

# **Success Stories on Development, Spread and Impact of Salt -Tolerant Varieties of Rice, Wheat and Mustard in India**

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## **Problems and Extent of Salt-affected soils**

Salinity affects about 1000 million hectares land globally posing a formidable task of taking up agriculture and enhancing productivity in these areas. About 100 million ha in South and South-East Asia are covered by problem soils where rice is the staple crop. In India, 6.73 million ha land is salt affected, out of which 3.77 and 2.96 million ha are covered sodic and saline soils, respectively. Harnessing the potential and prudent management of such salt afflicted soils can play a significant role in increasing and sustaining the national and global food security.

The target of producing more food grains in developing countries for feeding the burgeoning population in view of the shrinking cultivated area is an uphill task. One of the possible and achievable way is to reclaim the salt-affected areas and other waste lands which are hitherto barren or have low productivity. Reclaiming such salt-affected soils by chemical amendments and drainage interventions is one option, however it involves higher costs which are generally beyond the economic access of poor and marginal farmers inhabiting such areas. Another approach could be the genetic tailoring of the crop plants which is simple and economical to adopt and also prevents environmental degradation. A third approach could be the synergistic approach, based on harnessing the synergies between the environment modifying technologies and genetically enhanced plant types. This approach is considered to be more practical, economically viable, efficient and less pollution causing with tremendous potential. For better management and efficient soil amelioration programmes in salt affected areas, all the three approaches need to be used for achieving effective and stable gains.

## **Role of Biological Reclamation using Salt Tolerant Varieties (STVs) of Crops developed at CSSRI:**

Efforts made over the last four decades at the Central Soil Salinity Research Institute, Karnal, India have demonstrated that development of salt tolerant varieties is the key to successful biological approach of land reclamation. In this regard, good success in identifying suitable crops, developing and deployment of suitable salt tolerant varieties in major crops like rice, wheat and mustard has been achieved. With this aim, CSSRI has developed salt tolerant varieties in different crops suitable for cultivation in salt-affected soils. These varieties have been released and gazette notified by the Central Variety Release Committee (CVRC), of the Government of India for cultivation in the country. These varieties have made considerable direct as well as indirect impact in enhancing agricultural productivity and raising farmers' livelihood.

## ***Collection and Evaluation of Germplasm including Landraces and native materials***

CSSRI Karnal collected and evaluated more than 11,000 germplasm lines of rice comprising of introductions, land races, improved type materials from India and International

Rice Research Institute, Philippines. The materials were screened for salt tolerance through diverse sodic and saline conditions in Karnal, Gudda, Mundhlana, Sarswati and Kaithal farms as well as in the controlled sodic and saline micro plot facilities at Karnal. This work was facilitated by our collaborations with different National and International agencies and organizations from time to time. Similar efforts were undertaken for wheat and mustard crops.

After developing these materials using appropriate strategies, the promising lines were initially tested in pots, micro plots filled with saline and or sodic soils and fields at CSSRI Karnal and its outreach farms and regional centres. Successful materials were tested in different locations under the auspices of the Directorate of Rice Research, Hyderabad for rice, Directorate of Wheat Research, Karnal for wheat and National Research Centre on Rapeseed and Mustard, Bharatpur, Rajsathan, for Indian Mustard. These trial sites represent saline and sodic soils across diverse locations in different states and were coordinated by eminent scientists and research managers in the country.

## **RICE**

Breeding efforts in rice got impetus with the identification, selection and introgression of salt tolerance from land races like Damodar (CSR1), Dasal (CSR2) and Getu (CSR3) which were native to the coastal Sunderban areas in West Bengal. These are the traditional, tall and photo-sensitive selections which served as donors for salt tolerance for developing high yielding salt tolerant, semi-dwarf and early maturing varieties with better grain quality. Similarly, for developing the first salt tolerant successful basmati variety CSR30 (Yamini) derived from the cross BR4-10/Pakistan Bas.1, the donor BR4-10 from coastal saline areas of Maharashtra was used.

