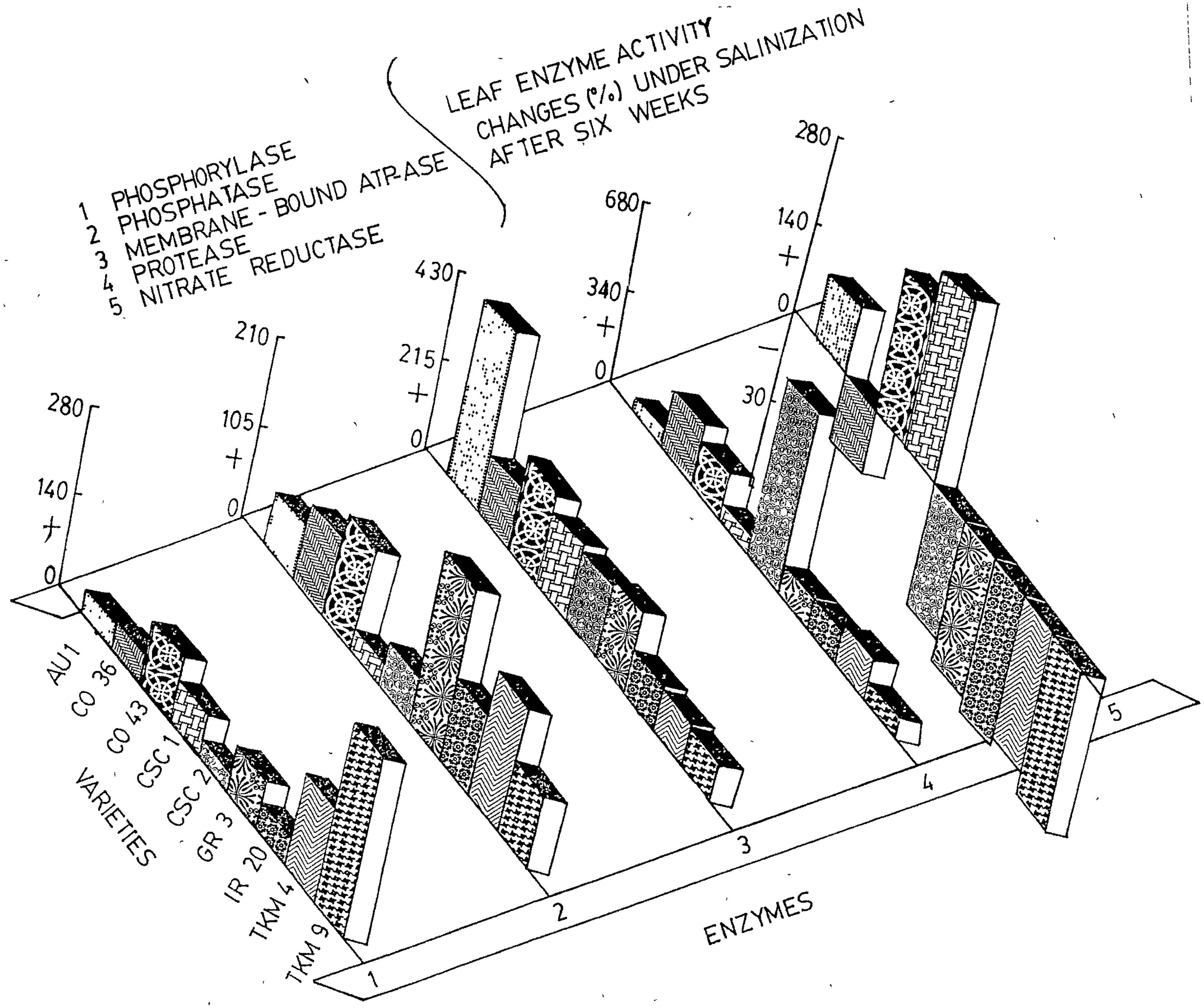
There was 2 to 4 fold promotion of memberane-bound ATPase activity in Co43 and AU1 as compared with their respective control (Table 17; Fig.32). IR20, CSC2, CSC1 and GR3 developed 1 to 1.9 fold increase of membrane-bound ATPase activity when compared to the control. In TKM4 and TKM9 the membrane-bound ATPase activity was less affected when exposed to salinization. Varieties TKM4 and TKM9 showed the maximum 1 to 2.7 fold increase of phosphorylase

Table 17 : Effect of NaCl on the activity of different enzymes from the third leaf of rice six weeks after initial salinization.

Cultivars	ATPase		Protease		Nitrate reductase		α-Ketoglutaric dehydrogenase		Succinic dehydrogenase		Pyruvic dehydrogenase	
	C	S	C	S	C	S	C	S	C	S	C	S
AU1	428	2238	7.7	9.6	271.7	543.4	0.31	1.53	14.6	19.8	11.5	18.9
Co36	210	481	1.9	5.6	452.8	362.3	0.40	1.10	12.5	30.1	12.5	32.2
Co43	710	2221	3.9	9.5	181.1	588.7	0.35	0.97	10.7	31.4	10.2	31.4
CSC1	527	1440	3.2	4.2	181.1	679.3	0.42	0.66	21.9	29.4	22.5	30.5
CSC2	241	626	0.8	6.3	452.8	271.7	0.29	0.76	13.5	34.6	12.7	68.8
GR3	929	2703	3.3	6.4	679.3	362.3	0.26	0.69	13.2	26.8	13.5	27.4
IR20	356	719	1.5	3.2	362.3	181.1	0.23	0.29	5.9	8.7	6.4	11.3
TKM4	811	1606	6.5	15.3	679.3	362.3	1.07	2.67	43.2	86.4	37.4	86.4
TKM9	527	969	3.6	6.0	769.8	362.3	0.36	0.83	10.2	12.6	8.3	16.2

C : Control
S : Salinized
ATPase : μ moles of phosphate released/30 minutes/mg protein
Protease: μ moles of glyeine released/hour/mg protein
Nitrate reductase : μmoles of NO_2 released/g fr.wt./hour
α-Ketoglutaric dehydrogenase : μ moles of DCPIP reduced/minute/mg protein
Succinic dehydrogenase : μmoles of $K_3Fe(CN)_6$ reduced/minute/mg protein
Pyruvic dehydrogenase : μ moles of $K_3Fe(CN)_6$ reduced/minute/mg protein

Fig. 32. Changes in the enzymes activity of phosphorylase, phosphatase, ATPase, protease and nitrate reductase from the third leaf of rice varieties as affected by NaCl stress at six weeks after initial salinization. Results are expressed as percentage of changes over the control. + : increase; - : decrease.


LEAF ENZYME ACTIVITY
CHANGES (%) UNDER SALINIZATION
AFTER SIX WEEKS
1 PHOSPHORYLASE
2 PHOSPHATASE
3 MEMBRANE - BOUND ATP-ASE
4 PROTEASE
5 NITRATE REDUCTASE
280
140
+
0
210
105
+
0
430
215
+
0
680
340
+
0
280
140
+
0
−
30
AU1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES
1
2
3
4
5
ENZYMES

activity as compared to the control. There was no marked varietal differences in the increase of phosphorylase activity to salinization except TKM4, TKM9 and Co43 (Table 18; Fig.32) when compared to the control.

Invariably, the nitrate reductase, glutamate oxaloacetate transaminase (GOT) and glutamate pyruvate transaminase (GPT) activity were promoted in AU1, Co43 and CSC1 but it was inhibited in others as compared to the control (Table 17 and 18; Fig.32 and 33). Significantly, 6.7 fold increase in protease activity was noticed in CSC2, whereas this increase was less in other varieties when compared to the control (Table 17; Fig.32). The increase in protease activity in response to salinity could be arranged in the descending series as CSC2 > Co36 > Co43 > TKM4 > IR20 > GR2 > TKM9 > CSC1 > AU1. The increase in protease activity of Co43, IR20 and TKM4 over the control was almost of the same magnitude (Fig.32). The NaCl treatment increased the activity of dehydrogenases in the tricarboxylic acid cycle in all the varieties to varying degrees. α-Ketoglutaric dehydrogenase activity was highly stimulated by sodium chloride treatment in AU1 and showed four fold increase when compared to the control (Table 17; Fig.33). Varieties Co36, Co43, CSC2, GR3, TKM4 and TKM9 responded to salinity with same degree of increase in the activity of α-Ketoglutaric dehydrogenase over the control (Fig.33). Compared to the above varieties,

Table 18 : Enzymes activity from the third leaf of rice varieties as affected by NaCl at six weeks after initial salinization.

Variety	Phosphorylase		Glutamate oxaloacetate transaminase (GOT)		Glutamate pyruvate transaminase (GPT)	
	C	S	C	S	C	S
AU1	2.32	3.01	811	2236	360	1290
Co36	2.60	3.48	517	224	558	317
Co43	15.05	28.49	2313	10030	1104	3690
CSC1	4.58	7.24	1346	3231	568	1080
CSC2	5.50	6.75	1076	709	362	76
GR3	2.76	4.49	1040	807	719	492
TR20	2.19	3.06	520	268	640	308
TKM4	7.06	17.02	2293	1486	688	507
TKM9	4.05	15.10	2013	1179	942	559

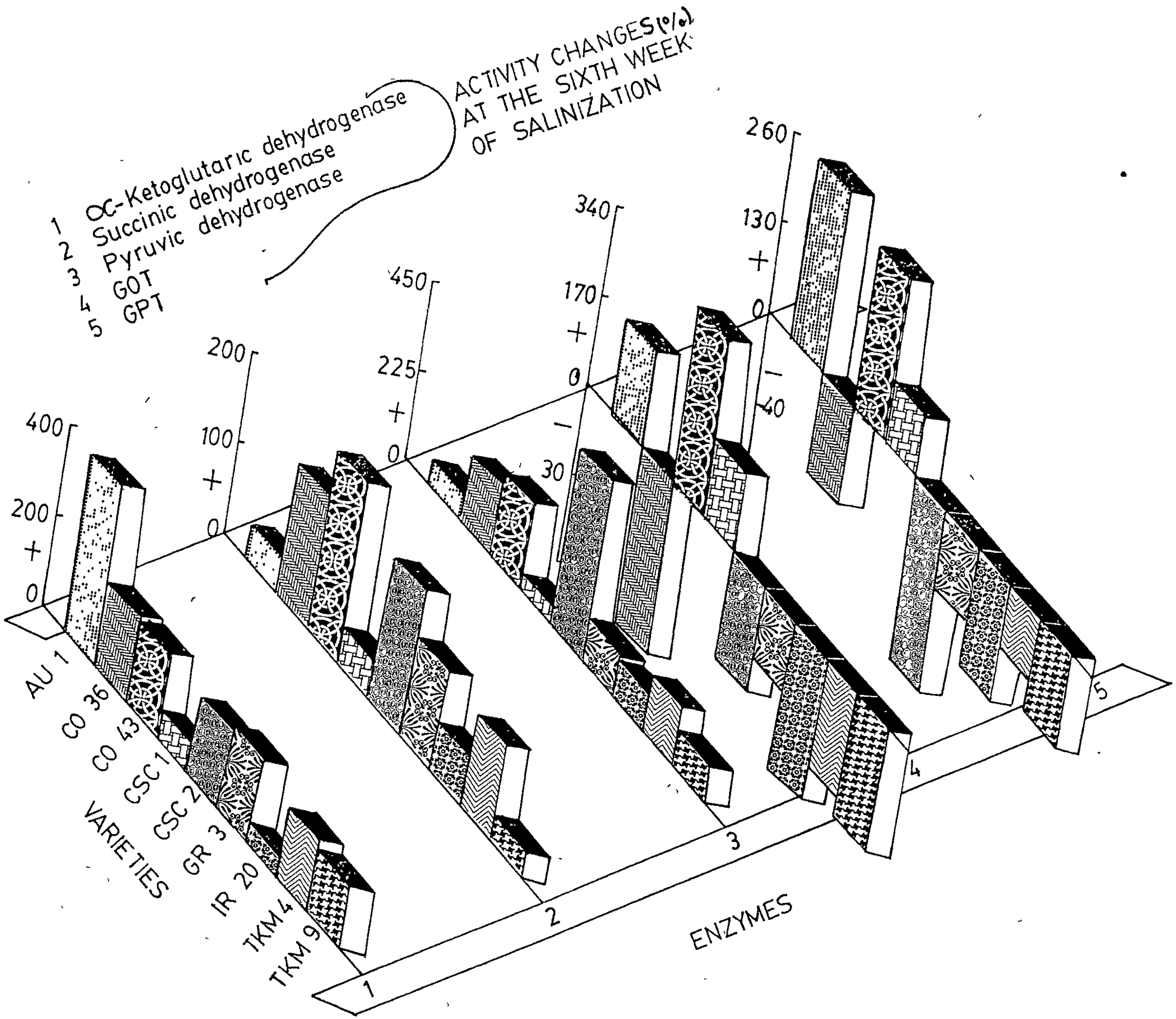
C : Control; S : Salinized

Phosphorylase : μ moles of phosphate released/40 min./mg. protein.

GOT : n moles of oxaloacetate formed/30 min./mg. protein.

GPT : n moles of pyruvate formed/30 min./mg. protein.

Fig. 33. α-Ketoglutaric dehydrogenase, succinic dehydrogenase, pyruvic dehydrogenase, glutamate oxaloacetate transaminase (GOT) and glutamate pyruvate transaminase (GPT) enzymes activity from the third leaf of rice varieties grown under saline (NaCl) stress condition in six weeks after initial salinization. Results are expressed as percentage of changes over the control. + : increase; - : decrease.



1 α-Ketoglutaric dehydrogenase
2 Succinic dehydrogenase
3 Pyruvic dehydrogenase
4 GOT
5 GPT
ACTIVITY CHANGES (%)
AT THE SIXTH WEEK
OF SALINIZATION
400
200
+
0
200
100
+
0
450
225
+
0
340
170
+
0
–
30
260
130
+
0
–
40
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES
1
2
3
4
5
ENZYMES

in CSC1 and IR20 the increase recorded in the activity of α-Ketoglutaric dehydrogenase was very low when exposed to sodium chloride salinity. The order of increase in succinic dehydrogenase activity was TKM9 $<$ CSC1 $<$ AU1 $<$ IR20 $<$ TKM4 $<$ GR3 $<$ Co36 $<$ CSC2 $<$ Co43 (Table 17; Fig.33). There was 1 to 2 fold increase in the activity of succinic dehydrogenase in TKM4, GR3, CSC2, Co36 and Co43 when compared to the control (Fig.33). The varieties CSC2 and Co43 indicated an improved activity of pyruvic dehydrogenase i.e. 4 and 2 fold respectively over the control in response to salinity (Table 17; Fig.33). In CSC1 the activity of pyruvic dehydrogenase was slightly stimulated to salinization. There was almost similar increase in the activity of pyruvic dehydrogenase (i.e. between 50 to 100 per cent over the control) by saline treatment in AU1, IR20 and TKM9. Whereas varieties GR3, TKM4 and CO 36 exhibited 1 to 2 fold increase in the activity of pyruvic dehydrogenase over the control (Fig.33).

5. Organic constituents

a. Free amino acid level of the third leaf

Sodium chloride treatment increased the free amino acid level in all the varieties (Table 19). The per cent increase in free amino acid pool over the control was very linear over the duration of salinization

Table 19: Effect of NaCl on the free amino acids from the third leaf of rice varieties.

Variety	Free aminoacids (mg/g fresh weight)						Free proline (µ moles/g fresh weight)					
	2		4		6		2		4		6	
	C	S	C	S	C	S	C	S	C	S	C	S
AU1	2.75	3.30	3.20	3.35	3.50	4.05	0.60	0.95	1.00	2.50	1.70	4.00
Co36	1.65	2.50	1.85	3.05	2.10	3.95	7.00	0.85	1.10	1.50	1.60	1.90
Co43	2.20	2.95	2.55	3.30	2.75	3.30	0.75	0.95	1.00	1.90	1.30	2.60
CSC1	1.30	2.20	1.65	2.75	1.75	2.95	0.90	1.30	1.20	2.40	1.50	3.50
CSC2	1.75	2.75	2.00	3.75	2.30	5.05	0.50	0.75	0.95	1.60	1.50	1.60
GR3	2.85	3.40	3.30	4.20	3.65	4.95	0.85	0.95	1.00	1.80	1.40	2.30
IR20	1.30	2.75	1.75	3.65	2.00	4.40	0.80	0.90	1.20	1.40	1.70	1.90
TKM4	2.95	5.20	3.05	5.50	3.30	6.05	0.45	0.60	0.90	1.10	1.10	1.40
TKM9	2.10	6.40	2.40	6.40	2.85	6.95	0.50	0.65	0.85	1.00	0.95	1.30

C : Control; S : Salinized; 2, 4 and 6 Weeks after initial salinization.

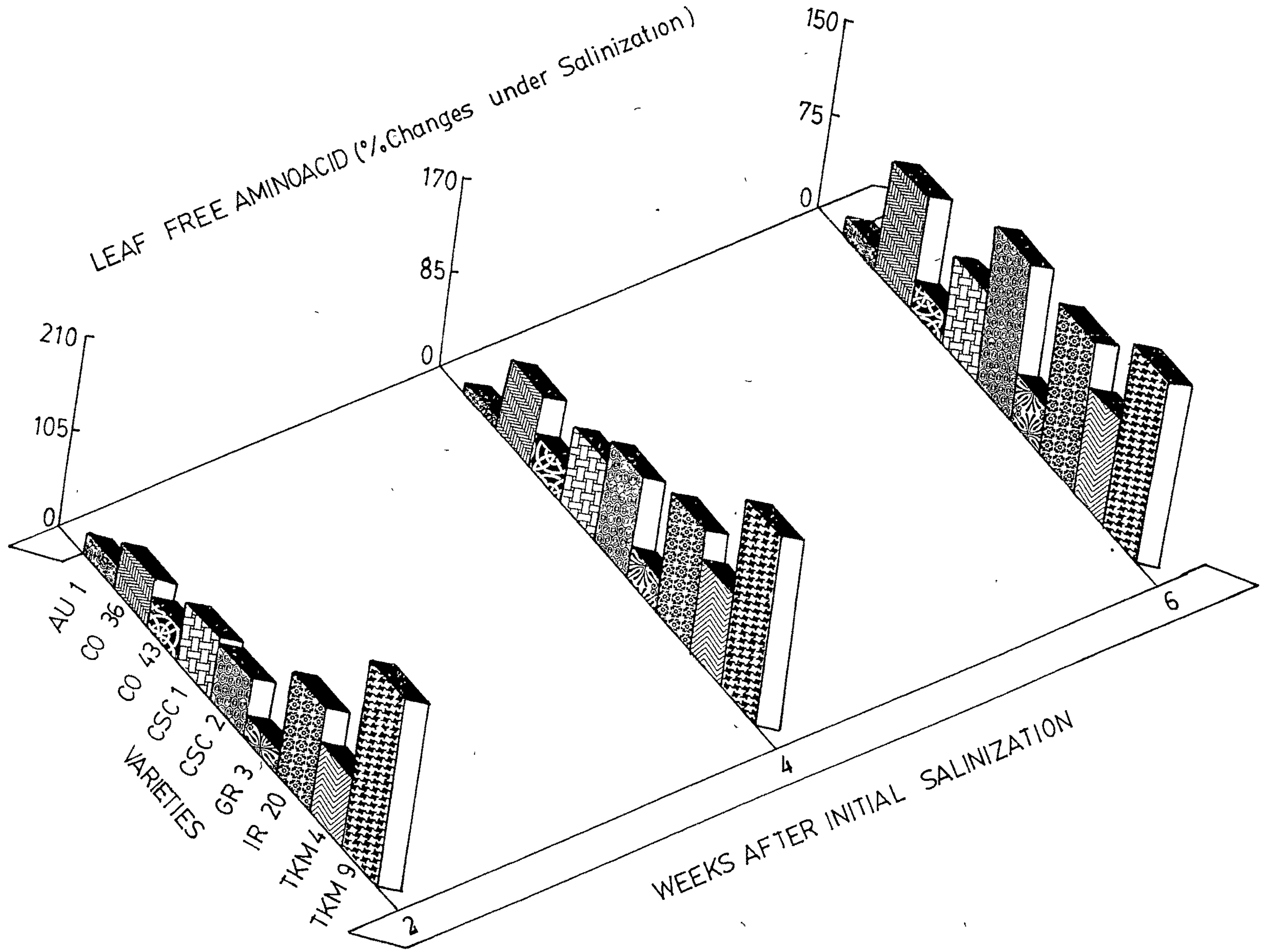
in Co36, CSC2, GR3 and TKM4 (Fig.34). The variety CSC1 constantly maintained the level of the free amino acid pool throughout the period of salinization and in IR20 the amino acid pool in control and treatment increased consistantly so as to maintain the degree of increase to the same per cent throughout the growing season. On the contrary, in TKM9 this consistent trend was not evident as the duration of salinization was extended.

