annual report

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CENTRAL SOIL SALINITY RESEARCH INSTITUTE
KARNAL (Haryana) INDIA, 132001

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CONTENTS

GENERAL

Introduction

The Central Soil Salinity Research Institute (C.S.S.R.I.), Karnal was established in March, 1969 under Fourth Five Year Plan as a national Institute for conducting research on problems related to soil salinity and alkalinity. The Institute has a Research Station at Canning in West Bengal, which forms a nucleus for catering to the research needs of coastal salt affected soils. In order to further strengthen the facilities at this Institute a scheme was sanctioned during the Fifth Five Year Plan by the Indian Council of Agricultural Research (I.C.A.R.) for providing more staff, equipments and buildings.

The research work in the Institute is conducted mainly in its three divisions : (i) Soils and Agronomy, (ii) Genetics and Plant Physiology and (iii) Engineering. The Institute also has an Extension Unit for carrying the results of research from the laboratories to the farmers' fields. Besides, the Coordination Cells of the two All India Coordinated Projects for Research on (a) Water Management and Soil Salinity and (b) Use of Saline Water in Agriculture also continued to function at this Institute. The Operational Research Project sanctioned by the Indian Council of Agricultural Research in 1974 to test and demonstrate the applicability of the technology for the reclamation of alkali soils on farmers' fields was implemented in a cluster of four villages during 1975, and continued to function during the year. A new scheme of Consultancy Services was also sanctioned at this Institute during the year to provide technical assistance to those desirous of reclaiming salt-affected soils.

A follow up action on the recommendations of the Achievement Audit Committee was taken. The Management Committee of the Institute, constituted during 1975, met to review the research programmes in progress and to make recommendations for improving the physical facilities. The Grievance Cell and the Joint Council of the Institute held several meetings so as to solve individual as well as collective grievances faced by the staff members in their efficient working. A dispensary was opened at the Institute on 11.8.1976 with the joining of a Medical Officer to provide the much-needed medical facilities to the staff. The Post Office which was started during 1975 continued to provide satisfactory service to the Institute.

Objectives

The objectives of the Institute as modified in view of the recommendations of the Achievement Audit Committee are as follows :

(1) To collect information on the extent, characteristics, genesis and classifications of the salt-affected soils in different parts of the country.

(2) To study salt and water dynamics in irrigated agriculture, to conduct detailed hydrological surveys and to provide suitable criteria for surface and sub-surface drainage for controlling the salt and water balance in the soil.

(3) To study the factors governing the chemical composition of surface and under-ground waters and evolve methods to check deterioration and pollution of these waters and to utilize waters of different qualities for agricultural purpose.

(4) To find physiological mechanism associated with salt tolerance of crops and to evolve crop varieties tolerent to saline-sodic conditions.

(5) To develop technology for the reclamation and utilization of salt-affected lands in the country.

(6) To serve as a centre for post graduate education and training in the field of soil salinity and related subjects.

(7) To collaborate with agricultural universities and other Central and State organizations in the development of research, training and extension programmes.

Staff

The scientific and some of the technical and administrative staff of the Institute as on 30.12.1976 is given in Appendix-I.

Promotions

Dr. K.K. Mehta, Jr. Soil Chemist was selected to the higher post of Soil Scientist at the Institute. Dr. D.K. Pal and Sh. C.R. Biswas who were earlier working as Senior Research Assistants were selected for S-I grade of the Agricultural Research Service.

New Entrants

Sh. P.S. Kumbhare, Sh. R.K. Gupta and Sh. R.K. Batta joined as Scientists S-I in the discipline of Water and Soil Engineering. Sarvshri V.K. Murthy, Gurkirpal Singh, J.N. Gupta and S. Venkatkrishanan joined as Scientists S-I in the d sciplines of Soil Science, Agronomy, Agricultural Economics and Microbiology respectively.

Dr. J.K. Jain, joined as Medical Officer on deputation from Central Health Services. Sh. D.K. Mukerji and Sh. A.S. Bhati joined as Administrative Officer and Assistant Administrative Officer (On deputation) respectively. Sh. A.K. Tiwari joined as S.R.A. in the Division of Engineering. S/Shri S.K. Sharma, S.K. Kataria, A.K. Chaterjee, G.S. Saini and Subhash Chander joined the Institute as Research Fellows.

Staff Left

Drs. R.K. Rajput, T.N. Singh and H.S. Sen, who were working as Agronomist, Plant Physiologist and Jr. Soil Physicist respectively, left the Institute on their selection to other Institutes. Sh. A.T. Raphael on retirement relinquished the charge of Administrative Officer.

Physical Facilities

The construction of the buildings of the Administrative and Library Blocks and Electric Sub-Station was nearly completed and the Administrative and Accounts Sections, which were earlier working in a private rented building in the city, were shifted to the new block. The construction of the laboratory blocks is under progress. Four Type-V quarters and Two Type-I quarters were completed. Two additional Pot Culture Houses were constructed and the construction of 30 Micro Plots is nearing completion. A Zetor tractor was purchased for the Research Station, Canning. Two power tillers were purchased for strengthening the facilities at Karnal. A large number of scientific instruments and equipments were also purchased for augmenting the research facilities at the Institute.

Library

During the year, 622 books were added to the Institute Library at Karnal, thereby raising the total collection to 6554. 13 new journals were added for regular subscription bringing the total to 218 (64 Indian and 154 Foreign).

Farm

The Institute has a research farm of about 82 ha, a large portion of which was having a serious problem of alkali soil. At the start of the Institute, the farm area was laidout in fields of 100m×25m and 100m×100m sizes. The irrigation is provided by 6 shallow cavity tubewells each with a discharge of 15 litres/sec. and one deep tubewell with a discharge of about 35 litres/sec.

About 40 ha of the farm area has an underground water conveyance system. In addition to this, there are three dugout ponds in the low lying area with a total storage capacity of about 246 ha cm which serve as reservoir for collection of excess rain water, thereby minimising the need for surface drainage and also for irrigation in the lean period. All the farm operations are mechanised with the help of 3 tractors and 5 power tillers. During the year, the tractors worked for 2934 hours.

The main cropping pattern followed on the soils on the farm continued to be rice-wheat. The other crops grown were barley, *dhaincha* etc. The total cropped area excluding the experimental area was 23.87 and 24.49 ha during *kharif* and *rabi* seasons respectively. The average yields of the general cultivated area were as below:

Season	Name of the Crop	Average yield (t/ha)
Rabi	*Wheat*	
	Kalyan Sona	3.575
	HD-2009	3.517
	S-1553	2.968
	Barley	
	Ratna	2.040
Kharif	*Rice**	
	IR-8	6.400
	Jaya	6.111
	P-2-21	4.465

Education and Training Programmes

(i) *Ph. D. Programme* : The Institute has collaboration with National Dairy Research Institute, Karnal; Haryana Agricultural University, Hissar

* The rice yield wherever mentioned in this report is of unhusked rice.

and Punjab Agricultural University, Ludhiana for Ph.D. Programme and is recognised by Agra and Banaras Hindu Universities for research work leading to Ph.D degree. Sh D.R. Sharma, Senior Research Assistant joined the Institute after completing his work for Ph.D degree in Soil Science at Indian Agricultural Research Institute, New Delhi. Sh. I.K. Girdhar, Senior Research Assistant continued to work for his Ph.D. at this Institute. Sh. S.K. Gupta, Scientist S-I (Assistant Engineer, Drainage) completed his studies for M. Tech. at the Punjab Agricultural University, Ludhiana. Sh. S.N. Singh, Sh. R.K. Chhillar, Senior Research Assistants and Sh. S.K. Sharma, Research Fellow got themselves registered for Ph.D. as in-service candidates at the National Dairy Research Institute, Karnal. Sh. K.N. Singh, Senior Research Assistant was registered with Banaras Hindu University for Ph. D in Genetics and Plant Breeding.

(*ii*) *Training Programme* : Dr. B.K. Khosla, Soil Physicist. proceeded to West Germany for higher studies under German Academic Exchange Fellowship programme. Sh. H.C. Nitant, Senior Research Assistant and Dr. C.L. Acharya, Scientist (S-I) continued their doctoral and post-doctoral studies in Yugoslavia and France respectively.

Awards and Honours

Dr. D.R. Bhumbla, Deputy Director-General, I.C.A.R. and Dr. I.P. Abrol, Head, Division of Soils and Agronomy were jointly awarded the Rafi Ahmed Kidwai Memorial Award by the I.C.A.R. in recognition of their research work on the management and reclamation of salt-affected soils. Dr. J.S.P. Yadav, Director was nominated as member of the Board of Management of the Punjab Agricultural University, Ludhiana. He continued to be a member of the Governing Body of the I.C.A.R. Dr J.S.P. Yadav, Director is recognized as a guide for P.G. Studies by HAU, Hissar and Agra Universities. Dr. I.P. Abrol, Head, Division of Soils and Agronomy is recognized guide of P.G. Studies by HAU, Kurukshetra & Agra Universities ; Dr V.V. Dhruva Narayana, Head, Division of Engineering by Jawaharlal Technological University and Agra University ; Dr R.S. Rana, Head, Division of Genetics and Plant Physiology by BHU, HAU, Kurukshetra and Agra Universities ; Dr R.K. Rajput, Project coordinator by Kurukshetra University and Dr S. Chandra, Senior Plant Breeder by HAU and Agra Universities.

Visits Abroad

Dr. J.S.P. Yadav, Director went to Hungary for two weeks on 23.6.1976 under Indo-Hungarian Cultural Exchange Programme to finalise

Dr. D.R. Bhumbla, Ex-Director of the Institute (presently DDG, ICAR) receiving Rafi Ahmed Kidwai Memorial Award from Shri Jagjivan Ram, President of the ICAR Society

Dr. I.P. Abrol, Head, Division of Soils and Agronomy receiving the Rafi Ahmed Kidwai Memorial Award from Shri Jagjivan Ram, President of the ICAR Society the details of holding Joint Indo-Hungarian Seminar on 'Management of Salt Affected Soils' and to familiarize with the problems of salt-affected soils in Hungary. Dr. R.S. Rana, Head, Division of Genetics and Plant Physiology, attended International Rice Research Conference in Manila, Philippines from 12 to 15th April, 1976 and also participated in International Rice Testing Programme Monitoring tour to several leading research centres in the region comprising Thailand, India and Pakistan during Oct. 12-22, 1976.

Finance

The Budget Allocation and Expenditure figures for Plan and Non-Plans schemes of the Institute including the Research Station, Canning are as below :

(Unit : Rs. in Lakhs)

	Sanctioned for the year 1976-77 (April—March)	Expenditure 1976-77 (April—March)
Plan	30.00	29.99
Non-Plan	18.18	18.17
Operational Res. Project	1.50	1.47
Consultancy services	1.65	1.17

Weather

During the months of January, February, April, May, July, September, October and November, the rainfall was below normal by 31 mm, 2.3 mm, 0.9 mm, 6.6 mm, 21.6 mm, 36.8 mm, 9.7 mm, and 4.1 mm respectively. However, in the months of March, June and August the rainfall was above normal by 19.7 mm, 63.3 mm, and 241.5 mm respectively. It helped in reducing the irrigation demand to a greater extent in both *Rabi* and *Kharif* crops. The distribution of rain was good in the months of June, July and August with only three high intensity storms. The heaviest downpour was recorded on 18th and 19th August with 181.8 mm rainfall. Number of average sunshine hours per day during rainy season were good for photo-synthesis activities. The highest average wind speed 9.9 km./hour and average max. temperature 38.5°C were recorded in the month of May with highest evaporation rate of 10.8 mm/day. During the months of January and February the average relative humidity 93% was higher as compared to the other months during the year.

The details of the various weather elements recorded in Meterological Observatory of the Institute have been given in the Table. Potential evapotranspiration with precipitation has been shown in Figure 1 indicating the components of soil water budget. Soil thermameters were installed in the observatory.

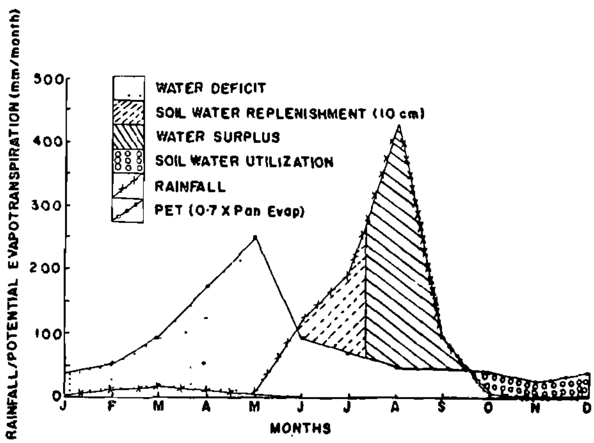


Fig. 1. Precipitation and potential evapotranspiration at C.S.S.R.I. Research Farm, Karnal for 1976

Mean monthly values of weather phenomena at Central Soil Salinity Research Institute's farm, Karnal during, 1976

Latitude......29°43, N   Longitude......76°58' E   Altitude 245 m. A.S.L.

Month	Temperature °C							Vapour (mm of Hg)		Relative humidity (Per cent)		Wind Speed (km/hr)	Evaporation		Rainfall mm	No. of rainy days	Sunshine (hr/day)
	Max.	Min.	Mean	Dry bulb I	Dry bulb II	Wet bulb I	Wet bulb II	I	II	I	II		mm/day	mm/month			
Jan.	20.7	7.2	18.9	7.8	19.8	7.2	14.0	7.5	8.5	93	49	4.8	1.7	53	1.0	2	6.9
Feb.	21.3	9.3	15.3	10.0	18.5	9.6	15.8	8.6	11.8	93	74	6.7	2.6	77	28.7	6	6.9
March	26.1	11.8	18.9	13.5	25.3	12.5	17.5	10.3	10.6	88	43	6.3	4.0	125	35.2	5	8.1
April	34.0	17.1	25.5	20.6	33.8	16.2	19.5	11.3	8.3	63	20	7.7	7.8	233	10.8	2	9.8
May	38.5	22.3	30.4	26.6	37.5	19.8	21.5	13.3	9.5	52	19	9.9	10.8	336	5.6	5	10.7
June	36.7	24.6	30.6	27.6	35.2	23.2	24.2	18.8	15.9	69	37	8.5	8.2	247	124.8	7	8.9
July	34.9	26.1	30.5	27.8	32.7	25.0	26.5	22.1	22.1	80	60	8.8	6.1	191	193.0	12	6.5
Aug.	31.1	24.5	27.8	26.0	29.9	25.0	26.5	23.1	23.6	92	75	8.5	4.1	128	456.1	21	6.5
Sept.	32.3	23.1	27.7	24.7	31.5	23.3	25.8	20.7	21.3	88	61	5.6	4.2	126	93.5	5	9.4
Oct.	32.3	17.1	24.7	19.2	31.5	17.9	22.0	14.8	14.0	88	40	3.5	3.4	107	3.2	2	9.9
Nov.	27.5	10.6	19.0	12.3	26.7	11.0	17.0	9.4	8.6	85	32	2.9	2.4	71	—	–	8,2
Dec.	22.4	5.2	13.8	6.4	21.6	5.6	13.2	6.4	6.3	87	33	3.7	1.9	59	2.4	3	8.6
Total	357.8	198.9	278.1	222.5	344.1	186.3	243.5	166.3	160.5	978	543	76.9	57.2	1753	954.3	69	100.4
Mean	29.8	16.6	23.2	18.5	28.7	15.5	20.3	13.9	13.4	82	45	6.5	4.8	146	—	—	8.4

I—First reading at 0722 hours and II—Second reading at 1422 hours

PROGRESS REPORTS

SOIL SURVEY

Characterization, classification and genesis of salt-affected-soils

S.A. 1.1. *Mapping and classification of salt-affected soils of Sonepat District, Haryana* (*G. P. Bhargava, R. C. Sharma and S. K. Sharma*)

Making use of aerial photographs and ground checks, an area covering 1270 Sq. km. of Sonepat district of Haryana State was surveyed and a soil and land use map was prepared. The survey brought out three main physiographic units—alluvial uplands, depressional areas and old channels, and sand dunes and sand bars occupying respectively 76.3, 8.8 and 14.9 per cent of the total area surveyed. In the upland plain a total of 19,677 ha or 15.5 per cent of the surveyed area is lying barren on account of high salinity and sodicity. Of the barren salt-affected areas about 1.2 per cent is highly sodic while the remaining 14.3 per cent is saline-sodic in character. In nearly one-third of the surveyed area, salinity/sodicity occurs in patches in the cultivated fields. Only 27.2 percent (34,586 ha) of the area is relatively free of salinity and sodicity problems. According to soil taxonomy, the soils of the surveyed area fall in 4 orders, their distribution being (1) Aridisols, 45,315 ha (ii) Alfisols, 42,593 ha (iii) Inceptisols, 32,982 ha and (iv) Entisols, 6,154 ha

S.A. 1.2. *Characteristics of coastal salt affected soils* (*G. P. Bhargava*)

Four profile soil samples were collected from the problem areas in Kerala state locally called *Kole*, *Kari*, *Pokalli* or *Kaipad* lands. The salt-affected soils are generally located 1 to 2 m below mean sea level and are subject to inundation by the back waters. Soils represented by profile K-I are slightly acidic to neutral and are highly saline. The soils lack a histic horizon and have ESP ranging from 23.0 to 28.5. Soils from profile K-II are distinctly acid, highly saline and have a humic horizon at 70 cm depth.

TABLE 1. *Physico-chemical characteristics of coastal saline soils from Andhra Pradesh and Kerala*

Depth (cm)	pHs	ECe (mmhos/cm)	CEC (me/100g)	Ex. H^+ (me/100g)	Composition of saturation extract (me/1) ESP	Ca+Mg	Na	HCO_3*	Cl	SO_4	Clay <2u	O.M. %
Profile K—I Village Charu Kunnu Thavam, Cannanore district												
0-18	6.5	29.4	31.6	3.3	28.4	103	244	2.2	218	132	53.0	2.8
18-44	6.4	12.6	37.4	4.4	23.0	36	138	0.6	136	22	54.2	2.0
44-62	6.3	13.4	33.9	2.2	24.1	33	116	0.6	120	35	51.6	1.5
62-96	6.4	17.6	43.5	2.1	25.2	41	148	2.4	158	30	53 8	1.7
96-116+	6.5	34.4	56.1	1.2	28.5	80	254	2.0	268	80	57.2	4.6
Profile K—II Village Arikum, Calicut district												
0-9	4.4	43.6	18.7	2.2	6.4	123	322	2.0	354	120	47.6	4.8
9-20	4.8	12.6	20.4	1.2	5.8	38	100	1.2	106	36	38.8	3.6
20-36	4.8	11.7	14.7	1.2	6.8	44	82	2.3	86	53	46.0	2.4
36-70	4.5	8.4	26.1	1.2	11.1	25	76	2.3	57	65	63.4	2.6
70+	3.4	38.6	69.2	18.7	20.5	112	285	2.0	337	75	50.2	40.5
Profile K—III Village Elamkunnapuzha, Ernakulam district												
0-18	7.0	44.6	38.6	1.3	25.7	104	385	1.0	448	70	32.0	3.0
18-36	7.5	38.6	52.0	—	20.7	76	319	3.0	343	65	51.4	5.0
36-110	7.2	74.7	61.6	—	10.3	128	633	2.2	696	87	43.6	12.0

Contd .....

(*Contd.*)

Profile K—IV Village Ambalapuzha, Aleppey district											
0-14	4.1	1.4**	19.2	8.8	2.0	Non Saline				28.0	3.1
14-32	4.2	0.9	20.8	8.8	2.4					29.0	1.5
32-46	4.3	0.9	19.6	7.7	3.0					19.4	0.9
46-100	5.5	0.8	10.6	2.4	3.7					17.6	0.5
Profile AP—VI (Bhimavaram) West Godavari (A.P.)											
0-10	6.6	36.5	67.8	—	16.2	145	244	1.2	378	tr.	60.6	2.1
10-25	6.7	28.9	75.6	—	16.1	103	189	0.2	284	1	69.8	1.6
25-65	6.7	29.3	80.8	—	16.7	120	178	1.2	280	12	70.0	1.5
65-100	6.7	75.3	67.8	—	20.0	405	479	1.2	888	9	60.4	1.0
Profile AP—VII (Idupalli) Guntur (A.P.)											
0-4	7.4	145.5	9.2	—	35.8	358	2423	4.8	2760	18	9.4	2.1
4-22	7.9	25.5	6.1	—	26.2	46	216	3.6	235	20	10.2	0.6
22-25	7.9	26.2	5.1	—	33.3	87	197	2.9	272	5	10.6	0.5
25-36	8.0	24.1	4.6	—	34.7	71	198	8.1	244	14	8.8	0.4
36-48	8.3	28.1	4.9	—	57.1	54	198	6.3	234	60	7.4	0.3
48-100	8.2	14.4	12.7	—	26.7	27	127	1.7	146	11	17.4	0.5

* CO_3 and $CaCO_3$ are absent in almost all the soils

** EC in 1:2 soil : water suspension

The soil appears to be an alluvium deposited over the remnants of a forest area. Soil from profile K-III are neutral to alkaline in reaction and are highly saline. Profile K-IV was non-saline but distinctly acidic. The physico-chemical characteristics of these are given Table I.

Chemical characteristics in respect of two soil profiles (AP-VI and AP-VII) from Andhra Pradesh are also presented in Table I. Soils represented by profile AP-VI are fine loamy vertisols of alluvial origin with ECe varying from 28.9 to 75.2 mmhos/cm and there exists a salic horizon with upper boundary at 65 cm depth. The shallow water table at 1 m depth is highly saline and rises during the months of July and August resulting in an aquic moisture regime for long periods. Profile AP-VII represents coarse loamy coastal saline soils characterized as entisols. The water table in these soils comes near to surface during the months of July and August and the ground water is distinctly saline with E.C. of 22.8 mmhos/cm. Chlorides and sulphates of sodium, magnesium and calcium are the dominant salts.

Chemical composition of ground water collected from some profile bottoms is presented in Table 2.

TABLE 2. *Chemical composition of ground waters in respect of some profile sites*

Particulars	Depth of water table (m)	EC (mmhos/cm)	Ionic composition (me/l)							
			Na	Ca	Mg	K	HCO_3	Cl	SO_4	SAR
From substratum of profile K-II	0.5	21.2	130	14.4	76	4.4	–	181	30.6	18.4
From substratum of Profile K-IV	0.7	3.8	34	2.8	87	0.2	0.5	30	5.0	14.1
From substratum of profile AP-VI	1.0	49.6	296	23.5	168	1.2	3.2	489	—	30.1
From Substratum of profile AP-VII	1.0	22.9	164	9.5	67	2.7	2.0	226	3.5	26.5

SOIL PHYSICS

S.A. 4. Effect of amendments including industrial and organic waste materials on soil physical and chemical properties and crop growth

S.A. 4.1. *Moisture retention characteristics of black soils as affected by exchangeable sodium (S.S. Sandhu and I.P. Abrol)*

Minerology of the clay fraction is an important factor in determining the effect of exchangeable sodium on soil properties. To study the effect of exchangeable sodium on soil moisture retention in a dominantly montmorillinitic soil, different ESP levels were created by addition of pre-determined quantities of $NaHCO_3$ in a soil collected from 0.15 cm surface layer from the Experimental Farm, Power-Kheda (M.P.). Water retained at different atmospheric tensions was determined using Richard's Pressure Plate extractor and 15 bar ceramic plate extractor. Water retained at different suctions increased with increasing soil pH and ESP at all the moisture tensions (Table 3). The results are somewhat different than those obtained for a dominantly illitic soil from Karnal, where at higher suction, water retention increased with increasing ESP, but at suction near saturation (below 0.2 atm), higher amount of water was retained in soils of low ESP.

TABLE 3. *Moisture retention characteristics of black soils (percentage)*

Soil	Soil moisture tension (bars)							
pH	.1	.33	.5	1	2	3	5	15
8.3	39.2	30.8	28.3	25.0	22.8	21.2	19.2	18.3
8.5	39.8	31.5	29.0	25.7	24.1	22.0	19.3	18.3
8.8	41.0	33.0	30.8	27.1	25.7	23.9	20.5	19.4
8.9	41.8	34.4	31.7	28.5	27.3	24.9	21.3	19.5
9.0	43.5	85.2	32.9	29.5	28.7	25.8	22.9	19.6
9.2	46.1	37.5	34.5	31.4	29.2	26.0	22.8	19.8
9.3	45.8	38.0	34.9	31.8	29.9	26.6	23.8	19.8

S.A. 4.2. *Evaporation from sodic soils as affected by degree of soil improvement and evaporative demand (S.S. Sandhu and I.P. Abrol)*

Intensive studies on the redistribution of soil water as a result of evaporation were carried out under high and low evaporative demand during summer 1975 and winter 1976 respectively in differentially gypsum treated plots. To monitor the suction changes, tensiometers at 7.5, 15, 30, 45, 60, 90 cm depth were installed in each of these plots, after levelling without much disturbance. Plots were flooded for a month, suction changes were recorded and soil samples were taken just after draining out the water from the plots. Soil moisture content at 2 cm intervals was determined gravimetrically upto 16 cm depth and at 7.5 cm interval upto 90 cm depth daily and after 10 days interval respectively for a period of 46 days. Water loss as a fraction of total open pan evaporation (OPE) is presented in Table 4.

TABLE 4. *Cumulative depletion of water (mm) and water loss as a fraction of total OPE*

Season	Treatment	Total water loss (mm)		Water loss as a fraction of total OPE	
		0-8 cm	8-16 cm	0-8 cm	8-16 cm
Summer (10 days)	Control	31.0	2.5	.247	.020
	Gypsum	25.5	10.0	.203	.079
Winter (46 days)	Control	33.3	10.4	.245	.076
	Gypsum	26.0	17.2	.192	.128
OPE (mm)	May 21 to May 30, 1975=125.6				
	Jan. 18 to March 8, 1976=135.7				

It is seen from the table that total water loss from 0-8 cm depth is nearly same in two seasons for gypsum treated and control plots. The water loss from 8-16 cm in the control plots is nearly 4 times more in winter than in summer. Similarly, in the gypsum treated plots water loss was considerably higher in winter season (17.2 mm) than in summer season (10.0 mm). During winter much higher quantity of water is contributed to evaporation from 8-16 cm soil than during the summer season. The studies bring out that soil-water behaviour in soils of different sodicity will be considerably influenced by evaporative conditions which in turn will influence the management of water in different seasons.

S.A. 4.9. *Optimum gypsum fineness for the reclamation of sodic soils (K.L. Chawla and I.P. Abrol)*

To study the effect of gypsum fineness on soil properties and crop yield, a field experiment was conducted in a highly sodic soil (pH of surface soil, 10.20) with randomized block design and quadruplicated treatments (plot size 5mx3m). The treatments included six degrees of fineness (gypsum passed through 2.5, 5, 10, 18, 30 and 60 mesh sieves with minimum of manual grinding), two levels of gypsum application (5 and 10t/ha) and a control. Gypsum was broadcast and mixed in about upper 10cm soil and water ponded for 15 days. 40 days old seedlings of rice variety P 2-21 were transplanted on August 2, 1976. Recommended fertilizer application, cultural and plant protection measures were adopted. Crop was harvested on November 9, 1976.

The particle size distribution (Fig. 2) of different grades of gypsum shows that when gypsum was crushed to pass through a 10 mesh sieve (opening 2mm) more than 50 per cent of the material was fine enough to pass through 60 mesh (0.25 mm) sieve. Data in Table 5 show that while higher gypsum rates resulted in higher infiltration rate as compared to the lower rate of gypsum application, there was no measurable difference between gypsum grades of varying fineness. Similarly, rice yield significantly increased with increasing level of gypsum application although gypsum fineness had no apparent effect. pH_2 of the soil sample taken after the crop harvest shows similar trend. It may be mentioned here that experiment had rather high variability because of heavy rains immediately after transplanting.

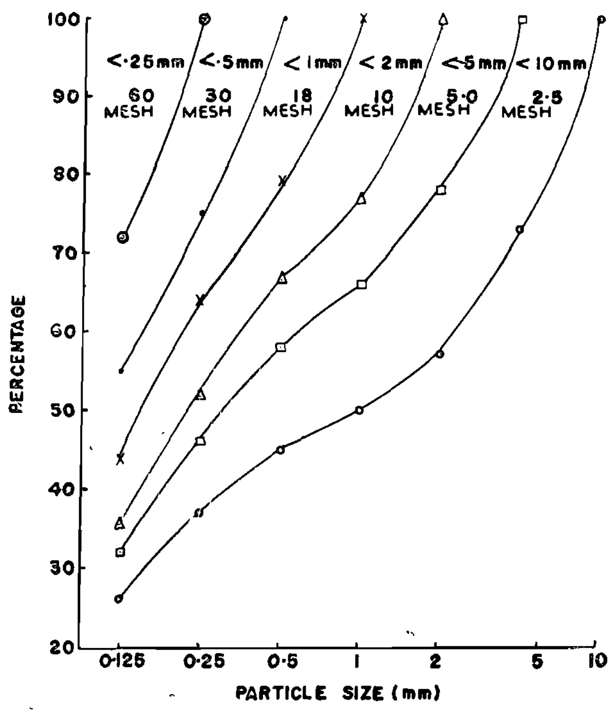


Fig. 2. Percentage particle size distribution of gypsum ground to a specified mesh size (Type I)

TABLE 5. *Effect of gypsum level and fineness on soil properties and crop yield*

Treatment	Infiltration rates + (mm/day)	Rice grain yield (kg/ha)	pH_2
Control	3	938	9.81
G_1F_1*	6	1741	9.39
G_1F_2	6	2018	9.42
G_1F_3	6	1761	9.52
G_1F_4	7	2108	9.60
G_1F_5	6	1561	9.60
G_1F_6	6	1475	9.50
G_2F_1*	9	3006	8.95
G_2F_2	9	3134	9.34
G_2F_3	10	3296	9.20
G_2F_4	9	3073	9.30
G_2F_5	9	3515	9.35
G_2F_6	9	3550	9.00

* G_1—Gypsum applied @ 5 t/ha. G_2—Gypsum applied @ 10 t/ha
F_1, F_2—etc. refer to increasingly finer grades of gypsum
+ measured after 10 days of continuous ponding

In a laboratory study, two sets of experiments were conducted using two types of gypsum grades, one having only the upper particle size limit defined and the second having both upper and lower particle size limits defined. Gypsum of a desired grade equal to the gypsum requirement was thoroughly mixed in soils of two sodicities (pH_2 9.5 and 10.0) and the saturated hydraulic conductivity (K) measured under a constant water head. Each successive 100 ml leachate was collected for chemical analysis.

When gypsum with only the upper size limit defined was used, initially the K values were higher with finer grade gypsum. After a small increase in K (Fig. 3) there was a decrease in its value, the rate of decrease being higher with increasing gypsum fineness. Finally K values were maximum in the case of gypsum crushed to pass 2 mm sieve.

In the second type of gypsum, the finer was the gypsum grade the higher was the initial K value (Fig. 4). The rate of decrease following a small initial increase was higher with finer grades. Gypsum having particles of size 0.25—0.125 mm maintained the highest K value. These studies show that crushing gypsum to very fine size is not likely to enhance the reclamation process.

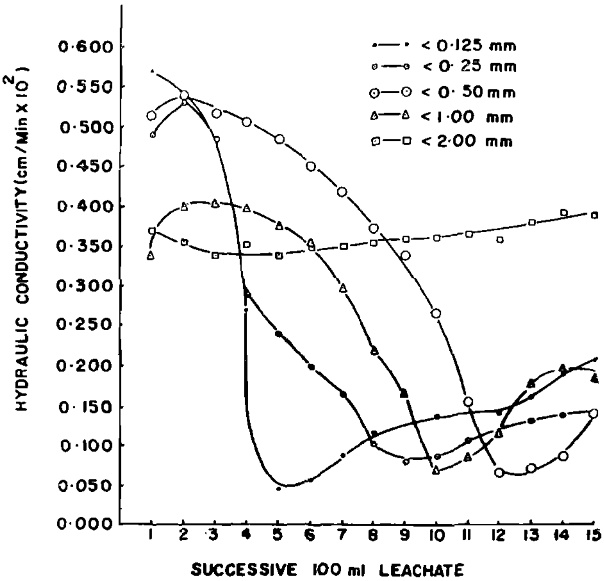


Fig. 3. Hydraulic conductivity of sodic soil (pH 10.0) as affected by application of gypsum ground to different fineness (Type-I)

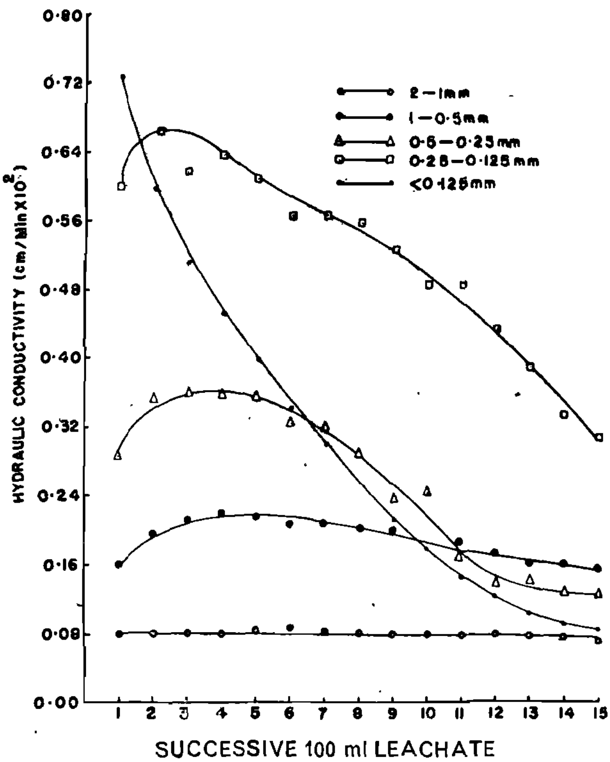


Fig. 4. Hydraulic conductivity of sodic soil (pH 9.5) as affected by application of gypsum ground to different fineness (Type-II)

S.A. 4.3. *Comparative effectiveness of pyrites and gypsum in the reclamation of sodic soils (K.S. Verma and I.P. Abrol)*

The effect of five levels of gypsum (0, 25, 50, 75 and 100 per cent of gypsum requirement) and equivalent quantities of pyrites on soil properties and rice yield was studied in a field experiment. The gypsum requirement of the experimental soil was 24 t/ha for surface 15 cm soil depth and the average pH_2 of surface soil was 10.24. Pyrites used had 31 per cent sulfur content. The treatments were replicated 4 times in a split plot design with level in the main plot and amendments in the sub plot. The plots were kept ponded for 15 days after application of amendments and seedlings of rice variety IR-8-68 were planted on July 14, 1976. Recommended fertilizer application, cultural and plant protection measures were adopted. The crop was harvested on October 28, 1976. Data on infiltration rate, soil pH at the time of harvest and crop yield show that gypsum was superior at all levels of application (Table 6). The relationship between rice yield and soil pH (Fig. 5) show that rice yield was reduced by about 50 per cent when soil pH was 9.95 which corresponds to an ESP of about 85. These results indicate that rice yield was higher in gypsum treated plots than those treated with pyrites.

TABLE 6. *Yield of rice and soil properties as affected by gypsum and pyrites*

Treatment	Grain yield (kg/ha)	Infiltration* rate (mm/day)	pH_2** 0-15 cm	pH_2** 15-30 cm		
G_0	3835	2.3	9.9	10.1		
P_0	3876	2.3	9.9	10.1		
G_{25}	6707	11.3	9.3	9.9	C.D. at 5%	
P_{25}	5714	3.4	9.7	10.1	Levels	4.53
G_{50}	6855	15.3	9.2	9.9	Amendments	2.87
P_{50}	6038	7.0	9.5	10.1	Average yield	
G_{75}	7436	20.0	8.8	9.6	Gypsum	Pyrites
P_{75}	6712	9.8	9.3	9.9	6414	5851
G_{100}	7239	21.1	8.6	9.5		
P_{100}	6914	12.9	9.2	9.9		

* measured 7 days after application of amendments

** soil samples taken after the harvest of rice crop

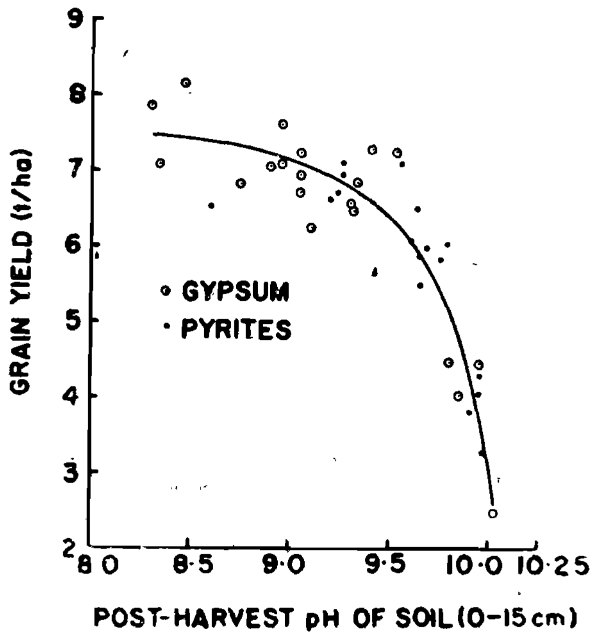


Fig. 5. Relationship between rice grain yield and post-harvest soil pH

SOIL CHEMISTRY

S.A. 3. Saline irrigation water and its effect on soil properties and crop growth

S.A. 3.1. *Lysimetric studies on the effect of saline water irrigation on soil properties and crop growth (R.C. Mondal)*

Fifth crop of wheat was grown in lysimeters as in previous years (S.A. 2.2, Annual Report 1975) and was irrigated with waters of varying salinities. Even after 4 seasons irrigation with saline water, the yield of wheat continued to remain unaffected upto 12,000 micromhos conductivity of irrigation water in the dune sand, but there was a significant reduction in grain yield when crop was grown in the sandy loam soil at this EC value (Table 7). This was apparently due to lower salinity development in the root zone in the dune sand because of salt leaching during rainy seasons. As a result of irrigation with 16 mmhos water for two years, the black soil failed to support any wheat crop.