### **Salient features and release of STVs developed at CSSRI:**

The salt tolerant varieties developed so far are the product of conventional breeding involving different breeding methods and are not transgenic in nature. Details of the salt tolerant rice varieties developed by CSSRI, Karnal are given in Table 1.

**Table 1. Salt tolerant rice varieties developed by CSSRI, Karnal and released by CVRC.**

<b>Name of variety</b>	<b>CSR10</b>	<b>CSR13</b>	<b>CSR23</b>	<b>CSR27</b>	<b>CSR30</b>	<b>CSR36</b>
<b><i>Parentage</i></b>	M40-431-24-114/ Jaya	CSR1/ Bas.370// CSR5	IR64// IR4630 -22-2-5-1-3/ IR 964- 45-2-2	NONA BOKRA/ IR565-33- 2	BR4-10 / Pak. Basmati	CSR13/ Panvel 2// IR36
<b>IET No.</b>	10349	10348	13769	13765	14720	17340
<b>Year of Release</b>	1989	1998	2004	1998	2001	2005
<b>Plant height (cm)</b>	85	115	115	115	155	110
<b>Maturity days</b>	120	145	130	125	155	140

Tolerance limits						
Salinity ECe - dS/m	<11.0	< 9.0	<10.0	<10.0	<7.0	<11.0
Sodicity (pH <sub>2</sub> )	<10.2	<10.0	<9.9	< 9.9	<9.5	<10.0
Yield ( t/ha)						
Non stress	>6.0	>6.0	>6.5	>6.5	>3.0	>6.5
Salt stress	>3.0	>3.0	>4.0	>4.0	>2.0	>4.0
Grain type	Short bold	Long slender	Long slender	Long slender	Basmati type	Long slender
Recommended Ecology	Acts as Biological amendment for deteriorated sodic and inland saline soils.	Sodic and inland saline soils of UP, Haryana, Gujarat and Maharashtra.	Sodic soils of Haryana, UP and coastal saline areas of Maharashtra. Gujarat, Tamil Nadu, Kerala and West Bengal.	Sodic and coastal saline soils of India	First salt tolerant basmati variety developed for sodic areas of UP, Haryana and Punjab.	Sodic soils of Haryana, U.P. and Pondi- Cherry.

