[*In India, about 7 million ha of land is estimated to be afflicted by the problem of soil salinity/alkalinity, mainly in the Indo-Gangetic plains, arid areas of Rajasthan and Gujarat, black cotton soil region and coastal tracts. From the management point of view the salt affected soils are divided broadly into (i) Alkali soils and (ii) Saline soils. The research findings on different aspects of the alkali soils obtained at the Central Soil Salinity Research Institute, Karnal, have been highlighted and the details of the package of technology developed at the Institute for the reclamation of the alkali soils for crop production have been elaborated. Already over one lakh ha of alkali land have been brought under reclamation with the adoption of the technology in the States of Haryana, Punjab and U.P. The need for an effective implementation of time-bound reclamation programme has been emphasized. Ed.*]

RECLAMATION AND CROP PRODUCTION IN ALKALI SOILS

J. S. P. YADAV

Director, Central Soil Salinity Research Institute, Karnal, Haryana, India

INTRODUCTION

SOIL salinity and alkalinity are important desertification processes reducing drastically the land's capability to produce the optimum crop yields or even leading to complete failure of agricultural production in large arable areas in the world. About 1/3rd of the cultivable land under irrigation in the world is considered to be already salt-affected[11]. The area under this problem has been increasing in extent greatly with the expansion of irrigation networks. The relevant data collected from some of the important irrigation projects in India (Table I) indicate that several thousands of hectares of once fertile land have been badly affected by waterlogging in these project areas within a few years of introduction of canal irrigation. Therefore, if proper soil and water management practices along with introduction of irrigation are not adopted, the problem of soil salinity is likely to increase day-by-day.

TABLE I

Waterlogged area and water table rise in different irrigation project areas

Project	Total command area (ha)	Water-logged area (ha)	Water table depth below ground level in summer (m)
Hirakud (Orissa)	106280	60000	2·7
Kosi (Bihar)	263000	117000	2·6
Nagarjuna Sagar (A.P.)	831000	114500	0·9 to 1·8
Chambal (M.P.)	700000	32725	0 to 1·5
Cauvery delta	364000	18200	
Tungabhadra (Karnataka)	234700	10110	1·2 to 2·0

Based on data from various papers of the symposium on "Waterlogging, Causes and Measures for its Prevention", C.B.I.P Publication No. 118, Vols. I and II.

It is estimated that a vast area, to the tune of about 7 million hectares in India alone is having the serious problem of soil salinity/alkalinity and has been lying barren for decades. The nature and characteristics of the salt-affected soils encountered in India vary depending upon the climate, topography, geology, soil texture, hydrology and management practices, etc. However, on the basis of the differences in the geographical location and other characteristics, four distinct regions can be identified :

(i) Salt-affected soils in the arid and semi-arid regions of the Indo-Gangetic plains encompassing an area of about 2·5 million ha.

(ii) Salt-affected soils in the arid regions of Rajasthan and Gujarat covering an area of about 1·0 million ha.

(iii) Salt-affected soils in the arid and semi-arid regions of black cotton soil group, affecting an area of about 1·4 million ha.

(iv) Coastal saline soils covering an area of about 2·1 million ha.

From the management point of view, the salt-affected soils in India can be broadly grouped into two distinct categories : (i) alkali (sodic) soils, and (ii) saline soils.

Considering the seriousness of the problem of soil salinity and alkalinity and the likely danger of its further extension in new areas, coming under irrigation on the one hand, and, the potentiality of the salt-affected soils for meeting the food production need, on the other, the Govt. of India established the Central Soil Salinity Research Institute (CSSRI) in 1969 under the Indian Council of Agricultural Research. The Institute has a research station at Canning Town in West Bengal to cater to the research needs of the coastal saline soils. This paper deals mainly with the research conducted on reclamation and management of alkali soils at CSSRI, Karnal.

Reclamation Techniques

Since the reclamation procedure is location-specific, generalisation of any technique is not desirable specially when the conditions differ widely. Successful reclamation involves a package of practices, suited to the nature and problem of the soil, quality and depth of groundwater, calcareousness of the soil, physical conditions of the subsoil, assured supply of good quality irrigation water, availability and economics of the ameliorative measures, and such other associated factors. In general, the various methods of reclamation can be grouped into : (i) chemical, (ii) agronomic and cultural, (iii) biological and (iv) hydro-technical including engineering aspects. The details of the work done on these topics have been reviewed elsewhere[22].