Interestingly, in AU1, Co43 and CSC1 there was a raise in the free proline level over the control with increasing time exposure of salinization (Table 19; Fig.35). In Co36 and CSC2 the increase of free proline content in the treated plants over their respective control was lowered during the prolonged salinization. In varieties IR20, TKM4 and TKM9 the treated plants steadily maintained the same ratio of the free proline content over the control as the period of salinization increased (Fig.35). The varieties AU1, Co43 and CSC1 showed the maximum of 1 to 3 fold increase in proline content as compared to the control at the sixth week of salinization (Fig.35). Comparing other cultivars, Co36, CSC2, IR20 and TKM4 exhibited lesser ability to maintain a high level of proline at the end of salinization.

b. Nucleic acid content of the shoot system

Two weeks after initial salinization, the RNA content was increased in AU1, CSC1, CSC2, GR3 and TKM4

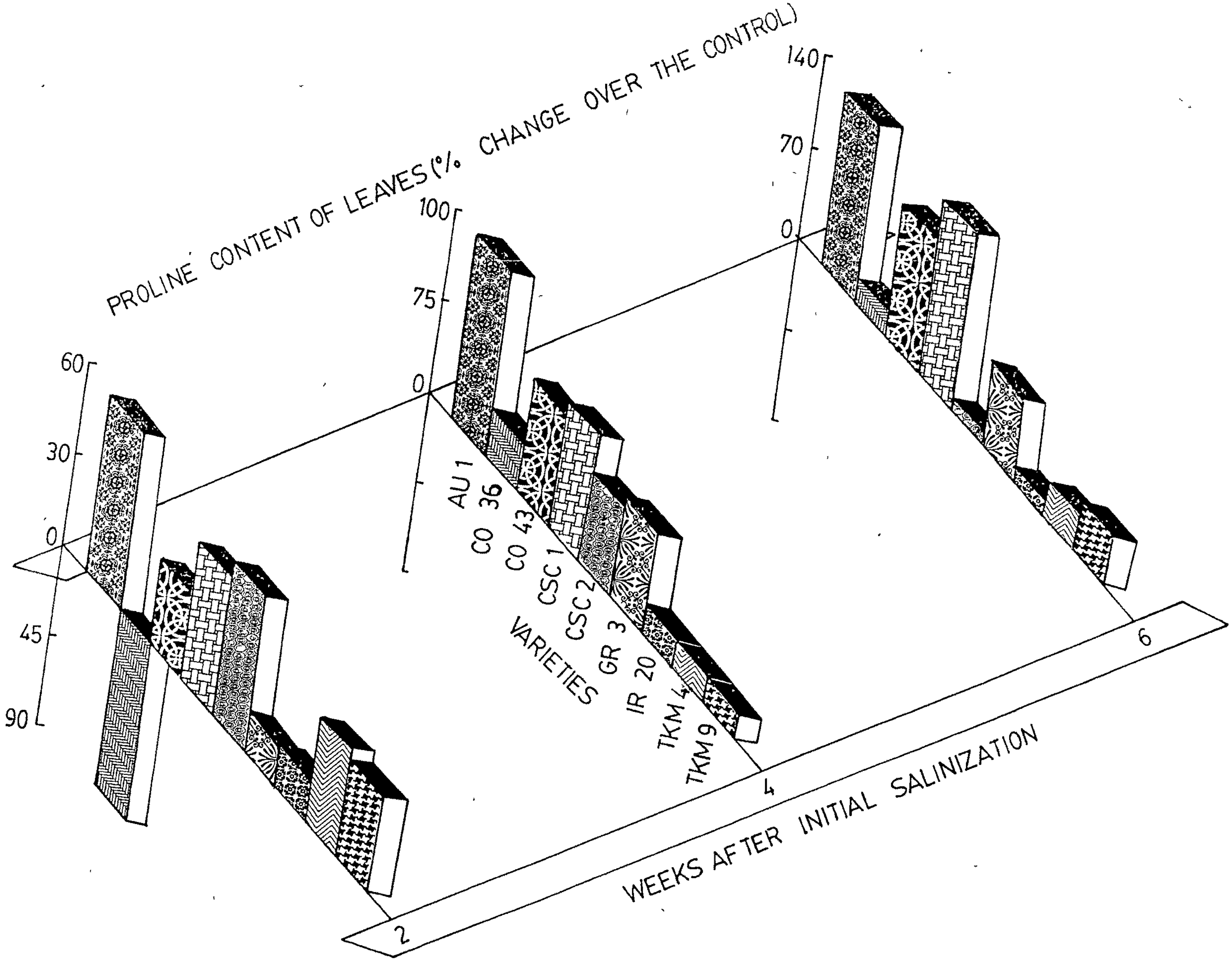
Fig. 34. Effect of sodium chloride on the free amino acid content from the third leaf of rice varieties at different weeks after initial salinization. Results are expressed as percentage of increase over the control.



LEAF FREE AMINOACID (%.Changes under Salinization)
210
105
0
170
85
0
150
75
0
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES
2
4
6
WEEKS AFTER INITIAL SALINIZATION

Fig. 35. Salt stressed changes as percentage over the control in the free proline content from the third leaf of rice varieties at different weeks after initial salinization.

+ : increase; – : decrease.


PROLINE CONTENT OF LEAVES (% CHANGE OVER THE CONTROL)
60
30
0
45
90
100
75
0
140
70
0
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES
2
4
6
WEEKS AFTER INITIAL SALINIZATION

but it was decreased in the subsequent weeks of salinization. Salinization always brought a decrease in the RNA content in Co36, Co43, IR20 and TKM9 (Table 20; Fig.36). Varieties AU1, Co43, CSC1 and IR20 showed 10 to 25 per cent decrease in RNA content in comparison with their respective control at six weeks of salinization, but in other varieties the decrease was above 47 per cent (Fig.36). Two weeks of saline treatment brought about a general decrease in the DNA content in all the varieties except CSC1 which responded with an increase in DNA content (Table 20; Fig.37). Significantly, in varieties AU1, Co43 and CSC1 there was an indication of increase in the level of DNA while in other varieties it decreased over the control from two weeks after initial salinization (Fig.37). Salinity resulted in a 1.5 fold increase of DNA content in Co43 and CSC1 in comparison with their control at the end of salinization.

c. Protein changes in the third leaf

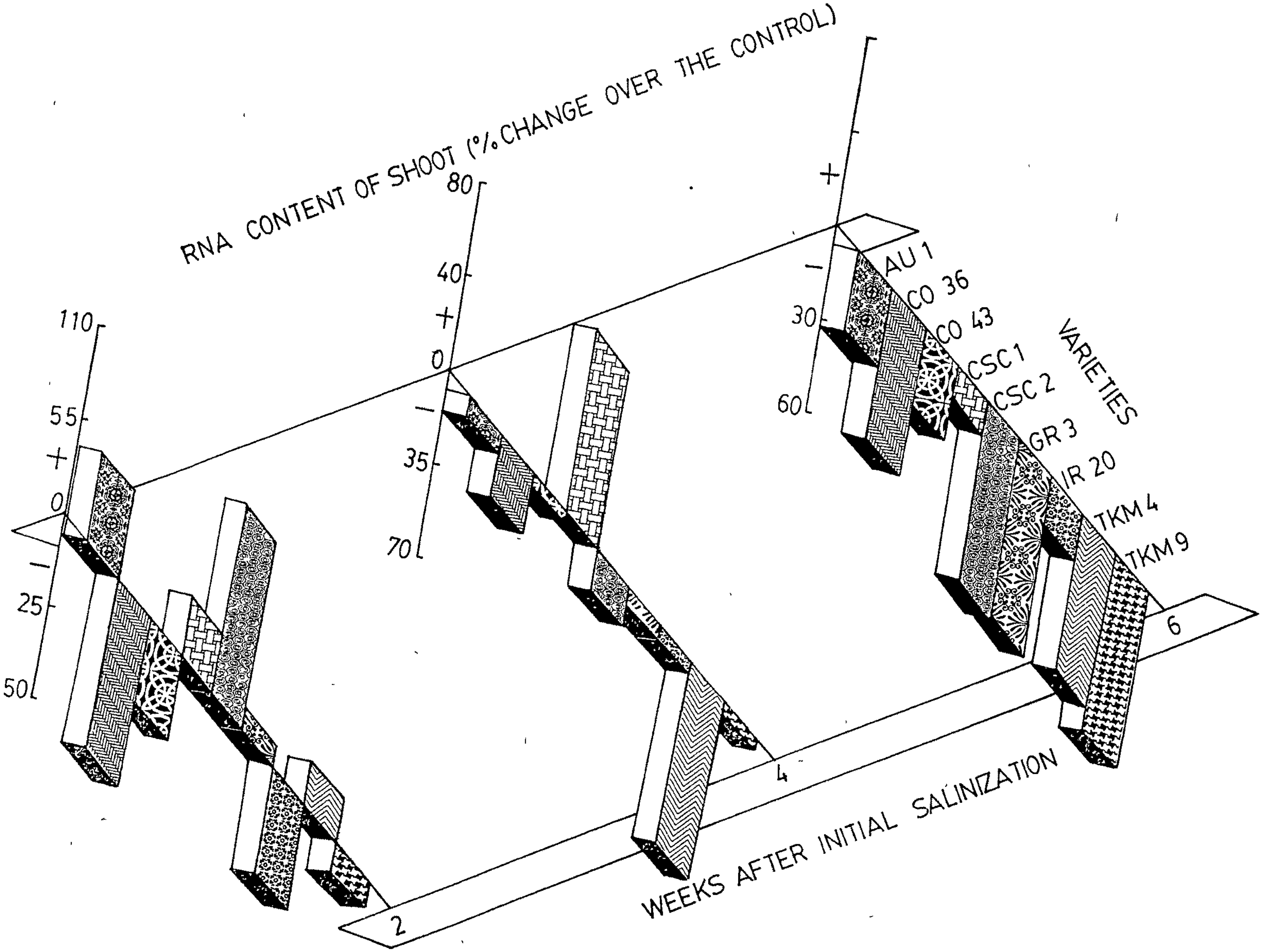
There was a regular increase in soluble protein content in CSC2 and GR3 to salinity when compared to the control (Fig.38). In the early weeks of salt treatment IR20 and TKM9 had a decreased level of soluble protein which increased considerably later over the control. At the end of salinization all the varieties increased the soluble protein content over the control except AU1, Co36 and Co43 (Fig.38). Four weeks of salt treatment generally brought

Table 20 : Changes in RNA and DNA contents of shoot system of rice varieties as affected by NaCl

Variety	RNA (mg/g dry weight)						DNA (mg/g dry weight)					
	2		4		6		2		4		6	
	C	S	C	S	C	S	C	S	C	S	C	S
AU1	1.75	2.63	2.83	2.63	2.33	1.75	4.16	4.10	8.33	13.49	9.49	15.15
Co36	4.25	2.33	4.67	3.58	3.75	2.00	10.16	5.00	12.16	6.66	13.49	5.00
Co43	2.33	1.83	3.17	3.08	3.50	2.63	8.83	4.33	8.33	18.48	8.16	20.15
CSC1	1.50	2.00	1.33	2.33	1.67	1.50	4.00	4.66	6.66	19.31	8.49	21.48
CSC2	2.00	4.17	3.67	3.08	3.50	1.50	4.66	4.33	7.33	4.33	11.82	3.33
GR3	2.50	2.67	3.83	3.73	4.00	1.75	4.83	4.66	5.00	3.33	10.16	5.00
IR20	3.00	2.17	4.00	3.83	4.00	3.50	8.99	7.16	12.16	6.66	10.82	5.99
TKM4	2.17	2.67	5.67	1.83	4.67	2.33	5.33	4.66	12.82	5.00	11.82	6.66
TKM9	2.00	1.85	3.17	3.14	3.50	1.50	6.66	2.83	13.49	6.33	16.82	7.33

C : Control; S : Salinized; 2, 4 and 6 Weeks after initial salinization.

Fig. 36. RNA content of shoot system of rice varieties grown under NaCl stress condition at 2, 4 and 6 weeks after initial salinization. Results are expressed as percentage of changes over the control. + : increase; -:decrease.



RNA CONTENT OF SHOOT (% CHANGE OVER THE CONTROL)
110
55
+
0
−
25
50
80
40
+
0
−
35
70
+
−
30
60
VARIETIES
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
2
4
6
WEEKS AFTER INITIAL SALINIZATION

Fig.37. Effect of NaCl on the DNA content of shoot system of rice varieties at different durations after initial salinization. Results are expressed as percentage of changes over the control. + : increase; - : decrease.

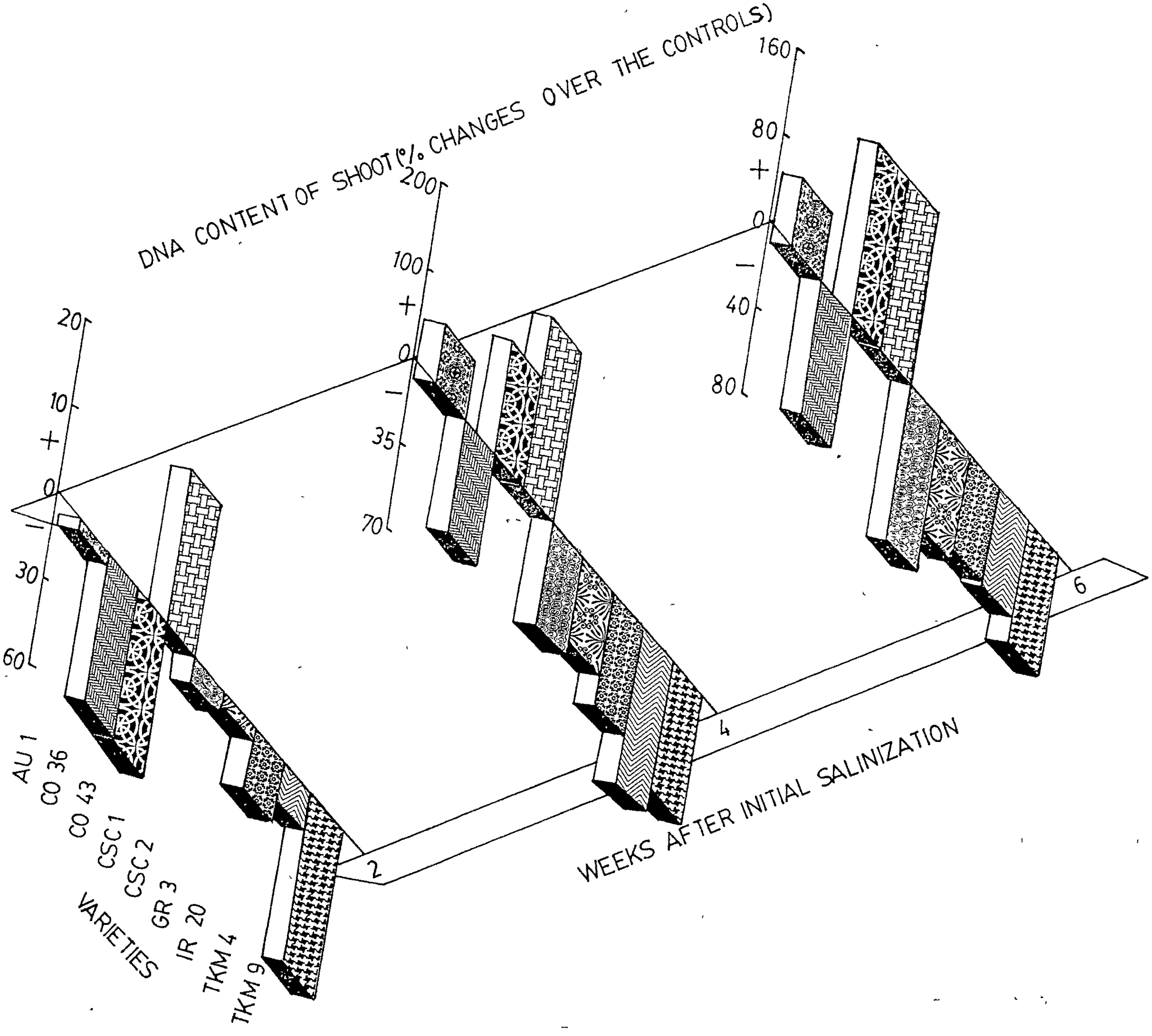
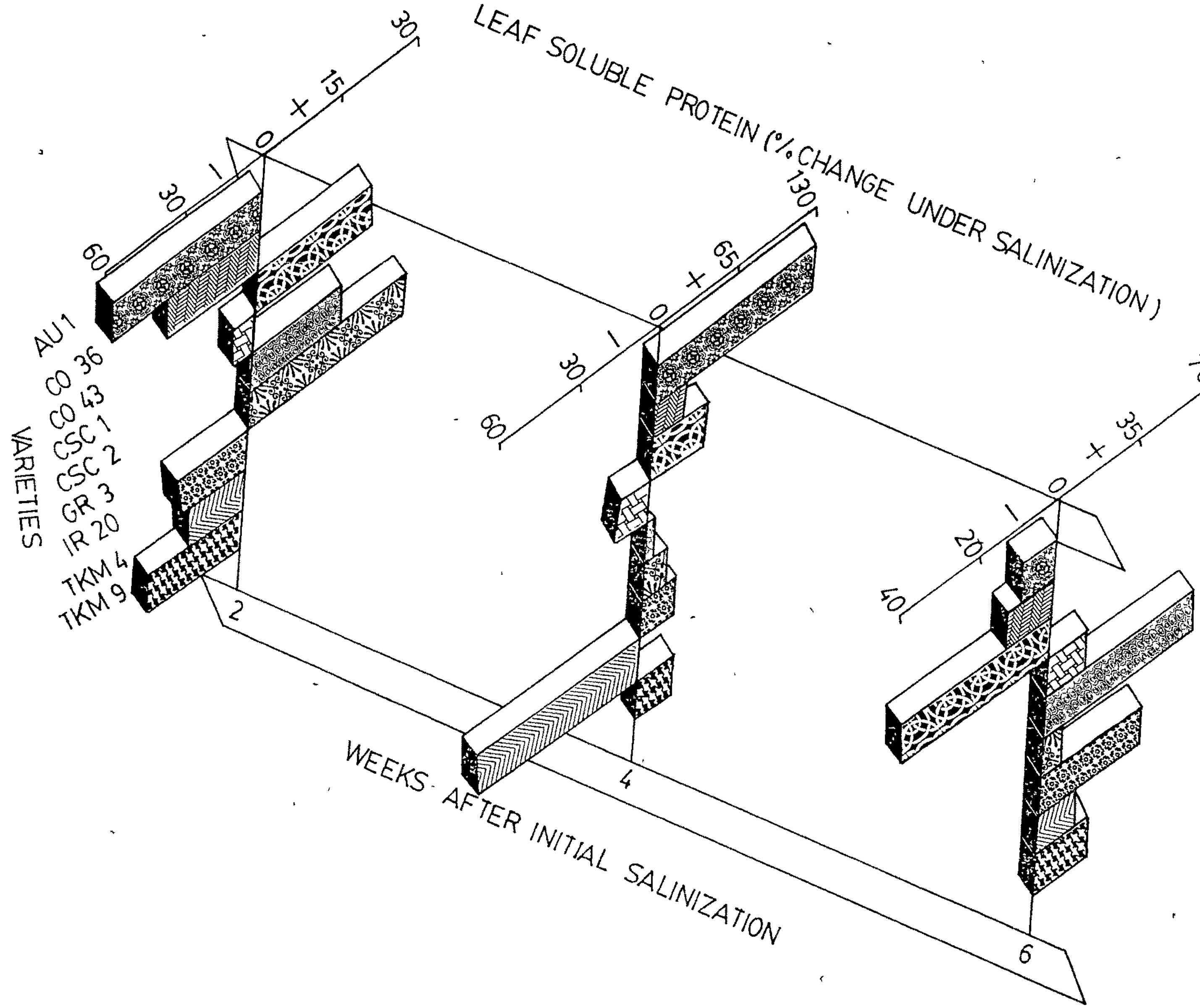

DNA CONTENT OF SHOOT (% CHANGES OVER THE CONTROLS)
20
10
+
0
−
30
60
200
100
+
0
−
35
70
160
80
+
0
−
40
80
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES
2
4
6
WEEKS AFTER INITIAL SALINIZATION

Fig. 38. Soluble protein changes in the third leaf of rice varieties in response to NaCl stress at 2, 4 and 6 weeks after initial salinization. Results are expressed as percentage of changes over the control. + : increase; - : decrease.



LEAF SOLUBLE PROTEIN (% CHANGE UNDER SALINIZATION)
WEEKS AFTER INITIAL SALINIZATION
VARIETIES
AU1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
30
15
+
0
–
30
60
130
65
+
0
–
30
60
70
35
+
0
–
20
40
2
4
6

about an increase in the soluble protein in all the varieties except CSC1 and TKM4 (Table 21; Fig.38).

Initially, salinization resulted in an increase of insoluble and total protein in AU1, Co43, CSC1 and CSC2 while it decreased in others (Table 21, and 22; Fig.39 and 40). Constant increase of insoluble and total protein was noticed in AU1, Co43 and CSC1 irrespective of the growth period. In Co36, CSC2, GR3, IR20, TKM4 and TKM9 four weeks of salinization brought about a decline in insoluble and total protein content over their control.

d. <u>Total nitrogen content of shoot system</u>

There was a marked increase of total nitrogen content in AU1, Co43 and CSC1 starting from four weeks of salt treatment (Table 22; Fig.41) whereas it decreased in Co36, CSC2, IR20, TKM4 and TKM9 throughout (Fig.41). GR3 exhibited a totally different pattern in the accumulation of nitrogenous compounds. There was an increase in total nitrogen after initial saline treatment but further imposition, resulted in decreased total nitrogen content over the control (Fig.41).

e. <u>Carbohydrate levels of shoot system</u>

Salinization resulted in accelerated accumulation of reducing, non-reducing & total soluble sugars and total carbohydrate in AU1, Co43 and CSC1, whereas it decelerated in other varieties in all the weeks of salinization

Table 21 : Effect of NaCl on the soluble and insoluble protein content from the third leaf of rice varieties.