**Photographs of Salt Tolerant Varieties of rice.**

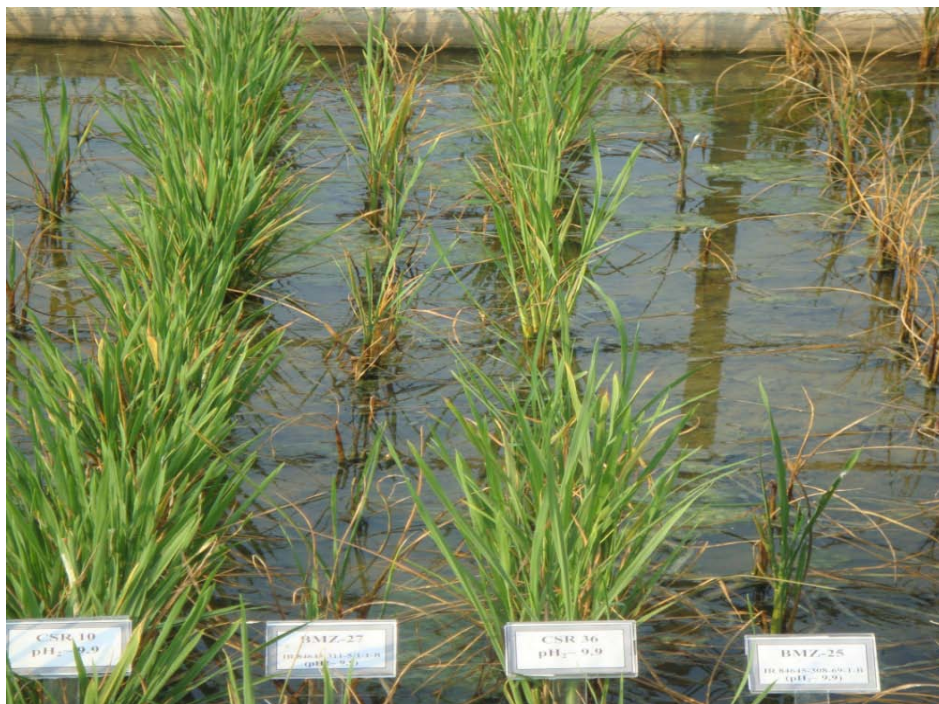




**A general view of the trial of rice genotypes in micro plots filled with normal (top), moderate sodic (middle) and high sodic (lower) soils**



**Trials of rice genotypes in micro plots filled with high sodic soil of pH 9.9. A close view showing tolerant and sensitive genotypes (Ist –CSR 10, IInd and IVth – Sensitive Lines and IIIrd- CSR 30).**



## **WHEAT**

In wheat, Kharchia 65 and other lines collected from Kharchi in Pali district in the state of Rajasthan were identified to possess higher salt tolerance to salinity and sodicity stresses. These land races have proved to be good donors for improving salt tolerance in wheat and have played a major role in our wheat breeding efforts at CSSRI, Karnal. Two salt tolerant wheat varieties, KRL 1-4 and KRL 19 have been developed by pedigree method of selection and released through CVRC in 1990 and 2000, respectively. In addition, two more varieties KRL 210 and KRL 213 have recently been identified and approved for release.

### ***KRL 1-4***

KRL 1-4 was the first salt tolerant variety of wheat released by CVRC in 1990 for saline and sodic soils of the North Western Plain Zones (NWPZ) of the country. This variety is improved from Kharchia 65 (the most salt tolerant variety) on account of amber grains, dwarf plant type, lodging resistance, high yield and disease resistance to all the prevalent rusts. This is a dwarf type with 145 days of maturity. The grain texture is hard, medium bold and amber in colour with 12% protein content, 79.7 Kg hectolitre weight and sedimentation value of 40. This has good yielding ability up to 4-5 t ha<sup>-1</sup> under normal soil condition and 2.5-3.5 t ha<sup>-1</sup> under sodic stress up to pH<sub>2</sub> 9.3 and salinity up to EC<sub>e</sub> 7.0 dS m<sup>-1</sup>.

### ***KRL 19***

KRL 19 was released in 2000 and can tolerate saline (EC<sub>e</sub> 5 -7 dS m<sup>-1</sup>) as well as alkaline soil (pH<sub>2</sub> 9.3 - 9.4). It also does well in areas with brackish or saline ground waters (EC<sub>iw</sub> 15-20 dS m<sup>-1</sup>, RSC 12-14 meq l<sup>-1</sup>). It has amber grain colour with good grain appearance, high protein content (12%), hecto liter weight (77.4 Kg) and sedimentation value of 47.4 ml. Though KRL19 has been specifically bred for adverse saline/alkali soils, it has yield potential under normal soil conditions is 4.5-5.2 t ha<sup>-1</sup> and 2.5-3.5 t ha<sup>-1</sup> in sodic soils up to pH<sub>2</sub> 9.3 and saline soils up to EC<sub>e</sub> 7.0 dS m<sup>-1</sup>.

### ***KRL 210***

KRL 210 has shown good yielding ability and salt tolerance with superiority in grain yield on three year's mean (+11.4%) as well as on individual year basis (two years significantly superior and one year numerically superior) over the salt tolerant check KRL 19. The variety has +26.8% yield gain over Kharchia 65 and is resistant to Yellow and Brown rusts, loose smut, Karnal bunt and flag smut. The variety has also shown tolerance to shoot fly. KRL 210 is a semi-dwarf type and takes about 143 days to mature. The grains are amber in colour, bold in size and contain about 11% protein. The hectolitre weight of the grain is 77 kg with sedimentation value of 39. The yield potential of KRL 210 is 5.5 tonnes/ha in normal soils, whereas its yield potential in salt affected soils (having pH up to 9.3 and EC up to 6 dS m<sup>-1</sup>) is 3 to 5 tonnes ha<sup>-1</sup>.