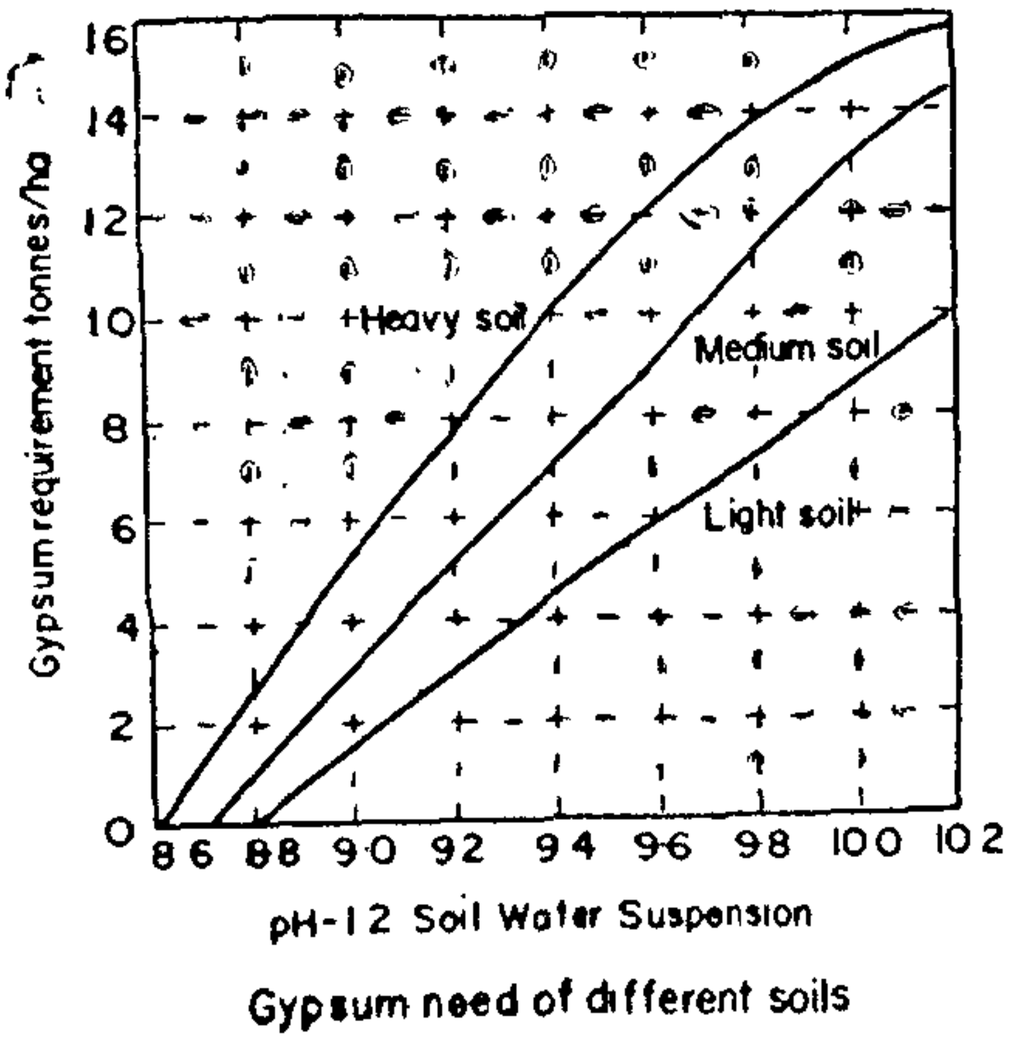
During the last few years, a series of experiments on the various aspects of the alkali soils including the methods of reclamation, kind, dose and method of application of amendment, crops and varieties, fertilizer requirement, agronomic and cultural practices, water management, etc., have been carried out and a package of technology has been developed. Some of the essential components of this package are :

(i) Proper bunding and land levelling,
(ii) Application of suitable amendment in right quantity and right manner,
(iii) Adequate application of fertilizers and manures along with zinc application,
(iv) Choice of proper crops and varieties and cropping sequence,
(v) Use of appropriate cultural and agronomic practices, and
(vi) Proper water management including requisite drainage.