TABLE 7. *Wheat yield as affected by varying levels of irrigation water salinity*

EC of irrigation water (mmhos/cm)	Wheat yield (g/lysimeter)		
	Dune sand	Sandy loam	Black soil
0.3 (tubewell water)	496 (668) *	533 (710)	440 (477)
2.0	467 (640)	509 (743)	350 (379)
4.0	491 (617)	576 (787)	440 (449)
8.0	466 (620)	499 (695)	407 (377)
12.0	551 (647)	341 (548)	356 (878)
16.0	371 (500)	61 (170)	Nil Nil
C.D. at P=.05	NS	165	

* Figures in parentheses are straw yields (g)

S.A. 3.4. *Boron adsorption equilibrium in soils (I.C. Gupta)*

(i) Three soils of varying texture were brought to equilibrium with boron containing solutions maintaining 1:1 soil solution ratio and boron was determined in the equilibrium solution. Results (Table 8) show that in all the three soils, adsorbed boron increased nearly linearly with an increase in the boron in the equilibrium solution. Boron adsorption was higher in finer textured soils.

(ii) Gypsum passed through 10, 30, 60 and 120 mesh screen was mixed with a highly sodic soil (pH_2 10.5) @ 2 g/100g soil. Boron concentration in the extract decreased from 7 ppm in untreated soil to 5.0, 3.3, 2.0 and 0 ppm when gypsum of increasing fineness was mixed.

TABLE 8. *Boron adsorption in three soils*

Dune Sand		Sandy Loam		Black soil (clay)	
B eq.	B ad.	B eq.	B ad.	B eq.	B ad.
3.8	1.2	3.0	2.0	1.2	3.8
7.8	2.2	6.4	3.6	3.8	6.2
16.5	3.5	14.8	5.2	8.5	11.5
25.0	5.0	24.0	6.0	14.0	16.0
34.0	6.0	33.0	7.0	19.0	21.0
43.0	7.0	42.2	8.0	25.0	25.0

B eq.—Boron in equilibrium solution mg/1; B ad.—Boron adsorbed

S.A. 3.5. *Potassium requirement of wheat and rice in a sodic soil (D.K. Pal and R.C. Mondal)*

(a) To study the effect of long term K application, an experiment was conducted in a semi-reclaimed alkali soil. Results (Table 9) show that application of K either to wheat and/or to rice did not affect the yield of these crops. The soil of the experimental plot had 2.62% K_2O, 416 kg/ha available K_2O and 21 kg/ha water soluble K_2O. On an average, wheat crop removed 108.8 kg/ha of K_2O.

TABLE 9. *Effect of potassium application on crop yields (t/ha)*

Treatment*	Wheat	Rice
$N_0P_0K_0$	0.84	2.70
W_0R_0	3.19	6.01
$W_{25}R_0$	3.01	5.35
W_0R_{25}	2.85	5.75
$W_{25}R_{25}$	2.75	6.29
$W_{50}R_0$	2.92	5.90
W_0R_{50}	2.86	6.01
$W_{50}R_{50}$	2.82	6.30

* W—Wheat, R—Rice. 0, 25 and 50 refer to K_20/ha

(b) In a pot study, the yield and uptake of K by berseem and rice was studied in a sodic soil (pH_2 9.8, ESP 62 and gypsum requirement 9.4 me/100 g). The yield of both crops was unaffected by K application (Table 10). Berseem removed 635 kg K_2O/ha in 6 cuts. The available K_2O decreased from 417 to 312 kg/ha as a result of growing berseem crop.

TABLE 10. *Yield of berseem and rice as affected by potassium*

Treatment	Fresh yield of berseem (6 cuttings) g/pot	Rice g/pot
B_0R_0	962	78.8
$B_{25}R_0$		75.5
$B_{25}R_{25}$	1003	69.4
$B_{50}R_0$		74.9
$B_{50}R_{50}$	1029	76.0

B—Berseem, R—Rice. 0, 25, 50 refer to K_20/ha

(c) To correlate the observed crop responses, laboratory studies were undertaken with two illitic soils—A,. semi-reclaimed (pH_2 8.4) and B, a sodic soil (pH_2 9.8, ESP 62). In one study, two soils were extracted daily with water and ammonium acetate continuously for 7 months and the amount of K and Na extracted were determined. In another study, only the sand fraction was extracted for 91 days. Results show that more K was extracted with water than with ammonium acetate (Table 11).

TABLE 11. *Distribution of K_2O content in different soil fractions and its release from two soils by different extractants*

Soil	%K_2O				K_2O released (kg/ha)		Na released (kg/ha	
	Clay	Silt	Sand	Soil	Ammonium acetate	Water	Ammonium acetate	Water
Soil A	4.62	3.29	1.68	2.62	571	1156	287	242
	(24)*	(24)	(41)		(288)**	(345)	(200)	(90)
Soil B	4.82	2.96	1.68	2.76	566	2702	263	247
	(28)	(19)	(63)		(278)	(351)	(124)	(88)

* % clay, silt etc.
** Quantities released in the sand fraction

S.A. 2.2. *Effect of $CaCO_3$ on the reclamation of a sodic soil (R.C. Mondal)*

To study the effect of $CaCO_3$ on reclamation, a $CaCO_3$ free sodic soil, (pH_2 10.1, exch. Na 9.1, exch. Ca+Mg 6.75 and GR 8.5 me/100g), sodic soil mixed with 2 per cent $CaCO_3$ and the sodic soil mixed with $CaCO_3$ and surface application of 8 me $CaSO_4$ were leached with distilled water for a period of 25 days. Data on cumulative leachate and cumulative sodium removed revealed that the efficiency of reclamation in the three treatments followed the order $CaCO_3+CaSO_4>CaSO_4>CaCO_3$ (Table 12). The effect of treatments on soil properties at the end of the experiment again shows that the treatment where $CaCO_3$ was added in addition to $CaSO_4$ was more effective in improving the sodic soil.

TABLE 12. *Reclaiming effect of $CaCO_3$ and $CaSO_4$ on a sodic soil*

Soil depth (cm)	$CaCO_3+CaSO_4$		$CaSO_4$	
	pH	ESP	pH	ESP
0-1	9.1	12.3	9.2	12.4
1-2	9.1	16.7	9.5	22.5
2-3	9.4	21.8	9.7	44.0
3-4	9.5	23.5	9.8	48.9
Total leachate (ml)	715		490	
Total Na removed (me)	12.99		10.30	

S.A. 4.4. *Effect of gypsum application on long term changes in soil properties and crop growth (I.P. Abrol and S.B. Singh)*

Cropping was continued in gypsum treated and untreated plots established in 1970 to follow changes in soil properties and yield of rice and wheat grown in a rotation. Data in Table 13 show that the grain yield of wheat in gypsum treated and untreated plots was same in 1975-76, although in previous years the yield in gypsum treated plots was significantly higher. No difference in the rice yield in two treatments has been recorded since 1974. Changes in soil pH as a result of continuous cropping (Fig. 6) show that pH_2 decreased to about 9.3 (which corresponds to an ESP of about 15) in surface 50 cm soil in case of gypsum treated and 40 cm in case of untreated plots.

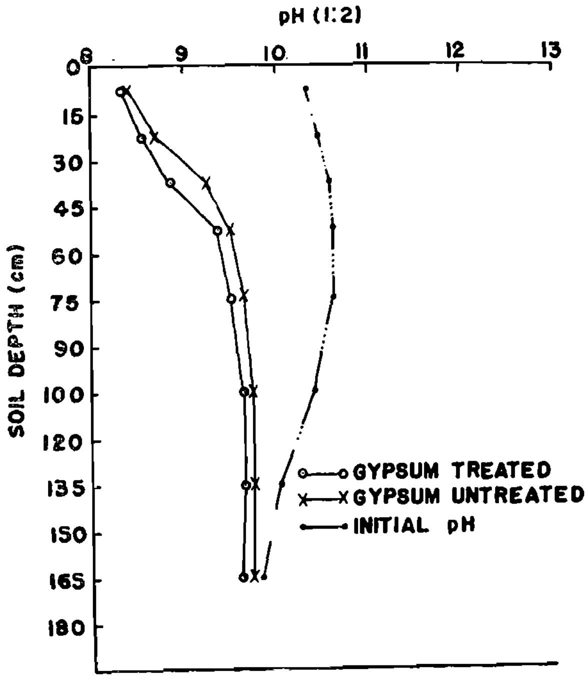


Fig. 6. Changes in soil pH as affected by gypsum application and continuous cropping

TABLE 13. *Yield of rice and wheat grain (t/ha) in gypsum treated and untreated plots*

Gypsum (t/ha)	Rice					Wheat				
	1972	1973	1974	1975	1976	1971-72	1972-73	1973-74	1974-75	1975-76
0	5.48	6.07	7.42	7.10	6.50	2.10	3.34	4.83	3.58	3.06
14.5	6.40	6.49	7.07	7.20	6.50	3.23	4.45	5.13	4.00	3.17
C.D. at P=0.05	0.52	0.26	NS	NS	NS	0.48	0.74	0.25	0.22	0.08

In other plots, Arhar (*Cajanus cajan*) variety *Prabhat* was grown in a

5 times replicated differentially gypsum treated plots (S. A. 2.1, Annual Report 1975). The pH_2 of surface soil varied from 8.5 to 9.9 and the corresponding ESP varied from 4 to 63. Because of heavy rain a few days after sowing, the crop was almost completely damaged in two replications. Yield data in respect of three replications plotted against ESP of surface soil (Fig. 7) show a sharp decrease in yield with increase in ESP value. Almost eight per cent reduction in yield was observed when the ESP of surface soil increased from about 5 to 20. In the same ESP range there is no loss in yield of rice and only slight reduction in wheat yield. Yield responses of *arhar* to ESP are very similar to those reported for gram and lentil earlier.

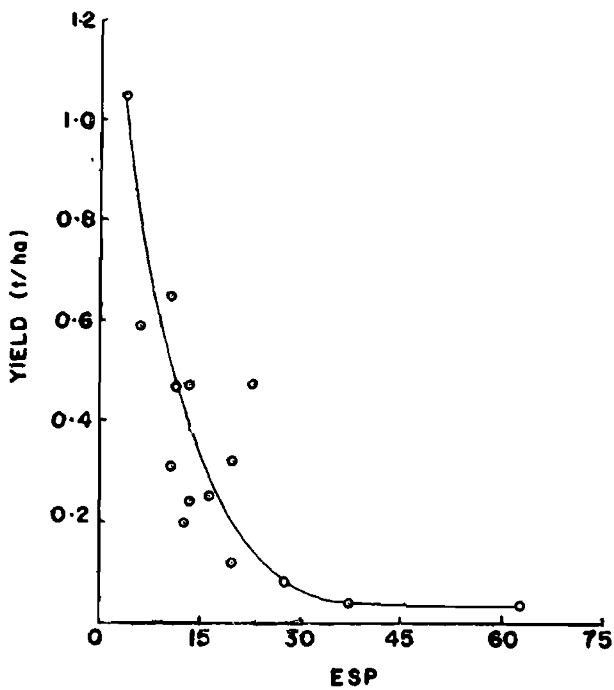


Fig. 7. Yield of arhar grain as affected by ESP of soil (0-15 cm)

S.A. 4.4.3. *Effect of leaching on reclamation of a sodic soil (S. B. Singh, R. Chhabra and I. P. Abrol)*

Previous studies have shown that growing of rice plants greatly enhanced the reclamation process of sodic soils. To investigate the effect of leaching alone on soil properties, laboratory tests were performed with 4 soils having ESP in the range of 3 to 90. The soils were leached for a period of

4 months with an electrolyte free water and a water having small amounts of electrolyte representing the common tubewell water (Ca^{++} 1.3; Mg^{++} 2.2 and Na^{+} 0.9 me/l). 1200 ml of cumulative leachate was collected in 12 leachings of 100 ml each. The soil cores were cut into upper and lower halves and analysed. The data (Table 14) show that leaching alone is likely to bring down the ESP and improve sodic soils considerably.

TABLE 14. *Effect of leaching on the properties of sodic soil*

Original Soil		Leaching with distilled water				Leaching with tap water			
		Surface soil		Subsurface soil		Surface soil		Subsurface soil	
pH_2	ESP	pH_2	ESP	pH_2	ESP	pH_2	ESP	pH_2	ESP
10.10	90	9.6	50	9.8	70	9.3	30	9.7	64
9,75	65	8.6	6	8.9	15	8.4	5	8.9	16
9.10	20	8.5	2	8.6	6	8.5	5	8.6	6
8.55	3	8.5	2	8.5	3	—	—	—	—

S.A. 4.4.4. *Tolerance of tree species to exchangeable sodium (S. B. Singh and I. P. Abrol)*

A pot experiment replicated five times was conducted to study the relative tolerance of two tree species (*Euclyptus hybrid* and *Acacia nelotica*). About six months old seedlings of uniform height and vigour were planted on March 4, 1976 in pots, each containing 20 kg soil. The plants were harvested on Oct. 1, 1976. Data in Table 15 show that the total dry matter yield of the two species followed the same trend with increasing soil ESP. In both cases there was an increase in dry matter with small initial ESP increase, but there was a sharp decrease as the ESP was increased from 30 to 65. *Euclyptus hybrid* accumulated much more sodium as compared to *Acacia nelotica* which had relatively higher potassium content. With increasing ESP, P content decreased in both the species.

TABLE 15. *Effect of ESP on the growth and chemical composition of leaves of two tree species*

ESP	Total dry matter (g/pot)		Chemical composition %							
	EH	AN	Na		K		Ca		P	
			EH	AN	EH	AN	EH	AN	EH	AN
2	76	83	.14	.03	.34	.70	1.12	.96	.52	.31
5	100	95	.33	.03	.35	.74	1.64	.72	.45	.24
30	86	75	.35	.05	.34	.72	1.28	.72	.40	.28
65	40	41	.42	.07	.38	.60	.096	.64	.37	.21
85	13	18	.70	.10	.57	.61	0.52	.52	.37	.18

EH—*Euclyptus hybrid* AN—*Acacia nelotica*

S.A. 4.8. *Effect of fluorine and phosphorus on the yield and chemical composition of rice plants (Anoop Singh, R. Chhabra and I.P. Abrol)*

Large quantities of by-product gypsum (also called phosphogypsum) will be available from the wet process phosphoric acid production units. The by-product gypsum contains about 1-2 per cent fluorine and some phosphorus. A pot experiment was conducted in 20 kg capacity glazed pots to study the effect of 5 levels of fluorine (0, 10, 20, 40 and 80 ppm) and four levels of applied phosphorus (0, 25, 50 and 100 ppm) on the yield and chemical composition of rice variety P.2-21 grown in two soils (ESP 33 and 75). Results in respect of one of the soils (ESP 75) are presented in Table 16. Fluorine did not affect the yield of either grain or straw. Increasing levels of P resulted in increased yield of both grain and straw. There is a tendency for sodium content to decrease and the potassium content to increase with increasing P application. The overall effect of ESP on yield and straw composition (Table 17) reveal significant differences in both yield and uptake of Ca, Mg, Na, K and P.

TABLE 16. *Effect of levels of fluorine and phosphorus on the yield and chemical composition of rice grown in a sodic soil (ESP 75)*

Treatment	yield g/pot		Straw composition %				
	grain	Straw	Ca	Mg	Na	K	P (x 1000)
P_0	44.8	39.6	.42	.39	2.54	.38	55
P_1	50.3	48.3	.45	.43	2.51	.42	59
P_2	49.3	44.5	.42	.39	2.40	.43	60
P_3	64.4	53.1	.47	.41	2.11	.56	60
F_0	55.1	45.0	.46	.41	2.44	.45	59
F_1	54.7	45.7	.45	.43	2.33	.47	57
F_2	46.5	43.8	.44	.42	2.37	.47	65
F_3	52.5	45.6	.45	.39	2.33	.48	60
F_4	52.1	45.5	.39	.37	2.47	.38	53

TABLa 17. *Effect of ESP on the yield and chemical composition of rice straw*

ESP	Yield g/pot		Composition %				
	grain	straw	Ca	Mg	Na	K	P
33	80.8	61.9	.58	.55	1.44	1.15	.048
75	52.2	45.1	.44	.40	2.39	0.45	.059

S.A. 6. Studies on phosphorus and zinc requirements and their interaction in salt-affected soils

S.A. 6.1. *Effect of ESP on the availability of soil phosphorus (R. Chhabra, Anoop Singh and I. P. Abrol)*

To study the effect of ESP on availability of soil phosphorus, fifty soil samples (25 surface and 25 sub-surface) were collected from plots which had varying ESP but had received uniform application of P-fertilizers during the past five years. The pH (1 : 2) of surface samples varied from 8.5 to 9.9 and that of sub-surface from 9.0 to 10.1. The corresponding ESP range for the soils was 4 to 63 for the surface and 20 to 94 for the sub-surface samples. The available-P as determined by different methods is given in Table 18. These data indicate that with increase in ESP and pH, there is an increase in available phosphorus status of these soils.

TABLE 18. *Soil available phosphorus as determined by different methods*

Method	Range of available-P (ppm-P)		Y values (Surface samples) with	
	Surface	Sub-surface	ESP	*pH*
Olsen's	11-23 (17)	9-22 (14)	0.75**	0.72**
Bray's	12-24 (18)	7-23 (12)	0.76**	0.71**
EDTA-I (pH=4.7)	14-67 (34)	4-22 (12)	0.58**	0.58**
EDTA-II (pH=8.5)	21-64 (41)	9-34 (18)	0.81**	0.76**

** Significant at P = 0.01

S.A. 6.1.1. *Forms of phosphorus in sodic soils*

The inorganic forms of phosphorus in soils with wide ranging ESP were evaluated so as to understand the chemistry of phosphorus in these soils. The data in Table 19 provide the range of various forms of phos-

TABLE 19. *Forms of inorganic phosphorus in sodic soils*

Form of P	Range (ppm P)		Y values (surface samples) with	
	Surface	Sub-surface	ESP	pH
Total P	425-637	280-550	—	—
Adsorbed P	1.2-8(5)	0.00-3.50(1)	0.75**	0.70**
Al-P	15-36(26)	9-20(14)	0.57**	0.54**
Fe-P	1.5-19.5(6)	2.3-20.5(6)	NS	NS
Ca-P	165-281(212)	111-169(134)	NS	NS
OccAl-P) OccFe-P)	traces	traces	—	—

** Significant at P = 0.01

phorus and their relationship to soil ESP and pH. It is seen that Ca-P is the major fraction of inorganic-P in these soils. With increase in ESP and pH of soil, adsorbed-P and Al-P increase and Ca-P remains unaffected.

S.A. 6.2. *Phosphorus requirement of rice and wheat at different stages of reclamation of sodic soil (R. Chhabra)*

To study the effect of long term P-fertilizer practices, an experiment with 8 treatments replicated four times in a randomized block design was initiated in a partially reclaimed sodic soil at the C.S.S.R.I. farm, Karnal with rice as first crop. The average pH of surface soil varied from 8.4 to 8.7 and that of sub-surface from 9.0 to 9.2. Rice variety Jaya, was transplanted on July 7, 1976 and harvested on Oct. 21, 1976. Full dose of P as per treatment, 50 kg. K_2O, 25 kg $ZnSO_4$ and 60 kg N/ha were applied before transplanting. The remaining dose of N was applied in 2 equal splits on Aug. 23, and Sept. 21, 1976. The results (Table 20) show that there was no response to phosphorus applied to rice. As a result of growth of rice there was a slight reduction in available P of soil as also slight reduction in soil pH. The experiment will be continued further.

TABLE 20. *Effect of P application on rice grain yield*

Treatment	Yield (t/ha)	pH (1:2) Before	pH (1:2) After	Olsen's—P (ppm) Before	Olsen's—P (ppm) After	P content (mg/g) Grain	P content (mg/g) Straw
R_0W_0*	6.58	8.6	8.2	9.1	8.4	.263	.085
$R_{25}W_0$	7.28	8.5	8.2	9.0	8.6	.255	.082
$R_{50}W_0$	6.78	8.5	8.3	8.4	9.6	.270	.089
R_0W_{25}	6.88	8.5	8.3	9.6	8.9	.268	.073
R_0W_{50}	7.11	8.7	8.2	9.1	7.9	.258	.082
$R_{25}W_{25}$	6.61	8.5	8.2	9.6	9.2	.278	.076
$R_{50}W_{50}$	6.68	8.6	8.2	9.7	8.4	.254	.086
$N_0P_0K_0$	3.94	8.5	8.2	8.3	8.2	.249	.054
CD at P-0.05=0.93							

* R — Rice
W — Wheat 0, 25 and 50 refer to P_2O_5 kg/ha applied as super phosphate

S.A. 6.3. *Effect of different levels, sources and methods of application of zinc on growth and yield of rice and wheat in sodic soils (R. Chhabra)*

Two pot experiments, with first having five levels of Zn (0, 2.5, 5.0, 7.5 and 10.0 ppm) compared for their response to rice on soils of three sodicities having pH_2 values 9.8, 9.2 and 9.8, and the second containing the same soils as in the first one, seven methods of Zn-application (Control, 2.5 ppm Zn applied in soil through $ZnSO_4$, 2.5 ppm Zn applied in soil through Zn-EDTA, root dipping of seedlings in ZnO root-dipping in Zn-EDTA solution, FYM @ 25 t/ha, FYM @ 25 t/ha + 2.5 ppm Zn through $ZnSO_4$) were conducted. Four seedlings of rice, variety Pusa-2-21 were transplanted in each pot containing 8 kg soil on July 6, 1976.

In case of the first pot experiment, after 15 days of transplanting severe Zn deficiency symptoms in the form of dark brown colouration, starting from the side of the fully mature leaves were noticed in control pots. The brown colour spread rapidly towards top and base making the whole leaf blade necrotic, which ultimately died with rolling around the mid-rib. The mid-rib, however, did not turn yellow. The deficient plants remained dwarf and less vigorous as compared to Zn-treated plants. The deficiency symptoms disappeared after 40 days of transplanting and the plants put up new shoots and leaves and ultimately gave yield equal to the Zn-treated plants. However, the emergence of inflorescence and maturity was delayed in control plants by about 20 days. There was no significant difference in grain yield among the various levels of Zn-application.

In case of the second pot experiment, severe Zn deficiency symptoms were recorded in control and treatment containing FYM alone. The symptoms, however, disappeared after 40 days of transplanting and the plants put up normal growth thereafter. The treatments FYM + Zn and FYM alone gave higher rice yield than other treatments (Table 21). Zn-EDTA root dipping gave the lowest yield because of death of certain plants in this treatment.

TABLE 21. *Effect of different sources and methods of Zn application to rice yield (g/pot)*

pH	Control	$ZnSO_4$ Soil app.	Zn-EDTA Soil app.	Root dipping in ZnO	Root dipping in Zn-EDTA	FYM	FYM+Zn	Mean
9.8	25.9	29.9	31.8	30.0	30.1	38.4	40.6	32.4
9.2	46.1	44.7	45.1	46.4	41.1	50.3	51.8	46.5
8.8	42.9	44.0	43.7	43.3	34.2	41.6	48.4	42.6
Mean	38.3	39.5	40.2	39.6	35.1	43.4	46.9	

SOIL MICROBIOLOGY

S.A. 5. Nitrogen fixation and transformation in saline and sodic soils

S.A. 5.4. *Effect of exchangeable sodium on nitrogen fixing microorganism in soil* (*Lalita Batra and K.K.R. Bhardwaj*)

(i) Effect of 5 levels of exchangeable sodium on the growth and N fixation by 5 legumes was studied in pots containing 1.5 kg soil. Legume seeds were inoculated with effective rhizobial cultures before sowing and P_2O_5 at 70 kg/ha was applied to the soil. Plants were harvested after 55 days growth and dry matter yield and N content determined. Results show (Fig. 8) that *dhaincha* (*Sesbania aculeata*) yielded highest dry matter at nearly all ESP levels and its relative yield reduction with increasing ESP was lowest. *Dhaincha* was relatively more sensitive to exchangeable sodium at germination but once established it grew even at higher ESP levels. N fixation (Fig. 9) followed the same trend as dry matter yield, fixation at higher ESP levels being higher in *dhaincha*.

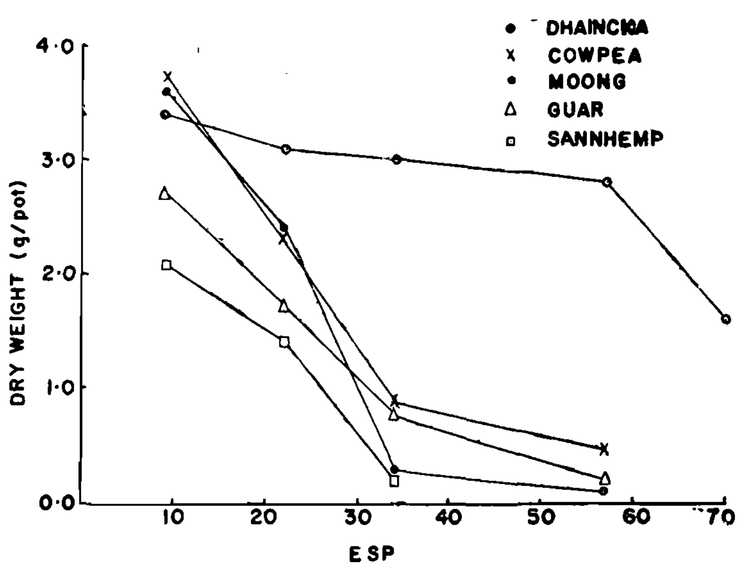


Fig. 8. Dry matter production of legumes in alkali soil amended to varying exchangeable scdium percentage (ESP).

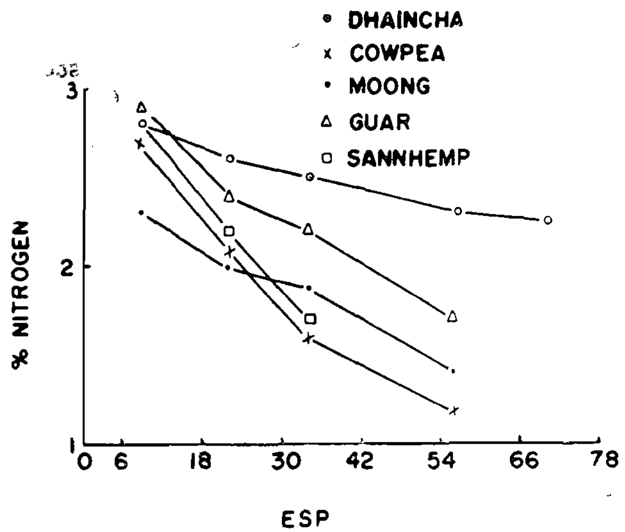


Fig. 9. Nitrogen fixation by legumes in an alkali soil amended to varying. exchangeable sodium percentage (ESP)

(ii) In another study, growth, nodulation and N fixation by *dhaincha* and *cowpea* in soils of varying ESP were compared at different times after sowing. Results show (Table 22) that decrease in growth, nodulation and N fixation with increasing ESP were

TABLE 22. *Effect of ESP on the growth, nodulation and nitrogen fixation in dhaincha (Sesbania aculeata) and cowpea (Vigna sinensis)*

ESP	15 days after sowing				60 days after sowing			
	Dry wt (g/pot)		No. of nodules/pot	% N shoot	Dry wt (g/pot)		No. of nodules/pot	% N shoot
	Root	Shoot			Root	Shoot		
				Dhaincha				
9	.15	.45	72	3.45	1.25	3.50	197	3.00
22	.10	.35	39	2.35	1.15	2.95	138	2.63
34	.07	.30	29	3.33	1.00	2.72	108	2.44
57	.06	.24	16	2.92	1.00	2.40	90	2.37
70	.02	.10	—	2.00	1.00	2,12	69	2.31
				Cowpea				
9	.35	1.32	95	3.10	1.42	3.70	138	2.82
22	.25	1.22	42	2.95	1.32	2.25	125	2.56
34	.20	0.55	15	2.50	0.40	0.95	49	1.65
57	.08	0.42	—	2.05	0.25	0.50	20	1.34
70	.05	0.20	—	1.85	—	—	—	—

more marked in *cowpea* than *dhaincha*. Results have further shown that nodulation decreased more rapidly with increasing ESP than the dry matter yield. This is probably due to adverse effect of high ESP on the capacity of rhizobial cells to cause infection. Ability of plants to grow at ESP levels where there is delayed nodulation is possibly due to the favourable effect of root growth on the rhizosphere for infection of roots by the root nodule bacteria.

S.A. 5.3. *Comparative performance of three legumes for green manuring in a semi-reclaimed alkali soil (K.K.R. Bhardwaj, Lalita Batra and K.S. Dargan)*

To evaluate the suitability of three legumes grown in summer for green manuring, a quadruplicated field experiment was conducted in a semi-reclaimed alkali soil (pH_2 8.3 to 8.6 in 0-15 and 8.8 to 9.1 in 15-30 cm soil depth). Three legumes were sown on April 26 and green manured on June 27, 1976. Rice, variety Jaya, grown at 3 N levels, was transplanted on July 13 and harvested on Oct. 31, 1976. Results (Table 23) show that *dhaincha* green manuring resulted in higher rice grain yield than green manuring with either sannhemp or cowpea. This can be attributed to higher green matter produced in case of *dhaincha*.

TABLE 23. *Effect of green manuring and nitrogen levels on rice yield (t/ha)*

Green manure crop	Green matter (t/ha)	N levels		
		O	60	120
Fallow	—	4.7	6.0	6.5
Dhaincha	13.5	5.8	6.4	6.5
Sannhemp	9.5	5.6	6.3	6.5
Cowpea	9.3	5.2	6.2	6.4
	Mean	5.3	6.2	6.5

C.D. at P=0.05 for N=0.7 ; for crops—NS

AGRONOMY

S.A. 2. Agronomic and cultural practices for different crops in saline-sodic soils

S.A. 2.2. *Nitrogen requirement of new barley varieties (R. K. Chhillar and K. S. Dargan)*

The effect of five N levels on the yield of five barley varieties was studied in a semi-reclaimed alkali soil (pH_2 8.7 for 0-15 cm and 9.4 for

15-30 cm soil depth) by adopting split-plot design with varieties in the main plots and N levels in the sub-plots. N as per treatments was given in 2 splits, at sowing and before first irrigation. Crop was sown on November 15, 1975 and harvested on April 3, 1976. The crop received 4 irrigations. Variety Ratna, in general yielded significantly higher than other varieties. Increasing levels of N resulted in increased yields upto 80 kg N/ha, though the differences were not significant in all cases (Table 24).

TABLE 24. *Barley grain yield (kg/ha) due to varieties and nitrogen doses*

N Kg/ha	Ratna	Local (C-164)	Jyoti	Vijay	DL-70	Mean
0	1210	879	781	781	1250	980
20	1386	1777	1250	1484	1601	1503
40	2500	2148	1757	1562	1796	1952
60	3047	2656	2441	2500	1757	2480
80	3163	2851	2988	2635	2461	2820
Mean	2261	2062	1843	1792	1772	

	Varieties	N
C.D. at P=0.05	190	260

S.A. 2.3 *Nitrogen requirement of rice after fallow and after green manuring and the residual effect on wheat crop (K. S. Dargan and R. K. Chhillar)*

Previous studies (Annual Report 1975) showed that effect of summer green manuring with *dhaincha* (*Sesbania aculeata*) was nearly equal to 80 kg N/ha applied directly to the rice crop. During the second year of the experiment similar results were obtained with regard to N responses to rice. During *rabi* 1975-76, wheat (HD-1553) was sown on December 4, 1975 in the same layout by dividing each plot in to two equal sub-plots to accommodate two levels of nitrogen at 60 and 120 kg/ha. Basal dose of P and K at 40 kg/ha and zinc sulphate at 20 kg/ha was applied at sowing time alongwith half the dose of N as per treatment. The remaining N was given in equal splits on Dec. 26, 1975 and Jan. 29, 1976. The crop received 6 irrigations and was harvested on April 19, 1976. Results showed that green manuring before rice and differential N application to rice had no residual effect on the yield of succeeding wheat crop. Directly applied N at 120 kg N/ha increased the wheat grain yield by 1.08 t/ha over 60 kg N/ha which produced grain yields of only 2.75 t/ha.

S.A. 2.4. *Effect of missing application of P or both P and K in rice or wheat or both crops on the yield in semi-reclaimed sodic soil (K. S. Dargan and R. K. Chhillar)*

A field experiment with randomized blocks having 8 treatments and four replications was initiated in *Kharif* 1974 to study the effect of missing P and K fertilization in rice-wheat rotation (Table 25). Cropping was continued in the year under report. Wheat, variety HD-1981 was sown in the fixed layout on Nov. 19, 1975. Full dose of P and K and half dose of N as per treatments was applied at sowing and the remaining half dose of N was top dressed in 2 equal splits on Dec. 27, 1975 and Jan. 22, 1976. The crop received 6 irrigations and was harvested on April 19, 1976. After wheat, rice variety IR-8-68 (i.e. 5th crop in sequence) was transplanted on June 26, 1976. Full dose of P and K and half dose of N as per treatments, was applied before transplanting and the remaining half dose of N was applied in two equal splits on July 24 and August 16, 1976. The crop was harvested on October 13, 1976. Results (Table 25) show that the yield of wheat and rice in the treatments where no P and K had been applied to the previous 3 crops was at par with the treatments where P and K had been applied to either of the crops. Available P status of the soil determined after harvesting wheat crop continues to be high in nearly all the treatments.

TABLE 25. *Effect of missing application of P or both P and K on crop yield (t/ha)*

	Treatment		Yields		
	Rice	Wheat	Wheat 1975-76	Rice 1976	Available P (kg/ha) in soil after wheat
1.	N_0P_0	N_0P_0	1.20	4.11	20.2
2.	N_{100}	N_{100}	3.80	8.15	18.0
3.	$N_{100}P_{50}$	$N_{100}P_{50}$	3.71	8.34	29.6
4.	$N_{100}P_{50}$	N_{100}	3.75	7.72	19.8
5.	N_{100}	$N_{100}P_{50}$	3.82	8.50	20.4
6.	$N_{100}P_{50}K_{50}$	$N_{100}P_{50}K_{50}$	3.71	8.50	26.9
7.	$N_{100}P_{50}K_{50}$	N_{100}	3.75	8.72	20.8
8.	N_{100}	$N_{100}P_{50}K_{50}$	3.66	8.04	22.5
	C.D. at P=0.05		.33	1.32	
Mean yield due to:					
1.	Control		1.20	4.11	
2.	N_{100}		3.79	8.22	
3.	$N_{100}+P_{50}$		3.76	8.07	
4.	$N_{100}+P_{50}+K_{50}$		3.69	8.38	

S.A. 2.5. *Cropping pattern for sodic soils* (*R.K. Chhillar and K.S. Dargan*)

The same cropping pattern was continued in the experiment, as initiated in *Kharif* 1972 (S.A. 2.5, Annual Report 1975). Wheat, variety HD-2009 was sown on Nov. 5, 1975 in rotation 1 to 6 (Table 26). Full dose of P_2O_5 (40 kg/ha) and half the dose of N (60 kg/ha) was applied at sowing and the remaining N was applied in 2 equal splits on Nov. 23 and Dec. 26, 1975. Crop received 7 irrigations and was harvested on April 7, 1976. Berseem was sown on Oct. 11 in rotation 7 and received 50 kg N, 100 kg P_2O_5 and 25 kg zinc sulphate/ha. The crop received 18 irrigations. It gave a total fodder yield of 122 t/ha in 7 cuts. Sugarbeet was sown on Oct. 10 in rotation 8, and received 120 kg N, 60 kg each P_2O_5 and K_2O and 25 kg zinc sulphate/ha. 16 irrigations were applied and the crop was harvested on May 20, 1976 with 56.5 t/ha root yield.

During summer, *dhaincha* was sown on April 18 in treatment 3 and green manured on June 25, 1976. The green matter added was 25.5 t/ha. Cowpea, *jowar* and *bajra* were sown in treatments 4, 5 and 6 respectively on April 18, 1976. N and P_2O_5 at 30 at 60 kg/ha were applied to cowpea and at 60 and 30 kg/ha to *jowar* and *bajra* respectively. Crops received 6 irrigations and were harvested on June 29/30.

Rice variety P_2-$_{21}$ was transplanted on July 15 in all the rotations. The crop received 120 kg N/ha, half at transplanting and the remaining half in 2 splits on Aug. 6 and 31 and 25 kg/ha zinc sulphate. The crop was harvested on Oct. 3, 1976.

Results (Table 26) show significantly higher rice yield (8.19 t/ha) after *dhaincha* green manuring followed by rice-berseem rotation. Wheat yield was highest in cowpea-rice-wheat rotation.

