3. RESULTS

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3.1 REMOTE SENSING STUDIES

3.1.1 Visual Interpretation

3.1.1.1 Selection of the Season and Suitable Data Products for the Study

For a successful delineation of saline soils, the correct choice of season is very essential. So, the pre and post-monsoon cloud free data were compared and the composite map prepared from Landsat 4 MSS FCC of the post-monsoon (November 1982) and pre-monsoon (March, 1983), exhibited the superiority of summer data in saline soil detection over that of winter (Fig. 6). The winter image indicated very less area under the different saline categories viz., the slightly saline affected, moderately saline affected and strongly saline affected (referred also as low, moderate and severe respectively in all the figures) (Table 5). The main interference was from the increase in vegetational cover after the monsoon. The photograph taken by Indian cosmonaut from the Kate-140 camera on Salyut-7 on quantification showed 4,3 and 2.4 fold increase in slightly, moderately and strongly affected saline soils respectively as compared to Landsat MSS data (Fig. 7) (Table 6). Though the Kate-140 data was suitable for saline delineation, it was not a correct choice in soil degradational studies, due to its non-repetitive nature.

3.1.1.2 Assessment of Saline Soil

i. Taluka Level Studies

The temporal study since 1975 indicated a steady increase in saline spread (Figs. 8-12, Table 7). Delineation of

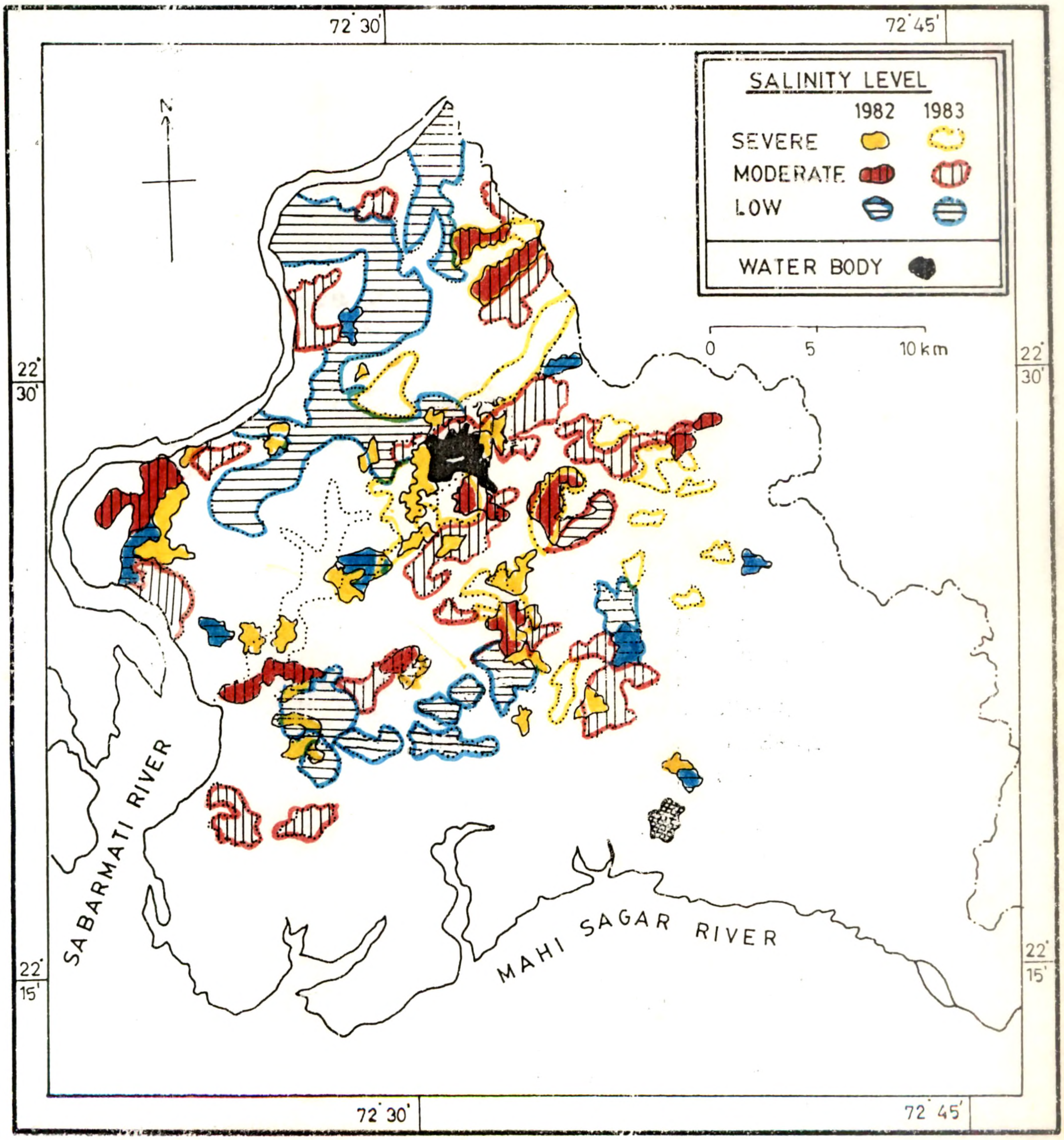

FIG.6. COMPOSITE MAP SHOWING SUPERIORITY OF SUMMER [MARCH 1983 MSS FCC] DATA OVER WINTER [NOV. 1982 MSS FCC] DATA.

Table 5. Area (ha) of saline affected soils computed from Landsat MSS FCC of winter 1982 and summer 1983.

Date of study	Saline levels			Total
	Slightly saline	Moderately saline	Strongly saline	
Winter 1982	3,726	2,467	3,160	9,353
Summer 1983	11,119	9,840	4,394	25,353

Table 6. Area (ha) of salinity computed from Landsat 4 MSS 1983 and Kate-140, 1984.

Date of study	Saline levels			Total
	Slightly saline	Moderately saline	Strongly saline	
MSS 1983	4,119	9,840	4,394	25,353
Kate-140 1984	14,773	17,934	1,773	34,680

Table 7. Area (ha) of degraded soils computed from Landsat-2 B/W 1977, TM FCC 1986, and TM FCC 1987

Date of study	Saline levels			Total
	Slightly saline	Moderately saline	Strongly saline	
1975	2,826	3,083	1,799	7,708
1977	6,346	5,036	2,133	13,515
1983	11,119	9,840	4,394	25,353
1986	13,643	10,174	4,034	27,851
1987	14,182	15,729	7,348	37,254

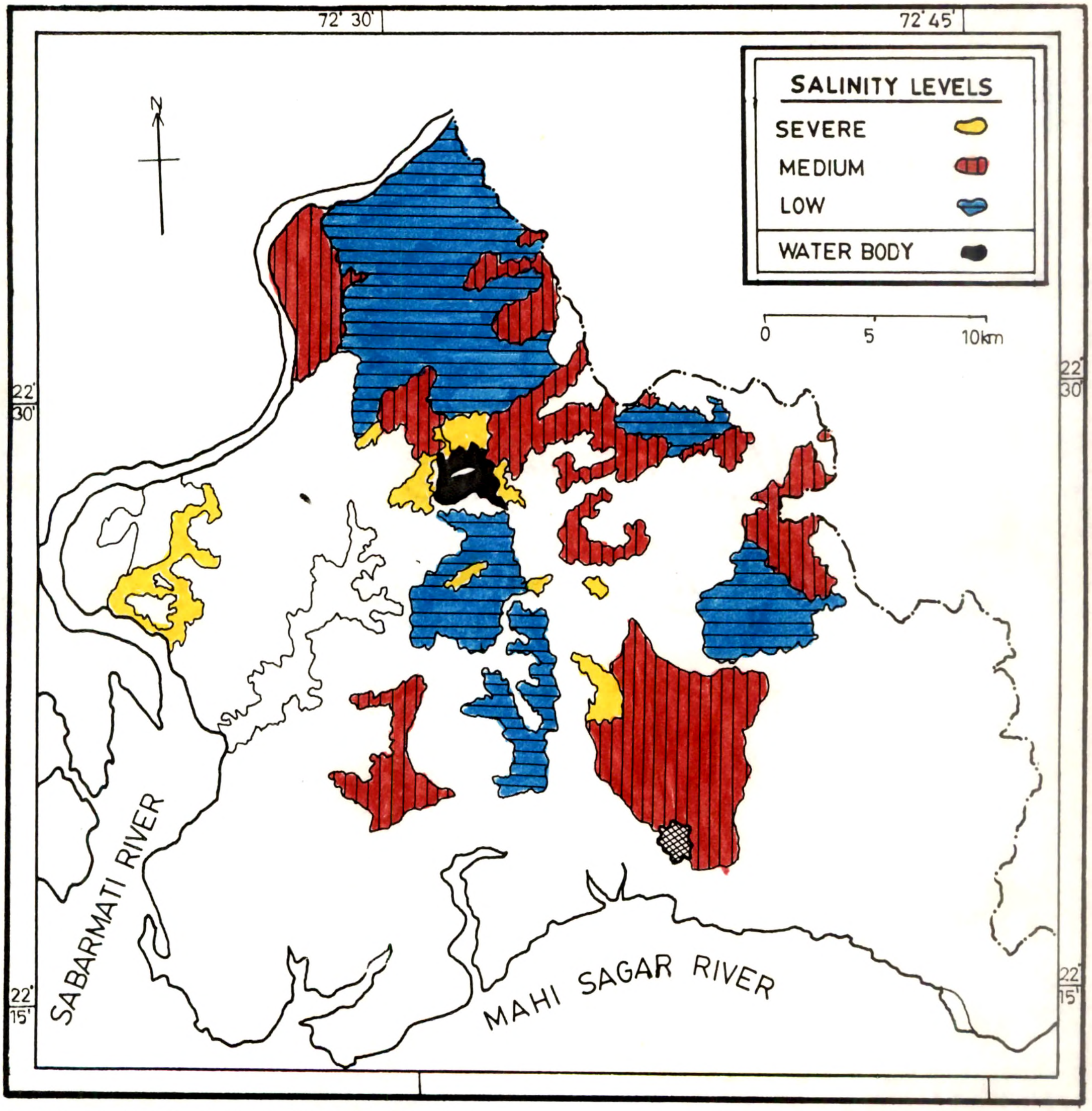

FIG. 7. DELINEATION OF SALINE LAND USING APRIL 1984 KATE 140 DATA

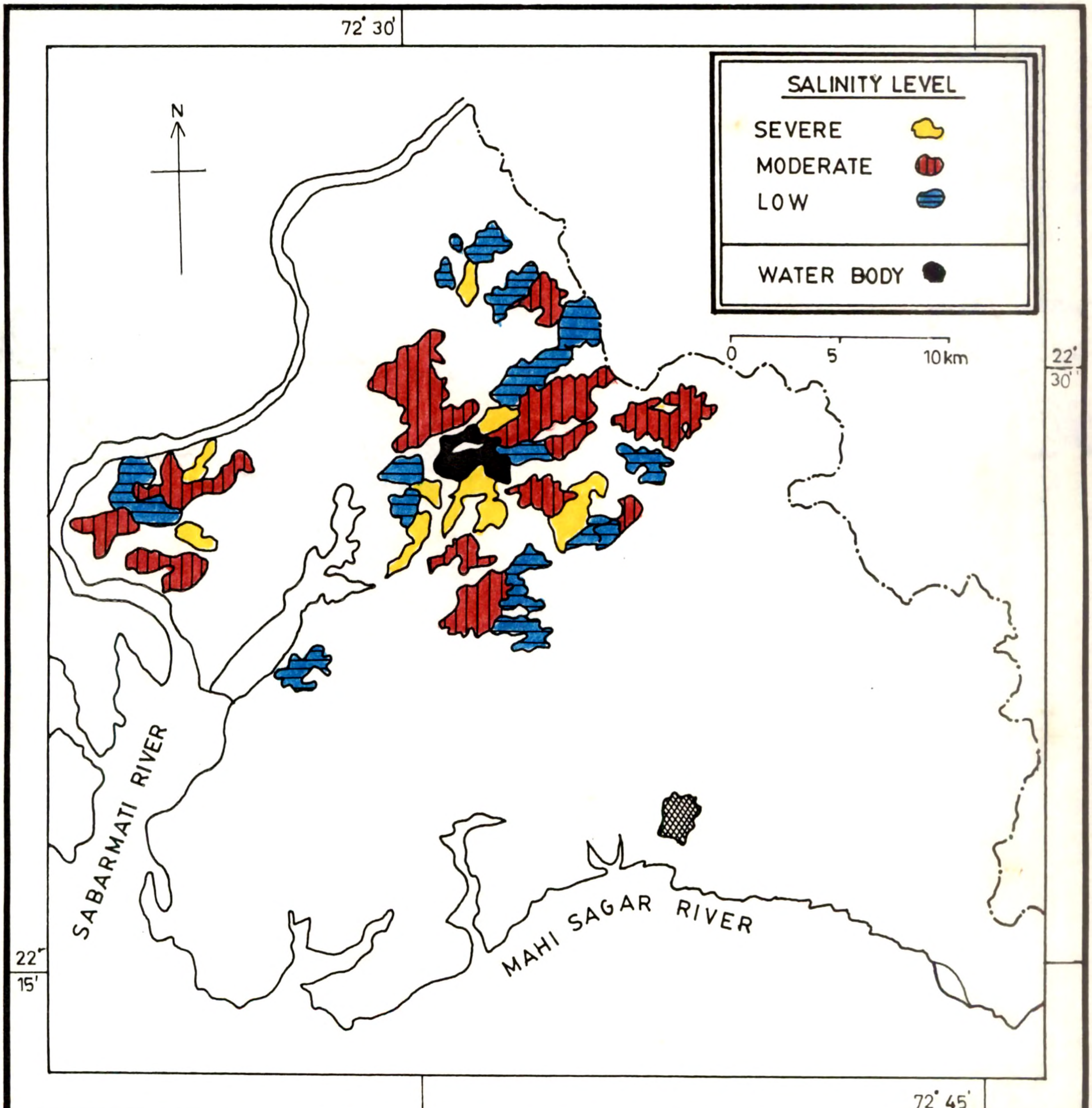

FIG. 8. DELINEATION OF SALT AFFECTED LAND FROM LANDSAT MSS 1977.

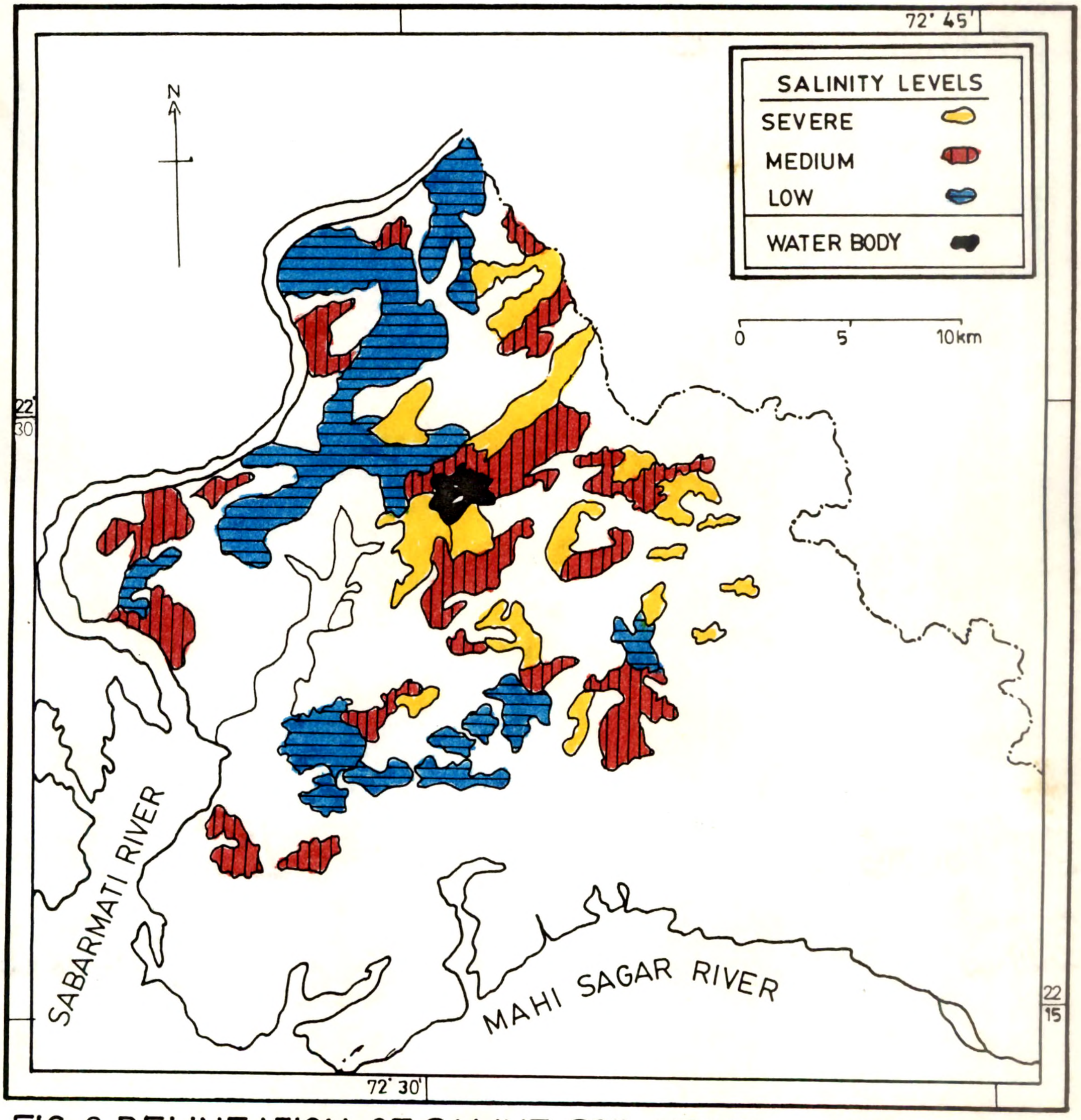

FIG. 9. DELINEATION OF SALINE SOIL USING LANDSAT MSS FCC 1983.

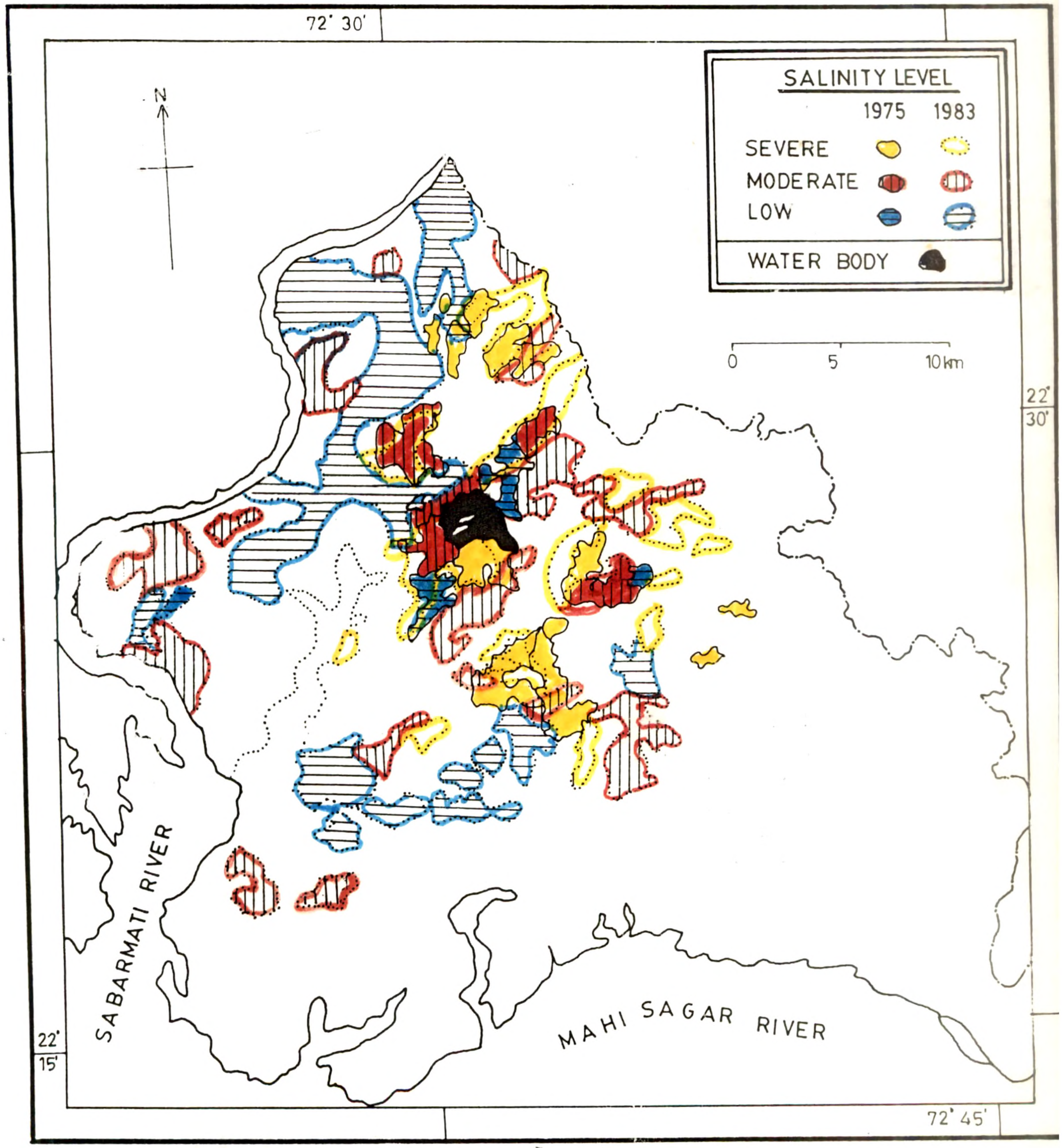

FIG.10. COMPOSITE MAP INDICATING INCREASE IN SOIL SALINITY FROM 1975 TO 1983.

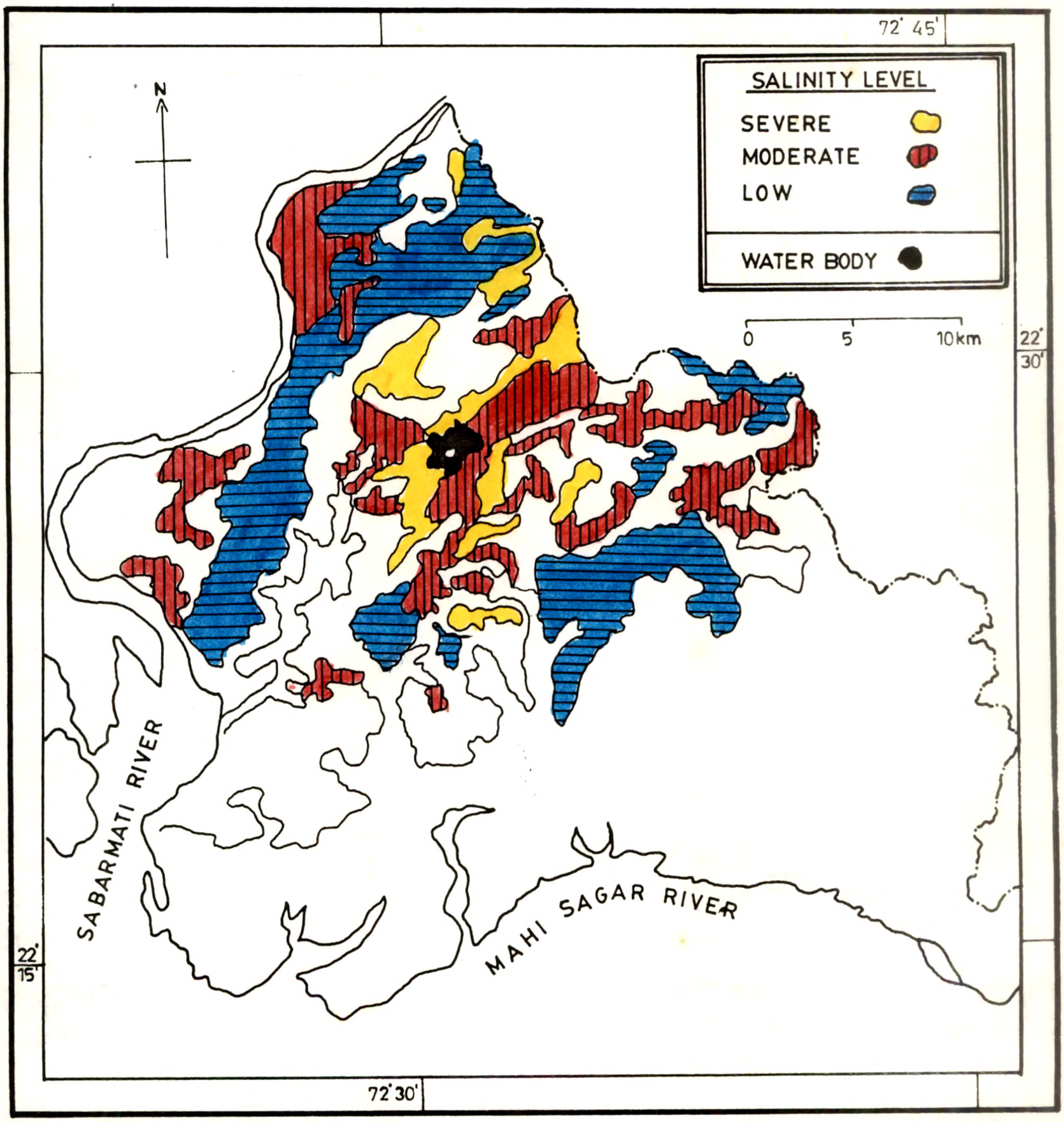

FIG. 11. DELINEATION OF SALT AFFECTED LAND FROM LANDSAT TM FCC 1986.

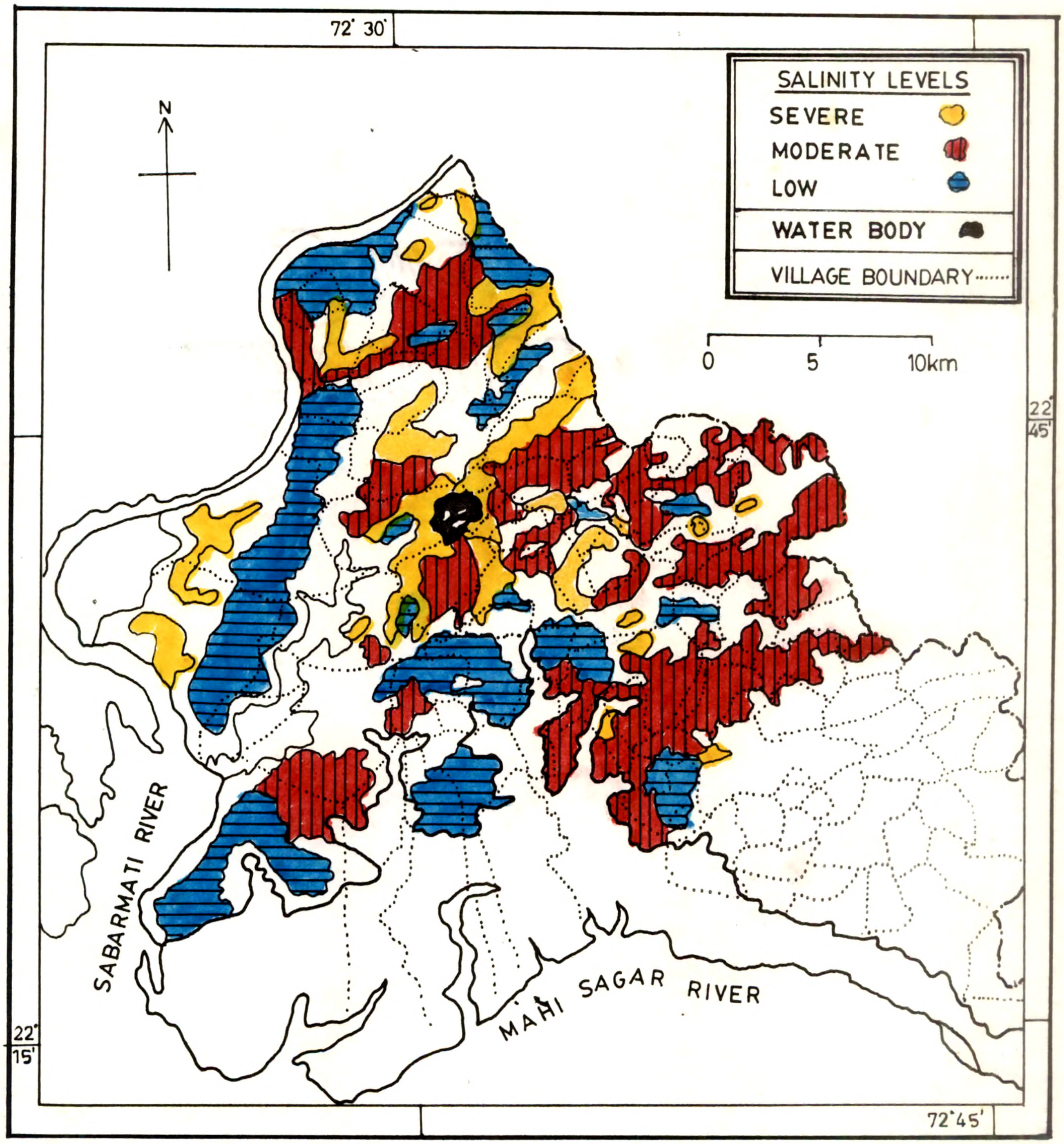

FIG.12. DELINEATION OF SALT AFFECTED LANDS FROM LANDSAT TM FCC 1987.

saline soils using Landsat 2 MSS B/W transparencies of band 5 and 7 clearly indicated a total area of 7,7Ø8 ha, to be affected by salinity in the year 1975 (Table 7). Categorisation of 3 distinct saline classes was possible with the overlapping of band 5 and 7 (Fig. 8). The salt-affected soils were found to be considerably increased from 1975 to 1977 (Table 7) and mostly were identified around the irrigation sources. A further increase was noted in all the three categories by 1983 (Figs. 9 to 11). The composite map obtained by overlapping 1975 with 1983 data exhibited an increase of 329 % during a span of eight years (Fig. 1Ø). The strongly affected land showed an increase of 2.4 fold, moderately affected soil increased by 3.2 and slightly affected saline soil increased by 3.9 fold. With the evolution of thematic technology the delineation of saline affected patches became more precise. The saline affected soils of 1986 and 1987 were generated from Landsat 5 TM FCC (Figs. 11 and 12). Seventy five villages have been identified to be affected to varying degrees either due to sea-ingress or excessive irrigation. Twelve villages viz., Akhol, Daheda, Lunej, Malasoni, Mitali, Pandad, Rahoni, Rel, Tamsa, Navagambara, Vadgam, and Vainaj were affected by sea-ingress, while the other remaining 63 villages were degraded due to excess irrigation and improper drainage. The increase in saline land around Kanewal tank from 1975-87 was evidenced by the appearance of saline efforescence. Also a change in the area of Kanewal tank because of change in water level was observed (Fig. 13).