I. *Chemical Measures*

(*a*) *Amendment.*—For the reclamation of alkali soils many inorganic and organic amendments are used. Amongst the inorganic amendments some are sources of calcium such as gypsum, while others are either acids or acid forming materials like sulphuric acid, sulphur and iron pyrites. In most cases reclamation of alkali soils involves replacement of sodium on the exchange complex

with calcium and improvement of physical conditions of the soil. However, gypsum is by far the most popular and is frequently used on a large scale in many countries. The dose of gypsum application depends upon the nature and the degree of deterioration of the soil, texture and other properties of the soil, the depth to which soil is to be reclaimed, the extent of improvement desired and the kind of crops to be grown, etc. The approach adopted at CSSRI, Karnal, has been to reclaim initially only the surface 0–15 cm soil, such that shallow rooted and tolerant crops like rice and wheat could be grown and this has ultimately helped in reducing the dose of amendment application to a considerable extent. Further, the best results in the case of these shallow rooted crops were obtained when gypsum was mixed only in surface 10 cm soil depth[13]. Application of gypsum only once in the beginning is adequate to achieve the desired results provided all other necessary management practices are followed properly and the land is not kept fallow for a long time. The dose of gypsum required for the soils of varying texture and pH are shown in Fig. 1[1]. The effectiveness of gypsum is enhanced if applied along with FYM. Significantly higher yields were recorded in the treatment having application of both



Gypsum need of different soils

FIG. 1

TABLE II

Effect of gypsum and FYM levels on rice yield (q/ha)

Gypsum levels	FYM levels (t/ha) 0	20	40	Mean of gypsum
0	24·5	35·9	37·4	32·6
25% GR	42·3	52·9	54·6	49·9
50% GR	57·0	57·6	68·9	61·2
Mean	41·3	48·8	53·6	

C.D. at 5%	Main effects	Interaction
	5·12 q/ha	8·87 q/ha

gypsum and FYM than in the treatment having either of the two (Table II) at CSSRI, Karnal[10].

According to Mehta and Yadav[15] the by-product phospho-gypsum is a promising amendment. It is however, necessary to work out in detail the adverse effect, if any, of the fluorine contained in phospho-gypsum, on soil and crop growth. Khosla and Yadav[14] in a field experiment on a sodic soil have observed that addition of 20 to 30 t/ha of rice husk in upper 10 to 12 cm soil resulted in a significant improvement in the infiltration rate and in increased paddy yields.

II. *Agronomic and Cultural Practices*

Due to the problematic nature of the salt-affected soils, the agronomic practices have to differ from those recommended for normal soils. Inclusion of rice crop in the rotation has been found to be very helpful in the reclamation of alkali soils, because of its relatively greater adaptability to the alkali conditions and its remarkable effectiveness in bringing about considerable reduction in pH and ESP values of the soils[6]. The data showing the reclamation effect of rice crop are given in Table III. Dargan *et al*[7] have shown that owing to higher mortality and lower tillering under alkali conditions, an increase in plant population from 2 to 4 or 6 seedlings per hill and transplanting of 5-6 week old seedlings resulted in significantly higher grain yields

TABLE III

Soil chemical properties as influenced by the growth of rice plants

		Original soil	Without rice plants	With rice plants
pH	A	10·3	9·6	8 9
	B	9·5	8·9	8·3
ESP	A	93·3	68·6	28·6
	B	26·0	26·3	1·2
Exch. Na (me., %)	A	7·9	5·9	2·4
	B	3 9	2·0	1·0
Exch. Ca + Mg (m.e. %)	A	0·1	2·1	5·7
	B	4·2	5·0	7·0

A and B indicate two different levels, artificially created in the soil.

of rice. Light and frequent irrigations result in better growth of wheat crop, though the total quantity of water used remains the same. If sufficient irrigation water is available during the summer months, growing of *dhaincha* (*Sesbania aculeata*) as a green manure crop after wheat has proved beneficial. Further, the experiments show that extended period of decomposition is not required for effective use of *dhaincha* green manure[20]. The paddy crop can, therefore, be transplanted just after burying *dhaincha*. The practice of puddling, which is normally used in growing rice on good soils, has been found to be harmful in sodic soils in the initial stage of reclamation. For sodic soils, rice–wheat–*dhaincha* rotation has been recommended.