TABLE 26. *Yield (t/ha) of different crops in various rotations*

Rotation	Yield rabi 1975-76	Summer 1976	kharif 1976
1. Rice-wheat-fallow	4.31	—	6.33
2. Rice-wheat-fallow (Irrigated)	4.54	—	6.82
3. Rice-wheat-*dhaincha* (GM)	4.22	25.52 (GM)	8.19
4. Rice-wheat-cowpea (Fodder)	4.76	27.36	6.12
5. Rice-wheat-Jowar (Fodder)	4.67	17.56	6.80
6. Rice-wheat-bajra (Fodder)	4.59	30.56	6.32
7. Rice-berseem (Fodder)	12.2	—	7.12
8. Rice-sugarbeet (Roots)	56.5	—	6.52
CD at P=0.05 (For wheat and rice)	NS		0.90

S.A. 2.6. *Transplanting versus direct seeding of bajra (Pennisetum typhoideus) in a semi-reclaimed alkali soil (K. S. Dargan and R. K. Chhillar)*

To compare the performance of transplanted and direct seeded *bajra*, an experiment with 6 treatments and 3 replications in a randomized block design was conducted in a semi-reclaimed alkali soil. *Bajra* variety HB-14, was sown as directly sown seed in the experiment and in the nursery bed on 3 dates viz., June 29 (D_1), July 9 (D_2) and July 31 (D_3). The seedlings from the nursery were transplanted on July 20 (D_1), July 31 (D_2) and August 16 (D_3). Due to rains, regular interval of 10 days for seed sowing and 20 days for transplanting could not be maintained as planned. Row to row spacing of 40 cm and plant to plant spacing of 15 cm was adopted. Continuous rain in July resulted in a set-back to the crop which was sown directly and transplanted in July and August. N was applied at 100 kg/ha and crop was harvested on Oct. 14, 1976.

Results (Table 27) show that direct sowing on June 29 gave significantly higher yield than all other treatments except in the case where transplanting was done on July 20. Yield difference among other 5 treatments were non-significant. Mean yield due to direct sowing and transplanting were at par while first sowing gave significantly higher yield than second and third sowings.

TABLE 27. *Bajra grain yield (t/ha) as affected by date and method of planting*

Dates	Direct Sown	Transplanted	Mean
D_1	2.47 (29/6)	1.84 (20/7)	2.15
D_2	1.36 (9/7)	1.59 (31/7)	1.48
D_3	1.46 (31/7)	1.36 (16/8)	1.41
Mean	1.76	1.60	
	Methods	*Date*	*Methods x dates*
C.D. at P=0.05	N.S.	0.51	7.8

Figures in parentheses are dates of direct seed sowing and transplanting

S.A. 2.9. *Comparative performance of wheat and barley in a semi-reclaimed soil (B. L. Gaul and K. S. Dargan)*

The comparative performance of wheat, variety HD-1553 and barley variety Vijay, was evaluated in semi-reclaimed alkali soil (pH 8.4 for 0-15 and 9.2 for 15-30 cm soil depth). Three sowing dates, 1st, 15th and 30th

Dec., and 2 nitrogen levels, 40 and 80 kg. N/ha, formed the treatments in main plot and the two crops formed the treatments in the sub plots, the number of replications being 4. Half the dose of N as per treatment was applied at sowing and the remaining half before the first irrigation. Each crop received 5 irrigations and harvesting was done on April 23, 1976. Wheat crop yielded significantly higher than barley. The second sowing yielded significantly higher than the first and the first sowing yielded significantly higher than the third sowing. Lower yield in Dec. 1 sowings as compared to Dec. 15 sowing is due to lower plant population resulting from low soil moisture status at the sowing time. At 40 kg N/ha wheat and barley yields were at par but at 80 kg N/ha wheat yielded significantly higher than barley (Table 28).

TABLE 28. *Wheat and barley yield (t/ha) as affected by sowing dates and nitrogen levels*

Sowing date	N 40		N 80		Mean		Mean of
	Wheat	Barley	Wheat	Barley	Wheat	Barley	dates
Dec. 1 (D_1)	1.71	1.70	2.40	2.06	2.06	1.88	1.97
Dec. 15 (D_2)	2.05	2.15	2.61	2.39	2.33	2.27	2.30
Dec. 30 (D_3)	1.65	1.53	2.10	1.51	1.87	1.52	1.70
Mean	1.80	1.79	2.37	1.99	2.09	1.80	
Mean of N		1.80		2.18			

	Dates	N	Crops	D×C	C×N
CD at P=0.05	1.93	1.58	0.98	1.69	1.37

S.A. 2.10. *Effect of dipping rooted slips and stem cuttings in zinc oxide and nitrogen levels on the fodder yield of para grass in a sodic soil (Ashok Kumar, K.S. Dargan and I.P. Abrol)*

The experiment was initiated during 1975 (S. A. 2.10, Annual Report 1975) to study the effect of 5 levels of N, 2 planting materials and 2 zinc treatments on the fodder yield of para grass in a sodic soil (pH 9.2 for surface 0-15 cm). During 1975, the rooted slips dipped in zinc oxide solution when fertilized at 40 kg N/ha/cut gave the highest yield of green fodder in two cuttings.

During 1976, 4 cuts of the crop were taken and N as per treatments was applied after each cut. Results (Table 29) show that increasing level of N upto 40 kg/ha increased the fodder yield significantly, while the differences due to other treatments were non significant. The yield level was much higher as compared to the last year, the highest yield being 90.3 t/ha as compared to 27.6 t/ha in 1975. This shows that the production potential of the crop on sodic soils will improve considerably with passage of time.

TABLE 29. *Para grass yield (t/ha) due to various treatments*

Treatment	N 0	N 10	N 20	N 30	N 40	Mean	Mean of Zinc
Rooted slips without Zn	46.69	66.26	74.41	77.88	90.25	71.17	
Stem cuttings without Zn	55.35	65.85	69.72	76.25	88.66	71.16	71.16
Rooted slips with Zn	54.09	71.60	72.05	78.66	90.29	73.34	
Stem cuttings with Zn	49.64	67.07	17.72	77.48	83.23	69.83	71.59
Mean of N	51.44	67.78	71.98	77.56	88.11		
	N			Interaction			
CD at P=0.05	5.10			6.00			

S.A. 2.11. *Effect of soil sodicity and nitrogen levels on the fodder yield of oats (B.L. Gaul and I.P. Abrol)*

Effect of 5 levels of N and 5 levels of exchangeable sodium (represented by pH_2 of 8.1, 8.5, 9.3, 9.7 and 9.9) on the yield of oats fodder was studied in a quadruplicate pot experiment. Oats, variety kent, was sown on Nov. 25 after applying half the dose of N as per treatment and 40 kg P_2O_5, 20 kg K_2O and 20 kg zinc sulphate/ha as basal dose to all the treatments. Remaining N was applied in 2 equal splits on Jan. 3 and Feb. 12, 1976. The crop for green fodder was harvested on March 26. The data in Table 30 show that the dry matter yield increased significantly with increasing dose of N upto 80 kg N/ha and above this the differences were non significant. With initial pH increase from 8.1 to 8.5 upto 80 kg N/ha, there was a significant increase in the yield. As the pH increased above 8.5, there was a regular decrease in dry matter yield. The interaction between N and soil sodicity was also significant.

TABLE 30. *Drymatter yield (g/pot) of oat fodder as affected by nitrogen and soil pH*

N kg/ha	Dry matter yield (g/pot)					
	pH					
	8.1	8.5	9.3	9.7	9.9	Mean
0	25.5	53.3	53.2	29.7	15.9	35.5
40	53.0	65.4	59.9	52.2	33.2	52.7
80	64.4	75.3	66.1	52.3	61.9	64.0
120	69.6	64.5	69.7	56.9	58.8	63.9
160	72.4	69.2	60.3	59.5	66.1	65.5
Mean	57.0	65.5	61.8	50.1	47.2	56.3
	N	pH	N×pH			
CD at P=0.05	4.6	4.6	5.2			

S.A. 2.12. *Effect of soil sodicity and cultural practices on the yield of fodder turnip (R.K. Chhillar, I.P. Abrol and K.S. Dargan)*

The experiment was conducted in plots to which gypsum had been applied @ 0, 13.5 and 27.0 t/ha and thus the average pH values of the surface soil were 9.8, 9.6 and 9.4. A split-plot design was adopted with nine main plots having treatments of 3 sodicity levels (corresponding to 3 pH values) x 3 spacings of 36, 45 and 60 cm between rows and sub plots in each main plot to accommodate 2 methods of sowing-ridge and flat. Each treatment was replicated 4 times. The crop was sown on Oct. 31, 1975 and received fertilizers @ 60 kg N, 30 kg P_2O_5 and 75 kg K_2O/ha. 8 irrigations were applied and the crop was harvested on Feb. 20, 1976. The data in Table 31 show that the fodder yield at pH 9.4 was significantly higher than at pH 9.6 and 9.8. Closer spacing at 36 cm resulted in significantly higher fodder yield than at 45 and 60 cm row spacing. Flat method of sowing gave significantly higher fodder yield than the ridge method of sowing.

TABLE 31. *Yield of fodder turnip as affected by soil sodicity, row spacing and method of sowing*

Treatment	Yield t/ha	CD at P=0.05
Soil pH		
9.8	6.64	
9.6	8.57	
9.4	11.16	2.57
Row spacings		
60 cm	7.45	
45 cm	8.11	2.59
36 cm	10.81	
Methods		
Ridge	7.02	
Flat	10.56	1.28

S.A. 2.13. *Effect of gypsum levels and plant spacings on rice yield in a sodic soil (R.K. Chhillar, I.P. Abrol and K.S. Dargan)*

The effect of 5 gypsum levels and 3 spacings was studied on rice yield in a sodic soil (pH of 0-15 cm soil 10.2 and average gypsum requirement of the plots, 24 t/ha). The experiment was laid in a split-plot design with gypsum levels in the main plot and spacings in the sub plot. The treatments were replicated 4 times. Rice, variety P-2-21 was transplanted on

July 24 and harvested on Nov. 3, 1976. The crop received fertilizers @ N_{120}, P_{40}, K_{30} and zinc sulphate at 25 kg/ha. The rice yield (Table 32) increased significantly with increasing dose of gypsum upto 16 t/ha which gave 4.87 t/ha. With each decrease in row spacing the yield increased significantly. The two factors did not interact significantly.

TABLF 32. *Grain yield of rice (t/ ha) due to gypsum and spacings*

Effect of gypsum		Effect of spacing	
Gypsum (t/ha)	Grain yield	Spacing	Grain yield
0	0.42	10× 15 cm	3.86
4	1.63	15× 15 cm	3.11
8	3.81	20× 15 cm	2.73
12	4.58		
16	4.87	CD at P=0.05	0.12
CD at P=0.05	0.27		

S.A. 2.13.1. *Effect of plant population, zinc and gypsum on the fodder yield of para grass in a sodic soil (Ashok Kumar, K.S. Dargan and I.P. Abrol)*

Effect of all possible combinations of two plant populations (spacing 50 x 50 cm, P_1, and 50 x 100 cm, P_2), two levels of zinc sulphate (0 and 20 kg/ha) and two gypsum levels (0 and 5 t/ha) was studied on the yield of para grass grown in the highly sodic soil (initial pH, 10.4, and gypsum requirement 25 t/ha). The treatments were replicated 4 times. Rooted slips were planted on July 9, 1976 and the crop received 40 kg N/ha for each cut. The data in Table 33 reveal significant increase in yield due to closer planting and application of zinc sulphate, but gypsum application did not increase the yield. These results show the highly tolerent nature of the grass to sodic soil conditions and the possibility of increasing its productivity by closer planting and the zinc sulphate application.

TABLE 33. *Effect of plant population, zinc and gypsum levels on the green yield of two cuts of para grass (t/ha)*

		Green yield		
		P_1	P_2	Mean
G_0	Z_0	15.96	11.78	13.87
	Z_{20}	18.16	21.10	19.63
G_5	Z_0	15.83	10.51	13.17
	Z_{20}	22.99	15.12	19.06
		Plant Population	Zinc	Interaction
C.D. at P=0.05		2.72	2.72	5.56

S.A. 2.13.2. *Effect of nitrogen levels and planting methods on the yield of Diplachne fusca grass (Ashok Kumar, I.P. Abrol and K.S. Dargan)*

Effect of two planting sources (rooted slips and stem cuttings) and five levels of nitrogen (0, 10, 20, 30 and 40 kg N/ha) on the yield of *Diplachne fusca* was studied in a highly sodic soil (pH_2 of 0-15 cm soil, 10.4) with each treatment replicated four times. Planting was done on August 10, 1976. Green yield of two cuttings (Table 34) increased significantly with N application upto 30 kg/ha. Planting the rooted slips gave significantly higher yield than the stem cuttings. The grass is highly tolerant to sodic conditions, although its yield potential appears to be relatively low.

TABLE 34. *Green yield (t/ha) of Diplachne fusca due to N levels and planting methods*

Treatment	N_0	N_{10}	N_{20}	N_{30}	N_{40}	Mean
Rooted slips	5.33	6.72	8.11	7.39	9.33	7.38
Stem cuttings	4.22	3.50	4.89	6.89	6.78	5.26

	N	Methods
C.D. at P=0.05	1.39	0.89

S.A. 2.14. *Crop responses to applied nitrogen, phosphorus and potassium in a sodic soil (K.S. Dargan, R. Chhabra and B.L. Gaul)*

Effect of application of P and K on response of rice crop grown in a hitherto uncultivated sodic soil, was evaluated in a quadruplicate field experiment. The pH_2 of original surface and subsurface soil was 10.3. Gypsum @ 17 t/ha was applied on June 29 and 42 days old seedlings of rice, variety IR-8-68, were transplanted on July 8, 1976. Full dose of P and K and half dose of N as per treatments was applied before transplanting and the remaining N was given in two equal splits on July 29 and Aug. 23. Zinc sulphate @ 25 kg/ha was applied at transplanting and again on July 24. Spraying of zinc sulphate at 5 kg plus unslaked lime @ 2.5 kg/250 litre water was done on Aug. 2 as the crop still showed zinc deficiency symptoms. Crop was harvested on Oct. 28. Results (Table 35) show that the application of either P or K did not result in any increase in yield. Olsen's available P decreased to less than half after the harvest of rice crop. Reduction in available P is probably related to pH or ESP decrease following growth of rice. The experiment will be continued.

TABLE 3 5. *Effect of N, P and K fertilizers on rice crop in a sodic soil*

Treatments		pH (1:2)		Olsen's P (kg/ha)		Grain Yield (t/ha)	P content mg/g	
Rice	Wheat	Before	After	Before rice	After rice		Grain	Straw
1. Control	Control	10.3	9.0	17	9	1.18	248	53
2. N_{120}	N_{120}	10.3	9.0	19	8	5.05	220	57
3. N_{120}	$N_{120}P_{50}$	10.4	8.8	18	7	5.13	228	54
4. N_{120}	$N_{120}P_{50}K_{50}$	10.1	8.6	14	6	5.95	230	47
5. $N_{120}P_{50}$	$N_{120}P_{50}$	10.4	9.1	22	7	4.79	234	50
6. $N_{120}P_{50}K_{50}$	$N_{120}P_{50}K_{50}$	10.4	9.0	22	7	5.65	234	57
CD at P=0.05						1.76		

S.A. 4.7. *Effect of soil sodicity on the yield of five forage grass species (Ashok Kumar, K.S. Dargan and I.P. Abrol)*

The effect of increasing soil sodicity on the growth of five forage grasses namely *Dicanthium annulatum* (S-65), *Chloris gayana, Cynodon dactylon, Brachiaria decumbans* (Australia) and *Urochloa stolonifera* (Australia) was studied in 20 kg capacity pots. Planting was done on July 17, 1976. The last two species failed to grow except in the lower

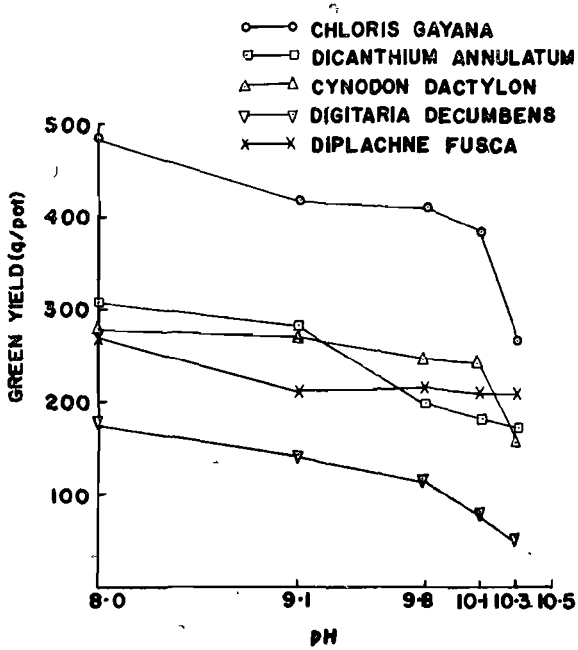


Fig. 10. Effect of different pH values on the green yield of grasses

pH soil and were therefore replaced by *Digitaria decumbans* and *Diplachne fusca* on August 12, 1976. Two cuts were taken from all the grasses except *Digitaria decumbans* in which only one cut was taken. *Chloris gayana* (Rhodes grass) yielded the highest followed by *Cynodon dactylon* (Bermuda grass) and *Dicanthium annulatum* (Fig. 10). *Diplachne fusca* although yielded lower than some other grasses, underwent nearly no yield reduction even at the highest pH indicating its high tolerance to highly sodic conditions.

S.A. 2.16. *Effect of nitrogen levels on the yield of wheat grown after fallow, green manuring with dhaincha (Sesbania aculeata) and a rice crop in a sodic soil (K.S. Dargan, K.K.R. Bhardwaj and Ashok Kumar)*

An experiment with factorial design, randomized block having 12 treatment combinations and 4 replications was initiated in *Kharif* 1976 to study the effect of 4 levels of N (0, 50, 100 and 150 kg/ha) after fallow, green manuring with *dhaincha* and growing a rice crop. Gypsum @ 12 t/ha was applied to all the 12 treatments (pH of 0-15 cm soil 10.3) and plots irrigated. Treatments 1 to 4 were left fallow, *dhaincha* was sown in treatments 5 to 8 and rice, variety IR-8-68 transplanted in treatments 9 to 12 on July 8. *Dhaincha* was green manured on Sept. 24 and rice harvested on Nov. 3, 1976. Rice crop received N, P, K and zinc sulphate @ 150, 40, 30 and 50 kg/ha respectively. No fertilizer was applied to *dhaincha.* Mean green-matter yield of *dhaincha* was 12.31 t/ha and that of rice 4.79 t/ha, The effect of these treatments and N levels will be studied on the succeeding wheat crop.

GENETICS & PLANT BREEDING

G.P. 1. Evaluation of Plant Materials and Breeding of Crop Varieties Suited to Saline/Sodic Conditions

1.1. *Wheat (R.S. Rana and K.N. Singh)*

Wheat research programme this year included intensive varietal evaluation for salt tolerance in partially reclaimed soils in the field as well as under more defined conditions in the laboratory and pot culture experiments. More than three hundred cultures, received from the All India Coordinated Wheat Improvement Project and from the Haryana and Punjab Agricultural Universities, were screened for tolerance to alkanity and salinity. Besides wheat, triticale materials were also tested for adaptation to salt-affected soils. A rust trap nursery of nearly two hundred lines was also grown this year to help monitoring the appearance and subsequent spread of rust flora in this area. In addition, a vast germplasm collection, which is being continuously enriched by obtaining seed materials from various sources, was grown in the observation nursery with a view to studying growth habit and plant characteristics as well as for cataloguing and maintenance. The growth season on the whole was favourable and there was no major incidence of any disease or pest.

Field evaluation : A field trial of 36 varieties laid out in randomized block design with four replications and a net plot size of 7.20m² was continued for the third year and concluded. Soil pH (0-15 cm depth) ranged from 8.2 to 9.0 in the testing field. Grain yields varied from 2.14 to 4.38 t/ha, while the critical difference between varietal yields was 0.66 t/ha. The first group, within which yield differences were not significant, consisted of eleven varieties. The data revealed that none of the varieties tested in this programme was statistically superior to the varieties HD-2009 and HD-1553.

Another field experiment with randomised block design having six replications with a net plot size of 5.6m² was conducted at two locations for assessing the grain yield potential of fourteen wheat and one barley varieties in partially reclaimed sodic soils. The pH of the soil at location I and II was in the range of 8.1 to 8.5 and 8.4 to 8.9 respectively. Grain yield data alongwith statistical analysis are presented in Table 36. Whereas

TABLE 36. *Comparative performance of wheat varieties grown in partially reclaimed sodic fields*

(Date of sowing : 15th Nov., 1975)

Variety	Av. grain yield (t/ha)		Overall mean
	Location I	Location II	
HD-1981	5.26	4.77	5.02
WG-377	4.95	3.46	4.21
HD-1553	4.86	3.68	4.27
WL-711	4.74	4.19	4.47
WH-157	4.62	4.49	4.55
Pb. C-306	4.58	3.49	4.03
HD-2009	4.53	4.21	4.37
HD-1982	4.49	3.18	3.83
ND-2160	4.26	4.24	4.25
Kalyan Sona	4.24	4.31	4.27
HD-2122	4.21	3.92	4.06
WG-357	3.75	4.09	3.92
HD-4530	3.75	3.80	3.77
Kharchia	2.50	1.97	2.23
DL-70 (Barley)	2.81	1.93	2.37
C.D. at 5% P	0.85	0.60	

the top group, wherein yield differences are not significant, comprises of eight varieties in the first location and six in the second location, the four varieties consistently superior in both the trials were HD-1981, WH-157, WL-711 and HD-2009. Stability of grain yield of the variety Kalyansona in both the locations is also remarkable. Vars. HD-1982 and WG-377 happened to be in a worse sodic patch in the second location despite randomisation and, hence, their yield levels were below expectation. Poor performance of the tolerant check variety Kharchia could be partly attributed to rust damage and severe lodging.

Eight wheat and one barley varieties were also evaluated for their yielding ability in partially reclaimed land under late sown conditions following harvest of long duration rice crop. The soil pH (0-15 cm depth) varied from 8.5 to 8.9. Grain yield data alongwith general information on testing conditions are given in Table 37. A statistical analysis of the data showed that the varieties HD-1553, HD-1981, HP-833, HP-916 and HD-1982 were at par. Yield level of 2.28 t/ha was obtained in case of variety HD-1553 despite late sowing on the 16th December. The barley variety DL-70 was kept as check variety.

TABLE 37. *Grain yield of wheat varieties sown after long-duration rice crop*

Variety	Av. grain yield (t/ha)	General information
HD-1553	2.28	
HD-1981	2.14	
HD-833	2.13	Date of sowing : 16-12-75
HP-916	2.10	No. of replications : 3
HD-1982	1.96	Net plot size : 13.20m²
Raj-821	1.83	C.D. at 5% P : .401 t/ha
WG-377	1.69	
Kalyan Sona	1.51	
DL-70 (Barley)	1.85	

One National Trial consisting of 16 varieties was conducted in a randomised block design with 6 replications and a net plot size of 8.28 m^2. The grain yield data showed that none of the tested varieties was statistically superior to WL-711, HD-2009 and HD-1553. The highest yield level obtained in this trial was 4.21 t/ha while critical difference between varietal yields was 0.58 t/ha.

An evaluation of 54 triticale entries in a replicated yield trial led to the identification of 13 cultures which compared favourably in grain production with the check wheat var. HD-2009. However, even the promising triticale lines in general suffered from common drawbacks of varying degrees of seed sterility, poor grain type and shattering.

Pot culture studies : Fourteen wheat varieties evaluated in partially reclaimed fields at two locations were also tested critically in pot culture at carefully prepared three levels of soil alkalinity (pH 8.2, 9.6 and 9.9). Each treatment had four pots per variety, while each pot had five seeds (plants). The highest pH level proved lethal to all the varieties. Observations were regularly recorded on seed germination, seedling emergence and growth rate, onset of flowering, pollen and seed sterility, plant height, survival to maturity, tillering, grain yield, grain no./spike and grain weight characteristics. Data on average grain yield and survival are presented in Table 38. Only eight varieties were able to survive and yield at higher alkalinity level (pH 9.6) and these included Kharchia, HD-2122, HD-1982, WH-157, HD-1553, WL-711, HD-1981 and Kalyansona (Table 38, Fig. 11).

TABLE 38. *Survival and grain yield of wheat varieties grown in pot culture at two levels of soil alkalinity*

Varieties	Av. grain yield/pl (g)		Survival%
	pH 8.2	pH 9.6	at pH 9.6
HD-2122	9.6	2.4	70
WH-157	12.1	1.7	55
HD-1553	10.4	0.5	35
Pb. C-306	10.8	0	0
HD-2009	10.7	0	0
K-Sona	11.3	0.7	5
WL-711	11.8	4.2	15
HD-2160	10.7	0	0
HD-1982	12.7	2.3	60
HD-1981	12.5	1.8	20
HD-4530	11.5	0	0
Kharchia	9.8	6.3	85
WG-357	9.5	0	0
WG-377	11.4	0	0

Testing in laboratory: Considering that critical stages of the wheat plant known to be sensitive to soil alkalinity/salinity are seed germination and seedling emergence, a comparative study was undertaken on varietal capacities for germination and seedling growth rate at three levels of salinity, viz., ECe 6, 10 and 20 mmhos/cm. Genotypes selected for intensive studies include Kharchia materials, HP-916, K-852, HD-2189, HD-1982, HD-1981, WH-157, HP-833, HD-1553, HP-1267, UP-270, HD-2009, WG-377, WG-357, HD-2122, HD-2177, WL-711 and Kalyansona.. Salt tolerant varieties identified on the basis of these tests are proposed to be studied more critically in pot culture and microplots regarding whole plant response with a view to standardising the methodology and to work the relationship between laboratory testing and pot culture evaluation.

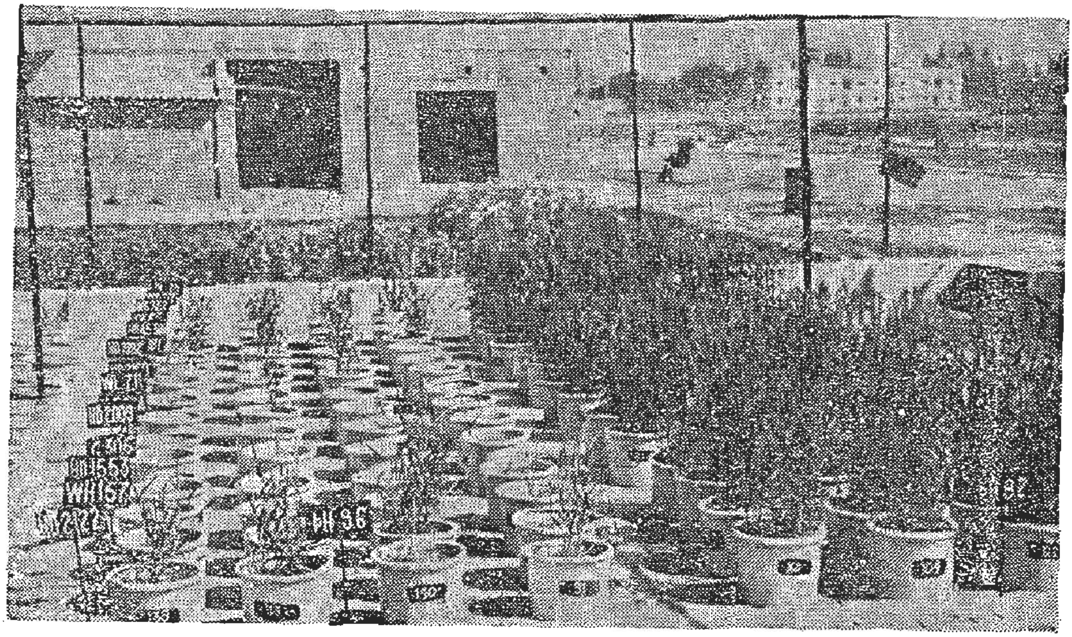


Fig. 11. Wheat varietal responses to soil alkalinity under pot-culture conditions

1.2. *Barley (S. Chandra)*

A set of barley varieties, selected for relatively better performance under All India Coordinated Trials at locations representing soil salinity/sodicity, were tested in microplots at varying salinity levels at the planting time. Of these, yield data for some genotypes are given in Table 39. The genotypes RD-197, RD-118, BL-2, DL-88, DL-203, BG-105, PL-56 and BHS-24 were found to be the best yielders on the basis of mean performance. However, the genotypes DL-70, DL-187, and K-153 were characterised by very low yield reduction as a result of increasing salinity, which is indicative of relative salt tolerance. Only three genotypes RS-6, RD-57 and BG-25 recorded a 53% or greater reduction of yield at the initial ECe 15 mmhos/cm as compared to the control.

Another set of 203 varieties, obtained under the All India Coordinated trial on barley, was grown for yield test in an augmented design simultaneously in normal and sodic soil (pH=9.0 to 10.0). The mean yield and 200 grain weight of some varieties are presented in Table 40. Out of check varieties Ratna, BL-2, RS-6 and Jyoti, only Ratna figured among the top yielders under normal soil while only BL-2 figured among top yielders under alkali field conditions. Cal. Mariout, K-153 and-BL 2 were found to be among the best yielders under alkali soil. These varieties also suffered minimum loss of seed weight due to alkali soil conditions.

TABLE 39. *Grain yield (g/meter / row) of some barley varieties at different soil salinity levels*

Genotype	Control	ECe 5	ECe 10	ECe 15	Mean
DL-2 Check	60	44	35	34	43.2
RS-6 ,,	71	51	51	29 †	50.4
Ratna ,,	54	49	39	37	46.2
Jyoti ,,	71	65	53	45	58.5
BL-2	81	69	62	64	69.0 *
RD-197	99	85	85	78	86.7 *
RD-153	64	51	48	35	49.5
RD-118	81	72	72	76	75.2 *
RD-31	62	62	49	33	51.4
K-153	56	43	39	38	44.0
HBL-95	95	61	63	66	71.2 *
BHS-24	81	79	76	69	76.0 *
PL-56	78	85	77	59	75.0 *
RD-57	71	69	27	25 †	48.0
BC-108	69	61	48	46	56.0
BG-105	87	77	68	73	76.2 *
BG-25	63	64	38	31 †	44.0
C-164	51	51	54	33	47.2
PL-73	64	41	35	36	44.0
DL-203	100	75	77	61	78.2 *
DL-36	78	70	61	51	65.0
DL-70	52	53	69	42	54.0
DL-38	84	76	78	51	72.3 *
DL-155	101	57	55	51	66.0
DL-187	63	58	56	58	59.0
DL-197	67	60	61	54	60.5

* Significantly higher yield than the best control
† Yield reduction is 50% or more of that under control

In addition to the above mentioned yield trials, three crosses involving the lines EB-1556, EB-226 and C-164 were also made.

TABLE 40. *Yield per plot and 200-grain weight of some selected barley varieties under normal and sodic soil conditions*

Variety	Yield (g/plot)		200-seed wt (g)	
	Normal	Sodic	Normal	Sodic
Ratna	850*	310	18.1	13.4
BL-2	830	350*	17.5	15.8
RS-6	530	205	17.8	14.0
Jyoti	650	200	19.5	12.9
Cal Mariout	670*	295	15.9	16.5
BHS-33	590	80	16.3	13.7
BHS-36	315	210	16.5	12.0
BHS-37	300	185	17.0	11.8
BHS-38	499	250*	16.8	12.7
BHS-39	545	245	18.5	13.6
K-153	705	460*	20.3	16.3
K-205	1050*	165	16.9	12.0
K-206	1105*	450*	17.6	16.1
K-1010	565	285	20.5	13.3
K-1012	1275*	230	21.2	14.5
HBL-81	530	165	17.1	12.6
HBL-95	925*	415*	16.5	15.8
HBL-102	700	90	17.0	12.7
P-142	930*	325*	17.5	13.7
RS-17	370	235*	16.9	13.5

* denotes variety statistically at par with the top yielder in the trial

1.3. *Rice (R.K. Bhattacharya, B. Mishra and R.S. Rana)*

The evaluation programme comprised of 882 cultures pooled from several sources, 89 advance-generation lines developed at the CSSRI and 95 entries obtained mostly under the All India Coordinated Rice Improvement Project. In addition, 16 Indian varieties known to be tolerant to soil salinity/alkalinity conditions were also included.

Evaluation was done in replicated randomised block design in plots each measuring 46.8 m x 1.95 m with planting spacing of 15 cm x 15 cm with a view to studying their growth habit, plant characteristics and yielding ability under conditions obtaining at CSSRI farm. Soil pH of this field ranged from 7.6 to 9.2 in 0-15 cms layer and 7.5 to 9.8 in the 16-30 cms. depth. Nutrients were applied @ 100 kg N, 60 kg P_2O_5, 40 kg K_2O and 25 kg $ZnSO_4$ per hectare. There was no major incidence of diseases and pests during the season except the recurrence of false smut. The salient results obtained in each trial are given in the following paragraphs.

Preliminary Evaluation (B. Mishra, R.K. Bhattacharya and R.S. Rana)

International Rice Salinity and Alkalinity Tolerance Observation Nursery comprised 86 entries. Grain yield averaged over replications ranged from 166 g to 871 g per two rows of 2.85 m length with a general mean of 556 g as against 333 g in case of the sensitive check variety M1-48. Thirty one cultures including Getu (CSR-3) and Damodar (CSR-1) were found to be better tolerant than the rest and these have been identified for more critical appraisal.

Ninety two entries pooled from the Central Rice Research Institute, Cuttack and International Rice Observation Nursery were grown in single rows of 2.4 m each. Grain yield ranged from 61 to 333 g per row with a general mean of 173 g. Fifteen cultures yielding at par or better than the check variety Jaya were selected for further study.

National Screening Nursery consisted of 119 cultures carried over from the previous season and 394 entries received this year. Unlike the former group which was normally transplanted, the latter was direct-seeded owing to very late arrival of seed materials from AICRIP. One hundred and sixty four cultures have been selected for further study including 38 from the former group and 126 from the latter. In addition, 191 cultures sent by the Punjab Agricultural University were evaluated for their growth and yielding ability. Twenty four fine grain types were found to yield higher than the check var. Sona and these will be further evaluated.

Recombinants and mutants (R.K. Bhattacharya)

Eighty nine uniform and stabilized cultures, 30 developed from inter-varietal crosses and 59 evolved through induced mutations by the author were evaluated following a replicated randomised block design. Thirty five cultures have been selected for further study including the twelve that were at par with the best tolerant check var. Getu. Some of these promising cultures were also sent to research centres in Tamil Nadu, West Bengal, Maharastra and Kerala for comparative evaluation under local conditions.

Varietal yield trials (R.K. Bhattacharya, B. Mishra and R.S. Rana)

Two major yield trials with 95 varieties of two distinct maturity groups (120 and 140 days) and two fine grain varietal trials with 59 entries were conducted in randomised block design. Grain yield data are presented in Tables 41 and 42.

In the short duration group (i.e. upto 120 days), the check variety Pusa-2-21 outyielded all other entries, however, thirteen entries of this group were at par with Pusa-2-21 (Table 41). In another trial of the same maturity group, entry *RP6-516-31-6* turned out to be significantly superior to the check var. Ratna. Six other entries in this trial were found to be at par with Ratna regarding the yielding ability (Table 41).

TABLE 41. *Maturity period and grain yield of some promising rice varieties of short duration group (upto 120 days)*

Varieties	Maturity (days)	Grain (kg/ha)	General information	
Trial No. 1				
Pusa-2-21 (Check)	114	6500	Replications	: 3
RP-6-51-31-6	126	6472	Net Plot size	: 2.4m × 1.5m
CR-142-3-8	114	6389	Transplanting date	: 4.7.76
CR-110-170	114	6278	General Mean	: 5361 kg/ha.
Pusa-4-1-11	114	6278	C.D. at 5% P	: 777 kg/ha.
RP-79-5	114	6167		
PR-106	136	6139		
Pusa-33-30-18-3	114	6000		
RP-79-9	114	5944		
RPCB-2-B-84	119	5944		
CR-142-3-2	109	5861		
Mut. I	111	5861		
RP-516-31-4	115	5750		
CR-44-35	116	5750		
Trial No. 2				
RP-6-516-31-6	116	6666	Replications	: 3
CR-115-76	109	5812	Net Plot size	: 2.4 m × 1.95 m
27092	109	5790	Transplanting date	: 10.7.76
TNAU-7892	102	5620	General Mean	: 5043 kg/ha.
MTU-6368	117	5556	C.D. at 5% P	: 555 kg/ha.
TNAU-13613	112	5513		
Ratna (check)	118	5470		

In the long duration group (i.e. about 140 days) also, the check var. Jaya out-yielded all the entries. Four other varieties including IR 8 were, however, at par with Jaya (Table 42).

Yield trials of fine grain types (described primarily on the basis of L/B index) showed that two cultures RP-967-4-7-2-1 and RP-967-4-7-3, both derived from the cross Improved Sabarmati x Sona, were significantly superior to the check var. Sona. Four other varieties also yielded at par with the check variety (Table 42).

TABLE 42. *Grain yield and maturity period of some promising rice varieties of long duration and fine grain group*

Varieties	Maturity (days)	Grain (kg/ha)	General information
Long Duration Group (upto 140 days)			Replications : 3
Jaya (Check)	139	7373	Net Plot size : 2.7m × 2.4m
RP-260-750-3	144	7130	Transplanting date : 15.7.76
IR-8	142	7099	General Mean : 6157 kg/ha
CR-129-118	140	6991	C.D. at 5% P : 494 kg/ha
C-8054	142	6867	
Fine Grain Group			Replications : 2
RP-967-4-7-2-1	130	6474	Net Plot size : 2.4m × 1.95m
RP-967-4-7-3	137	6218	Transplanting date : 12.7.76.
RP-967-4-7-4	134	6047	General Mean : 5427 kg/ha
UPR-80-1-1-2-1	130	5940	C.D. at 5% P : 555 kg/ha
Pusa-33-40-1-1	120	5940	
RP-107-11	129	5833	
Sona (check)	130	5644	Replications : 3
PAU-29-108	129	5556	Net Plot size : 2.4m × 1.95m
RP-31-49-2	129	5363	Transplanting date : 8.7.76
RP-107-8	118	5342	General Mean : 4508 kg/ha
C-321	124	5150	C.D. at 5% P : 662 kg/ha
CR-10-266	118	5128	

1.4. *Bajra (S. Chandra)*

Evaluation for tolerance to moderate levels of soil salinity (upto ECe 15 mmhos/cm at the planting time) was continued for the second year in succession in an artificially created saline soil in microplots. The yield data pertaining to some of the best yielding genotypes, including hybrids and composites, confirmed the last year's findings that some of the PHB entries were among the best yielders as well as among the best tolerant ones (Table 43). Nevertheless, a slight distinction could be made amongst them to the effect that whereas PHB-14 and PHB-50 yielded significantly lower at ECe 10 mmhos/cm than the control, PHB-12 did so at ECe 15 mmhos/cm.