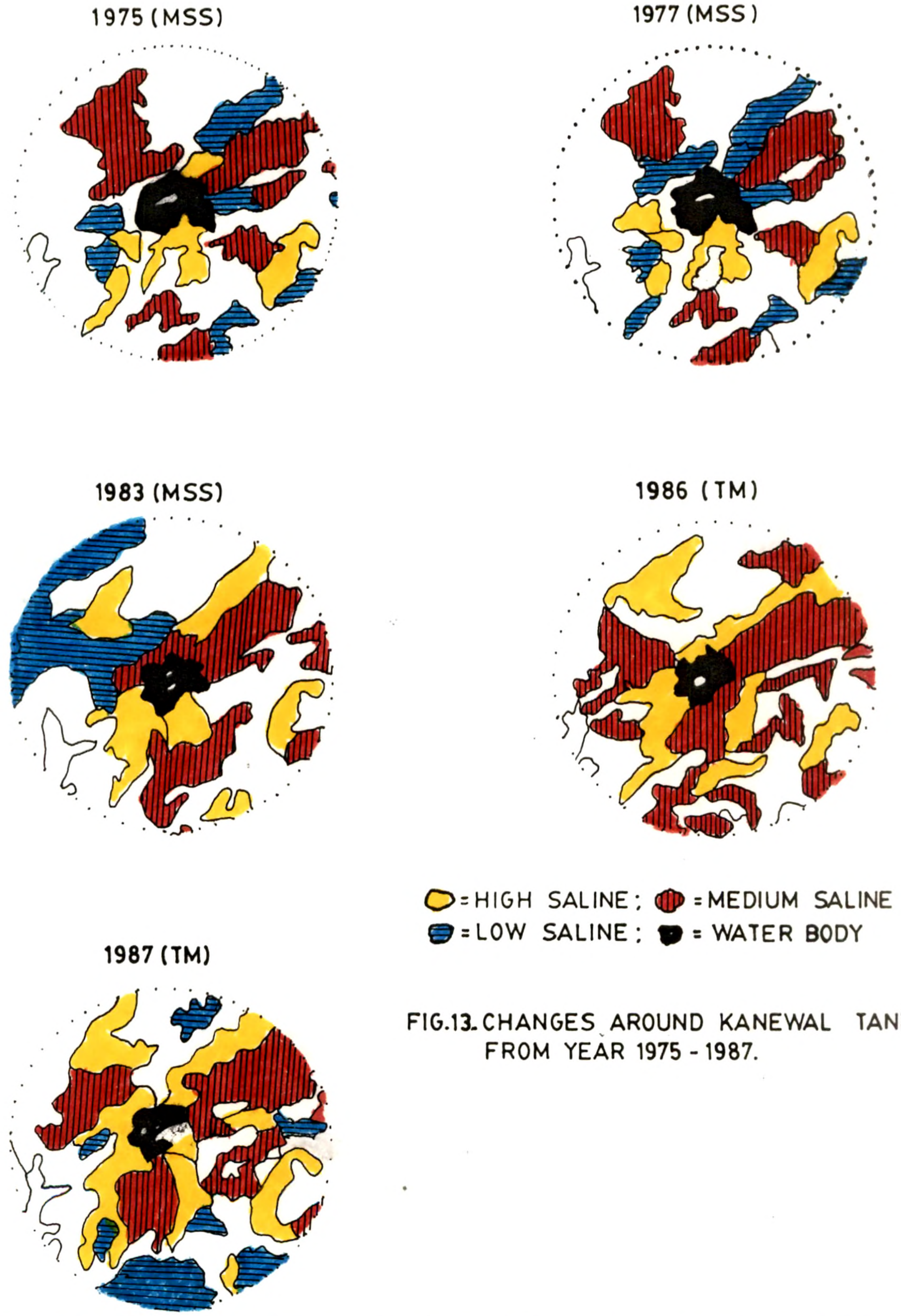

FIG.13. CHANGES AROUND KANEWAL TANK FROM YEAR 1975 - 1987.

ii. Microlevel Studies

The enlargement of 1:1 million scale image from Landsat TM FCC March 1986 to 1:50,000 scale gave the detailed and accurate information of salinity distribution at village level as compared to the MSS data (Fig. 14). The saline patches of different degree which appeared to be as single patch of one class in four fold expansion were seggregated clearly when 1:1 million positive transparency was expanded 20 times to 1:50,000 scale (Figs. 15a to c). Making use of this precise information twenty six villages were surveyed for ground truth study. The area under different saline levels in each village was computed from the map (Table 8). In villages like Untwada, Mahiyari, Chikhaliya, Gorad, Malpur and Khanpur more than 50 % of Agricultural lands were damaged by salinity. Villages like Amaliyara, Valli and Padra showed more of strongly affected area when compared to Changda, Jafrabad, Khanpur, Mahiyari, Tarapur, Tol, Vanktalav and Vaghatalav, where moderately saline lands were high. In the rest of the affected villages the slightly saline affected soil was found to be the maximum. The summary of commission and omission errors calculated from visual interpretation of Landsat TM data indicated 98 % accuracy at 90 % confidence level (Table 9).

The information derived from 1:50,000 scale were transferred on the cadastral map of the villages to generate saline delineation on the plot-wise basis. Five villages namely, Jafrabad, Jichka, Khaksar, Padra and Valli were selected for this study (Figs. 16-20). In the village Jafrabad of the affected 80 plots 41 were strongly affected, 16 were moderately and 23 were

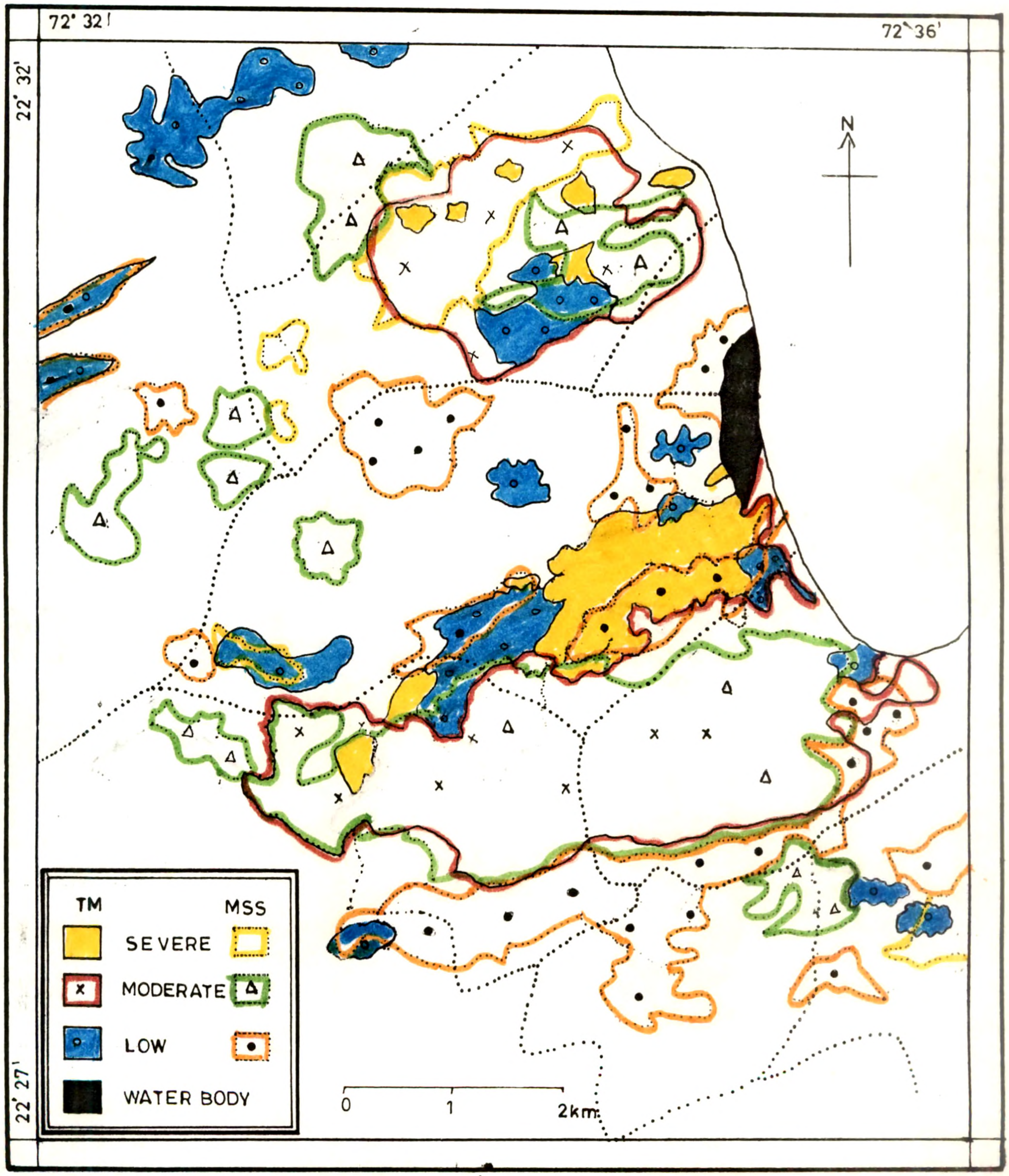

FIG. 14. COMPARISON OF MSS DATA OVER TM DATA AT 1:50,000 SCALE.

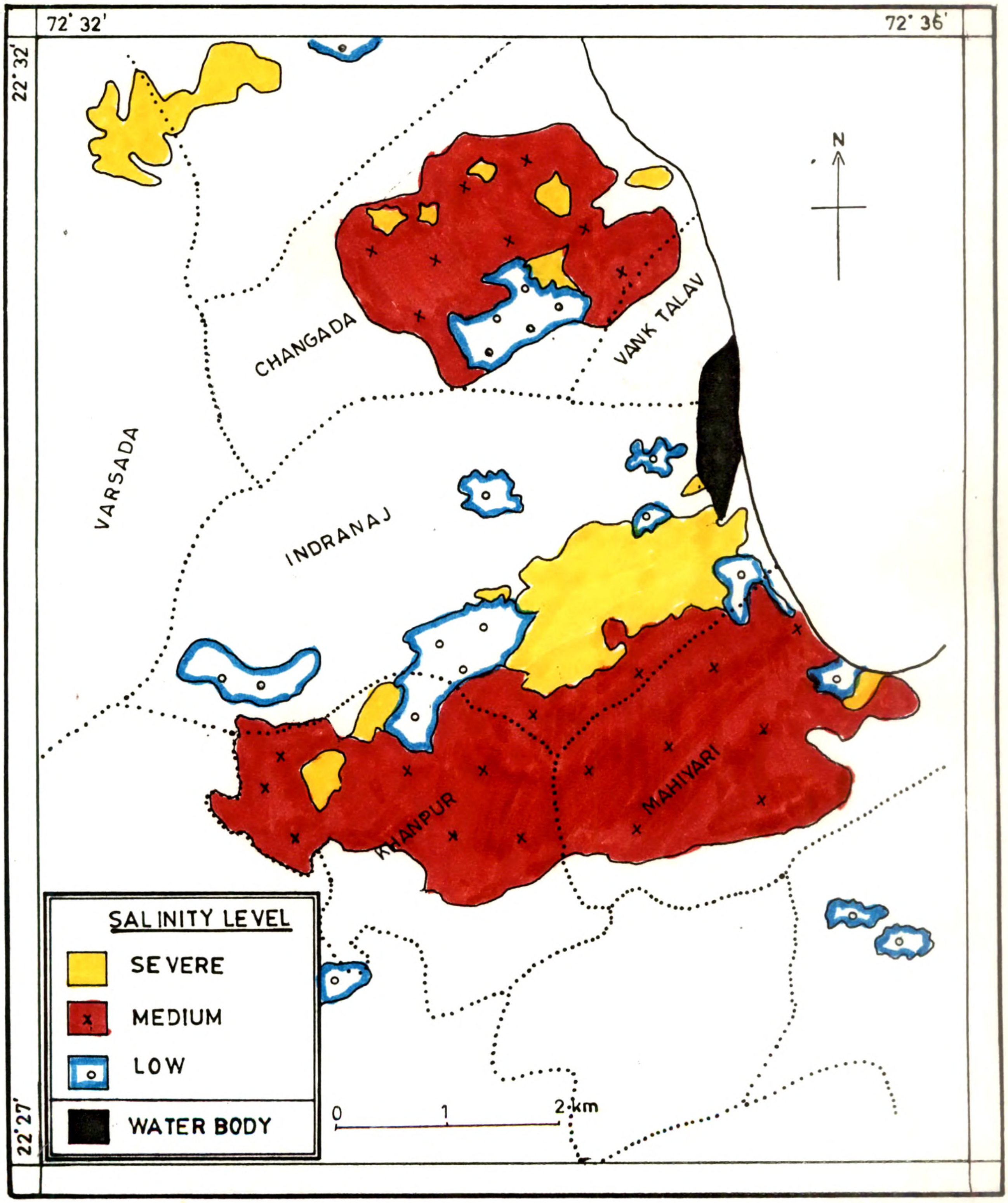

FIG.15a. DETECTION OF SOIL SALINITY AT VILLAGE LEVEL IN KHAMBHAT TALUKA USING TM FCC OF MARCH 1986.

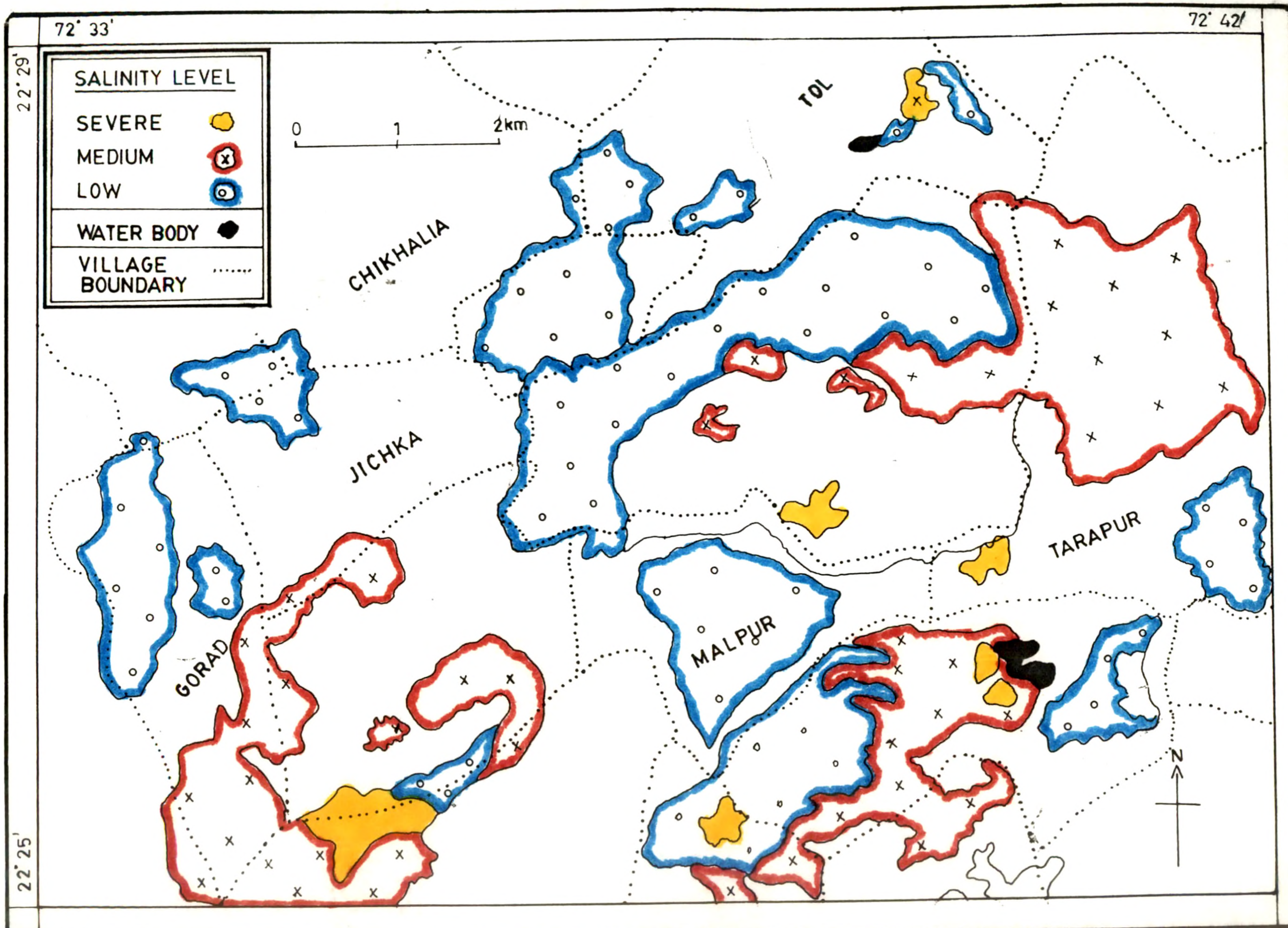

FIG. 15b. DETECTION OF SOIL SALINITY AT VILLAGE LEVEL IN KHAMBHAT TALUKA USING TM FCC OF MARCH 1986.

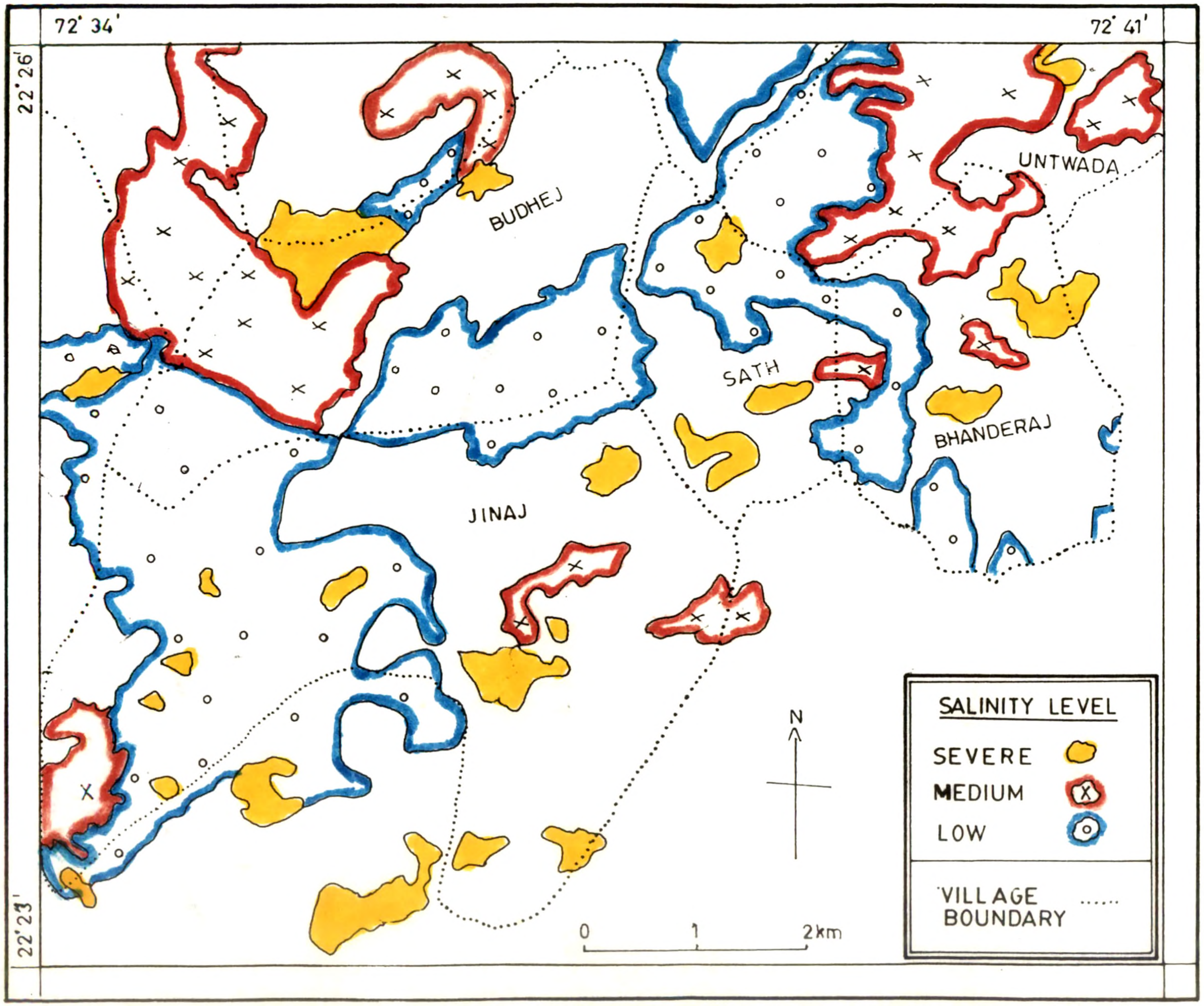

FIG. 15c. DETECTION OF SOIL SALINITY AT VILLAGE LEVEL USING TM FCC OF MARCH 1986 IN KHAMBHAT TALUKA.

Table 8. **Quantification of saline areas (ha) on village basis in Khambhat taluka using Landsat TM, March, 1986 at 1:50,000 scale**

Sr. No.	Location code	Village	Total area	Saline levels				Percentage of affected area
				Slightly Saline	Moderately Saline	Strongly Saline	Total affected area	
1.	31	Adruj	253	119	-	-	119	47
2.	33	Amaliara	535	22	5	208	235	44
3.	46	Bhanderaj	680	163	82	46	291	43
4.	41	Budhej	1174	235	187	49	471	40
5.	14	Changada	1080	68	834	33	435	41
6.	25	Chikhalia	256	157	-	-	157	61
7.	34	Gorad	570	183	161	-	344	60
8.	16	Indranaj	1326	103	14	38	155	12
9.	28	Isarwada	635	57	-	-	57	9
10.	40	Jafrabad	388	20	81	9	110	28
11.	24	Jichka	403	41	26	-	67	17
12.	48	Jinaj	1691	621	74	66	761	45
13.	36	Khaksar	1124	97	328	178	603	54
14.	23	Khanpur	596	-	303	-	303	51
15.	26	Mahiyari	791	-	479	-	479	61

Sr. No.	Location code	Village	Total area	Saline levels				Percentage of affected area
				Slightly Saline	Moderately Saline	Strongly Saline	Total affected area	
16.	32	Malpur	272	141	-	-	141	52
17.	30	Moraj	1434	487	123	-	610	43
18.	35	Padra	1070	81	109	183	373	34.8
19.	42	Sath	561	130	38	14	182	32.4
20.	29	Tarapur	2227	86	439	-	527	24
21.	27	Tol	184	-	84	-	84	45.6
22.	43	Untwada	561	227	187	-	414	73.8
23.	18	Vaghatalav	460	-	71	-	71	15.4
24.	15	Vanktalav	921	-	41	-	41	4.5
25.	17	Varsada	3150	603	211	187	1001	32
26.	20	Valli	1981	64	346	634	1044	53

- = absent.

Table 9. Summary of commission and omission errors for visual interpretation of Landsat TM data

Category	Omission errors		Commission errors		Correct	
	Total	Per cent	Total	Per cent	Total	Per cent
Normal	3	6.8	3	7	41	93
Slightly saline	3	6.8	2	5	42	95
Moderately saline	Ø	Ø	Ø	Ø	44	1ØØ
Strongly saline	Ø	Ø	1	2	43	98

Accuracy 98 % at 9Ø % confidence level.

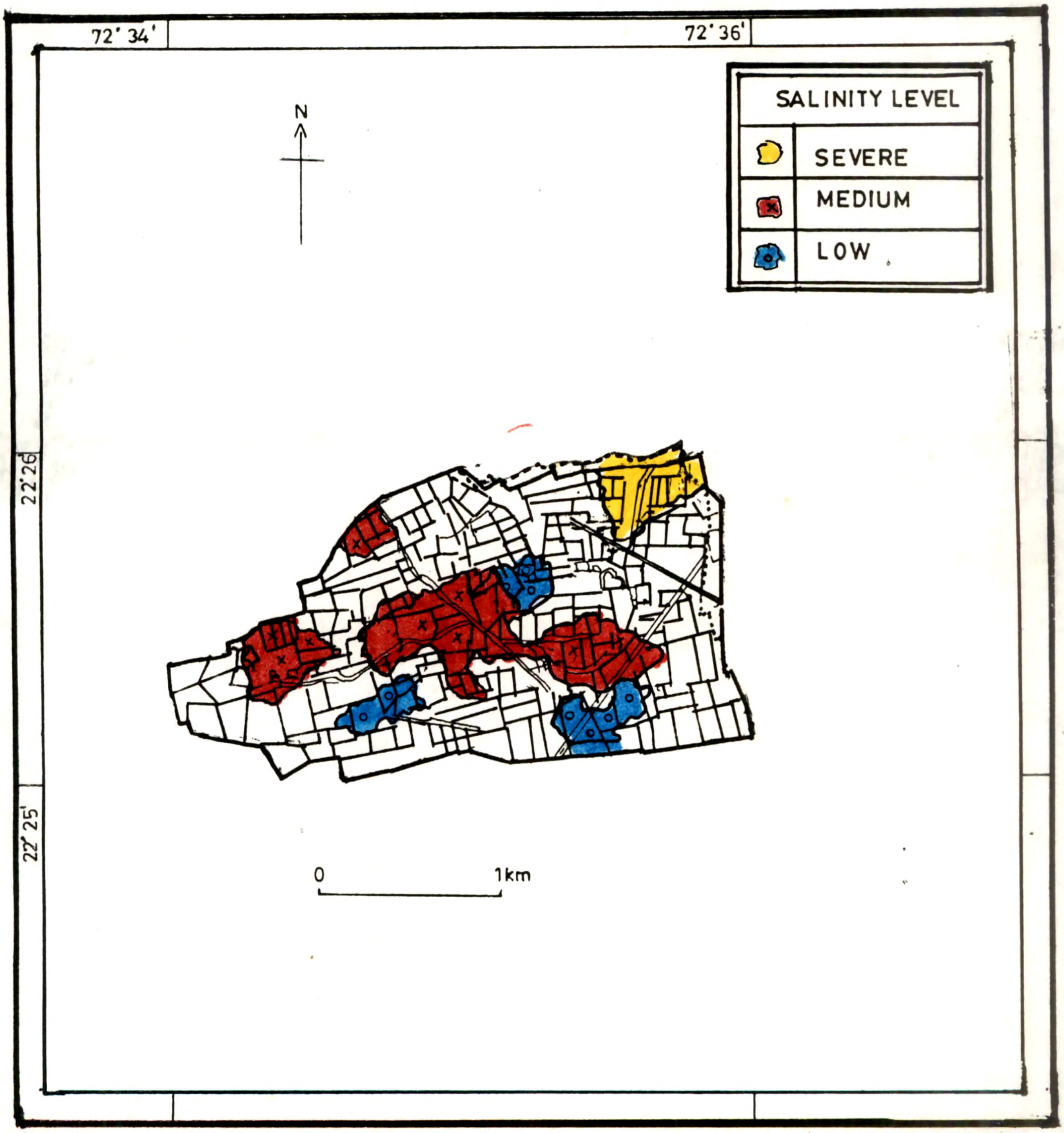

FIG.16. PLOT WISE MAP OF JAFRABAD VILLAGE SHOWING DISTRIBUTION OF DIFFERENT LEVELS OF SALINITY FROM TM FCC MARCH 1987.

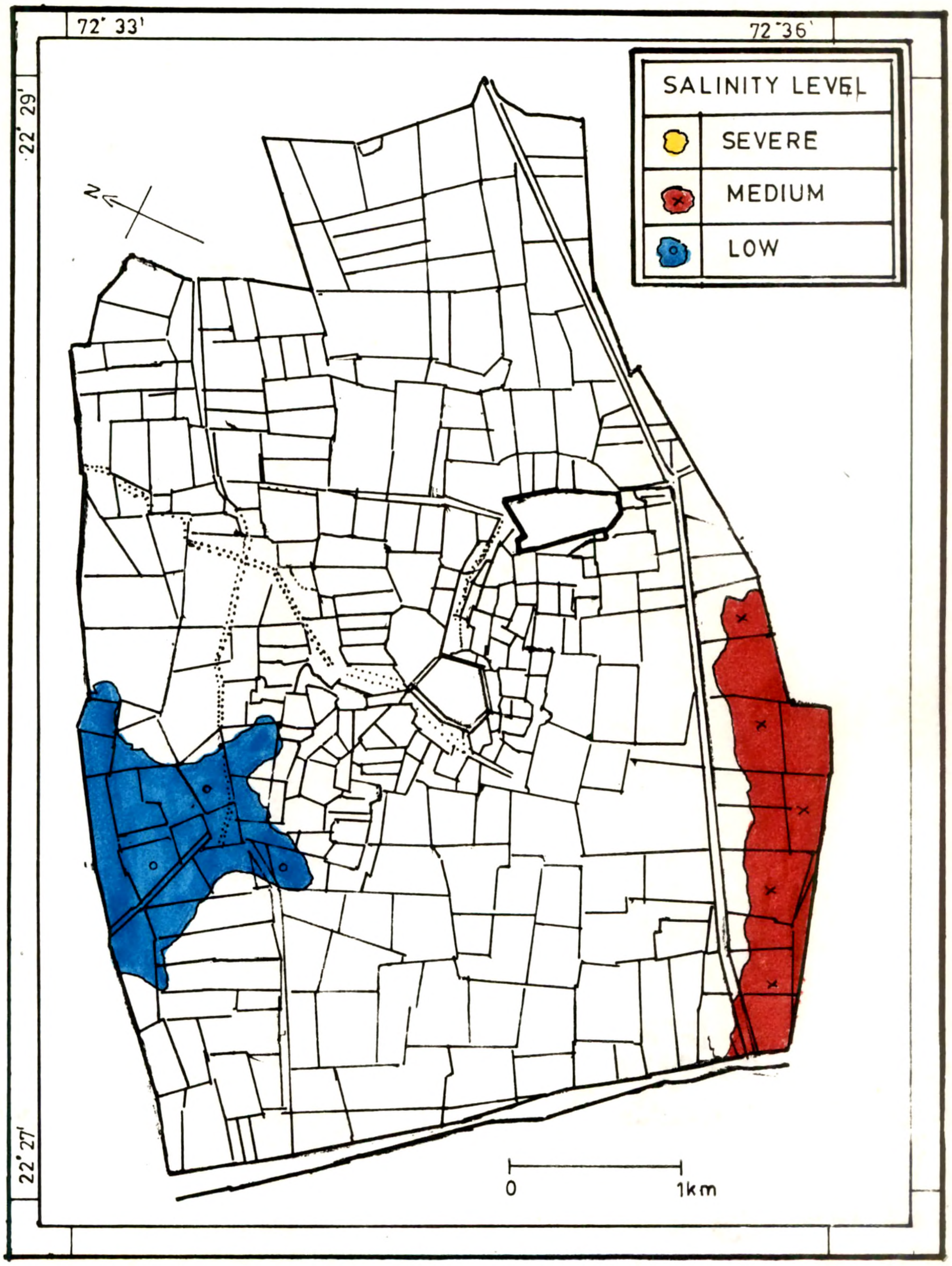

FIG.17. PLOT WISE MAP OF JICHKA VILLAGE SHOWING DISTRIBUTION OF DIFFERENT LEVELS OF SALINITY FROM TM FCC MARCH 1987

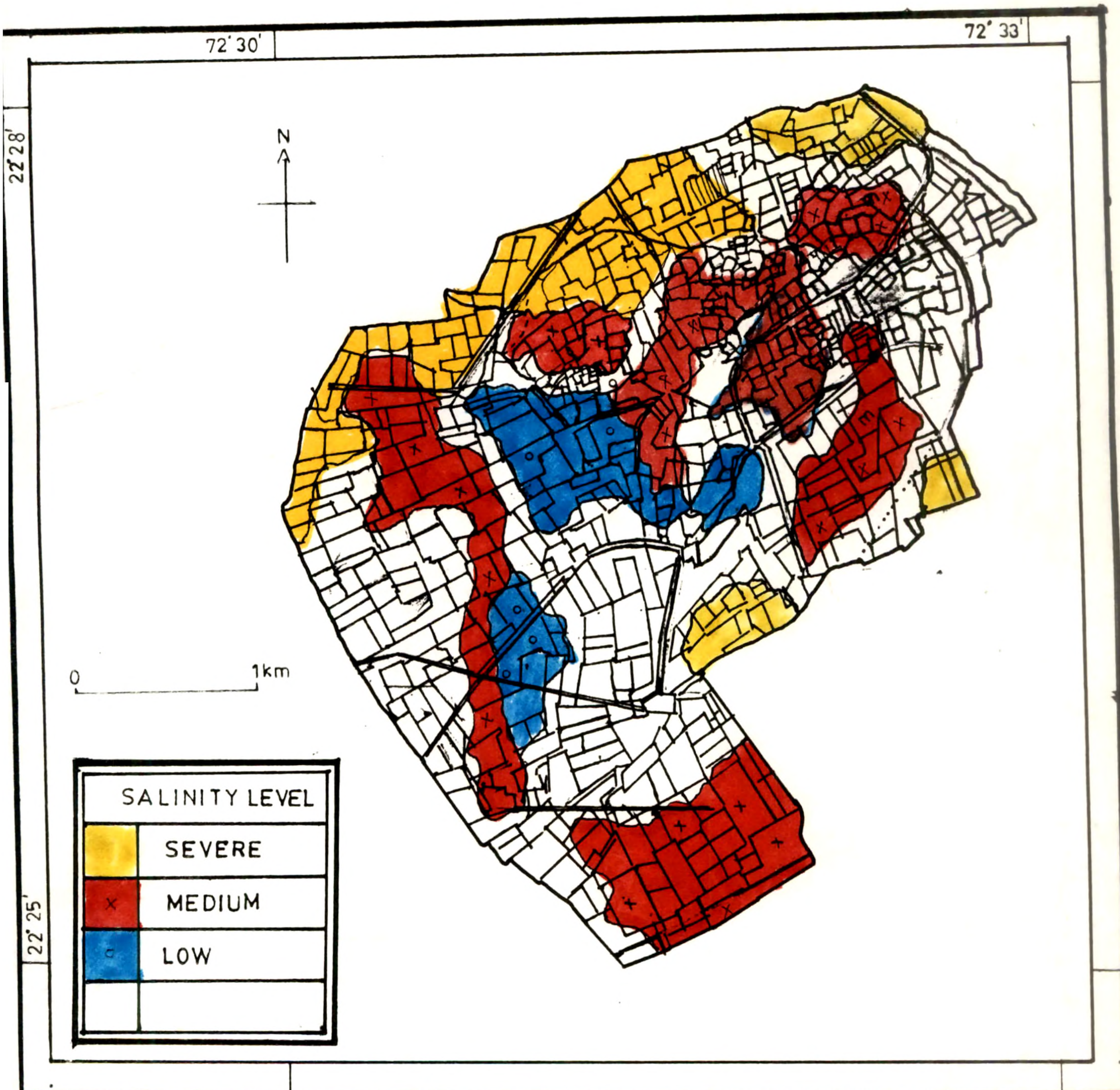

FIG.18. PLOTWISE MAP OF KHAKSAR VILLAGE SHOWING DISTRIBUTION OF DIFFERENT LEVELS OF SALINITY FROM TM FCC MARCH 1987.