Manures and fertilisers.—The use of manures and fertilizers in alkali soils is important as these soils are generally deficient in available plant nutrients like nitrogen, calcium and zinc and are often poor in organic matter. The work done at CSSRI, Karnal, has shown that an increase in the dose of nitrogen by about 20 to 25% as compared to normal soils benefits the crops. It is better to supply half the dose at sowing and the rest in two equal parts at three and six weeks in the case of rice and wheat crops. Amongst nitrogenous fertilizers, ammonium sulphate has given better results as compared to either urea or calcium ammonium nitrate. The studies on the rate of transformation of nitrogen in the salt-affected soils have revealed that both salinity and high pH adversely affect the process of N-mineralization[18]. Deficiency of available zinc is a common feature in the alkali soils and, therefore, application of zinc sulphate has been found to be beneficial. It has been observed that by missing the application of both *P* and *K*, there is no reduction in the yields of rice and wheat crops when compared to nitrogen application alone in the initial years of reclamation of the sodic soils[8].

III. *Biological Methods*

The reclamation process of salt-affected soils is enhanced and continued further if suitable biological methods, which include green manuring, growth of crops, addition of organic materials, etc., are also followed taneously[21]. Dargan and Chhillar[9] have reported that green manuring with *dhaincha* benefited the succeeding paddy crop with nitrogen equivalent to 80 kg/ha applied nitrogen (Table IV). The application of farm yard

TABLE IV

Nitrogen requirements of rice after fallow and after dhaincha *green manuring (yield, q/ha)*

Treatments		N_0	N_{40}	N_{80}	N_{120}	Mean
Fallow	1974	26·4	28·6	55·6	60·1	45·2
	1975	34·1	42·7	58·7	63·5	49·7
	Mean	30·2	40·6	57·1	61·8	47·4
G.M.	1974	56·4	63·1	73·0	77·1	67·4
	1975	53·5	62·5	69·5	75·3	65·2
	Mean	54·9	62·8	71·2	76·2	66·3
			1974		1975	
C.D. at 5% for fallow v/s G.M.			3·88		2·25	
C.D. at 5% for nitrogen			5·48		3·19	

manure, molasses, pressmud, paddy straw, etc., has been used in the reclamation of salt-affected soils.

IV. *Hydro-technical Methods*

In the areas which have serious problem of soil alkali, leaching in combination with gypsum application has been found more efficient. However, more detailed studies are required to determine the period, extent and method of leaching which may be most suitable under a given set of conditions. The drainage requirements of the salt-affected soils are location specific and vary according to the local conditions like extent and nature of deterioration, soil texture, hydraulic conductivity, depth of water table and quality of groundwater. Although the principles of drainage are simple to state, yet their application at the field scale entails many constraints. The sub-surface drainage in the sodic soils of Indo-Gangetic Plains having poor water transmission characteristics as obtaining at the CSSRI Research Farm is not effective and therefore, proper manipulation of the excess rain water alone could yield good results[16].

The studies carried out to examine the progressive changes resulting from reclamation of sodic soils indicate that reclamation reduces the runoff, enhances the groundwater recharge in the area and minimises the drainage needs. According to Narayana and Singh[17] the unreclaimed area produced 46 cm of runoff during the monsoon period of 1976 as against the corresponding value of only 8 cm in the reclaimed area (Fig. 2). Thus, by reclaiming alkali soils, not only agricultural production can be enhanced but also favourable water balance situation can be created to meet the water needs for reclamation.