Among the new entries tested, the composite line HS-1 and also CM-46 and 71-1015 yielded at par with the highest yielder at ECe 15 mmhos/cm particularly HS-1. However the Composites 1, A and

PSB-8 did not appear to be tolerant as indicated by the significant yield reduction at the low salinity level of ECe 5 mmhos/cm, two of them at ECe 15 mmhos/cm yielded less than 50% of their corresponding yields at the lowest level of salinity.

TABLE 43. *Grain yield of some pearlmillet genotypes under different levels of salinity*

Genotypes	Grain yield (g/row)			
	Control	ECe 5	ECe 10	ECe 15
PHB-10	183	186	158	*123
PHB-12	183	175	172	*151
PHB-14	221	203	*137	131
PHB-50	199	173	*152	147
GHB-1399 (Check)	164	158	158	*133
CM-46	231	212	*163	149
71—1015	176	160	*139	136
Composite 1	153	*120	107	90
Composite A	136	*105	74	21**
PSB-8	209	*139	127	86**
HS-1	222	198	*169	156

CD for genotype × salinity level interaction (p=0.05)=29

* level at which significant yield reduction from normal was obtained

** genotype whicn has reached 50% yield of normal at ECe 15

Data obtained during the previous season on plant height, tiller number per plant, leaf number per plant and dry plant weight simultaneously under normal soil (pH 7.8 to 8.2) and highly sodic soil (pH 9.2 to 10.0) were analysed. The analysis of variance for combining ability and the estimates of genetic components of variance obtained for the two environments were consistant for leaf number and dry plant weight but not for plant height or tiller number (Table 44). It appeared that for latter two characters genic interactions could not be expressed by the plants under adverse stress of soil sodicity. However, the expression for additive genetic variance did not seem to be affected except perhaps in a favourable manner by the sodic-soil environment. Genetic analysis for grain yield could not be done because under sodic conditions, several lines failed to reach flowering and several others did not set any seed. It was noted, however, that flowering was hastened under sodic soil as compared to normal soil.

TABLE 44. *Analysis of combining ability variance and estimates of components of variance in pearlmillet crosses*

Source	d.f.	M.S.							
		Plant height		Tiller number		Leaf number		Dry plant wt.	
		Normal	Sodic	Normal	Sodic	Normal	Sodic	Normal	Sodic
Replications	2	425.9	227.5	4.23	0.25	32.32	25.79	2080.7	369.1
Females	2	*380.5**	*233,6**	*20.72**	*6.32**	*106.55**	*23.38**	*12750.8**	*582.7**
Males	9	485.2*	420.4*	26.28*	12.58*	162.30*	68.82*	25831.9*	739.4*
F_1s	18	973.3*	347.8*	34.71*	8.95*	120.75*	55.33*	13719.2*	420.0*
Error	58	209.1	139.2	7.08	1.13	52.66	32.50	1983.5	218.9
Estimates of components of variance									
σe^2		209.1	139.2	7.08	1.13	52.66	32.50	1983.5	238.9
σ^2 Sca		255.4	69.5	9.21	2.62	22.70	7.61	3911.9	67.0
σ^2 gca (males)		-54.5	8.1	-1.05	0.40	13.85	4.50	4037.6	319.4
σ^2 gca (females)		-59.5	-11.4	-1.40	-2.63	-1.42	3.20	-96.8	16.3
σ^2 gca (pooled)		-10.5	0.8	-0.20	0.05	0.62	0.20	190.9	15.7

*Denotes significance at P=0.05

G.P. 1.5. *Forages (R.S. Rana, I.P. Abrol and K.N. Singh)*

To explore the possibility of utilising sodic soils without the use of soil amendments, organic manures and chemical fertilizers and to study changes in soil properties accompanying successive growth cycles of salt-tolerant forage grasses in otherwise barren soils, evaluation of thirty grass species and interspecific hybrids regarding their ability to survive under severe sodic conditions was undertaken which led to the selection of twelve species for this year's study. The trial was laid out in randomised block design with 4 replications using plot size of 3 m x 3 m with a distance of 60 cm between rows and 30 cm between plants. Soil pH (0-15 cm depth), ranged from 10.2 to 10.7 and ECe from 1.4 to 3.6 mmhos/cm. The following grasses have been identified for more critical evaluation either in monoculture or in mixed plantings.

Diplachne fusca	*Sporobolus marginatus*
Panicum antidotale	*P. laevifolium*
Cynodon dactylon	*Chloris gayana*
Brachiaria brizantha	*B. mutica*

Besides showing satisfactory capacity to establish, grow, survive and regenerate under highly sodic conditions, *Diplachne* and *Panicum* species gave promising forage yields in three cuttings taken on the 7th July, 10th August and 10th September, 1976. Highest yields were obtained from the second cutting taken in August.

PLANT PHYSIOLOGY

G.P. 2. Adaptive characteristics of salt tolerant genotypes (R. S. Rana, Y. C. Joshi, Ali Qadar and K. N. Singh)

G.P. 2.1. *Mineral analysis and growth characteristics (Y. C. Joshi, Ali Qadar and R. S. Rana)*

Eight wheat (HD-1981, Kh-65, HD-2122, WL-711, HD-1553, Kalyansona, Pb.C-306 and HD-4530) and two barley (DL-70 and RD-31) varieties were grown in porcelain pots in normal soil having 6 ESP and three higher sodic levels of 45, 65 and 70 ESP to take observations on germination, survival, grain yield and its component factors. Sodium and potassium contents of four growth stages (tillering, anthesis, grain development period and maturity) in various plant parts such as leaves, stem, flag, leaf, spike and grains were also analyzed.

Seed germination was not much affected in both wheat as well as barley at the ESP level of 45. Kh-65 showed the highest germination among the wheat varieties upto ESP 70. Beyond 65 ESP, none of the varieties survived to maturity. Reduction in grain yield varied from 32.4% in Kh-65 to 79.2% in HD-4530 at the ESP 45.

Sodium and potassium contents of various plant parts at all the four growth stages was in general higher in barley varieties than in wheat varieties. Varietal differences were, however, observed regarding Na and K contents at various ESP levels. Sodium content was remarkably more in HD-4530, considered to be sensitive type, than in other wheat varieties. Sodium content of grains increased strikingly at the 65 ESP. Interestingly there was no appreciable decrement in K content of grains even at the ESP 65 indicating a preferential mobilisation of K to the developing grains despite relatively low K content of other plant parts growing at higher ESP levels.

Sodium and potassium content at tillering stage of three wheat varieties are presented in Table 45 which show that Na/K ratio increases with the increase in ESP. Sensitive varieties appeared to be characterised by higher Na/K ratio. In the tolerant var. Kh-65, for example, Na/K ratio was strikingly low as compared to that in the sensitive var. HD-4530 (Fig. 12). The trend was uniform at all the four growth stages studied. In barley, var. RD-3 showed lower reduction in grain yield and also lower Na/K ratio as compared to the variety DL-70 (Table 46). Proline content of leaves increased remarkably, both in wheat as well as in barley, with the increase in Na content of plants at higher ESP levels. This aspect, however, needs more experimental work in order to elucidate the relationship, if any, between plant tolerance to sodicity and proline accumulation.

TABLE 45. *Na and K content of wheat seedlings at tiller stage at three sodicity levels*

Varieties	Treatment (ESP)	Na	K	Na/K	Grain yield
		(% dry wt. basis)			(g/pot)
Kh-65	6	0.06	3.90	0.015	11.1
	45	1.55	2.38	0.651	7.5
	65	1.90	1.05	1.881	2.6
C-306	6	0.04	3.83	0.024	11.1
	45	1.58	1.45	1.090	3.9
	65	2.70	0.65	4.154	0.0
HD-4530	6	0.36	0.50	0.103	11.1
	45	2.40	0.65	3.692	2.3
	65	3.21	0.50	6.420	0.0

TABLE 46. *Na and k content in wheat and barley at 3 stages of plant growth at 45 ESP level*

Variety	Anthesis		Grain development		Maturity	
	Leaves	Flag leaf	Leaves	Flag leaf	Leaves	Flag leaf
Kh-65	0.396	0.314	0.512	0.206	1.395	1.571
HD-4530	2.692	2.097	3.033	1.618	3.692	9.600
DL-70	0.905	9.501	1.662	0.555	2.493	0.698
RD-31	0.735	0.428	1.272	0.439	2.204	0.444

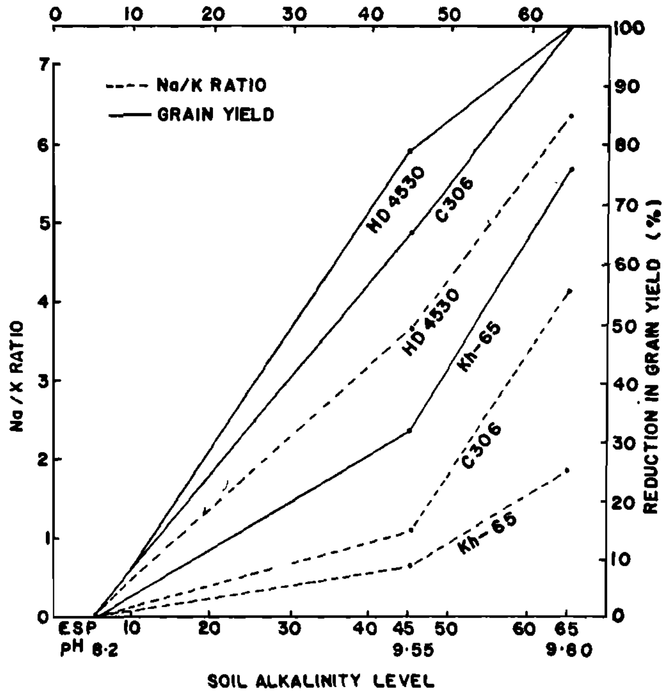


Fig. 12. Effects of varying soil sodicity on grain yield and leaf Na/K ratio in wheat varieties

Responses of five rice varieties (Pokkali, Jhona-349, Jaya, Basmati-370 and IR-6632) were also studied by growing in normal soil (5 ESP) and in sodic soil having 39, 60, 74 and 82 ESP. Samples for mineral analysis were collected at four growth stages and analysed. Data on growth characteristics and grain yield as well as its components were also compared (Table 47). Quantum of yield reduction at higher ESP levels in comparison to the 5 ESP level showed that the var. Basmati-370 was more sensitive to sodicity than Jhona-349 and Jaya. Variety Pokkali did not appear to be appreciably adapted to sodic conditions.

TABLE 47. *Grain yield and plant characteristics of five rice varieties grown at five sodicity levels*

Variety	Treatment (ESP)	Total tillers/ plant	Panicle No./ plant	Yield/ plant (g)	% Reduction in plant yield	1000 grain weight (g)	Plant height (cm)
Jhona-349	5	13.5	10.2	32.9	—	24.8	119.5
	39	12.6	10.6	35.8	0	24.6	129.0
	60	11.4	10.1	25.3	23.1	21.8	112.0
	74	9.7	9.0	20.9	36.4	20.4	100.7
	82	9.8	8.7	16.8	50.0	20.2	100.2
Basmati-370	5	16.2	12.4	30.7	—	21.3	175.4
	39	19.3	13.0	24.7	19.5	17.1	173.9
	60	14.4	10.9	17.0	44.6	16.2	150.5
	74	12.0	9.3	14.6	52.4	16.0	153.4
	82	13.2	9.1	12.1	60.5	16.3	145.9
Pokkali	5	54.5	15.4	33.2	—	28.1	135.6
	39	29.6	17.2	31.0	6.6	26.1	132.3
	60	22.9	16.2	18.2	45.1	21.7	102.9
	74	21.0	14.8	13.0	60.8	20.9	100.9
	82	23.2	15.8	14.5	56.3	21.3	98.7
Jaya	5	15.5	11.7	37.3	—	25.7	90.6
	39	18.0	14.9	35.5	5.0	25.1	85.8
	60	19.6	14.7	26.5	29.9	20.9	81.8
	74	15.7	12.5	23.3	37.5	21.0	80.9
	82	14.8	10.8	19.3	48.2	20.0	73.9
IR-6632	5	20.9	15.1	36.9	—	21.2	89.2
	39	20.5	19.0	32.0	13.2	17.9	82.4
	60	21.4	16.5	27.6	25.6	18.5	80.2
	74	18.2	13.2	18.0	51.0	15.4	71.0
	82	16.1	13.7	18.6	51.0	14.8	72.4

G.P. 2.2. *Inducing adaptation to saline/sodic conditions (Ali Qadar, Y. C. Joshi and R. S. Rana)*

Maize seeds of Vijaya Composite were soaked for twelve hours in solutions of CCC (500 ppm), KNO_3 (20 mm) and kinetin (10mg/l). Seed soaking in distilled water for the same duration served as the check. Soaked seeds were subsequently sown in soils of four ESP levels, viz., 4.9, 29.7, 38.5 and 53.3. Each treatment was replicated four times. Data showed that none of the treatments led to significant improvement in either the level of seed germination or the rate of germination under various sodicity levels.

Rate of germination as well as the germination percentage were adversely affected by ESP. Seed sampling was done daily for a week to study the mobilization of reserved seed food materials and their utilization by the germinating seeds under different ESP levels. Hydrolysis of starch was observed to decrease with increase in ESP. Concentration of total as well as reducing sugars increased with time under sodic conditions. It appeared that even all the hydrolysed starch was not being efficiently utilized by the germinating seeds under increasing ESP since sugar levels of seeds germinating under these stress conditions remained high in comparison to those germinating in normal soil (4.9 ESP) under comparable conditions.

G.P. 2.3. *Cytological Studies (K. N. Singh and R. S. Rana)*

With a view to understanding the effects of sodicity/alkalinity on reproductive potential of wheat plants, observations were recorded on pollen viability as an index of pollen fertility. Acetocarmine-glycerine mixture was used as the stain for smear tests. Although variation in pollen size under high alkali soil conditions (soil pH 9.6) was noteworthy, yet there was no correlation between pollen viability estimates and observed seed sterility.

G.P. 3. Physiology of growth and metabolism in relation to saline/sodic and water logging conditions

G.P. 3.1. *Growth and nitrogen metabolism (A. R. Bal)*

(i) *Barley* : An experiment was conducted on 24 genotypes to study genotypic difference regarding germination and free proline accumulation under five salinity levels. Seeds were sown in wooden trays (10 cms deep) of 16 kg capacity with alkathene lining. There were two replications. The salinity levels were created by adding Na Cl, $CaCl_2$ and Na_2SO_4 in the ratio of 7:2:1. The wooden trays were covered with polythene sheets to protect the moisture for twenty five days, after which one light irrigation was given. Data on seedling emergence are presented in Table 48, showing that it decreased with the increase in salinity level. In the case of control level (1.86 ECe) and ECe 8.72 mmhos/cm germination and seedling establishment were completed rapidly. Under ECe 26.7 and 38.3 mmhos/cm on the other hand, most of the varieties failed to germinate with initial soil moisture. Germination however, improved markedly following the light irrigation. Among the genotypes tested vars. K-153, DL-70, DL-3, DL-88, DL-36, RD-197 and DL-155 gave the best performance at the germination stage.

TABLE 48. *Seedling emergence (%) of 24 barley genotypes sown in salinised trays at five levels of salinity*

Genotypes	Salinity Levels (ECe) mmhos/cm 1.9	8.7	18.9	26.7	38.3
DL-3	98	97	68	68	48
DL-36	100	95	67	65	47
DL-70	97	97	78	57	55
DL-88	100	98	88	62	48
DL-155	97	95	90	35	28
BL-2	98	92	87	65	13
DL-166	95	85	46	23	22
Ratna	97	68	65	68	13
DL-186	97	92	48	3	3
DL-187	100	100	67	7	3
Jyoti	98	100	88	27	15
DL-197	97	98	92	32	18
DL-202	100	95	90	35	22
DL-203	97	95	95	22	17
BH-6	98	97	85	33	3
BH-10	88	62	33	20	18
BH-11	100	75	12	5	5
BH-25	97	98	78	7	5
RD-193	100	98	80	23	23
RD-197	100	93	85	52	31
K-153	97	88	88	82	65
HBL-93	98	95	48	17	15
HBL-95	100	88	60	15	15
C-138	100	77	—	28	5

Proline accumulation was analysed in ten barley genotypes. The results (Table 49) showed that the proline content gradually increased with increasing levels of salinity in all the genotypes. It was also observed that there were remarkable varietal differences regarding proline accumulation in response to salinity stress. There was, however, no clear relationship between observed salt tolerance of various genotypes and the level of proline accumulation. Studies on this aspect will be intensified.

(ii) *Bajra* : A pot experiment was conducted during kharif '76 with three bajra varieties (viz. HB-3, PHB-14 and GHB-1399) to

TABLE 49. *Accumulation of free proline in 10 barley genotypes under different salinity levels (ug/g dry weight)*

Barley genotypes	Salinity Levels ECe mmhos/cm				
	1.9	8.7	18.9	26.7	38.3
Jyoti	87	682	1485	2811	3575
BH-10	221	1193	1516	3604	4133
DL-203	354	1801	2550	2825	3125
DL-186	256	1833	1791	4400	—
DL-187	615	1064	1521	1608	—
DL-197	333	1214	1285	1660	2416
BH-6	603	958	2062	3850	—
DL-202	634	1177	2145	2300	3400
K-153	750	1291	2057	3192	4254
HBL-95	562	875	2022	2833	4020

—Sample was not sufficient

TABLE 50. *Effects of exchangeable sodium on germination, growth and yield characteristics of three bajra varieties*

	HB—3				PHB—14				GHB—1399			
	ESP LEVELS				ESP LEVELS				ESP LEVELS			
	8	24	35	48	8	24	35	48	8	24	35	48
Germination (%)	91	91	69	56	99	95	75	55	99	95	65	53
Plant height (cm)	145	117	92	85	155	126	113	82	103	81	78	66
Effective tiller/pot	4.2	3.7	3.5	—	4.0	3.5	3.2	—	3.5	2.2	2.2	—
50% Flowering Date	$8\frac{9}{76}$	$13\frac{9}{79}$	$17\frac{9}{76}$	$28\frac{9}{76}$	$12\frac{9}{76}$	$22\frac{9}{76}$	$24\frac{9}{76}$	$29\frac{9}{76}$	$17\frac{9}{76}$	$17\frac{9}{76}$	$27\frac{9}{76}$	$29\frac{9}{76}$
Dry matter (g/pot)	144.6	73.4	49.9	30.2	147.3	76.7	55.2	27.3	93.3	42.2	34.6	10.8
Grain yield (g/pot)	43.9	25.2	19.1	0	43.0	27.3	20.4	0	44.9	17.4	7.9	0

Grain yield
C.D. at 5% (ESP levels) =2.25 gm/pot, C.D. at 5% (Varieties) =2.22 gm/pot

study nitrogen metabolism and growth of these varieties under artificially created varying levels of ESP. The results (Table 50) indicate that the germination percentage was not appreciably affected upto 24 ESP but decreased sharply afterwards in all the varieties. There was also gradual reduction in plant height, effective tillers and dry matter accumulation with the increase in ESP levels. Flowering was delayed with the increase of alkalinity. Statistical analysis of grain yield revealed that effects of ESP levels and varieties were significant. In normal soils (8 ESP) all the varieties were at par. At the higher ESP levels, however, varieties HB-3 and PHB-14 were at par but were significantly superior to GHB-1399.

Chlorophyll a, b, total chlorophyll and proline accumulation of the 6th leaf (at the flowering stage) were analysed. Chlorophyll a, b and total chlorophyll were appreciably reduced with the increase in ESP levels. However, the magnitudes of reduction at 35 and 48 ESP levels were almost the same. Chlorophyll 'a' content was always higher than that of chlorophyll 'b' in all the levels. Proline accumulation increased with the increasing levels of ESP. HB-3 accumulated highest proline upto 35 ESP but at the 48 ESP, PHB-14 showed the highest proline accumulation. GHB-1399 accumulated lower amount of proline than other varieties under normal soil conditions but at the higher ESP levels, there was no appreciable difference among the three varieties.

G.P. 3.2. *Root Growth Studies* (*B.P. Singh*)

A preliminary study was conducted in pot culture on root and shoot growth of the wheat variety HD-2009 with a view to understanding the effects of vertical and horizontal variations in soil in relation to salinity and alkalinity. Data obtained alongwith the information on soil analysis are presented in Table 51. Root growth in a uniform saline or sodic pro-

TABLE 51. *Effects of soil profile variations on root growth and other characteristics of wheat var. HD-2009*

Sr. No.	Treatment	Root length (cm) 70 days	Root Volume (ml)		Plant height (cm) 100 days	Dry weight (g) 100 days		Ear number/ pot	Grain yield (g)/ pot
			70 days	100 days		Stem	Root		
A.	**Uniform Profile**								
1.	N	80.0	50.0	85.0	68.6	52.7	8.4	21.7	37.6
2.	S	18.0	7.5	23.0	45.8	12.0	4.0	6.1	11.2
3.	A	16.5	7.0	20.0	41.0	11.6	3.4	5.6	10.4
B.	**Vertically variable profile**								
4.	$\frac{N}{S}$	27.0	21.0	50.0	60.2	11.6	5.1	18.1	26.5
5.	$\frac{N}{A}$	47.0	39.0	67.0	66.6	43.8	6.8	19.2	34.2
C.	**Horizontally variable profile**								
6.	S:N	49.0	35.0	67.5	62.9	35.8	8.0	16.2	34.9
7.	A:N	49.5	29.5	75.0	61.5	40.3	8.1	19.4	36.7
8.	A:S	18.0	10.0	30.0	47.6	13.9	31.1	7.4	15.8

N=Normal soil, S=Saline soil (ECe 15.0 mmhos/cm) artificially prepared, A=Sodic soil (pH 9.6) collected from the field file was only 20 to 22 per cent of the control with respect to length and about 14 per cent with regard to volume at the 70 day stage. Root length in top half normal and bottom half saline (vertically variable) profile was about 60 per cent of the normal sodic (vertical) profile. Under a horizontally variable normal-sodic or normal-saline profile, the root length was about 60 per cent of the control. In a saline-sodic horizontal profile, the root length was only about 22 per cent of normal. At the 100-day stage, a substantial improvement was observed in root volume as compared to control and was upto about 90 per cent of normal in a normal-sodic horizontal profile. It was further observed that the soil salinity in the profile caused browning of roots. The plant height was more or less similarly affected by the different soil profiles as the root growth. The grain yield under uniform saline or sodic profile was less than 30 per cent of that in normal soil. However, it was at par with the normal in a normal-sodic profile (vertical as well as horizontal) and in a vertical-saline profile.

G.P. 3.3. *Photosynthesis and respiratory metabolism* (*B.P. Singh*)

An investigation was initiated to study the effects of soil salinity stress on the activity levels of two photosynthetic CO_2-fixing enzymes : ribulose-1, 5-diphosphase carboxylase (RuDPase) and phosphoenolpyruvate carboxylase (PE Pase). Enzyme activities were measured in leaf extracts of the wheat var. HD-2009 grown at six levels of salinity, ECe ranging from less than one to ten. Activity levels of RuDPase and PE Pase were found to be the same under comparable conditions in plants grown in normal soil (having ECe less than one). The observations which were of a preliminary nature, indicated that RuDPase appeared to be much less sensitive to salts than the PEPase.

G.P. 3.4. *Physiological effects of water logging* (*B.P. Singh*)

A pot-culture investigation was carried out with two pearl millet varieties (HB 3 and GHB-1399) to study the effect of water-logging upto 120 hours commencing at tillering or flowering stages under normal as well as sodic soil conditions. Pots were flooded by maintaining the water level in the pots at 3 cm above the soil-surface. Data are presented in Table 52 and 53. Water-logging at the flowering stage affected the grain production more adversely than at the tillering stage. Conversely, the shoot length and dry matter accumulation was more adversely affected at the tillering stage than at the flowering stage. Under sodic soil conditions, water-logging caused extremely poor seed set resulting in practically no grain yield. An increase in free proline in the leaves of the plants was

TABLE 52. *Effect of waterlogging at tillering stage in two pearl millet varieties*

	Treatment											
	C		WL 24h		WL 48h		WL 72h		WL 96h		WL 120h	
	N	S	N	S	N	S	N	S	N	S	N	S
Shoot length (cm)												
HB-3	146.3	74.6	143.6	73.3	140.0	72.6	111.6	66.7	107.3	58.7	105.0	56.7
GHB-1399	146.6	81.6	144.0	78.6	136.6	76.6	133.3	70.3	131.7	68.5	114.0	65.7
Dry wt. of shoot per pot (g)												
HB-3	131.0	18.6	77.5	15.7	67.7	15.1	56.4	13.3	42.4	11.7	37.8	9.4
GHB-1399	166.8	28.8	154.4	27.6	141.5	27.2	121.5	18.7	114.2	15.5	93.8	13.5
Head length (cm)												
HB-3	18.5	13.5	17.8	12.6	17.6	11.3	16.3	10.5	14.1	10.1	13.6	9.2
GHB-1399	30.2	17.9	25.6	17.6	24.9	16.7	24.3	15.9	23.2	14.4	19.1	12.3
Head weight per pot (g)												
HB-3	35.2	8.0	33.8	7.9	32.2	5.5	28.5	4.5	24.1	3.8	13.6	3.6
GHB-1399	70.6	16.3	62.6	15.3	59.7	14.8	57.4	13.3	55.8	10.3	38.1	6.7
Grain weight per pot (g)												
HB-3	19.8	4.7	18.9	3.9	17.8	3.5	16.6	2.8	15.8	1.9	8.4	1.1
GHB-1399	33.7	8.9	29.6	6.8	28.1	5.9	26.4	4.3	23.3	3.9	20.1	2.9
Free Proline (g/g fresh wt.)												
HB-3	140	180	220	240	280	320	460	520	140	160	120	160
GHB-1399	60	120	80	120	140	220	260	300	60	40	20	20

C=Control, WL=Waterlogging, h=Hour, S= Sodic soil (pH 9.4), N=Normal soil

TABLE 53. *Effect of waterlogging at flowering stage in two pearl millet varieties*

	Treatment											
	C		WL 24h		WL 48h		WL 72h		WL 96h		WL 120h	
	N	S	N	S	N	S	N	S	N	S	N	S
Shoot length (cm)												
HB-3	150.7	72.0	156.7	70.7	153.3	69.0	147.7	64.7	146.0	59.0	145.5	59.0
GHB-1399	142.7	86.3	135.0	82.0	134.3	66.0	130.3	60.0	128.0	60.0	124.3	53.0
Dry weight of shoot/pot (g)												
HB-3	128.7	20.8	86.4	18.3	61.9	16.8	54.9	16.2	52.8	13.2	51.0	10.2
GHB-1399	163.2	29.8	160.1	22.1	151.0	19.8	145.5	15.5	130.8	13.8	126.2	11.8
Head length (cm)												
HB-3	18.1	13.7	17.2	12.3	17.1	10.2	15.9	9.3	14.2	9.2	13.4	8.4
GHB-1399	28.0	17.6	24.8	16.7	21.5	15.6	20.8	15.0	16.5	13.2	15.7	12.5
Head weight per pot (g)												
HB-3	29.7	7.9	25.1	6.5	24.6	5.0	15.4	7.1	12.2	3.7	12.9	3.4
GHB-1399	64.4	20.4	73.6	9.0	61.5	8.8	69.8	10.0	72.9	8.0	55.3	2.5
Grain weight per pot (g)												
HB-3	15.9	6.9	11.9	1.8	10.9	2.2	8.9	1.2	7.3	0.7	6.2	0.7
GHB-1399	38.4	10.5	36.6	3.7	32.9	3.3	32.3	2.9	27.0	2.1	25.2	0.6
Free proline (g/g fresh wt.)												
HB-3	120	140	180	200	220	220	260	280	60	120	40	60
GHB-1399	60	120	60	120	60	140	120	160	40	20	20	20

C=Control, WL=Waterlogging, h=hour, S=Sodic soil (pH 9.4), N=Normal soil observed after 24 hours of waterlogging. This increase was maximum after 72 hours of waterlogging. Following 96 hours of waterlogging, the proline level in the leaves decreased. The variety HB-3 appeared to be more sensitive to waterlogging than GHB-1399.

WATER AND SOIL ENGINEERING

E.1. Drainage Studies

E.1.3. *Efficiency of rainwater storage in surface ponds as a measure of surface drainage (V.V. Dhruva Narayana, S.K. Gupta and R.N. Pandey)*

The total amount of runoff outflow from the farm area of this Institute during the monsoon season was 60 mm., out of a total monsoon rainfall of 743 mm. The total rainfall stored in the three dugout ponds is 122 mm (Table 54).

TABLE 54. *Details of rain water storage on the C.S.S.R.I. Research farm*

Year	Rainfall (mm)	Runoff (mm)	Water stored in the dugout ponds (mm)	No. of storms producing runoff
1972	695	121	80	3
1973	585	94	100	6
1974	384	5	16	3
1975	604	12	52	2
1976	743	60	122	3

The water stored in the ponds is reutilized for irrigation during the lean spells of the rainy season and in the early *rabi* season. The electrical conductivity of the stored waters are in the acceptable range of irrigation waters (Table 55).

TABLE 55. *Electrical conductivity (micromhos/cm) of water stored in different dugout ponds*

Date	Dugout Ponds		
	1	2	3
5-8-76	561	724	367
21-8-76	454	561	309
8-9-76	408	520	249
22-9-76	561	469	302

E.1.6. *Effect of different levels of surface drainage on the crop and water yields from problem areas (R.N. Pandey and Suresh K. Gupta)*

To study the crop responses to different levels of surface drainage and simultaneously to obtain the design criteria for storage capacity of dugout ponds, an experiment was continued during the monsoon of 1976.

TABLE 56. *Crop and water yields in response to different levels of surface drainage*

Total Rainfall (Transplant-harvesting)	64 cm
Maximum storm rainfall	18 cm
Pre-transplanting irrigation	30 cm

Treatment	Drainage water removed (mm)	%age of seasonal rainfall	Irrigation water applied (mm)	Crop yield (t/ha)
T_1 Removal of all water above 5 cm, 24 hrs after the storm	526	82	497	6.54
T_2 Removal of all water above 5 cm, 7 days after the storm	141	22	215	6.15
T_3 Removal of all water above 20 cm, 24 hours after the storm	364	57	360	6.30
T_4* Removal of all water above 20 cm, 7 days after the storm; T_5 No removal	—	0	72	5.80

* This treatment condition did not occur during the growing season. Hence the treatment data are the same as per T_5 and the average of two treatments are reported.

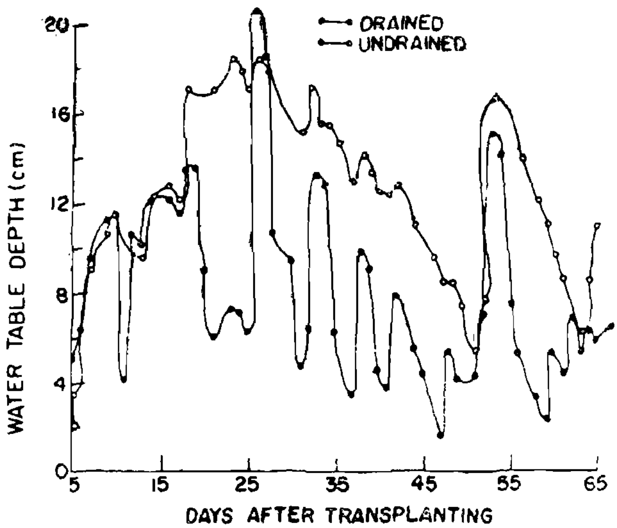


Fig. 13. Water table depths in drained and undrained plots during monsoon 1976

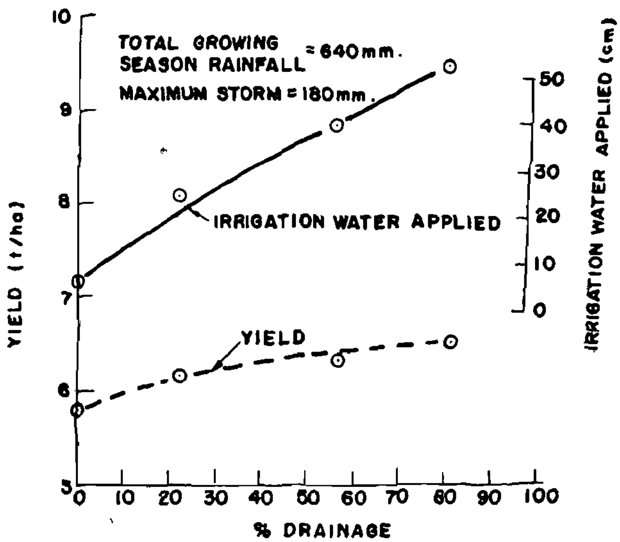


Fig. 14. Irrigation requirement and rice crop yield in relation to different levels of drainage

Rice (IR-8) was transplanted on 16.7.1976 and harvested on 18.10.1976. Each treatment was duplicated with a plot size of 30 m x 40 m. The data on the drainage and crop yields are presented in Table 56.

The typical hydrographs of water levels in the drained and undrained plots during the *kharif* season are presented in Fig. 13. When storms as high as 18 cm. occur, the average yield (6.33 t/ha) of treatments (T_1, T_2 and T_3) providing some drainage is better than the average yield (5.8 t/ha) of treatments (T_4 and T_5) with no drainage. The yields of T_1, T_2, T_3 among themselves are not very much different as indicated by the flat gradient of the regression in Fig. 14. However, irrigation water requirement increases in a linear manner with increasing levels of drainage. This means that for storms as high as 18 cm, 20 to 30% of surface drainage will have to be provided.

E.2. Hydrologic Studies

E.2.1. *Studies on water table fluctuation and their interrelationships with the climatic, soil and acquifer characteristics (V.V. Dhruva Narayana and V.D. Kalra)*

The water table levels during 1976 (Table 57) are generally higher than those in 1975 but were still below those of 1973. The annual recharge to the ground water, as indicated by the total water table rise of 2.36 m in 1976, is sufficient.

TABLE 57. *Average depth of the water table on the research farm below the ground surface and quality of ground water*

Month	Depth (cm)						EC of ground water (micromhos/cm)	
	1971	1972	1973	1974	1975	1976	1975	1976
January	224	183	296	375	456	425	—	663
February	248	201	316	375	489	438	—	761
March	251	259	331	380	511	454	—	1021
April	327	301	371	399	529	456	—	1017
May	346	337	381	440	500	483	666	916
June	343	367	352	424	491	491	744	780
July	295	253	279	470	451	471	729	622
August	114	172	244	346	394	284	735	659
September	71	117	260	384	254	236	907	733
October	110	216	195	406	306	296	920	721
November	136	261	285	461	342	338	847	680
December	157	259	324	463	381	368	714	464

The annual ground water recharge (as indicated by the difference between the highest and the lowest water table levels) is following the pattern of the June-September rainfall (Fig. 15). The general regression equation (Fig. 16) for rise in water table R_W (m), in terms of the June-September rainfall P_M (cm) can be expressed by :

$$19\ R_W = P_M - 17$$

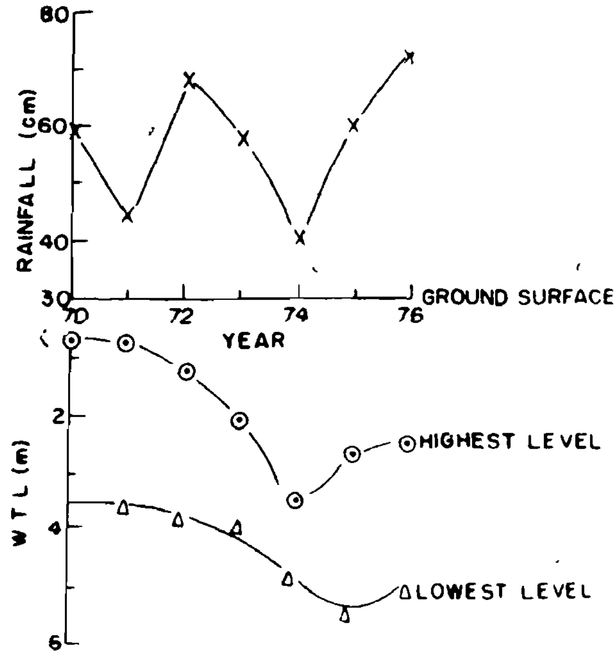


Fig. 15. Highest and lowest water table levels in each year in relation to June-Sept. rainfall

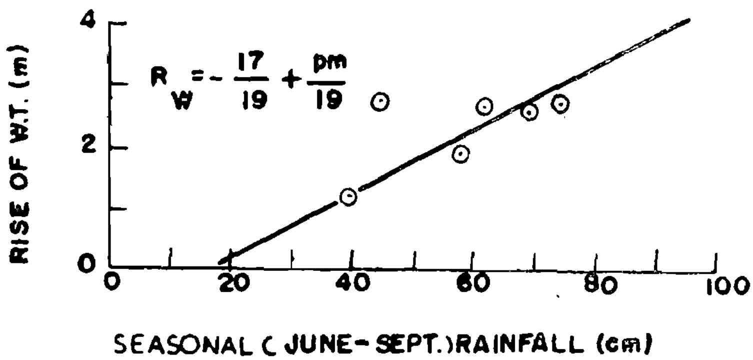


Fig. 16. Rise of water table in relation to the June-Sept. rainfall each year

The ground water quality (Table 57) remained good and EC varied between 622 to 1021 (micromhos/cm) during the year.

