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Varietal selection in sodic soils of Indo-Gangetic plains through farmers' participatory approach

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Participatory varietal screening, selection and testing of a large number of salt tolerant varieties/genotypes of rice were conducted at Central Soil Salinity Research Institute, Regional Research Station, Lucknow, India during 2001 to 2007. This is aimed to identify and develop a high yielding, adaptable and acceptable rice variety for sodic soil environment through farmers' participatory approach. Generally plant breeders tend to develop varieties through centralized breeding method are popular among farmers at favorable rice production system and often they are not suitable for stressed environments. A large number of varieties/genotypes were screened and evaluated under researchers managed on-station trials during 2001. From 2002 to 2005, farmers became a part of the varietal selection and testing process in order to incorporate their preferences. In this direction variety CSR 36 and genotype CSR-89IR-8 not only performed better in different locations, but was also deeply appreciated and adopted by farmers in sodic areas consistently over years. It can withstand sodicity tolerance up to pH_2 ~ 9.9 and gives higher grain yield performance than other varieties/genotypes tested. The selected varieties/genotypes were evaluated under farmers managed baby trials during 2006 to 2008 and compared with traditional varieties. Based on the farmer's preference, grain yield, farmer to farmer seed dissemination and large scale adoption in the target environment, the genotype CSR-89IR-8 has emerged as the best genotype and released as a variety named CSR 43 by the State Variety Release Committee in 2011. The success of PVS in the sodic environments convinced researchers, stakeholders and partner organizations for adopting this approach for rice variety development and larger impact particularly under resource poor and salt affected conditions.

Key words: Sodic soils, salt tolerant, genotypes, rice variety.

INTRODUCTION

One of the major challenges for improving food security in rural resource poor communities is to develop cultivars that are tailored to specific local environments. Although, germplasm can be developed at a national and international level to incorporate a number of genetically useful traits, it is a major challenge for scientists with

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limited resources to test the full range of genetic diversity generated by a breeding programme under all possible environments. It is conjectured that about 1.2 billion hectare land around the world (Massoud, 1974; Ponnamperuma, 1984; Tanji, 1990; FAO, 2007) are affected with different levels of salinity and sodicity. In India about 7.00 million hectare land is affected by salt including salinity and sodicity (Sharma et al., 2006). Of this, about 3.77 million hectare land is affected by sodicity (NRSA and Associates, 1996). These lands can be ameliorated but need solutions like incorporation of soil amendments like gypsum that require large investments and transportation cost from place of mining to the targeted areas.

This often goes beyond the reach of small and marginal farmers mostly owning such lands covering about 5.70 million hectare area in the Indo-Gangetic plains. Besides this, easy availability of chemical amendments like gypsum for sodic soils is a big concern. Rice is recommended as the first crop for the reclamation of sodic soils and preferred during initial years after reclamation due to certain adaptive reasons (Chhabra and Abrol, 1977).

However, complementing the reclamation technology with salt tolerant high yielding and suitable rice varieties holds great promise and has delivered lot of dividends and impact under such conditions (Singh et al., 2004; CSSRI, 2006; Gautam et al., 2010). Thus genetic tailoring of rice plants to adapt under salt stress situations proved to be economically feasible and environmentally viable plant based approach.

There are a large number of rice genotypes that are grown from coastal to inland saline and sodic ecosystems. Genotypes suitable for one ecology like coastal areas may or may not be suitable for other ecology like inland saline and sodic areas. Since, the ecology of salt affected environments is a big issue as it differs from one target area to another, it is imperative to develop cultivars which are specific to the target environment and meet the specific plant type requirements. The farmers' continuous cultivation of traditional low yield rice varieties is due to non-availability of improved varieties of their choices for the soils marred with salt stress and associated complexities.