### ***KRL 213***

The variety KRL 213 has shown salt tolerance and good yielding ability with superiority in grain yield on three year's mean (+8.2%) as well as on individual year basis (two years significantly superior and one year numerically superior) over salt tolerant check KRL 19. The variety has shown +24.1% yield gain over Kharchia 65 and is resistant to yellow as well as brown rusts, leaf blight, Karnal bunt and hill bunt. KRL 213 has an excellent plant



type with semi-dwarfness, 97 days for days to flowering, 145 days to days to maturity in North West Plain Zone (NWPZ). However, in North East Plain Zone (NEPZ) the variety attains flowering and maturity at 91 and 128 days respectively. KRL 213 has been specifically bred for salt tolerance to saline ( $EC_e$  6.0  $dSm^{-1}$ ) as well as alkaline soils (up to  $pH_2$  9.2) conditions. It also does well in areas where the ground water is either brackish and/or saline ( $EC_{iw}$  15  $dSm^{-1}$ ; RSC 12-14  $meq\ l^{-1}$ ). This variety has amber coloured grain with 11% protein content, 77 Kg hecto liter weight and sedimentation value of 29. It has a good yield potential under salt stress condition (Average yield 3.3 tonnes  $ha^{-1}$ ). However the variety can produce up to 5 tonnes  $ha^{-1}$  in normal soils.

### Photographs of Salt Tolerant Varieties in Wheat



### Donor germplasm

Three salt tolerant genetic stocks in wheat i.e. KRL 35, KRL 99 and KRL 3-4 have been registered with NBPGR, New Delhi. KRL 35 and KRL 99 are amber grain salt and waterlogging tolerant genotypes. The red grain genotype KRL 3-4 has been found to be highly tolerant to salinity and sodicity and is also being used as a tolerant check in the Salinity/Alkalinity nursery of All India Coordinated wheat and barley improvement program.

**KRL 35** -Registered with NBPGR, New Delhi in 2004. It has also been rated as the genotype most tolerant to B toxicity – pers. commn. Tim Setter, 2010.

**KRL 99** – Registered with NBPGR, New Delhi in 2007. Excellent performance under waterlogging for 15 days after 22 days of sowing at high sodicity (pH<sub>2</sub>: 9.5).

**KRL 3-4** - Registered with NBPGR, New Delhi in 2009. A wheat genotype developed for salinity, sodicity and waterlogging tolerance. It has red colour grains, high level of tolerance to sodicity, salinity and waterlogged sodic conditions and lower uptake of sodium under salinity and sodicity.

**Photographs of donor germplasm lines of wheat registered for salinity, sodicity and/ or waterlogging tolerance.**



**Photograph showing the effects of sodicity (pH 9.3) and 10 days waterlogging in the normal and sodic soils on wheat genotypes.**

First row at bottom - HD 2009 (sodicity and salinity sensitive),

And Top row - KRL 3-4 (salinity and sodicity tolerant) genotypes of wheat.

First & Second pots (pH 7.8), - Normal soil drained & Waterlogged for 10 days, respectively;

Third & Fourth pots (pH 9.3) –Sodic soil drained & Waterlogged for 10 days respectively.





**Photograph showing the effects of increasing levels of sodicity on HD 2009 (sodicity and salinity sensitive) and KRL 3-4 (salinity and sodicity tolerant) genotypes of wheat.**



## **Indian Mustard**

Amongst different *Brassica* species, Indian mustard (raya) showed higher tolerance to salinity/ alkalinity stresses compared to Gobhi sarson, Karan rai, yellow and brown sarson. Different genotypes of Indian mustard also showed differential tolerance to saline and alkali stresses. The sustained breeding efforts for the development of high yielding salt tolerant genotype of Indian mustard at CSSRI have led to the development and release of three salt tolerant varieties: CS 52, CS 54 and CS 56 (Triveni). Some more promising lines are in the pipeline. These varieties were identified on the basis of superior performance over nationally adapted high yielding checks continuously for four years with respect to seed and oil yield *per se* in moderate to high soil salinity in salinity and alkalinity trials in salt affected soils. To start with, the germplasm lines were collected from different sources and evaluated for their salt tolerance ability. High yielding mustard lines were evaluated for minimum percentage reduction in yield under saline and alkali conditions. The better adapted lines were identified and used as parental material along with other high yielding lines under normal conditions.