E. 2.2. *Studies on rainfall distribution in problem areas (V. V. Dhruva Narayana and A. K. Tiwari)*

In order to compute the hydrologic data for the design of drainage systems in the Karnal region, the daily rainfall data (1948-72) were also statistically analysed for Indri and Israna. The values of average and maximum rainfall for Indri and Israna and the probability of rainfall for more than 5 mm and the values of rainfall of different return periods for these stations are presented in Tables 58 and 59 respectively.

TABLE 58. *Five day rainfall values (cm) of different return periods for Indri in Karnal District (Haryana)*

Months	Recurrence interval	Period (yrs.) 2.33	5	10	25	Maximum rainfall	Probability of occurrence of rainfall greater than 0.5 cm	Average rainfall (4m)
	1-5	–	0.76	1.52	2.54	2.54	24	0.36
	6-10	—	—	—	—	2.59	20	0.38
	11-15	–	—	—	—	2.67	16	0.28
JUNE	16-20	–	1.65	3.30	5.08	5.33	32	0.71
	21-25	1.27	2.28	4.06	6.47	6.35	32	1.03
	26-30	0.64	4.45	7.62	11.56	11.43	56	2.03
	1-5	1.78	5.59	8.89	13.21	21.67	44	2.66
	6-10	4.83	11.43	16.76	23.37	24.13	80	6.20
	11-15	4.19	9.14	13.21	18.67	19.05	72	4.63
JULY	16-20	4.05	10.16	17.27	26.16	27.05	64	4.64
	21-25	3.05	8.13	10.41	13.46	12.45	60	4.33
	26-31	2.29	6.60	9.65	14.23	13.72	72	3.29
	1-5	4.31	9.91	14.22	19.30	19.40	80	4.65
	6-10	4.82	9.91	13.97	19.30	14.68	80	4.48
	11-15	4.31	8.38	11.68	15.75	37.33	84	5.02
AUGUST	16-20	4.82	8.64	11.68	16.26	14.35	72	4.54
	21-25	5.08	8.89	11.94	15.75	21.58	76	5.10
	26-31	2.29	6.10	9.40	13.46	21.97	52	3.11
	1-5	0.76	3.18	5.33	7.87	19.30	44	1.76
	6-10	0.20	5.33	7.87	11.18	10.77	52	2.10
	11-15	1.78	5.59	8.64	11.68	11.23	56	2.53
SEPTEMBER	16-20	0.51	3.30	5.33	8.00	8.13	44	1.40
	21-25	1.90	9.14	14.58	21.34	22.80	24	1.97
	26-30	–	1.01	7.11	15.24	21.51	28	1.85

TABLE 59. *Five day rainfall values (cm) of different return periods for Israna in Karnal District (Haryana)*

Months	Recurrence interval	Period 2.33 Yrs	5 Yrs	10 Yrs	25 Yrs	Maximum rainfall	Probability of occurrence of rainfall greater than 0.5 cm	Average rainfall (cm)
	1-5	—	—	—	—	3.99	20	0.51
	6-10	—	—	—	—	0.2	—	0.02
	11-15	—	—	—	—	1.9	40	0,48
JUNE	16-20	—	—	—	—	3.14	20	0.58
	21-25	—	—	—	—	12.6	30	0.79
	26-30	—	—	—	—	4.39	30	1.09
	1-5	—	1.27	4.31	8.63	10.77	60	1.95
	6-10	—	5.33	12.41	21.33	33.87	80	7.35
	11-15	0.6	4.6	7.6	11.5	11.71	60	3.59
JULY	16-20	—	4.3	10.9	11.3	11.58	80	4.42
	21-25	—	0,89	2.03	3.55	3.2	50	0.85
	26-31	—	3.81	7.11	11.17	11.5	70	4.25
	1-5	—	2.03	6.47	12.19	12.27	70	3.57
	6-10	—	6.09	12.44	20.32	31.75	80	7.62
	11-15	—	5.08	9.90	16.51	10.59	80	5.35
AUGUST	16-20	0.76	3.81	6.09	10.03	9.52	80	3.93
	21-25	—	—	—	—	22.25	40	4.05
	26-31	—	—	—	—	9.32	40	2.05
	1.5	—	—	—	—	4.44	20	0.93
	6-10	—	1.77	5.84	10.60	11.00	60	3.66
	11-15	—	2.28	6.86	12.44	10.59	60	4.29
SEPTEMBER	16-20	—	—	—	—	2.41	30	0.48
	21-25	—	—	—	—	9.91	20	1.19
	26-30	—	—	—	—	1.37	10	0.18

(—) Blank space : Sufficient data not available

The above data indicate that the probability of occurrence of rainfall greater than 5 mm in the continuous five day periods is 40 to 84% during the period from July 1st to 31st August. The maximum values of five day period rainfall is 37.33 cm (August 11-15) in this region.

E. 2.3. *Studies on hydrologic balance and trends in ground water exploitation (V. V. Dhruva Narayana, V. D. Kalra and A. K. Tiwari)*

Runoff measurements were continued on the C.S.S.R.I. Research farm, Karnal from different gauging stations. Typical runoff hydrographs of

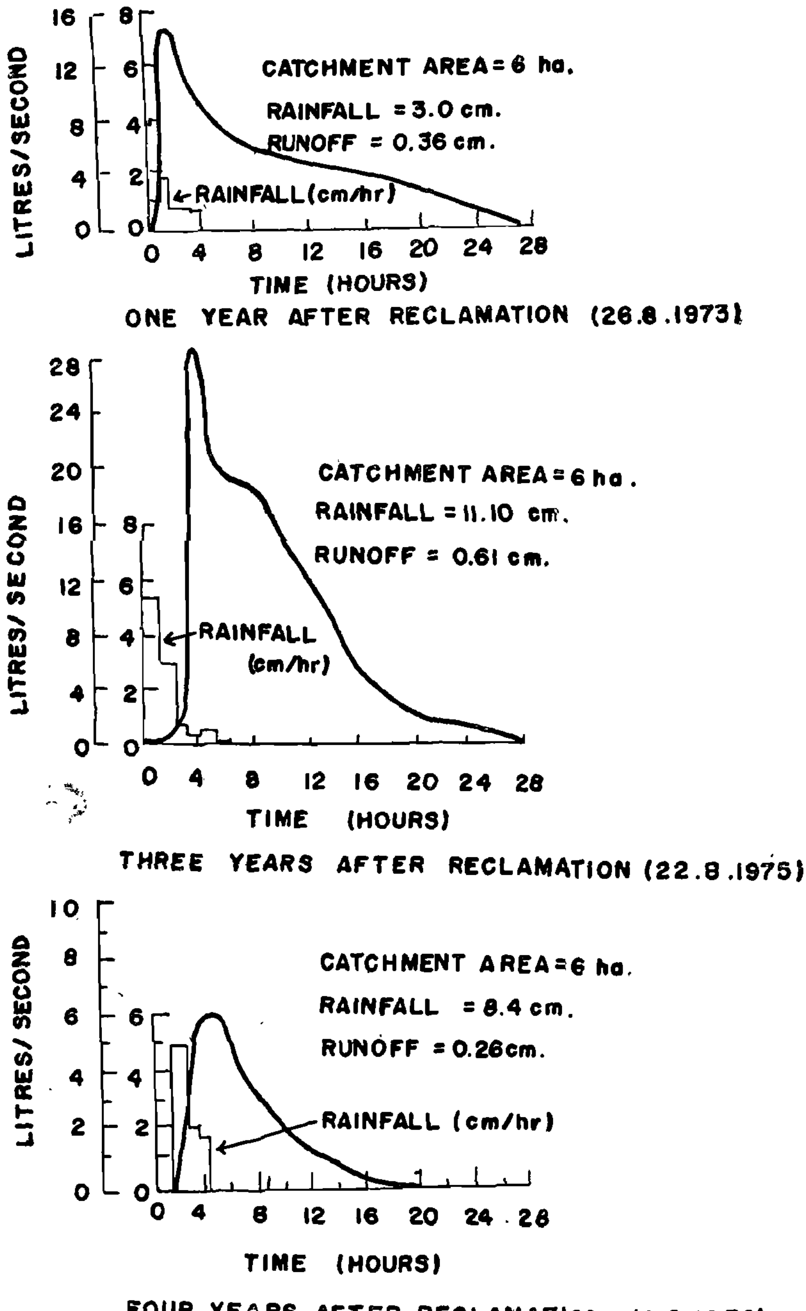


Fig. 17. Runoff hydrographs at C.S.S.R.I. Research Farm after different periods of reclamation

different years at the same gauging station (Fig. 17) indicate that the run-off is progressively decreasing with time in the reclaimed area.

A water balance analysis of a reclaimed and unreclaimed catchment areas (Table 60) indicate that the design discharge capacity for the field surface drains in Karnal region could be reduced from 23 cm to 4 cm for a ten year return period storm of 25 cm, if the catchment of '*alkali*' soils were to be reclaimed. With a permissible drainage detention of six days, the drain could be designed only for half their present design capacity.

TABLE 60. *Comparative values of runoff and ground water recharge in an unreclaimed and reclaimed alkali problem area*

Treatment	Unreclaimed	Reclaimed
Infiltration rate in cm/day	0.5	5
Depth of water retained in the cropland (cm)	—	5
Depth of water retained in the dugout pond (cm)	—	5
Runoff in cm from a storm of 25 cm that occurs once in 10 years	23	4
Average monsoon season rainfall (cm)	57	57
Runoff produced during the monsoon (cm)	46	8
Evapotranspiration during the monsoon season as observed on the C.S.S.R.I. farm (cm)	36	36
Water available for recharge to ground water (cm)	—	13

TABLE 61. *Water balance (cm) analysis of the Research Farm*

Supply & demand	1972	1973	1974	1975	1976
Supply					
Precipitation	69.5	58.9	38.4	60.4	74.3
Canal seepage	4.0	4.0	4.0	4.0	4.0
Total measured supply	73.5	62.9	42.4	64.4	78.3
Demand					
Runoff	12.1	9.4	0.5	1.2	6.0
Evapotranspiration	34.2	37.2	37.9	35.8	35.4
Addition to soil moisture storage	7.9	8.0	6.8	8.8	10.9
Addition to ground water	29.1	8.7	17.1	23.9	25.5
Total demand	83.3	63.3	62.3	69.7	77.8
Probable ground water recharge from other area	9.8	0.4	19.9	4.2	Negligible
(Total demand—Total Supply)					
Amount of water stored on the farm	57.4	49.5	37.9	54.0	68.3
Percentage of rainfall	82.5	84.5	99.0	90.0	91.0

By reclaiming the catchment, the ground water recharge component from the local rainfall could be enhanced from practically nothing to about 13 cm (Table 60). This has also been confirmed by the June-September Water balance analysis of the research farm since 1972 (Table 61). The analysis indicates that the total additions to ground water reservoir under the research farm are increasing from a value of 8.7 cm in 1973 to 25.5 cm. in 1976, while the ground water withdrawls on the research farm generally increased and the net ground water inflow from outside the farm area reduced from 9.8 cm in 1972 to practically nothing in 1976, because of good rainfall in the last two years and the adoption of various reclamation and rainwater management practices on the research farm.

E. 2.4. *Collection of basic hydrologic data required for drainage system (O.P.Singh and R.N. Pandey)*

The survey was done in 1976 in the coastal districts of Maharashtra and south Gujrat to collect basic hydrologic information needed for drainage system design. The basic data collected at different places in the problem area are presented in Table 62. The possible improvement measures for these areas are : (a) construction of sea dykes to prevent inland incursion by sea water with provisions for drainage of inland runoff whenever required, (b) provision of seepage ditches and pumping of poor quality ground water into sea or inland lakes to maintain the ground water table below critical levels and (c) good cultural and agronomic practices for soil improvement for promoting good drainage and crop production.

E. 2.5. *Studies on changes in salt and water balance components in an area being reclaimed (O.P. Singh and A.K. Tiwari)*

Detailed data on various components of the hydrologic cycle are being collected from a large size catchment in the Operational Research Project area, where nearly 40% of the catchment has alkali soils. The catchment area is about 1500 ha (actual survey is now in progress). The alkali soils are being reclaimed by the farmers through the reclamation technology developed at C.S.S.R.I. During 1976 with nearly 40% of the catchment unreclaimed, a total runoff outflow of 258 mm was gauged. This consisted nearly 30% of the total yearly rainfall of 870 mm. A typical runoff hydrograph from the area is shown in Fig. 18. The ground water level and its quality data are presented in Table 63.

TABLE 62. *Soil and drainage characteristics of problem areas in Gujrat and Maharastra State*

Place	Soil Characteristics			Drainage properties			Monsoon rainfall (cm)	Watertable level (b.g.l.) (m)	Special drainage problems
	Texture	pH	EC (1:2)	Surface	Sub-surface	General			
1	2	3	4	5	6	7	8	9	10
1. Ubrahat (Surat)	Top 30 cm clay loam below it clay mixed with sand	7.4 to 8.5	0.67 to 14.5	Good with slope varying from 0.5to 1%	Poor, 1.8 cm/day basic infiltration rate	Possibility of gravity outlets exist	145.0	1 to 3.0	Sea water inundation during high tides
2. Ghodbunder (Thana)	Top 30 to 45 cm clay and below it murram	7.3 to 9.5	1.1 to 15.0	Good with slope varying from 0.5 to 1.2%	Poor, 1.2 cm/day basic infiltration rate	-do-	213.2	0.5 to 2.5	-do-
3. Panvel & Pargat (Kolaba)	Top 30 to 45 cm clay and below it murram	7.3 to 9.0	1.0 to 12.0	Good with slope 0.1 to 0.5%	Poor, 1.5 cm./day basic infiltration rate	-do-	279.5	0.5 to 5	Flooding during rainfall synchronized with high tides.
4. Narayan Mani (Ratangiri)	Lateritic	6.6 to 7.2	1.0 to 4.0	Excellent because of rolling topography	Good, 22 cm/day	—	308.3	1.0 to 8	No problem of drainage

TABLE 63. *Ground water levels and quality in the Operational Research Project Area*

Month	Water table depth below ground surface (metres)	Electrical conductivity (micromhos/cm)
June	5.08	860
July	5.62	1160
August	4.37	1160
September	4.31	900
October	4.66	900
November	4.87	880
December	5.12	790

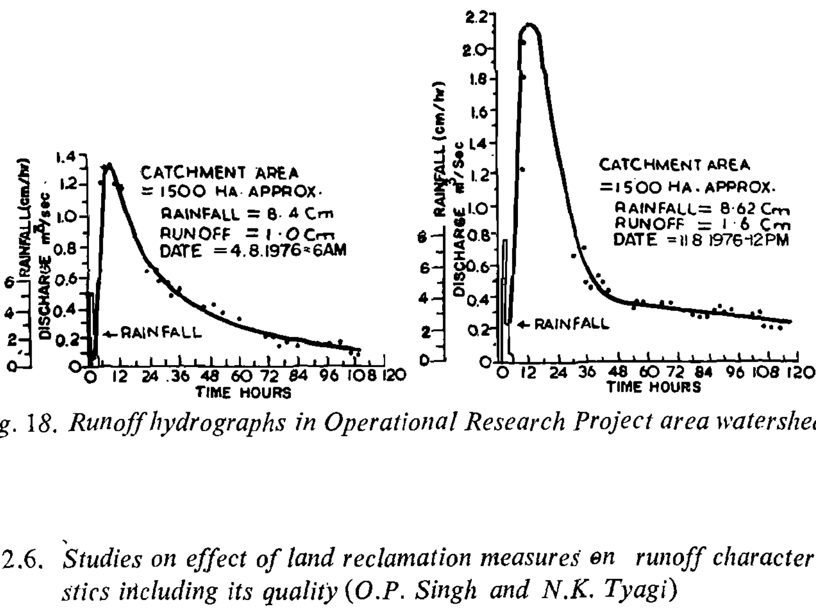


Fig. 18. Runoff hydrographs in Operational Research Project area watershed

E. 2.6. *Studies on effect of land reclamation measures on runoff characteristics including its quality (O.P. Singh and N.K. Tyagi)*

Two identical watersheds, one in unreclaimed alkali soil catchment and the other a normal soil, 1.26 ha in area were selected for this study. The runoff measurements from these watersheds (Fig. 19) indicate that the runoff peak and volumes from reclaimed catchment were 58% and 74.3% of the corresponding values from the unreclaimed catchment. The storage detention (Fig. 20) for the reclaimed catchment is higher for reclaimed area than for the unreclaimed one. The dimensionless unit hydrographs (Fig. 21) were fitted by the following expressions :

$$\frac{a}{q_p} = \left(\frac{t}{t_p}\right)^{0.184} \exp\left(-0.184 \left(\frac{t}{t_p} - 1\right)\right) \text{—unreclaimed area.}$$

$$\frac{q}{q_p} = \left(\frac{t}{t_p}\right)^{0.291} \exp\left(-0\ 291 \left(\frac{t}{t_p} - 1\right)\right) \text{—reclaimed area.}$$

The electrical conductivity values of runoff from reclaimed (500 micromhos/cm) and unreclaimed (587 micromhos/cm) are not very different as also those of the soils from both the catchments.

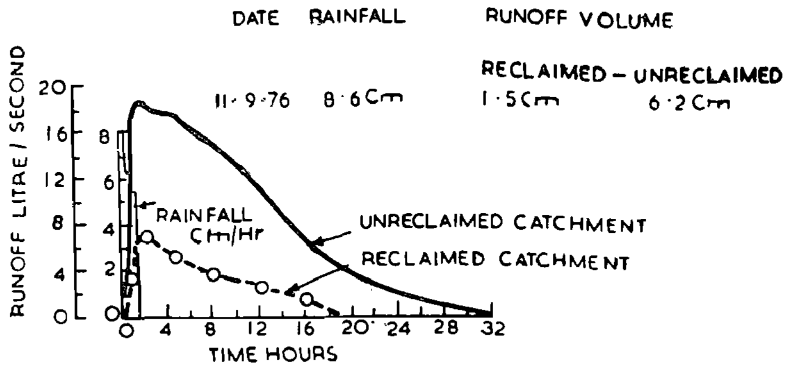


Fig. 19. Runoff hydrographs from reclaimed and unreclaimed catchments

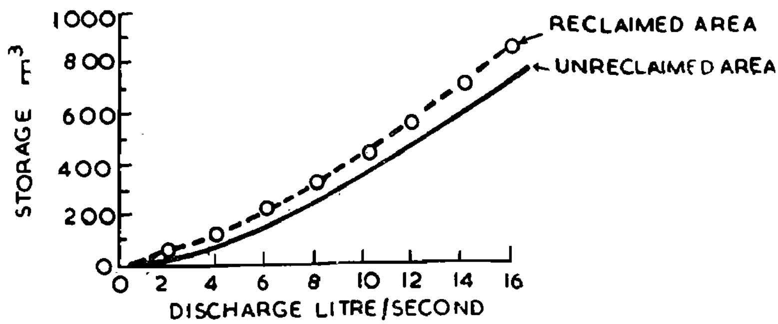


Fig. 20. Discharge storage relationship for reclaimed and unreclaimed area

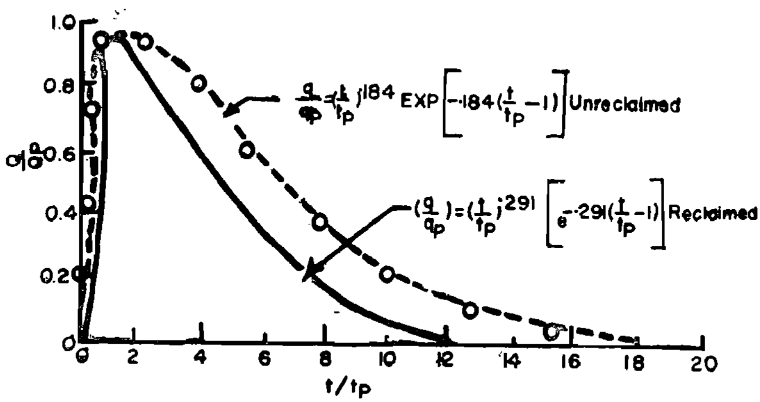


Fig. 21. Average dimensionless unit hydrograph

E. 3.3. Water conveyance and application

E. 3.3. *Studies on methods of adopting a single monoclinal border for cultivating rice in kharif (R.N. Pandey, V.V. Dhruva Narayana and N.K. Tyagi)*

In general, graded borders (·1 to ·15% is the prevailing slope) are better suited for wheat. However, reclamation of alkali soils usually start with rice as the first crop. This requires uniform ponding depth for uniform leaching in the reclaimed plot and for uniform plants growth. These ideal conditions are obtained only in level plots. In order to meet the ideal land requirement of both rice and wheat, and to minimize the land shaping costs by taking advantages of the prevailing slope, graded borders are compartmentalized with small earthen checks, provided with pipes connecting the compartments for taking rice crop in the rainy season.

Let :

L be the length of the border.
S the slope of the border.
D the average depth of ponding nearly equal to the depth of irrigation.
h the depth of ponding at the head end of the border.
H the height of the pipeline above the ground level or the depth of ponding at the lower end of the border.
n the number of compartments into which the graded border is divided.

In any sloping border, when water of average depth 'D' is applied, the depth of water at the head end, $h = D - \frac{LS}{2n}$

and the depth of water at the tail end, $H = D + \frac{LS}{2n}$

The maximum deviation of the ponding depth, either at the tail end or at the head end $= \frac{LS}{2n}$

For any given depth of irrigation 'D', the maximum deviation $\frac{LS}{2n}$ has to be minimized so that uniform ponding depth can be accomplished (Fig. 22). This is done :

i) by increasing the number of compartments so that the uniformity coefficient defined at $UC = 1 - \frac{LS}{2n\,D}$ is increased.

ii) by keeping the connecting pipe at a height $H_n = D + \frac{LS}{2n}$

With this consideration, the experiment on adopting the sloping borders for rice with 1, 2 and 3 compartments as in the previous years was continued. The values of uniformity coefficient and rice crop yields under different treatments are reported in Table 64. These data, as in the previous year, indicate that the crop yields from the sloping borders could be increased by splitting the plot into two or three compartments.

TABLE 64. *Uniformity coefficient and rice crop yields under different compartments*

Treatment	Uniformity* coefficient (%)		Rice crop yield
	Theoretical	Actual	(t/ha)
T_1 Sloping border as a single compartment	42	42	6.3
T_2 Sloping border with two compartments	71	48	6.5
T_3 Sloping border with three compartments	81	56	6.8
L = 93 m, S = 0.1% D = 8 cm in the experiments			

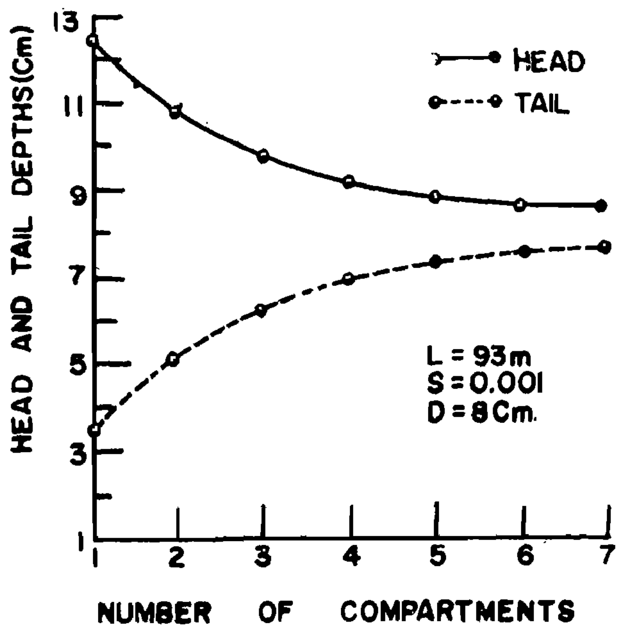


Fig. 22. Effect of compartmentalization on head and tail depths

E. 3.4. *Studies on water conveyance and application in tubewell command areas at C.S.S.R.I. research farm (N.K. Tyagi, O. P. Singh and V. V. Dhruva Narayana)*

In order to obtain basic data on temporal pattern of water withdrawals and the working efficiencies of different tubewells, the pumps and the farm irrigation systems, this investigation was started in 1975 at the C.S.S.R.I. research farm of 80 ha where best available farming technology is adopted.

The farm has ten tubewells, out of which three cavity wells are operated only intermittently. Two are deep tubewells' and the remaining five are shallow cavity wells (Table 65). The irrigation water is conveyed through 2000 m of underground pipes, 950 m of open lined channels and nearly 3000 m of open unlined channels thus giving an irrigation conveyance channel density of 75 m/ha. The details of working pattern for different tubewells, are presented in Table 65.

The average pumping efficiency is about 62% which is quite high. The deep tube wells are the most efficiently operated, and the diesel driven shallow cavity wells have only 36% pumping efficiency. About 62,000 Kwh of power is consumed on the farm and half of this is for domestic water supply. The total annual water withdrawl of 825,000 cuM from the ground water is about 103 cm of water depth for the farm. The water

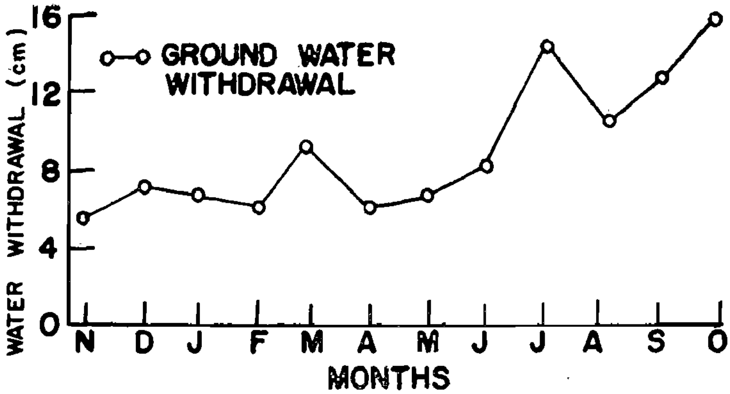


Fig. 23. Monthly ground water withdrawal from Nov. 75 to Oct. 76 at C.S.S.R.I.

withdrawls pattern during the year (Fig. 23) shows that the peak water withdrawls are in the rice transplanting month of July (160×10^{3}cuM) and in the post-monsoon month of October (128×10^{3}cuM)

TABLE 65. *Details of tubewell operations and water withdrawals for the period from 1st November, 1975 to 31st October, 1976*

Type of T/well	Pump	Power (H.P.)	Number	Discharge lit/sec	Hrs. of Pumping	Water withdrawn cu mx 10^3	Energy* Kw H	Water* Hrs. Power Kw H	Pump-effic. %
Deep-well	Turbine	12.5 (Elect.) Motor	1	35	1795	224.4	13,215	9,250	70
-do- Water supply	Turbine	10 (-do-)	1	21	3780	283.0	30,866	20,865	68
Shallow cavity well. +	Centrifugal	5 (-do-)	3	15	1522	241.8	4,200	2,196	52
-do- +	-do- Diesel Engine	5 (Diesel)	2	11	950	75.8	2,346	816	36
Total						825	61,273	38,335	62

$$* \text{ WHP} = \frac{\text{Tubewell discharge (Litre/sec)} \times \text{Pumping Head, (m)} \times 0.74}{75}$$

+ All the figures are average values

The details of water use, irrigation efficiencies and yields of different crops on the research farm are presented in Table 66. The irrigation efficiencies for various crops are reasonably good and this may be attributed among other things to good water management practices.

TABLE 66. *Details of water use, irrigation efficiencies and yields for different crops*

Crop	Depth in each irrigation (cm)	No. of irrigations	Total depth (cm)	Yield (t/ha)	Water use efficiencies (kg/ha/cm)	Application efficiency (%)
Wheat	6-8	4-6	40-50	2.8-3.7	69-74	54-61
Barley	4-8	3	17	2.0	118	71
Rice	10-20	12-13	120-172	4.7-6.3	52	56

E. 3.5. *Studies on the performance of closed level and graded borders in alkali soils (N. K. Tyagi)*

For efficient application of irrigation water in alkali soils, the question whether the land should be perfectly levelled or the prevailing land

TABLE 67. *Irrigation efficiencies and crop yield in different border irrigation treatments*

Item	Graded border cut off ratio				Level border cutoff ratio			
	0.55	0.70	0.85	1.00	0.55	0.70	0.85	1.00
Irrigation depth cm	28.5	29.1	28.3	32.7	36.9	36.3	39.3	44.6
Excess application level borders % age	—	—	—	—	29.6	21.5	32.1	36.1
Percentage area covered	86	100	100	100	57	73	89	100
No. of irrigations	7	6	5	5	6	5	5	4
Based on advance recession data								
Application efficiency % age	88.2	89.7	96.0	67.3	64.9	55.2	54.0	53.3
Distribution efficiency % age	67.7	96.2	88.2	84.6	19.5	53.7	58.8	87.5
Based on soil moisture data								
Application efficiency % age	87.9	73.0	57.7	65.9	53.0	47.6	45.5	45.0
Distribution efficiency % age	51.3	74.8	70.8	70.1	20.2	33.0	66.0	86.2
Crop yield t/ha (Wheat)	3.06	3.53	3.50	3.43	2.56	2.89	2.99	2.72
Water use efficiency kg/ha/cm.	107.5	121.5	123.9	104.8	69.4	79.7	75.9	61.1

Note : The total rainfall during the crop season was 6.80 cm slope be advantageously incorporated in the graded border for wheat cultivation is being investigated in this experiment. The treatments included four cutoff ratios of .55, .70, .85 and 1.0 for both level and graded (9.1% slope) borders. The inflow rate was kept constant at 10 Litres/sec. Irrigation was scheduled on the basis of pan evaporation with .70 as the pan coefficient. The data on irrigation efficiencies, total irrigation depths, percentage area covered and wheat crop yields are presented in Table 67.

The results in Table 67 indicate that graded border with 70% cutoff ratio (for first irrigation, the cutoff ratio is 0.85) gives the highest application, distribution and water use efficiencies of 89%, 96% and 122 kg/ha/cm respectively. In comparison, the best treatment (.7 cut off ratio) among the level border gives 55%, 54% and 80 kg/ha/cm. These efficiencies are also more or less confirmed by the hydraulic characteristics of the border.

The irrigation application efficiency based on soil moisture data in both graded and level borders decrease with increase in cutoff ratio (Fig. 24) probably because of percolation losses at the lower end.

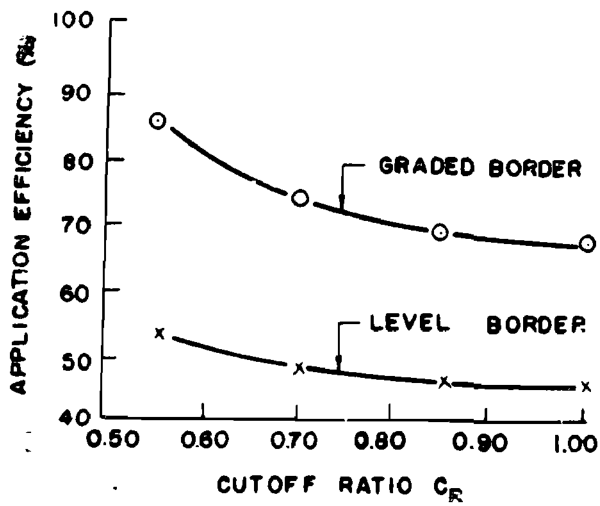


Fig. 24. Relationship between cutoff ratio and application efficiency (%)

The water advance and recession rates did not show much variation with different cutoff ratios probably because of constant supply rate. The water advance rates were, however, much slower in the level borders than in the graded ones and, therefore, comparatively more water had to be applied in the case of level borders. The advance and recession curves (Fig. 25) were fitted by the following general equation for these soils.

$t_A = a x^b$ Advance curve (a = ·4; b = 1.2)

$t_R = a\ (e^{bx}-1)$ Recession curve (a and b are as in Fig. 25)

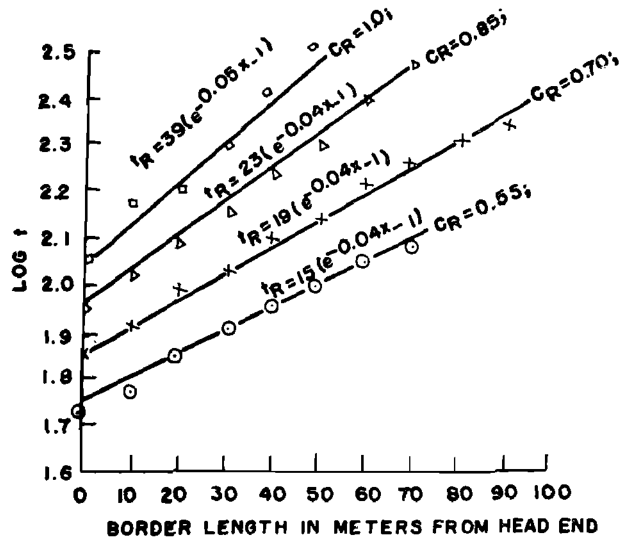


Fig. 25. Recession curves in level and graded borders

E.3.6. *Evaluation of the performance of land grading and levelling implements (N.K. Tyagi and O.P. Singh)*

The performance of different tractor drawn land shaping implements such as levelling blade, float, and super leveller were investigated by including the following: (a) levelling efficiency index L_E , (b) optimum soil moisture level at which the wheel slip value of the soil is lowest, (c) the relationship between the shear stress and the soil moisture, (d) the relationship between the earth carrying capacity of different implements and (e) the time and cost of levelling.

During the year, the investigation was mainly conducted with two implements, namely the levelling blade, float and the combined operation of the two. The levelling efficiency indeed is high for the combined operational levelling blade and the float (Table 68). Although 5 hours of additional discing was needed for this operation; the cost of land shaping is still cheaper than the operations with levelling blade alone and that too with a higher efficiency index. In all cases, an expenditure of Rs. 500/- per ha was incurred for the common operations of ploughing and discing and this is necessary even in reclaimed soils. Since this is the first land shaping operation for reclamation, levelling blade and float are recommended. However, in subsequent years, the float alone may be sufficient to keep the land in good shape.

TABLE 68. *Details of land shaping performance of various levelling implements*

Implements	Time for common operation (hrs) Ploughing	Discing	Time for land shaping operations (hrs)	Cost per ha for common operations (Rs.)+	Cost per ha land shaping alone (Rs.)+	Total cost ha (Rs.)+	Levelling efficiency index
Levelling blade	10	10	26.4	500	660	1160	7.2
Levelling float	10	10	15.0	500	375	875	6.3
Levelling blade and float	10	10	18.5*	500	453	953	9.0

* This includes five hours of extra discing done in this treatment

\+ Cost per one hour of operation is fixed at Rs. 25

The slip value is seen to be lowest (16%) at a soil moisture value of 10.5% (Fig. 26). The shear stress-soil moisture relationship is shown by Fig. 27 for computing the actual loads and traction efficiencies at different soil moisture contents. The relationship between the earth carrying capacity of different levelling implements, Y_C (CuM), and the soil moisture content, M_C (%), are given in Table 69. The maximum value of Y_C is obtained with float in relatively drier soils and it is less than the capacity for the blade in each operation.

TABLE 69. *Maximum earth carrying capacities of different implements and the corresponding moisture contents*

Levelling Implement	Regression equation	R-value	Mc for $\frac{dyc}{dMc}=0$ (%)	Field value of Mc min. wheel slip	Maximum Yc (cum)
Blade	$Yc = -1.4 + 0.298\ M_c - .012\ M_c^2$	.80	12.4	10.5	.46
Float	$Yc = -0.66 + 0.171\ M_c - .007\ M_c^2$	.82	11.1	10.5	.32

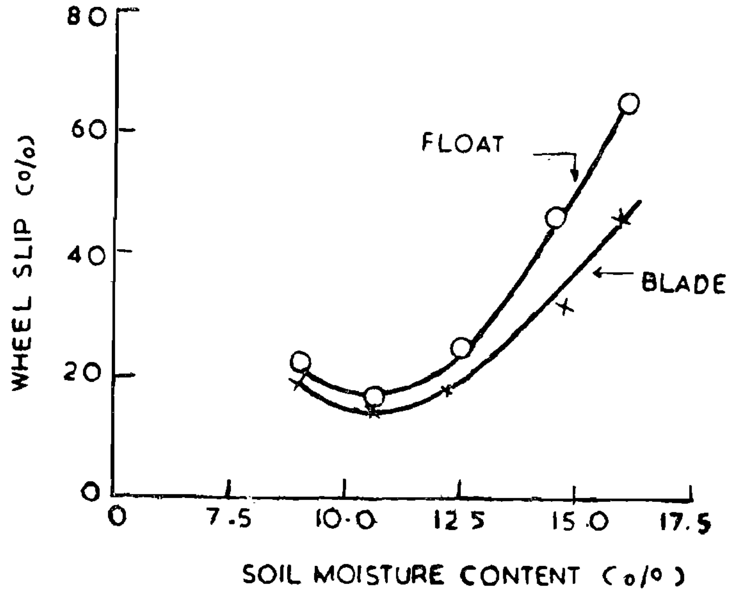


Fig. 26. Relationship between wheel slip and soil moisture

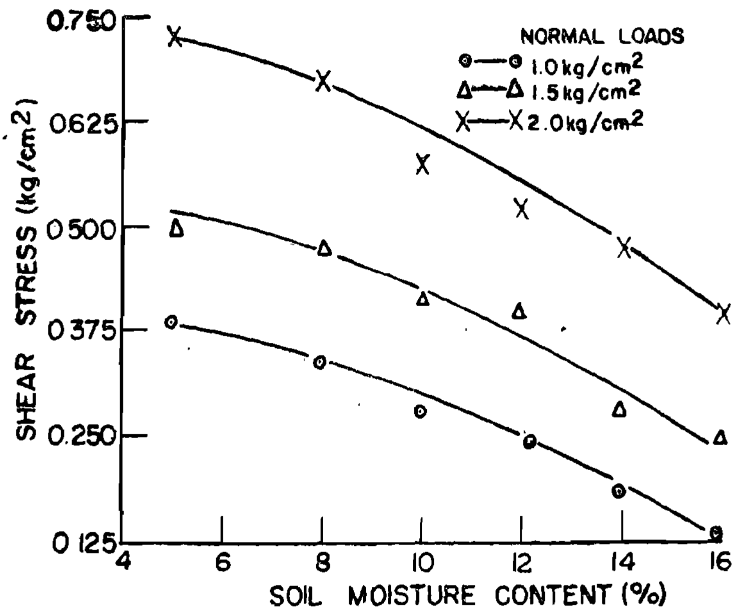


Fig. 27. Relationship between direct shear stress and soil moisture content

E.3.7. *Evaluation of optimum border dimensions for a given stream size under the local conditions (V.V. Dhruva Narayana, and V.D. Kalra)*

In cavity well irrigated areas, the well discharge is limited and is usually 10 litres/sec. In order to determine the border dimensions for optimum irrigation efficiencies, an experiment with a constant border length of 67 m and four border widths of 4 m, 6 m, 8 m and 10 m were tried. The cut-off ratio was kept at .85 for first irrigation and .7 for subsequent irrigations. Wheat (S-1553) was grown and the irrigation interval was determined by adopting a pan coefficient of .7. The performance of borders with different widths alongwith the crop yields are presented in Table 70. The crop yields are nearly same in all the cases. This may be due to the shorter border lengths provided in the treatment which is normally the case with the small farms.