Variety	Soluble protein (mg/g fresh weight)						Insoluble protein (mg/g fresh weight)					
	2		4		6		2		4		6	
	C	S	C	S	C	S	C	S	C	S	C	S
AU1	5.50	2.50	7.00	16.00	12.50	11.50	19.80	30.50	13.00	19.50	15.00	25.00
Co36	7.50	5.00	10.50	12.50	18.00	16.00	10.00	9.30	20.00	14.00	17.50	9.00
Co43	4.50	5.50	13.00	18.50	14.00	9.00	5.00	9.80	12.00	14.00	14.00	26.50
CSC1	8.00	7.50	14.50	13.00	9.50	11.00	9.80	15.30	21.00	27.50	24.00	32.50
CSC2	3.00	3.50	13.00	13.50	12.00	19.50	15.30	20.30	29.50	18.00	28.50	8.00
GR3	5.00	6.50	15.00	17.50	15.00	16.00	14.80	12.80	22.50	13.00	25.50	10.00
IR20	6.50	5.00	10.00	12.50	13.00	18.50	10.00	8.80	22.50	18.00	24.50	6.00
TKM4	9.30	7.50	23.50	10.00	13.00	15.00	15.30	9.30	12.00	8.50	26.50	5.00
TKM9	9.80	6.50	14.50	18.50	13.50	16.50	19.30	13.30	13.00	6.00	20.00	6.00

C : Control; S : Salinized; 2, 4 and 6 weeks after initial salinization.

Table 22 : Total protein content of third leaf and total nitrogen content of shoot system of rice varieties as affect by NaCl.

Variety	Total protein (mg/g fresh weight)						Total nitrogen (mg/g dry weight)					
	2		4		6		2		4		6	
	C	S	C	S	C	S	C	S	C	S	C	S
AU1	25.5	33.0	20.0	35.5	27.5	36.5	32.0	22.0	24.0	32.0	23.2	41.0
Co36	17.8	14.3	30.5	26.5	35.5	25.0	28.0	26.0	25.2	16.0	26.0	15.6
Co43	9.8	15.3	25.0	32.5	28.0	35.5	24.0	22.0	25.2	32.0	26.0	41.2
CSC1	17.8	22.8	35.5	40.5	33.5	43.5	24.0	16.0	21.2	32.0	26.0	43.2
CSC2	18.3	23.3	42.5	31.5	40.5	27.5	23.2	22.0	20.0	16.0	24.0	12.0
GR3	19.8	19.3	37.5	30.5	40.5	26.0	15.6	21.2	16.0	8.0	26.0	15.6
IR20	16.8	13.8	32.5	30.5	37.5	24.5	40.0	26.0	24.0	16.0	31.2	13.2
TKM4	24.3	16.8	35.5	18.5	39.5	20.0	24.0	23.2	31.2	21.2	31.2	16.0
TKM9	29.0	19.8	27.5	24.5	33.5	22.5	29.2	20.0	16.0	10.0	26.0	12.8

C : Control; S : Salinized; 2, 4 and 6 weeks after initial salinization.

Fig. 39. Insoluble protein in the third leaf of rice varieties grown in salinized soil at 2, 4 and 6 weeks after initial salinization. Results are expressed as percentage of changes over the control. + : increase; - : decrease.

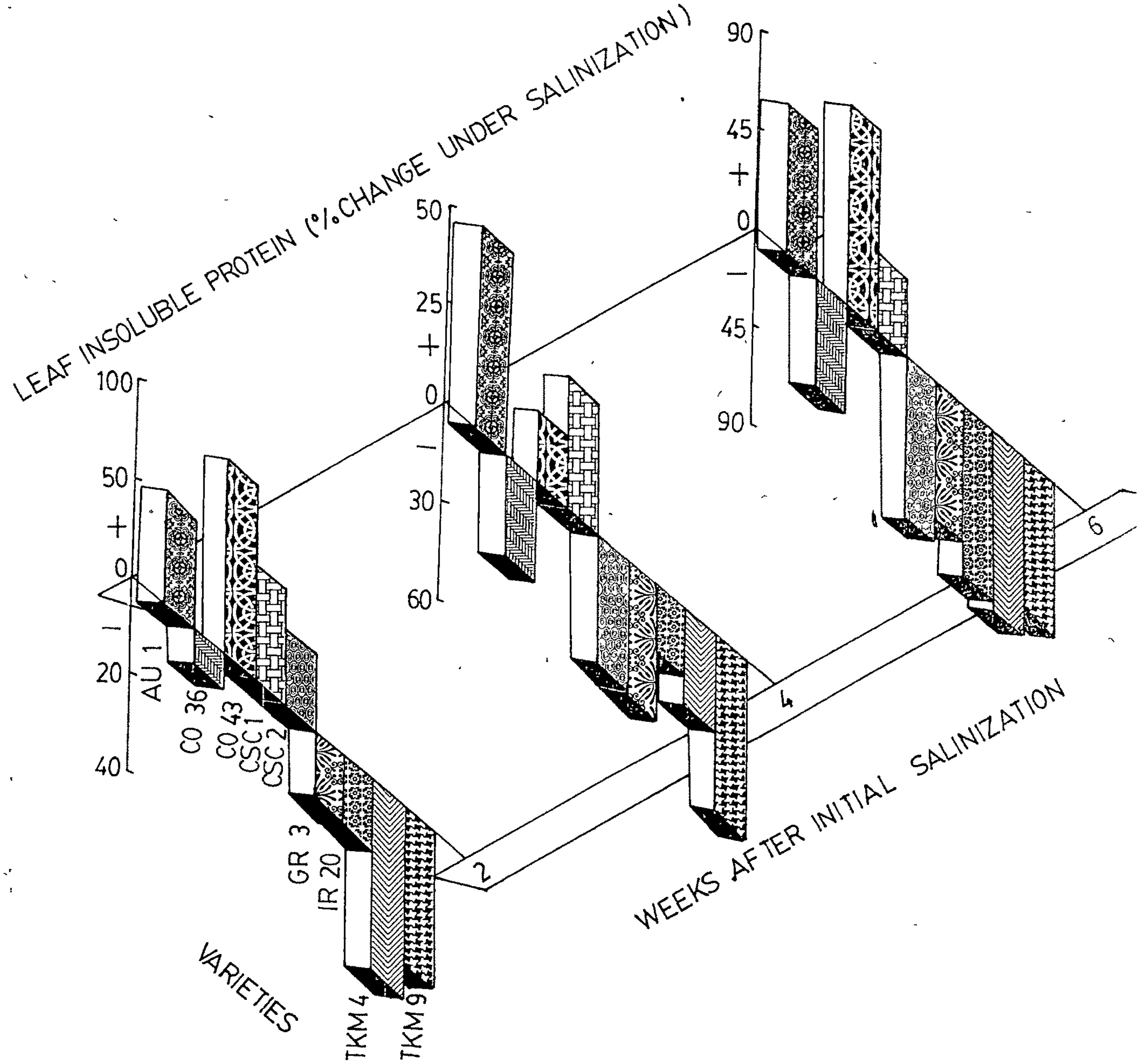
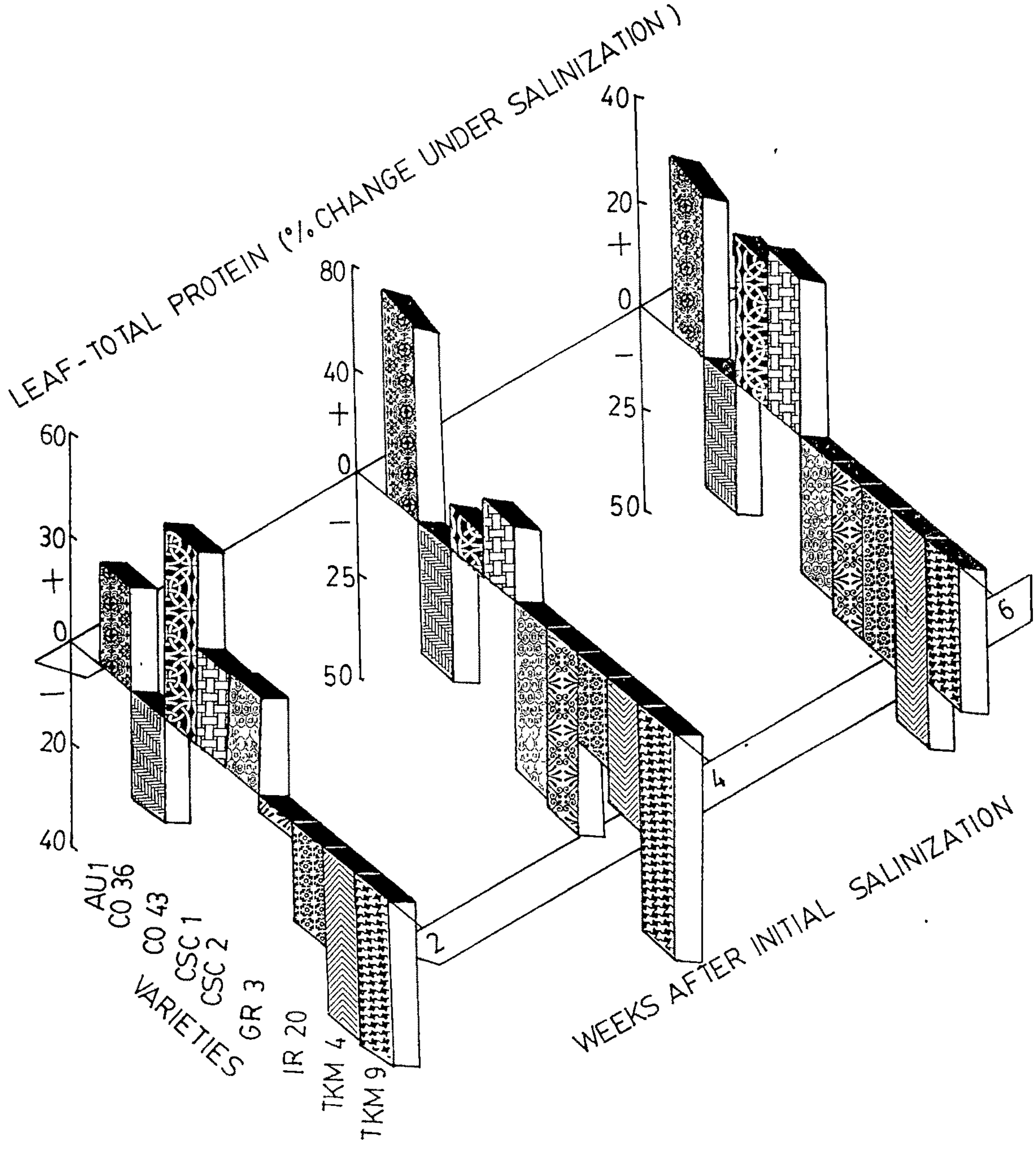

LEAF INSOLUBLE PROTEIN (%.CHANGE UNDER SALINIZATION)
100
50
+
0
-
20
40
50
25
+
0
-
30
60
90
45
+
0
-
45
90
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES
2
4
6
WEEKS AFTER INITIAL SALINIZATION

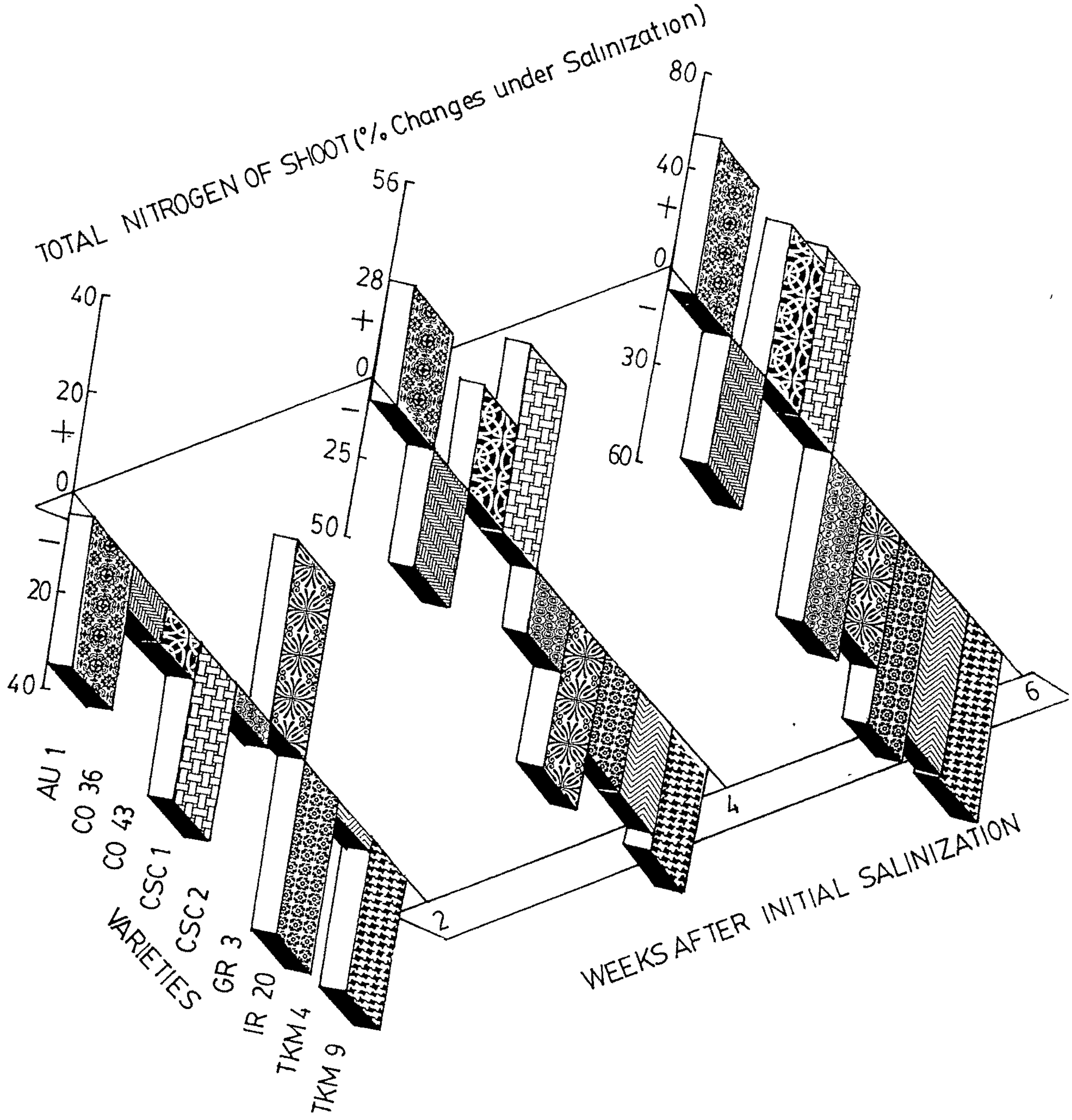
Fig. 40. Salinity and total protein content in the third leaf of rice varieties at 2, 4 and 6 weeks after initial salinization. Results are expressed as percentage of changes over the control. + : increase; - : decrease.



LEAF-TOTAL PROTEIN (% CHANGE UNDER SALINIZATION)
60
30
+
0
–
20
40
80
40
+
0
–
25
50
40
20
+
0
–
25
50
AU1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES
2
4
6
WEEKS AFTER INITIAL SALINIZATION

Fig. 41. Salt stressed (NaCl) changes in the total nitrogen content from the shoot system of rice varieties at different weeks after initial salinization. Results are expressed as percentage of changes over the control.

+ : increase; – : decrease.



TOTAL NITROGEN OF SHOOT (% Changes under Salinization)
40
20
+
0
−
20
40
56
28
+
0
−
25
50
80
40
+
0
−
30
60
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES
2
4
6
WEEKS AFTER INITIAL SALINIZATION

(Table 23 and 25; Fig.42, 43, 44 and 46). In the shoot system salinization for four weeks increased the reducing sugar content of IR20 and non-reducing sugar content of Co36 and GR3 (Fig.42 and 43). Generally, the reduction in the starch content was noticed in all the varieties at all the weeks of salinization. After six weeks of salinization the Co43, CSC1 and AU1 showed a minimum of 11 to 40 per cent reduction in the starch content (Table 24; Fig.45) and a maximum of 50 to 70 per cent was observed in IR20, TKM4, CSC2, GR3 and Co36.

f. Ascorbic acid content and titrable acid number of third leaf

Ascorbic acid content was increased in all the varieties except AU1 at two weeks of salinization. Later on, there was a constant decrease in Co36, TKM4 and TKM9 as compared to their respective controls (Table 26; Fig.47). However, in CSC2 and IR20 there was an initial increase in the ascorbic acid level which was not followed by a consistent decrease. With sodium chloride treatment in Co43, CSC1 and GR3, there was a regular increase in ascorbic acid level at all durations of the study. Varieties AU1, Co43, and CSC1 accumulated higher levels of ascorbic acid than the others after six weeks of salinization (Fig.47). The increase was 78, 110 and 69 per cent over the control in AU1, Co43 and CSC1 respectively. CSC2, GR3 and IR20 were exhibited less ability to maintain high levels of ascorbic

Table 23 : Reducing and non-reducing sugar contents of shoot system of rice varieties grown under NaCl saline condition

Variety	Reducing sugar (mg/g dry weight)						Non-reducing sugar (mg/g dry weight)					
	2		4		6		2		4		6	
	C	S	C	S	C	S	C	S	C	S	C	S
AU1	4.88	8.63	4.88	10.13	8.25	10.50	10.50	13.13	2.63	1.88	4.88	6.38
Co36	7.50	3.75	15.00	7.12	14.25	7.88	29.63	14.25	1.50	4.50	21.00	8.63
Co43	3.75	6.00	6.00	7.88	8.25	10.50	7.13	13.50	3.75	11.25	4.50	7.50
CSC1	3.38	7.50	4.88	8.25	7.50	10.13	6.38	10.50	4.88	13.13	5.63	9.00
CSC2	7.50	3.75	6.38	4.50	9.38	6.00	11.63	4.50	15.00	1.13	27.00	3.38
GR3	3.75	3.38	4.88	1.88	8.25	4.88	9.94	4.88	6.00	6.38	9.75	4.88
IR20	6.00	3.75	4.00	4.88	7.50	3.75	15.75	7.13	13.50	3.75	21.75	3.38
TKM4	6.00	3.75	10.50	8.25	9.38	7.88	1.13	1.13	9.00	6.38	24.00	8.63
TKM9	7.88	6.38	20.50	7.88	18.38	10.13	11.63	8.25	20.63	15.38	19.88	11.63

C : Control; S : Salinized; 2, 4 and 6 weeks after initial salinization.

Table 24 : Starch content of shoot system of rice varieties as affected by NaCl

Variety	Starch content (mg/g dry weight)					
	2		4		6	
	C	S	C	S	C	S
AU1	6.75	3.38	5.63	2.25	5.63	3.38
Co36	9.00	6.75	6.75	5.63	11.25	3.38
Co43	5.63	4.50	9.00	6.75	10.13	9.00
CSC1	6.75	5.63	9.00	6.75	9.00	6.75
CSC2	10.13	3.38	12.38	3.38	12.38	5.63
GR3	12.38	5.63	6.75	3.38	11.25	3.38
IR20	11.25	6.75	6.75	5.63	11.25	5.63
TKM4	10.13	2.25	6.75	2.25	12.38	5.63
TKM9	11.25	5.63	10.13	2.25	16.88	9.00

C : Control;

S : Salinized;

2, 4 and 6 weeks after initial salinization

Table 25 : Changes in the total soluble sugar and total carbohydrate levels of shoot system of rice varieties grown under NaCl saline condition.

Variety	Total soluble sugar (mg/g dry weight)						Total Carbohydrate (mg/g dry weight)					
	2		4		6		2		4		6	
	C	S	C	S	C	S	C	S	C	S	C	S
AU1	15.38	21.75	7.50	12.00	13.13	16.88	22.13	25.13	13.13	14.25	18.75	20.25
Co36	37.13	18.00	16.50	11.63	35.25	16.50	46.13	24.75	23.25	17.25	46.50	19.88
Co43	10.88	19.50	9.75	19.13	12.75	18.00	16.50	24.00	18.75	25.88	22.88	27.00
CSC1	9.75	18.00	9.75	21.38	13.13	19.13	16.50	23.63	18.75	28.13	22.13	25.88
CSC2	19.13	8.25	21.38	5.63	36.38	9.38	29.25	11.63	33.75	9.00	48.75	15.00
GR3	13.13	8.25	10.88	8.25	18.00	9.75	25.50	13.88	17.63	11.63	29.25	13.13
IR20	21.75	10.88	18.00	8.63	29.25	17.13	33.00	17.63	14.75	14.25	40.50	12.75
TKM4	7.13	4.88	19.50	14.63	33.38	16.50	17.25	7.13	26.25	16.88	45.75	22.13
TKM9	19.50	14.63	40.88	23.55	38.25	21.75	30.75	20.25	51.00	25.50	55.13	30.75

C : Control; S : Salinized; 2, 4 and 6 weeks after initial salinization.

Table 26 : The levels of ascorbic acid and titrable acid number from the third leaves of rice varieties during different stages of growth in response to NaCl.