Plant breeders tend to develop rice varieties through on-station trials and often consider yield, ability to withstand salt stress, flowering duration and height as important traits. However, farmers may have some other important unknown considerations as often reflected in the mismatch between the breeding lines selected by the farmers and lines that scientists offer for cultivation. Moreover, varieties which perform well under controlled, researcher -managed on-station experiments may yield lower or even fail in farmers' fields, where more challenges are encountered. Farmers also lay emphasis on traits that breeders might not have considered during variety development, such as more straw yield, suitable plant height, threshability, earliness, grain quality and disease resistance etc. (Ceccarelli et al., 2001). The reasons for this discrepancy include different properties, input use, and management of fields in the station experimentation and those of farmers. Participatory varietal selection (PVS) has been reviewed and described for many crops and countries (Weltzein et al., 2000). PVS has proven to be effective approach in harnessing productivity potential of varieties and increasing genetic diversity in crops (Maurya et al., 1988; Joshi and Witcombe, 1996; Joshi et al., 1997; WARDA, 1999; Witcombe et al., 2001; Bellon and Reeves, 2002). Keeping these advantages in consideration, like fast adoption of selected genotype and farmer to farmer seed dissemination network, we conducted screening and evaluation of salt tolerant rice genotypes and pre-breeding materials at on- station conditions followed by farmers' participatory varietal selection under varying sodic environments during 2001 to 2007. These experiments were conducted mostly under CGIAR-IRRI sponsored research program under Challenge Programme on Water and Food which focused on harnessing productivity potential of salt-affected soils in the Indo-Gangetic river basin with available technology.

MATERIALS AND METHODS

Screening and evaluation of genotypes

We initiated screening and evaluation of a large number of rice varieties/genotypes including local types, advanced salt tolerant materials developed at International rice Research Institute, Philippines and germplasm collected from different parts of India. A total of 126 geographically and genetically diverse rice genotypes were screened at two locations having soil pH 9.6 to 9.8 with three replications. Two rows of five meter length of each genotype were planted during rainy season on 12th July 2001 and 14th July, 2001 at research farm Shivri and farmers field respectively situated at 26° 47' 58" N and 80° 46' 24" E. Recommended package of practices for growing rice in sodic soils was followed. Genotypes were harvested according to their maturity and yield was recorded accordingly. Complete protocol followed for screening, evaluation and selection of rice genotypes across years is given in Table 6.

Participatory varietal selection (PVS)

On-station and on-farm trials (Mother trials)

Based on the performance and grain yields (>3.5 t ha^{-1}) in the screening and evaluation of large number of genotypes, eighteen genotypes shown in Table 1 were selected and subsequently evaluated in researchers managed mother trials at four locations (two on-stations and two on-farms) with three replications under randomized block design. The soil pH_2 of the experimental sites ranged from 9.4 to 9.7. Twelve rows of 5 m length under each genotype were planted during the month of July 2002. Preference analysis was conducted at maturity following the PVS protocol. The participating farmers were divided in to 3 groups (8 to 10 farmers per group), and each group was led by a researcher. First, farmers were asked to move around the field together with the scientists, observe each genotype, and search for the traits they look for in a desired variety. After that they were given two pieces of each type

Table 1. Grain yield of 18 rice genotypes selected from 126 genotypes at different locations in 2002.

Genotype	On-station		On-farm		Mean
	Shivri (pH_2 9.7)	Ainthu (pH_2 9.6)	Dhora (pH_2 9.5)	Itaara (pH_2 9.6)	
CSR-89IR-8	5.27	5.32	5.24	5.43	5.32
CSR 36	5.14	5.2	5.2	5.21	5.19
CSR 13	5.12	4.95	5.03	5.12	5.06
CSR- 2K 239	5.1	5.04	5.2	4.86	5.05
CSR- 2K 262	5.07	5.12	5.12	5.24	5.14
CSR 38	5.06	5	5	5.17	5.06
CSR 23	5.04	5.12	4.81	4.96	4.98
IR 64	5	5.14	4.86	4.86	4.97
CSR 29	5	4.97	4.96	4.96	4.97
NDR 359	4.99	5.12	4.94	5.24	5.07
CSR 27	4.93	5	4.86	4.63	4.86
CSR- 2K 219	4.87	5.02	4.73	4.82	4.86
Pant Dhan 12	4.85	5	4.73	5.03	4.9
96416	4.79	4.87	4.91	5	4.89
CSR 32	4.64	4.89	4.35	4.89	4.69
CSR 24	4.39	4.76	4.44	5.07	4.67
CSR 21	4.25	4.58	4.17	4.32	4.33
Tilak Chandan	3.95	3.8	3.7	4.03	3.87
LSD (P=0.05)	0.42	0.51	0.63	0.72	