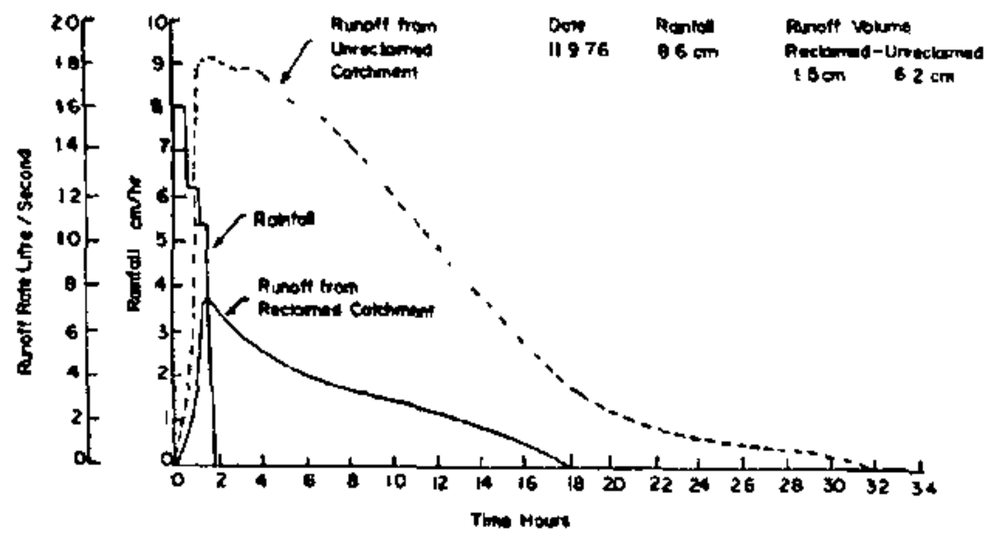


FIG. 2

SELECTION OF CROPS AND VARIETIES

Crop production in salt-affected soils can be made an economic proposition by either suitably modifying the soil conditions in the root zone to suit the plant type or by genetically manipulating plants to suit the existing (or partially improved) soil conditions. However, judicious combination of both the approaches is more advantageous. Since crops differ considerably in their tolerance to soil salinity/alkali conditions, proper selection of crops, their varieties and cropping sequence depending upon the stage of improvement of soil is of paramount importance in the reclamation programme. Agarwal and Yadav[3] proposed a salinity-*cum*-alkali scale to evaluate the saline alkali soils of Indo-Gangetic plains for crop responses.

Rice crop offers some unique features because of its remarkable adaptation to the culture under ponding conditions. Amongst the late maturing group, varieties like IR-8 and Jaya and among the early maturing group, the variety Pusa-2-21 have shown superior performance than others in alkali soils[4]. In the case of wheat crop, varieties HD 2009, HD 1553, HD 1982, WH 157 and WL 711 have been found to do better in alkali soils than others[19]. In the case of barley, the varieties DL-70, DL-36, BG-105, K-153, K-198 and BHS-24 have outyielded the other varieties included in the trial[5].

After critical evaluation of various parameters, it has been found that the slope of the regression line can be considered as a criterion for judging the tolerance of a particular crop. Comparative studies[12] on mineral analysis of wheat plants growing in normal and sodic soils have revealed that Na/K status at the tillering phase of the plants growing in