Variety	Ascorbic acid (mg/g fresh weight)						Titrable acid number (T.A.N.)					
	2		4		6		2		4		6	
	C	S	C	S	C	S	C	S	C	S	C	S
AU1	2.03	0.87	0.89	1.24	0.40	0.71	8	12	9	16	9	33
Co36	0.48	0.61	0.61	0.56	0.40	0.37	6	8	9	13	10	13
Co43	0.40	0.70	0.58	0.76	0.20	0.42	8	12	10	16	10	39
CSC1	0.56	0.91	0.61	0.98	0.42	0.71	4	8	7	10	7	37
CSC2	1.04	1.12	1.09	1.04	0.46	0.48	2	14	8	12	8	14
GR3	0.42	0.55	0.56	0.64	0.22	0.34	4	10	5	9	5	8
IR20	0.55	0.66	0.66	0.59	0.29	0.32	6	12	6	10	8	12
TKM4	0.66	1.06	0.76	0.66	0.40	0.32	10	17	15	19	17	23
TKM9	0.46	0.72	0.56	0.48	0.47	0.29	10	14	14	18	18	25

C : Control; S : Salinized; 2, 4, and 6 weeks after initial salinization.
T.A.N.: Results are expressed in centinormal NaOH required to neutralize the acid extract of 10 g fresh material.

Fig. 42. Effect of NaCl on the reducing sugar content of shoot system of rice varieties at 2, 4 and 6 weeks after initial salinization. Results are expressed as percentage of changes over the control. + : increase; – : decrease.

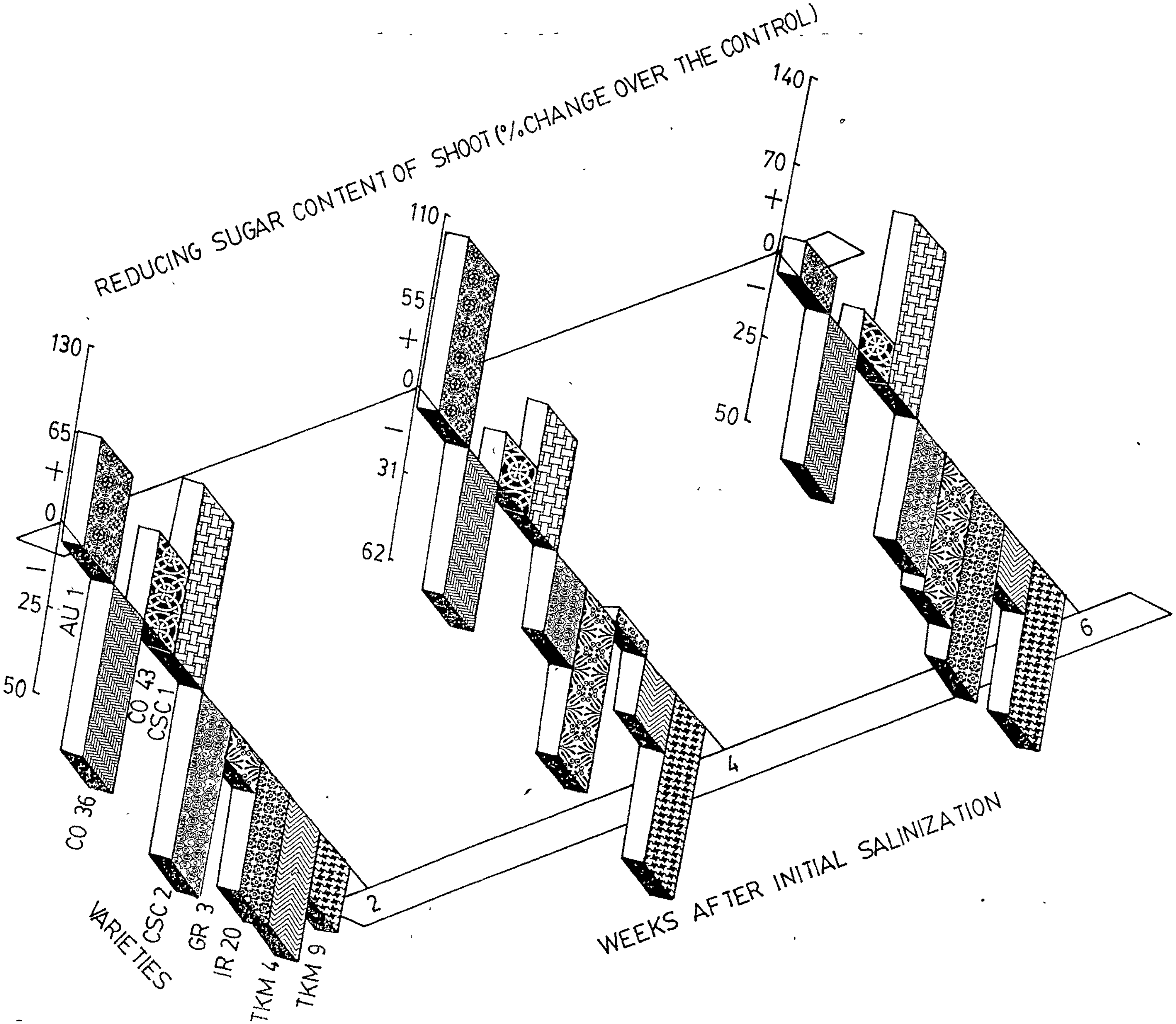

REDUCING SUGAR CONTENT OF SHOOT (%.CHANGE OVER THE CONTROL)
130
65
+
0
–
25
50
110
55
+
0
–
31
62
140
70
+
0
–
25
50
AU 1
CO 43
CSC 1
CO 36
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES
2
4
6
WEEKS AFTER INITIAL SALINIZATION

Fig. 43. Changes in the non-reducing sugar level of shoot system of rice varieties as affected by NaCl. Results are expressed as percentage of changes over the control. + : increase; - : decrease.

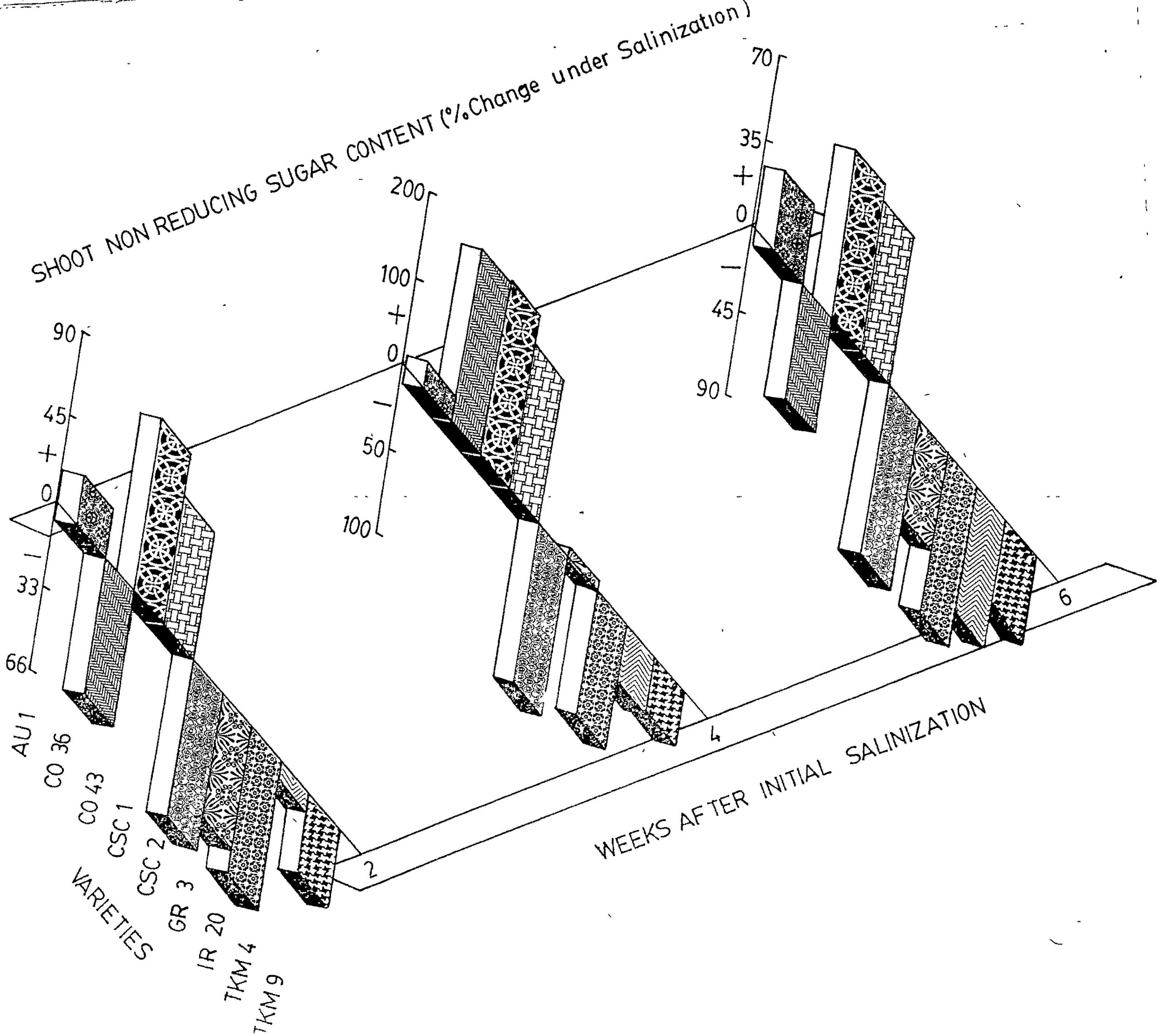

SHOOT NON REDUCING SUGAR CONTENT (%Change under Salinization)
90
45
+
0
–
33
66
200
100
+
0
–
50
100
70
35
+
0
–
45
90
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES
2
4
6
WEEKS AFTER INITIAL SALINIZATION

Fig. 44. Total soluble sugar level of shoot system of rice varieties in response to saline stress (NaCl) at 2, 4 and 6 weeks after initial salinization. Results are expressed as percentage of changes over the control. + : increase; - : decrease.

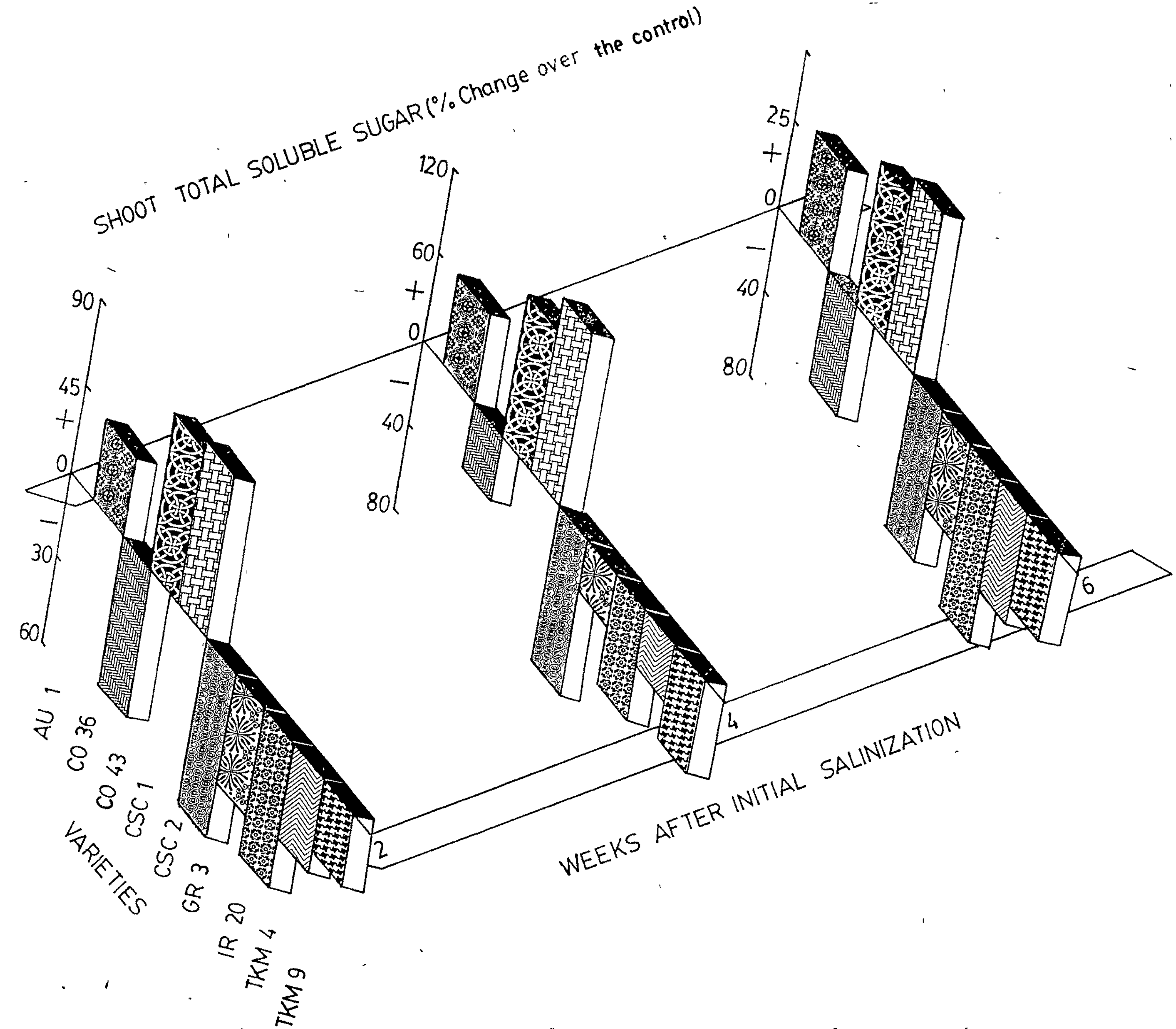
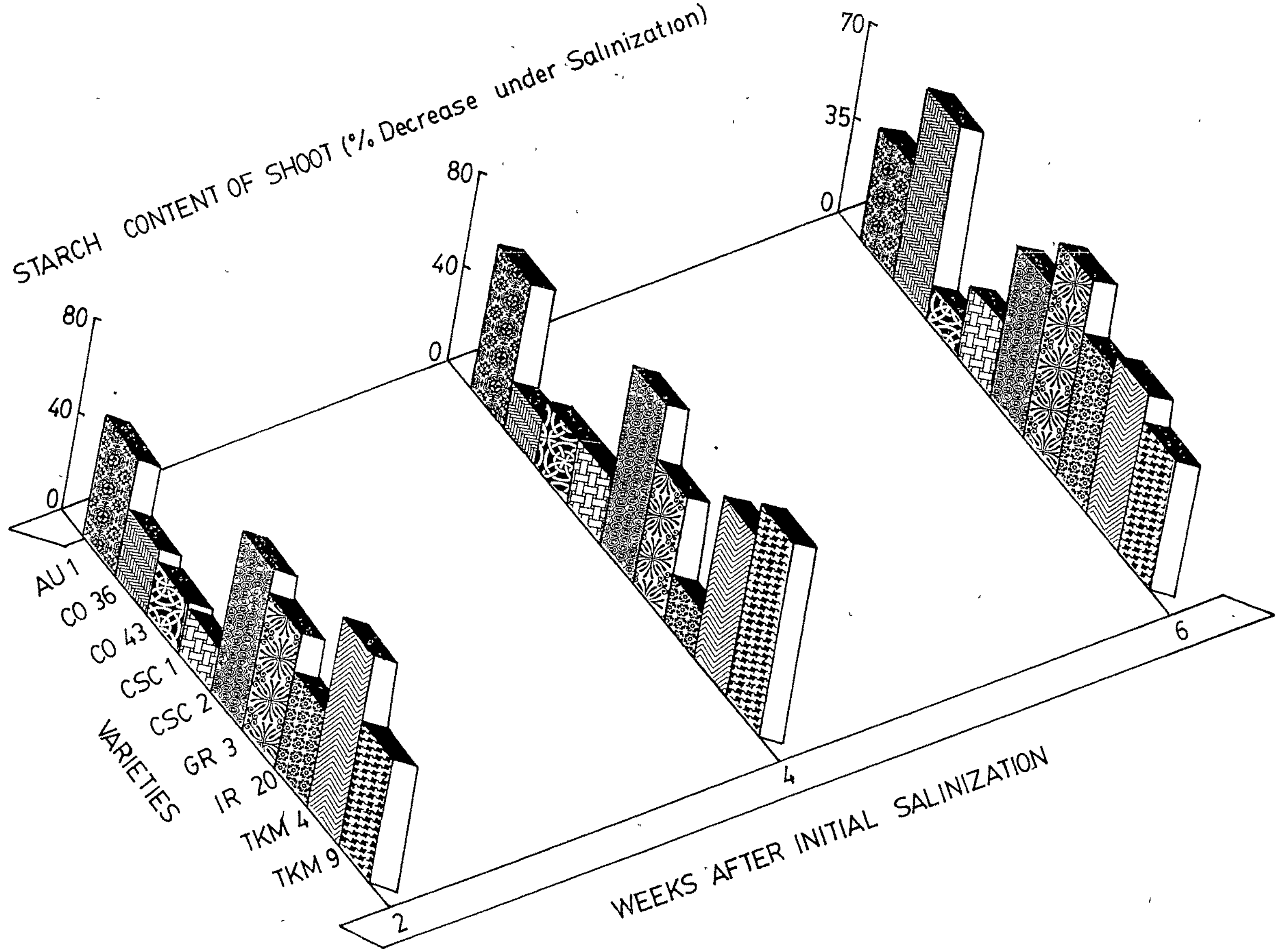

SHOOT TOTAL SOLUBLE SUGAR (% Change over the control)
90
45
+
0
–
30
60
120
60
+
0
–
40
80
25
+
0
–
40
80
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES
2
4
6
WEEKS AFTER INITIAL SALINIZATION

Fig. 45. Changes in the reduction of starch content in the shoot system of rice varieties as affected by NaCl stress at different weeks after initial salinization. Results are expressed as percentage of decrease over the control.



STARCH CONTENT OF SHOOT (% Decrease under Salinization)
80
40
0
80
40
0
70
35
0
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES
2
4
6
WEEKS AFTER INITIAL SALINIZATION

Fig.46. Salt stressed (NaCl) changes in the total carbohydrate of the shoot system of rice varieties. Results are expressed as percentage of changes over the control. + : increase, - : decrease.