of ballots - the check and the cross, to vote for the two most preferred and two least preferred genotypes, correspondingly. Each genotype had stick and bag with coded as G_1 to G_{18}. On the second round, farmers and scientists were asked to vote for the two best and two worst genotypes. After the voting, bags were collected, votes were tallied, and preference scores were computed. The farmers who voted for the genotypes were also asked to state the reasons for selecting the best and worst genotypes. On the basis of preference ranking /voting of the farmers on the best genotypes and grain yields, twelve genotypes were again planted at five locations (three on-stations and two on-farm) having different sodicity levels during 2003. Preference analysis was again repeated following the above procedure. Nine top yielders selected on the basis of grain yield and preference ranking, were again planted during kharif 2004 at six locations (three on-station and three on-farm) covering three highly sodicity (pH_2 9.2 to 10.3) affected districts (Unnao, Pratapgarh and Raebareli) of Uttar Pradesh lying in Indo-Gangetic river basin. Among the genotypes selected during 2004, six high yielding genotypes were planted at six (three on- station and three on-farm) different sodicity levels. To elicit the post-harvest preference for cooking and eating qualities of the genotypes identified during PVS, sensory analysis was conducted by involving 26 women and 21 men farmers.

Baby trials

Two most preferred salt tolerant genotypes (CSR-89IR-8 and CSR 36) selected from the PVS exercises, were compared with farmer's traditional varieties in sodic soils through farmers' managed baby trials during 2006. Selection of districts and villages was made on the basis of maximum area under sodic soil in the district as well as in the village. Before selecting the farmers in each village, focus group discussion was conducted to know the causes of low yield and their choice of rice varieties. Sixteen farmers having 1.0 to 1.5 ha sodic lands were selected for baby trial in three villages. One kilogram seed of two selected varieties/genotypes "CSR-89IR-8 and CSR 36" each was given to each farmer and asked them to grow nursery of each varieties/genotypes in separate beds and transplant them separately as per his prevailing practices along with their own variety. The same exercise was repeated at five different villages in the same districts during 2007. Before transplanting the seedlings, soil samples from 0-15 and 15-30 cm depth were collected from individual field to analyze the level of sodicity. The nursery for the baby trials was grown mostly during first week of June and transplanting varied from first week of July to third week of July depending upon the availability of labour, irrigation water with the farmer and onset of monsoon rainfall. The grain yield data were recorded at harvest. The varieties were compared through appropriate statistical software and stability analysis was performed as per Eberhart and Russel (1966).

RESULTS

Screening of genotypes through researchers managed trials

The grain yield data obtained after screening of 126 genetically and geographically diverse rice varieties/genotypes initially under on- station trials revealed significant genotypic differences. Based on relatively better grain yields (≥ 3.5 t ha^{-1}) under tested sodicity stress situation, 18 genotypes (CSR 13, CSR 21, CSR 23, CSR 24, CSR 27, CSR 29, CSR 32, CSR 36, CSR 38, IR 64, CSR-2K 219, CSR-2K 239, CSR-2K 262,

Table 2. Growth and yield of selected rice genotypes under different environments in 2003.