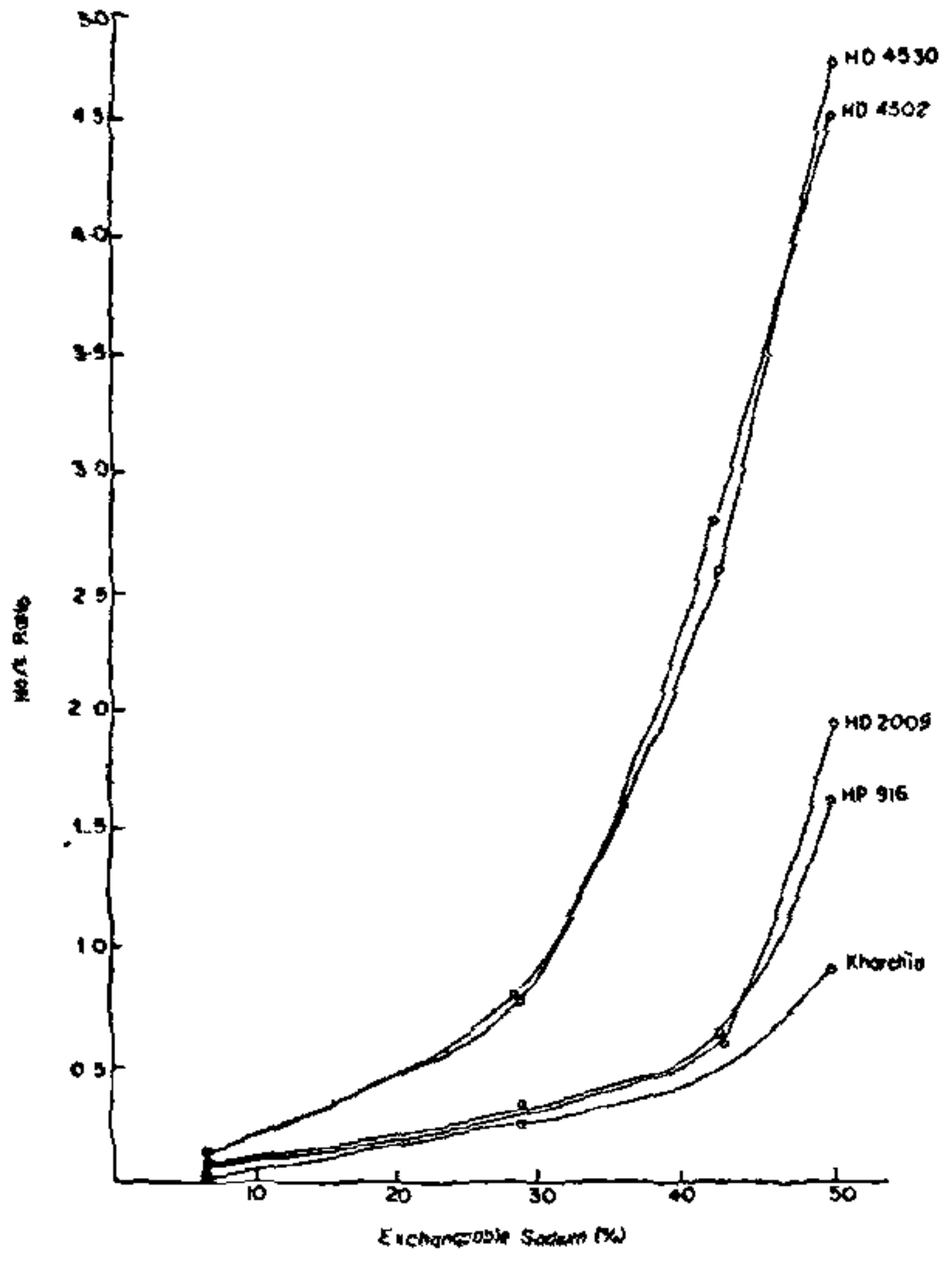


FIG. 3

alkali soils gives a negative correlation with the sodicity tolerance (Fig. 3). Thus, Na/K index of plants at early growth stage can be used to predict sodicity tolerance of adult plants without causing much damage to the growing plants. Detailed studies on this aspect are underway to correlate the tolerance with K and Na uptake in different crops.

PROSPECTS OF GROWING FODDER CROPS AND TREES IN ALKALI SOILS

A significant advancement has been made at the CSSRI recently, to explore the possibility of utilization of the alkali soils, without or with the addition of very small quantity of soil amendments, for growing salt tolerant forages and trees. In this context performance of *Brachiaria mutica, Panicum antidotale, Diplachne fusca, Prosopis juliflora, Eucalyptus hybrid, Acacia nilotica*, etc., has been found to be promising. In a field experiment initiated in 1970 on a calcareous sodic soil with pH above 10·0 and EC ranging from 0·45 to 1·75 mmhos/cm Yadav *et al.*[23] found that the growth of *Eucalyptus hybrid* after treating the soil with gypsum + FYM in the planting pit was almost as good as when the original soil was replaced with good soil. Most of the planted seedlings died in the control. The height of the plants increased further with fertilizer application. In a recent trial, planting of Eucalyptus seedlings in auger holes has also shown promising results[2]. The plantation of suitable trees has a great scope in the common village panchayat alkali lands to meet the local demands of fuel, timber and fodder.

TRANSFER OF ALKALI SOIL RECLAMATION TECHNOLOGY ON FARMERS' FIELDS

The results of the various researches on reclamation of the alkali soils have not been confined to the research farm of the CSSRI only, but concerted efforts have been made to transfer this technology to the farmers, for its large scale adoption. A large number of field demonstrations have been carried out in the States of Haryana, Punjab and Uttar Pradesh for the reclamation of the alkali soils under the farmers' conditions.