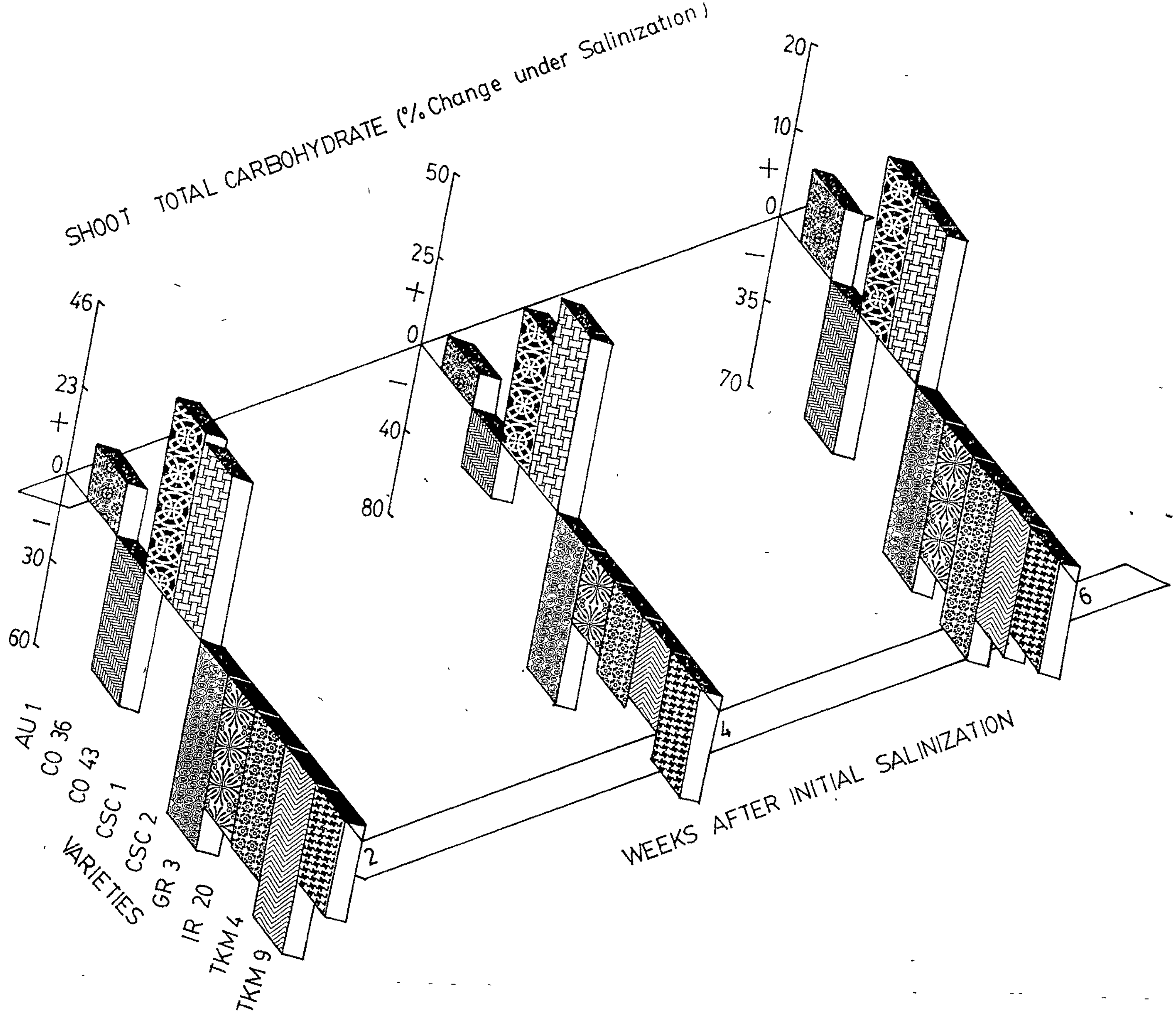
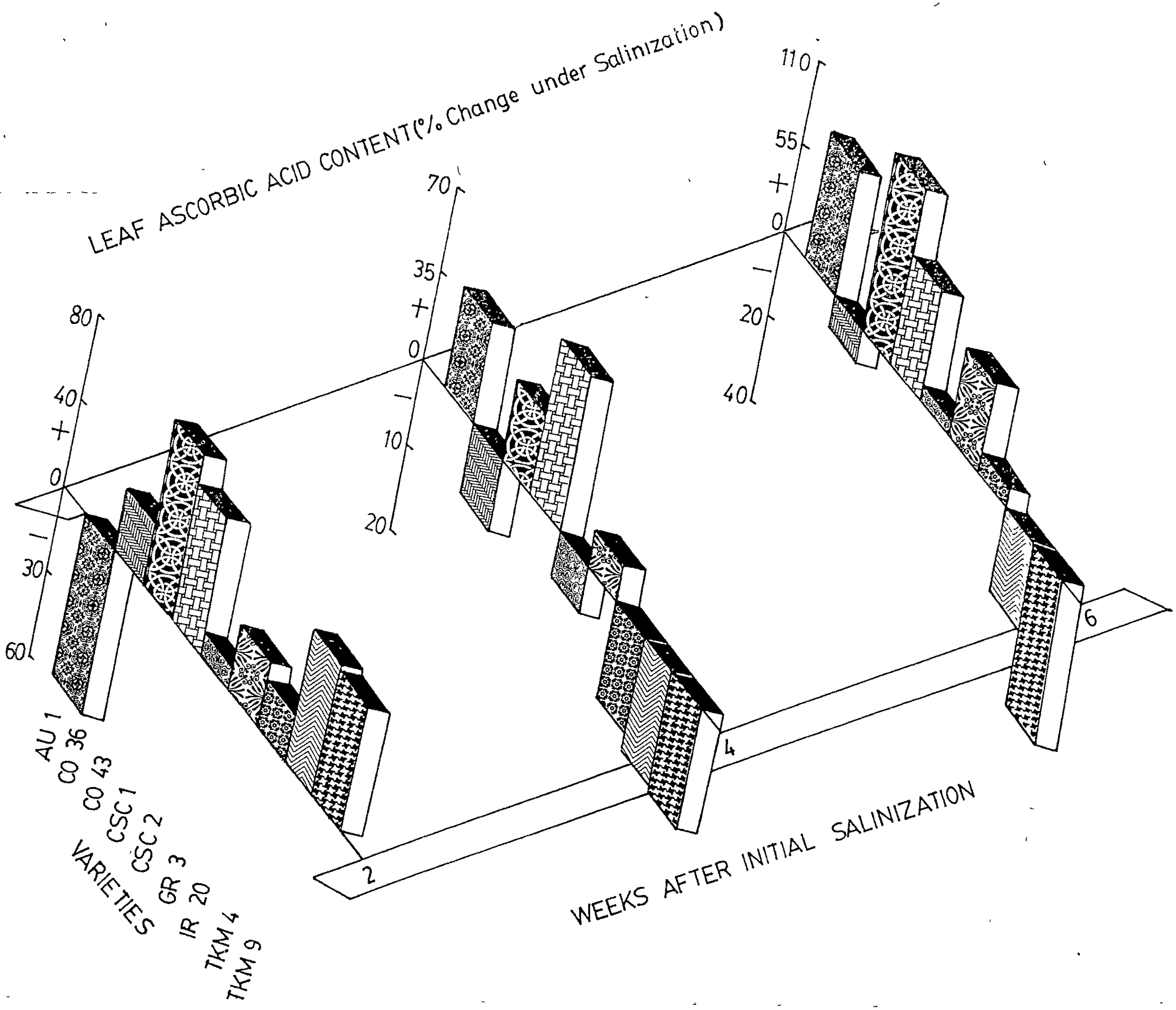

SHOOT TOTAL CARBOHYDRATE (% Change under Salinization)
46
23
+
0
–
30
60
50
25
+
0
–
40
80
20
10
+
0
–
35
70
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES
2
4
6
WEEKS AFTER INITIAL SALINIZATION

Fig. 47. Effect of NaCl on the ascorbic acid level from the third leaf of rice varieties at different weeks after initial salinization. Results are expressed as percentage of changes over the control. + : increase; – : decrease.



LEAF ASCORBIC ACID CONTENT(% Change under Salinization)
80
40
+
0
–
30
60
70
35
+
0
–
10
20
110
55
+
0
–
20
40
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES
2
4
6
WEEKS AFTER INITIAL SALINIZATION

acid to sodium chloride treatment (Fig.47). Titrable acid number was increased in all the varieties at all growth periods under salinization (Table 26). In the leaves of TKM4 and TKM9, high titrable acid number was observed under non-saline conditions and this was increased further when the plants were exposed to salinity. In varieties, AU1, Co43 and CSC1 a low titrable acid number was evident under nonsaline conditions but resulted in an increase of 2 to 4 fold at the sixth week of salinization (Fig.48). Other varieties Co36, CSC2, IR20 and GR3 did not respond to salinity by exhibiting a high titrable acid number at the end of salinization.

g. Chlorophyll content of third leaf

Initially the chlorophyll content of control rice varieties were from 1.8 to 3.9 mg/g fresh weight and were increased towards growth. The varietal response to salinity also varied. In general there was a reduction in total chlorophyll of saline exposed plants. The IR20, TKM9 and CSC2 exhibited highest reduction of total chlorophyll, between 50 and 59 per cent over the control, whereas in the susceptible varieties it was much less at the time of final harvest (Fig.52). AU1, Co43 and CSC1 could manage with least reduction of 10-15 per cent in chlorophyll 'a', and 17-29 per cent in chlorophyll 'b' due to saline treatment at six weeks (Fig.49a, c and d; Fig.50, 51 and 52). Significantly, these varieties increased

Fig.48. Salt stressed (NaCl) increase of titrable acid number from the third leaf of rice varieties at 2, 4 and 6 weeks after initial salinization. Results are expressed as percentage of increase over the control.

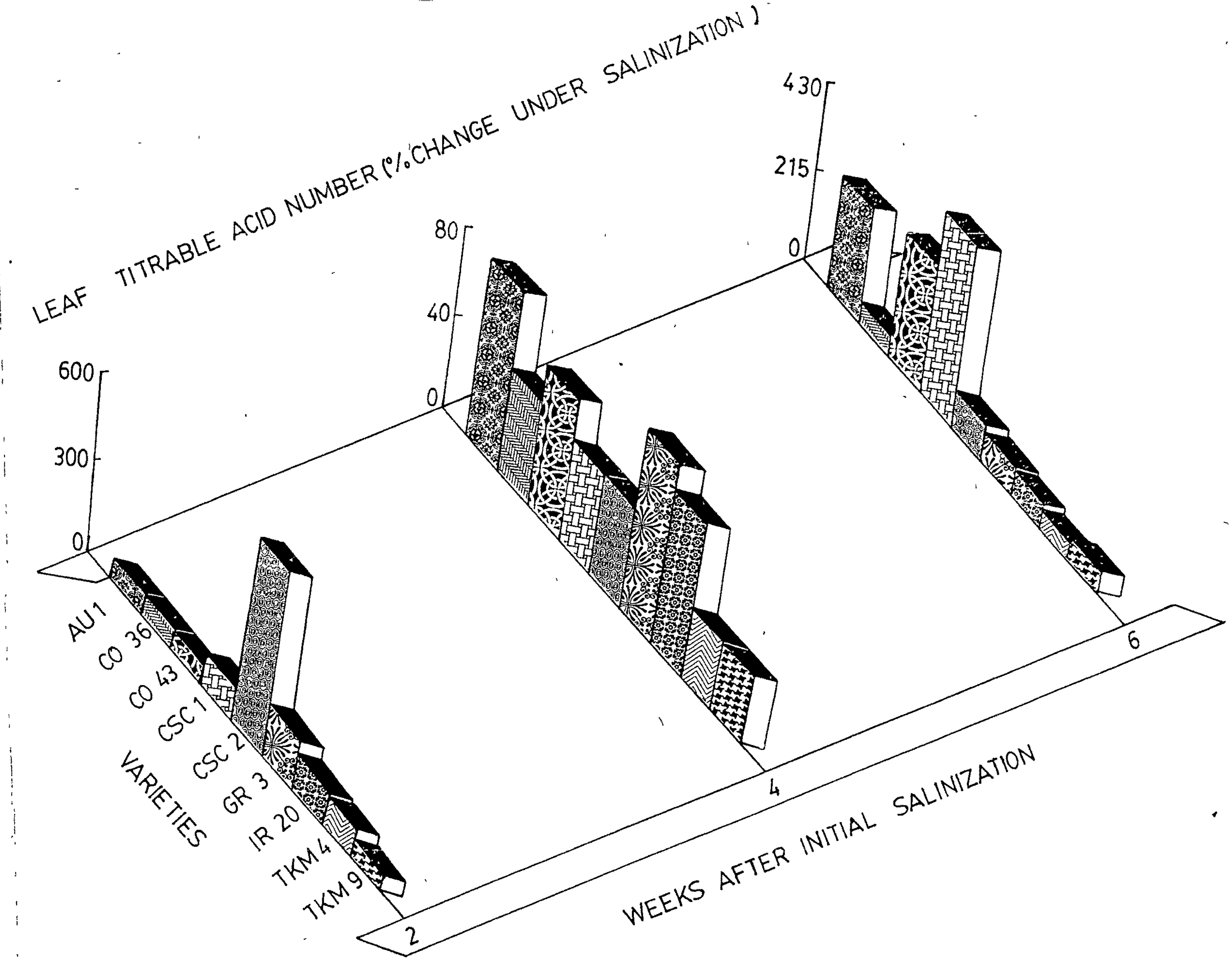

LEAF TITRABLE ACID NUMBER (% CHANGE UNDER SALINIZATION)
600
300
0
80
40
0
430
215
0
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES
2
4
6
WEEKS AFTER INITIAL SALINIZATION

Fig. 49. Effect of sodium chloride on the chlorophyll content of third leaf of rice varieties in 2, 4 and 6 weeks after initial salinization and total leaf area in 6 weeks after initial salinization.

○——○ : Control, chlorophyll a;

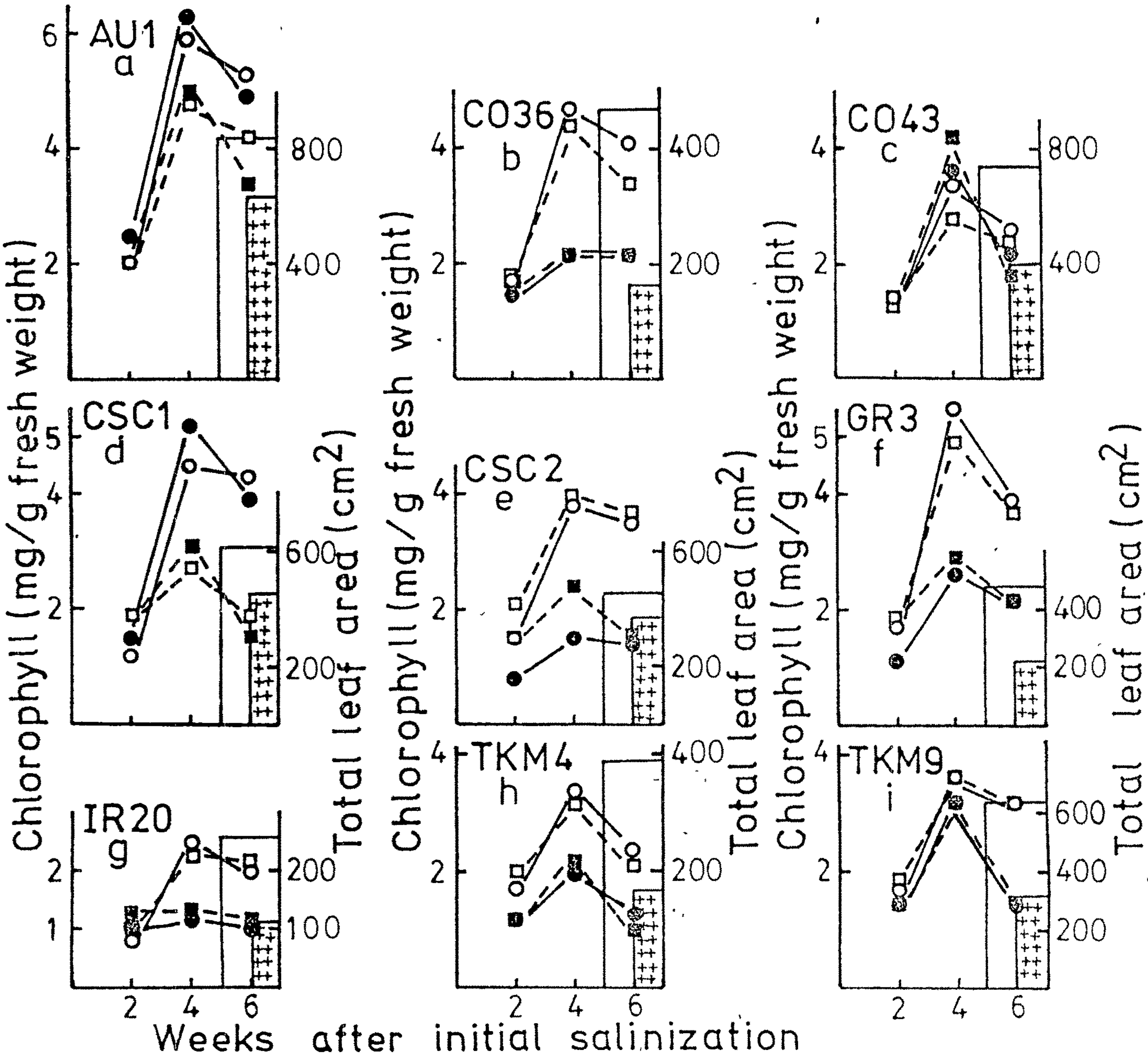
●——● : Salinized, chlorophyll a;

□---□ : Control, chlorophyll b;

■---■ : Salinized, chlorophyll b;

□ : Control, total leaf area;

⊞ : Salinized, total leaf area.



AU1
a
CO36
b
CO43
c
CSC1
d
CSC2
e
GR3
f
IR20
g
TKM4
h
TKM9
i
Chlorophyll (mg/g fresh weight)
Total leaf area (cm2)
Weeks after initial salinization

Fig. 50. Chlorophyll a content from the third leaf of rice varieties grown under saline (NaCl) condition at different weeks after initial salinization. Results are expressed as percentage of changes over the control.

+ : increase; – : decrease.

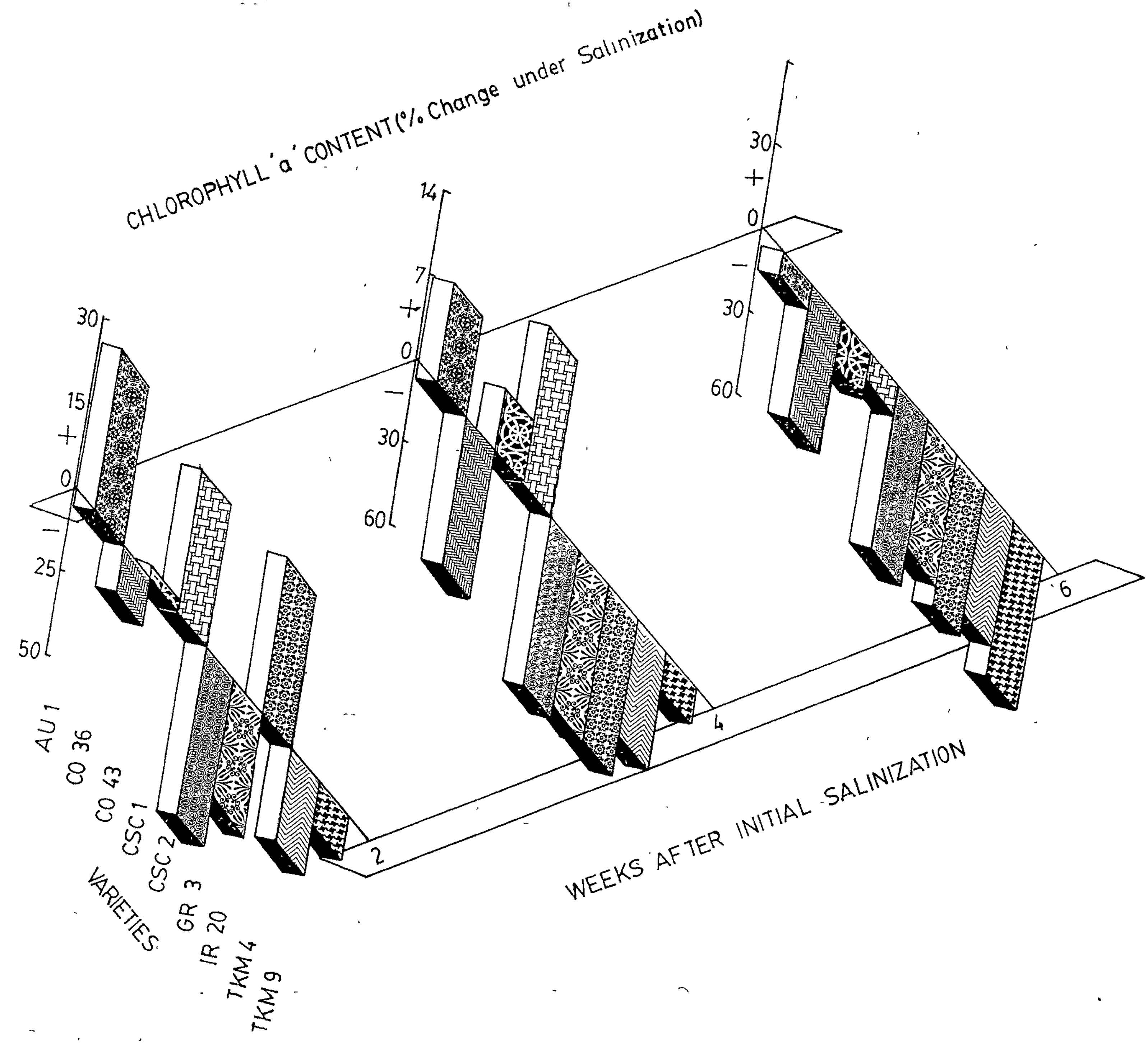
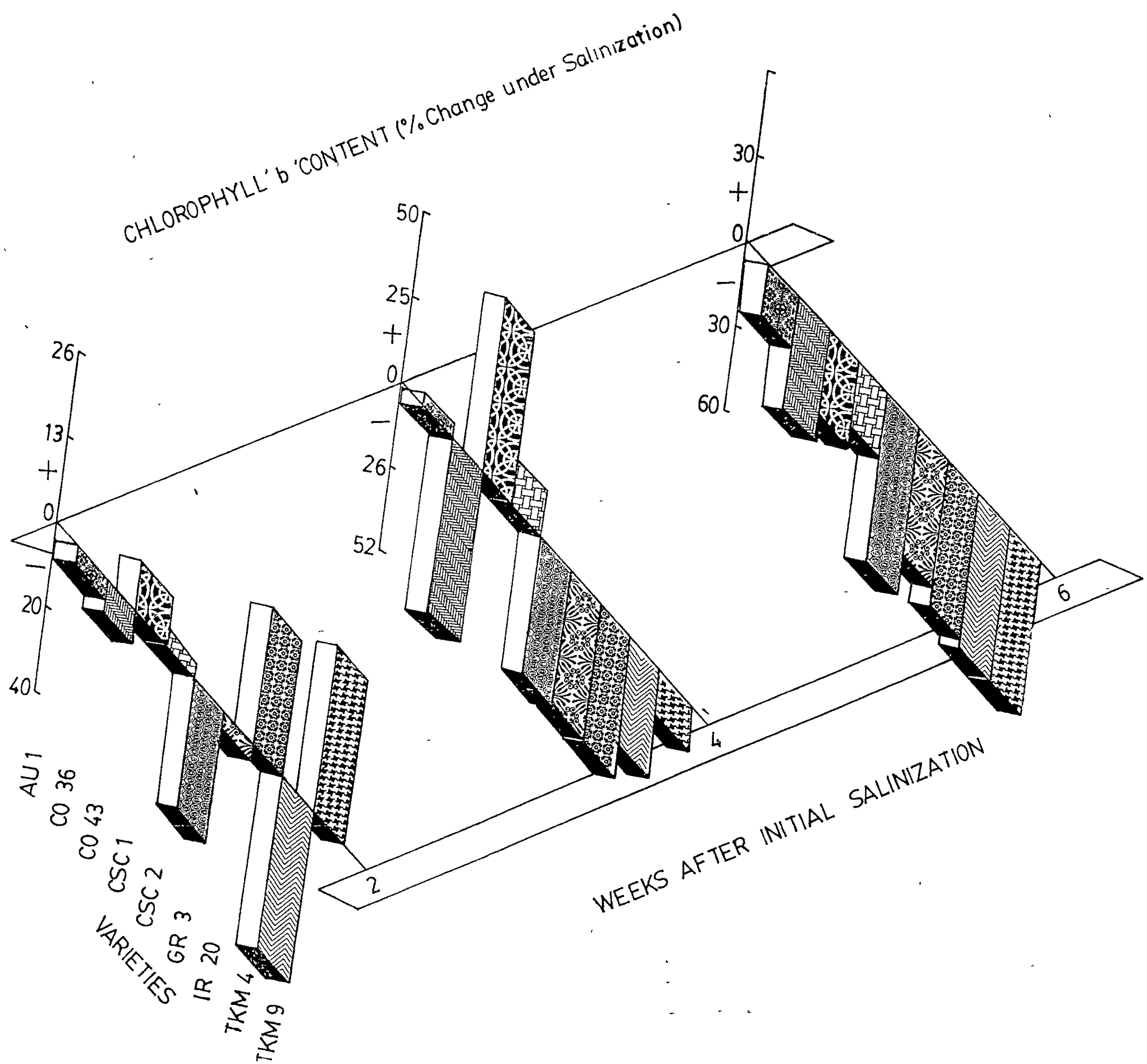
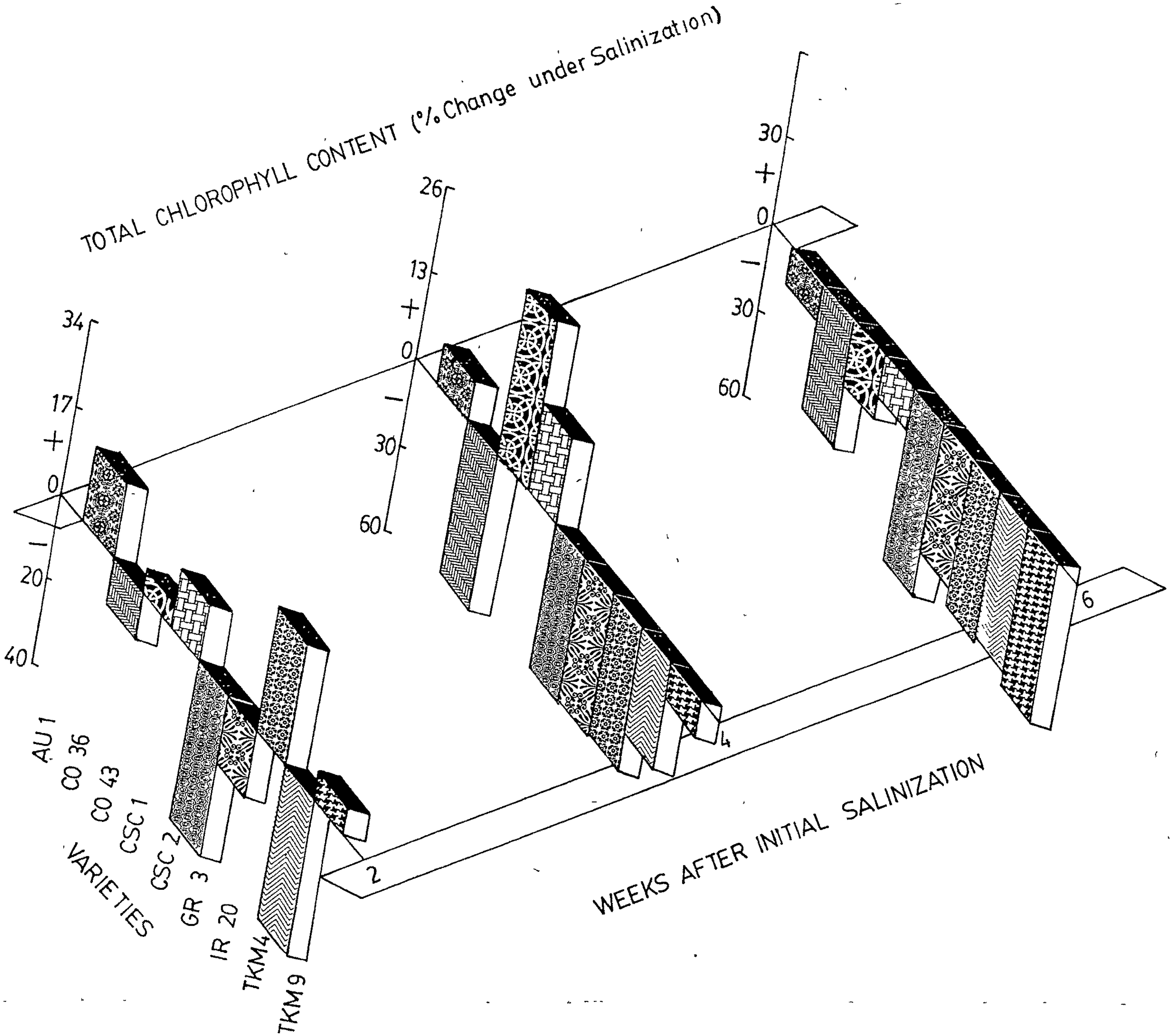