### **CS 52**

CS 52 is an Indian mustard variety (*Brassica juncea* L. Czernz and Coss) released by CVRC in 1997 for salt affected soils. This variety was identified by screening and evaluation of a large number of *B. juncea* genotypes in saline and sodic soils and with brackish irrigation water over the years. This variety was identified on the basis of superior performance (nearly 20%) over nationally adapted high yielding checks continuously for four years with respect to seed and oil yield *per se* in moderate to high soil salinity in salinity and alkalinity trials. This is a tall (170 – 180 cm), bearing basal branching, relatively late maturing (7-10 days) as compared to checks and less prone to aphid and pests attack. This variety is recommended for cultivation in saline and sodic soils up to a critical limit of  $EC_e$  6.0-8.5  $dS\ m^{-1}$  and  $pH_2$  9.3, respectively. The average yield of this variety, within the critical limits of soil salinity, is around 1.5-1.6  $t\ ha^{-1}$  with 36% oil.

### **CS 54**

CS 54 was released by CVRC for cultivation in salt affected soils in 2005. It was identified on the basis of superior performance (nearly 20%) over high yielding checks. Its

plant height is around 160 cm, bearing basal branching, matures in around 121 days and is less prone to aphid and pests attacks. This variety is recommended for cultivation in saline and sodic soils up to a critical limit of  $EC_e$  6.0-9  $dS\ m^{-1}$  and  $pH_2$  9.3, respectively. The average yield of this variety, within the critical limits of soil salinity, is around 1.6  $t\ ha^{-1}$  having more than 38% oil content.

## CS 56

CS 56 (Triveni) is the latest variety of Indian mustard (*Brassica juncea* L. Czernz and Coss) released by CVRC in 2008 for the late sown conditions of Zone II of the country (Sriganganagar, Navagaon, Bathinda, Hisar and Delhi) comprising the states of Punjab, Haryana, Rajasthan and Delhi. Its overall mean seed yield over 12 locations in three years under late sown conditions was nearly 15, 57 and 17% higher over the National Checks-Vardan, Varuna and Kranti, respectively. The oil yield over 12 locations in 3 years was also higher by 12, 52 and 15% over the three National Checks Vardan, Varuna and Kranti, respectively. This variety can be sown up to 15<sup>th</sup> November with the minimum yield reduction and can yield upto 1.6  $t\ ha^{-1}$ . This variety is also recommended for cultivation in saline and sodic soils up to a critical limit of  $EC_e$  6.0-9  $dS\ m^{-1}$  and  $pH_2$  9.3 respectively. The average yield of this variety, within the critical limits of soil salinity, is above 1.6  $t\ ha^{-1}$  with 38% oil content.

### Photographs of Salt tolerant Varieties in Indian Mustard: CS 52, CS 54 and CS 56



## GRAM

Similar efforts were made to collect, evaluate and assess the gram varieties and materials from different areas and sources for their tolerance to salinity and sodicity. These efforts led to identification and release of Karnal Chana 1 as variety suitable for marginal saline and or sodic areas. This variety yields upto 2.1  $t\ ha^{-1}$  in normal soils and 1.5  $t\ ha^{-1}$  at these stress levels ( $EC_e$  4-6  $dS\ m^{-1}$  and  $pH_2$  <9.0). CSG 88101, another gram genotype has been registered with NBPGR, New Delhi as a donor for salt tolerance.