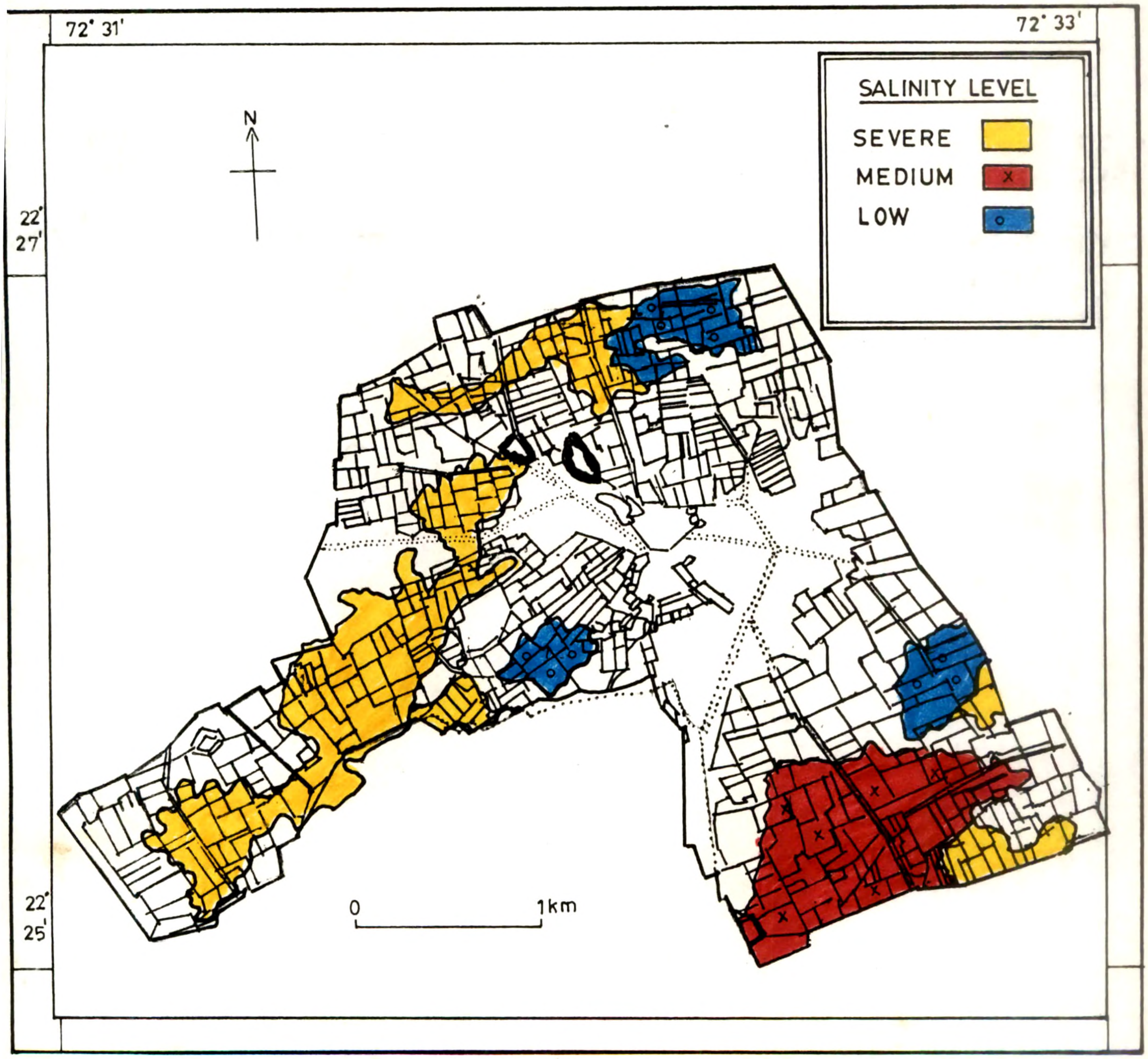

FIG. 19. CADASTRAL MAP OF PADRA VILLAGE SHOWING DISTRIBUTION OF DIFFERENT LEVELS OF SALINITY FROM TM FCC MARCH 1986.

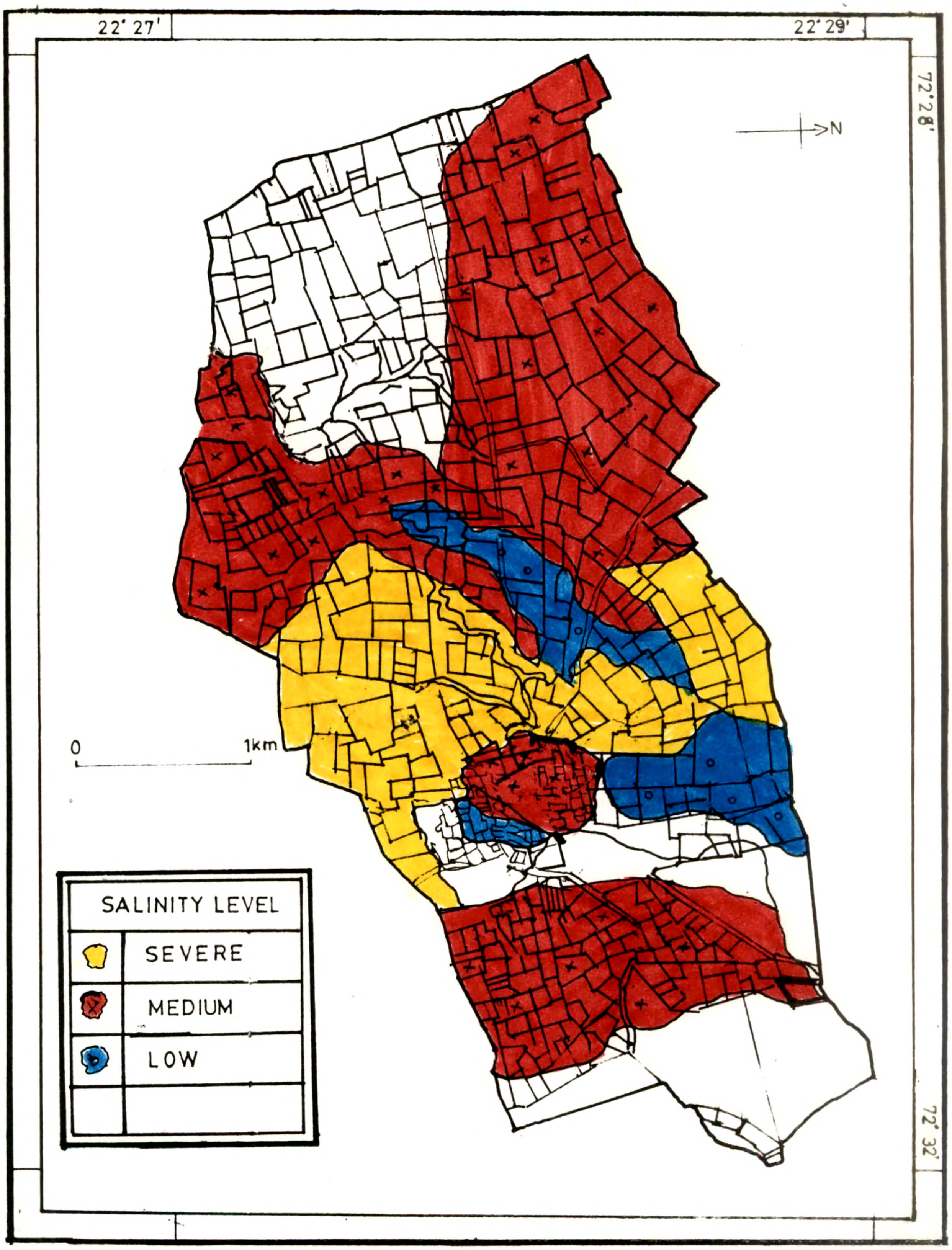

FIG.20. PLOT WISE MAP OF VALLI VILLAGE SHOWING DISTRIBUTION OF DIFFERENT LEVELS OF SALINITY FROM TM FCC MARCH 1987.

slightly affected. The survey numbers of different plots have been given in Table 10. The interpretation accuracy was 90 % at 90 % confidence level (Table 11). In the village Jichka out of total 308 plots, 12 were moderately affected and 26 were slightly affected. 7 plots of the normal soils were committed to various degrees of saline affected land (Table 12). The mapping was found to be 100 % accurate at 90 % confidence level (Table 13). Khaksar was a medium size village having a total area of 1124 ha. It had a total number of 816 plots. Fifty four per cent of its agricultural plots were affected by salinity. The maximum of 223 plots were affected by moderate salinity and 121 by severe salinity, and 63 were designated as low saline and 45 plots of normal soils were misinterpreted as saline affected (Table 14). The accuracy estimation revealed 90 % accuracy at 90 % confidence level (Table 15). Padra having a total area of 1070 ha and 749 agricultural plots, exhibited 90 plots to be strongly saline, 60 moderately saline and 44 slightly saline (Table 16). In this village 34 plots of normal soil were committed to moderately saline soil. The accuracy tested was 90 % at 90 % confidence level (Table 17). The distribution of salinity in the village Valli having a total area of 1981 ha and 760 plots indicated a large number of plots, about 424 under moderately saline soil, 92 under strongly saline soil, and 64 under slightly saline (Table 18). Interpretation of this village indicated 11 plots of strongly saline soil to be committed to moderately saline soil and 14 plots of moderately saline class were committed to strongly saline category. Likewise the mixing up of slightly

Table 10. Survey numbers of plots of Jafrabad village affected by different levels of salinity as mapped from Landsat 5 TM (FCC) March 1986

Slightly saline	Saline levels	
	Moderately saline	Strongly saline
6-10, 40-42, 44,	1,3,4,45,46,48,93,	13-34,107-118,
48,51,53,58,137,	99,100,101,103,104,	36-38,81,84,87.
138,139,141,146,	145,181,182,184,	
148,167,168,206,	186-192,200,204,	
207,212,213.	205,214,215,217.	

Total number of plots = 264

Total misinterpretation = 16

Table 11. Summary of commission and omission errors for the data on Jafrabad

	Omission errors		Commission errors		Correct	
	Total	Per cent	Total	Per cent	Total	Per cent
Normal	00	00	13	7.2	168	92.8
Slightly saline	3.0	12	0	0	23	100
Moderately saline	13	45	0	0	16	100
Strongly saline	00	00	3.0	6.8	41	93.2

90 % accurate at 90 % confidence level.

Table 12. Survey numbers of plot of Jichka village as identified from Landsat 5 TM (FCC) March 1986 under different saline lands

Saline levels	
Slightly saline	Moderately saline
150-155, 170-180	1-3,100,256-259,
166-167, 240-246	295,297

Total number of plots = 308

Total number of plots misinterpreted = 7

Table 13. Summary of commission and omission errors of the data on Jichka village

	Omission errors		Commission errors		Correct	
	Total	Per cent	Total	Per cent	Total	Per cent
Normal	0.0	0.0	7.0	3.0	253	93
Slightly saline affected	5.0	16.0	0.0	0.0	26	100
Moderately saline affected	2.0	14.0	0.0	0.0	12	100

100 % accuracy at 90 % confidence level.

Table 14. Survey numbers of plots of Khaksar village as identified from Landsat 5 TM (FCC) March 1986 under different saline lands

Saline levels		
Slightly saline	Moderately saline	Strongly saline
26Ø, 262, 263	8-6Ø, 8Ø-1Ø3,	1Ø5-117, 12Ø-127
268, 275-277,	153-155, 157, 17Ø-	131, 137-149,
323-328, 331-	199, 236, 238, 241,	162, 163, 164,
333, 374, 377-	242, 247, 329, 33Ø,	167-169, 22Ø
379, 41Ø-42Ø,	347, 348, 359, 361,	228, 23Ø-233,
44Ø-443-447,	371-373, 384, 4ØØ,	284-287, 29Ø,
45Ø, 452-455,	4Ø2, 421, 425-434,	291, 292, 294;
46Ø, 463-466,	45Ø-47Ø, 472, 473,	296, 341, 349,
471-474, 478,	476, 478, 495, 496,	351-357, 364,
496, 499-5Ø1,	497, 549, 555, 556,	366, 367, 393,
5Ø3, 532-533,	557, 567, 568, 57Ø,	613, 622, 624,
545-548,	6Ø3, 675, 677-684,	625, 629,
	693, 737, 743-745,	633-673, 728-732
	765-776, 796, 798-8Ø9,	

Total number of plots = 816; Total misinterpretation = 49

Table 15. Summary of commission and omission errors of information from Khaksar village

	Omission errors		Commission errors		Correct	
	Total	Per cent	Total	Per cent	Total	Per cent
Normal	45	9.8	45	9.7	416	91.3
Slightly saline	9.Ø	12.5	Ø.Ø	Ø.Ø	6.3	1ØØ.Ø
Moderately saline	25.Ø	1Ø.Ø	4.Ø	17.Ø	223	83.Ø
Strongly saline	14.Ø	1Ø.3	Ø.Ø	Ø.Ø	121	1ØØ

9Ø % accurate at 9Ø % confidence level.

Table 16. Survey number of plots identified in the village Padra from Landsat-5 TM (FCC) March, 1986 under different saline levels

Saline levels		
Slightly saline	Moderately saline	Strongly saline
55,57,62,68,71-73,	58,59,83-86,261,262,	205-213,415,424,429,
75-78,86,91-93,96,	266,267,294,295,299,	430,431,434,435,441,
99,100,101,104,108,	300,305,307,308,310,	455-468,470-474,478-
109,168,169,171,172,	312,314,326,610,615,	482,496-497,502-507,
239,256,257,258,260,	620,621,632,636,639,	510-516,518,521,533,
261,262,469.	641,642,644,680,681-	542,548,552,566,572,
	685,687-692,694,696,	573,574,575,580,581,
	697,698.	582,584-589,591-593,
		595.

Total number of plots = 749
Plots misinterpreted = 40

Table 17. Summary of commission and omission errors for Padra village

	Omission errors		Commission errors		Correct	
	Total	Per cent	Total	Per cent	Total	Per cent
Normal	0.0	0.0	39	6.6	555	93.4
Slightly saline	1.0	2.2	0.0	0.0	43	100
Moderately saline	34	5.7	1.0	3.7	26	96.3
Strongly saline	5	5.6	0.0	0.0	85	100

90 % accurate at 90 % confidence level.

Table 18. **Survey numbr of plots from the village Valli identified from Landsat 5 TM March 1986 FCC under different saline levels**

Slightly saline affected	Moderately saline affected	Strongly saline affected
14-19, 26-51,	1-3, 50-95, 94-122,	60-69, 70, 74, 79-92,
266-268, 270-278,	131-214. 223-260,	294-333, 550-553,
284-290, 346, 351,	337-440, 467-492,	576-578, 601-611,
354, 356, 533-537	495-502, 503-532,	618-627
	538-549, 629-660	

Total number of plots = 660

Total misinterpretation = 34

Table 19. **Summary of commission and omission errors for the village Valli**

	Omission errors		Commission errors		Correct	
	Total	Per cent	Total	Per cent	Total	Per cent
Normal	0.0	0.0	9.0	16.4	46.0	83.6
Slightly saline	9.0	12.0	0.0	0.0	64.0	100
Moderately saline	11.0	2.5	14.0	3.7	424	96.8
Strongly saline	14.0	13.6	11.0	5.7	92	94.3

92 % accurate at 90 % confidence level.

saline soil with that of the normal soil was also indicated. However, the accuracy testing of the complete village indicated 92 % accuracy at 90 % confidence level (Table 19).

3.1.1.3 Vegetational Status in the Degraded Soil

The vegetational status was studied at 1:250,000 scale from the 1:250,000 paper print FCC of Landsat 4 TM of December 1985 (Fig. 21). The vegetational status of Khambhat taluka with the exemption of coastal and river sandy areas was delineated into four different categories and the data were quantified (Table 20). The satellite data of early winter 1985-86 indicated an inverse correlation of vegetational status with that of the degraded soil and this correlation was more clear in summer. There was an increase in the area having nil vegetation concurrent with a decrease in the area having dense vegetation, indicating to the probable lack of cultivation in the salinised lands during summer. Also the mapping at 1:50,000 scale have brought out very vivid negative correlation between vegetation and salinity (Fig. 22).

3.1.2 Digital Analysis

3.1.2.1 Salinity

Since superimposing of taluka boundary was not possible with the facility at RRSSC at Jodhpur in 1988, an area lying between 22°-15' and 23°-18' north latitude and 72°-15' and 72°-45' east longitudes covering 1340 km^2 was chosen for the digital analysis as this included 75 % of Khambhat taluka. The false

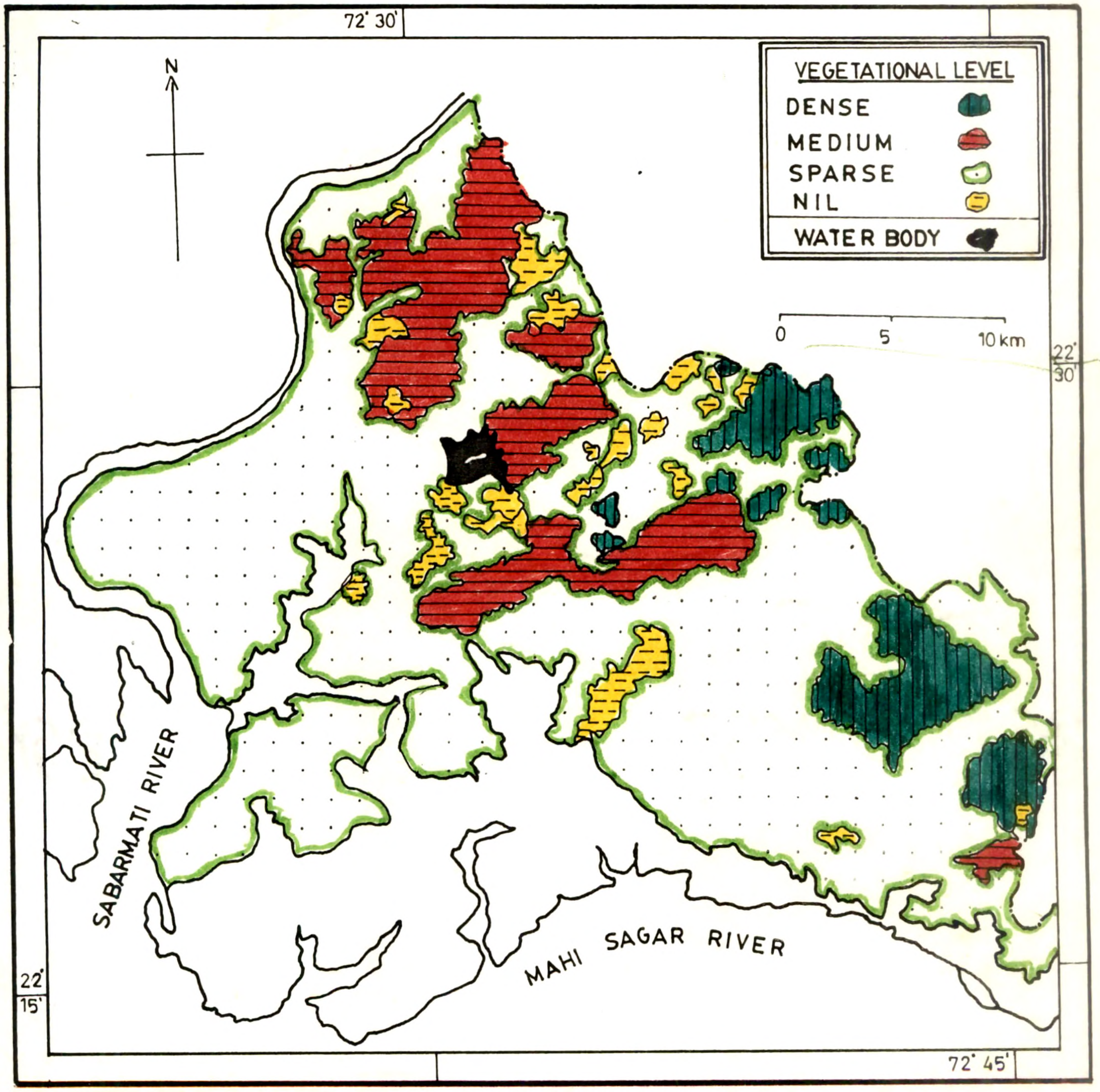

FIG.21. VEGETATIONAL STATUS OF KHAMBHAT TALUKA FROM LANDSAT TM PAPER PRINT DECEMBER 1985.

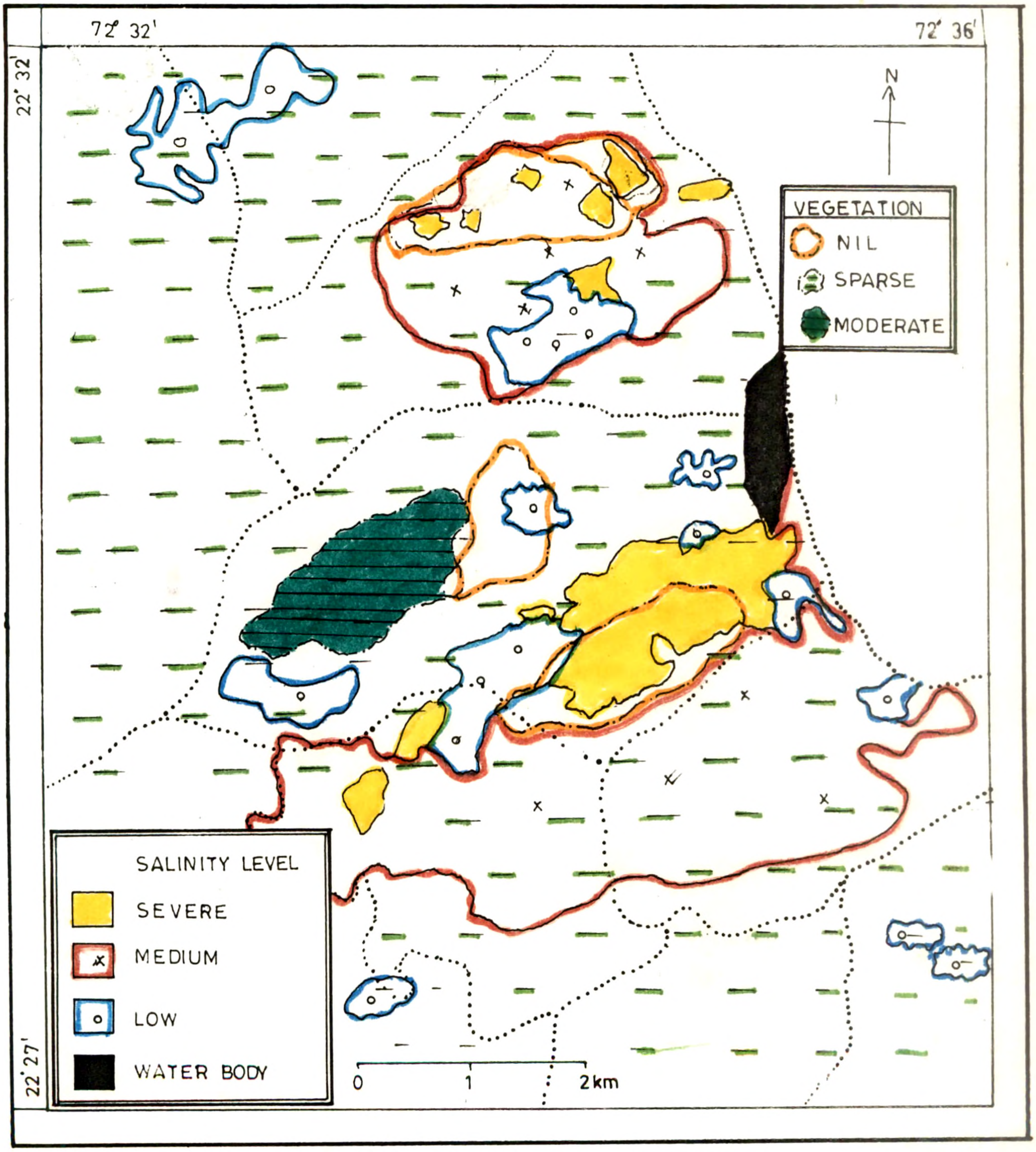

FIG. 22. CORRELATION OF VEGETATIONAL STATUS WITH SALINITY LEVELS AT. 1:50,000 SCALE.

Table 20. Vegetational cover (ha) in Khambhat taluka as computed from Landsat TM FCC 1985 (Winter) and Landsat-5 TM FCC 1987 (Summer)

Vegetational level	Winter 1985	Summer 1987
Nil	2,749	8,530
Low	43,473	36,792
Moderate	10,406	15,981
Dense	7,811	3,083

Table 21. Classification of salt affected area of the site of study using digital analysis

Salinity levels	Area in km^2	%
Severe 1	5.1	0.4
Severe 2	20.8	1.5
Moderate 1	48.6	3.6
Moderate 2	69.2	5.2
Low 1	37.3	2.8
Low 2	65.1	4.8
Water bodies	5.0	0.4

Total Study Area 1340 km^2

colour composite generated using IRS-1A LISS II band 2,3,4 seggregated the saline areas as white to white blue patches (Plates 3-5). In addition to this, other advanced digital techniques involving Soil Brightness Index (SBI) was attempted. The Index generated applying the MSS equivalent coefficients to the IRS-1A LISS II data yielded very clear delineation of the soil, based upon its brightness (Plates 6-8). The degraded soil levels were indicated in the order of severe to normal as red, yellow, green, light blue and dark blue. The severe patches around Kanewal tank had dark red, and yellow colours. Further the supervised classification scheme was followed for further categorisation of soil into six saline classes (Plates 9-11). The area under moderately salt affected soil formed a major part when compared to the other categories (Table 21). The summary of commission and omission errors indicated misinterpretation of 107 for a total of 1060 points (Table 22). The Divergence matrix presented in Table 23 indicated the inseparability of S_1 with S_2 and M_1 with M_2 and L_1 with L_2 (Table 23).

3.1.2.2 Vegetation

The Green Vegetation Index (GVI) image generated by the application of MSS equivalent coefficient to IRS data proved a base for the categorisation of vegetational levels for a supervised classification scheme and 5 vegetational classes viz., Dense, moderate, low, sparse and nil were seggregated (Plates 12-14; Table 24).

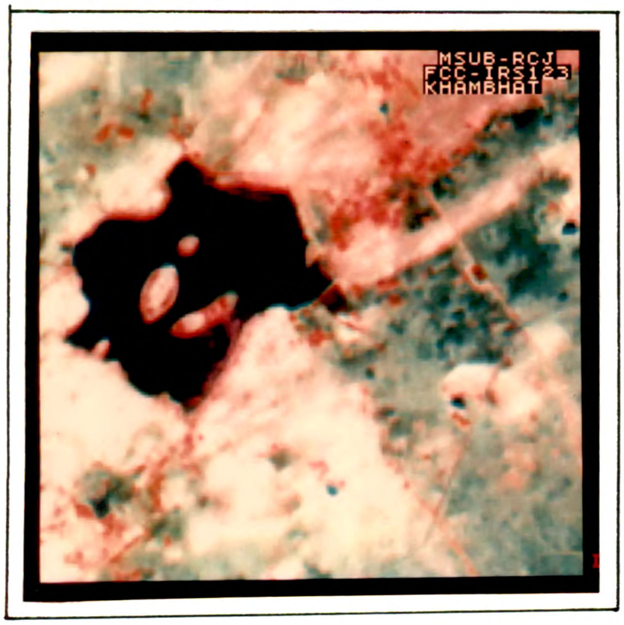

PLATE 3

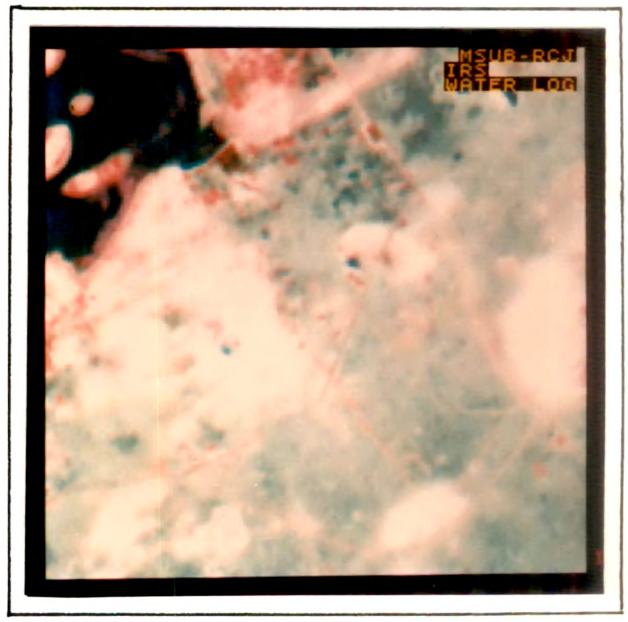

PLATE 4

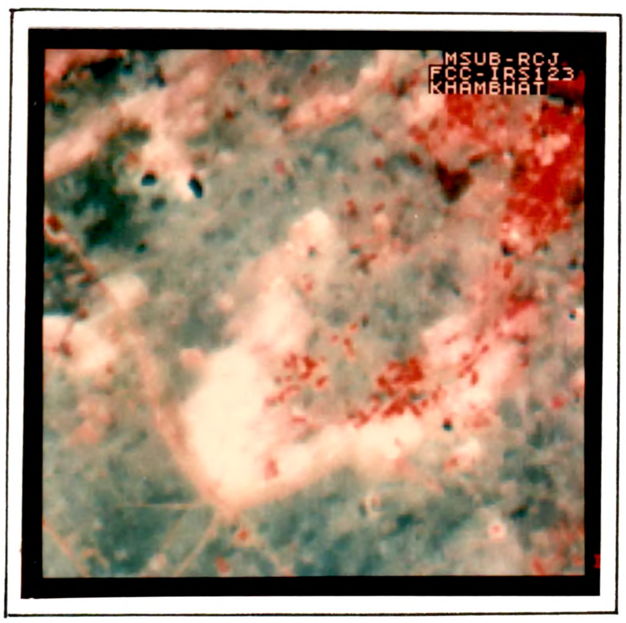

PLATE 5

Zoomed false colour composite images showing white saline patches in different areas of Khambhat taluka.

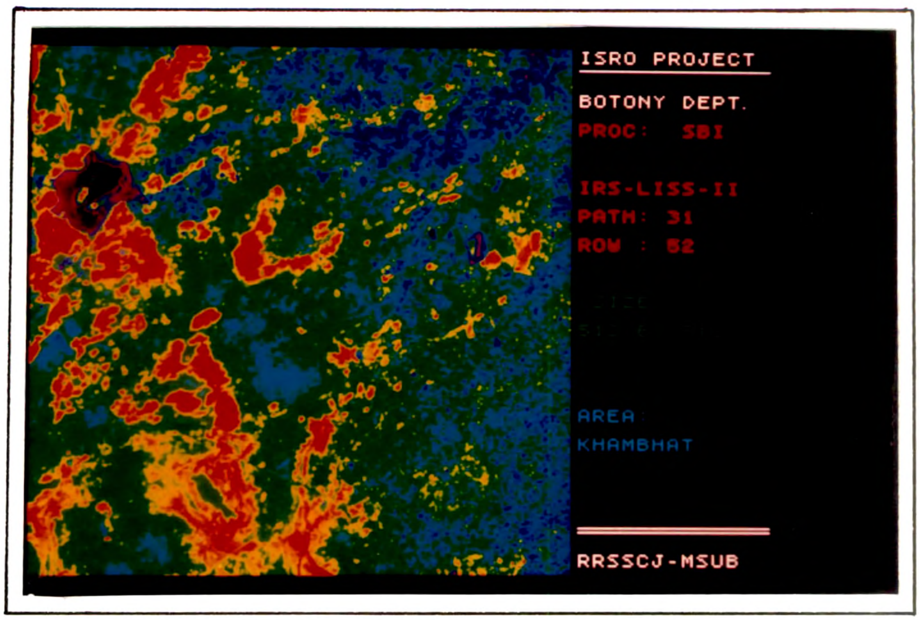

PLATE 6

Soil Brightness Index (SBI) image exhibiting different levels of soil degradation.

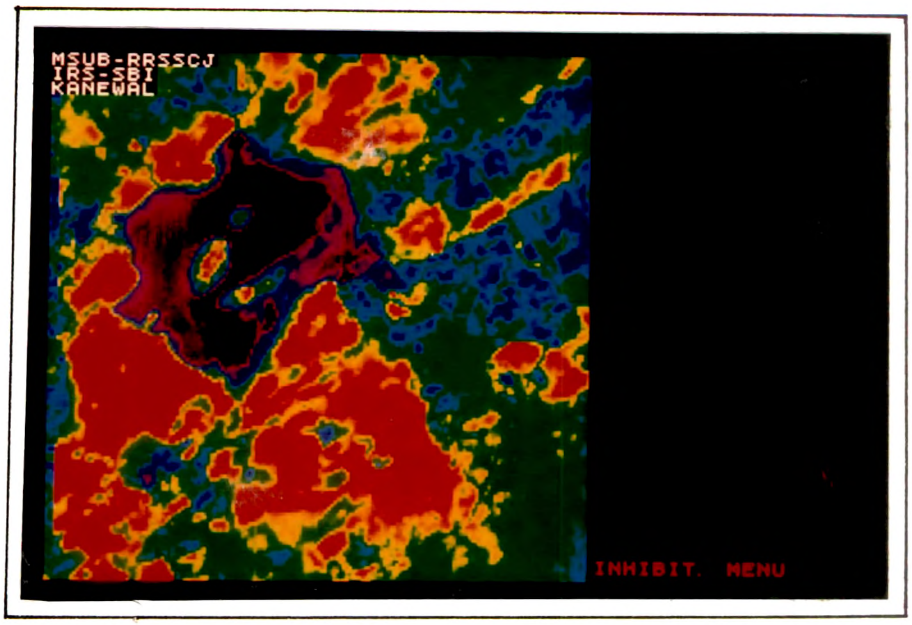

PLATE 7

Zoomed Soil Brightness Index (SBI) image exhibiting different levels of soil degradation.