CHLOROPHYLL 'a' CONTENT(% Change under Salinization)
30
15
+
0
–
25
50
14
7
+
0
–
30
60
30
+
0
–
30
60
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES
2
4
6
WEEKS AFTER INITIAL SALINIZATION

Fig.51. Changes in the chlorophyll b content of third leaf of rice varieties as affected by saline stress (NaCl) in 2, 4 and 6 weeks after initial salinization. Results are expressed as percentage of changes over the control. + : increase; - : decrease.



CHLOROPHYLL 'b' CONTENT (% Change under Salinization)
26
13
+
0
–
20
40
50
25
+
0
–
26
52
30
+
0
–
30
60
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES
2
4
6
WEEKS AFTER INITIAL SALINIZATION

Fig.52. Salt stress (NaCl) and total chlorophyll content of third leaf of rice varieties in 2, 4 and 6 weeks after initial salinization. Results are expressed as percentage of changes over the control. + : increase; - : decrease.


TOTAL CHLOROPHYLL CONTENT (% Change under Salinization)
34
17
+
0
−
20
40
26
13
+
0
−
30
60
30
+
0
−
30
60
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM4
TKM 9
VARIETIES
2
4
6
WEEKS AFTER INITIAL SALINIZATION

the chlorophyll 'a' and chlorophyll 'b' contents when compared to the control upto four weeks of sodium chloride treatment. In varieties CSC2, IR20, TKM4 and TKM9 50 per cent reduction in the chlorophyll 'a' and chlorophyll 'b' was resulted at the six week of salinization (Fig.49, 50 and 51).

III. Yield components

1. Yield parameters

Sodium chloride treatment delayed the flowering from 11 to 15 days in Co36, IR20, CSC2 and TKM4, and 6 to 9 days in Co43, AU1, CSC1 and TKM9. On the contrary, salinity stimulated 10 days early flowering in GR3 (Table 27). Salinity adversely affected the length of the panicle by 12 to 47 per cent over the control in CSC2, GR3 and TKM4, and the panicle length retardation by salinity was more in TKM4 (Fig.53a) More than 50 per cent reduction in the number of panicle per plant was noticed in CSC2, IR20 and TKM9. A less degree reduction of panicle number was observed in GR3, Co43, CSC1, AU1 and TKM9 (Table 28; Fig.53b). There was a reduction in the number of spikelets per panicle by saline treatment and the lowest decrease of 8 per cent in CSC1 and a high 53 per cent in TKM4 over the respective controls was recorded (Fig.53c). Salinity increased the unfilled

Table 27 : Changes in the flowering days of rice varieties as affected by NaCl.

Variety	Date of sown	Flower initiation (days)		Early flowering (days)	Flowering delayed (days)	Harvested (days)
		Control	Salinized	Salinized	Salinized	
AU1	5.7.1985	71	77	-	7	120
Co36	5.7.1985	76	87	-	11	130
Co43	5.7.1985	81	87	-	6	135
CSC1	5.7.1985	69	77	-	8	120
CSC2	5.7.1985	73	87	-	14	120
GR3	5.7.1985	63	53	10	-	105
IR20	5.7.1985	60	72	-	12	110
TKM4	5.7.1985	73	88	-	15	130
TKM9	5.7.1985	65	74	-	9	120

Salinization was imposed on three week - old seedlings.

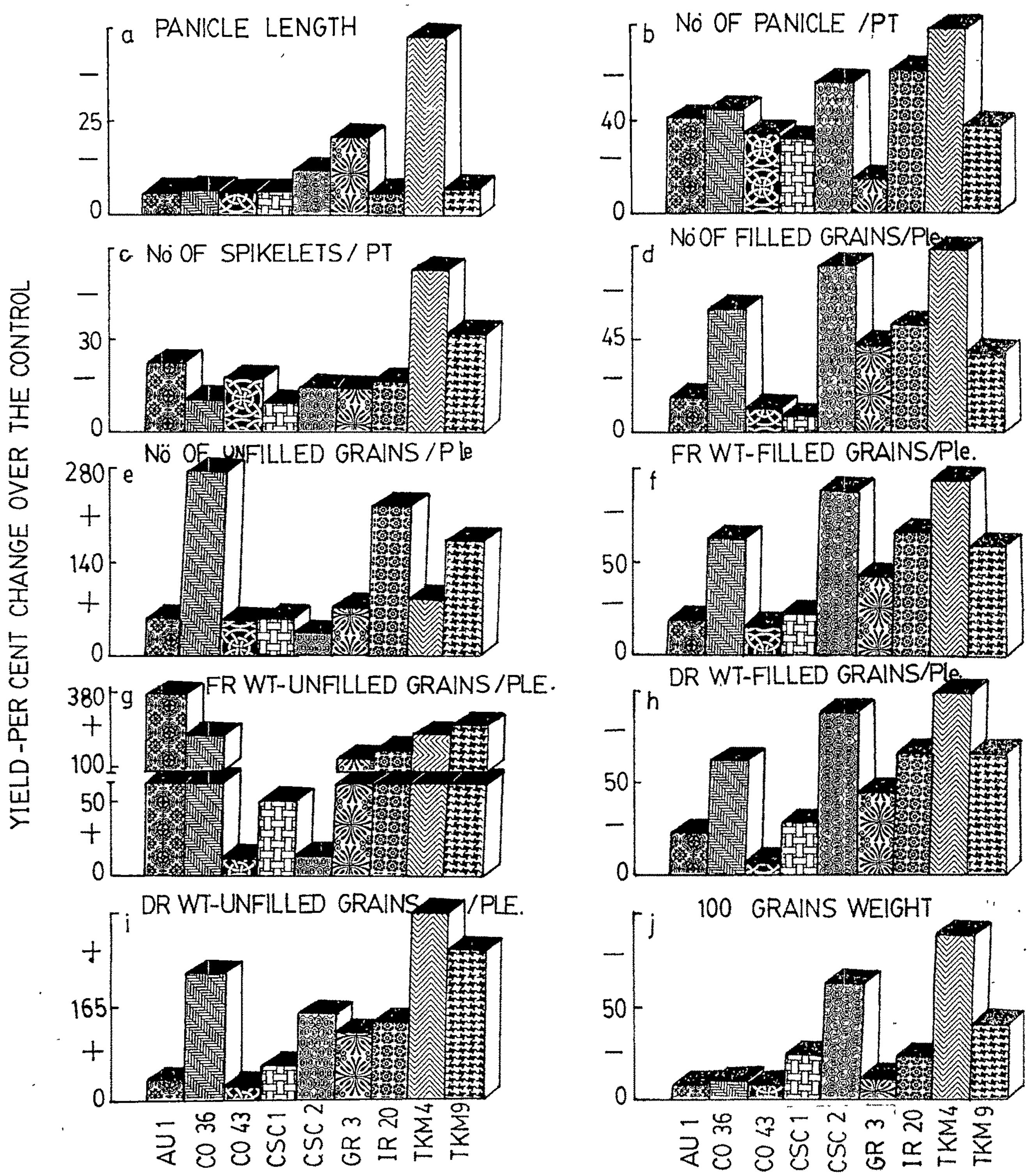
Table 28 : Effect of NaCl on the yield components of rice varieties.

Variety	Panicle length (cm)		No.of panicle/ plant		No.of spikelets/ panicle		No.of filled grain/panicle		No.of unfilled grain/panicle	
	C	S	C	S	C	S	C	S	C	S
AU1	17.9	17.0	3.2	1.9	9.4	7.3	91.7	76.5	15.6	23.5
Co36	19.1	18.0	2.2	1.2	8.0	7.2	71.2	29.2	14.6	54.4
Co43	22.4	21.1	3.0	2.0	10.9	9.1	73.3	65.6	31.5	47.3
CSC1	18.8	17.8	2.2	1.5	10.7	9.8	103.5	95.1	24.5	38.3
CSC2	21.7	19.2	2.7	1.2	11.5	10.0	59.4	11.1	65.4	88.3
GR3	20.1	16.1	1.3	1.1	7.9	6.9	62.1	36.5	12.4	21.7
IR20	17.4	16.5	2.6	1.0	7.6	6.4	62.4	29.0	18.2	59.2
TKM4	20.8	11.1	2.8	0.60	10.4	4.9	93.0	11.6	16.6	30.0
TKM9	20.4	19.1	2.8	1.8	10.8	7.5	80.7	49.7	10.6	28.7
L.S.D.5%	2.6		0.4		1.3		10.8		12.6	

C : Control; S : Salinized

Fig.53a-j. Effect of sodium chloride on the yield components of rice varieties. Results are expressed as percentage of changes over the control.

+ : increase; - : decrease.


YIELD-PER CENT CHANGE OVER THE CONTROL
a PANICLE LENGTH
b Nö OF PANICLE /PT
c Nö OF SPIKELETS / PT
d Nö OF FILLED GRAINS/Ple
e Nö OF UNFILLED GRAINS / Ple
f FR WT-FILLED GRAINS/Ple.
g FR WT-UNFILLED GRAINS /PLE.
h DR WT-FILLED GRAINS/Ple.
i DR WT-UNFILLED GRAINS /PLE.
j 100 GRAINS WEIGHT
AU1
CO 36
CO 43
CSC1
CSC 2
GR 3
IR 20
TKM4
TKM9

grains and decreased the number of filled grain per panicle. In AU1, Co43 and CSC1 the reduction in the number of filled grains was less but it was more than 50 per cent in Co36, CSC2, IR20 and TKM4 over their controls (Fig.53d). There was a considerable increase in the number of unfilled grain per panicle in Co36, IR20, TKM4 and TKM9 to saline treatment. The decrease in the fresh weight of filled grain per panicle over the nonsaline plants in AU1, Co43 and CSC1 was much less while comparing the varietal response to salinity. Parallel to the decrease in the weight of filled grains, the fresh weight of unfilled grains per panicle was highly increased in AU1, Co36, GR3, IR20, TKM4 and TKM9 to saline treatment. Similarly dry weight of filled grain per panicle was decreased to a lesser extent and dry weight of unfilled grain per panicle was also increased to a much less level in AU1, Co43 and CSC1 than the other varieties due to exposure to sodium chloride treatment (Table 29; Fig.53h and i).

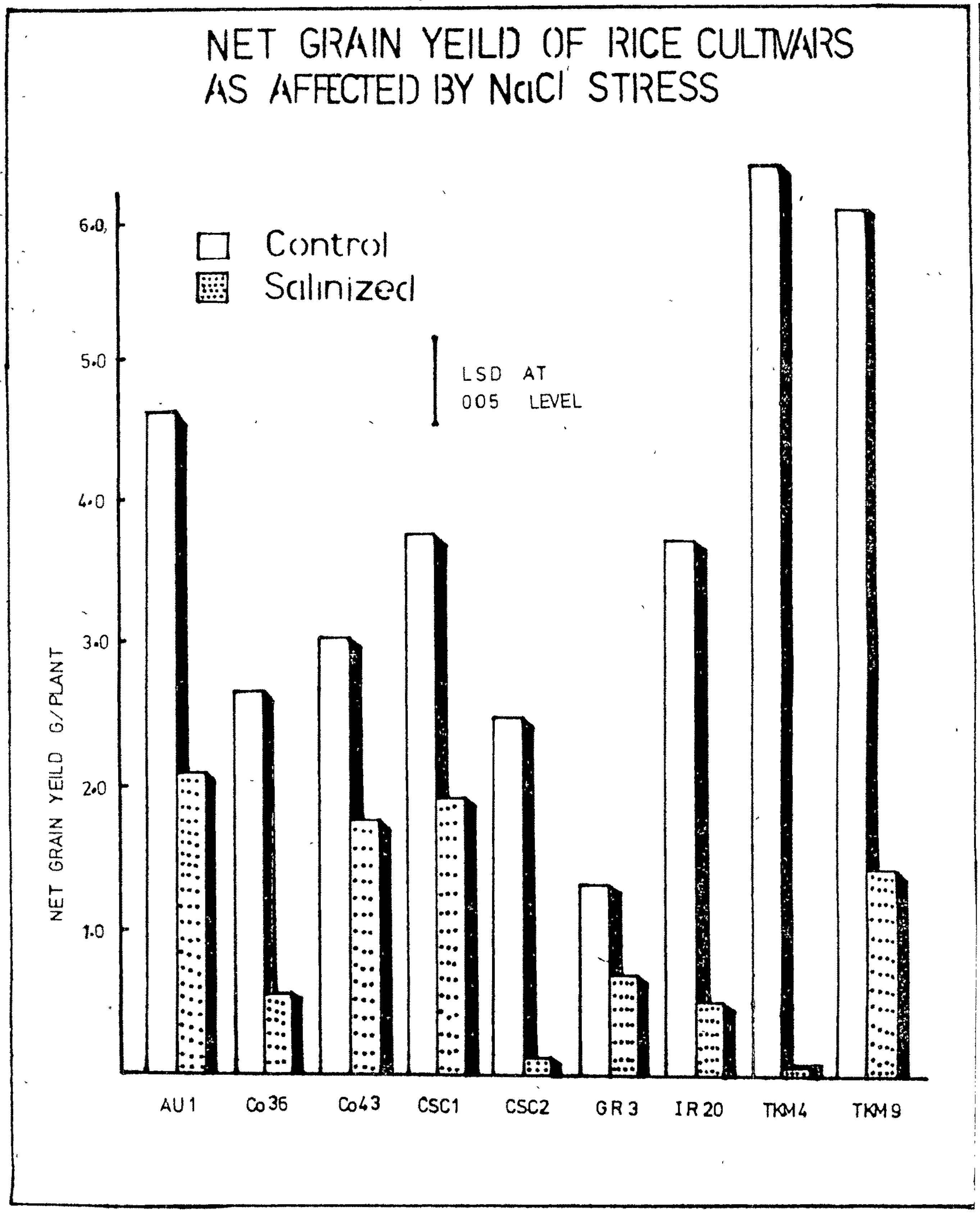
Salinity, thus, brought about a definite reduction in the net grain yield per plant to varying extent in different varieties. It was found to be between 41 and 50% in Co43, CSC1 and AU1, 57 and 79% in GR3, TKM9 and Co36, and 86 and 95% in IR20, TKM4 and CSC2 over their control (Fig.54, 57a). However, weight of 100 grains was not much affected in AU1, Co36, Co43 and GR3 while

Table 29 : Effect of NaCl stress on the yield components of rice varieties.

Variety	Fr.wt. of filled grain/ panicle (g)		Fr.wt. of unfilled grain/ panicle (g)		Dr.wt. of filled grain/ panicle (g)		Dr.wt. of unfilled grain/ panicle (g)		Biological yield		Harvest index	
	C	S	C	S	C	S	C	S	C	S	C	S
AU1	1.70	1.40	0.09	0.11	1.40	1.10	0.08	0.11	10.35	7.15	0.45	0.29
Co36	1.32	0.51	0.04	0.11	1.21	0.46	0.03	0.10	5.44	1.82	0.48	0.30
Co43	1.21	1.05	0.09	0.09	1.01	0.88	0.07	0.08	5.42	3.68	0.56	0.47
CSC1	2.24	1.75	0.07	0.10	1.72	1.26	0.06	0.09	6.47	4.13	0.58	0.47
CSC2	1.07	0.14	0.26	0.29	0.93	0.12	0.11	0.28	4.99	1.59	0.49	0.09
GR3	1.25	0.72	0.06	0.14	0.09	0.62	0.06	0.12	2.74	1.70	0.49	0.40
IR20	1.67	0.57	0.06	0.13	1.44	0.51	0.05	0.12	5.62	1.44	0.66	0.35
TKM4	2.94	0.07	0.03	0.09	2.68	0.07	0.02	0.09	9.87	1.50	0.76	0.04
TKM9	2.51	1.06	0.04	0.14	0.23	0.08	0.03	0.10	8.66	2.69	0.71	0.54
L.S.D.5%	0.20		0.04		0.17		0.03		0.60		0.07	

C : Control; S : Salinized

Fig.54. Effect of sodium chloride on the net grain yield of rice varieties.


NET GRAIN YEILD OF RICE CULTIVARS
AS AFFECTED BY NaCl STRESS
Control
Salinized
LSD AT
005 LEVEL
NET GRAIN YEILD G/PLANT
6.0
5.0
4.0
3.0
2.0
1.0
AU 1
Co 36
Co 43
CSC1
CSC2
GR 3
IR 20
TKM 4
TKM 9

it was extremely affected in CSC2, TKM4 and TKM9 to saline treatment (Fig.53j and 55). Salinity also affected straw production in rice. About 11 to 20 per cent reduction in the straw weight was noticed in AU1, Co43 and CSC1 (Fig.56 and 57b) whereas in IR20, TKM9 and Co36 much higher reduction of 54 to 58 per cent in their straw weight resulted as a result of saline treatment. The biological yield of AU1, Co43, CSC1 and GR3 was reduced by 31 to 38 per cent, while in others the decrease was found to be above 50 per cent (Table 29; Fig.57c). Likewise there was a resultant decrease in the harvest index of different varieties amounting 15 to 35 per cent in Co43, GR3, CSC1, TKM9 and AU1, 38 to 46 per cent in Co36 and IR20, and 81 to 94 per cent in CSC2 and TKM4 (Table 29; Fig.57d).