### **Trials and Demonstrations of STVs at target sites and farmer's fields**

#### *Adaptive trials and popularization of CSR30:*

These STVs were tested at farmers fields and demonstration trials were also conducted in different areas prior to and after their release. These trials were successful in demonstrating their salt tolerance and yield potential under the stress situations leading to their acceptability

and popularity with the farmers. CSR 30 was tested at farmers' field by Krishi Vigyan Kendra, Jind (Haryana) before its release and yielded  $3.737 \text{ t ha}^{-1}$  at pH 9.3. Large area demonstrations of CSR 30 were conducted during *Kharif* 2000 at its outreach farm at Bhaini Majra, Kaithal (soil pH<sub>2</sub>~9.3 – 9.4 with poor quality water of RSC > 10 meq l<sup>-1</sup>; the safe limit for irrigation being <2.5 meq l<sup>-1</sup>). Until maturity, both CSR30 and HBC19 varieties behaved in an almost similar manner but at the time of panicle initiation/flowering, HBC 19 experienced heavy damage of about 75% as compared to 20- 25% observed in case of CSR 30 (Plate A). After the release of CSR 30, Front Line Demonstrations (FLDs) were also conducted in the states of Uttar Pradesh, Uttarakhand and Haryana, where it performed better than the check variety at all the locations (Plate B). An average yield advantage of 15- 37% over the local check HBC 19 was recorded. This variety though developed for moderate stress conditions also performed better in the normal soils and became popular in commercial cultivation. Some of the popular varieties like CSR23, CSR36 and CSR30 are being up-scaled on a larger scale in the sodic areas of Indo-Gangetic plains.



Similarly, varieties KRL 1-4 and KRL 19 (Plate C) of wheat and CS 52, CS 54 and CS 56 of mustard were also grown in many demonstration trials conducted at the farmer's fields in Haryana and UP and have received positive feedback from the farmers.

### **Contribution of STVs in increasing productivity of salt affected soils towards national food production and environmental improvement**

#### **Rice:**

During the years 2000-2009, CSSRI, Karnal has supplied 31.7 tonnes of breeder seed of these salt tolerant varieties to different seed multiplication agencies. Besides, CSSRI has also produced and supplied C.45 tonnes of labelled/certified seed to different organizations with the major share for Uttar Pradesh Land Development Corporation, Lucknow.

Multiplication ratio of breeder seed to certified seed is about 1:80, 1:20 and 1: 100 and seed rate @ 30, 100 and 6 kg ha<sup>-1</sup> are used for rice, wheat and mustard, respectively. These values are adopted as per the guidelines of the Department of Agriculture & Cooperation, Government of India (<http://www.dacnet.nic.in/seednet/seeds/material/SMR.pdf>). Breeder to foundation and foundation to certified seed chain is not included in this case study, otherwise it would be much more. If we extrapolate these figures for rice, then 31.7 tonnes of breeder seed would have produced 202,880 tonnes of certified seed. In addition to this, CSSRI supplied 182.4



tonnes of the certified seed, making the total quantity of the certified seed for rice 20,3062.4 tonnes (Table 2). Even with these conservative estimates, if we consider only a total of 20,3062.4 tonnes of the certified seed in the production chain, this might have been cropped in more than 67,688,747 ha area producing 20306240 tonnes of paddy (taking an average production of 3.0 tonnes ha<sup>-1</sup>). This additional food grain particularly from the salt-affected areas is worth Rs. 19,291 Crores (4,384 million US\$) besides providing employment and generating extra income.

## **Wheat**

About 15.1 tonnes of breeder seed and 108.1 tonnes of the certified seed was produced and supplied to seed agencies for multiplication and sold directly to farmers for cultivation in salt affected areas of the country. CSSRI produced around 15.1 tonnes of breeder seed of the two salt-tolerant varieties of wheat (KRL 1-4 and KRL 19) during the last ten years which together with 108.1 tonnes of certified seed is expected to cover around 61,481 ha area. These salt-tolerant varieties have been adopted by the farmers and are being primarily cultivated in the states of Punjab, Haryana and UP.