Genotype	No. of effective tillers hill^{-1}	No. of grains panicle^{-1}	Length of panicle (cm)	Test weight (g)	Grain yield (t ha^{-1}) on-station (pH_2 9.5-9.7)			Grain yield (t ha^{-1}) on-farm (pH_2 9.4-9.5)	
					Shivri pH_2 9.7	KVK Dhora pH_2 9.5	KVK Ainthu pH_2 9.4	Dhora pH_2 9.5	Itaara pH_2 9.4
CSR- 2K 262	10.0	132.0	30.5	25.7	3.86	4.02	4.21	4.62	4.82
CSR -2K 239	10.0	122.0	28.5	23.5	3.86	4.12	4.21	4.68	4.62
IR 64	14.0	110.0	30.4	25.0	3.41	3.76	4.03	4.36	4.46
CSR 38	11.0	104.0	35.2	28.6	2.92	3.12	3.46	3.60	3.85
CSR-89IR-8	14.0	142.0	31.2	26.7	4.65	4.82	4.91	5.20	5.42
CSR 29	10.0	101.4	25.2	28.2	3.49	4.10	4.23	4.10	4.35
CSR 23	12.0	134.0	25.6	25.5	3.91	4.05	4.10	4.81	4.73
CSR 13	11.0	132.0	28.5	25.6	4.23	4.40	4.53	4.76	4.82
CSR 36	12.0	150.0	31.2	29.5	4.73	5.10	4.95	5.12	5.21
NDR 359	10.6	142.0	28.7	28.0	4.35	5.02	4.98	4.93	5.00
CSR 27	11.5	137.7	24.5	26.2	4.24	5.00	4.87	4.65	5.03
CSR- 2K 219	11.0	127.0	30.5	26.4	3.92	4.65	4.53	4.73	4.74
LSD(P=0.05)	1.24	8.64	3.21	ns	0.35	0.68	0.73	0.42	0.48

CSR-89IR-8, NDR 359, Tilakchandan, Pant Dhan 12 and 96416) were found suitable for further evaluation and thus included in participatory varietal selection.

Varietal selection through farmers' participatory varietal selection

Eighteen varieties/genotypes selected through researcher's managed screening trials were planted at four locations (two on-station and two on-farm) at pH_2 9.5 to 9.7 during 2002 to assess the worth of the varieties/genotypes for stress performance across the locations. All the selected varieties/genotypes were found significantly different for their yielding ability at all the locations. The varieties/genotypes were classified into different non-significant groups based on LSD value (P=0.05) and arranged in ascending order for grain yield (Table 1). The table clearly showed the superiority of some of the genotypes across the environments. Based on the preference score (analyzed on the basis of positive and negative votes given by the individual farmer to the particular genotype) and grain yields, twelve top yielders (CSR-89IR-8, CSR 36, CSR 13, CSR- 2K 239, CSR-2K 262, CSR 38, CSR 23, IR 64, CSR 29, NDR 359, CSR 27 and CSR-2K 219) were selected for further evaluation. The results of these selected varieties/genotypes evaluated during 2003 across five (three on-station and two on-farm) locations having soil pH_2 from 9.4 to 9.7 revealed that all the genotypes differed significantly for most of the traits (Table 2). It indicated that the differential response of the genotypes for various attributes starts diminishing when grown under higher stress conditions (pH>9.7). Under moderate sodicity levels (pH_2 9.4), highest grain yield was recorded by genotype CSR-89IR-8 (4.91-5.42 t ha^{-1}) followed by CSR 36 (4.95-5.21 t ha^{-1}) and NDR 359 (4.98-5.00 t ha^{-1}). However, under high sodicity level (pH_2 >9.7), CSR 36 produced higher yield (4.73 t ha^{-1}) followed by CSR-89IR-8 (4.65 t ha^{-1}) and NDR 359 (4.32 t ha^{-1}). Overall preference ranking and crop performance indicated that CSR-89IR-8 and CSR 36 were at par but significantly superior across the locations over rest of the genotypes evaluated. The important parameters of the farmers which ranked CSR-89IR-8 on top were more number of productive tillers hill^{-1}, dwarf plant stature to combat lodging even at high fertilizer application, early maturity to facilitate timely sowing of succeeding crop like wheat, attractive long slender grains and better threshability besides higher grain yield in sodic soils. Similarly farmers preferred CSR 36, due to its higher grain yield especially in high sodic soils (pH_2>9.7), good grain type and medium maturity.