2. Inorganic constituents of straw and filled and unfilled grains

With sodium chloride treatment, varieties AU1, Co43, and CSC1 increased the K^+, Ca^{2+} and Mg^{2+} levels with increase of Na^+ and Cl^- in their straw& filled and unfilled grains. On the contrary, K^+, Ca^{2+} and Mg^{2+} levels in the straw& filled and unfilled grains of Co36, CSC2, GR3, IR20, TKM4 and TKM9 decreased with increasing concentration of Na^+ and Cl^- (Table 30, 31 and 32; Fig.58 and 59). AU1, Co43, GR3 and TKM9 accumulated less sodium, Table : 30 : Effect of NaCl on the mineral constitution of straw in rice varieties.

Variety	Control (m moles/g dry weight)					Salinized (m moles/g dry weight)				
	Na^+	Cl^-	K^+	Ca^{2+}	Mg^{2+}	Na^+	Cl^-	K^+	Ca^{2+}	Mg^{2+}
AU1	1.09	0.47	1.60	1.20	0.48	1.62	1.51	2.44	1.80	0.92
Co36	0.69	0.51	1.52	1.08	0.64	2.42	2.20	0.99	0.96	0.52
Co43	0.85	0.77	1.71	0.80	0.76	1.45	1.92	2.29	1.28	0.92
CSC1	0.97	0.69	1.71	1.00	0.60	2.30	1.65	2.67	1.48	1.04
CSC2	0.97	0.52	1.30	1.40	1.00	2.75	2.06	0.76	1.04	0.76
GR3	1.25	0.82	1.79	1.36	0.60	1.86	1.92	0.91	1.08	0.32
IR20	1.01	0.37	1.79	1.52	1.28	2.26	1.98	1.03	1.00	0.80
TKM4	1.17	0.66	0.95	1.08	1.28	2.91	1.65	0.72	0.88	0.88
TKM9	0.97	0.71	1.83	0.88	1.00	1.66	2.20	1.41	0.64	0.48

Table 31 : Effect of NaCl on the inorganic levels of filled grain in rice varieties

Variety	Control (m moles/g grain)					Salinized (m moles/g grain)				
	Na^+	Cl^-	K^+	Ca^{2+}	Mg^{2+}	Na^+	Cl^-	K^+	Ca^{2+}	Mg^{2+}
AU1	0.11	0.04	0.17	0.25	0.15	0.16	0.05	0.21	0.35	0.35
Co36	0.28	0.03	0.18	0.25	0.11	0.33	0.05	0.14	0.16	0.07
Co43	0.35	0.05	0.18	0.11	0.26	0.39	0.06	0.24	0.15	0.28
CSC1	0.13	0.04	0.13	0.15	0.20	0.19	0.05	0.18	0.20	0.28
CSC2	0.20	0.04	0.24	0.09	0.37	0.23	0.06	0.16	0.08	0.33
GR3	0.07	0.04	0.19	0.09	0.28	0.09	0.05	0.16	0.07	0.27
IR20	0.06	0.03	0.24	0.18	0.63	0.36	0.05	0.15	0.11	0.33
TKM4	0.11	0.03	0.18	0.13	0.18	0.28	0.05	0.12	0.09	0.11
TKM9	0.10	0.03	0.17	0.09	0.27	0.14	0.05	0.14	0.10	0.28

Table 32 : Effect of NaCl on the inorganic levels of unfilled grain in rice varieties.

Variety	Control (m moles/g unfilled grain)					Salinized (m moles/g unfilled grain)				
	Na^{+}	Cl^{-}	K^{+}	Ca^{2+}	Mg^{2+}	Na^{+}	Cl^{-}	K^{+}	Ca^{2+}	Mg^{2+}
AU1	0.11	0.10	0.24	0.13	0.30	0.17	0.12	0.28	0.16	0.64
Co36	0.28	0.10	0.31	0.30	0.19	0.43	0.16	0.26	0.20	0.11
Co43	0.35	0.14	0.21	0.37	0.23	0.39	0.16	0.40	0.58	0.55
CSC1	0.09	0.09	0.28	0.17	0.26	0.21	0.12	0.33	0.18	0.34
CSC2	0.17	0.11	0.27	0.24	0.39	0.25	0.16	0.21	0.15	0.30
GR3	0.07	0.11	0.27	0.15	0.26	0.11	0.15	0.21	0.13	0.25
IR20	0.12	0.08	0.42	0.59	0.37	0.81	0.13	0.37	0.25	0.26
TKM4	0.13	0.10	0.39	0.40	0.05	0.31	0.12	0.22	0.33	0.03
TKM9	0.16	0.13	0.35	0.36	0.33	0.21	0.17	0.29	0.33	0.15

Fig. 55. Salt stress (NaCl) affected changes in the 100 grains weight of different rice varieties.

WEIGHT OF 100 GRAINS AS ALTERED BY NaCl STRESS

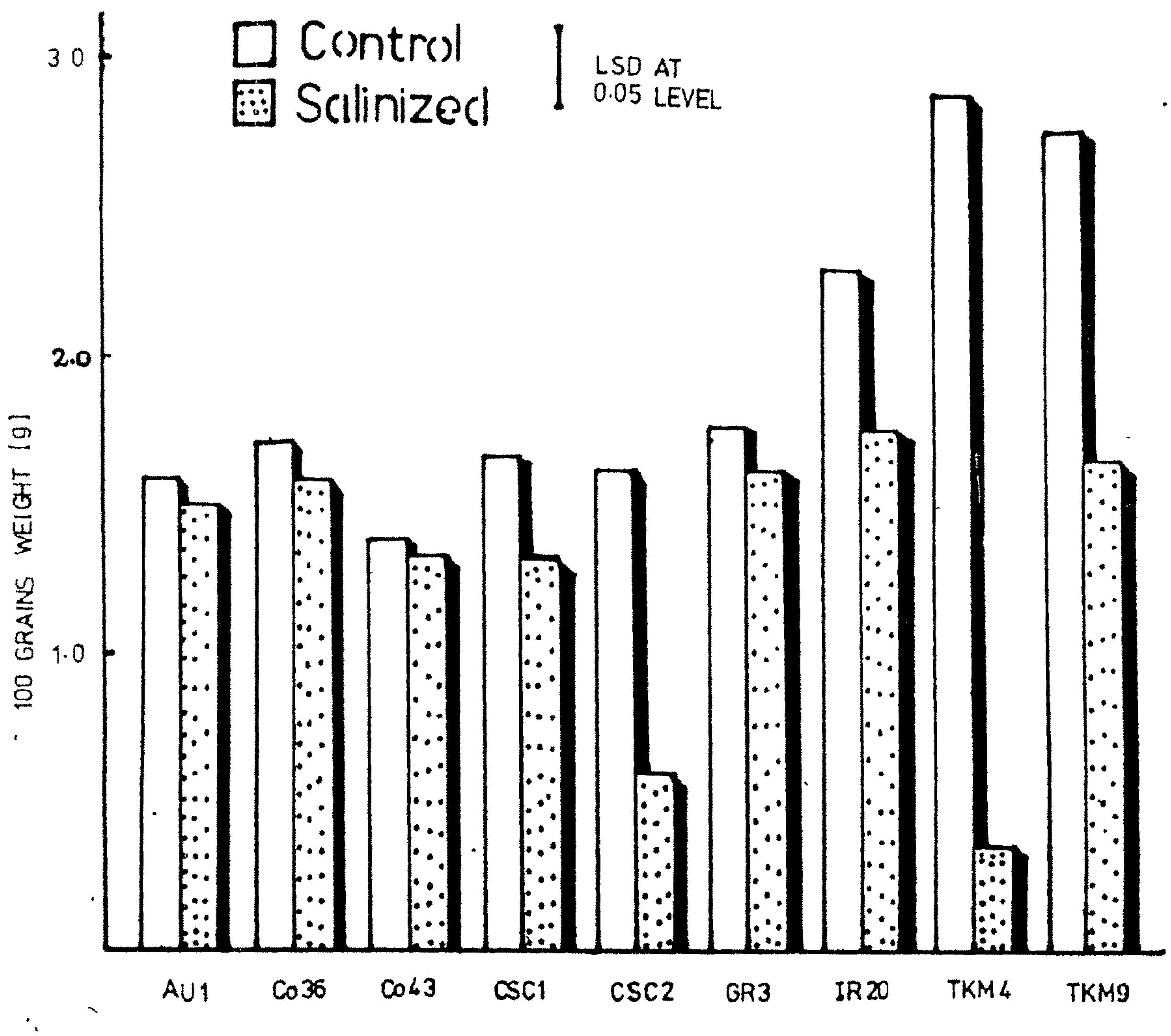
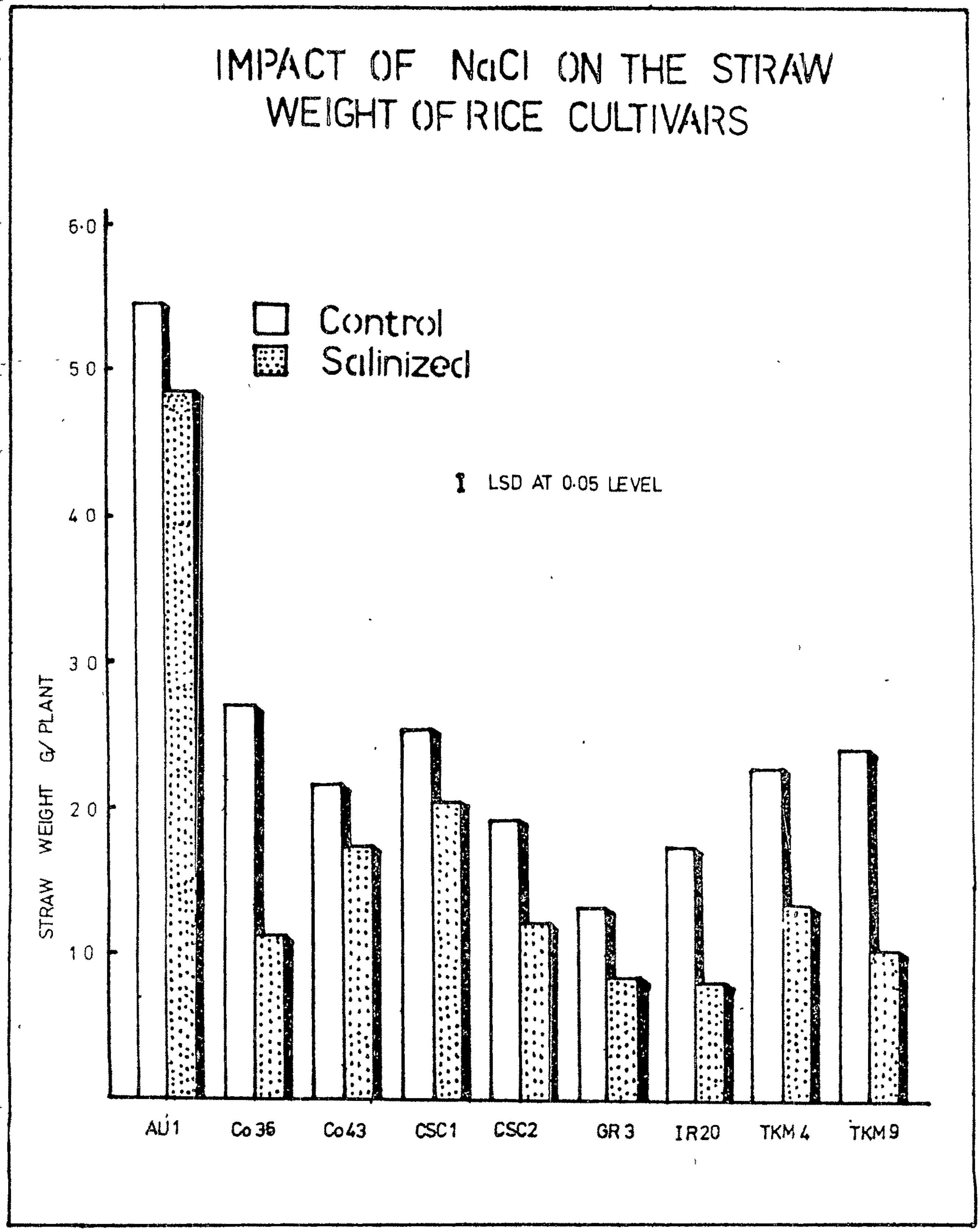
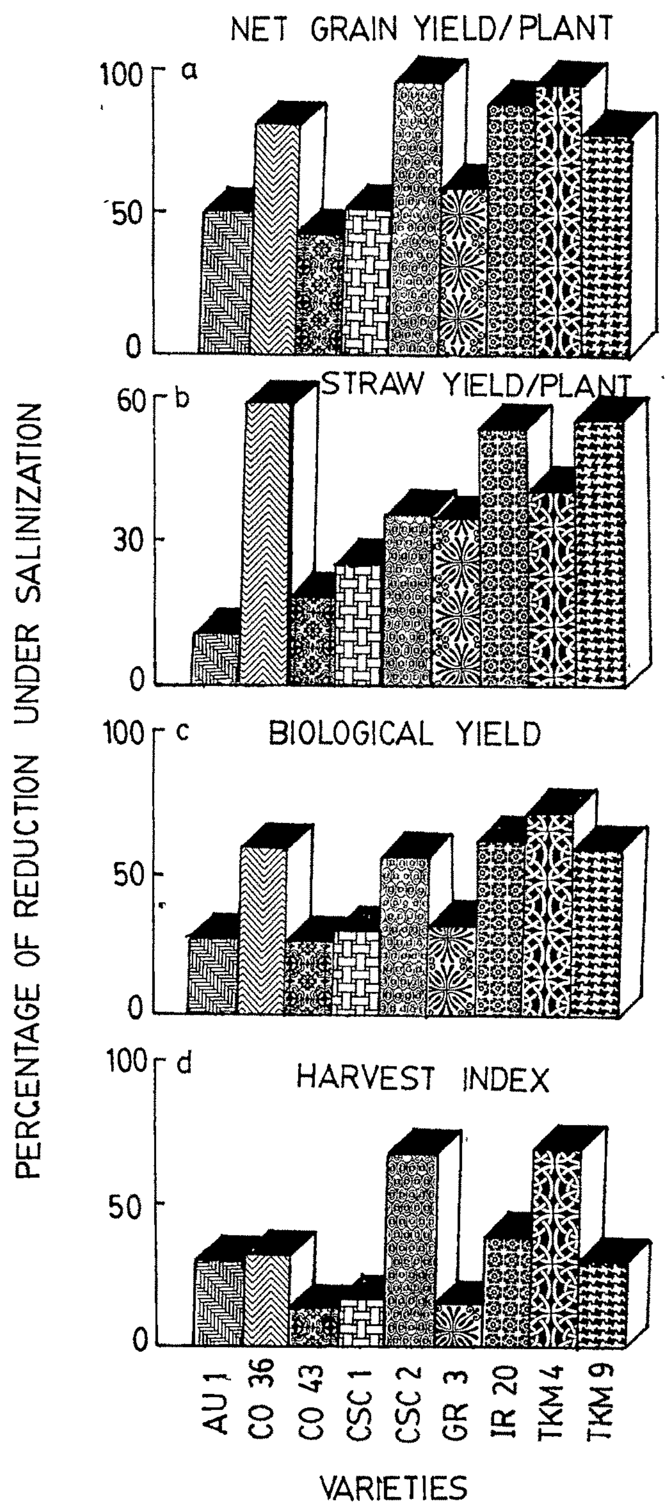


Fig.56. Changes in the straw yield of different rice varieties as affected by sodium chloride salinity.



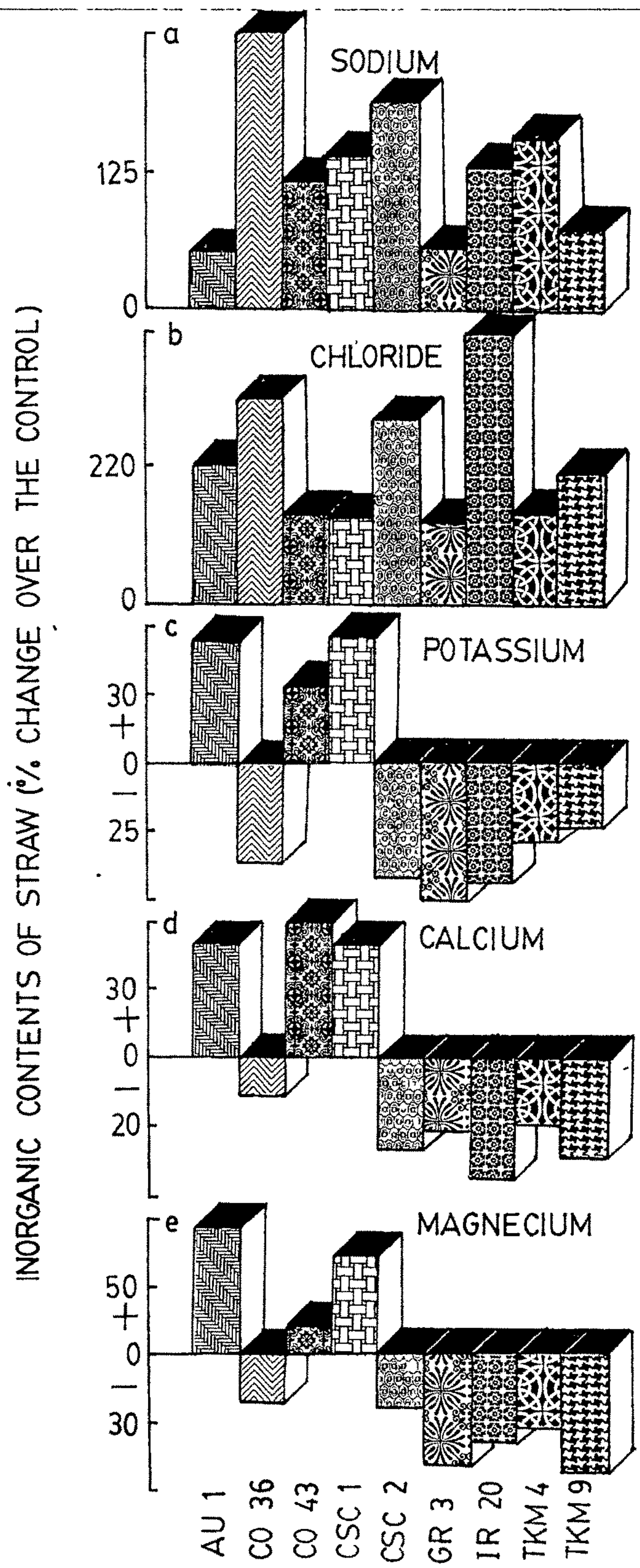
IMPACT OF NaCl ON THE STRAW WEIGHT OF RICE CULTIVARS
Control
Salinized
LSD AT 0.05 LEVEL
STRAW WEIGHT G/ PLANT
6.0
5 0
4 0
3 0
2 0
1 0
AU 1
Co 36
Co 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9

Fig.57a-d. Effect of sodium chloride on the yield components of rice varieties. Results are expressed as percentage of decrease over the control.