## **Mustard**

Further, CSSRI also produced about 2.42 tonnes of breeder seed of the three salt-tolerant varieties of mustard during this period and is expected to cover around 605,686 ha area in different states of the country. These salt-tolerant varieties are also being cultivated in Rajasthan and Gujarat, in addition to Punjab, Haryana and UP.

Farmers in India normally do not replace the seed every season and use their own produce as seed for a couple of years before its replacement. In addition, the farmers exchange seed among themselves also. As the cost of seed is always more than the cost for food consumption there is little chance of the seed being diverted for food purposes. This scenario is for only one season and this estimate of the output and worth of seed is repeated with possible further increases in subsequent years. In this example, seed distributed by only one organization i.e. CSSRI, Karnal has been considered. Many other seed multiplication agencies at the state and national levels, both in private and government sectors, are engaged in bulk seed production and supply the seed directly to the farmers. As per our information, farmers who adopt the salt tolerant varieties will continue to grow it, and even more farmers will begin to use it. This means the benefits and returns on investments from this work would grow significantly over time. Considering this scenario, the worth and use of salt tolerant rice varieties would be much more than this projection. Moreover, there is large scope for further spread of these varieties in the niche target areas which can be achieved by creating more awareness supplemented by efforts through the related extension agencies.

Another major notable impact is bringing back the unproductive barren or very low productive lands into production chain. There could be 2 scenarios; first: the unproductive barren land is cultivated using a salt tolerant variety with application of a small amount of gypsum producing about 3.0 -5.0 t ha<sup>-1</sup> of rice and around 3.0 tonnes of wheat in the first year which increases further in the subsequent years. In the second scenario, a salt-tolerant variety replaces an old variety in marginal salt-affected lands leading to increase in yield from the existing 5 to 6 t ha<sup>-1</sup> with an advantage of 1 tonne. Comparing the two scenarios, in the first scenario there are two advantages: production of moderate amounts of food grain from a hitherto barren land with no production and putting more land under cultivation chain with increasing production potential with time. In the second scenario, the productivity is more

**Table 2. Estimates of Seed Impact of the Salt-Tolerant Varieties in Rice, Wheat and Indian Mustard.**

Crop	Multiplication ratio	Breeder seed produced (t)	Certified seed (CS) estimated (t)	CS already sold (q)	Total seed (q)	Estimated area coverage (ha)	Estimated produce (tonnes)	Estimated value of produce (Crore Rs)**	Estimated value or produce (m \$US)
Rice	1:80	31.7	202880	182.4	203062.4	6770747	20316240	19291	4384
Wheat	1:20	15.1	6040	108.1	61481	61481	184443	203	46
Mustard *	1: 100	2.42	3630	4.1	36341	605686	302843	303	69

(\* In mustard, 15% of breeder seed produced was estimated to be used in the multiplication chain for producing certified seed,

\*\* Calculated on the basis of Minimum Support Price rates for the years 2009 & 2010).

**Farmers waiting for the purchase of seed of salt tolerant varieties at the Farmer's fare at CSSRI campus.**



though it has lower yield advantage. Therefore the long-term impact of the biological or chemical-cum-biological reclamation is tremendous for increasing productivity with reduced costs, betterment of environment, employment generation and food security. Besides, the variety technology is quite simple for adoption by farmers. In addition, salt-tolerant crops and varieties have a much lower leaching requirement than salt-sensitive crops and so lessen the costs of an irrigation scheme, both in the need to import fresh water and to dispose of saline water.

Therefore, faster conversion of degraded lands into the production chain with the use of resilient varieties can cover more areas thus increasing food productivity from these reclaimed lands. These facts indicate that the CSSRI is contributing significantly in the production and distribution of salt tolerant varieties to those areas where sodicity and salinity problems are the major hurdles in crop production. The development of salt tolerant varieties

by CSSRI has provided a viable option for the farmers where soils are affected by soil salinity, sodicity and waterlogging.

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