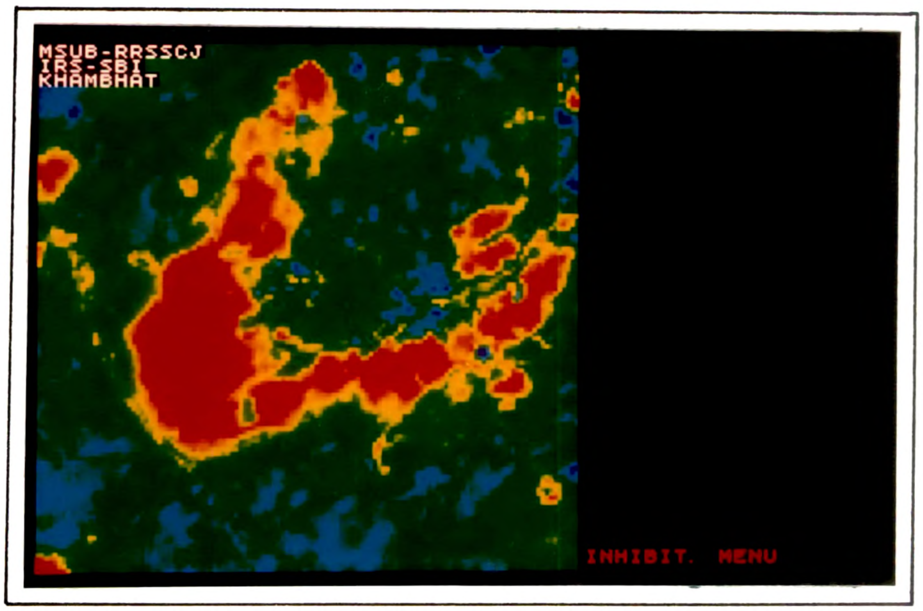

PLATE 8

Zoomed Soil Brightness Index (SBI) image showing distinct saline patches.

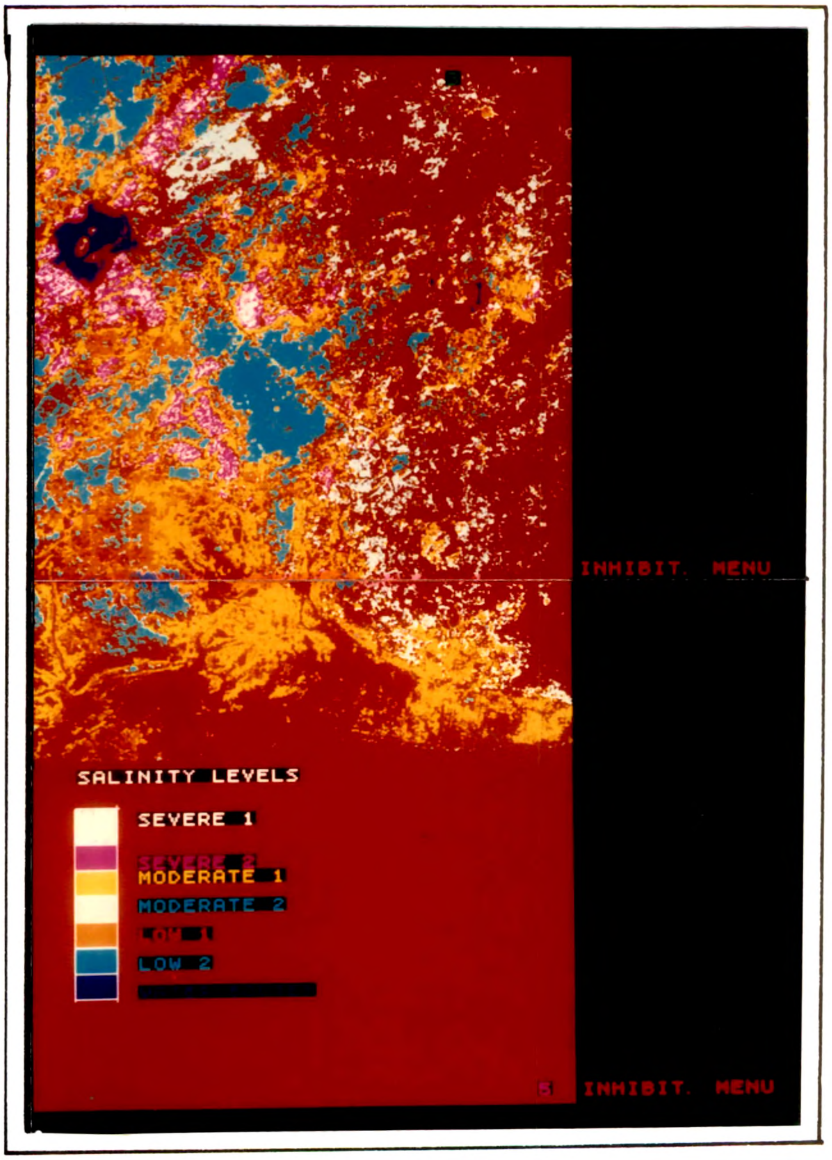

PLATE 9

Supervised classification image showing different saline soil categories.

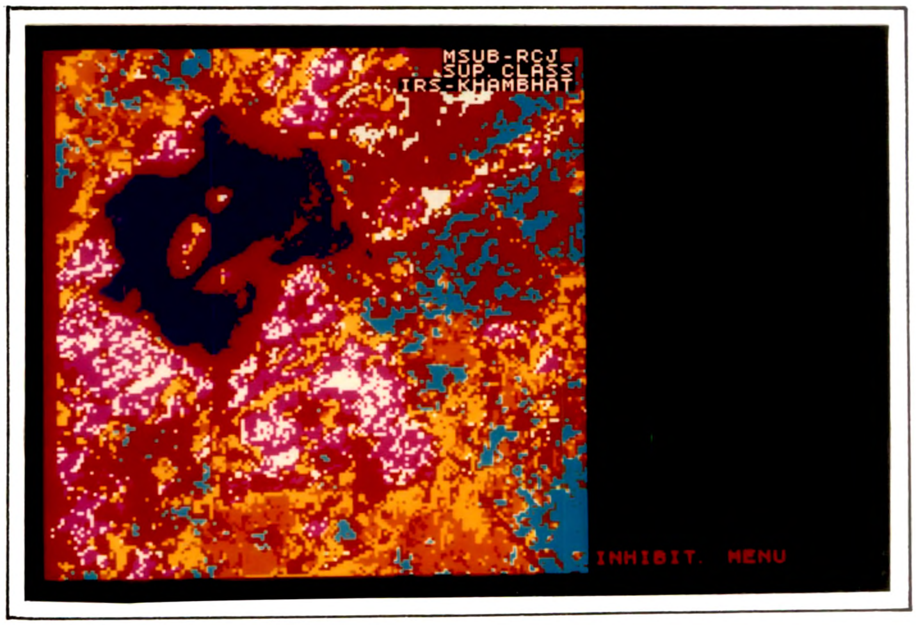

PLATE 10

Zoomed supervised classification image showing different categories of saline soil around Kanewal tank (colour key is same as shown plate 9).

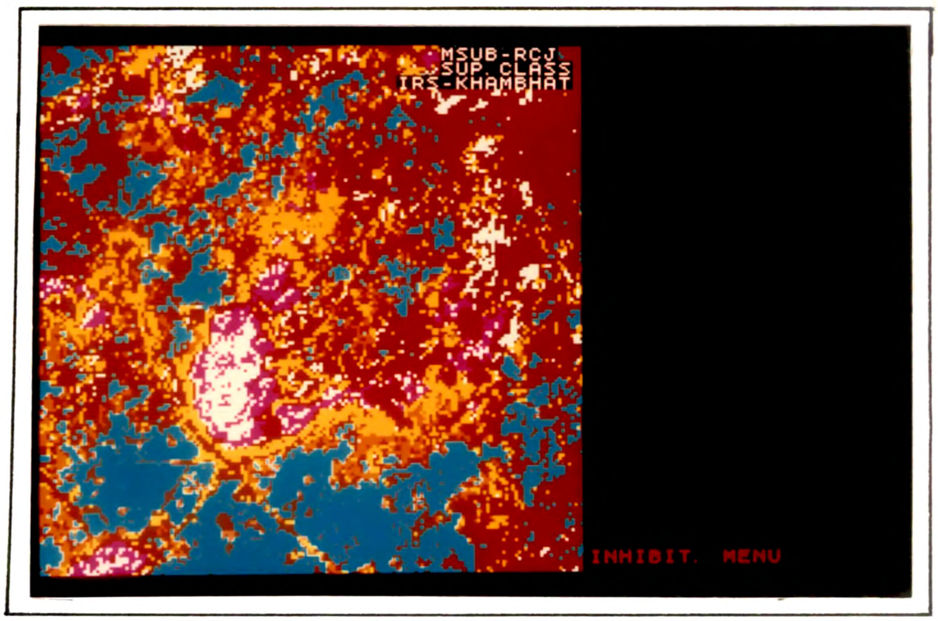

PLATE 11

Zoomed supervised image of saline soil classification (colour key is same as shown in plate 9).

Table 22. Summary of comission and omission errors of digitised data

Saline classes	Omission errors		Commission errors		Correct	
	Total	Per cent	Total	Per cent	Total	Per cent
Severe 1	67	29.5	23	15.9	121	58.4
Severe 2	23	17.Ø	67	44.9	82	68.4
Moderate 1	22	29.3	9	14.5	53	7Ø.6
Moderate 2	15	9.4	1	Ø.7	145	9Ø.6
Low 1	13	14.1	7	8.1	79	85.9
Low 2	2Ø	9.1	Ø	Ø	199	9Ø.9
Water bodies	31	1Ø.1	Ø	Ø	274	89.4

Table 23. Divergence matrix from the data computed by digital analysis

Salinity levels	S_1	S_2	M_1	M_2	L_1	L_2	WB
Severe 1 - S_1	Ø	-	-	-	-	-	-
Severe 2 - S_2	1.8	Ø.Ø	-	-	-	-	-
Moderate 1 - M_1	71.2	66.7	Ø.Ø	-	-	-	-
Moderate 2 - M_2	253.8	211.7	32.Ø	Ø.Ø	-	-	-
Low 1 - L_1	12Ø.2	125.7	6.6	63.5	Ø.Ø	-	-
Low 2 - L_2	411.2	393.2	71.1	132.8	48.2	Ø.Ø	-
Water bodies (WB)	1264.4	1214.1	678.7	1Ø65	794.8	591.6	-

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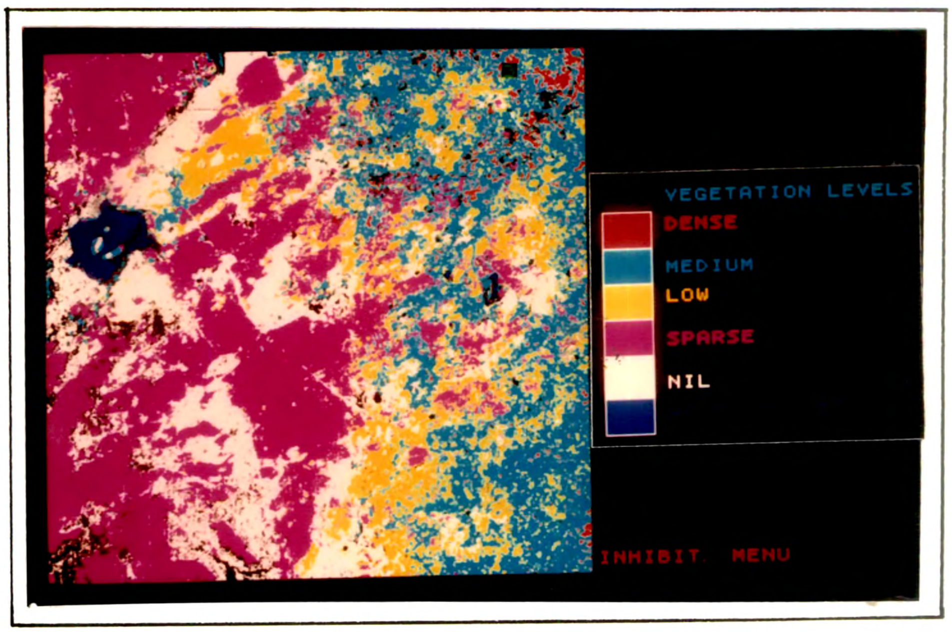

PLATE 12

Supervised classification of vegetation showing different categories of vegetation.

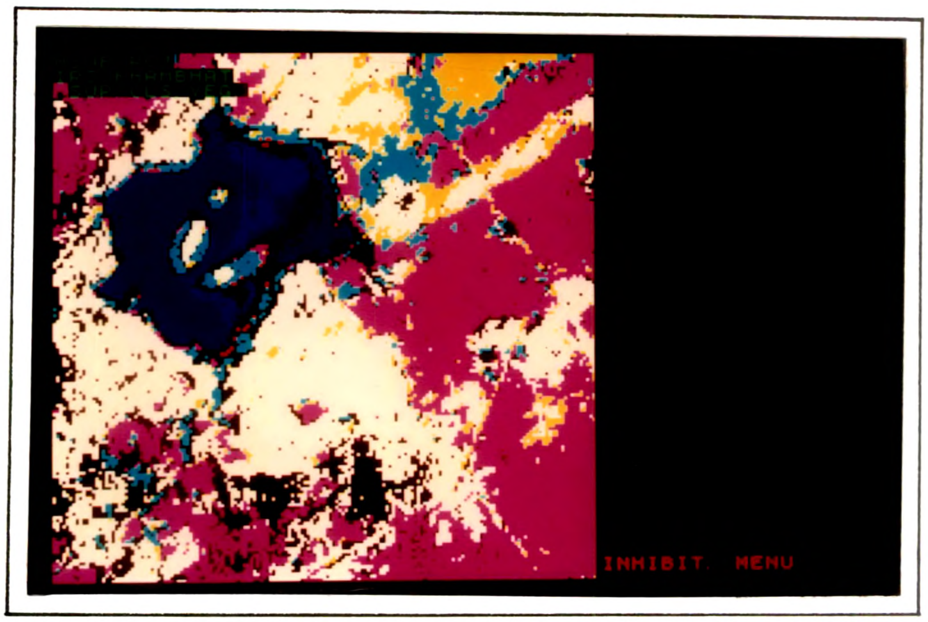

PLATE 13

Zoomed supervised classification image of vegetation around Kanewal tank (colour key is same as shown in plate 12).

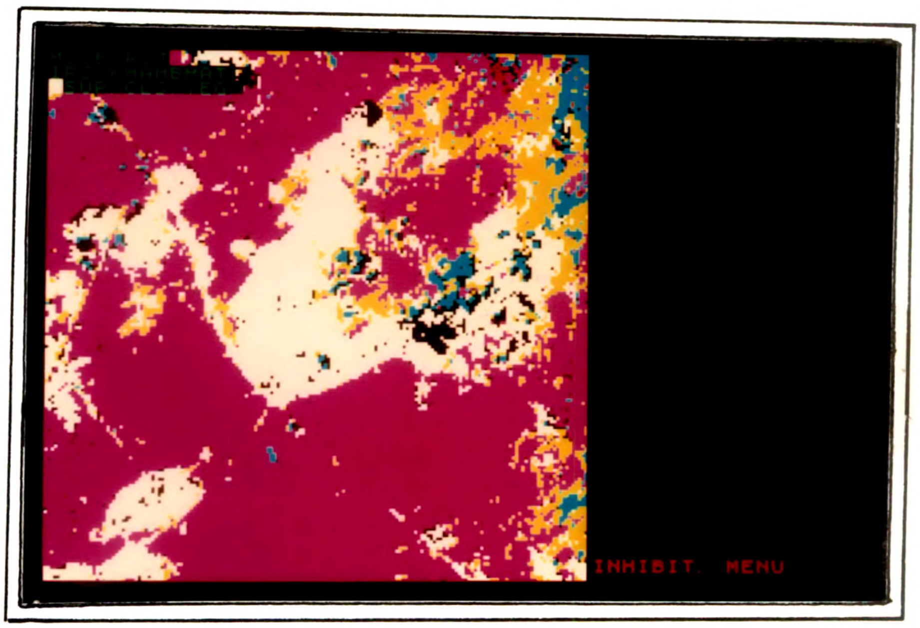

PLATE 14

Zoomed supervised classification in saline affected area of Khambhat taluka (colour key is same as shown in plate 12).

Table 24. **Quantification of different vegetational levels in the site of study from the digitised IRS-1A LISS II Data**

Vegetational levels	Area (km^2)	Per cent
Dense	2Ø3.5	15.2
Moderate	516.1	38.6
Low	128.9	9.6
Sparse	194.6	14.6
Nil	156.6	11.7

3.2 FIELD STUDIES

3.2.1 Chemical Characteristics of the Soil

The ionic status of the surface soil (1-10 cm depth) has been presented in Table 25. The mean ECe values of the samples collected from different sites were 1.0, 3.5, 11.4 and 42.5 dSm^{-1} in normal, slightly affected, moderately affected and strongly affected saline soils respectively. the pH values were less than 8.0 in all categories of soil confirming that all the soils were saline soils. Generally, there was an increase in the cationic levels from normal to strongly affected saline soil. Na^{+} ions increased from 2.0 to 45.8 meq/100 g. Except for a decrease in K^{+} content in slightly salt affected soil K^{+} content exhibited an increase from 0.7 to 1.4 meq/100 g soils in strongly salt affected soils. There was a 3, 5.9 and 14.8 fold increase in Sodium Absorption Ratio (SAR) in slightly, moderately and strongly affected saline soils when compared to normal soils. The anionic content also exhibited an increasing trend (Table 26). A very slight increase was noted in CO^{2-}_{3} and HCO^{2-}_{3} content. The chloride content increased drastically by 3.6 and 32.5 fold in moderately and strongly salt affected soils when compared to normal soil while the SO^{-2}_{4} content was increased by 2.8 and 4.9 accordingly.

The ionic status of the surface soil during the winter season was not much different from that of the summer as indicated by the ECe values of normal, slightly, moderately and strongly affected saline soils that were 1.5, 5.9, 11.8 and 34.86 dSm^{-1} respectively (Table 27). A decrease in pH from 7.7 to 7.6 in normal to strongly salt affected soil was noted. The

Table 25. Cationic levels (meq/1ØØ g) in soils of Khambhat taluka during summer season from 1-1Ø cm depth.

Category	ECe dSm^{-1}	pH	Na^{+}	K^{+}	Ca^{2+}	Mg^{2+}	SAR
Normal	1.Ø (Ø.1)	7.7 (Ø.1)	2.13 (Ø.Ø4)	Ø.7 (Ø.Ø1)	1Ø (Ø.5)	5.Ø (Ø.7)	1.Ø (Ø.Ø2)
Slightly saline	3.5 (Ø.Ø5)	8.1 (Ø.25)	5.7 (Ø.24)	Ø.47 (Ø.12)	5.Ø5 (Ø.89)	4.22 (Ø.32)	3.Ø (Ø.12)
Moderately saline	11.4 (Ø.9)	7.52 (Ø.6)	17.1 (Ø.58)	Ø.8 (Ø.22)	7.4 (Ø.14)	6.Ø6 (Ø.15)	5.9 (Ø.14)
Strongly saline	42.5 (4.3)	7.5 (Ø.1)	45.8 (4.2)	1.4 (Ø.2)	11.76 (1.7)	1Ø.8 (Ø.18)	14.8 (2.2)

Figures in parentheses represent standard error; SAR : Sodium Absorption Ratio.

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Table 26. Anionic levels (meq/100 g) in soils of Khambhat taluka during summer season 1986

Categories	CO_3^{2-}	HCO_3^{2-}	Cl^-	SO_4^{2-}
Normal	0.01 (0.003)	0.12 (0.02)	1.6 (0.4)	3.7 (0.4)
Slightly saline	0.01 (0.06)	0.12 (0.02)	1.7 (1.57)	4.5 (0.7)
Moderately saline	0.01 (0.01)	0.17 (0.04)	5.8 (2.2)	10.2 (5.3)
Strongly saline	0.04 (0.02)	0.19 (0.07)	52.0 (18)	18.03 (4.8)

Figures in parentheses represent standard error.

Table 27. Cationic levels (meq/100 g) in soils of Khambhat taluka during winter season, 1986

Category	depth (cm)	ECe dSm^{-1}	pH	Na^{+}	K^{+}	Ca^{2+}	Mg^{2+}	SAR
Normal	1-10	1.5 (0.02)	7.7 (0.1)	2.2 (0.04)	0.6 (0.1)	8.7 (0.6)	4.8 (0.1)	1.1 (0.02)
	30-40	1.4 (0.1)	7.8 (0.1)	5.5 (0.8)	1.2 (0.14)	26.3 (2.2)	5.7 (0.5)	1.5 (0.2)
Slightly saline	1-10	5.9 (0.6)	7.7 (0.3)	8.8 (0.8)	1.0 (0.03)	28.3 (0.6)	4.4 (0.06)	4.2 (0.22)
	30-40	5.8 (0.3)	7.6 (0.1)	9.8 (0.5)	1.2 (0.03)	24.8 (4.2)	2.0 (0.6)	2.0 (0.6)
Moderately saline	1-10	11.8 (0.7)	7.5 (0.1)	12.8 (2.0)	2.9 (0.8)	25.4 (3.6)	5.1 (0.7)	7.1 (0.08)
	30-40	12.0 (0.6)	7.6 (0.1)	17.7 (2.7)	0.7 (0.1)	24.2 (2.9)	4.8 (0.6)	6.1 (0.2)
Strongly saline	1-10	34.8 (3.3)	7.6 (0.1)	60.0 (2.0)	0.9 (0.02)	30.6 (4.4)	9.0 (0.9)	20.3 (3.1)
	30-40	26.4 (3.2)	7.5 (0.1)	37.1 (11.1)	1.2 (0.2)	38.2 (3.1)	6.5 (1.0)	8.3 (2.6)

Figures in parentheses represent standard error; SAR : Sodium Absorption Ratio.

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cationic content exhibited a similar pattern of increase as witnessed in summer, from normal to strongly salt affected soil except for slight decrease in Mg^{2+} content in less affected soil. The Na^{+} content increased by 4, 5.8 and 27.2 fold in slightly, moderately and strongly salt affected soil respectively. The Ca^{2+} content increased from 8.7 to 30.0 meq/100 g soil in normal to strongly affected soils. The SAR also increased by 3.8, 6.5 and 18.5 fold accordingly. The anionic content also exhibited an increasing pattern from normal to strongly salt affected soil (Table 28). The SO^{2-}_{4} content also increased by 5.9 fold in strongly salt affected soil when compared to normal soils. Analysis of the soils from 30-40 cm depth revealed not much difference in the general pattern of the chemical characteristics of the soil from 1-10 cm and 30-40 cm except for some minor differences as follows. The ECe values of the strongly affected soil was more at the surface (Table 27). Similarly the Na^{+} content and Sodium Absorption Ratio (SAR) were more at the surface in the affected soils. Larger variation in the Na^{+} content and SAR values of the above soil samples was evident from their high standard error. The nitrogen and phosphorous content estimated from different levels of saline soils during different seasons did not show any distinct trend pertaining to the soil stress involved (Table 29). The status of Fe^{2+}, Mn^{2+} and Zn^{2+} during summer and winter clearly indicated a general increase of all the three ions in the saline soils as compared to the low saline soils though exceptions were also recorded (Table 30 and 31).

Table 28. Anionic contents (meq/1ØØ g) in the soils of Khambhat taluka in the winter season of 1986

Category	CO_3^{2-}		HCO_3^{2-}		Cl^-		SO_4^{2-}	
	Depth from the surface (cm)							
	1-1Ø	3Ø-4Ø	1-1Ø	3Ø-4Ø	1-1Ø	3Ø-4Ø	1-1Ø	3Ø-4Ø
Normal	Ø.Ø3 (Ø.Ø1)	-	Ø.28 (Ø.Ø2)	-	Ø.4 (Ø.1)	-	3.5 (Ø.3Ø)	-
Slightly saline	Ø.Ø3 (Ø.Ø1)	Ø.99 (Ø.Ø1)	Ø.1Ø (Ø.ØØ)	Ø.27 (Ø.1Ø)	1.4 (Ø.2)	2.45 (1.42)	4.5 (Ø.5)	4.8 (Ø.7)
Moderately saline	Ø.Ø4 (Ø.Ø1)	Ø.Ø3 (Ø.Ø1)	Ø.15 (Ø.Ø3)	Ø.3 (Ø.12)	4.5 (1.Ø)	Ø.8 (Ø.3)	4.4 (Ø.4)	3.7 (Ø.4)
Strongly saline	Ø.11 (Ø.ØØ)	Ø.Ø2 (Ø.ØØ)	Ø.11 (Ø.Ø2)	Ø.22 (Ø.Ø8)	72.8 (22.6)	4.4 (5.1)	2Ø.8 (5.1)	6.1 (1.8)

Figures in parentheses represent standard error.

- = not determined

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Table 29. Nitrogen and phosphorous content (mg/g dry wt.) in soils of Khambhat taluka during different seasons

	Nitrogen	Phosphorous
Summer		
Slightly saline	8.4 (Ø.2)	19.6 (Ø.2)
Moderately saline	15.1 (Ø.4)	2Ø.4 (Ø.7)
Strongly saline	7.1 (Ø.1)	21.1 (Ø.6)
Winter		
Slightly saline	9.7 (Ø.2)	25.9 (Ø.7)
Moderately saline	7.4 (Ø.8)	9.1 (Ø.2)
Strongly saline	7.1 (Ø.2)	19.9 (Ø.6)

Figures in parentheses represent standard error

Table 30. Status of Fe^{2+}, Mn^{2+} and Zn^{2+} in some villages of Khambhat taluka during summer, 1987

Village	Fe^{2+} (meq/100 g)			Mn^{2+} (meq/100 g)			Zn^{2+} (μeq/100 g)		
	LS	MS	SS	LS	MS	SS	LS	MS	SS
Moraj	0.41	0.79	1.56	0.40	0.57	3.1	4.0	6.0	20.0
Jichka	0.60	1.04	0.35	0.66	0.90	1.1	8.0	18.0	14.0
Padra	0.50	0.75	0.97	0.40	0.85	0.6	-	9.0	9.0
Varasda	0.34	0.36	0.12	0.72	0.50	1.4	7.0	10.0	8.0
Vainaj	1.80	0.84	3.7	1.44	0.85	3.0	8.0	19.0	7.0
Amaliara	1.05	1.54	1.97	-	-	-	9.0	5.0	7.0
Mean	0.78	0.89	1.45	0.72	0.73	1.8	7.2	11.1	10.8
(SE)	(0.22)	(0.16)	(0.53)	(0.19)	(0.08)	(0.51)	(0.9)	(0.4)	(2.1)

LS : Slightly Saline; MS: Moderately Saline; SS: Strongly Saline

- = not determined

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Table 31. Status of Fe^{2+}, Mn^{2+} and Zn^{2+} in some villages of Khambhat taluka during winter, 1987

Village	Fe^{2+} (meq/100 g)			Mn^{2+} (meq/100 g)			Zn^{2+} (µeq/100 g)		
	LS	MS	SS	LS	MS	SS	LS	MS	SS
Moraj	0.34	1.1	4.1	0.5	0.4	1.6	7.0	7.0	19.0
Jichka	0.16	1.3	0.3	1.4	0.7	0.3	8.0	7.0	5.0
Padra	0.17	0.5	0.7	3.1	0.6	0.7	7.0	20.0	7.0
Varasda	0.30	0.2	2.6	0.4	2.7	4.4	7.0	7.0	2.0
Vainaj	0.29	1.3	3.9	0.5	0.7	2.5	10.0	7.0	10.0
Amaliara	0.34	0.6	2.2	0.7	0.7	1.2	20.0	7.0	10.0
Mean	0.26	0.8	2.3	1.0	1.0	1.8	9.8	9.2	11.8
(SE)	(0.03)	(0.2)	(0.7)	(0.34)	(0.35)	(0.6)	(2.1)	(2.2)	(2.6)

LS : Slightly Saline; MS: Moderately Saline; SS: Strongly Saline; SE = Standrd error.

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3.2.2 Productivity in Saline Soils

3.2.2.1 Crop Cultivated and their Yield as Affected by Salinity

Of the different crops grown in the Kharif season Trigonella foenum-graecum L., Gossypium herbaceum L. var. acerifolium (Guill. & Perr.), Cajanus cajan (L.) Millsp and Ricinus communis were found to be grown only in the less affected saline soils (Table 32). In addition others like Phaseolus aureus L., Cicer arietinum L., Sorghum vulgare Pers., Pennisetum typhoides (Burm. f.) Stapf & Hubb. and Oryza sativa L., could be grown in the moderately saline affected soils too. Only three cultivars of Pennisetum typhoides and 4 cultivars of Oryza sativa L. were found growing under saline condition against the six cultivars of Bajra and 10 cultivars of rice being grown under less saline conditions. None of these crops except rice or Mahsuri could be grown under severe saline conditions. During Rabi season only three varieties of Triticum aestivum L. were found to be grown under less saline soils. Ecological studies undertaken in the rice fields indicated a decrease in relative density and relative dominance of rice as the soil salinity increased from normal to strongly saline soil. The Leaf Area Ratio (LAR) also decreased in response to increasing salinity. However, the Specific Leaf Area (SLA) was more under the moderately saline condition as compared to plants grown in normal soils (Table 33).

The inhibiting effect of salinity was very evident in the yield attributes of rice cultivar Mahsuri grown under different saline soils. The panicle length of rice cv. Mahsuri

Table 32. Cultivars of crops grown in the salt affected soils

	Saline levels (ECe dSm^{-1})		
	Slightly saline 2.0-6.0	Moderately saline 6.0-15.0	Strongly saline above 15.0
A. Kharif crops			
1. Oryza sativa L. (Rice)	Krishnakamod, GR3,GR4,Jirasal 280 Gujarat 70, Basmati, GR-101,Jaya,Mahsuri	Gujarat 70, Gujarat 11 Lachko Mahsuri	Mahsuri
2. Pannisetum typhoides (Burm.F.) Stapf & Hubb. (Bajri)	GJ 104, BJ 104, BK 560, GHB-27, X5, X002	Bk 560 GSB 27,X5	
3. Sorghum vulgare Pers. (Juwar)	Deshi	Deshi	
4. Cicer arietinum L. (Chana)	Deshi	Deshi	
5. Ricinus communis (L.) (Castor)	Gujarat 1		
6. Cajanus cajan (l.) Millsp. (Tuver)	Dahod Piru		
7. Phaseolus aureus (l.) (Mung bean)	Gujarat 1 Gujarat 2, Deshi	Gujarat 1 Gujarat 2	
8. Gossypium herbaceam L. (Cotton)			
9. Trigonella foenum graecum L. (Methi)	Deshi		
B. Rabi crop			
Triticum aestivum L. (Wheat)	Arnej 28,6-10-1 Deshi		

Table 33. Changes in the agricultural rice fields due to salinity

ECe dSm^{-1}	Saline levels			
	Normal	LS	MS	SS
	below 2.Ø	2.Ø-6.Ø	6.Ø-15.Ø	Above 15
1. Relative density of rice	65	44	6	Ø
2. Relative dominance of rice	98	94	61	Ø
3. Number of weeds in the rice fields	18	13	9	3
4. Leaf Area Index of rice				
a. One month crop	43	-	23	14
b. Pre-harvest crop	132	-	49	32
5. Leaf Area Ratio of rice	Ø.54	-	Ø.55	Ø.37
6. Specific Leaf Area of rice	1.88	-	4.8	1.3

LS = Slightly Saline; MS = Moderately saline; SS = Strongly Saline;
- = not determined.

was not significantly affected except in plants grown under strong salinity. The strong salinity reduced the panicle length of 41 % (Table 34). However, the number of panicles in each hill was reduced in moderately or strongly salt affected plants. The spikelet number per panicle was also reduced in strongly affected soil by 28 %. The reduction in number of filled grains per hill was reduced by 70, 75 and 88 % in the slightly, moderately and strongly salt affected soil respectively. With a parallel decrease in economic yield by 70, 74 and 90 per cent over the normal plants. Though the unfilled grain number was decreased in slightly and moderately affected soils, it was significantly increased in strongly affected soil by almost 81 %. In contrast, a significant increase in the straw weight was also noted in moderately and strongly affected soils. The biological yield (total dry standing crop) also exhibited tremendous decrease due to salinity. The harvest index was significantly reduced by 43, 57, and 86 per cent in slightly moderately and strongly saline soils. The analysis of variance of different yield attributes indicated that the effect of different levels of salinity was highly significant on the panicle length, number of filled grains and unfilled grains, dry weight of filled and unfilled grains, biological yield and harvest index (Table 35). Of the two salt resistant cultivars namely, Mahsuri and Bhura rata grown on experimental plots having moderate salinity Mahsuri proved to be more salt resistant when compared to Bhura rata (Table 36). There was a significant reduction in panicle length by 26 per cent and number of filled grain and dry weight filled grain by 67 and 65

Table 34. **Effect of different levels of salinity on yield and yield attributes (per hill) of rice cv. Mahsuri**

Soil condition (ECe : dSm^{-1})	No.of Panicle	Panicle length (cm)	No.of spikelets panicle	No.of filled grains	No.of unfilled grains	Straw yield (g)	Dry filled grain (g)	Dry unfilled grain (g)	Biological yield (g)	Harvest Index
Normal (1.4)	15.0	20.3	11.1	1859	469	8.8	27.1	1.7	39.1	0.7
Slightly saline (6.3)	13.2	19.0	10.2	564**	211	10.3	8.2**	1.4	20.0**	0.4**
Moderately saline (11.8)	5.2**	16.3	9.7	472**	46**	12.5*	7.1**	0.55*	19.9**	0.3**
Strongly saline (25.6)	4.8**	12.0**	8.0**	232**	850*	14.6**	2.7**	3.4**	23.1**	0.11**
CD at 5 %	3.7	4.9	1.7	439	380	3.4	12.3	1.12	10.3	0.1
CD at 1 %	5.6	7.4	2.6	661	440	5.1	8.2	1.7	15.4	0.2

Significant over the normal at CD 1 % = **; at CD 5 % = *

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Table 35. **Mean squares from the ANOVA of yield and yield attributes of rice (<u>Oryzo</u> <u>sative</u> L.) response variables.**

Source	Panicle length (cm)	No. of panicles	No.of spikelets x1Ø	No.of filled grains x 1Ø[5]	No.of unfilled grains x1Ø[4]	Dry filled grain (g)	Dry unfilled grain (g)x1ØØ	Straw yield (g)	Biolo-gical (g)	Harvest Index x 1Ø[-3]
Replicate	2Ø.69	21.75	5	15.17	24.14	32.28	6.75	5.69	77.Ø2	5
Treatment	69.84	138.Ø7**	82.9	26.77**	61.39**	588.2**	745.Ø**	3Ø.99**	636.67**	28Ø**
Error	18.94	1Ø.73	14.Ø	91.24	3Ø.14	52.7	98.5	7.69	82.97	5

Levels of significance at 1 % = **

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Table 36. Yield and Yield attributes (per hill) of two cultivars of rice grown under moderate saline fields

Cultivar	Pancile length (cm)	No. of panicle	No.of spikelets/ panicle	No.of filled grains	No.of unfilled grains	Straw yield (g)	Dry filled grain (g)	Dry unfilled grain (g)	Biological yield (g)	Harvest Index
Mahsuri**	19.0	5.2	9.7	472	46.0	12.3	7.1	0.55	19.9	0.33
Bhura-rata***	14.0*	5.0	11.4	155*	84.0*	8.8	2.5	0.38	12.3	0.28
CD at 5 %	4.3	4.6	2.4	40	37	4.5	4.1	0.8	8.0	0.16

* Significant at CD 5 %

** Salinity for Mahsuri = ECe 11.6 dsm^{-1}, ESP = 18.1; pH = 7.6

*** Salinity for Bhura rata = ECe 10.0 dsm^{-1}, ESP = 12.9; pH = 7.15

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per cent respectively in case of rice cv. Bhura rata when compared to Mahsuri. No significant difference was observed in any other yield parameter.