TABLE 70. *Performance of borders with different widths*

	Border width (m)			
	4	6	8	10
No. of irrigations	4	4	4	4
Cut off time for a cutoff ratio of 0.7 (minutes)	23	32	38	44
Total depth of irrigation applied (mm)	167	164	144	148
Rainfall during the growing period (mm)	68	68	68	68
Uniformity coefficiency (%)	89	88	92	92
Water application efficiency (%)	62	62	71	64
Wheat yield (t/ha)	2.8	2.9	3.0	3.0
Water use efficiency (kg/ha/cm)	122	128	148	156

E.3.8. *Evaluation of irrigation methods under salt-affected soils (R.N. Pandey and O.P. Singh)*

Evaluation of different methods of irrigation (sprinklers, perfo-pipes, surface methods—borders, and sub-surface pipes) in sodic soil was done to obtain the information on minimum possible depths of irrigation, their frequencies and the irrigation efficiencies attainable in the field irrigation systems.

During the first irrigation by sprinklers and perfo-pipes, the depths of irrigation applied without causing any surface ponding were determined and the same depths were applied in each irrigation at a frequency obtained by pan coefficient of .7. In surface irrigation, a cutoff ratio of .7 was adopted. In sub-surface irrigation, water was applied through an underground storage tank and the tiles laid at 1.5 m. b.g.l. at 3.5 mm/

day. The last two irrigations with sprinklers, three with the perfo-pipes and one by surface border were applied with a pan coefficient of .8. Average depth, number of irrigations and the crop yields are presented in Table 71. The data indicate that sub-surface irrigation is the poorest method and the best efficiencies are obtained with sprinkler system.

TABLE 71. *Average depth, number of irrigations and crop yields for different irrigation systems*

Irrigation system	Average depth in each irrigation (mm)	No. of irrigations	Wheat crop yield (t/ha)	Water use efficiency (kg/ha/cm)
Perfo	6.0	13	2.24	127
Sprinkler	12.5	8	2.80	137
Surface border	45.0	4	1.85	76
Sub-surface irrigation	3.5 per day	Continuously 274 mm	.95	35

E.3 9. *Studies on seepage rates and hydraulic conductivity through different lining materials (V.V. Dhruva Narayana, A.K. Tiwari and V.D. Kalra)*

In order to determine the effect of different lining materials on the seepage in canals, preliminary analysis of the water table levels in the observation wells in the vicinity of the Western-Jamuna Canal (an unlined canal) and the H.S.M.I.T.C. Augmentation Canal (a canal lined fully with brick masonry) was done.

The water table levels (Table 72) in the vicinity of the W.J. Canal are 1.6 m above the average water table level in the C.S.S.R.I. farm, indicating the seepage effect of the unlined canal. On the other hand, the water table level in the vicinity of the lined augmentation canal is 1.3 m below the average water table level on the C.S.S.R.I. farm. The lower water level in the vicinity of the lined canal may be due to the effect of lining as well as the effect of tubewell pumping. The data are being analysed for determining the relative seepage losses and hydraulic conductivities.

TABLE 72. *Depth of water (in metres) from ground surface*

Months	Near W.J.C.	Near Augmentation canal	Average of the farm
January	2.72	5.83	4.25
February	2.76	6.04	4.38
March	2.94	5.96	4.54
April	3.10	6.04	4.56
May	3.31	6.18	4.83
June	3.07	6.36	4.91
July	2.77	6.33	4.71
August	1.16	4.44	2.84
September	0.87	3.27	2.36
October	1.75	4.03	2.96
November	2.16	4.35	3.38
December	2.52	4.47	3.68
Average for the year	2.40	5.30	4.00

WATER MANAGEMENT

C.3. *Effect of moisture regimes on the availability of phosphorus to important pulse crops (B.M. Sharma and J.S.P. Yadav)*

A field experiment with *moong* (*Phaseolus aureus*), variety S-8 was conducted during summer 1976. The treatments included four levels of phosphorus (0, 40, 80 and 120 kg P_2O_5/ha) and three levels of moisture (60 mm irrigation after 100 mm CPE(I_1), 150 mm CPE(I_2) and 200 mm CPE(I_3)). 20 kg N and 30 kg K_2O/ha were given as basal doses of fertilizers.

The data show that there was significant increase in the grain yield of *moong* upto 80 kg P_2O_5/ha, while a further dose of 40 kg decreased the yields (Table 73). Though the effect of irrigation was not significant, the yields and water use efficiency of the crop were higher in I_2 as compared to the other two treatments. Available phosphorus in soil and total phosphorus in plant were found to increase both with irrigation and phosphorus application.

TABLE 73. *Effect of irrigation and phosphorus levels on grain yield of moong*

Treatment	Grain yield (kg/ha)	No. of irrigations	Depth of water applied (mm)	Consumptive use (cm)	W.U.E.* (kg/ha/cm)
I_1	858	6	36	36.6	23.4
I_2	888	4	24	33.2	26.7
I_3	868	3	18	32.7	26.4
C.D. at 5%	N.S.				
P_0	796				
P_{40}	864				
P_{80}	945				
P_{120}	881				
CD at 5%	11.3				

* Water use efficiency

C. 4. Irrigation requirements of crops under varying moisture stress

C.4.1. *Studies on the influence of varying initial depths of wetting of root zone soil profile and different criteria of irrigation scheduling on water use efficiency of wheat (R.K. Rajput and S.N. Singh)*

In order to find out optimum depth of pre-sowing irrigation and to select the best criteria for scheduling post-sowing irrigation to wheat, the field experiment in split plot design was repeated during the year on a sandy loam soil. The treatments included : (a) depth of pre-sowing irrigation equal to moisture deficit in soil depth of 0-60 cm (D_1); 0-120 cm (D_2) and 0-240 cm (D_3) and (b) post sowing irrigation of 6 cm depth (I_1) at IW/CPE ratio of .9 throughout the crop season; (I_2) .75 ratio upto jointing stage; at .9 ratio upto milk stage and at ·6 ratio thereafter; (I_3) crown root initiation, (CRI), jointing (J), booting (B) and flowering (F) stages; (I_4) jointing, booting and flowering stages and (I_5) CRI and flowering stages.

Unlike the previous year when T_3 and T_4 of post-sowing irrigation schedules remained alike because of sufficient rainfall to obviate the need for irrigation at CRI and jointing stages, all the post-sowing irrigation schedules were differentiated. The results summarised in Table 74 reveal that the beneficial effect of deeper depth of presowing irrigation has been more distinct only in T_5 in which two irrigations at CRI and flowering stages were applied. The results are of value for most of the canal command areas in the country where assured water is generally not available later in the crop season.

TABLE 74. *Effect of initial depth of wetting and different post-sowing irrigation schedules on grain yield of wheat (kg/ha)*

Post-sowing irrigation schedules	1975-76 Depth of pre-sowing irrigation (cm) D_1 5 cm	D_2 8 cm	D_3 10 cm	Mean
I_1—IW/CPE ratio .9	4930 (5)	5190 (5)	5160 (5)	5110 (5)
I_2—IW/CPE ratio .75 upto jointing followed by .9 ratio upto milking and .6 ratio thereafter	4770 (4)	5140 (4)	5180 (4)	5100 (4)
I_3—CRI+J+B+F	5090 (5)	5180 (5)	5170 (5)	5150 (5)
I_4—J+B+F	5030 (4)	5240 (4)	4980 (4)	5080 (4)
I_5—CRI+F	4500 (3)	4900 (3)	4900 (3)	4780 (3)
Mean	4910	5130	5090	

C.D. at 5%	Pre-sowing irrigation	N.S.
	Post-sowing irrigation	2.6
	Interaction	N.S.

C.4.7. *Effect of different irrigation schedules, methods of planting and nitrogen levels on irrigation requirement, water use and yield of sugarbeet on a sodic soil (R.K. Rajput, J.S.P. Yadav* and *S.N. Singh)*

To find out the optimum irrigation schedule for sugarbeet in relation to the method of planting and nitrogen fertilization, the field experiment with split plot design and four replications was repeated on a loamy sodic soil during 1975-76 with var. Maribo-resistapoly. Between the two sugarbeet crops a general crop of rice was taken during monsoon season. The treatments comprised all combinations of 4 irrigation schedules based on cumulative pan evaporation values (40, 60, 80 and 100 mm before irrigation), two methods of planting (ridge and raised flatbeds alternated with a shallow furrow and three nitrogen levels (0,50 and 100 kg/N/ha).

The results of root yield reveal that unlike the previous year, only the main effects of irrigation and nitrogen were found significant. Irrigation application at 40 mm CPE value produced the highest root yield followed by a significant decline in yield under the treatment of irrigation at 60 mm CPE values (Table 75). The effect of nitrogen was linear like the results of previous year. The two methods of planting were at par in root yield but the bed-method of planting on an average, effected 17 percent economy in irrigation water. None of the interactions was found to be significant (Table 75).

TABLE 75. *Effect of irrigation, method of planting and nitrogen levels on root yield of sugarbeet*

Treatments	Root yield (t/ha)			No. of	Total water applied (cm)	
	Ridge	Bed	Mean	Irrigations	Ridge	Bed
CPE at Irrig. (mm)						
40	44.6	47.9	46.2	20	72	60
60	35.5	38.0	36.8	15	54	45
80	32.3	32.0	32.1	13	47	39
100	27.2	28.1	27.7	11	40	33
Nitrogen levels						
0	24.6	25.1	24.8	—	—	—
50	35.4	36.3	35.9	—	—	—
100	44.8	48.0	46.4	—	—	—

C.D. at 5% Irrigation—6.8; Nitrogen—3.6
Methods —NS, Interactions—NS

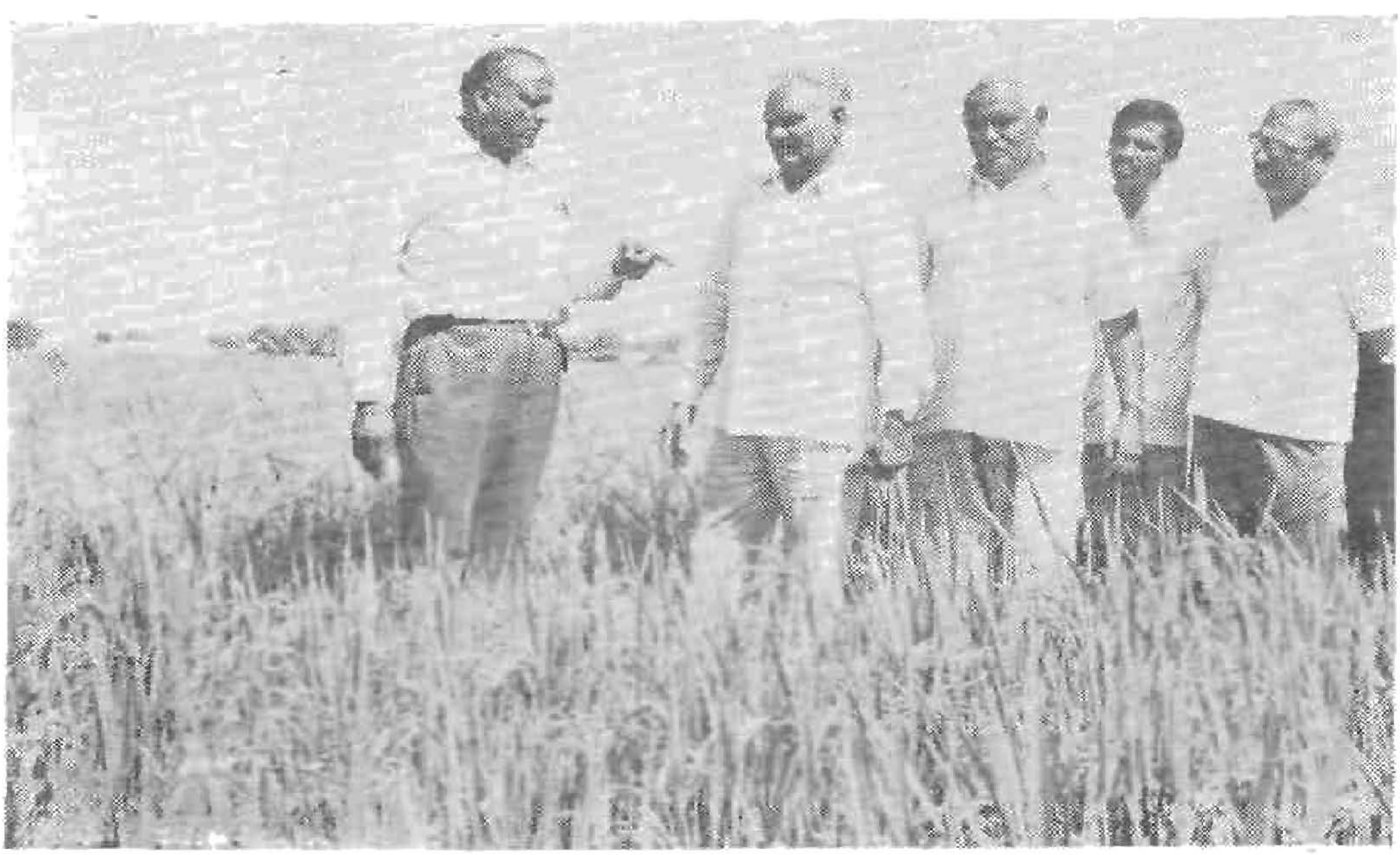
EXTENSION ACTIVITIES

Farmers' Days (R. Parshad)

To acquaint the farmers with different practices of the technology related to reclamation and utilization of alkali soils, the Institute organised 2 Farmers' Days. The Farmers' Day in *rabi* season was held on 18th March, 1976 in village Kachwa (Distt. Karnal) at the fields of Sh. Jessa Ram and Sh. Raghbir Chand. A large number of farmers and extension personnel visited the Farmers' Day to see for themselves the success of the reclamation technology evolved by this Institute. Sh. M.D. Asthana, Director of Agriculture, Haryana, who was the Chief Guest on this occasion, greatly applauded the work done at this Institute and motivated the farmers for large scale adoption of reclamation technology.

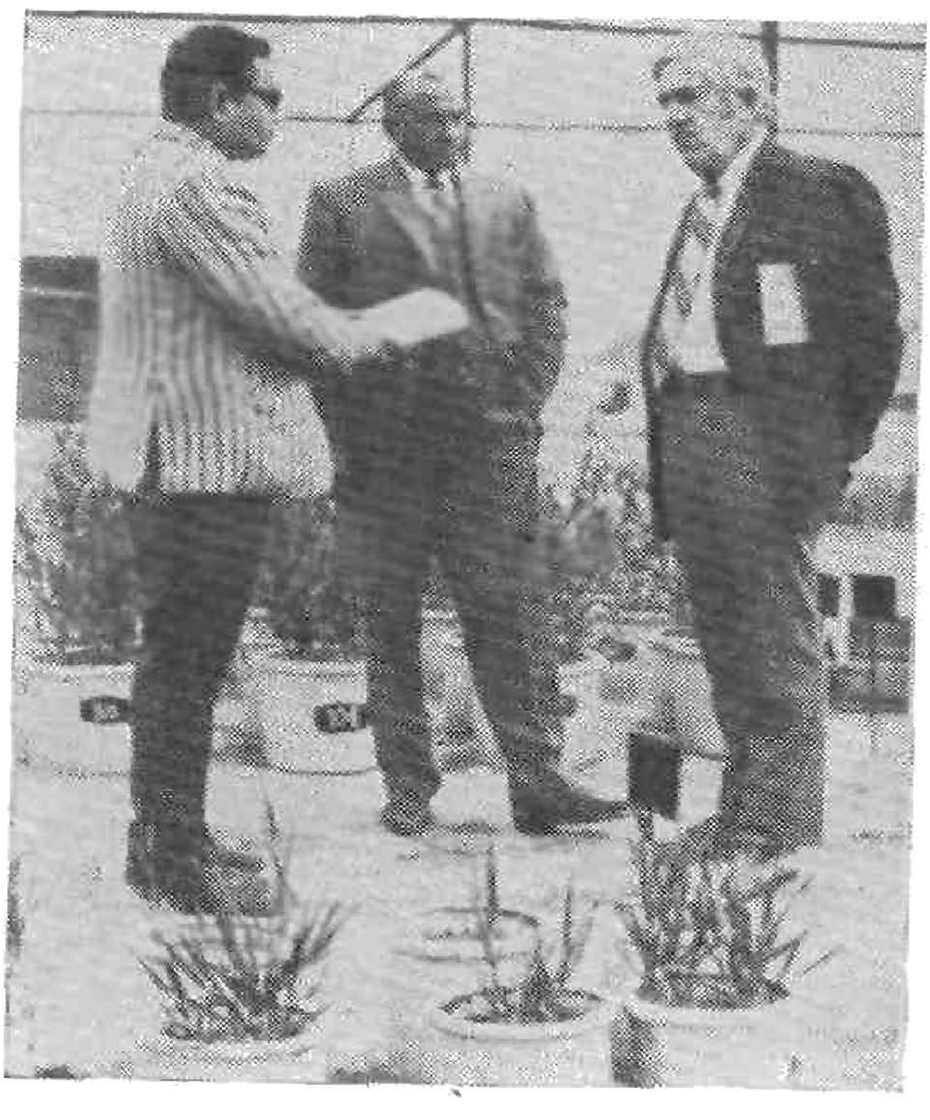
The Farmers' Day in *kharif* season was organised on 8th October, 1976 at the Central Soil Salinity Research Institute in collaboration with the Intensive Agricultural District Programme, Karnal. There was a large gathering of farmers, scientists, extension personnel etc., who were explained various practices involved in the technology for reclamation and

A group of farmers being explained the 'package of practices' for reclamation of alkali soils on the occasion of rabi season Farmers' Day held in Village Kachwa



Col. Maha Singh, Minister of Agriculture, Haryana being shown a first bumper crop of rice after reclamation of alkali land on a farmers' field on the occasion of kharif season Farmers' Day

His excellency the Governor of Haryana, Sh. J.L. Hathi evincing keen interest in Institutes' research activities during his visit



Dr. M. Fireman, Soil Specialist of the World Bank being explained the Institute-research work utilization of alkali soils. Colonel Maha Singh, Minister of Agriculture, Haryana, addressed the visitors on this occasion. A mimeographed publication 'Kallar Bhoomi Ke Sudhar Ki Karyakram Saarni' in Hindi was also distributed.

Visitors (R. Parshad)

Sh. J.L. Hathi, Governor of Haryana visited the Institute on 14.10.76. Sh. K.S. Narang, Secretary to the Government of India, Ministry of Agriculture & Irrigation, accompanied with Dr. B. K. Soni, Deputy Director General (Animal Sciences), ICAR, came to see the research work of this Institute on 23.10.76, Dr. G.S. Vidayarthi, Commissioner (Fertilizers), Ministry of Agriculture, Govt. of India, accompanied by Dr. T.S. Bolaria, Director (Farm Advisory Unit), Govt. of India, came to the Institute on 4.9.76. Dr. D.R. Bhumbla, Deputy Director General-(Soils), ICAR visited the Institute on 4.9.76 and 23.10.76. Dr. Milton Fireman, Soil Specialist, World Bank; Dr. G.S. Kalkat, Agricultural Production Commissioner, Government of India and Dr. J. C. Bakshi, Director of Research, Punjab Agricultural University, Ludhiana visited the Institute on 16.2.76, 20.2.76 and 24.2.76 respectively. Colonel Maha Singh, Minister of Agriculture, Haryana and Shri M.D. Asthana, Director of Agriculture, Haryana came to this Institute on 21.5.76 and 8.10.76; 18.3.76 and 17.9.76 respectively. The list of some important visitors to this Institute is given in Appendix-II.

Mass-media-Coverage (R. Parshad and K.K. Mehta)

Three T.V. teams visited the Institute to cover the research and extension activities on 2nd March, 22nd March and 27th November, 1976. Besides, the representatives of The Tribune, Hindustan Times, Samachar News Agency also paid a visit.

Enquiries (R. Parshad)

As many as 49 letters from farmers and other organizations were received, seeking information on various aspects of reclamation of salt affected soils. These letters were promptly replied to.

Training Programmes

The Institute organized a Summer Training Programme for a group of 4th year Agricultural Engineering students from the College of Engineering, Mahatma Phule Krishi Vidya Peeth, Akola. Similarly, training of entrants to Agricultural Research Service (S-I), allocated to this Institute was also conducted.

Soil Testing and Advisory Services (K.K. Mehta)

The soil samples collected from Narendra Deo University of Agriculture & Technology, Faizabad and Usar Farm, Lalganj were analysed for giving advice on reclamation of these soils. Soil samples of 3 sites near Sambhli, Gudha and Naultha were also taken for analysis. Personal visit was made to the alkali affected lands of the Thermal Plant, Panipat.

Consultancy Service Scheme

A large number of letters received from various organizations, farmers etc., on reclamation of salt affected soils were replied. Soil and water samples were also tested. A folder outlining the objectives and services provided under the scheme was also published. About 40 ha. of badly affected sodic soil of the Narendra Deo University of Agriculture & Technology, Faizabad, was put under reclamation by the University by following the reclamation technology evolved by the Central Soil Salinity Research Institute, Karnal and a good yield of rice as the first crop was obtained during *kharif* 1976. Wheat was grown during *rabi* 1976-77. The Institute helped the University in drawing-up a detailed crop plan of the area also.

OPERATIONAL RESEARCH PROJECT

O.R. 1.1. *Operational research project for reclamation of alkali soils (J.S.P. Yadav and K.K. Mehta)*

An Operational Research Project for reclamation of alkali soils on a large scale under the farmers' conditions, which was initiated in a cluster of 4 villages (Kachwa, Sagga, Sambhli and Birnaraina) during *Kharif* 1975 was continued. The objectives of the project are to test and demonstrate the technology on farmers' fields, to determine its credit worthiness, to identify different bottlenecks in its transfer and to suggest modifications, if any, so as to make it more applicable under the farmers' conditions. Data on the number of demonstrations and total area reclaimed are given in Table 76. Rice-Wheat rotation was followed.

The average grain yield of wheat on the demonstration plots was

TABLE 76. *Number of demonstrations and alkali area reclaimed in the Operational Research Project area during 1975-76*

Village	No. of demonstrations					Area reclaimed (ha)						
	Kharif 1975	*Rabi* 75-76	*Kharif* 76	*Rabi* 76-77	Total	Under demonstrations 1975	1976	Additional area reclaimed by demonstrating farmers 1975	1976	Area Reclaimed by other farmers. 1975	1976	Total
Kachwa	35	35	21	21	112	11.0	5.5	75.8	29.6	28.2	8	158.1
Sagga	12	12	10	10	44	3.6	2.0	14.2	10.4	6.2	6	42.4
Sambhli	21	10	12	11	54	7.0	3.6	59.8	25.6	21.2	4	121.2
Birnaraina	—	—	1	1	2	—	0.4	—	3.6	—	—	4.0
Total	68	57	44	43	212	21.6	11.5	149.8	69.2	55.6	18	325.7

1.5 t/ha and 1.3 t/ha in the additional area reclaimed by the farmers. The village-wise data on the average grain yield of crops during 1975-76 and grain yield of rice as a follow-up in these demonstration plots during 1976 is given in Table 77. The average rice yield in these fields during *Kharif* 1976 was 4.6 /ha, which is 0.6 t/ha more than the yields of the last year.

TABLE 77. *Grain yield & improvement in soil properties of alkali soils of ORP area*

Village	Initial Soil Properties		Gypsum applied (t/ha)	Average yield (t/ha)					Soil conditions after one year (April, 1976)	
				Demonstration plots		Area reclaimed by farmers		On demonstration plots (Follow up)		
	pH (1:2)	EC (1:2) mmhos/cm		Rice 1975	Wheat 75-76	Rice 1975	Wheat 75-76	Rice 1976	pH (1:2)	Ec mmhos/cm
Kachwa	10.2	2.2	12.0	4.0	1.9	3.0	1.5	4.5	9.0	0.67
Sagga	10.2	2.1	12.3	4.0	1.5	3.4	1.2	4.7	9.2	0.91
Sambhli	10.2	1.9	12.1	4.1	1.1	2.6	1.2	4.6	9.1	0.75
Average:	10.2	2.1	12.1	4.0	1.5	3.0	1.3	4.6	9.1	0.78

During *kharif* 1976, 44 new demonstrations were conducted. The grain yield of rice ranged from 3.2 to 7.7 t/ha with an average of 5.1 t/ha. On the other hand, the average yield on the additional area reclaimed by these farmers was 4.0 t/ha. On an average, the initial soil pH decreased from 10.2 to 9.1 (Table 78).

TABLE 78. *Grain yield of rice & improvement in soil properties during the first year of reclamation of alkali soils (kharif, 1976)*

Village	No. of new demonstrations (1976)	Initial soil Properties		Gypsum applied (t/ha)	Average grain yield (t/ha)		Soil Properties after Rice (1976)	
		pH (1:2)	Ec mmhos/cm (1:2)		Demonstration plots	Additional area reclaimed by the farmers	pH (1:2)	Ec mmhos/cm (1:2)
Kachwa	21	10.2	1.65	10.3	4.8	4.1	9.3	.62
Sagga	10	10.2	3.77	11.8	5.4	4.3	8.3	.92
Sambhli	12	10.1	2.31	10.7	5.6	4.5	8.9	.61
Birnaraina	1	10.3	1.77	12.5	4.7	3.1	9.7	.71
Average:		10.2	2.37	11.3	5.1	4.0	9.1	.71

Pyrites for reclamation of alkali soils : Five demonstrations were conducted using pyrites (on average 14.5 t/ha) as an amendment. The average rice yield obtained in these five demonstrations was 4.2 t/ha (Table 79). Long term effect of pyrites and gypsum was studied through 2 demonstrations laid out at farmers' fields in village Kachwa during 1974. The yield data of rice did not show much difference between the treatments of gypsum and pyrites over the last 2 years.

TABLE 79. *Effect of pyrites on reclamation of alkali soils*

Farmer	Village	Pyrites added (t/ha)	Soil properties				Rice yield (t/ha)
			Original		After rice		
			pH (1:2)	EC mmhos/cm (1:2)	pH (1:2)	Ec mmhos/cm (1:2)	
Khajan Chand	Kachwa	15.0	10.0	1.02	9.5	.61	4.1
Ganga Ram	Kachwa	15.0	10.4	1.63	9.7	.68	5.0
Khan Chand	Kachwa	15.0	10.4	1.73	9.7	.64	4.2
Mool Chand	Sagga	12.5	9.9	1.43	8.3	.76	3.5
Prem Kumar	Sambhli	15.0	10.0	0.58	9.5	.52	4.0
Average:		14.5	10.1	1.28	9.3	.64	4.2

Use of rice husk in the reclamation of alkali soils : Three demonstrations were conducted during 1976 on the use of locally available rice-husk in the reclamation of alkali soils, so as to reduce the cost of reclamation. The trial was conducted by following randomized block design with 4 replications. In addition to the above replicated trial, 2 demonstrations of 1 acre plot each were laid out in village Kachwa by using rice-husk @ 30 t/ha+gypsum @ 4.2 t/ha. The incorporation of rice husk alongwith some quantity of gypsum seems to be promising.

Effect of missing P and K on the yield of wheat : Soil phosphorus status was determined at 3 farmers' fields in Kachwa which ranged from 74-130 kg. P_2O_5/ha. The information regarding treatments and replications has been given in Annual Report 1975. During *rabi* 1975-76, wheat was grown as second crop. There was varying wheat yield in control as well as in the treatment plots, whereas in case of rice, practically no difference in yield was noticed (Annual Report 1975).

Field Day : One Field Day was organized on December 6, 1976 on the fields of Sh. Bhim Singh in village Sagga to demonstrate the proper method of irrigating wheat crop in alkali soils to the farmers.

Selection of 2nd Cluster in O.R.P. : Second cluster consisting of three villages namely Gudha, Dadlana and Begampur has been tentatively selected. These villages are situated at about 2 to 8 kms. away from G.T. Road on a link road from Karnal to Assandh. These villages have large areas of soil alkali problem which are lying barren. Soil analysis of three such affected sites in these villages shows that the surface soil has pH 10.6 and EC 3.2 mmhos/cm in 1:2 soil water suspension. The pH remains almost constant in the deeper layers also (0-90 cm), but the salt concentration becomes lower in the deeper layers.

Bottlenecks experienced in large scale reclamation on farmers' fields :

(a) Difficulty in getting loans: Some Government alkali lands have been sold to the Scheduled Castes on instalment basis through auction. These people cannot get loan from any bank until they have paid all the instalments and land ownership rights are transferred to them.

(b) Difficulty in getting electric connection: Due to paucity of electric materials with the Haryana State Electricity Board, the electric connections to the tubewells are often delayed. This causes hinderance in obtaining water supply for irrigation and other reclamation operations.

(c) Common land of the Panchayats: Most of the Panchayat lands are badly affected by alkali and are used primarily as grazing grounds. Some working system needs to be developed so that these lands can be reclaimed.

(d) Drainage problem: Every year during the rainy season some low lying areas in the operational research project get flooded by outside water which necessitates provision of drainage facilities,

(e) Non application of gypsum in time: According to the technology, gypsum has to be applied a few days before transplanting of rice. After application of gypsum the farmers do not maintain standing water because of shortage of labour and/or to save money.

(f) Non-availability of ammonium sulphate: This fertilizer which is preferred over other nitrogeneous fertilizers in case of alkali soils, is sometimes not available in the market.

(g) Insufficient use of inputs some : Farmers do not use the recommended quantity of inputs specially fertilizers, zinc sulphate application and seeds etc.

Observance of Principle of Social Audits

A bench mark survey was conducted in the beginning of 1975 with 540 farming and 364 non-farming families to know their financial position. 60 per cent of the non-farming families had annual income less than Rs. 2000/, whereas only 26 per cent of farming families had income less than this. Average number of members in a family ranged from 6 to 10 and most of the families had joint family system. During 1975-76, out of a total of 68 demonstrations, 18 were laid on the alkali fields of poor farmers, in whose case the condition of reclaiming other alkali area with their own resources was relaxed. Free amendments and fertilizers were supplied to these farmers for the demonstration plots. During 1976-77, out of 44 demonstrations, 9 demonstrations (three each with rice husk, pyrites and para grass) were laid on poor farmers' fields who could not reclaim their remaining area simultaneously because of poor economic conditions.

O.R. 1.2. *Economics of crop production on sodic soils under reclamation* (*Parmatma Singh*)

The research findings of the Institute are being tested and demonstrated on the farmers; fields in a cluster of four villages viz. Kachwa, Sagga, Sambhli and Bir Naraina under an Operational Research Project. During 1975-76 agricultural year, 68 farmers selected for demonstration purposes formed the sample of this study. Survey method by personally interviewing the farmers was used for data collection. The final analysis is based on only 64 farmers. From each of the selected farmer, the data regarding land preparation, amendment application and cost of crop production were collected itemwise. The physical units of inputs were evaluated at the prevailing rates in the villages. The cost of gypsum was taken as Rs. 200/- per tonne. Interest on the cost of land preparation and amendment application @ 10.5% was also added towards cost side. Similarly, for cost of cultivation of crops, interest on working capital @ Rs. 14% per annum for half the period the crop stood in the field was added to the cost. The imputed rental value of land per ha. was also added to the cost of crops production. The output was converted into monetary units at prevailing prices in the villages. The detailed analysis of the data is in progress.

O.R. 1.4. *Comparison of improved water management practices with the conventional methods of water use and crop yields under the farmers condition (P. S. Kumbhare and N. K. Tyagi).*

Twelve farmers whose demonstration plots were properly levelled and bunded and with good irrigation channels were selected out of total of 44 demonstrations conducted in Operational Research Project area during 1976. On an average, farmers used 10 cm more water as compared to the water used in plots with improved management (Table 80). Saving in water in demonstration plots may be attributed to comparatively better levelling as compared to farmers' fields. The water distribution efficiency was 72% in demonstration plots as compared to only 60% in farmers' fields. In plots where land slope was between 0-0.1 per cent, the yield of rice was 7,000 kg/ha as compared to 5,560 kg/ha in plots with 2% slope. The yield further reduced to 5130 kg/ha in fields which had not been properly levelled and had undulated surface. The cumulative effect of improved practices in demonstration plots resulted in yield which was higher by 15.3% as compared to yield on farmers' field.

TABLE 80. *Comparison of irrigation efficiencies and crop yields in farmers; fields with improved water management*

Item	Farmer's field	Demonstration Plot
Irrigation water applied (cm)	120.3	110.8
No. of irrigations	10-11	10-11
Depth per irrigation (cm)	11-12	10-11
Distribution efficiency (%)	60.2	72.0
Rice crop yield (kg/ha)	5282	6091
Water use efficiency (kg/ha/cm)	29.3	35.4
% age water saving		9

RESEARCH STATION—CANNING (WEST BENGAL)

The Research Station, Canning forms the nucleus for catering to the research needs of coastal salt affected soils. The research station has a farm of about 12 ha and another 12.75 ha of land on the adjoining eastern side from the bed of river Matla is under procurement. An earthen embankment is being constructed to protect this area from inundation with tidal water. The ground water is saline with predominance of chlorides and sulphates of sodium and also of magnesium and calcium. The ground water table remains high with small fluctuations being from ground level to about 1.5 m during the year. The soil of the farm is silty clay loam in texture and is salinised from ground water. The avarage ECe in surface soil varies from 4 to 15 mmhos/cm in different periods of the year. The total rainfall from January to December is 1687 mm. The max. temperature during the year varied from 35.8°C in April to 25.8°C in December to 26°C in July. The mean relative humidity remained quite high, around 80% in most part of the year. The rate of open pan evaporation ranged from 2 to 7 mm/day.

SOIL SCIENCE

C.S. 1. Soil and water management of coastal salt-affected lands

C.S. 1.1. *Critical depths of water table for different crops (H. S. Sen and A. K. Bandyopadhya)*

The study was conducted in lysimeters packed with soil (Sand 35.6%, Silt 38.9% and Clay 25.5%) having ECe from 1.0 to 3.3 mmhos/cm. Two water table depths viz. 0.57 m (D_1) and 1.07 m (D_2) with three qualities of water viz. EC 1.2 (Q_0), 5.0 (Q_1), and 10.0 (Q_2) mmhos/cm were maintained. Salt movement through the soil profile resulting from the upward capillary movement of water during dry spell and downward movement of water following rainfall (total of 8.75 cm in 97 days during study period) was monitored. Mercury manometers were installed at different depths. Water was estimated from Darcy's equation V=K i; where, K is Hydraulic conductivity. K in relation to soil moisture suction (Ψ) was evaluated separately from the relationship, $K=D\frac{d\,x}{d\,\theta}$, where Diffusivity (D) vs soil moisture content (θ) and soil moisture suction (Ψ) vs soil moisture content (θ) relationships were calculated; $i\frac{\Delta\,\phi}{\Delta H}$, where, ϕ, the hydraulic potential= —(Ψ+g), g being the gravitation potential with reference to the soil surface, or in other words, depth of installation of the tensiometer cup (negative in sign) and $\triangle$ H is the distance between two successive tensiometer cups.

The upward and downward flux of water observed during dry spells and following rainfall respectively was in general, higher near the surface and decreased gradually with depth. The accumulation of salts in the soil profile during 97 days period of study was within the safe limit of tolerance for almost all crops, which may be attributed to a relatively smaller values of upward flux of water during drying and larger values of downward flux of water following rains in case of water table at 1.07 m depth. It seemed that critical depth to water-table may be between ·57 and 1.07 m.

C.S.1.2. *Study on the leaching efficiency of salts as affected by different initial soil moisture contents and their redistribution before next irrigation* (*A.K. Chatterjee and A.K. Bandyopadhya*)

A three years' study showed that salts are not adequately leached from the soil profile during the monsoon though about 1500 mm rainfall was received during the period. A laboratory experiment in 45 cm high plastic columns having 7.5 cm internal diameter was, therefore, undertaken to study the leaching efficiency of salts from the soil profile having different initial soil moisture content.