The Central Soil Salinity Research Institute, Karnal, through its Operational Research Project on the reclamation of alkali soils initiated in 1975 and 1976 in two clusters, one of 4 villages and another of 3 villages around Karnal, has amply demonstrated on more than 300 farmers' fields that the use of alkali soil reclamation technology evolved by the Institute leads not only to good harvest in the first year of reclamation but also to the progressive soil improvement and increase in the crop yields during subsequent years. These villages have large areas severely affected by the soil alkali conditions. In the demonstration plots on an average 40 q/ha of rice and 15–18 q/ha of wheat were obtained during the very first year. Nearly 1200 ha of alkali land has already been brought under reclamation under the project. The work is still in progress.

The successful application of alkali soil reclamation technology at the farmers' fields has prompted the affected States of Punjab, Haryana and Uttar Pradesh to launch ambitious programmes of land reclamation through the Development and Land Reclamation Corporations by providing the necessary inputs to the needy farmers, creating infra-structural facilities and providing credit, etc., on easy terms. It is estimated that more than 100,000 hectares of alkali land have already been brought under reclamation through these efforts.

In conclusion, it is obvious that the technology developed by the CSSRI has proved effective and has been adopted on a large scale on the farmers' fields in the States of Haryana, Punjab and Uttar Pradesh in the Indo-Gangetic plains. Substantial additional quantities of rice and wheat grains are being produced on the alkali lands which have been lying barren for many years and where nothing was grown before. The work has also been undertaken to develop alternative uses of these problematic lands with minimum use of inputs. What is now desired is an effective formulation and implementation of time bound reclamation programme of alkali soils to bring maximum area of such lands under productive uses.

1. Abrol, I. P. and Bhumbla, D. R., *Indian Farmig* 1973, **23**, 23.
2. — and Sandhu, S. S., *Intensive Agric.*, 1980, **18**, 5.
3. Agarwal, R. R. and Yadav, J. S. P., *J. Indian Soc. Soil Sci.*, 1956, **4**, 141.
4. Bhattacharya, R. K., *Annual Rep.*, CSSRI, Karnal, 1976, p. 50.
5. Chandra, S., *Ibid.*, 1976, p. 49.
6. Chhabra, R. and Abrol, I. P., *Ibid.*, 1975, p. 43.
7. Dargan, K. S., Abrol, I. P. and Bhumbla, D. R., *Agron. J.*, 1974, **66**, 279.
8. — and Chhillar, R. K., *Annual Rep.*, CSSRI, 1975, p. 53.
9. — and —, *Op. cit.* 1975.
10. —, Gaul, B. L. and Abrol, I. P., *Annual Rep.*, CSSRI, Karnal, 1971, p. 60.
11. Framji, K. K. (ed.), *International Commission on Irrigation and Drainage*, New Delhi, 1976.
12. Joshi, Y. C., Qadar, Ali and Rana, R. S., *Annual Rep.*, CSSRI, 1977, p. 63.
13. Khosla, B. K., Dargan, K. S., Abrol, I. P. and Bhumbla, D. R., *Indian J. Agric. Sci.*, 1973, **43**, 1024.
14. — and Yadav, J. S. P., *Indian Farming*, 1976, **25**, 9.
15. Mehta, K. K. and Yadav, J. S. P., *Ibid.*, 1977, **27**, 6.
16. Narayana, V. V. D., Gupta, S. K. and Bhumbla, D. R., *Ibid.*, 1972, **22**, 9.
17. — and Singh, O. P., *Proc. Nat. Symp. Hydrological Problems*, Kanpur, I.I.T., September 27-29, 1977, Vol. III.
18. Nitant, H. C. and Bhumbla, D. R., *Annual Rep.*, CSSRI, 1973, p. 30.
19. Rana, R. S. and Singh, K. N., *Ibid.*, 1976, p. 47.
20. Venkata Krishna, S., Batra, L. and Dargan, K. S., *Ibid.*, 1978, p. 43.
21. Yadav, J. S. P., *Indian Farm.*, 1975, **101**, 385.
22. —, *Proc. Indo-Hungarian Sem. Management Salt-Affected Soils*, CSSRI, Karnal, 1977, p. 134.
23. —, Bhumbla, D. R. and Sharma, O. P., *Int. Symp. on New Develop. in the Field of Salt-Affected Soils*, Cairo, December 4–9, 1972.