The average yield of rice (Oryza sativa L.) as observed in different villages was increasing from 1983-1984 (Table 37) with a simultaneous increase in acreage under rice cultivation upto 1986. However, an average of 93 per cent reduction was noted in the year 1987-88. The yield decrease in rice at different salinity levels in different plots of Padra village was obtained from the farmers (Table 38). It is noted that there is a drastic reduction in the yield from normal to strongly affected saline soil. Though in the year 1986 normal and slightly affected soils did not register any decrease as compared to the year preceded there was no yield in moderately and strongly affected soils. The yield of other crops such as Pennisetum typhoides and Triticum aestivum were affected severely on slightly affected soils and with the increase in salinity successful cultivation of these crops was not possible (Table 39).

3.2.2.2 Weeds in the Rice Field

Phytosociological analysis of plant communities of the various sites revealed distinct influence of soil salinity on different weeds. A sharp decrease in number of species with increasing soil salinity was noted. The total number of weeds observed in the normal fields was 19 which decreased in the order of 14, 9 and 5 for fields having slightly, moderately and strongly saline affected soils respectively (Tables 40-43). The maximum Important Value Index (IVI) of the weed species increased

Table 37. Average acreage (ha) under rice cultivation and their productivity (yield Q/ha) from 1983 to 1988 in different villages of Khambhat taluka

Name of village	1983-84		1984-85		1985-86		1986-87		1987-88	
	A	B	A	B	A	B	A	B	A	B
Amaliyara	425	29	415	30	430	32	425	34	2	39
Chikhalia	85	26	100	29	112	32	117	35	4	36
Gorad	199	27	215	29	220	31	230	32	10	36
Jichka	210	29	215	31	215	33	240	36	10	40
Moraj	850	27	920	31	950	34	987	37	155	40
Padra	109	24	225	27	50	28	180	30	25	32

A = Average acreage as ha

B = Yield as Q/ha.

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Table 38. Yield of rice (*Oryza sativa* L.) in Q/ha in Kharif information collected from the farmers of Padra village of Khambhat taluka

Year	Saline levels			
	Normal	LS	MS	SS
	Ø-2.Ø	2.Ø-6.Ø	6.Ø-15.Ø	Above 15
1984	35-4Ø	2Ø-25	1Ø-18	1-2
1985	35-4Ø	2Ø-25	1Ø-18	1-2
1986	35-4Ø	2Ø-25	Nil	Nil
1987**	Nil	Nil	Nil	Nil

LS = Slightly Saline; MS = Moderately Saline; SS = Strongly Saline;

* ECe range in dSm^{-1} of the fields

** Severe drought year

Survey nos. of plots from where information collected:

Normal : 293-297; :S = Slightly Saline 21Ø-214;

MS = Moderately Saline: 251-251; 382, 383.

SS = Strongly Saline: 335, 835

Table 39. Yield (Q/ha.) of different crops as affected by salinity

Crops	Saline levels			
	Normal <2	Slightly saline 2-6*	Moderately saline 6*-15*	Strongly saline above 15
Oryza sativa L. (Rice)	30-40	20-25	10-20	0-3
Pennisetum typhoides (Burm.f) Stapf & Hubb. (Bajri)	18-25	7-9	Nil	Nil
Triticum aestivum (L.) (Wheat)	55-65	27-35	Nil	Nil

* ECe range in dSm^{-1}

Table 40. Distribution of weeds in fields having normal soil

	Species	Relative			
		Frequency	Density	Dominance	IVI
1.	Acalypha indica (L.)	6.7	1.78	0.26	8.74
2.	Alysicarpous longifolius W & A.	8.9	3.6	0.1	12.6
3.	Ammannia baccifera (L.)	6.7	3.9	0.61	11.21
4.	Astercantha longifolia Nees	2.2	3.2	0.82	6.22
5.	Bergia capensis (L.)	6.7	3.2	0.09	9.99
6.	Centella asiatica (L.)	6.7	2.1	0.33	9.13
7.	Celsia coromandeliana Vahl	2.2	1.96	0.17	4.33
8.	Cleome viscosa (L.)	2.2	0.9	0.1	3.2
9.	Cyanotis axillaris Schuff F.	6.7	2.5	0.53	9.73
10.	Cyperus rotundus L.	4.4	4.6	1.18	10.18
11.	Dinebra retroflexa (Vahl) Panz.	6.7	0.7	0.1	7.5
12.	Eclipta prostrata (L.)	2.2	3.7	0.32	6.22
13.	Enicostemma hyssopifolium (Willd.) Verdoon	4.4	1.1	0.15	5.65
14.	Euphorbia hypericifolia (L.) var. parviflora (L.) Prain	2.2	0.4	0.09	2.69
15.	Fimbristylis monostachya Hassk	8.9	1.8	0.16	10.86
16.	Ipomoea acquatica Forsk	4.4	1.1	0.07	5.57
17.	Leucas aspera (Willd.)Spr.	8.9	5.2	1.54	15.64
18.	Ocimum canum Sims	2.2	5.7	0.65	8.55
19.	Oryza sativa L.	6.7	52.6	92.7	152

IVI = Important Value Index

Table 41. **Distribution of weeds in fields having slightly saline soil**

Species	Relative Frequency	Relative Density	Relative Dominance	IVI
1. *Ammannia baccifera* (L.)	9.7	6.45	1.17	17.32
2. *Alysicarpus longifolius* W. & A.	4.88	1.76	0.07	6.7
3. *Brachiaria ramosa* (L.) Stapf	7.3	3.52	0.26	11.08
4. *Bergia capensis* (L.)	2.44	0.29	0.01	2.74
5. *Centella asiatica* (L.)	2.44	1.47	0.27	4.18
6. *Commelina benghalensis* L.	4.88	2.35	0.24	7.47
7. *Cyanodon dactylon* Pers.	7.3	20.82	1.54	29.66
8. *Cyperus rotundus* L.	7.3	4.1	1.21	12.61
9. *Dinebra retroflexa* (Vahl) Panz.	9.7	6.74	1.12	17.56
10. *Eclipta prostrata* (L.) L.	4.88	0.59	0.06	5.53
11. *Fimbristylis monostachya* Hassk.	4.88	0.88	0.28	6.04
12. *Limnophila indica* (L.) Druce	9.7	4.4	0.28	14.38
13. *Oryza sativa* L.	7.3	45.75	94	147.1
14. *Vernonia cinerea* (L.) Less.	2.44	0.88	0.07	3.39

IVI = Important Value Index

Table 42. Distribution of weeds in fields having moderately saline soil

Species	Relative Frequency	Relative Density	Relative Dominance	IVI
1. Corchorous acutangulus Lam.	16.67	Ø.48	Ø.47	17.62
2. Cressa cretica (L.)	16.67	65.6	75.3	151.57
3. Cyanodon dactylon Pers.	16.67	2Ø.9	5.3	42.87
4. Digera arvensis Forsk.	4.45	Ø.48	Ø.19	5.12
5. Euphorbia hypericifolia (L.) var. parviflora (L.) Prain	3.33	Ø.1	Ø.Ø6	3.49
6. Prosopis cineraria (L.) Druce	6.67	Ø.39	Ø.3	7.36
7. Suaeda fruticosa (L.) Forsk. ex Gmel.	16.67	1Ø.17	16	42.84
8. Vernonia cineria (L.) Less	4.45	Ø.75	Ø.95	6.18
9. Vicoa indica (L.) DC.	6.67	1.Ø6	1.6	9.33

IVI = Important Value Index

Table 43. Distribution of weeds in fields having strongly saline soil

Species	Relative			IVI
	Frequency	Density	Dominance	
1. *Alhagi comelorum* Fisch.	9.1	4.3	3.56	16.96
2. *Aeluropus lagopoides* Trin.	27.27	6.4	7.54	41.21
3. *Cressa cretica* L.	27.27	76.6	77.11	180.98
4. *Suaeda fruticosa* (L.) Forsk. ex Gmel.	9.1	4.3	5.84	19.24
5. *Prosopis cinerara* (L.) Druce	27.27	8.5	5.95	41.72

IVI = Important Value Index

from normal to strongly saline soils as indicated from the phytograph drawn considering the maximum IVI values at each salinity level. Also the Relative Dominance was seen to be increasing (Fig. 23). Nevertheless the phytograph drawn considering the average values of all the species at different salinity levels could not bring out any particular aspect of the communities at different salinity levels (Fig. 24). The phytographs of different species revealed that there was a decrease in the values of IVI of Alysicarpus longifolius (Rottl. ex Spr.) W. & A., Ammania baccifera L., Bergia capensis L., Centella asiatica (L.) Urb., Cyperus rotundus L., and Fimbristylis monostycha Hassk. (Fig. 25 a to f) while it increased in Vernonia cineria (L.) Less as the soils change from normal to slight salinity (Fig. 25 k). Amongst different weeds Cressa cretica L. exhibited an increase in IVI from moderately to strongly affected lands (Plate 1) (Fig. 25 g) Suaeda fruticosa (L.) Forsk ex Gmel. showed a decreased IVI from moderate to strongly salt affected areas while Prosopis cineraria (L.) Druce showed an increase (Fig. 25j and i).

Diversity of species in all the sites was quite low. The Species Diversity index decreased towards increasing salinity with a parallel increase in Dominance Index (Table 44). The evenness index exhibited reduction from normal to moderate but an increase was noted towards strongly saline affected lands. The species richness also exhibited an inverse relation with salinity levels. Similarity Index of weed species between normal and slightly salt affected fields was Ø.3 and it decreased to Ø.2 between weeds of slightly and moderately affected saline fields

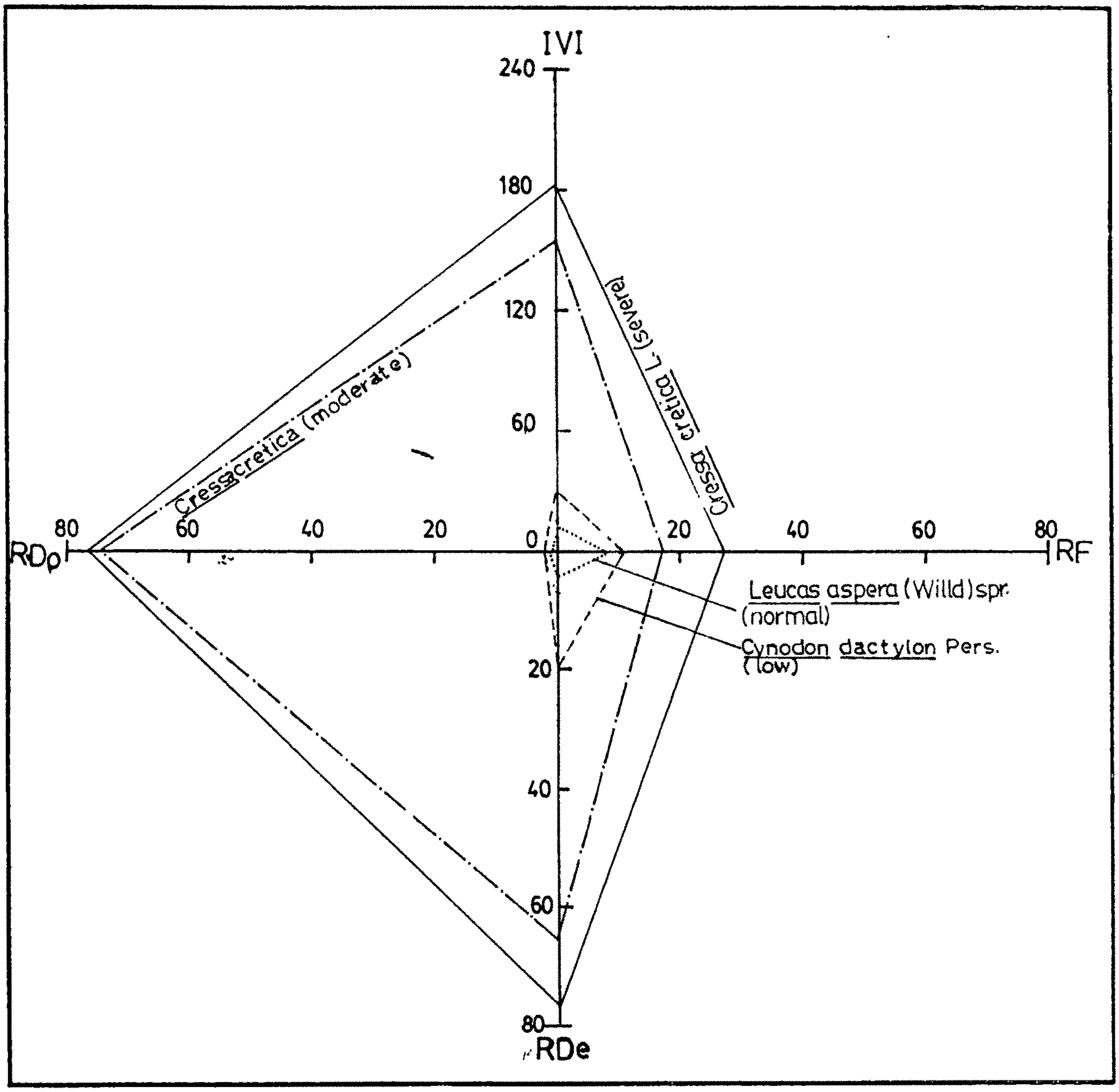

FIG.23.PHYTOGRAPH SHOWING MAXIMUM IMPORTANT VALUE INDEX OF SPECIES AT DIFFERENT SALINE SOILS.

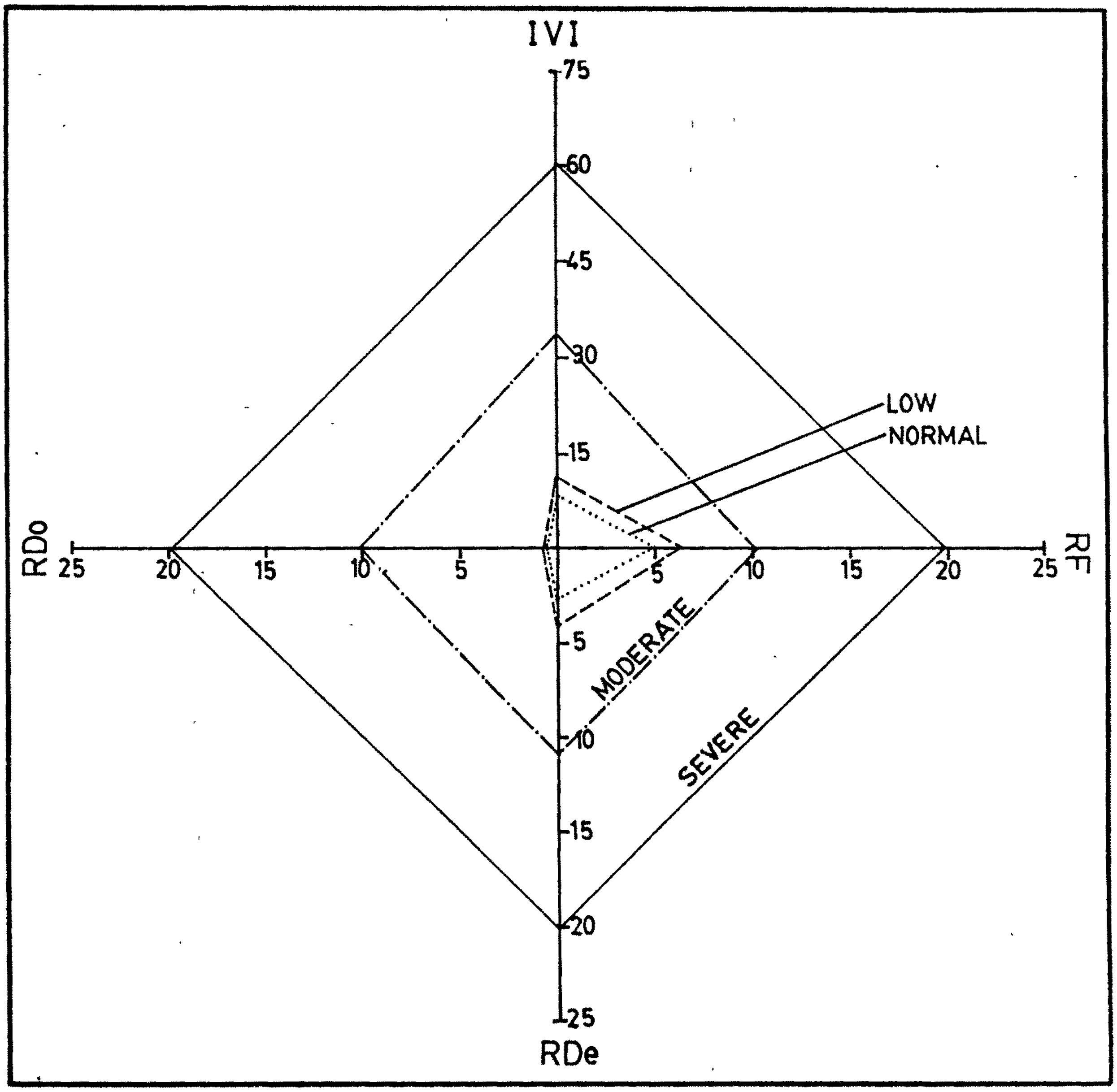

FIG.24. PHYTOGRAPH SHOWING THE INCREASING AVERAGE IMPORTANT VALUE INDEX OF WEEDS FROM NORMAL TO SALINE (LOW, MODERATE, SEVERE) AFFECTED SOILS.

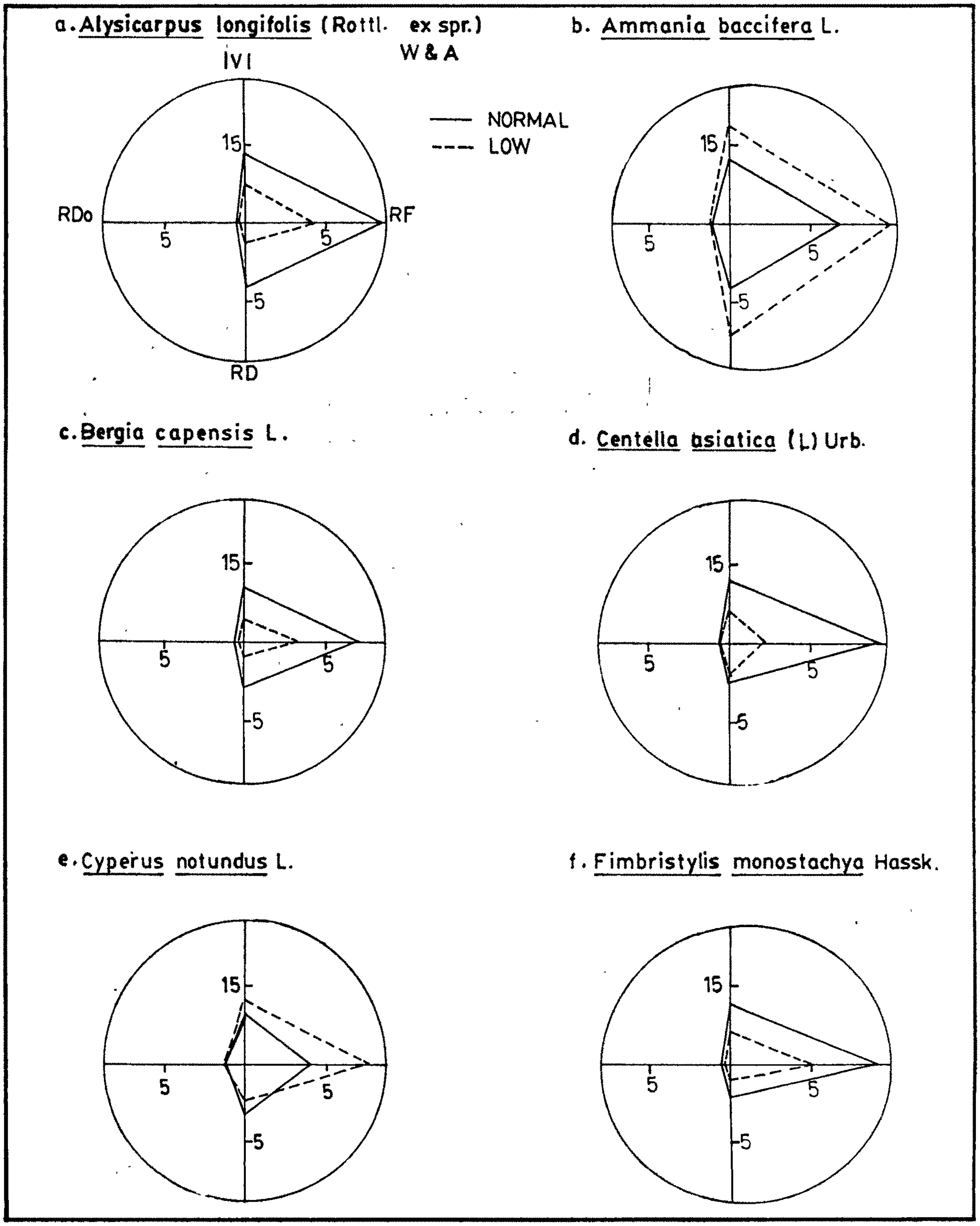

FIG. 25 IMPORTANT VALUE INDICES [PHYTOGRAPHS] OF IMPORTANT SPECIES FROM LOW SALINE AND NORMAL SOIL.

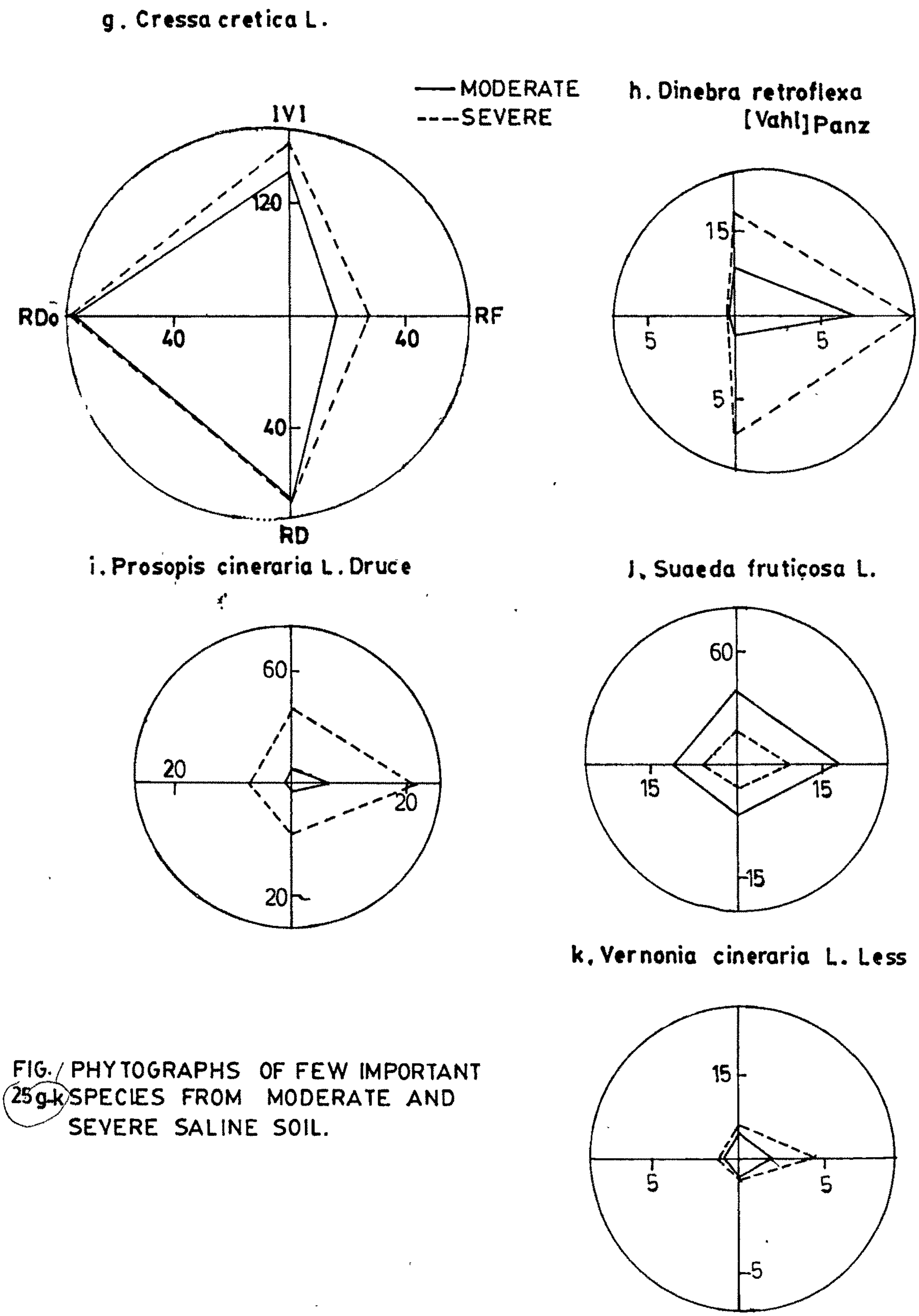

FIG. 25g-k / PHYTOGRAPHS OF FEW IMPORTANT SPECIES FROM MODERATE AND SEVERE SALINE SOIL.

Table 44. Phytosociological study showing weed structure at different salinity levels

	Normal	LS	MS	SS
Species diversity Index	0.86	0.77	0.44	0.37
Evenness Index	0.31	0.31	0.15	0.22
Dominance Index	0.29	0.27	0.49	0.60
Richness Index	6.56	5.13	2.66	2.4

LS = Slightly Saline; MS = Moderately Saline;

SS = Strongly Saline

whereas weeds of normal and moderate fields or normal and strongly affected fields exhibited total dissimilarity. Thus the change in weed composition with increasing stress condition was evident. At severe salinity totally emerged new species which could survive and adapt in the stress condition with complete disappearance of certain species (Table 45). Weeds like Acalypha indica L., Astercantha longifolia Nees, Celsia coromandeliana Vahl, Cleome viscosa L., Cyanotis axillaris (L.) Schult. f., Enicostema hyssopifolium (Willd). Verdoon, Ipomoea acquatica Forsk disappeared at slight salinity. Though Alysicarpus longifolius W. & A. (Rottl. ex Spr.) and Ammania baccifera L. and Bergia capensis L., Centella asiatica (L.) Urb., Cyperus rotundus L. were present at slight salinity, they ceased to exist as the soils become saline further. Commelina benghalensis L. was observed only at slight salinity while Aleuropus lagopoides, Prosopis cineraria (L.) Druce and Suaeda fruticosa Forsk ex Gmel. emerged only at moderate and strong salinity (Plate 15-17). Plotting the number of species on a log scale against species sequence indicated that in normal and low conditions species tend to assume a log normal form while in moderate and severe condition, the curves tend to assume a straight line form and fitted best in the geo-metric series of niche-premption model (Fig. 26). Graphical representation between the number of species and number of individuals per species (N/S) showed a concave hollow curve for the normal fields as observed in most of the natural communities, but with increasing salinity stress the curves flattened (Fig. 27). The shoot system of certain weeds

Table 45. Trend of species appearance or disappearance at fields of different salinity levels

	Name of the weeds	NS	LS	MS	SS
1.	*Acalypha indica* L.	+	-	-	-
2.	*Alysicarpous longifolius* W. & A.	+	+	-	-
3.	*Aeluropus lagopoides* (L.) Trin	-	-	-	+
4.	*Ammannia baccifera* L.	+	+	-	-
5.	*Astercantha longifolia* Nees	+	-	-	-
6.	*Bergia capensis* L.	+	+	-	-
7.	*Brachiaria ramosa* (L.) Stapf	-	+	-	-
8.	*Centella asiatica* (L.) Urb.	+	+	-	-
9.	*Celsia coromandeliana* Vahl	+	-	-	-
10.	*Cleome viscosa* (L.)	+	-	-	-
11.	*Commelina benghalensis* L.	-	+	-	-
12.	*Corchorus acutangulus* Lam.	-	-	+	-
13.	*Cressa cretica* (L.)	-	-	+	+
14.	*Cyanotis axillaris* (L.) Schult. f.	+	-	-	-
15.	*Cyperus rotundus* L.	+	+	-	-
16.	*Dinebra retroflexa* (Vahl) Panz.	+	+	-	-
17.	*Digera arvensis* Forsk	-	-	+	-
18.	*Eclipta prostrata* (L.)	-	+	-	-
19.	*Enicostema hyssopifolium* (Willd.)	+	-	-	-
20.	*Euphorbia hypericifolia* (L.) var. Parviflora (L.) Prain	-	+	-	-

Name of the weeds	NS	LS	MS	SS
21. Fimbristylis monostachya Hassk.	+	+	-	-
22. Ipomoea acquatica Forsk	+	-	-	-
23. Leucas aspera Spr.	+	-	-	-
24. Limnophila indica (L.) Druce	-	+	-	-
25. Ocimum canum Sims	+	-	-	-
26. Prosopis cineraria (L.) Druce	-	-	+	-
27. Suaeda fruticosa (L.) Forsk ex Gmel.	-	-	+	+
28. Vernonia cineria (L.) Less.	-	+	+	-
29. Vicoa indica (L.) DC.	-	-	+	-

\+ = Present; - = Absent

NS = Normal; LS = Slightly Saline

MS = Moderately saline; SS = Strongly saline

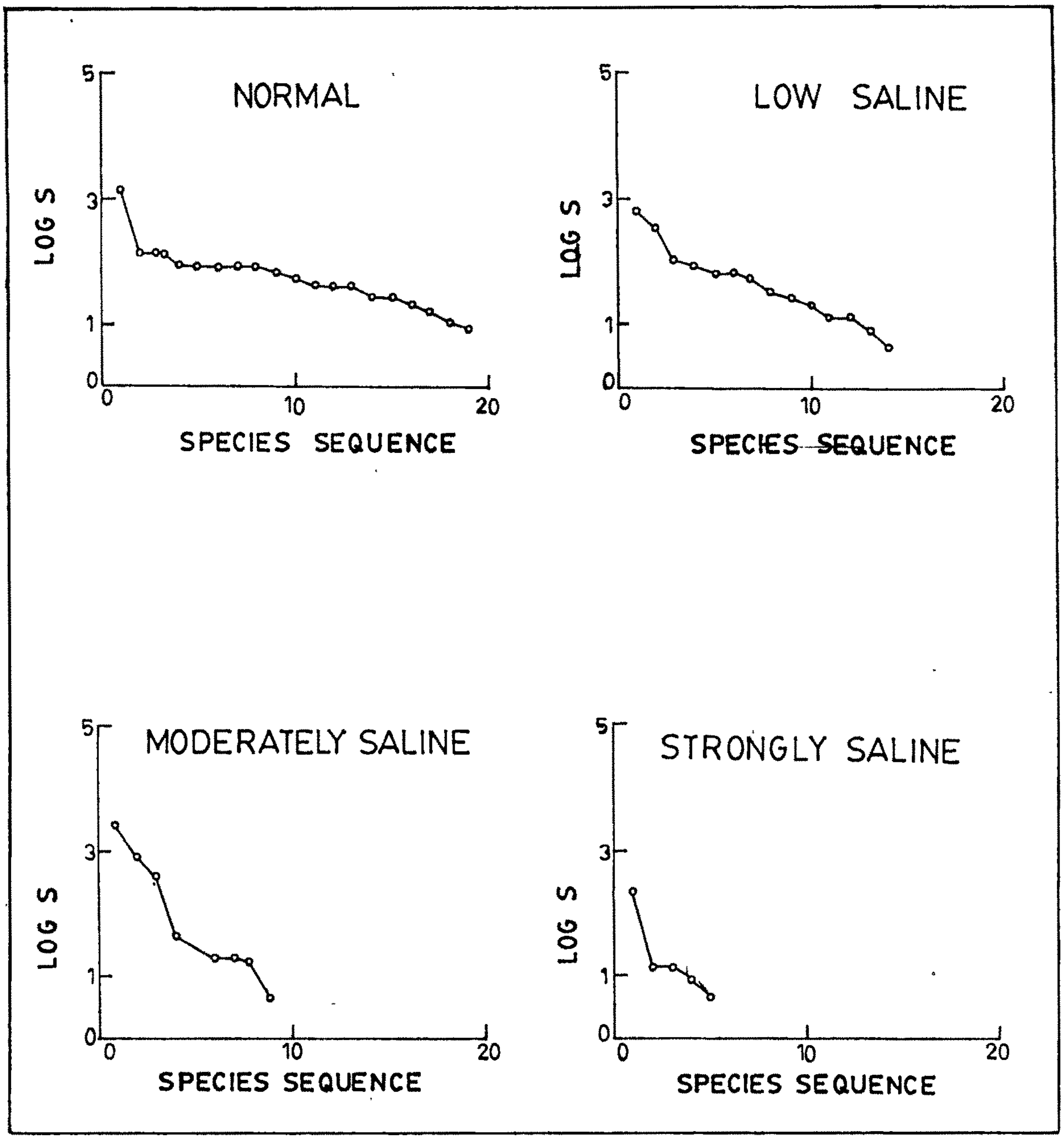

FIG. 26. DOMINANCE DIVERSITY CURVES FOR WEED SPECIES AT DIFFERENT SALINITY LEVELS.