Soils (silty-clay loam, ECe 3.2 mmhos/cm) having 10% (wilting point), 15%, 20% and 30% (field capacity) initial soil moisture contents were packed (bulk density 1.4 g/cc) in the column and 4 cm irrigation water (EC 1.5 mmhos/cm) was applied. After **3** days when there was no standing water on the soil column, one set of columns were sectioned each at 5 cm interval, and moisture and electrical conductivity of the soil determined. The other sets were burried perpendicularly in the soil with their open surface above the ground so as to get identical atmospheric condition. When the cumulative open pan evaporation figure became 40 mm (here 4 cm irrigation water is given when open pan evaporation is 4 cm), the other sets were also sectioned and analysed for moisture and salinity of the soil.

The results showed that more salts leached down the column when the soil moisture contents were less than field capacity. Practically no salts were leached when the soils were at field capacity and the irrigation water could pass through the water filled porocity. Probably, leaching of salts is not possible during the *kharif* season with sufficient rain water as was observed in previous studies.

C.S. 1.3. *Displacement of soluble salts from saline soil with the addition of sand (H.S. Sen and A.K. Bandyopadhya)*

Masonry lysimeters (0.75 m × 0.75 m × 2.0 m) were filled and uniformly packed with soils having sand 35.6%, silt 38.9%, clay 25.5%. There were two treatments each replicated twice viz., i) surface 15 cm soil mixed with 30% (by volume) sand as the ameliorating agent (S_{30}) and ii) no sand added which is the normal practice (S_0). The profiles were equiliberated with artificially prepared water (EC 10-11 mmhos/cm, Na^+32.6, K^+62.7, Ca^{++} 3.2, Mg^{++} 5.2, Cl=8 1.6, SO_4=13.5, HCO^-_3 9.5 meq/litre) having ionic compositions similar to that of the field soil solution. Leaching was done with irrigation water (EC 1-1.5 mmhos/cm) under a constant water head of 4 cm maintained on the soil surface and leachate was collected daily through a perforated G.I. pipe, installed at 1.15 m depth below the soil surface. The leachate and soils (initial and final) were analysed for EC, Cl^-, Na^+, $Ca^{++}+Mg^{++}$.

The average pore-water velocity for S_{30} and S_0 treatments were 0.074 and 0.031 cm/ha (Table 81). The fresh water appeared with the affluent earlier in S_0 treatment. This was expected, following the classical discussions of Nielsen and his co-workers that S_0 soil profile with much slower average porewater velocity has a very high molecular diffusivity (Table 81), which coupled with the velocity distribution would result in an early appearanee of the fresh water with the affluent. The S_0 soil profile, characterised by a much slower average pore-water velocity, has number

TABLE 81. *Physical constants associated with breakthrough plots*

Treatments	Av. water-filled porosity	One pore volume (Ltrs)	Av. pore-water velocity (v) (cm/hr)	vL/D L=length of soil column	Const. molecular Diffusion Coeffi-cient (C)	Slope of break-through curve at p=1.0
Sand (S_{30})	0.46	2.98	0.074	4.83	1.76	0.62
No sand (S_0)	0.53	3.42	0.031	0.25	14.49	0.14

of smaller pores, acting as static sinks to ionic diffusion, which are not completely invaded by the leaching water. This resulted in a less rapid break-through curve for S_0. After leaching for 53.2 days (upto which the data for break through curves are reported), the S_{30} soil profiles had less salts at all depths, except at 90-115 cm (Fig. 28), (73.5 cm water leached in S_{30} as compared to 53.9 cm in S_0). Similar trends in results were obtainad with Cl^-, Na^+ and $Ca^{++}+Mg^{++}$. It may be possible to obtain better agreement for S_0 if the reaction of solutes with the adsorbed phase during flow of leaching water is taken into account in the model.

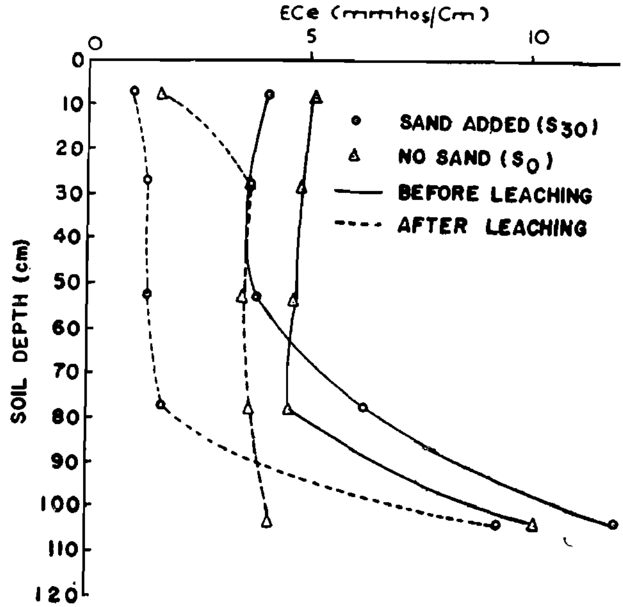


Fig. 28. Salt distribution in the soil profile before and after leaching

C.S. 1.4. *Physico-chemical changes in saline soils as affected by flooding*

(*a*) *Physico-chemical properties of the farm soils* (*R.K. Gupta*)

The physico-chemical properties of the soil samples collected from C.S.S.R.I., Research Station, Canning Farm and Sir Hamilton Trust Farm, Gosaba are presented in Tables 82, 83 and 84. The soils are heavy textured varying from silty to silty clay. The sum of exchangeable basis was found to be more than the NH_4 OAc, pH 7.0 CEC. Upon heating the saturated soil samples to 110°C the decrease in CEC was 0.37 to 5.5 meq/100 gm soil indicating the presence of sufficient vermicullite clay content. The available P content is medium to high. The exchangeable sodium content of the soils based on sum of exchangeable basis varied from 17 to 35 per cent. The soils are acidic in reaction with pH values ranging from —0.45 to —0.75, the negative pH values indicate that the soils contain constant charge type clay colloids. The $BaCl_2$, TEA, pH 8.0 extractable acidity was between 5.08 and 12.5 meq/100 gm soil. The gypsum content of the soils varied from 1.5 to 4.2 meq/100 gm soil based on dilution method (USDA 1966).

TABLE 82. *Physico-chemical properties and Na and K-selectivity coefficients of the soils at Gosaba farm*

Saturation per cent	Organic carbon	Sand	Silt	Clay	Exch. Na / Exch. bases	SAR	Sat. paste pH	$K_{G_{Na}}$ (moles/l)	K_{G_k} (moles/l)	ECe mmhos/cm	0.5M $NaHCO_3$ Ext. P[3]	CEC		BaCl$_2$TEA (pH8.0) acidity
		%										NH_4OAc	K-NH_4 Heating 110°C	
											ugP/g	........meq/100 gm	....	
48.9	0.524	17.8	52.0	30.1	23.77	23.6	6.10	0.89	10.95	13.81	11.2	14.9	12.6	10.4340
55.2	0.568	8.6	49.7	41.6	22.59	11.9	5.70	1.09	3.89	4.48	13.6	19.6	13.8	5.0825
55.5	0.559	10.0	51.2	38.7	22.81	10.9	5.70	1.18	6.01	8.58	12.0	14.9	13.0	11.4581
52.7	0.530	10.1	55.2	34.7	29.76	11.4	5.90	1.62	6.01	10.12	27.6	13.7	13.0	6.2499
55.6	0.525	13.2	54.7	31.9	35.87	6.8	6.85	3.49	3.87	5.74	19.6	14.8	12.8	9.3749
53.7	0.475	16.3	44.0	39.6	17.37	10.7	6.00	0.86	5.32	9.08	14.8	15.0	13.0	12.4998
55.4	0.542	19.7	56.8	23.4	34.38	19.0	6.90	1.22	9.28	4.94	14.8	12.8	12.2	10.4165
51.7	0.549	14.7	60.3	24.9	18.05	8.8	6.65	1.10	4.62	4.90	13.6	12.3	11.9	12.4998

TABLE 83. *Soil profile characteristics of C.S.S.R.I. Canning Farm soils*

Depth (cm)	Organic carbon	Sand	Silt	Clay	pH of sat. paste (H_2O)	pH of sat. past (KCl)	pH KCl-H_2O	CEC (me/100g)	ECe (mmhos/cm)	$BaCl_2$-TEA (pH 8.0) acidity (me/100g)
			%							
Silty Soil										
0-15	.54	19.70	56.80	23.40	6.70	6.60	—0.10	12.85	14.70	12.10
15-33	.42	25.60	47.80	26.00	7.15	6.85	—0.30	12.65	12.77	14.80
30-45	.36	20.90	52.60	26.50	7.35	6.95	—0.40	12.65	15.08	10.40
45-60	.22	25.40	48.20	26.40	7.40	6.25	—0.45	12.28	12.59	6.08
60-75	.27	20.90	54.20	25.10	7.20	6.75	—0.45	14.14	12.11	—
75-100	.28	29.10	47.00	23.90	7.00	6.65	—0.35	10.23	34.40	6.08
Silty Clay Loam										
0-15	.57	8.60	49.78	41.60	5.50	4.60	—0.90	20.14	9.23	13.90
15-30	.49	8.60	40.70	41.70	6.35	5.95	—0.70	19.81	8.26	13.00
30-45	.43	8.10	51.40	40.40	6.50	5.75	—0.75	20.48	7.72	19.10
45-60	.41	9.30	41.20	49.50	6.60	—	—	—	—	—
60-75	.40	8.30	47.50	44.20	6.55	5.90	—0.65	20.48	13.08	19.10
75-100	.41	7.30	53.30	39.50	5.90	5.25	—0.65	17.31	11.87	18.20
Silty Clay										
0-15	.56	10.00	51.20	38.80	5.50	5.25	—0.35	15.61	8.96	9.10
15-30	.45	7.10	51.80	41.10	5.80	5.70	—0.10	16.21	6.54	6.90
30-45	.41	8.00	49.60	42.40	6.40	5.95	—0.45	16.08	8.72	13.00
45-60	.38	1.40	55.60	43.00	6.70	6.15	—0.55	15.27	11.14	11.30
60-75	.39	7.20	52.80	40.00	6.70	6.05	—0.65	15.21	11.62	14.80
75-100	.42	8.50	49.00	42.60	6.70	5.30	—0.40	17.84	12.62	12.20

TABLE 84. *Water soluble and exchangeable cation distribution in three soil profiles*

Depth (cm)	Water soluble cations					ECe (mmhos/cm)	SAR	CEC	Exchangeable cations			
	Mg^{++}	K^+	Na^+	Ca^{++}	Total				Mg^{++}	Na^+	K^+	Ca^{++}
	...............me/litre.....................							...........me/100 g soil....................				
					Site-1							
0-15	37.24	0.52	94.50	20.20	152.46	14.70	17.70	12.85	8.77	3.29	0.96	8.40
15-30	51.96	0.44	80.00	17.36	149.76	12.77	13.40	12.65	8.33	5.33	0.82	8.34
30-45	34.32	0.45	100.70	18.98	153.55	15.08	19.67	12.65	10.20	3.76	0.84	8.83
45-60	33.14	0.47	83.50	18.08	135.19	12.59	16.52	14.14	10.48	4.33	0.87	8.73
60-75	11.96	0.50	80.00	17.68	110.14	12.11	15.44	12.28	11.58	4.53	0.94	9.07
75-100	143.52	0.45	50.00	58.48	252.45	34.40	4.95	10.23	9.72	5.08	0.81	6.69
					Site-II							
0-15	40.64	0.42	40.00	19.76	100.82	9.43	7.28	20.14	5.29	6.46	0.78	4.04
15-30	18.80	0.60	55.50	7.56	82.46	8.26	15.06	19.81	8.69	4.99	1.15	5.81
30-45	25.44	0.47	40.00	7.16	73.07	7.72	14.91	20.48	8.72	4·47	0.89	6.05
45-60	—	—	—	—	—	—	—	—	—	—	—	—
60-75	36.84	0.45	86.50	19.24	143.03	13.08	16.34	20.48	10.70	0.95	0.83	5.03
75-100	27.52	0.55	77.50	18.20	123.77	11.87	17.05	17.31	9.06	2.28	1.03	5.42
					Site-III							
0-15	24.20	0.61	50.00	9.16	83.97	8.96	12.24	15.61	11.33	6.28	1.16	5.91
15-30	16.84	0.64	41.00	7.56	66.04	6.54	11.75	16.21	12.45	10.21	1.23	6.12
30-45	23.32	0.63	60.00	8.12	92.07	8.72	15.13	16.08	11.07	10.50	1.20	5.77
45-60	33.64	0.53	27.50	11.72	123.39	11.14	16.49	15.27	20.80	4.28	1.00	5.18
60-75	31.24	0.41	80.00	9.88	121.53	11.62	17.64	15.21	7.07	3.13	0.75	7.34
75-100	44.00	0.45	83.50	12.60	139.95	12.62	15.78	17.88	7.59	4.73	0.83	8.12

The sum of water soluble plus exchangeable Potassium and Potassium Selectivities Coefficients indicate that the soils may respond to K fertilization. Three soil series were observed in the Research Station Farm. Data in Table 84 indicate that the soils are saline in nature and are member of fine clay mixed hyperthermic family of Fluentic Haplaquepts.

(b) *Chemical properties of the soils as affected by dilution of soil system (R.K. Gupta, A.K. Bandyopadhya)*

Irrigating the fields was observed to afflict severe damage to the summer and winter season crops like barley, linseed and safflower etc. resulting in-general chlorosis and death. The dilution of the soil system by irrigation water increased electrical conductivity of the soils (Table 85) and also the ECe measured after airdrying the moist core (Fig. 29). The electrical conductivity reached a peak value after 7 hrs. The ECe slump was followed by a gradual increase after seventh day.

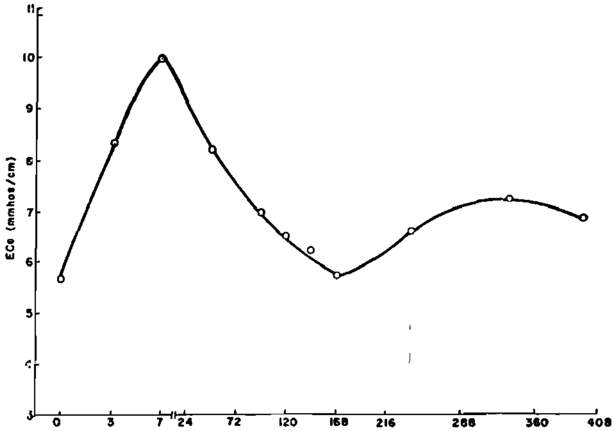


Fig. 29. Variation in the content of soluble salts after irrigation

Laboratory studies also indicated that dilution of the saturation paste to a 1:5 soil : water suspension ratio, increased total soluble cations and anions by a factor of 1.8 times (Table 86). Data in Table 86 reveal that release of Na^+ was more than the calculated value. The increase in ECe values following dilution of soil system was due to exchange and hydrolysis. The low pH value of 1:5 soil : water extract indicate that hydroxyl ions did participate in anion exchange reactions. The dilution of the system decreased exch. Na^+ and Mg^{++} by 17 and 8.1 per cent, respectively. However, Exch. Ca^{++} increased by 12 per cent. In the presence of natur-

TABLE 85. *Effect of irrigation waters on the electrical conductivity of the soils*

Date	Plot No.	ECe before irrigation	Electrical conductivity of soils after irrigation			
			6 Hrs	24 Hrs	36 Hrs	EC of water
			....mmhos/cm at 25°C....			
14-1-1976	A9-10	10.08	14.72	13.18	16.45	1.59
5-3-1976	A6-7	8.19	10.52	13.52	11.01	1.82

TABLE 86. *Ionic composition (me/100 g) of the soil solutions in saturation paste in 1 : 5 soil : water extracts and on soil complex under these moisture regimes*

Treatment	Ca^+ (in soil solution)	Mg^{++}	K^+	Na^+	HCO_3^+	Cl^-	SO_4^-	Cations + Anions	ECe (mmhos/cm)	Ca^{++} (on exchanger)	Mg^{++}	K^+	Na^+	X_{Na}	pH
Sat. Extracts*	0.70	1.94	0.05	3.37	0.02	3.50	1.84	11.43	8.96	5.24	9.87	0.99	5.69	—	7.31
1 : 5, Soil : Water extracts*	1.07	3.90	0.15	5.40	0.66	4.73	5.83	20.73	2.16	7.87	8.11	1.01	1.72	0.98	6.90

* Mean value of eight observations

ally occurring gypsum, surface washing of soils by first few showers will improve soil conditions without causing defloculation of soil particles.

AGRONOMY

C.S. 4. Agrenomic management of crops in coastal saline soils

C.S. 4.1. *Nutrient requirement of different crops in coastal saline soils.*

Studies on optimum plant density and nitrogen requirement of high yielding rice varieties (C.R. Biswas)

The study was conducted in two *kharif* and two *rabi* (1974-75 and 1975-76) seasons with Rice, variety Mut-1 (a mutant of IR-8) as test crop. A field trial (Plot size 5m x 3m) with R.B.D. in 4 replications for each treatment was carried out to assess the optimum plant population and nitrogen requirement of high yielding rice variety. Nitrogen (urea) was applied @ 0 (N_0), 50 (N_1), 100 (N_2), 150 (N_3) and 200 (N_4) kg/ha with spacing of 15 cm x 10 cm (S_1), 15 cm x 15 cm (S_2) and 15 cm x 20 cm (S_3) between the hills in both *kharif* and *rabi* seasons. The initial soil (0-15 cm) had ECe value of 6.2 mmhos/cm, pH 7.17 and N 0.056%.

During *rabi* 1975-76 (Table 87), it was found that with the increase in nitrogen dose to 100 kg/ha, there was a significant increase in yield of rice at all spacings. Maximum yield was obtained from minimum spacing (S_1) with 100 kg N/ha (N_2), which was at par with medium spacing (S_2) with 150 kg N/ha (N_3). However, with 200 kg of N/ha (N_4) there was decline in yield at all spacings. There was no significant difference in yield among the spacings. The results were almost similar as in previous years. ECe and pH of the soil varied between 5.0 to 5.9 mmhos/cm and 7.2 to 7.6 respectively during the *rabi* 1975-76.

TABLE 87. *Effect of planting density and amount of nitrogen on the grain yield (t/ha) of rice (rabi 1975-76)*

Nitrogen (kg/ha)	Spacing (cm)			Average yield (t/ha)
	15×10	15×15	15×20	
0	2.85	2.77	2.60	2.74
50	3.42	3.57	3.07	3.35
100	4.30	4.02	3.60	3.91
150	3.00	4.30	4.07	3.99
200	3.35	3.70	3.57	3.54
Average (t/ha)	3.50	3.67	3.38	C.D. at 5%=0.59

C.S. 4.2. *Studies on the evaluation of suitable cropping pattern for coastal saline soils of Sunderban (C.R. Biswas)*

The investigation was continued since *kharif* 1973 to evaluate a suitable cropping pattern for coastal saline soils of Sunderban with rice as the principal crop in *kharif* in all the six combinations viz., rice-fallow-fallow (T_1), rice-cotton-fallow (T_2) rice-wheat-mesta (T_3), rice-rice-*dhaincha* (T_4), rice-sunflower-bhindi (T_5) and rice-rice-rice (T_6) and plot size of 6 m x 6 m. R.B.D., with 4 replications in each, was followed. The initial soil (1973) had the ECe value of 6.0 mmhos/cm and pH value of 7.3 at 0-15 cm depth.

The yields obtained from different crops in different seasons and determination of ECe of the soil revealed that out of six cropping patterns, rice-rice-rice, rice-rice-*dhaincha* and rice-wheat-mesta appear to be promising in this agro-climatic situation. Rice-rice-rice rotation, wherever ample water for irrigation is available, is of greater scope from both grain yield and soil properties point of view. In case of shortfall of irrigation water, rice-wheat-mesta rotation had high economic viability than the others and rice-rice-*dhaincha* is most suited for the grain yield as well as in improving soil characteristics. The ECe was lowered down in the treatments where maximum crops, preferably with irrigation, were taken and it was increasing with the decreasing intensity of cropping. *Dhaincha* was beneficial in lowering down the salinity under such conditions.

C.S., 4.3. *Study on irrigation requirement of wheat for coastal saline soil conditions (C.R. Biswas)*

Based on climatological approach, frequency of irrigations were determined from the cumulative value of PET obtained from the fixed depth of irrigation water to be applied divided by fixed ratio (depths of irrigation were 4, 5 and 6 cm and ratios were 0.88, 0.66 and 0.53). Treatments were fitted in R.B.D. with 3 replications in each with a plot size of 8 m x 2 m. Wheat, var. Sonalika was used as a test crop. A total of 120, 60 and 60 kg of N, P_2O_5 and K_2O per ha. were applied, of which only $\frac{1}{2}$ N was applied in two foliar sprays and all the rest were applied at sowing. ECe and pH of initial soil (0-15 cm) were 4.3 and 6.2 mmhos/cm respectively. Percentage of soil moisture at the time of sowing in 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm was 32.91, 26.79, 26.76, & 27.97 respectively. One spring irrigation was given equally to all the plots just after sowing for proper germination and PET value was recorded after 48 hours of this irrigation.

Maximum yield was obtained by frequent irrigation (PET 4.5 cm) with shallow depth (4 cm) of water (Table 88). There was a regular trend of decrease in yield with the decrease in frequency of irrigation irrespective of depth of water applied. The yield of wheat grain at 0.88 and 0.66 ratios at 5.7 and 6.0 PET was statistically at par with the highest frequency (Ratio 0.88, PET 4.5) of irrigation.

TABLE 88. *Effect of frequency and amount of irrigation on the yield of wheat (rabi 1975-76)*

Treatment	T-1	T-2	T-3	T-4	T-5	T-6	T-7	T-8	T-9
PET (cm)	4.5	5.7	6.0	6.8	7.5	7.5	9.1	9.4	11.3
Ratio (I.W/PET)	0.88	0.88	0.66	0.88	0.53	0.66	0.66	0.53	0.53
Depth of Irrigation (cm)	4	5	4	6	4	5	6	5	6
Yield (t/ha)	2.2	1.8	1.9	1.6	1.5	1.5	0.9	1.1	0.7

C.D. at 1%=.49

PLANT BREEDING

C.S. 2. Evaluation of plant materials and breeding of crop varieties suited to coastal saline conditions

C.S. 2.1. *Rice*

(a) *Evaluation and isolation of plants in different segregating generations (T.S. Sinha and M. Rai)*

IR8 × SR 26B : A part of the F_1 seeds of IR8 x SR 26B were used to have F_2 progenies in *rabi* 1975-76. Out of 609 seedlings raised, 50 plants were selected on the basis of earliness, plant type and grain characteristics. Among the 2 parents raised along with the F_2 progenies, SR26B and some of the progenies did not flower because of their photosensitivity.

The remaining part of the F_1 seeds and 50 selected plant progenies were grown in *kharif* 1976 as F_2 and F_3 populations respectively. Out of the F_2 progenies selections were made. In F_3 progenies, desirable plants were further selected, as segregation was observed. The salinity of the plot in which these populations were raised varied from 6.05 to 9.78 mmhos/cm in 0-15 cm top soil.

Damodar × IR20, Damodar × IR 24, Damodar × IR 2153-43 and Damodar × Ratna : Bulked F_2 seeds obtained in *kharif* 1975 were divided in 2 parts, first half was sown in *rabi* 1975-76 while second half was used in *kharif*, 1976. In *rabi*, 1975-76 seedlings transplanted in each cross were 5888 in Damodar × IR 20, 12696 in Damodar × IR 24, 11190 in Damodar × IR 2153-43 and 4914 in Damodar × Ratna. ECe of the top 0-15 cm soil varied from 9.7 to 11.0 mmhos/cm at the time of transplanting and 11.4 to 14.0 mmhos/cm at flowering.

None of the parents could survive. However, 15 plants of Damodar × Ratna, 9 of Damodar × IR 24, 26 of Damodar × IR 20 and 46 of Damodar × IR2153-43 were harvested. Single plant progenies were raised in *kharif* 1976. Because of considerable segregation in each line further selections were made. The salinity of 0-15 cm soil (ECe) in the plot was 5.22-7.60 mmhos /cm at the time of transplanting and 4.08-5.21 mmhos/cm at the time of harvesting.

The remaining half seed of *kharif*, 1975 was used to raise F_3 progenies in *kharif*, 1976. At transplanting, there were 8470 seedlings in Damodar × IR 2153-43, 77365 in Dmodar × IR 24, 6090 in Damodar × Ratna and 27425 in Damodar × IR 20. Out of this population desirable plants were selected, and seeds kept separately for further sowing in F_4 generation.

IR8 × Basmati (T-3) : Plants selected in F_2 were grouped into tall, medium and dwarf categories. Dwarf F_3 progenies were raised in *rabi*, 1976. The salinity of 0-15 cm top soil increased from 5.4 to 6.3 mmhos/cm at the time of flowering. Due to segregation, desirable plants were selected and their F_4 progenies were raised in *kharif*, 1976. The seeds of tall and medium groups were sown in *kharif*, 1976 as F_2 and out of 36432 plant population, desirables were selected.

b) *Induction of desirable mutations and their effective utilization (T.S. Sinha and M. Rai)*

Single plant progenies of 25 Basmati (T-3) mutants were grown in M_5 generation. Parent and CSR-4 (resistant check) were interpolated. In the experimental plot, ECe of 0-15 cm soil varied from 6.5 to 9.7 mmhos/cm during the crop growth. As segregation in each line was observed, further selections were made.

With a view to induce variability in Pokhali—a salt tolerant rice variety and thereby to isolate better plant types, 4 hours distilled water soaked seeds were treated for 2 hours with 0.1, 0.2, 0.3 and 0.4 moles solution of diethylsulphate. The seeds were then washed in running water for 2 hours and placed in petri dishes under adequate moisture condition. The sprouted seeds were placed in nursery beds and 40 days old seedlings were transplanted. At maturity, seeds were obtained and kept for growing as M_2 generation.

(c) *Screening of rice varieties for their tolerance to salinity (M. Rai and T.S. Sinha)*

A trial comprising of 76 entries including 69 entries of IRSTON

TABLE 89. *Plant mortality, ovule sterility and grain yield potential of certain promising salt tolerant rice varieties*

Variety	Origin	Plant mortality (%)	Ovule sterility (%)	Grain yield/plot (gm)
Damodar	India	0.00	39.61	490.80
IR-36	Philippines	0.00	48.80	349.67
BG-33-2	Sri Lanka	12.50	28.77	215.27
BG-24-8	Sri Lanka	2.78	19.27	279.87
Nona Bokara	India	5.56	16.80	286.17
Pokkali (Resistant Check)	India	4.17	24.35	278.57
IR-4-11	Philippines	0.00	38.93	440.07
IR-841-36-2	Philippines	6.94	22.50	294.03
IR-1154-243	Philippines	2.78	41.41	312.80
IR-2035-290-2-1-1	Philippines	0.00	37.15	316.07
IR-2070-435-4-5-5	Philippines	0.00	13.68	402.80
IR-2070-719-3-5	Philippines	—	43.58	222.03
B-58b-Mr-105-2	Indonesia	1.39	36.98	403.37
Mut-2	India	12.50	21.68	182.80
Nonasail	India	0.00	34 03	105.70
RP-6-516-34-1-8	India	0.00	35.04	347.53
Tongil	Africa	0.00	28.64	256.73
Yushin	Africa	0.00	26.93	165.03
R-110-2578	India	0.00	51.21	299.00
M-1-48 (Susceptible Check)	Philippines	48.60	76.93	51.33

1976 was conducted in a Variability Grid Randomised Block Design with 3 replications. The lay out was such that susceptible variety M_1—48 and resistant variety Pokkali could grow as checks along with each entry. At the juncture of susceptible and resistant checks, one plant of Jaya was grown as standard variety.

For quantitative assessment, data were recorded on 5 randomly selected plants of each entry in each replication. ECe (0-15 cm) of top soil was determined at transplanting, 30 days after transplanting and at the time of harvesting for each entry. Apart from the visual scoring based on salinity symptoms such as burning and rolling of leaves, stunted growth etc., plant mortality, ovule sterility and yield potential of the varieties were taken as important criteria in judging the salt tolerance of a variety under study. In the plot in which experiment was conducted, ECe (0-15 cm) varied from 8.25—18.43 mmhos/cm at the time of transplanting,5.82—17.46 mmhos/cm 30 days after transplanting and 9.95—15.17 mmhos/cm at the time of harvesting.

Depending on visual observations and quantitative assessment, 19 promising varieties were selected. The data on these varieties and also on resistant and susceptible checks are presented in Table 89. Variety IR-2070-435-4-5-5 was found to be best. However, other varieties such as Damodar, IR-36, IR-4-11, Nona Bokara, IR-2035-290-2-1-1, RP-6-516-34-1-8, Nonasail, Tongil, B 58b-Mr-105-2 etc. were in merit in one or more traits.

(d) *Screening rice varieties for different standing water depths* (*T. S. Sinha and M. Rai*)

Thirty five days old seedlings of twenty one rice cultures suited to different water depths were transplanted on 8th August, 1976 in a split plot design with two replications. Four water depths, 10 cm, 25 cm, 50 cm and 75 cm with ± 1.0 cm were maintained from 16th day onwards after transplanting till the 1st week of November, 1976. The water depths were in the main plot while varieties were grown as sub plots in each main plot. Each sub-plot was represented by a single line comprising of 18 plants grown 15 cm apart. At harvesting, 5 plants from each variety in each replication were selected randomly. Data on plant height, number of internodes, internode length, panicle bearing tillers, survival percentage and grain yield per plant were recorded.

Under 75 cm water depth, highest survival was observed in BKN-6986-71 (80.4%) followed by Lob Mue Phang (65.5%). In 50 cm depth, Bowra was the best (100%) followed by Mut-15 (97.2%) and BKN-6887-105-4 (96.7%). Grain yield/plant in almost all the varieties exhibited a decreasing trend with an increase in water depth. Among the varieties studied, Malabati in both 75 cm (4.9 gm) and 50 cm (6.9 gm) was the best. However, its plant survival value was low (43.8% and 75.5%, respectively). In 50 cm standing water depth, Bowra (5.66 gm) and SR 26 B (4.6 gm) were better than others. Taking both, plant survival and grain yield/plant into account, Bowra may safely be recommended for commercial cultivation in those areas where standing water depth is about 50 cm.

C.S. 2.2. *Barley*

(a) *Initial evaluation trial* (*M. Rai and T. S. Sinha*)

To screen out certain promising lines, seeds of 308 indigenous and exotic varieties or strains (203 varieties supplied by AICBP) were sown in the field on 3rd and 4th December 1975, in small plots of size 3 m x 0.91 m. Each entry was sown in 4 rows laid at 23 cm apart. N, P and K were applied @ 40, 20 and 20 kg/ha. respectively. The crop received two irrigations and 8.6 cm precipitation.

Salinity status (ECe) of the top 15 cm soil varied from 3.83 to 6.54 mmhos/cm at the time of sowing and 5.67 to 18.75 mmhos/cm at the time of harvesting. During the crop growth, 79 promising lines were marked and data were recorded on these lines. Because of variability in the salinity status of the soil, varieties were placed in 4 different clusters based on different salinity levels.

In cluster-I (ECe $<$ 11.0 mmhos/cm), RD-167, RD-137, DL-223, P-259, BG-105, P-103, IW-112/B-6 and MUZ-6; in cluster-II (ECe 11.0-14.0 mmhos/cm), RS-17, DL-3, BH-28, Amber and Majhera Local; in cluster-III (ECe 14.0-17.0 mmhos/cm), K-251, K-140, DL-48, BH-25, DL-187 and BG-118 and in cluster-IV (ECe$>$ 17.0 mmhos/cm) RD-217, BH-21 and HBS-31 appeared to be better than others studied, when ovule sterility, plant stand per unit area and yield potential were taken into account. However, the performance of these lines could have been better if there has been no mortality following each irrigation and rain. The yellowing and drying-up of seedlings following each irrigation and rain was a common phenomenon in all the varieties studied. In certain varieties, the plant mortality was cent per cent.

(b) *Confirmatory varietal trial* (*T. S. Sinha and M. Rai*)

In an initial evaluation trial conducted with 203 varieties, eleven varieties of barley namely, DL-100, DL-120, DL-155, DL-164, DL-196, BH-6, BH-10, BH-11, BH-12, Ratna and Jyoti were found to be better in 1974-75. Therefore, a confirmatory trial on these varieties was conducted in 2.80 x 1.15 m plots in 1975-76 in a Randomised Block Design with 3 replications. Each plot consisted of 5 rows, at 23 cm apart. The plots were fertilized with N, P and K @ 40, 20 and 20 kg/ha respectively. One light surface irrigation was given besides 8.6 cm precipitation during the crop growth. ECe of top 15 cm soil varied from 6.3 to 10.3 mmhos/cm at the time of sowing and from 7.3 to 25.5 at the time of harvest.

The mean yield of varieties over all the blocks was compared over average salinity of the plots located in all the 3 blocks. In the first group (ECe 11.0-15.0 mmhos/cm), BH-11 (0.37 t/ha), Jyoti (0.34 t/ha), BH-6 (0.36 t/ha) varieties were better. In the second group (ECe 15.0-19.0 mmhos/cm), DL-120 (0.57 t/ha), Ratna (0.24 t/ha) and BH-12 (0.24 t/ha) were in the order of merit. In the third group (ECe 19.7 mmhos/cm), DL-164 was the only variety grown and yielded 0.05 t/ha. Overall, DL-120 appeared better than other varieties, However, yellowing and drying up of the seedling following each irrigation and rain and thereby reducing the plant population per unit area was the main cause of poor yield.

(c) *Induction and utilization of genetic variability* (*M. Rai and T. S. Sinha*)

Barley variety Jyoti is among a few tolerant varieties and possesses a good yield potential. Therefore, it was of interest to induce genetic variability in the variety and to utilize the same for an improvement in salt tolerance as well as in yield of the crop. With this view, 5, 10 and 15 kR gamma irradiated and 10, 15 and 20 kR X-irradiated barley variety Jyoti seeds were sown along with the unirradiated check in 1975-76. At harvest, bulk seeds of each treatment were kept for growing M_2 generation. M_2 progenies are being raised and promising mutants will be selected for further testing.

C.S. 2.3. *Linseed*

(a) *Initial evaluation trial* (*M. Rai and T. S. Sinha*)

An initial evaluation trial with 735 indigenous and exotic lines was conducted in the field. The seeds of these cultures were collected from different educational and research organizations in the country. Sowing was done without replication during 11th to 15th Dec., 1975. Each entry was represented by two, 3.0 m long rows displayed 0.3 m apart. The N, P and K were applied @ 50, 30 and 30 kg/ha, respectively. One light surface irrigation was given. However, there was 8.6 cm rain too.

TABLE 90. *Selected salt tolerant linseed varieties on the basis of ovule sterility, plant mortality and grain yield*

Parameter	Cluster I ECe <8.0 mmhos/cm	Cluster II ECe 8.0-11.0 mmhos/cm	Cluster III ECe 11.0-14.0 mmhos/cm	Cluster IV ECe 14.0-17.0 mmhos/cm	Cluster V ECe > 17.0 mmhos/cm
Ovule sterility (%)	EC 534 (8.3)	Flax dwarf (5.3)	NP 98 (27.0)	NP 23 (24.5)	Bengal 20 (22.5)
	EC 22685 (8.3)	EC 1453 (7.1)	NP 53 (44.5)	NP 50 (28.0)	NP 48 (37.0)
		NP34 (11.1)			
Plant mortality (%)	NP 73 (0.0)	NP (RR) 448 (20.0)	EC 61671 (60.0)	BR 26 (55.1)	NP 59 (60.3)
	LC 185 (1.9)	EC 1453 (26.9)	NP 71 (64.0)	NP 23 (69.6)	5/19 (66.6)
	LC 268 (10.2)				
Grain yield/plot (g)	LC 216 (40.6)	219-1 (30.5)	NP 21 (16.5)	NP 65 (19.6)	NP 43 (11.8)
	LC 268 (36.4)	219-2 (35.5)	NP 71 (16.4)	NP 109 (17.5)	NP 48 (8.2)
		NP 68 (30.5)			

ECe of the 15 cm top soil was from 4.08 to 9.88 mmhos/cm at the time of sowing, 5.35 to 15.65 mmhos/cm 45 days after sowing and 5.38 to 22.36 mmhos/cm at the time of harvest.

Out of 735 cultures, 111 could survive till maturity and could yield. Among those survived, considerable variability from 5.3 to 87.5% in ovule sterility and zero to 97.5% in plant mortality was recorded. The range in grain yield was 1.2 to 40.6 g/plot. Because of wide variability in salinity, the varieties were placed in five different clusters. The promising varieties in one or more traits are listed in Table 90.

PLANT PHYSIOLOGY

C.S. 3. Physiological criteria of salt tolerance of rice and barley under coastal saline conditions

C.S. 3.1. *Barley*

Physiology of salt tolerance in barley varieties (K.S. Gill and S.K. Dutt)

An experiment with five barley varieties (Amber, Vijay, RD-31, DL-3 and Ratna) under ECe levels of 2.2,5.4, 8.4 and 12.3 mmhos/cm was conducted. Sowing was done on 27.12.75 in earthen pots lined with polythene sheet each containing 5 kg soil. Plants were thinned to six per pot one month after sowing and harvested in the first week of April, 1976. The varieties Amber, Ratna and Vijay gave higher percentage of germination than others. The variety Vijay gave highest yield and RD-31 lowest yield at ECe 12.3 mmhos/cm. The slope of the regression line was lowest for Vijay and highest for RD-31, indicating higher salt tolerance in Vijay and lower in RD-31 (Table 91).