NET GRAIN YIELD/PLANT
a
STRAW YIELD/PLANT
b
BIOLOGICAL YIELD
c
HARVEST INDEX
d
PERCENTAGE OF REDUCTION UNDER SALINIZATION
100
50
0
60
30
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES

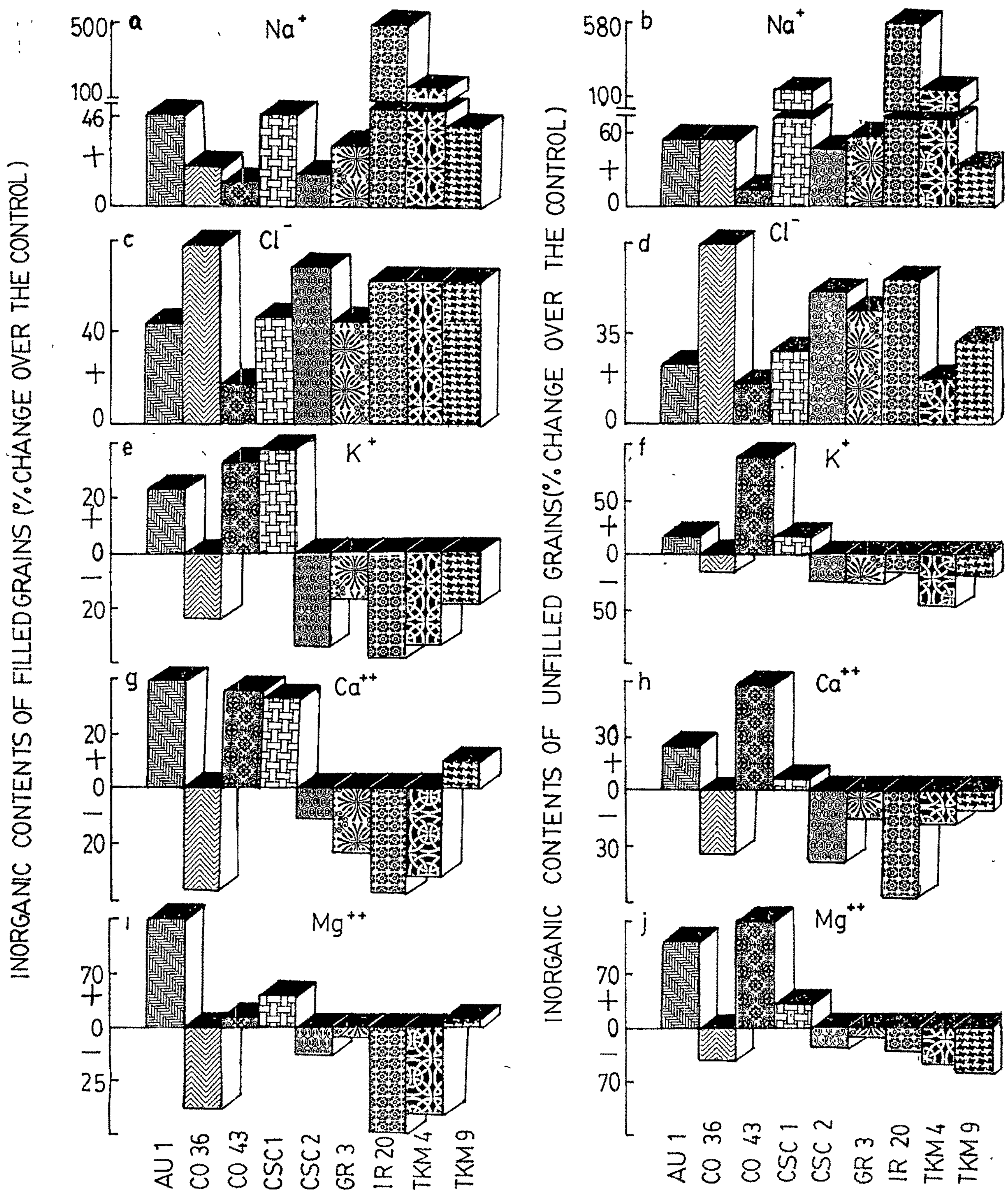
Fig.58a-e. Inorganic constituents of final harvest (straw) of rice varieties as affected by NaCl. Results are expressed as percentage of changes over the control. + : increas; - : decrease.



INORGANIC CONTENTS OF STRAW (% CHANGE OVER THE CONTROL)
a
SODIUM
125
0
b
CHLORIDE
220
0
c
POTASSIUM
30
+
0
–
25
d
CALCIUM
30
+
0
–
20
e
MAGNECIUM
50
+
0
–
30
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9

Fig. 59a-j. Inorganic constituents harvested filled and unfilled grains of rice varieties exposed to NaCl stress. Results are expressed as percentage of changes over the control.

+ : increase; - : decrease.



INORGANIC CONTENTS OF FILLED GRAINS (% CHANGE OVER THE CONTROL)
INORGANIC CONTENTS OF UNFILLED GRAINS (% CHANGE OVER THE CONTROL)
a
Na+
b
Na+
c
Cl−
d
Cl−
e
K+
f
K+
g
Ca++
h
Ca++
i
Mg++
j
Mg++
500
100
46
580
60
40
35
20
50
30
70
25
0
AU 1
CO 36
CO 43
CSC1
CSC 2
GR 3
IR 20
TKM 4
TKM 9

whereas Co36, CSC2 and IR20 accumulated high level of chloride in their straw in comparison with their respective controls (Fig.58a and b).

Varieties IR20 and TKM4 increased the higher concentration of sodium in their filled and unfilled grains than the others when exposed to salinity (Fig.59a and b). Compared to the control, variety Co43 had less ability to accumulate high level of sodium and chloride in both the filled and unfilled grains to sodium chloride treatment (Fig.59a, b, c and d) while Co36 could collect chloride more than the control and the per cent increase was maximum in the filled and unfilled grains (Fig.59c and d). Chloride concentration was almost similar in the filled grains of CSC2, IR20, TKM4 and TKM9 to sodium chloride treatment (Fig.59c).

3. Organic constituents of grains obtained from saline exposed plants

a. Carbohydrate level

Reducing, non-reducing and total soluble sugar contents were decreased in all the varieties except AU1, Co43 and CSC1 which maintained increased level of sugars due to saline exposure over the nonsaline control (Table 33; Fig.60a, b and c). CSC2, TKM4 and TKM9 exhibited 50 per cent reduction in the reducing sugar content as compared to

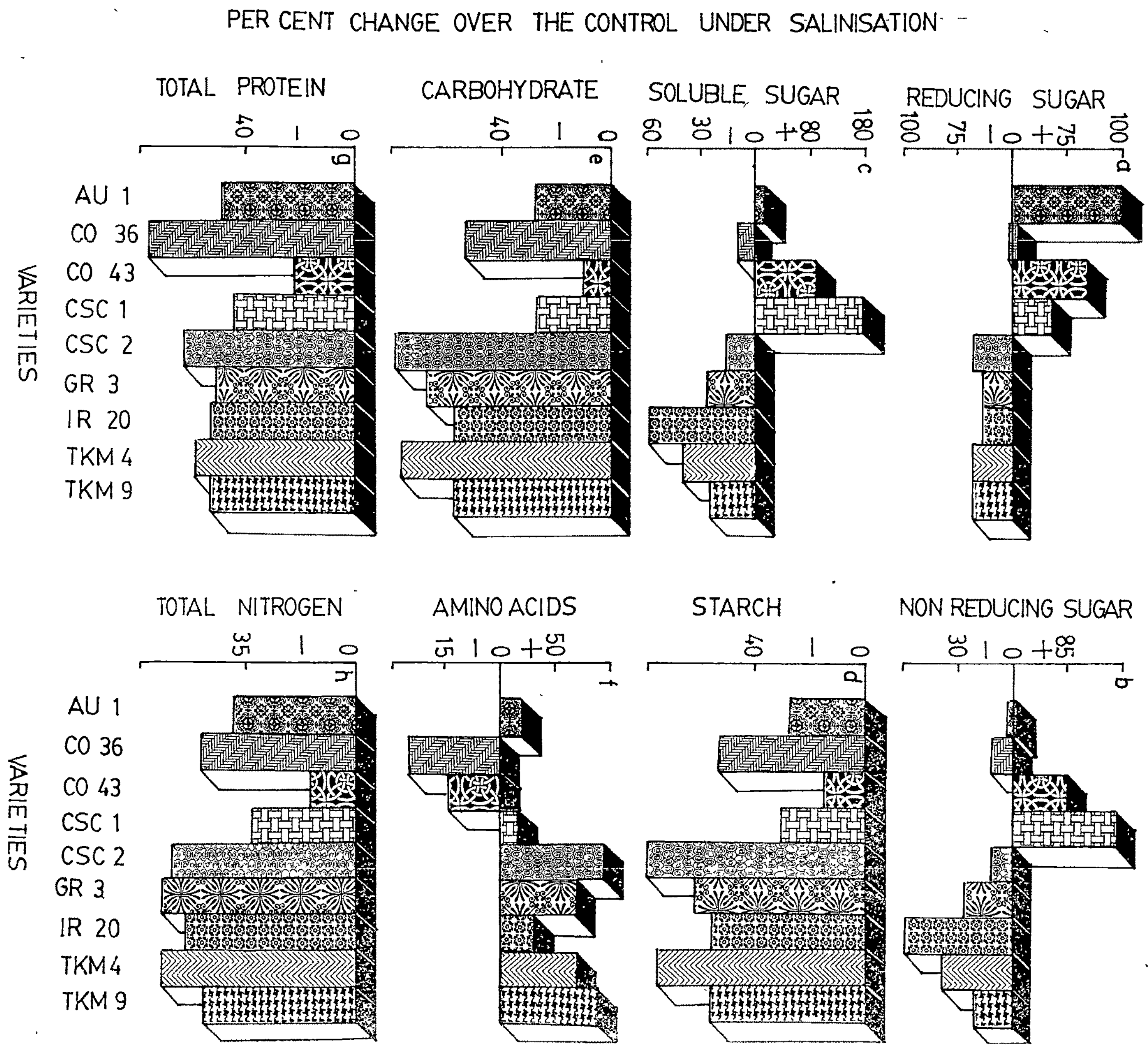
Table 33 : Carbohydrate levels of harvested grain from saline exposed (NaCl) rice varieties.

Variety	Reducing sugar		Non-reducing sugar		Total soluble sugar		Starch	
	(mg/g milled grain)							
	C	S	C	S	C	S	C	S
AU1	1.50	3.75	18.00	18.00	19.50	21.75	880	640
Co36	1.50	1.50	8.25	7.50	9.75	9.00	752	352
Co43	0.75	1.50	42.75	78.00	43.50	79.50	816	704
CSC1	1.50	2.25	20.25	53.35	21.75	55.50	880	608
CSC2	1.50	0.75	9.75	9.00	11.25	9.75	784	176
GR3	2.25	1.50	29.25	21.75	31.50	23.25	672	256
IR20	2.25	1.50	41.25	17.25	43.50	18.75	688	304
TKM4	3.00	1.50	35.25	21.75	38.25	23.25	736	176
TKM9	3.00	1.50	22.50	18.00	25.50	19.50	784	336

C : Control; S : Salinized

Fig. 60a-h. Carbohydrates, amino acids, total protein and total nitrogen levels in the harvested grains of rice varieties exposed to NaCl salinity. Results are expressed as percentage of changes over the control.

+ : increase; − : decrease.



PER CENT CHANGE OVER THE CONTROL UNDER SALINISATION
REDUCING SUGAR
SOLUBLE SUGAR
CARBOHYDRATE
TOTAL PROTEIN
NON REDUCING SUGAR
STARCH
AMINO ACIDS
TOTAL NITROGEN
a
b
c
d
e
f
g
h
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9
VARIETIES

the control. There appeared to be 57 to 58 per cent reduction in the non-reducing and total soluble sugars in IR20 due to salt treatment (Fig.60b and c).

Salinity treatment decreased the starch and total carbohydrate levels in the grains of all the varieties (Table 33 and 34; Fig.60). High reduction in the starch and total carbohydrate content was noticed in CSC2 and TKM4. Varieties AU1, Co43 and CSC1 experienced less reduction in the starch and total carbohydrate content when exposed to salinity (Fig.60d and e). The starch and total carbohydrate levels were decreased by 52 to 57 per cent as compared to the control in Co36, IR20 and TKM9.

b. Amino acid content

Generally, amino acid content improved in all the varieties except in Co36 & Co43 under saline treatment. 70 to 92 per cent increase over the control in the amino acid content resulted in GR3, TKM9 and CSC2 due to salinization, which was comparatively higher than the others, while in others like AU1 and CSC1, 17 to 18 per cent increase in the amino acid level was witnessed (Table 34; Fig 60f).

c. Total protein content

Total protein content was found to decline in all the varieties when exposed to salinity. Co43, CSC1 and AU1 showed less reduction in the total protein when compared

Table 34 : Changes in the carbohydrate levels of harvested grain from rice varieties grown under NaCl saline condition.

Variety	Total carbohydrate		Amino acids		Total protein		Total nitrogen	
	(mg/g milled grain)							
	C	S	C	S	C	S	C	S
AU1	900	662	4.7	5.5	74	40	17.0	11.0
Co36	762	361	2.0	1.5	76	20	13.0	6.6
Co43	860	784	2.3	2.0	40	32	7.0	6.0
CSC1	902	664	1.7	2.0	70	40	12.0	8.0
CSC2	795	186	1.2	2.3	74	28	9.6	4.0
GR3	794	279	2.3	3.9	82	40	20.6	8.0
IR20	732	323	2.0	2.5	62	30	17.1	8.0
TKM4	774	199	3.0	5.0	72	32	20.0	7.8
TKM9	810	356	2.0	3.8	54	26	21.0	10.6

C : Control ; S : Salinized

to others (Table 34; Fig.60g). There was 51 to 74 per cent reduction in the total protein content over the control in GR3, IR20, TKM9, TKM4, CSC2 and Co36 to saline treatment.

d. Total nitrogen content

All the varieties were found to decrease the total nitrogen level in their grains as a response to salinization (Table 34; Fig.60). Interestingly, in AU1, Co43, and CSC1 the decrease in the total nitrogen was less while in others it was more (Fig.60h). A reduction amounting 49-61 per cent in the total nitrogen content was noticed in Co36, TKM9, IR20, CSC2, GR3 and TKM4 to salinization as compared to their control.

4. Germination studies of grains obtained from saline exposed plants

a. Germination percentage

The performance of the grains harvested from the saline exposed plants indicated reduction in germination amounting 18 to 46 per cent, but reduction in the percentage of germination was less pronounced in AU1, Co43, and CSC1 when compared to their control on all the days of observation. Above 50 per cent but below 60 per cent reduction over the control in the percentage of germination was seen upto three days of germination in Co36, CSC2, TKM4 and TKM9 (Table 35; Fig.61a and b). At tenddays of germination AU1, Co43 and CSC1 had 18 to 20 per cent reduction and TKM9, TKM4, Co36, GR3, IR20 and CSC2 had 33 to 46 per cent reduction in their germination while comparing to their respective controls (Fig.61d).

b. Vegetative growth

Similar to the emergence, the harvested grains from the saline treated crop resulted in a reduced seedling performance in all the varieties. However, the reduction in length of shoots and roots, and fresh weight of shoots and roots never exceeded 55 per cent even in the most susceptible variety to salinity, whereas the reduction in dry matter accumulation of shoots and roots were more, the maximum level being 70 per cent and the minimum being 14 per cent. AU1, Co43 and CSC1 were little affected in their shoot length, fresh and dry weight of shoots when compared to others (Table 36; Fig.61e, f and g). High decrease in shoot length by 29 to 49 per cent in TKM9, TKM4, Co36 and CSC2 was noticed by salinization and 45 to 52 per cent decrease in fresh weight of shoot was recorded in CSC2, GR3, IR20 and Co36 (Fig.61f). Dry weight of shoot was reduced by 59 to 70 per cent in Co36, TKM9, IR20, GR3, TKM4 and CSC2 as compared to their controls (Fig.61g).

Table 35 : Germination performance in the harvested seeds of rice varieties exposed to NaCl stress condition.

Variety	Percentage of germination							
	Days							
	2		3		4		10	
	C	S	C	S	C	S	C	S
AU1	54	46	77	59	86	69	91	75
Co36	69	31	80	37	85	45	91	59
Co43	58	41	75	55	85	68	94	75
CSC1	69	49	81	60	89	65	93	74
CSC2	64	27	77	32	88	38	91	49
GR3	67	40	81	44	83	52	94	59
IR20	64	33	76	49	84	45	90	55
TKM4	63	29	78	35	83	38	92	60
TKM9	52	23	74	36	87	47	95	64
L.S.D. 1%	10.9		13.8		16.5		11.3	

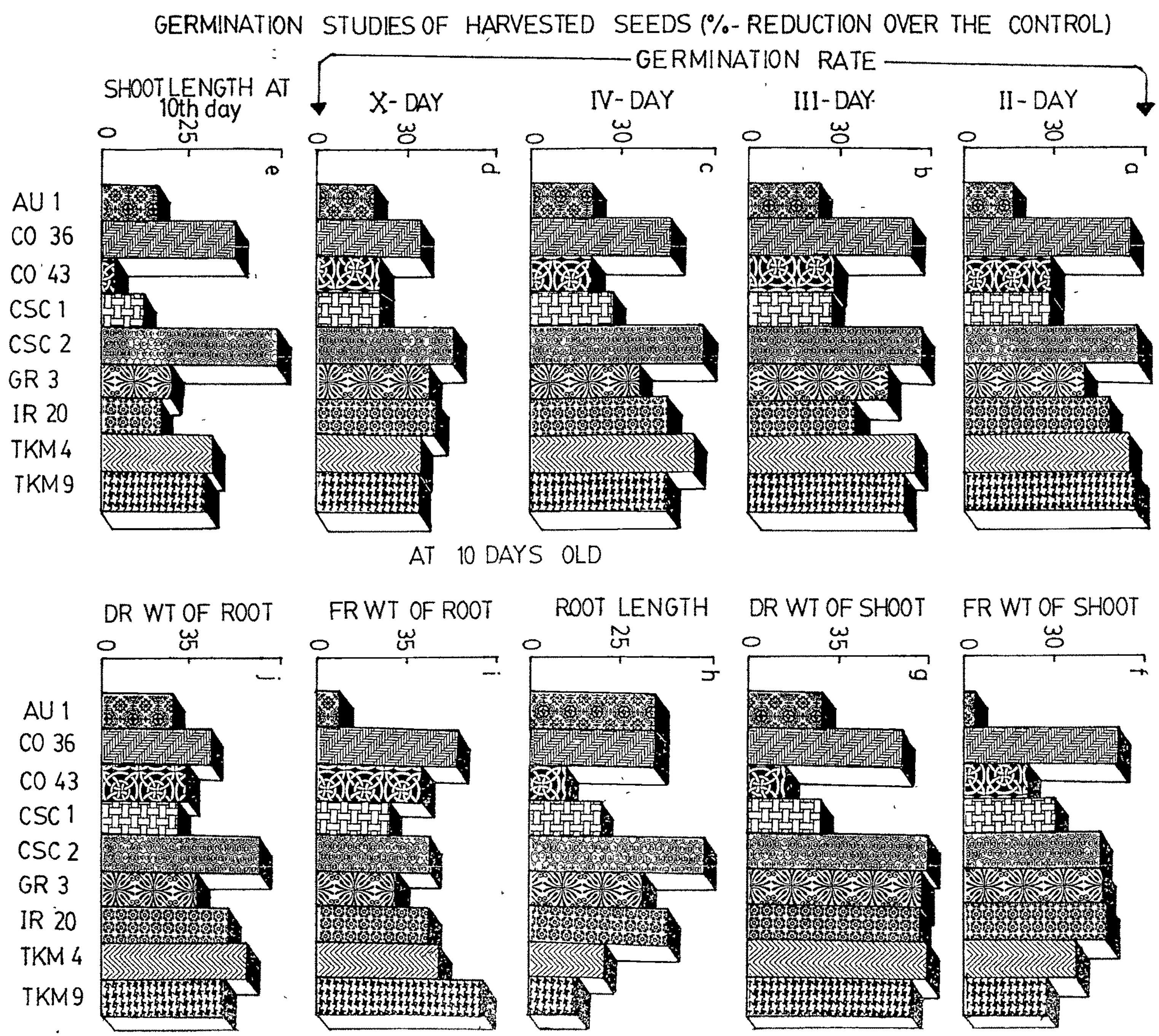
C : Control ; S : Salinized

Table 36 : Vegetative growth of harvested seeds (tenth day after germination) of rice varieties grown under NaCl saline condition.

Variety	Shoot length (cm)		Fresh weight of shoot (mg/ 5 seedlings)		Dry weight of shoot (mg/ 5 seedlings)		Root length (cm)		Fresh weight of root (mg/ 5 seedlings)		Dry weight of root (mg/ 5 seedlings)	
	C	S	C	S	C	S	C	S	C	S	C	S
AU1	7.5	6.3	114	113	25.4	18.2	9.3	6.1	84	76	18.8	13.6
Co36	8.2	5.1	210	101	28.0	11.4	11.0	7.2	97	45	19.8	8.6
Co43	8.2	8.5	230	182	22.2	19.0	13.6	12.3	98	58	16.4	10.8
CSC1	8.4	7.4	196	138	27.0	19.4	13.0	10.4	96	66	19.6	13.6
CSC2	7.4	3.8	176	97	28.0	8.4	14.2	7.4	93	53	19.8	7.8
GR3	7.9	6.3	169	92	31.0	10.2	13.8	9.5	70	48	20.6	12.8
IR20	5.8	4.8	181	94	29.0	9.8	9.5	5.9	97	54	18.2	9.0
TKM4	8.8	6.1	184	116	29.0	9.0	15.2	12.2	87	46	19.6	8.2
TKM9	9.4	6.7	172	123	32.0	11.8	11.1	9.7	77	49	20.8	10.6
L.S.D. 1%	1.49		14.61		6.33		1.91		9.93		2.30	

C : Control; S : Salinized

Fig.61a-j. Germination percentage and vegetative growth of harvested seeds of rice varieties exposed to sodium chloride salinity. Results are expressed as percentage of decrease over the control.


GERMINATION STUDIES OF HARVESTED SEEDS (%- REDUCTION OVER THE CONTROL)
GERMINATION RATE
SHOOT LENGTH AT 10th day
X- DAY
IV- DAY
III- DAY
II - DAY
a
b
c
d
e
AT 10 DAYS OLD
DR WT OF ROOT
FR WT OF ROOT
ROOT LENGTH
DR WT OF SHOOT
FR WT OF SHOOT
f
g
h
i
j
0
25
30
35
AU 1
CO 36
CO 43
CSC 1
CSC 2
GR 3
IR 20
TKM 4
TKM 9

There was no marked varietal differences in the reduction of root length in AU1, Co36, GR3 and IR20 when compared to their control. Co43 and TKM9 were similarly less affected in their root length when compared to others (Table 36; Fig.61h). The reduction in the fresh weight of AU1 was not considerable while Co43, CSC2, IR20, TKM4, Co36 and TKM9 resulted in 43 to 64 per cent reduction (Fig.61i). 43 to 61 per cent depression in the dry matter accumulation of root has been evident in Co36, TKM9, IR20, TKM4 and CSC2 as compared to their control (Table 36; Fig.61j). Varieties AU1, Co43 and CSC1 were more resistant in terms of dry matter accumulation of root than the other varieties by showing 28 to 34 per cent reduction as compared to their control (Fig.61j).