Refer "Communities and Ecosystem" By Whitaker.

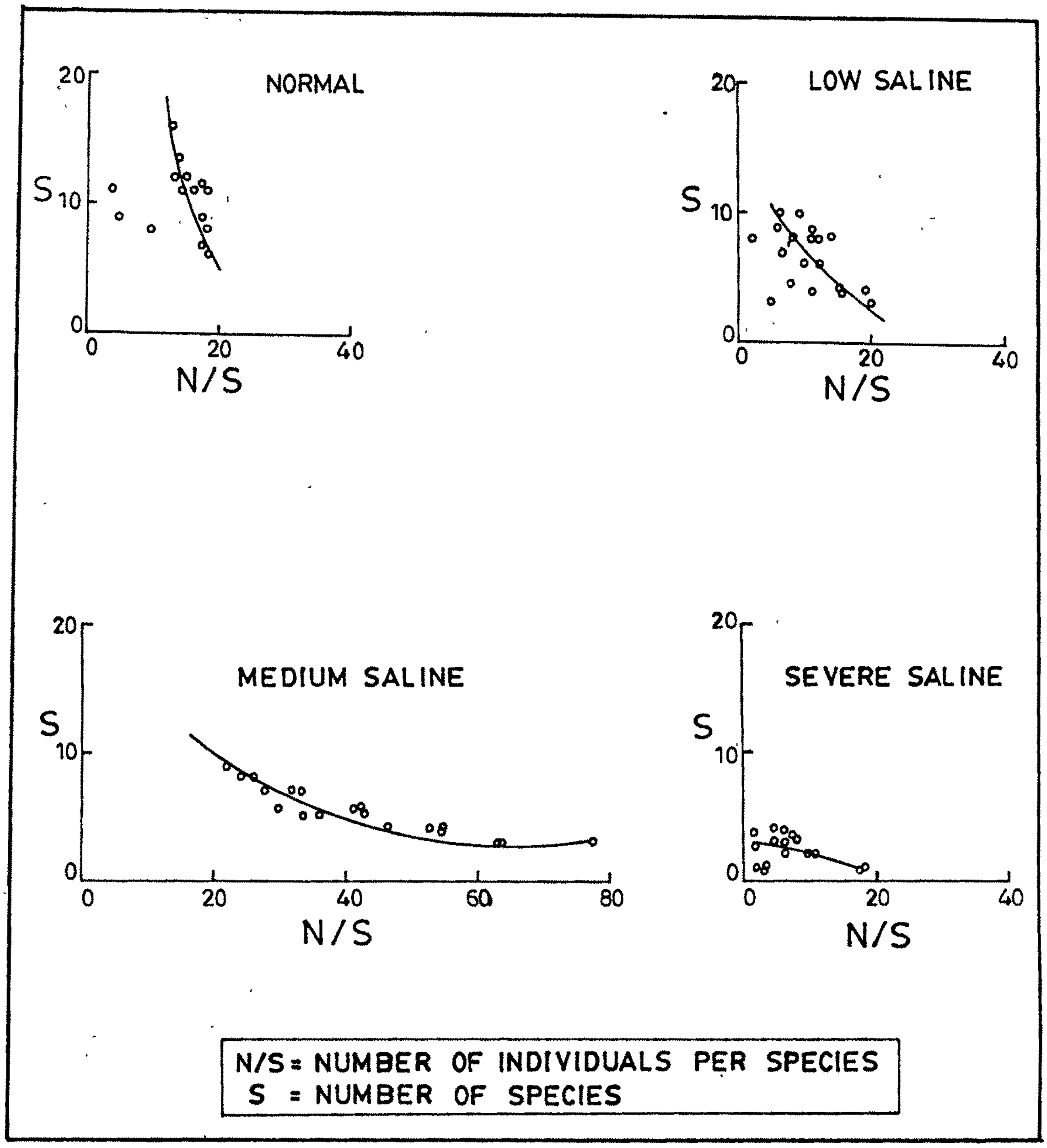

FIG 27. GENERAL RELATIONSHIP BETWEEN THE NUMBER OF SPECIES AND NUMBER OF INDIVIDUALS AT DIFFERENT SALINITY LEVELS.

is it based on quadrats employed during different months/seasons/ sites of same level - ?

PLATE 15

Strongly affected saline soil with weed
<u>Prosopis</u> <u>Cineraria</u> (L.) Druce.

PLATE 16

Strongly affected saline soil with weed Aeluropus Lagopoides Trin.

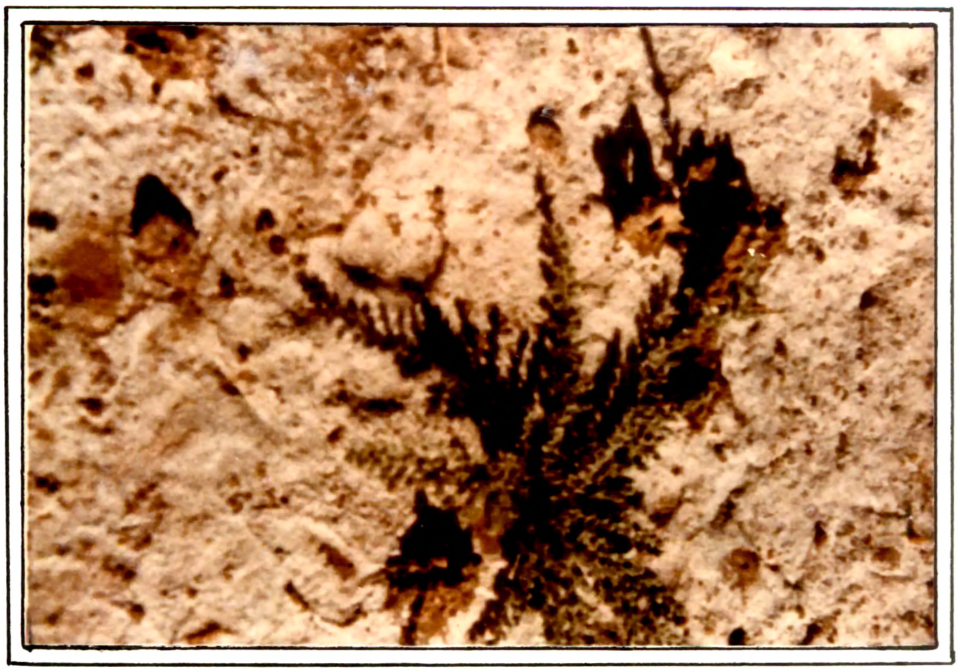

PLATE 17

Strongly affected saline soil with _Suaeda fruticosa_ (L.) Forsk. ex Gmel.

harvested from the severe saline affected fields exhibited a very high accumulation of Na^+, K^+ and Ca^{2+} (Table 46). The Na/K ratio was also found to be very high.

3.2.3 Ionic Status of Plants

The ionic content of rice cultivar Mahsuri at different salinity levels revealed an accumulation of sodium with a concurrent increase of potassium content. The Na^+ content increases almost by 2.4, 1.6 and 2 fold in root, stem and leaf, respectively at strong salinity. The K/Na ratio increased in stem and leaf but decreased in root (Table 47). There was a drastic reduction in Ca^{2+}, and Mg^{2+} content of root, stem and leaf with the increasing levels of salinity. Rice cv. Mahsuri could accumulate Cl^- in different parts amounting to 20 to 32 fold. The ionic accumulation capacity of rice cultivars Bhura rata and Mahsuri indicated interesting results (Table 48). Mahsuri accumulated more sodium as compared to Bhura rata almost by 13, 67 and 15 per cent in the root, stem and leaf respectively. Mahsuri also accumulated potassium content in the stem and leaves more than Bhura rata. The same cultivar also accumulated a large amount of calcium and magnesium ions in its root and stem. There was not much differences in the accumulation of Cl^- in the leaves of both varieties whereas the stem and root of Bhura rata could accumulate more (Cl^-).

Table 46. Ionic levels (meq/g dry matter) in different weeds growing in strongly salt affected soils

Name of the weed	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	K^+/Na^+
1. *Alhagi camelorum* (Fish)	0.88 (0.01)	0.26 (0.01)	0.65 (0.02)	0.93 (0.01)	1.02	0.29
2. *Aeluropus lagopoides*(L.) Trin.	1.53 (0.01)	0.22 (0.01)	0.34 (0.02)	0.5 (0.04)	1.32 (0.06)	0.14
3. *Cressa cretica* L.	1.08 (0.07)	0.25 (0.01)	0.85 (0.06)	0.14 (0.01)	1.24 (0.04)	0.23
4. *Heliotropium ellipticum* Ledeb	0.66 (0.09)	0.28 (0.02)	0.71 (0.07)	0.12 (0.01)	1.26 (0.01)	0.42
5. *Prosopis cineraria* (L.) Druce	0.82 (0.01)	0.23 (0.01)	1.01 (0.00)	0.34 (0.02)	1.5 (0.02)	0.28
6. *Suaeda fruticosa* (L.) Forsk ex Gmel.	1.25 (0.01)	0.14 (0.00)	0.43 (0.02)	0.31 (0.01)	0.96 (0.01)	0.112
7. *Tamarix troupii* Hole	0.85 (0.02)	0.13 (0.01)	0.66 (0.00)	0.47 (0.01)	1.15 (0.05)	0.15

Figures in parentheses represent standard error.

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Table 47. Cationic levels (µeq/g dry matter) in different parts of rice cultivar Mahsuri grown in field of different salinity levels

	Root				Stem				Leaf			
	N	LS	MS	SS	N	LS	MS	SS	N	LS	MS	SS
Na^+	29 (2.6)	50 (1.2)	70 (2.2)	70 (1.5)	69 (5.3)	75 (3.6)	102 (6.8)	110 (5.2)	38 (3.0)	66 (5.3)	70 (3.3)	75 (7.9)
K^+	90 (0.01)	65 (1.2)	75 (7)	113 (9)	20 (0.01)	74 (1.0)	74 (10)	125 (7.1)	30 (0.01)	69 (3.4)	103 (7)	118 (3)
K^+/Na^+	3.1	1.3	1.1	1.6	0.3	1	0.7	1.1	0.8	1	1.5	1.6
Ca^{2+}	740 (11)	350 (6)	340 (3.5)	140 (2)	350 (2.9)	240 (3)	216 (7)	80 (3.1)	285 (2.1)	160 (8.5)	105 (3.1)	50 (5.0)
Mg^{2+}	2168 (14.2)	1222 (30.0)	1122 (69)	330 (26.8)	2250 (22)	2400 (52)	1767 (17)	312 (3)	2018 (67)	1228 (89)	1208 (43)	343 (13)
Cl^-	44 (7)	55 (3)	727 (15)	1402 (57)	35 (2.5)	45 (2.8)	575 (44)	725 (47)	62 (10)	63 (3)	713 (59)	1260 (18)

N = Normal; ECe, 1.4 dSm^{-1}; L= Slightly saline 6.3 dSm^{-1}; M = Moderately saline; ECe, 11.6 dSm^{-1}; S = Strongly saline ECe, 25.6 dSm^{-1}; Figures in parentheses represent standard error.

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Table 48. Ionic levels (μeq/g dry wt.) in different rice cultivars grown in fields of moderate salinity

Ions	Root		Stem		Leaf	
	Mahsuri	Bhura rata	Mahsuri	Bhura rata	Mahsuri	Bhura rata
Na^+	70 (2.2)	62 (4.7)	102 (6.8)	61 (1.0)	70 (3.3)	61 (1.0)
K^+	75 (7.0)	142 (2.5)	74 (1.0)	113 (5.6)	103 (7.0)	74 (1.0)
K^+/Na^+	1.1	2.3	0.7	1.8	1.5	1.2
Ca^{2+}	340 (3.5)	84 (2)	216 (7)	94 (3.0)	105 (3.1)	240 (3.0)
Mg^{2+}	1122 (6.9)	414 (13)	1767 (17)	850 (5.0)	128 (4.3)	177 (16.8)
Cl^-	73.7 (15)	105 (1.15)	575 (44)	766 (56)	713 (59)	727 (15)

Figures in parentheses represent standard error; Salinity for Mahsuri; ECe=11.6 dSm^{-1}; ESP = 18.1; pH = 7.6; Salinity for Bhura rata = ECe = 10.0 dSm^{-1}; ESP = 12.9; pH = 7.5

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3.3 LABORATORY STUDIES

3.3.1 Growth and Yield as Affected by Salinity

3.3.1.1 Mortality Rate of Rice Cultivars under Different Saline Levels

The study on mortality rate showed cv. SRB-26 with nil mortality under control as well as under salt treatment, while the other four varieties tested indicated varying degrees of mortality rates (Fig. 28). Salinity treatment for 22 days increased the mortality rate of GR3from 8 per cent to 50 and 55 per cent under Low Salinity (LS) and High Salinity (HS). The next susceptible varieties were IR 28, IR 20 and the least susceptible was Mahsuri. As the salinity treatment prolonged upto thirty two days, there was 100 % mortality under the HS in cvs GR 3 and IR 28 and under LS in IR 28. The cvs IR 20 and Mahsuri responded less adversely under HS. In the third set salinisation was introduced from 25 days to 39 days in a step-wise increase (Fig. 29). Of the four varieties used cvs. Bhura rata and IR 28 succumbed completely 70 days after the salinisation SLR 51425 and Mahsuri were more resistant and their mortality rate ranged from 40-62 %. Thus the rice cultivars GR 3, IR 20, IR 28 and Bhura rata were unable to withstand salinity levels of 8 ECe and 14-16 ECe whereas rice cvs. SRB 26, Mahsuri and SLR 51425 were found to be more promising than the others to survive under the saline substratum.

3.3.1.2 Growth of Rice Cultivars under Different Saline Levels

Salinity affects the growth of rice cultivars (Plates 18-24; Figs. 30-38; Tables 49-52). Amongst the different rice

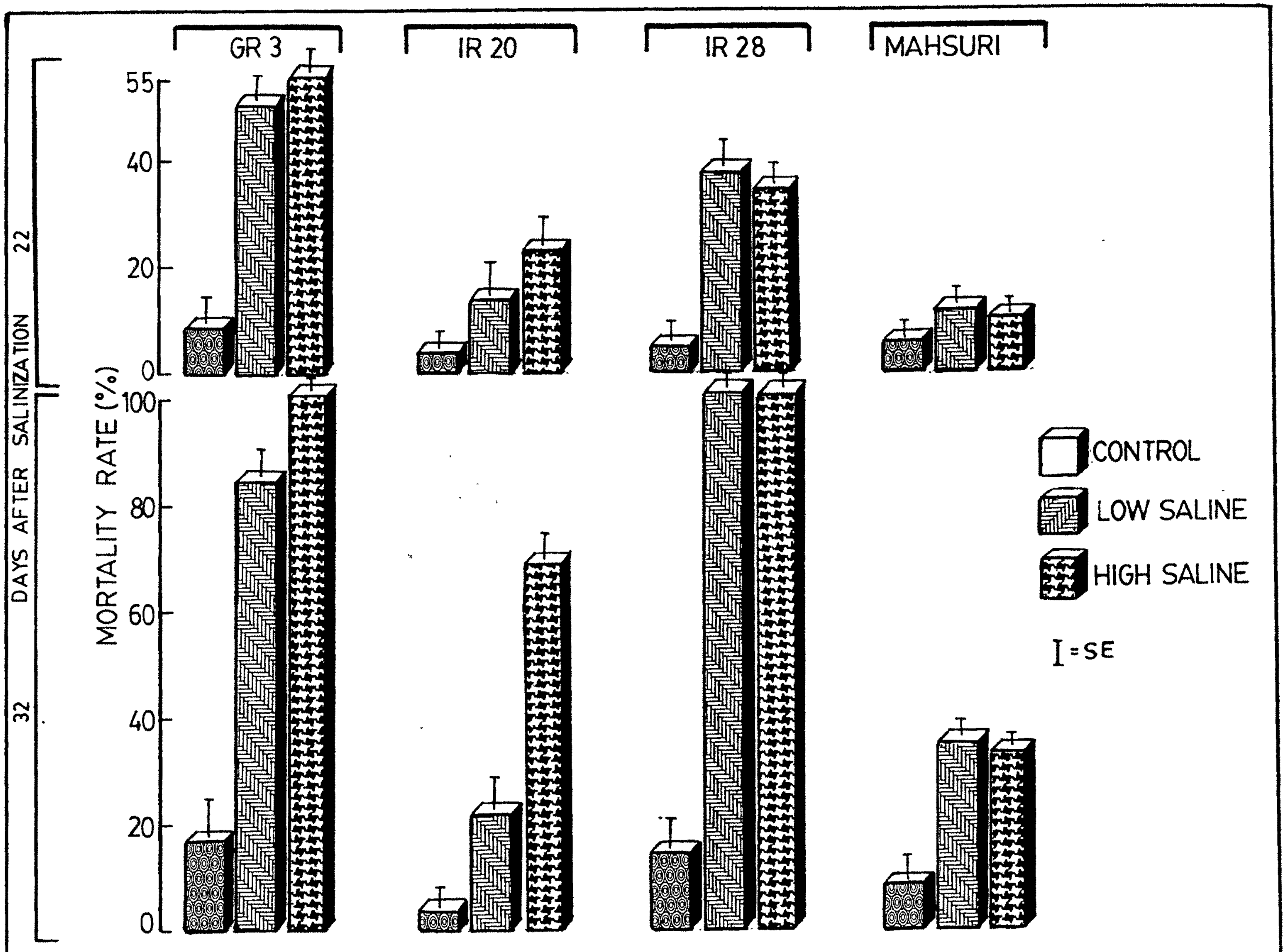

FIG.28.MORTALITY RATE OF RICE CULTIVARS OF SET III TOWARDS NaCl SALINITY.

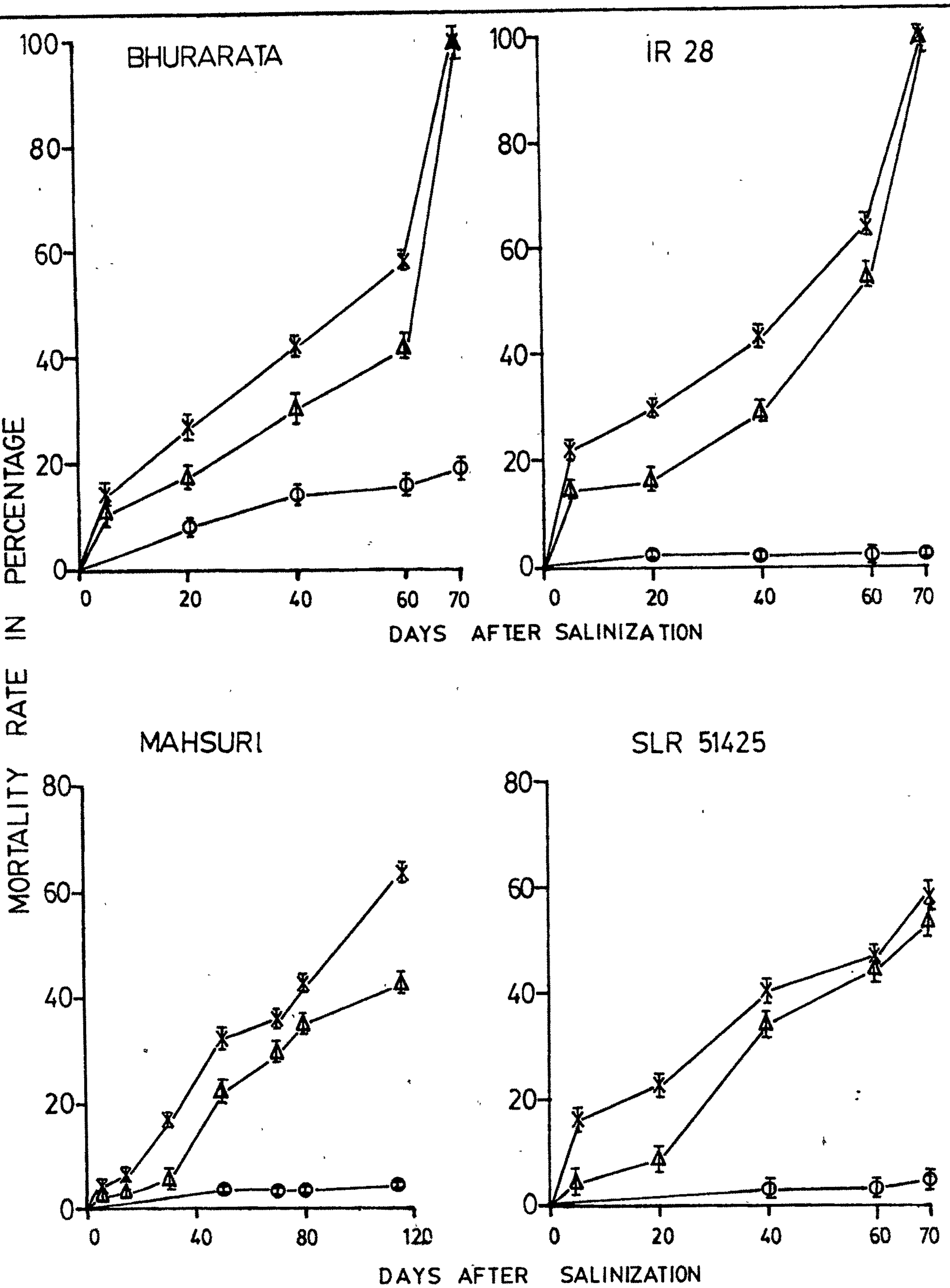

FIG.29. MORTALITY RATE OF RICE CULTIVARS OF SET I TOWARDS NaCl SALINITY.

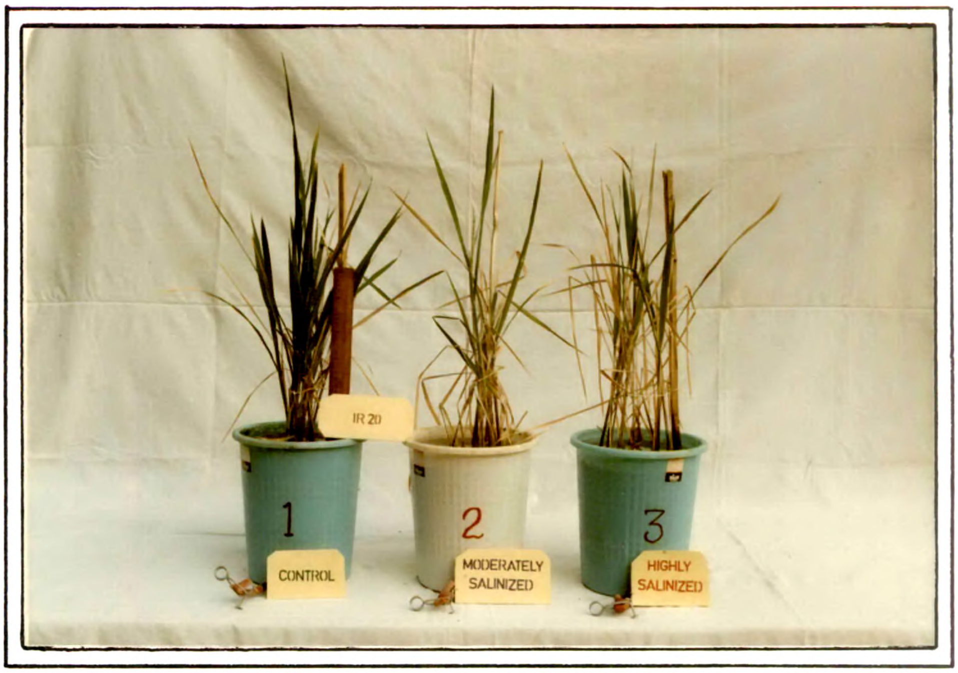

PLATE 18

Growth of rice cultivar IR 20 at different salinity levels.

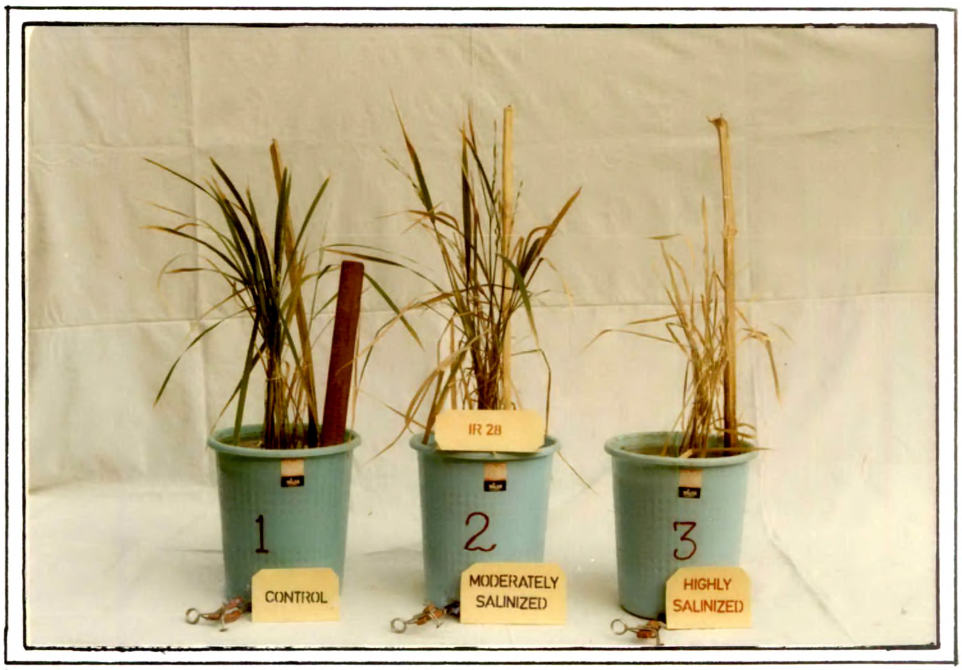

PLATE 19

Growth of rice cultivar IR 28 at different salinity levels.

PLATE 20

Growth of rice cultivar Mahsuri at different salinity levels.

PLATE 21

Growth of rice cultivar SRB-26 at different salinity levels.

PLATE 22

Comparison of rice cultivars SRB-26 and Mahsuri at moderate salinisation.

PLATE 23

Comparison of rice cultivars Mahsuri and SRB-26 at high salinity.

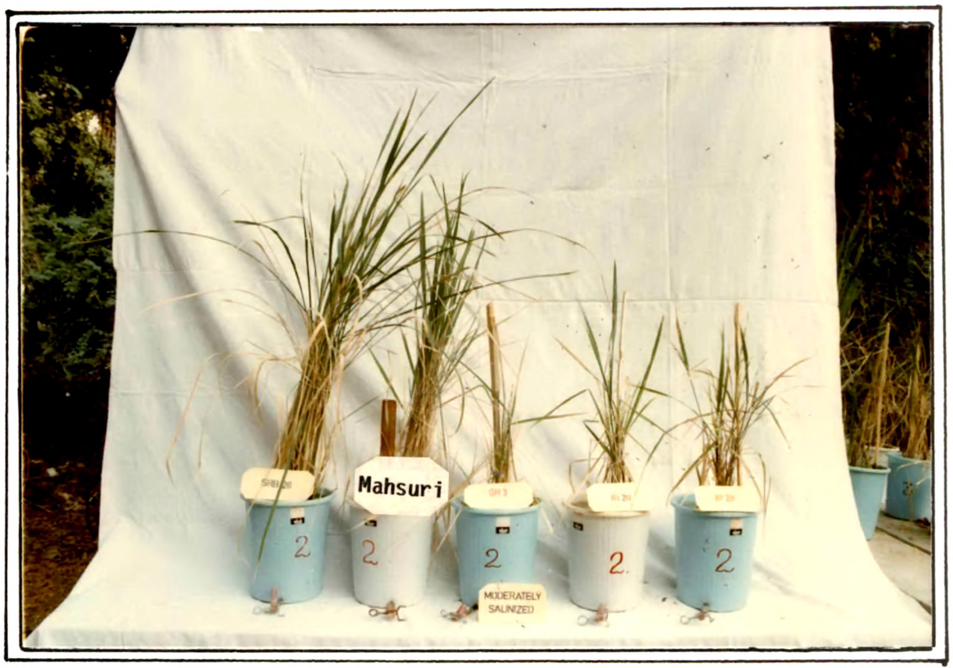

PLATE 24

Comparison of different rice cultivars viz., SRB-26, Mahsuri, GR 3, IR-20, IR-28, at moderate salinization.

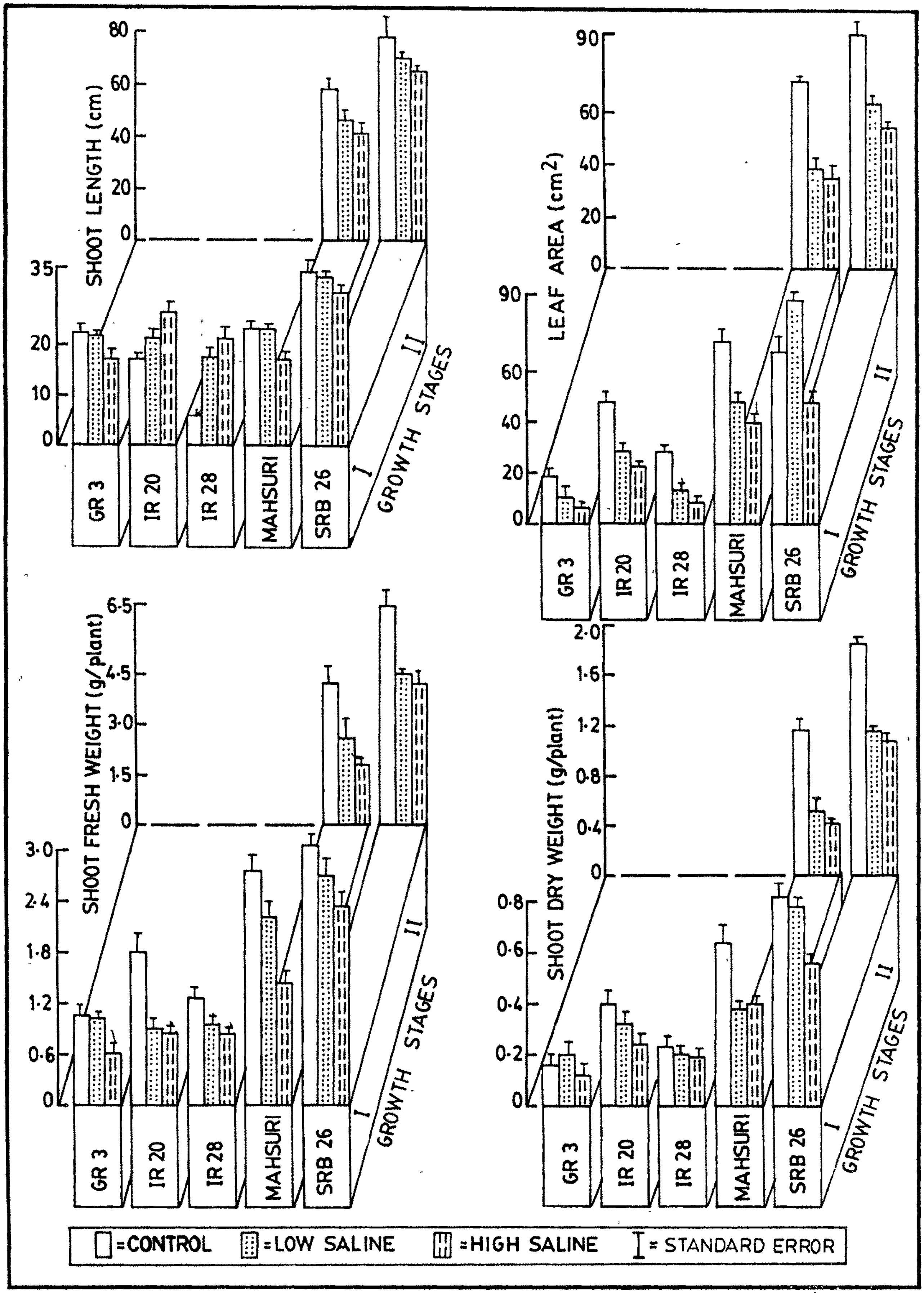

FIG.30.EFFECT OF NaCl TREATMENT ON THE GROWTH PARAMETERS OF GROWTH STAGES I AND II RICE CULTIVARS OF SET 1.