TABLE. 91. *Effect of different salinity levels on yield in barley varieties*

Varieties	Total yield (g/pot) ECe levels (mmhos/cm) 2.2.	5.4	8.4	12.3	Slope of regression line
Amber	11.16	11.04	9.76	7.68	y=—.50x+13.53
Vijay	10.95	12.12	10.01	8.17	y=—.43x+13.64
RD-31	11.19	11.08	9.04	5.32	y=—.81x+15.53
DL-3	10.43	8.79	7.07	6.63	y=—.49x+12.02
Ratna	12.31	10.12	7.94	6.63	y=—.73x+14.80

C.D. at 5% Var.=0.661, Sal.=0.540, V x S=1.325

Chemical Parameters

Tillering stage : Vijay showed better plant height than others. Na content in shoot portion increased with increase in ECe in all the varieties, but k content decreased slightly. Ca increased over control in varieties Vijay and DL-3, and decreased in Amber and Ratna, whereas it was constant in RD-31. Mg content increased in Vijay, Amber, RD-31 and Ratna but decreased in DL-3.

Grain Composition

Carbohydrate percentage: It remained fairly constant in relatively tolerant varieties like Vijay and Amber at ECe 12.3 mmhos/cm as compared to control and also increased in less tolerant Ratna but decreased in lower yielding varieties like DL-3 and RD-31 which might have utilized their carbohydrate in adjusting to salt stress (Table 92).

TABLE 92. *Effect of soil salinity on carbohydrate content in barley varieties*

Varieties	Carbohydrate (%) in grains			
	ECe levels (mmhos/cm)			
	2.2	5.4	8.4	12.3
Amber	71.8	72.2	70.3	72.2
Vijay	73.9	75.2	73.2	74.9
RD-31	74.3	75.5	72.7	70.6
DL-3	66.8	61.5	61.5	61.4
Ratna	77.1	79.3	79.3	79.3

Ionic Composition : Na was constant in Vijay and RD-31, increased in DL-3 and Ratna and decreased in Amber with rise in ECe. A similar trend was also observed for K in all varieties. Ca and Mg did not show any definite trend (Table 93). The Na/K ratio decreased in tolerant varieties, Vijay, Amber and RD-31 and increased in DL-3 and Ratna but the magnitude of decrease was less in Vijay and Amber than others.

Total uptake : The total Na uptake in grain per pot decreased with increase in ECe in varieties Vijay, Amber, RD-31 and Ratna and increased in DL-3. K-uptake remained constant in Vijay and decreased in Amber, DL-3 and Ratna. Mg-uptake decreased in all varieties, but magnitude of decrease was less in Vijay and Amber than others.

TABLE 93. *Effect of Soil Salinity on ionic uptake in grains of barley varieties*

Varieties	ECe	Na	K	Ca	Mg
		(me/g dry weight)			
Amber	2.2	.017	.22	0.98	2.22
	5.4	.021	.21	0.94	2.93
	8.4	.014	.19	0.92	2.58
	12.3	.013	.19	0.76	2.67
Vijay	2.2	.012	.15	1.07	2.50
	5.4	.012	.13	1.09	2.76
	8.4	.012	.16	0.85	2.50
	12.3	.012	.16	1.44	2.49
RD-31	2.2	.010	.13	1.10	2.60
	5.4	.011	.15	0.95	2.69
	8.4	.013	.27	1.11	2.59
	12.3	.013	.29	0.94	2.61
DL-3	2.2	.014	.30	1.26	2.66
	5.4	.015	.33	1.04	3.28
	8.4	.018	.33	0.99	1.83
	12.3	.024	.34	1.21	1.59
Ratna	2.2	.016	.26	1.26	1.80
	5.4	.028	.28	1.16	1.78
	8.4	.022	.28	1.16	2.20
	12.3	.026	.28	1.36	1.58

C.S. 3.2. *Rice*

(a) *Response of rice varieties to salt stress at germination stage (K.S. Gill and S.K. Dutt)*

An experiment in petri dishes under laboratory conditions was conducted with 26 varieties of rice. EC levels of 1.08, 10.17 and 17.6 were obtained by making required dilutions of sea water. Rice varieties behaved differently under salt stress and based on their response curve, varieties were divided into five different groups and their idealised curves drawn (Fig. 30). In the first group, varieties suffer only little reduction in germination. In the second group, there is an increase upto EC 10.17 and then decreased. In the third group, varieties do not suffer reduction upto EC 10.17 and then decrease. In the fourth group, varieties suffer linear reduction in response to salinity. In the fifth group, a very gradual reduction occurred upto EC 10.17 which was followed by a sharp decrease at EC 17.6. Generally, the varieties are divided into different groups according to salt tolerance based on critical difference values which take into consideration only one level of EC. Thus, the C.D. values do not give precise idea about the entire response spectrum of a particular variety under different levels (Table 94). In the present study, evaluation of the

TABLE 94. *Comparison of varieties for salt tolerance according to critical differences and response curves*

Groups according to C.D. values salinity levels (mmhos/cm)						Groups according to response curve hased on slope of regresion	
(1.08)		(10.17)		(17.64)			
Variety	Group	Variety	Group	Variety	Group		
IR-8		Damodar		IR-8		IRS-47	
Jaya		IR-8		Jaya		IR-8	
IR-8-68		Jaya		IR-8-68		Jaya	A
P-2-21		IR-8-68		P-2-21	A	Dasal	
Mut-2		P-2-21		Mutant-2		Getu	
Dasal		Mutant-2	A	Dasal			
Getu		Dasal		Getu			
IRS-32	A	Getu		IRS-47		Damodar	
IRS-36		IRS-35				IR-8-68	
IRS-38		IRS-37				P-2-21	
IRS-39		IRS-38		Damodar		Mutant-2	
IRS-47		IRS-39		IRS-36		IRS-33	B
IRS-49		IRS-46		IRS-37		IRS-37	
C-5		IRS-47		IRS-38	B	IRS-46	
C-8		IRS-49		IRS-39		C-2	
		C-2		IRS-46		IRS-11	
		C-5		C-2		Pokali	
Mutant-II		C-8		C-5			
Damodar		IRC-11		C-8			
IRS-33				IRC-11		IRS-39	
IRS-37						IRS-49	C
IRS-46	B	Mutant-I				C-5	
IRS-48		IRS-33		IRS-48			
IRS-51		IRS-36	B	IRS-49	C	IRS-36	
C-2		IRS-48		Pokali		IRS-38	
IRON-353		Pokali				IRS-48	D
IRC-11						IRS-51	
		IRS-51		Mutant-I		C-8	
Pokali	C	IRON-353	C	IRS-32		IRON-353	
				IRS-33	D		
				IRS-51		Mutant-I	
				IRON-353		IRS-32	E

crop varieties for their tolerance to salt, based on the slope of regression line, has been observed to be a better criterion as it takes into consideration the entire spectrum of response at varying levels. The slope of the regression line was inversely related to the germination%.

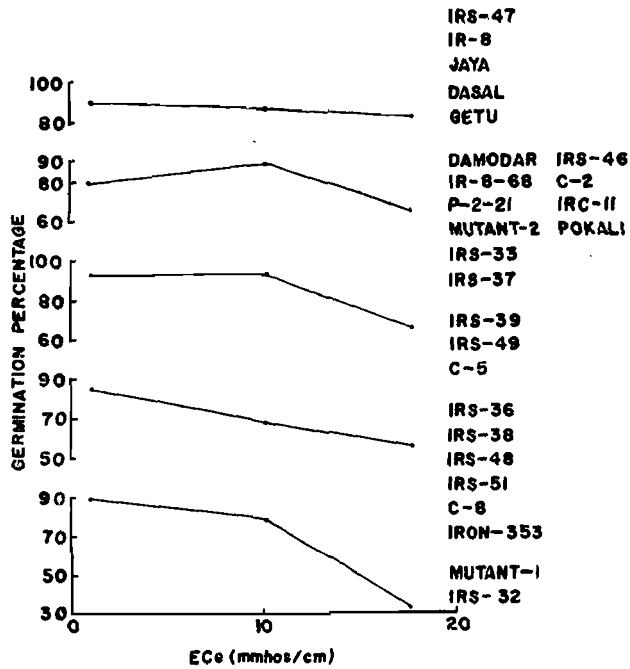


Fig. 30. Response of rice varieties to varying levels of salinity at germination

(b) *Effect of soil salinity on leaf water potential of rice varieties (S.K. Dutt and K.S. Gill)*

A pot experiment was conducted in *kharif* 1976 with seven varieties of rice to test their tolerance in relation to their leaf water potential at tillering and flowering stages under varying levels of salt stress (ECe 2, 6, 10 and 14 mmhos/cm) created by adding required amount of different dillution of river water having EC 29.14 mmhos/cm).

Leaf water potential (L.W.P.) increased with increase in salinity both at tillering and flowering stages (Table 95). L.W P. also increased with increase in the age of the plant both under normal as well as under saline conditions in all the varieties except Mutant-I in which it decreased at 6 and 10 ECe but increased slightly when ECe was 14.

TABLE 95. *Effect of a salinity on leaf water potential of rice varieties at different stages of growth*

Varieties	Leaf water potential (bars)							
	Tillering Stage ECe(mmhos/cm)				Flowering stage ECe mmhos/cm			
	2	6	10	14	2	6	10	14
Jaya	1.00	1.25	1.90	2.25	2.00	2.25	2.25	2.75
Mutant-I	1.00	2.25	2.40	2.40	1.75	2.00	2.20	2.75
Damodar	1.20	1.50	2.00	2.00	2.00	2.20	2.80	3.00
Nonasoil	1.25	1.75	1.75	1.75	2.00	2.30	2.60	2.75
IRSTON-32	1.20	1.75	2.50	2.50	1.50	2.50	3.00	3.50
IRSTON-36	1.00	1.50	2.50	3.00	1.75	2.20	2.80	3.00
IRSTON-39	1.30	1.50	1.50	2.00	1.50	2.00	2.75	3.20

(c) *Physiological basis of salt tolerance in wild rice (Oryza coarctata) (K.S. Gill and S.K. Dutt)*

A pot experiment was conducted in 5 kg earthen pots lined with polythene bags, with one variety of cultivated rice (Jaya) and the wild rice (*Oryza coarctata*) to know the physiological basis of salt tolerance in wild rice. Two levels of ECe i.e. 2.5 and 14 were maintained for comparison of morphological and physiological characteristics. Root stocks of wild rice were taken from river bed and regenerated for root growth for seven days in Hoagland solution. Transplanting was done in first week of August, 1976 alongwith one month old Jaya seedlings. The following morphological and physiological observations were recorded at late tillering, booting and grain filling stages.

Morphological characters

The plant height, dry weight of leaf and stem increased under salinity over control in wild rice but decreased in Jaya (Table 96). It was noticed that wild rice develops underground stem which enables it to have 80-85 per cent extra moisture in comparison with Jaya, which might be of great help for plant survival and also for maintaining the progeny under adverse conditions.

Chlorophyll : In both the varieties the chlorophyll increased under salinity over control whereas with age there was decrease in chlorophyll, the trend was reverse incase of wild rice.

Proteins : It increased with age in both the varieties but under salinity there was decrease in Jaya and increase in wild rice.

Leaf water potential : In both the crops there was increase in leaf water potential under salinity stress and age. Leaf water potential is more in Jaya under salinity than in wild rice upto boot leaf stage. Beyond this stage, water potential increased rapidly both in wild rice and Jaya under both saline and non-saline conditions, but it was more pronounced in wild rice.

TABLE 96. *Effect of salinity on growth and physiological characteristics in Jaya and wild rice*

Stages	Plant ht. (cm)	Leaf dry wt. (g)/ plant	Stem dry wt. (g)/ plant	Leaf water potential (bars)	Chlorophyll O.D. at 660 mu	Proteins (mg/g)
			Jaya			
I Non-saline	74.6	4.12	2.54	1.80	0.87	24.0
Saline	62.3	2.33	1.61	2.50	1.02	24.0
II Non-saline	79.7	6.41	4.84	1.75	0.95	30.0
Saline	63.7	3.37	3.38	2.75	0.92	24.0
III Non-saline	79.5	8.08	3.68	2.75	0.69	30.0
Saline	64.5	4.46	2.93	3.25	0.83	30.0
			Wild rice			
I Non-saline	45.8	0.54	0.27	1.50	0.56	19.5
Saline	64.5	1.09	0.37	1.80	0.56	24.0
II Non-saline	49.5	1.20	0.94	1.25	0.93	22.0
Saline	63.0	1.46	1.33	2.00	1.05	24.0
III Non-saline	49.0	1.71	1.73	3.25	0.68	24.0
Saline	65.0	3.41	3.73	3.75	0.77	30.0

N.B. I=Late tillering, II=Booting stage, III=Grain filling stage

Stomatal response : Preliminary observations show that stomatal frequency is much greater in wild rice than Jaya (Table 97) with much larger stomata in Jaya than in wild rice.

TABLE 97. *Effect of soil salinity on stomatal distribution size and stomatal behaviour in Jaya and wild rice*

	Stomatal	Stomatal size		Stomatal pore size	
	frequency Number/mm^2	Length X Width)u) 7 A.M.	2. P.M.	Length X Width (u) 7 A.M.	2 P.M.
		Jaya			
Non-saline	8.03	44.5×33.0	58.0×32.6	40.6×26.7	39.9×21.8
Saline	7.49	52.3×31.3	34.3×25.1	37.3×16.2	27.4×18.1
		Wild rice			
Non-saline	58.9	30.0×18.5	33.3×19.1	19.1×3.9	17.5×1.9
saline	35.3	33.3×19.1	37.6×18.5	18.2×1.8	20.8×1.6

DRAINAGE

C.S. 5. Drainage studies in coastal saline soils

C.S. 5.1. *Efficiency of rain water drainage by the existing system in the Sunderbans and its posssible improvement (K.V.G.K. Rao)*

To investigate the efficiency of sluice gates in the protective bunds for the drainage of rain water in creating desired conditions at the farm level, the commanding area of one sluice gate was selected. The sluice gate consists of a 90 cm dia hume pipe with a gate shutter on the country side and a flap gate on the river side to prevent the entry of salt water inland during high tides, and is designed to provide drainage for 250 he of land. Rainfed rice is the only crop under cultivation during rainy season. Within the command area two plots of 5.8 ha. and 7.7 ha were selected with the objective of investigating the efficiency of drainage system in terms of the depth of standing water in the fields and time required to bring down this depth to the desired level after a heavy rainfall. The above two plots were selected from two different locations, one 0.5 K.M. away and the other 2 K.M. away from the sluice gate.

During the period of operation of sluice gate there is time lag in the fall of depth of standing water in the distant plot. The water level has continued to rise for another day in the distant plot after opening the sluice gate and then started receding. After this period, the sluice gate has been operated just before the harvest and so the dynamic conditions of drainage of the commanding area could not be studied further. The depth of standing water in both the plots is much more than the desired level of standing water of about 10 cm, especially in the distant plot where the depth of standing water was more than 25 cm for three quarters of crop period. The drainage coefficient of the sluice gate came out to be 2.3 cm per day which was much more than the design value of 1.8 cm per day. Eventhough the sluice gate was having sufficient capacity to carry the excess rainfall, it was closed before the desired drainage took place, for storing water in the fields to meet the water requirement of the subsequent probable dry period. This storage caused severe inundation ranging from 40 to 60 cm even after a moderate rain of 16.82 cm in the previous two days of 29th July, 1976. This points out that planning is required in the operation of sluice gate such as continuous opening during the pre and post transplanting of rice and its closure in the last fortnight of monsoon season to store water to meet the water requirements of the subsequent period. The data of the standing water show that the daily water requirement of crop from 15th September to the harvest is about 0.6 cm/day with negligible amounts of percolation loss as the daily pan evaporation rate is about 0.4 cm/day. The EC value of standing water in the fields just before the harvesting is 1.5 mmhos/cm. The salinity status of soil in the middle of September is also very low, the ECe values lying between 0.5 and 2.0 mmhos/cm. An effective drainage with channelisation and peripheral bunding of the fields in the months of July, August and early part of September and a storage of about 30 cm of water in the fields from middle of September is the necessary planning for this area. However a statistical analysis of the rainfall for fixing the above time schedules and for determining the drainage coefficient in the critical periods is to be taken up.

There was no set frequency of drainage cycle through the sluice gates. Because of no proper peripheral bunding to the rice fields, the standing water in the fields was maintained by keeping the sluice gate closed. When the depth of ponding water rose alarmingly, the sluice gate was opened until the level fell down somewhat. During this study, it was opened only once on 29.8.76 after a rainfall of 168.2 mm in the previous two days, the water level in the fields rose to 40 cm and in some pockets even upto 60 cm. It was closed again on 8.9.76 when the level had fallen to 25 cm and opened again on 15.11.76 just before the harvest of rice.

PUBLICATIONS

A. Research Papers

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2. Acharya, C.L. and Abrol, I.P. 1976. Effect of river sand on the permeability of a sodic soil. *J. Ind. Soc. Soil Sci.* **24** : 245-152.
3. Bal, A.R. 1976. Salinity tolerance through seed treatment with proline. *Biologia Plantanum* **18** : 227-29.
4. Bhargava, G.P., Abrol, I.P. and Bhumbla, D.R. 1976. On the nomenclature of some salt affected soils in the Indo-gangetic plains. *J. Ind. Soc. Soil Sci.* **24** : 81-83.
5. Bhattacharya, R.K. 1976. Promising rice selections suited to coastal saline soils. *J. Soc. Expt. Agric.* **1** : 21-24.
6. Bhattacharya, R.K. 1976. New salt tolerant rice varieties for coastal saline soils of Sunderban (West Bengal). *Sci. & Cult.* **42** : 122-23.
7. Dargan, K.S., Gaul, B.L. and Abrol, I.P. 1976. Effect of gypsum, farmyard manure and method of sowing on the yield of sugarcane in a sodic soil. *Ind. J. Agron.* **21** : 349-53.
8. Dargan, K.S., Gaul, B.L., Abrol, I.P. and Bhumbla, D.R. 1976. Effect of gypsum, farmyard manure and zinc on the yield of berseem, paddy and maize in a highly sodic soil. *Indian J. Agric. Sci.* **46** : 535-41.
9. Dutt, S.K. 1976. Leaf water potential and wheat and barley and its relation to soil salinity and alkalinity. *Biologia Plantanum* **18** : 299.
10. Gaul, B.L., Abrol, I.P. and Dargan, K.S. 1976. Note on the irrigation needs of *Sesbania aculeata poir* for green manuring during summer. *Indian J. Agric. Sci.* **46** : 434-36.
11. Girdhar, I.K., Yadav, J.S.P. and Rajput, R.K. 1976. Irrigation requirement of maize under fluctuating high water table conditions. *Indian J. Agric. Sci.* **45** : 38-43.
12. Joshi, Y.C. 1976. Relative tolerance of wheat varieties to alkalinity. *Indian J. Pl. Physiol.* **19** : 190-193
13. Khosla, B.K. (1976) Infiltration and water distribution in a sodic soil as affected by rice husk incorporation. *J. Indian Soc. Soil Sci.* **24** : 436-38.
14. Mondal, R.C. 1976. Effect of farmyard manure on the solubility of

calcium sulphate under alkaline condition. *J. Indian Soc. Soil Sci.* **24** : 91-92.

15. Sen, H.S., Bandyopadhya, A.K. and Roy, P.C. 1976. Relative movement of water and salts in surface layers of soil under varying soil water regime. *Agrokimia ES Talajtan* **24** : 365-70.
16. Shaima, B.M. and Yadav, J.S.P. 1976. Availability of phosphorus to gram as influenced by phosphate fertilization and irrigation regime. *Indian J. Agric. Sci.* **46** : 205-10.
17. Sharma, B.M., Rajput, R.K. and Yadav, J.S.P. 1976. Studies on the phasic water needs of sugarcane. *J. Indian Soc. Farm Sci.* **3**: 69-74.
18. Tyagi, N.K. 1976. An empirical approach to design of check irrigation. *J. of the Central Board of Irrigation and Power* **33** : 85-89.
19. Yadav, J.S.P. and Sharma, B.M. 1976. Soil changes in differently treated planting pits under *Eucalyptus hybrid* in a saline sodic soil. *Agrokemia Es Talajtan* **25** : 327-39.
20. Yadav, J.S.P. and Singh K. 1976. Effect of forest plantations on water stable aggregates of soil. *J. Indian Soc. Soil Sci.* **24** : 363-68.

B. Technical Papers

1. Abrol, I.P. 1976. Gypsum as an amendment for alkali soils. *Alok.* Aug.-Sept. : 8-10.
2. Bandyopadhya, A.K. and Sen, H.S. 1976. Winter crops in saturated soils of Sunderbans. *Indian Fmg.* **26(3)** : 15-17.
3. Dhruva Narayana, V.V. and Pandey, R.N. 1976. In alkali soils store excess rain water. *Indian Fmg.* **26(2)** : 3-6.
4. Mehta, K.K. and Abrol, I.P. 1976. Pyrites for reclamation of alkali soils. *Indian Fmg.* **26(1)** : 20-21.
5. Yadav, J.S.P. 1976. saline, alkaline and acid soils in India and their management. *Fertilizer News.* **21** : 15-23.
6. Yadav, J.S.P. 1976. Diagnosis of saline & sodic soils. *Souvenir 41st Annual Convention. Indian Sci. Cong.* : 77-86.

C. Reports

1. Rana, R.S. 1976. Report on recent developments in rice research; Visit to Philippines during April, 1976.
2. Rana, R.S. 1976. Report on rice breeding for problem soils—All India Rice Research Workers Conf., AICRIP, Hyderabad.
3. Rana, R.S. 1976. Report on evaluation of rice genotypes for tolerance to Salinity/Alkalinity—Visit to Thailand and Pakistan during October, 1976.

4. Sharma, R.C., Abrol, I.P. and Bhumbla, D.R. 1976. Report on Quality of ground waters in Karnal District, Haryana. No. 3, Division of Soils & Agronomy.
5. Sharma, R.C. Singh, H.B. and Singh, Y.P. 1976. Report on soil survey of parts of Coorg, Mysore and Hassan district, Karnataka, Soil Survey Division, Indian Photo-Interpretation Institute, Dehradun (U.P.)

D. All India Radio & T. V. Talks

1. Abrol, I.P. *Reh Kallar Bhoomi Ka Sudhar Kaise Karen* A.I.R. talk (18th Feb.)
2. Abrol. I.P. *Khad Ka Sahi Estemal—Mitti Ki Janch* A.I.R. talk (30th April)
3. Abrol, I.P. *Banjar Va Kallar Bhoomi Sudhar Sambandhi Suvidhain* A.I.R. talk (25th November)
4. Yadav, J.S.P. Reclamation and Utilization of Salt affected Soils, T.V. talk (9th Feb.)

E. Participation in Seminars & Symposia

1. Abrol, I.P. Presented a lead paper on N management in alkali soils at a symposium on Nitrogen Assimilation and Crop Productivity held at H.A.U. Hissar from October 5-7.
2. Dhruva Narayana, V.V. Attended National Symposium on hydrologic problems held at I.I.T., Kanpur during September 27-29, and also presented a paper on Application of simulation techniques for the analysis of run off characteristics from alkali soils catchment under reclamation at All India Symposium on Agricultural Systems Theory and Application held at P.A.U. Ludhiana from December 6-7.
3. Gupta, S.K. Attended All India Symposium on Agricultural Systems Theory and Application, held at P.A.U. Ludhiana during December 6-7.
4. Pandey, R.N. Attended All India Symposium on Agricultural Systems Theory and Application, held at P.A.U. Ludhiana during December 6-7.
5. Parshad, R. Presented a paper on Information needs of small/marginal farmers in a National Seminar on New Agricultural Technology and Extension Strategy for Small & Marginal Farmers, held at P.A.U. Ludhiana from July 13-17.
6. Singh, O.P. Attended National Symposium on Hydrologic Problems held at I.I.T., Kanpur during Sept 27-29 and also attended All India

Symposium on Agricultural Systems Theory and Application, held at P.A.U. Ludhiana during December 6-7.

7. Singh, P. Attended 36th Annual Conference of Indian Society of Agricultural Economics, held at Surat from November 17-19.
8. Tiwari, A.K. Attended All India Symposium on Agricultural Systems Theory and Application held at P.A.U., Ludhiana during December 6-7.
9. Yadav, J.S.P. Presented a paper in All India Science Congress Association Meeting, held at Waltair from January 3-7.
10. Yadav, J.S.P. Attended workshop on Nutritional Evaluation of Forages held at National Dairy Research Institute, Karnal on Feb. 3.

APPENDIX—I

LIST OF STAFF

Director

1. J.S.P. Yadav, M.Sc. (Ag.), Ph.D., Dip. For. (Oxon), F.N.A.Sc.

Main Institute, Karnal

Division of Soils and Agronomy

2.	I.P. Abrol, Assoc, I.A.R.I., Ph.D.	Head of Division (S-3) Soil Science
3.	K.S. Dargan, M.Sc. (Ag.); D.Phil.	S-3 (Agronomy)
4.	R.C. Mondal, M.Sc. Ph.D.	S-2 SoilScience (Soil Chemistry)
5.	G.P. Bhargava, M.Sc. (Ag.); Ph.D.	S-2 Soil Science (Soil Survey)
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8.	I.C. Gupta, M.Sc., Ph.D.	S-1 Soil Science (Soil Chemistry)
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12.	Gurkirpal Singh, M.Sc. (Ag.)	S-1 (Agronomy)
13.	S. Venkatakrishnan, M.Sc. (Ag.)	S-1 (Microbiology)
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15.	H.C. Nitant, M.Sc. (Ag.)	S, Soil Science (Soil Chemistry), On study abroad
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19.	R.K. Chhillar, M.Sc. (Ag.)	S (Agronomy)
20.	Ashok Kumar, M.Sc. (Ag.)	S (Agronomy)
21.	S.B. Singh, M.Sc. (Ag.), Ph.D.	S, Soil Science (Soil Chemistry)
22.	K.L. Chawla, M.Sc. (Ag.)	S, Soil Science (Soil Physics)
23.	S.S. Sandhu, M.Sc. (Ag.)	S, Soil Science (Soil Physics)
24.	Lalita Batra, M.Sc. (Hons.)	S (Soil Microbiology)

25.	S.K. Sharma, M.A.	S (Cartography)

Division of Genetics & Plant Physiology

26.	R.S. Rana, Assoc. I.A.R.I., Ph.D.	Head of Division (S-3) Genetics & Cytogenetics
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28.	R.K. Bhattacharya, M.Sc., Assoc. I.A.R.I.	S-2 (Plant Breeding)
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30.	Y.C. Joshi, M.Sc. (Ag.)	S (Plant Physiology)
31.	K.N. Singh, M.Sc. (Ag.)	S (Plant Breeding)
32.	Ali Qadar, M.Sc. (Ag.)	S (Plant Physiology)
33.	B. Mishra, M.Sc. (Ag.)	S (Plant Breeding)
34.	A.R. Bal, M.Sc. (Ag.)	S (Plant Physiology)
35.	G.S. Saini, M.Sc.	Research Fellow

Division of Engineering

36	V.V Dhruva Narayana, M.S; Ph.D	Head of Division (S-3) Water & Soil Engg.
37.	R.N. Pandey, M. Tech.	S-2 (Water & Soil Engg.)
38.	N.K. Tyagi, M. Tech.	S-2 (Water & Soil Engg.)
39.	O.P. Singh, M. Tech.	S-2 (Water & Soil Engg.)
40.	S.K. Gupta, M.Sc.	S-1 (Water & Soil Engg.)
41.	R.K. Gupta, B. Tech.	S-1 (Water & Soil Engg.)
42.	R.K. Batta, B. Sc.	S-1 (Water & Soil Engg.)
43.	V.D. Kalra, B.Sc.	S (Water & Soil Engg.)
44.	A.K. Tiwari, B. Tech.	S (Water & Soil Engg.)
45.	K.G. Aggarwal, Dip. Civil Engg.	Overseer

Water Management and Soil Salinity—Coordinated Project

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46.	B.K. Khosla, M.Sc. (Ag.), Ph.D.	S-2 Soil Science (Soil Physics) On study abroad
47.	I.K. Girdhar, M.Sc. (Ag.)	S, Soil Science (Soil Physics)
48.	B.M. Sharma, M.Sc. (Ag.)	S, Soil Science (Soil Chemistry)
49.	S.N. Singh, M.Sc. (Ag.)	S (Agronomy)
50.	Subhash Chander, M.Sc.	Research Fellow

51.	R.P. Mangla, Dip. Comm. Arts.	Artist

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52.	R. Parshad, M.Sc. (Ag. & A.H.), Ph.D.	S-2 (Agril. Extension)
53.	K.B. Singh, B.A., LL.B.	Reprographist
54.	B.N. Sharma	Photographer

Economics Unit

55.	Parmatma Singh, M.Sc. (Ag.), Ph.D.	S-2 (Agril. Economics)
56.	Jagan Nath Gupta, M.A.	S-1 (Agril. Economics)

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59.	Shyam Kishore Sharma, M.Sc. (Ag.)	Research Fellow
60.	S.K. Kataria, M.Sc. (Ag.)	Research Fellow

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62.	M.S. Kiladhari, B.A.	Asstt. Administrative Officer
63.	A.S. Bhati, Intermediate	Asstt. Administrative Officer
64.	M.C. Chaurasia, B.A.	Accounts Officer
65.	J.K. Jain, M.B.B.S.	Medical Officer
66.	K.N. Pahwa, M.A., Dip. Lib. Sci.	Librarian

Research Station, Canning, West Bengal

67.	A.K. Bandyopadhya, M.Sc., Ph.D.	S-2 Soil Science (Soil Physics) (Officer-In-charge)
68.	K.V.G.K Rao, M.Tech., Ph.D.	S-2 (Water & Soil Engg.)
69.	R.K. Gupta, M.Sc. (Ag.), Ph.D.	S-1 Soil Science (Soil Chemistry)
70.	Mangla Rai, M.Sc. (Ag.), Ph.D.	S-1 (Plant Breeding)
71.	K.S. Gill, M.Sc. (Ag.),	S-1 (Plant Physiology)

72.	C.R. Biswas, M.Sc. (Ag.)	S-1 (Agronomy)
73.	T.S. Sinha, M.Sc. (Ag.)	S (Plant Breeding)
74.	S.K. Dutt, M.Sc. (Ag.)	S (Plant Physiology)
75.	A.K. Chatterjee, M.Sc. (Ag.)	Research Fellow

APPENDIX—II

LIST OF IMPORTANT VISITORS

C.S.S.R.I, Karnal

1. Dr. D.M. Freitas, Secretary Agriculture (Supply), Paraiba State, Brazil (3.2. 76).
2. Dr. E.L. Stefanelo, Director, Deptt. of Rural Economics, Parana State, Brazil (3.2.76).
3. Dr. S.K. De Datta, International Rice Research Institute, Philippines (15.2.76)
4. Dr. Milton Fireman, Soil Specialist, World Bank (16.2.76).
5. Dr. G.S. Kalkat, Agricultural Production Commissioner, Ministry of Agriculture & Irrigation, Govt. of India, New Delhi (20.2.76).
6. Sh. M.D. Asthana, Director of Agriculture, Haryana, Chandigarh (18.3.76 and 17.9.76).
7. Dr. Y. Sechuyak, All Union Academy on Agricultural Sciences, Moscow, USSR (22.3.76).
8. Mrs. N. Bogdanova, All Union Academy on Agricultural Sciences, Moscow, USSR (22.3.76).
9. Dr. V.R. Crangal, International Rice Research Institute, Philippines (5.5.76).
10. Col. Maha Singh, Minister of Agriculture, Haryana, Chandigarh (21.5.76 & 8.10.76).
11. Sh. J. N. Mondal, Member Parliament (23.5.76).
12. Sh. M.R. Lakshminarayanan, Member Parliament (23.5.76).
13. Sh. L. Haque, Member Parliament (23.5.76).
14. Sh. G.S. Geijs, Institute of Plant Protection, Ministry of Agriculture, Wageningen, Netherland (9.7.76).
15. Dr. H.L. Uppal, Professor Emeritus, Deptt. of Soils, P.A.U. Ludhiana (10.6.76).
16. Sh. K.K. Duggal, Assistant Editor, Samachar, New Delhi (20.8.76).
17. Dr. G.S. Vidyarthy, Commissioner (Fertilizers,) Ministry of Agriculture, Govt. of India, New Delhi (4.9.76).
18. Dr. T.S. Bolaria, Director (Farm Advisory Unit), Directorate of Extension, Govt. of India, New Delhi (4.9.76).
19. Dr. D.R. Bhumbla, Deputy Director General(S), I.C.A.R. New Delhi (4.9.76 & 23.10.76).

20. Dr. Mohammed Sanullah, Dy. Chief, Planning Commission, Govt. of Bangla Desh, Dacca (17.9.76).
21. Sh. Waliul Islam Khan, Dy. Chief, Ministry of Planning, Govt. of Bangla Desh, Dacca (17.9.76)..
22. Sh. J.P. Joshi, Regional Manager, Agricultural Development Bank, Kathmandu, Nepal (17.9.76).
23. Sh. R.C. Sood; Joint Secretary-cum-Extension Commissioner, Ministry of Agriculture & Irrigation, Deptt. of Agriculture, Govt. of India, New Delhi (17.9.76).
24. Dr. Ranbir Singh, Director of Agriculture, Rajasthan, Jaipur (17.9.76).
25. Dr. Murry, D. Dawson, Professor of Soils, Oregon State University, USA(22.9.76).
26. Sh. J.L. Hathi, Governor of Haryana (14.10.76).
27. Dr. M.F. Franpa, Overseas Development Council, Washington (19.10.76).
28. Sh. K.S. Narang, Secretary to Govt. of India, Ministry of Agriculture & Irrigation, Krishi Bhavan, New Delhi (23.10.76).
29. Dr. B.K. Soni, D.D.G. (A. Sciences), I.C.A.R. New Delhi (23.10.76).
30. Sh. Moh. Ashraf Ali, State Minister of Agriculture, Govt. of Manipur (Imphal) (5.11.76).
31. Dr. S.S. Khanna, Director of Extn. Edn., H.A.U., Hissar (10.11.76).
32. Dr. I.P. Riley, Utah Water Research Laboratory, Utah (14.11.76).
33. Sh. J.G. Landry, Producer, Canadian Broadcasting Corporation, Canada (27.11.76).
34. Dr. Charles, S. Halling, Soil Scientist, USDA, Maryland, USA (7.12.76).

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35. Dr. K.B.L. Jain, Project Coordinator (Barley), IARI, New Delhi (11.3. 76).
36. Sh. Gerhard Neufeld, Mennonite Central Committee, Dacca (22.3.76).
37. Sh. Vayne Berg, Mennonite Central Committee, Dacca (22.3.76).
38. Sh. Ron Prins, Mennonite Central Committee, Dacca (22.3.76).
39. Dr. S.R. Freiberg, World Bank Consultant, Washington (18.5.76).
40. Dr. N.C. Kuff, World Bank Consultant, Washington (18.5.76).
41. Sh. K. Sengupta, Director of Agriculture, West Bengal (18.8.76).
42. Dr. Hiroshi Ikehashi, Plant Breeder, IRRI, Philippines (15.10.76).

APPENDIX-III

Statement-1

Statement showing the number of reserved vacancies filled by members of Scheduled Castes and Scheduled Tribes during the year 1976

Class of Posts	Total No. of vacancies		No. of posts exempted/do not attract the provision of reservation orders		No. of vacancies to which reservation applicable	Scheduled Castes			No. of reservation lapsed after carrying forward for three years
	Notified	Filled	Out of Col. 2	Out of col. 3		No. of vacancies reserved out of Col. 6	No. of S.C candidates appointed	No. of S.T, candidates appointed against vacancies reserved for S.C. in the 3rd year of carry forward	
1	2	3	4	5	6	7	8	9	10
A. Class I Rs. 1100-1600 and above)	6	1	—	—	—	—	—	—	Previously such posts were exempted from the purview of reservation order. Now reservation is being maintained at the Headquarters.
B. Jr. Class I (Rs. 700-1300)									
C. Class II	1	—	1	—	—	—	—	—	—
D. Class III	33	15	33	15	33	12	7	—	—
E. Class IV	23	11	28	11	23	4	3	—	—

Contd.

Scheduled Tribes				
No. of vacancies reserved out of Col. 6	No. of S.TS. Candidates appointed.	No. of S.Cs. Candidates appointed against vacancies reserved for STs. in the 3rd year of carrying forward.	No. of reservations lapsed after carrying forward for three years.	Remarks
11	12	13	14	16
A.	—	—	—	Previously such posts were exempted from the purview of reservation order. Now reservations being maintained at the Head-quarters.
B.	—	—	—	
C.	—	—	—	
D.	3	1	—	—
E.	3	1	—	—

STATEMENT—2

Statement showing total number of employees and the number of Scheduled Castes and Scheduled Tribes amongst them as on 1st January, 1977

Class	Permanent/ Temporary	Total No. of Employees	Total No. of employees excluding those holding the posts exempted/ do not attract the provision of reservation order	No. of S.C. employees out of col. 4	Percentage of S.C. employees with ref. to col. 4	No. of S.T. employees out of col. 4	Percentage of of S.T. employees with ref. to col. 4	Remarks
1	2	3	4	5	6	7	8	9
Class I	Permanent	6	*	—	—	—	—	* Previously such posts were exempted from the purview of reservation. Now being maintained at Headquarters.
	Temporary	32	*	—	—	—	—	
Class II	Permanent	—	—	—	—	—	—	
	Temporary	3	3	—	—	—	—	
Class II (Non-Gazetted)	Permanent	—	—	—	—	—	—	
	Temporary	28	28	3	10.7	—	—	
Class III	Permanent	14	14	7	50	—	—	
	Temporary	68	68	15	22	3	4.4	
Class IV	Permanent	18	18	15	88.3	—	—	
	Temporary	40	40	13	32.5	1	2.5	

NOTE : (i) The statement be prepared with reference to persons and not with reference to posts. Vacant posts should not be taken into account.

(ii) A person on deputation should be included in the establishment of borrowing office.

(iii) Persons permanent in one grade but officiating or holding temporary appointment in the higher grades should be shown in the figures relating to such higher grades.