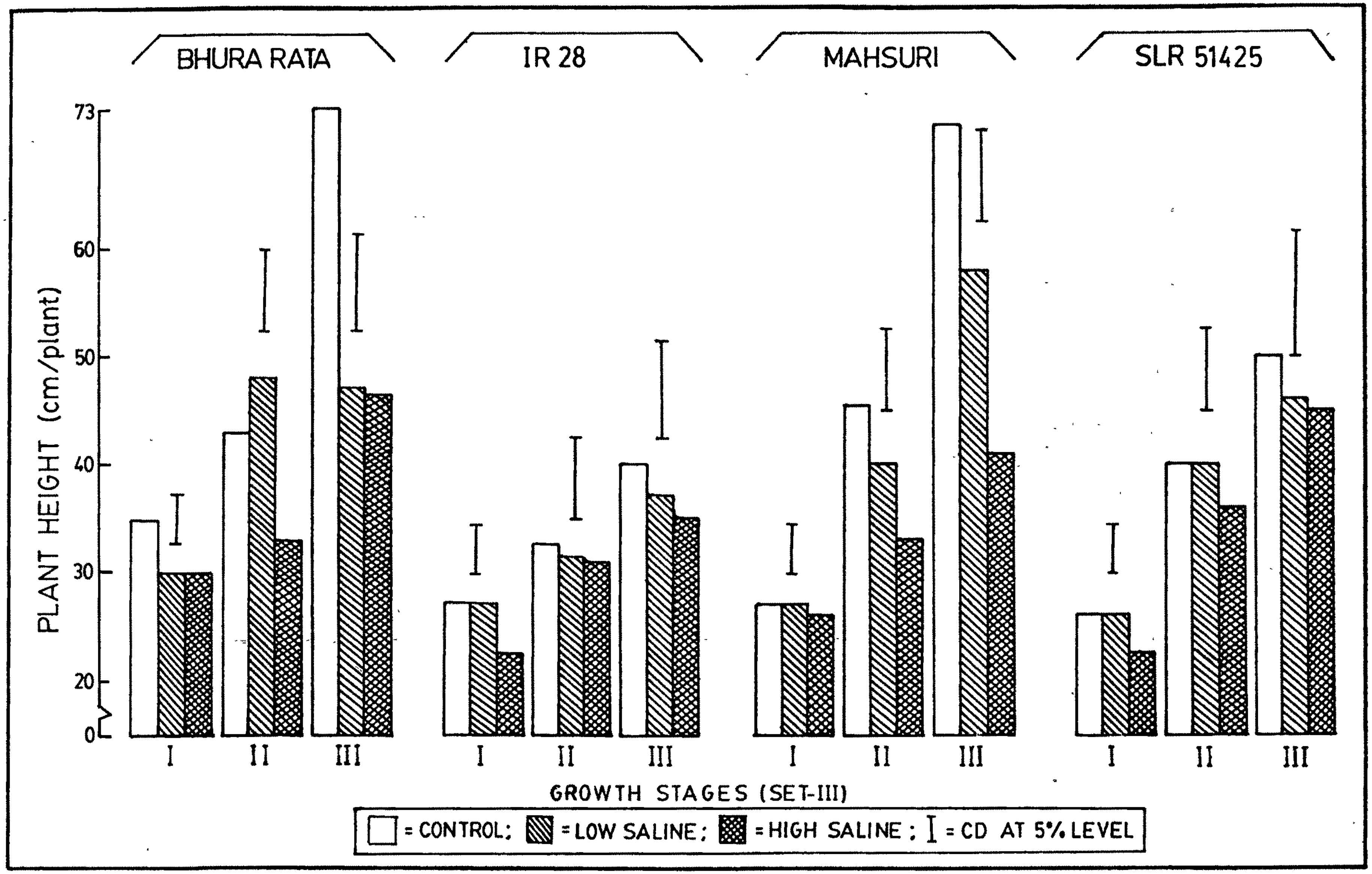

FIG. 31. EFFECT OF NaCl SALINITY ON THE LENGTH OF SHOOT SYSTEM OF RICE CULTIVARS AT DIFFERENT GROWTH STAGES OF SET III.

Table 49. Mean squares from the ANOVA of the growth parameter of rice response variables (growth stage I) of Set I

Source	df	Length of shoot	Shoot fresh wt.	Shoot dry wt.	Leaf area
Replicate	14	61.0	246	7.5	75.2
Cultivar	4	444.3**	5610**	2255	8827.5**
Salt treatment	2	2.2	920**	11.3	2990.5**
Cultivar x salt treatment	8	94.9*	480	36	505.0**
Error	56	46.9	212	10	158.9

Levels of significance at 1 % =(**) and 5 % = (*) analysed separately.

Table 5Ø. **Mean squares from the ANOVA of different growth parameters of rice response variables growth stage II of set I**

Source	df	Length of shoot	Fresh wt. of shoot	Dry wt. of shoot	Leaf area
Replicate	4	265.9	45.Ø	21.Ø	89.6
Cultivar	1	332Ø **	3Ø5Ø **	198.Ø **	4Ø18 **
Salt treatment	2	3785 **	111.Ø **	118.Ø **	57.1
Cultivar % salt treatment	2	45.9	7Ø.Ø	46.Ø **	12.4
Error	2Ø	5Ø6.9	128.Ø	6.Ø	85.1

** Significant at 1 % level.

Table 51. Mean squares from the ANOVA of different growth parameters of rice response variables of set III

Source	df	Length of shoot system			Leaf area x10			Length of stem			Root length x10^{-1}		
		GROWTH STAGES											
		I	II	III	I	II	III	I	II	III	I	II	III
Replicate	4	0.5	1.8	7.7	1.7	11.1	50.3	2.2	6.8	48.7	0.9	11.7	22
Cultivar	3	14.4**	26.9**	125.3**	4.3	91.6**	92.4**	22.0*	61.6**	171.5**	19.7	153.5**	207**
Salt treatment	2	2.8	31.4**	145.8**	4.5	104.1**	117.4**	6.6	18.8	765.2**	212.5	100.3**	104.2**
Cultivar X saltt treatment	6	2.1	79.4	32.5	1.4	15.2	27.2	2.7	17.8	133.3**	74	105**	339.5**
Error	44	2.1	5.2	7.9	1.7	12.4	25.4	5.5	6.1	24.8	10.9	8.3	13.8

Level of significance; at 5 % (*); at 1 % (**)

Table 52. Mean squares from ANOVA of rice response variables of set III on biomass accumulation

Source	df	Dry weight of shoot system I	Dry weight of shoot system II	Dry weight of shoot system III	Dry weight of stem I	Dry weight of stem II	Dry weight of stem III	Dry weight of leaf I	Dry weight of leaf II	Dry weight of leaf III	Dry weight of root I	Dry weight of root II	Dry weight of root III
Replicate	4	92.1	1.1	3.1	88	1.0	2.0	4.1	0.1	1.1	5.2	21	125
Cultivar	3	6539**	124	82**	6427**	83**	50*	112**	41.0**	32.0**	125**	2070**	6809**
Salt treatment	2	1408	45.1	61**	1363	0.1	30**	45	23**	31**	71**	16.6**	1059**
Cultivar x salt treatment	6	5701**	23.0	8.7	5701**	1.0	5.0	0.6	21**	37	34**	278	1134**
Error	44	834	45.0	4.7	790	1.0	2.5	44	0.4	2.2	10	118	163

Levels of significance: at 1% (**) and 5 % (*)

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cvs. tried in the Kharif season of 1987, SRB 26 and Mahsuri were found to be tolerant to the moderate salinity of ECe 8 dSm^{-1}. The above varieties could also survive in highly salinised medium having the ECe of 16 dSm^{-1}. More than 20 days of salinisation had an adverse effect on shoot length of all the rice cultivars used in the experiment (Fig. 30-31). The effect of salinity on the plants at Growth Stage I(GSI) of Set III was very mild due to the dilution effect that existed in the initial stages of treatment. Salinity decreased the photosynthetic leaf area in general (Fig. 30 and 33). However, SRB 26 at GSI in first set and Bhura rata and Mahsuri at GS II of third set indicated a tendency to increase the photosynthetic area under LS. The reduction in the photosynthetic leaf area computed at the last stage of growth under HS amounted to 40-92 %. The photosynthetic dry matter accumulation was decreased significantly at the growth stage II and III under HS (Fig. 34, Table 52). Interestingly Mahsuri in Set III accumulated leaf dry matter without any inhibition at LS at all stages of growth studied and the inhibition was found to be low at HS in the last stage of growth (Fig. 34). The length of the stem was affected by salinity and the effect was significantly evident at the last stage of growth (Fig. 35). The saline medium did not affect the length of stem of Mahsuri significantly. In general Mahsuri was also capable of accumulating high or equal amount of culm dry matter (Fig. 36). In response to low salinity this cultivar could increase its culm dry matter by 2.2 fold. When it was exposed to prolonged saline condition, the culm dry matter did not register any significant decrease. Likewise the cv. SLR 51425 indicated a tendency to

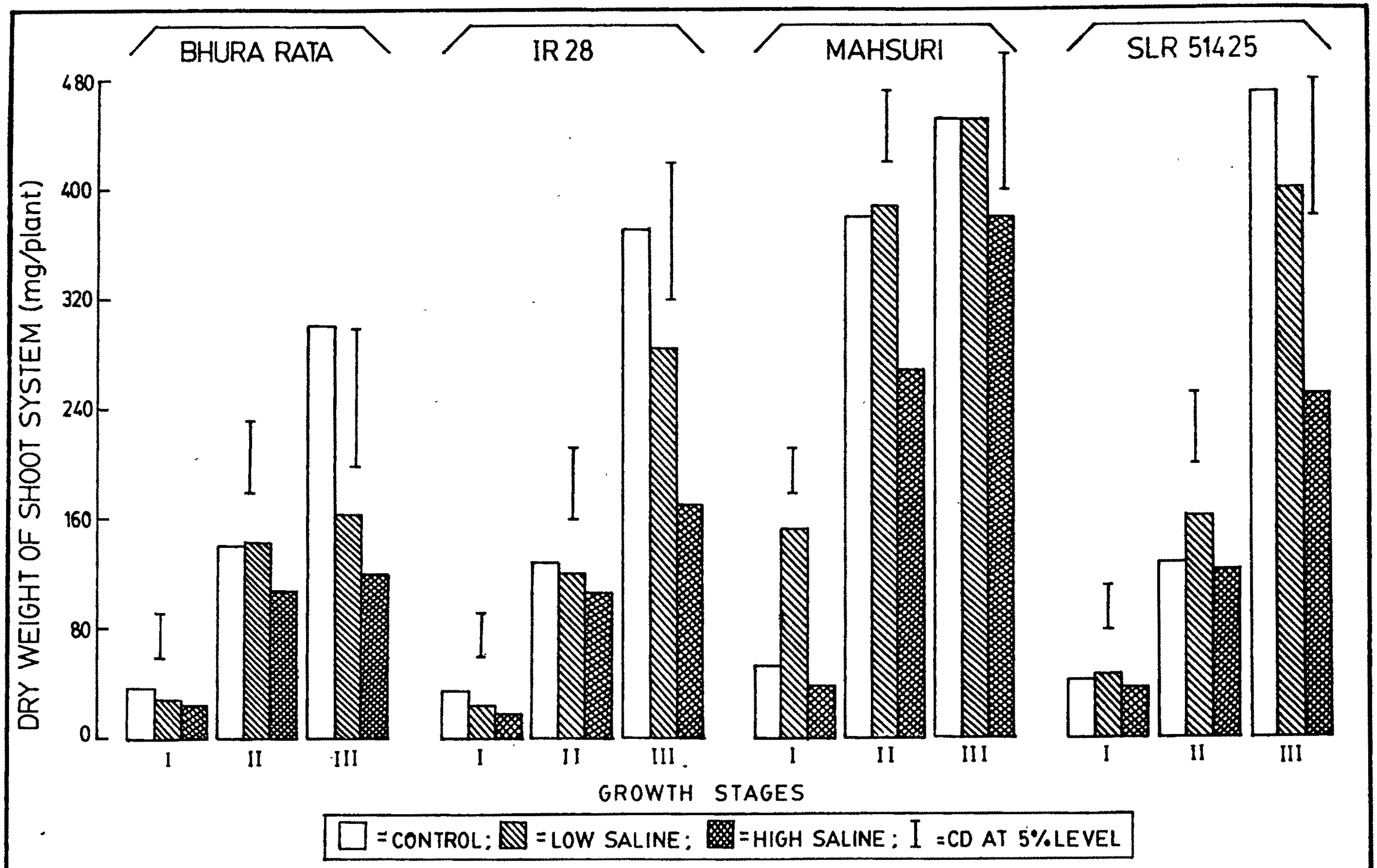

FIG.32. EFFECT OF NaCl SALINITY ON THE SHOOT DRY MATTER ACCUMULATION OF RICE CULTIVARS AT DIFFERENT GROWTH STAGES OF SET III.

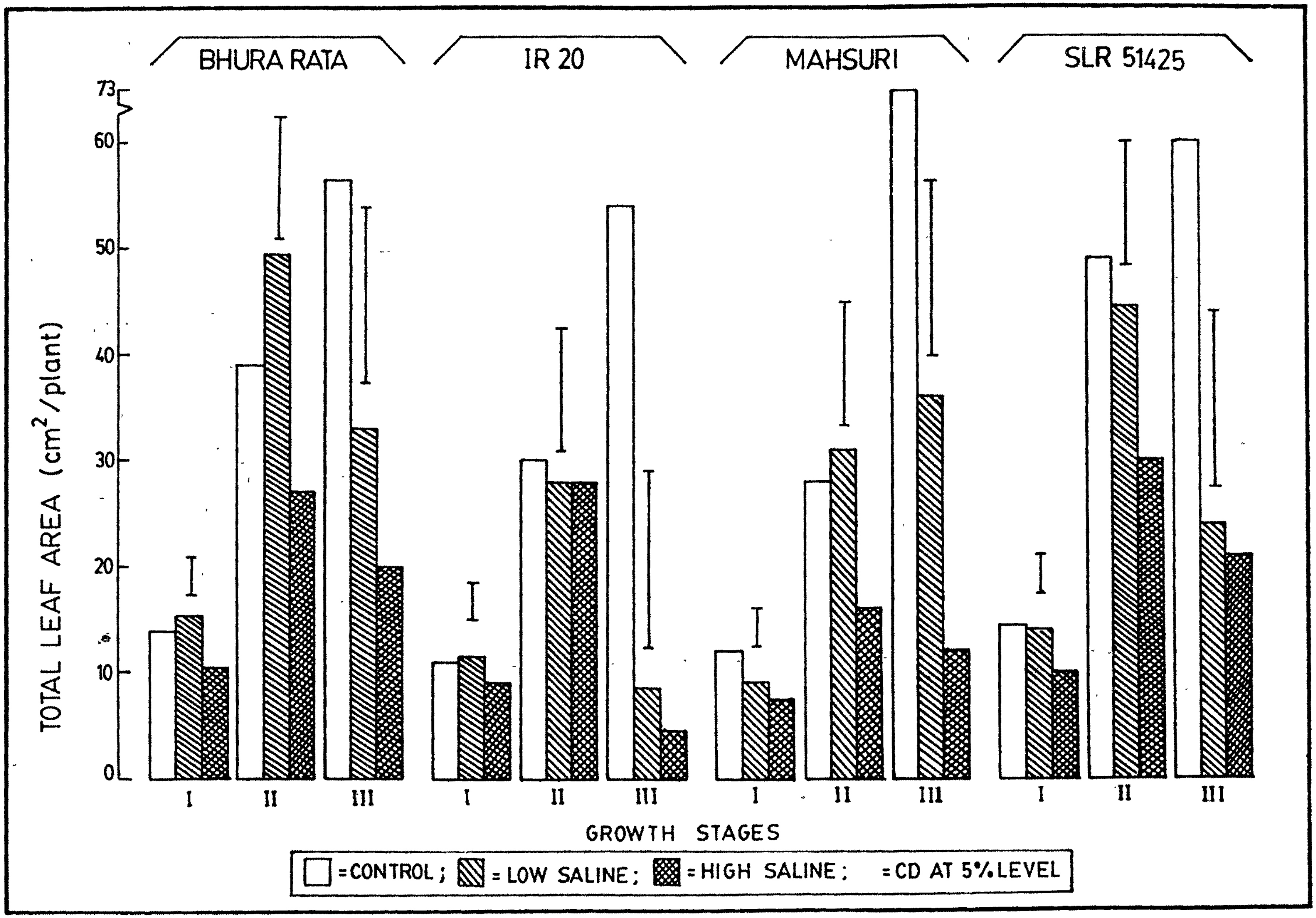

FIG.33. EFFECT OF NaCl SALINITY ON PHOTOSYNTHETIC LEAF AREA OF RICE CULTIVARS AT DIFFERENT GROWTH STAGES OF SET III.

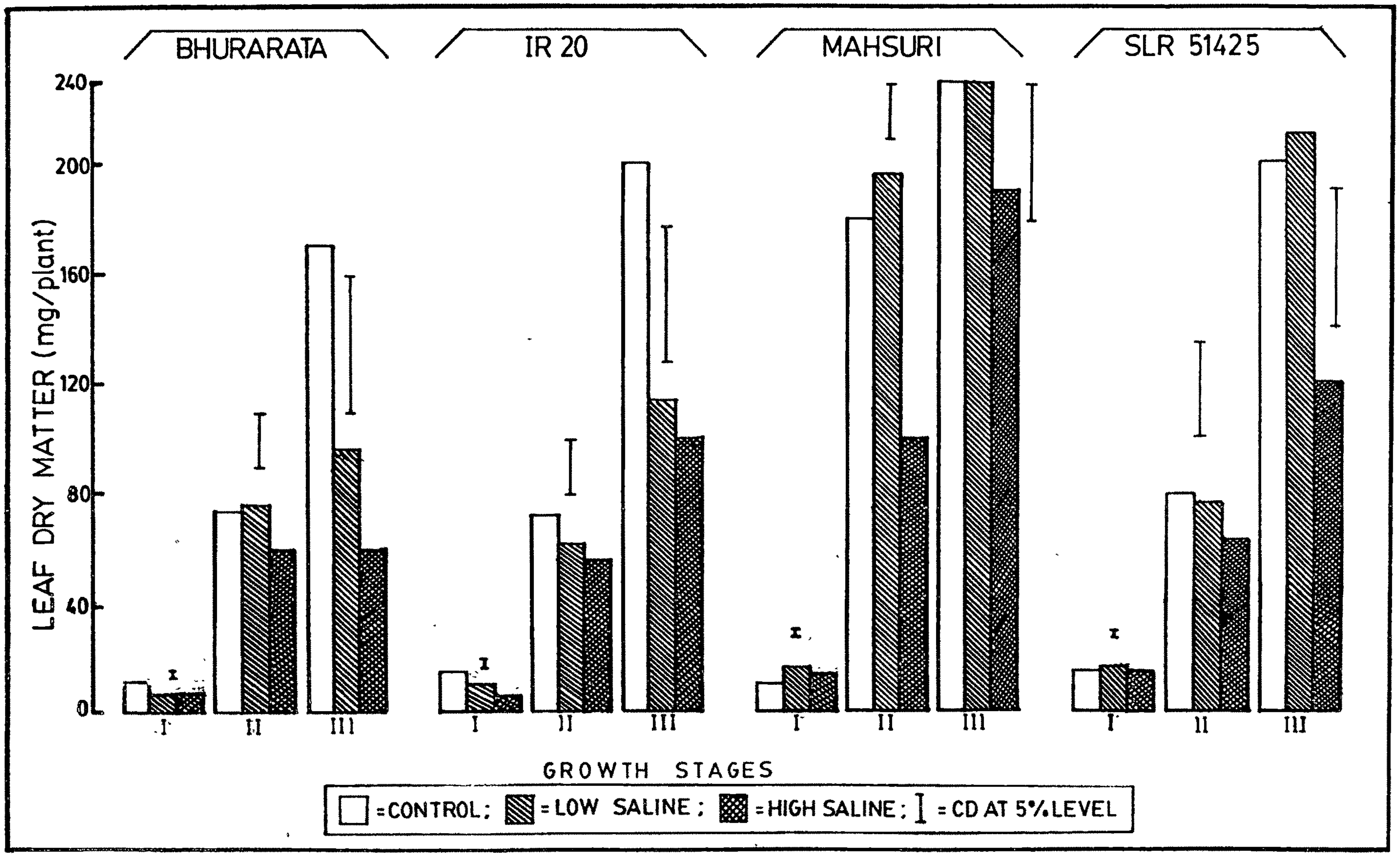

FIG.34. EFFECT OF NaCl SALINITY ON LEAF DRY MATTER OF RICE CULTIVARS AT DIFFERENT GROWTH STAGES OF SET III.

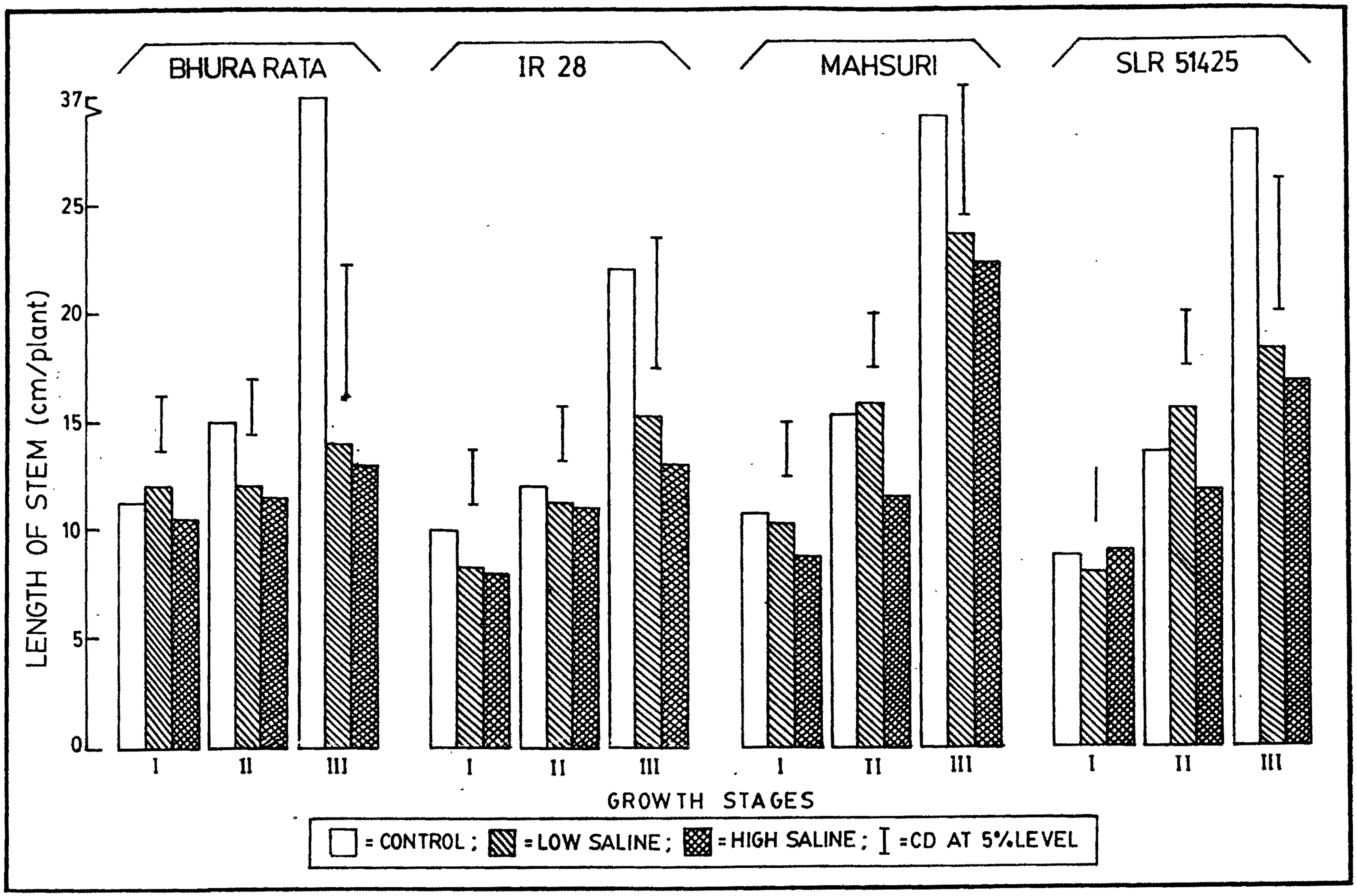

FIG.35.EFFECT OF NaCl SALINITY ON THE LENGTH OF STEM OF RICE CULTIVARS AT DIFFERENT GROWTH STAGES OF SET III.

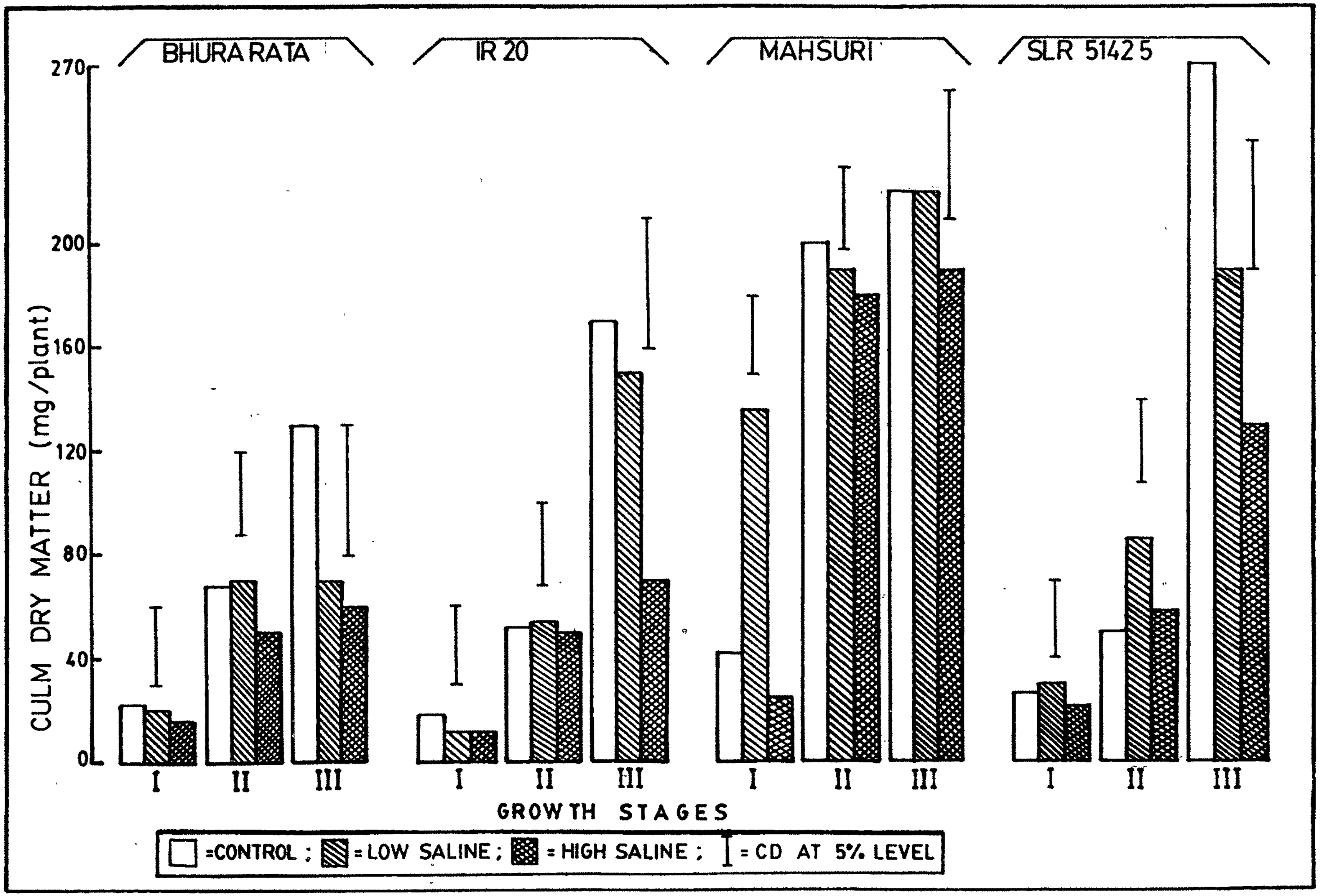

FIG. 36. EFFECT OF NaCl SALINITY ON CULM DRY MATTER OF RICE CULTIVARS AT DIFFERENT GROWTH STAGES OF SET III.

accumulate more dry matter in the culm than its leaves. However, in the last stage of growth it along with the other two cvs. exhibited significant decrease in the culm dry weight. Salinity affected the fresh matter accumulation of the rice cv. as seen in Set I (Fig. 30). The reduction in the fresh matter was much reflected in dry matter accumulation at HS in Set I. Similarly, in Set III 10-60 % inhibition was brought about in the dry matter accumulation of rice varieties in the last stage (Fig. 32).

The length of the root system was significantly affected at the second and third growth stages of Set III (Fig. 37). The cultivars Bhumrata and Mahsuri were inhibited at all stages of growth and at both saline levels, whereas SLR 51425 was inhibited significantly at both saline levels the last stage of growth only. Almost the same trend was exhibited in the biomass accumulation of root system in response to salinity (Fig. 38).

The mean square values indicated a significant impact of salinity on different growth characteristics like height of shoot system, fresh and dry matter accumulation of shoot system, area and dry matter accumulation of leaf and length and dry weight of root system (Table 49-52). The interaction between the cultivar and salt treatment was observed in the height of shoot system, dry matter accumulation of shoot system, leaf and root, and length of stem and root.

3.3.1.3 Yield and Yield Attributes

Salinity at different levels affected all the yield components of rice cultivars (Table 53-54). Of the five cultivars used in the Set I only two survived under saline conditions.

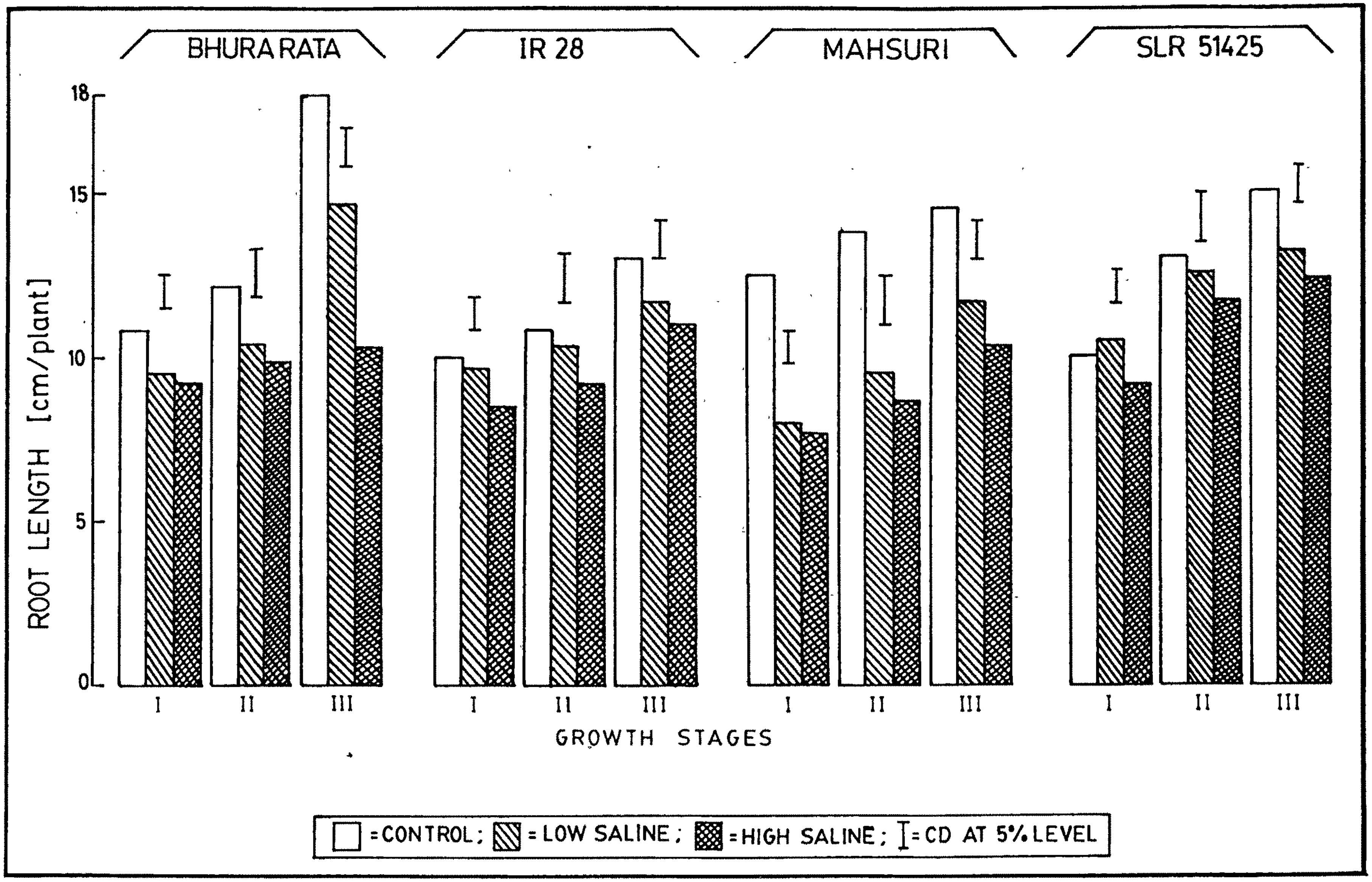

FIG.37. EFFECT OF SALINITY ON ROOT LENGTH OF RICE CULTIVARS AT DIFFERENT GROWTH STAGES OF SET III.

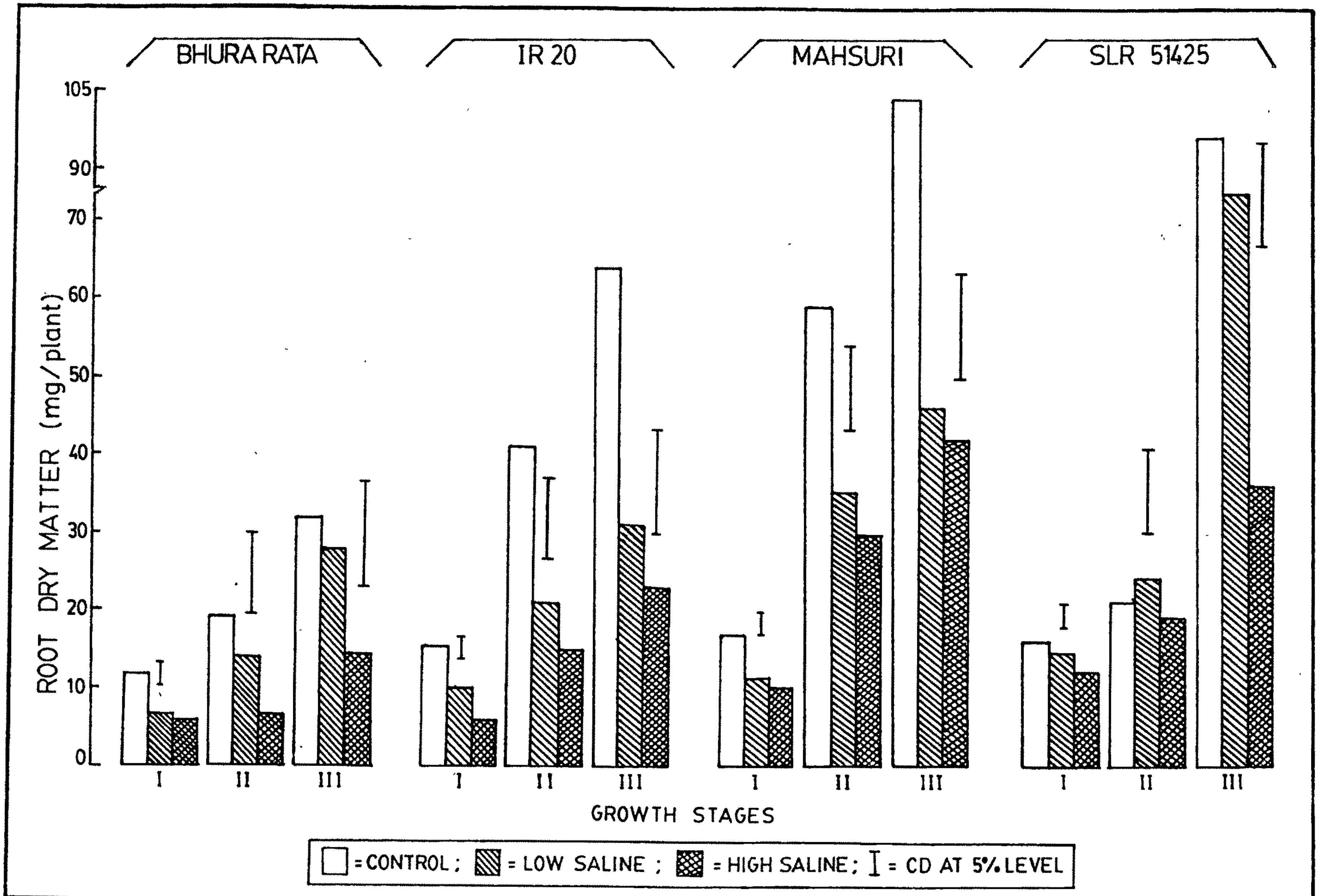

FIG. 38. EFFECT OF NaCl SALINITY ON ROOT DRY MATTER ACCUMULATION OF RICE CULTIVARS AT DIFFERENT GROWTH STAGES OF SET III.

Table 53. **Yield and yield attributes (per plant) of rice cvs. SRB-26 and Mahsuri under different levels of salt treatment (Set I)**

	SRB-26			Mahsuri			CD	
	C	LS	HS	C	LS	HS	1 %	5 %
Panicle length (cm)	17.10	15.0	14.7**	14.1	13.4	11.1**	2.67	1.87
Spikelets/panicle	7.00	5.8	5.6	7.2	5.2**	4.4**	2.43	1.7
Economic yield (g)	0.85	0.2**	0.00**	0.98	0.22**	0.02**	0.41	0.3
Dry unfilled grains(g)	0.08	0.13	0.11	0.05	0.16*	0.13	0.12	0.09
Weight of 100 grains(g)	1.46	0.66	0.00**	2.4	1.03**	0.60**	0.54	0.78
No. of filled grains	54.0	21.2**	0.00**	45.4	11.2**	2.00**	24.9	23.75
No.of unifilled grains	21.00	37.6	48.4**	39.2	44.2	43.2	77.43	16.6
Biological yield (g)	2.72	1.47**	1.23**	1.84	0.83**	0.61**	0.77	0.53
Harvest index	0.28	0.12**	0.00**	0.37	0.19*	0.05**	0.23	0.16

C = Control: ECe 1.6 dSm^{-1}; LS = Low Saline : ECe = 8 dSm^{-1}; HS = High Saline : ECe = 16 dSm^{-1};

Significant difference over control at CD 1 % =(**) and at CD 5 % =(*).

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Table 54. Yield and yield attributes (per plant) of different rice cvs in response to NaCl salinity (Set II)

	Bhura rata			IR 28			Mahsuri			SLR 51425			CD at	
	C	LS	HS	C	LS	HS	C	LS	HS	C	LS	HS	1 %	5 %
Penicle length (cm)	10.3	0.0 **	0.0 **	15.4	12.9	10.7 **	16	15.2	9.3 **	14.3	13.3	14.1	4.00	2.86
Spikelet/ panicle	2.9	0.0	0.0	4.9	4.0	2.4 **	7.2	5.7 *	3.4 **	4.4	4.33	4.34	1.8	1.3
Economic yield (g)	0.5	0.0 **	0.0 **	0.26	0.08 **	0.0 **	0.65	0.23 **	0.0 **	0.44	0.16 **	0.00 **	0.17	0.12
Dry unfilled grains (g)	0.04	0.0	0.0	0.12	0.05	0.03	0.15	0.19	0.19	0.08	0.14	0.1	0.14	0.0
100 grains (g)	2.9	0.0 **	0.0 **	2.23	1.87	0.0	1.26	2.86	0.0	1.81	1.38	0.0 *	2.37	1.68
No. of filled grains	25.3	0.0 **	0.0 **	12.1	4.4 *	0.0 **	52	13 **	0.0 **	25.1	10.0 **	0.00 **	9.8	6.6
No. of un-filled grains	10.0	0.0	0.0	18.0	22.0	14.0	46	50	48	12	22	27	34.7	24.5
Biological yield (g)	0.39	0.14 **	0.13 **	0.76	0.38 **	0.22 **	1.25	0.84 **	0.6 **	1.0	0.71	0.35 **	** 0.22	0.16
Harvest Index	0.12	0.0 *	0.00 *	0.36	0.21 *	0.00 **	0.52	0.23 **	0.00 **	0.45	0.22 **	0.00 **	0.16	0.12

C = Control : ECe 1.6 dSm^{-1}; LS = Low Salinity; ECe = 8 dSm^{-1}; HS = High Salinity; ECe 16 dSm^{-1}

Significant difference over control at CD 1 % (**) and at CD 5 % (*)

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Similarly, of the four cultivars used in the Set III Bhura rata did not yield any economic yield at LS and HS while the other three cultivars gave much reduced economic yield, almost amounting to 64 to 69 per cent. Though the panicle length was not highly reduced the combined manifestation of reductions in number of spikelets/panicle dry weight per grain and number of filled grain per panicle ultimately resulted in very low economic yield. The per cent reduction ranged from 52-71 % taking both the sets into consideration. The decrease in the economic yield and biological yield brought about a consequent decrease in harvest index. The mean square values of ANOVA analysis of yield characteristics of both the sets indicated the independent effect of salinity in the length of panicle, number of spikelets, number of filled grains, economic yield, weight per 100 grains, biological yield and harvest index (Table 55-56). However, salinity and cultivar interaction was seen only in the third set in the length of panicle, number of spikelets, economic yield, weight per 100 grain and harvest index.

3.3.2.4 Pigments as Affected by Salinity

The concentration of pigments in general was low due to salinisation in all rice cultivars (Fig. 39 and 40). The rate of reduction was lesser at LS than HS. the degree of reduction in chlorophyll 'b' was more than that of chlorophyll 'a'. The percentage reduction in the levels of carotenoids in the cvs. SLR and Mahsuri is very low in the second and the third growth stage.

Table 55. Mean squares from the ANOVA of yield parameters of different rice cultivars of Set I

Source	df	Length of panicle	No. of spike-lets	No. of filled grain	No. of unfilled grain	Dry Wt. of unfilled grain $\times 10^{-3}$	Economic yield $\times 10^{-2}$	Wt. of 100 grains $\times 10^{-1}$	Biolo-gical yield $\times 10^{-2}$	Harvest Index $\times 10^{-2}$
Replicate	4	4.6	2.2	323.3	140.8	14	10	6.8	34	5.5
Cultivar	1	61.1*	1.63	229.63	320.3	380**	20	30.6**	402*	55
Salt treatment	2	18.28**	11.7	623.3	645	20	230**	226.5	549*	236
Cultivar x salt treat-ment	2	1.6	0.99	107.6	342.2	5.0	1.0	2.1	7.0	2.0
Error	20	2.99	2.67	263.6	239.6	6.0	8.0	2.9	24.0	21

Levels of significance at 5 % =(*) and 1 % =(**) analysed separately.

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Table 56. Mean squares from the ANOVA of the yield components of Set III

Source	df	Length of panicle	No.of spikelets	No.of filled grain x 10	No.of unfilled grain x 10	Economic yield $\times 10^{-3}$	Wt.of unfilled grain $\times 10^{-3}$	100 grain weight	Biological yield $\times 10^{-2}$	Harvest Index $\times 10^{-2}$
Replicate	11	11.9	2.52	1.4	77.4	7.0	74.0	1.8	4.0	1.0
Cultivar	3	380.0**	54.6**	117.8**	51.6	210**	70**	0.7	132**	13.2**
Salt treatment	2	157.1**	26.8**	274.2**	1.7	625**	4.0	26.8**	139.5**	64.8**
Cultivar x salt treatment	6	38.9**	4.5*	61.7	19.4	80.0**	6.0	6.3*	3.0	4.0**
Error	44	7.6	1.5	4.4	50.4	13.0	9.0	2.6	2.3	1.2

Levels of significance; at 1 % =(**) at 5 % =(*).

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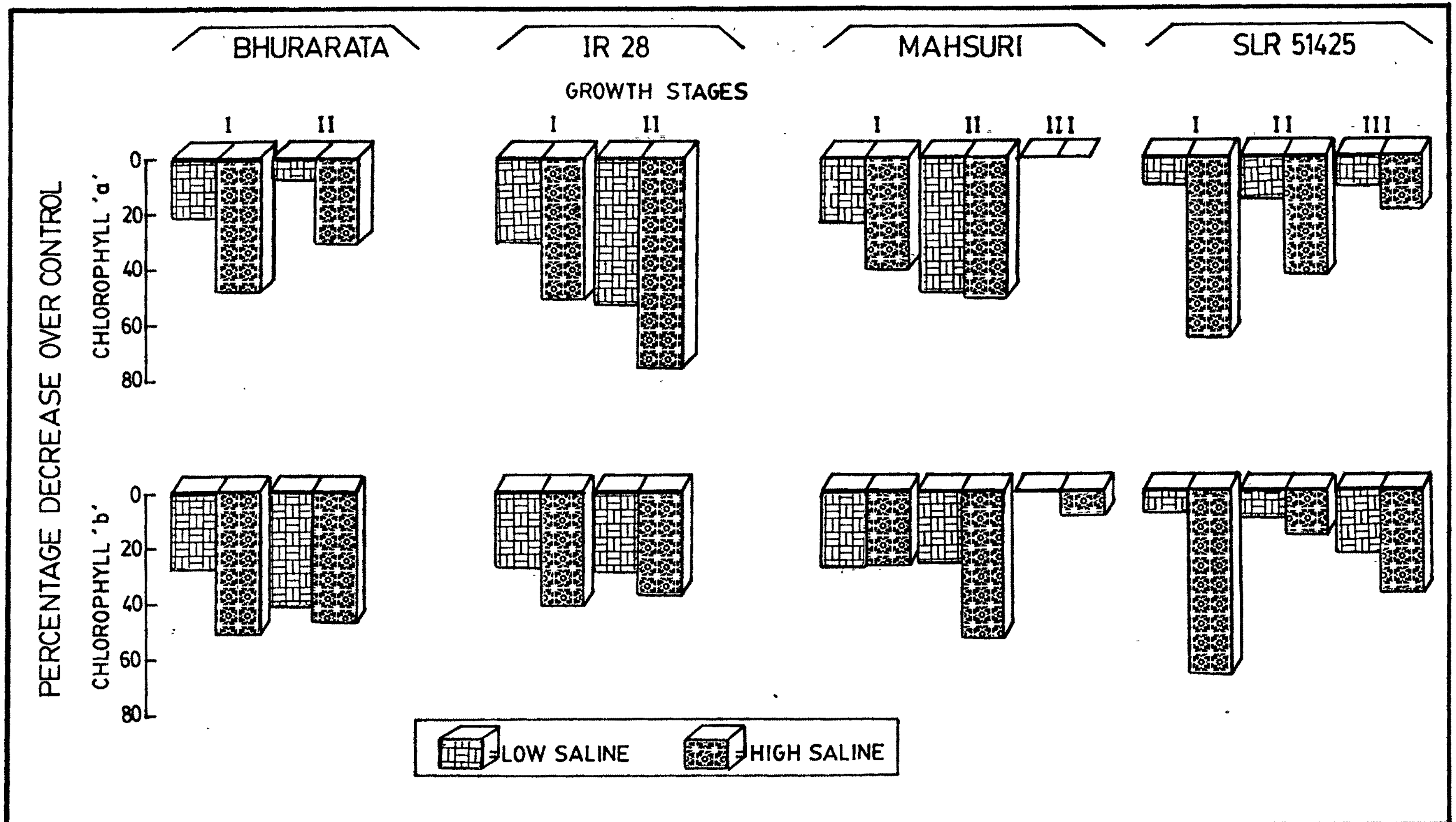

FIG.39.EFFECT OF NaCl SALINITY ON CHLOROPHYLL 'a' AND 'b' OF RICE CULTIVARS AT DIFFERENT GROWTH STAGES OF SET III.

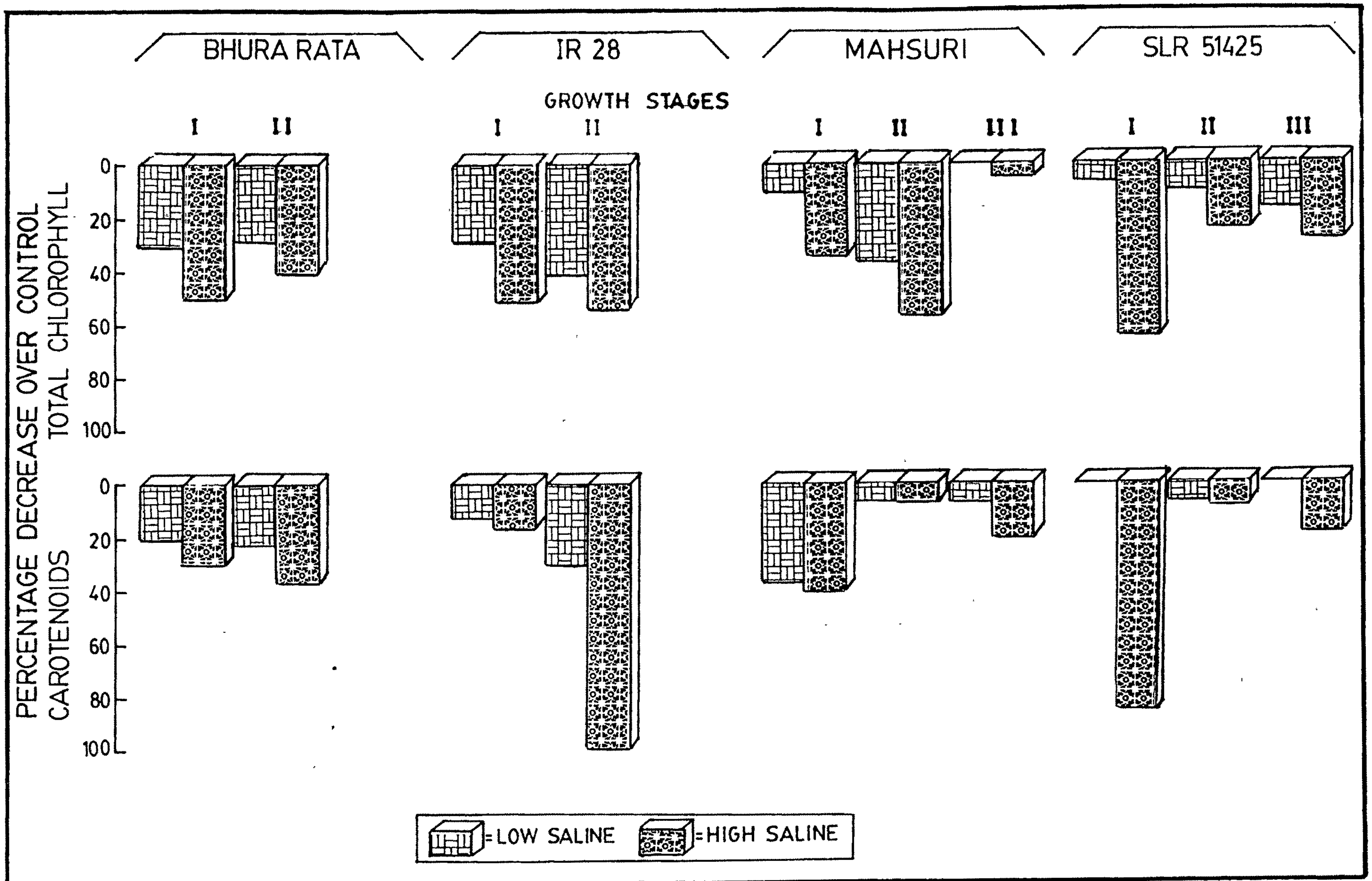

FIG. 40. EFFECT OF NaCl SALINITY ON TOTAL CHLOROPHYLL AND CAROTENOIDS OF RICE CULTIVARS AT DIFFERENT GROWTH STAGES OF SET III.

3.3.3 Ionic Accumulation

The ion accumulation pattern varied in different cultivars in response to salinity (Table 57 to 66). Among the cations sodium was accumulated 10 to 47 fold in the different parts of the plant when it was present at toxic levels in the root medium. The sodium content increased almost to 9.6 to 19.6 fold at LS levels and further increase in salinity in the root medium increased it in all the cultivars, except for IR 28 and to a certain extent SRB 26. Rice cv. GR 3 did not exhibit much difference in the K^+ accumulation in leaf and stem. While cvs. like IR 20, Mahsuri, SRB 26, Bhura rata and SLR-51425 could accumulate large amount of K^+ under saline treatment in different parts of the plant. In contrast in cv, IR-28 the level of K^+ decreased in response to NaCl toxicity. The endogenous levels of Ca^{2+} and Mg^{2+} decreased in all the studied cultivars in response to salinity. The chloride accumulation in response to salinity rated 9 fold to 189 at LS and 18 to 206 fold in HS in the saline treated plants as compared to the untreated ones (Table 65 and 66). This anion accumulation was more in its equivalents to the cation Na^+ under NaCl treatment.

Table 57. Effect of salinity on the endogenous sodium content (µeq/g dry matter) in different rice cultivars at growth stage I of Set I

Cultivar	Stem			Leaf		
	C	LS	HS	C	LS	HS
GR 3	8.9 (0.4)	96.4 (1.7)	114.6 (2.1)	9.0 (1.4)	96.7 (1.6)	110.3 (6.9)
IR 20	2.4 (0.1)	41.0 (3.4)	113.4 (3.8)	4.2 (0.3)	118.0 (6.0)	130.0 (3.6)
IR 28	4.7 (0.1)	97.1 (0.8)	-	5.4 (0.6)	1.0 (1.1)	-
Mahsuri	7.2 (0.7)	103.7 (2.7)	108 (5.7)	7.3 (0.2)	105.5 (6.7)	106.4 (3.2)
SRB-26	5.5 (0.2)	94.6 (1.7)	94.7 (4.6)	5.7 (0.2)	87.7 (1.3)	101.7 (12.4)

Figures in parentheses represent SE; C = Control; LS = Low Saline;

ECe = 8. dSm^{-1}; HS = High Salinity; ECe = 16.dSm^{-1}

- = data not available;

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Table 58. **Effect of salinization on the sodium content (µeq/g dry matter) of different parts of rice plants at the growth stage III of Set III**

Cultivar	Stem			Leaf			Root		
	C	LS	HS	C	LS	HS	C	LS	HS
Bhura rata	6.4 (0.4)	76.3 (2.2)	102.0 (4.3)	9.2 (0.1)	93.0 (1.3)	10.7 (1.0)	8.9 (0.3)	119.3 (4.0)	187.0 (5.7)
IR 28	8.1 (3.6)	86.0 (5.7)	86.7 (3.6)	7.7 (0.6)	86.3 (7.0)	88.7 (3.1)	5.6 (0.2)	73.3 (4.7)	25.3 (2.3)
Mahsuri	4.6 (0.2)	79.0 (1.1)	120.0 (4.7)	6.9 (0.3)	89.6 (6.3)	92.6 (0.9)	4.1 (0.2)	62.3 (0.5)	85.0 (4.0)
SLR 51425	5.5 (0.4)	70.0 (0.5)	75.3 (0.7)	6.6 (0.3)	72.3 (1.0)	100.7 (1.0)	7.2 (0.3)	72.3 (1.3)	76.0 (4.7)

Figures in the parentheses represent SE; C = Control ECe = 1.6 dSm^{-1};

LS = Low Salinity; ECe = 8 dSm^{-1} HS = High Salinity ECe = 14 dSm^{-1}

Table 59. Potassium content (µeq/g dry wt) in different rice cultivars of growth stage I of Set I as affected by salinity

Cultivar	Stem			Leaf		
	C	LS	HS	C	LS	HS
GR 3	216 (8.1)	235 (3.2)	260 (10.1)	216 (7.8)	236 (2.2)	237 (6.8)
IR 20	171 (5.0)	225 (12.9)	256 (8.0)	158 (9.8)	244 (3.8)	262 (6.2)
IR 28	217 (8.4)	166 (8.9)	-	738 (32.8)	237 (21.2)	-
Mahsuri	379 (3.9)	677 (17.2)	1744 (22.0)	434 (8.6)	671 (39.8)	1730 (10.7)
SRB-26	251 (20.1)	315 (8.7)	629 (22.4)	325 (5.3)	621 (9.6)	729 (16.4)

Figures in parentheses represent SE; C = Control ECe : 1.6 dSm^{-1};

LS = Low Salinity ECe : 8 dSm^{-1}; HS = High Salinity ECe: 16 dSm^{-1}

- = data not available

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Table 60. Effect of salinity on the endogenous potassium content (μeq/g dry wt.) of rice cultivars at the growth stage III in Set III

Cultivar	Stem			Leaf			Root		
	C	LS	HS	C	LS	HS	C	LS	HS
Bhura rata	260 (4.4)	576 (14.0)	637 (14.4)	295 (6.0)	326 (15.2)	414 (4.4)	261 (5.6)	492 (2.8)	1148 (9.6)
IR 28	225 (0.8)	128 (0.8)	56 (1.6)	156 (1.2)	104 (0.8)	100 (0.72)	144 (1.2)	120 (0.8)	116 (0.6)
Mahsuri	476 (4.0)	580 (12.0)	528 (3.6)	348 (2.4)	532 (1.6)	569 (4.4)	416 (7.2)	488 (2.4)	520 (3.2)
SLR 51425	1040 (16.0)	1112 (16.4)	552 (21.2)	720 (8.0)	1000 (8.0)	680 (12.0)	760 (4.0)	960 (6.8)	168 (0.8)

Figures in parentheses represent SE; C = Control ECe: 1.6 dSm^{-1}; LS = Low Salinity ECe : 8 dSm^{-1}; HS = High Salinity ECe : 14 dSm^{-1}

Table 61. Endogenous level of calcium (μeq/g dry weight) as affectd by salinity in different rice cultivars at the GSI in Set I

Cultivar	Stem			Leaf		
	C	LS	HS	C	LS	HS
GR 3	534 (6.0)	342 (6.0)	157 (1.0)	529 (9.0)	178 (3.3)	84 (3.0)
IR 20	1957 (8.9)	1080 (10.0)	1049 (40.0)	540 (18.0)	430 (19.0)	166 (20.0)
IR 28	590 (10.0)	168 (3.0)	-	170 (6.0)	90 (2.0)	-
Mahsuri	836 (16.7)	343 (15.0)	170 (6.0)	167 (1.3)	179 (9.0)	113 (2.0)
SRB-26	471 (18.0)	185 (9.0)	101 (1.0)	147 (18.0)	1159 (9.0)	146 (2.0)

(*) Figures in the parentheses represent indicate standard error.

C = Control; ECe = 1.6 dSm^{-1}; LS = Low Salinity; ECe = 8 dSm^{-1};

HS = High Salinity; ECe = 14 dSm^{-1}

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Table 62. Calcium content (µeq/g dry wt.) in different rice cultivars at growth stage III of set III under salinity

Cultivar	Stem			Leaf			Root		
	C	LS	HS	C	LS	HS	C	LS	HS
Bhura rata	710 (6)	224 (18)	120 (4)	271 (2)	170 (4)	140 (4)	650 (6)	570 (13)	334 (6)
IR 28	1240 (40)	840 (30)	810 (50)	1500 (33)	1000 (46)	740 (40)	1430 (11)	790 (7)	470 (12)
Mahsuri	840 (30)	333 (18)	272 (9)	1570 (13)	1430 (10)	335 (18)	1340 (16)	430 (11)	250 (14)
SLR 51425	1010 (60)	380 (3)	310 (2)	700 (5)	560 (23)	500 (38)	1460 (25)	670 (40)	600 (30)

Figures in parentheses represent SE; C = Control ECe : 1.6 dSm^{-1};

LS = Low Salinity ECe : 8 dSm^{-1}; HS = High Salinity ECe : 14 dSm^{-1}

Table 63. Effect of salinity on the endogenous magnesium content (µeq/g dry wt.) of different rice cultivars at growth stage I in Set I

Cultivar	Stem			Leaf		
	C	LS	HS	C	LS	HS
GR 3	215 (4.0)	156 (10.0)	106 (2.0)	217 (7.0)	162 (7.0)	121 (5.0)
IR 20	937 (20.0)	760 (10.0)	428 (8.5)	111 (4.2)	112 (1.3)	129 (4.0)
IR 28	389 (14.0)	123 (11.0)	-	345 (23.0)	188 (10.0)	-
Mahsuri	415 (10.0)	302 (10.1)	123 (2.0)	440 (13.0)	439 (12.0)	175 (17.0)
SRB 26	454 (15.0)	363 (25.0)	225 (6.0)	421 (3)	374 (31)	355 (16)

Figures in parentheses represent SE; C = Control ECe : 1.6 dSm^{-1};

LS = Low Salinity ECe : 8 dSm^{-1}; HS = High Salinity ECe : 16 dSm^{-1};

-= not determined.

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Table 64. Magnesium content (µeq/g dry wt.) as affected by salinity in different cultivars of rice at the growth stage III in set III

Cultivar	Stem			Leaf			Root		
	C	LS	HS	C	LS	HS	C	LS	HS
Bhura rata	2257 (20.0)	538 (17.0)	301 (28.0)	1910 (12.0)	480 (8.0)	420 (8.0)	393 (4.0)	254 (2.0)	243 (6.5)
IR 28	733 (45.0)	691 (74.0)	630 (30.0)	1090 (38.0)	1030 (36.0)	608 (50.0)	1065 (28.0)	627 (8.0)	325 (12.0)
Mahsuri	447 (56.0)	565 (26.0)	377 (29.0)	1190 (38.0)	608 (3.8)	379 (23.0)	370 (13.0)	370 (3.0)	330 (12.0)
SLR 51425	860 (17.0)	830 (11.0)	240 (16.0)	890 (32.0)	591 (17.0)	43 (11.0)	1150 (60.0)	950 (24.0)	580 (4.8)

Figures in parentheses represent SE; C = Control ECe 1.6 dSm^{-1};

LS = Low Salinity ECe : 8 dSm^{-1}; HS = High Salinity, ECe: 14 dSm^{-1}

Table 65. Chloride accumulation (µeq/g dry matter) in the salt affected rice cultivars of set I at GS III

Rice cultivar		C	LS	HS
GR 3	Stem	41.0 (0.6)	830 (6.0)	1437 (11.0)
	Leaf	42.7 (0.9)	637 (18.0)	1565 (11.0)
IR 20	Stem	9.4 (0.2)	1156 (9.0)	1387 (40.0)
	Leaf	10.1 (0.4)	1286 (43.0)	1440 (46.0)
IR 28	Stem	47.0 (1.0)	1074 (44.0)	1748 (62.0)
	Leaf	54.0 (0.6)	1169 (11.0)	1499 (25.0)
Mahsuri	Stem	64.3 (3.5)	1184 (13.0)	1223 (12.0)
	Leaf	11.6 (1.0)	1163 (15.0)	1434 (22.0)
SRB-26	Stem	15.2 (0.5)	1553 (52.0)	1755 (17.0)
	Leaf	56.1 (0.8)	1498 (23.0)	1633 (29.0)

Figures in parentheses represent standard error; C = Control;

LS = Low Salinity; ECe: 8 dSm^{-1}; HS = High Salinity;

ECe : 16 dSm^{-1}

Table 66. **Chloride accumulation (µeq/g dry matter) different parts of rice cultivars in response to salinity at GS III of Set III**

Cultivar		C	LS	HS
Bhura rata	Stem	8.3 (0.8)	1375 (11.0)	1605 (16.0)
	Leaf	8.9 (0.3)	939 (38.0)	1465 (12.0)
	Root	11.5 (0.6)	1319 (20.0)	1755 (86.0)
IR 28	Stem	8.9 (0.3)	565 (26.0)	1205 (9.0)
	Leaf	7.5 (0.2)	379 (4.0)	1202 (9.0)
	Root	7.8 (0.2)	325 (13.0)	846 (8.0)
Mahsuri	Stem	10.6 (0.7)	1090 (40.0)	1300 (50.0)
	Leaf	9.8 (0.8)	1230 (13.4)	1564 (8.0)
	Root	10.5 (0.4)	1125 (9.0)	1250 (11.0)
SLR 51425	Stem	21.9 (1.9)	2260 (20.0)	2720 (40.0)
	Leaf	17.1 (1.1)	2312 (21.0)	2622 (160.0)
	Root	12.3 (0.8)	2340 (120.0)	2540 (160.0)

Figures in parentheses represent standard error; C = Control; ECe : 1.6 dSm^{-1}; LS = Low Salinity; ECe: 8 dSm^{-1}; HS = High Salinity; ECe : 14 dSm^{-1}