Table 3. Growth and yield attributes of different genotypes in sodic soil in 2004.

Genotype	Plant height (cm)	No. of effective tillers hill^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	Test weight (g)
CSR- 2K 219	126.15	9.10	25.24	121.20	28.74
CSR 23	123.70	13.30	23.46	134.20	26.75
CSR- 2K 239	127.05	10.20	24.70	110.23	24.72
NDR 359	104.75	10.85	25.53	124.00	28.76
CSR 13	112.20	11.70	22.07	112.00	18.73
CSR-89IR-8	95.35	14.00	21.48	142.00	27.73
CSR 27	115.10	13.10	25.20	110.00	27.50
CSR 36	116.90	13.35	22.92	150.00	27.06
CSR- 2K 262	120.55	12.00	24.30	132.00	30.03
LSD (P=0.05)	10.23	0.20	1.03	6.32	0.72

Table 4. Grain yield of rice genotypes grown at different locations in 2004.

Genotype	Grain yield(t ha^{-1}) on-station			Grain yield(t ha^{-1}) on-farm		
	Shivri (pH$_2$ 9.5)	KVK Dhora (pH$_2$ 9.7)	KVK Ainthu (pH$_2$ 9.5)	Dhora (pH$_2$ 9.4)	Itaara (pH$_2$ 9.5)	Kashrawan (pH$_2$ 9.5)
CSR- 2K 219	4.73	4.87	5.00	4.93	4.88	4.90
CSR- 2K 262	5.12	5.07	5.03	5.10	5.17	5.03
CSR 13	5.03	5.12	5.04	4.97	5.10	4.95
CSR- 2K 239	4.90	5.10	4.86	5.10	5.06	4.87
CSR-89IR-8	5.34	4.87	5.20	5.32	5.45	5.21
CSR 23	4.24	4.16	4.50	4.96	4.46	4.32
CSR 27	4.31	4.72	4.70	4.63	4.84	4.73
CSR 36	5.12	5.14	5.00	5.07	5.16	5.10
NDR 359	4.94	4.64	4.75	5.00	5.10	4.84
Plot size (m^2)	7.5	20.0	8.0	12.0	19.2	27.0
LSD (P=0.05)	0.16	0.24	0.14	0.21	0.26	0.18

Based on grain yield and preference score, nine varieties/genotypes (CSR-89IR-8, CSR 36, CSR 13, NDR 359, CSR 23, CSR- 2K 262, CSR- 2K 219, CSR- 2K 239 and CSR 27) were selected and evaluated during 2004 at high (pH$_2$ 9.7), medium (pH$_2$ 9.5) and low (pH$_2$ 9.3-9.4) at six locations (three on-station and three on-farm). The data given in Table 5 revealed that CSR-89IR-8, CSR 36 and NDR 359 were ranked as 1st, 2nd and 3rd, respectively. There is a strong significant correlation between the preference scores of male and female farmers and also between farmers and researchers. Preference scores of different varieties indicated that CSR-89IR-8 and CSR 36 were highly preferred across the locations and years. About 80% farmers preferred genotype CSR-89IR-8 followed by CSR 36 (73%) However, CSR 13 and CSR 23 were preferred by 43 and 25% farmers respectively. Significant varietal differences for yield were unfolded in the stress locations. Highest average grain yield (5.25 t ha^{-1}) was recorded by CSR-89IR-8 at all the locations followed by CSR 36 and CSR 2K 262. However, the average grain yields of CSR 36 and CSR 2K 262 across the locations was at par. Significant differences were recorded among genotypes for growth attributes and yield contributing traits across locations and sodicity levels (Table 3). From the data, it is revealed that under high sodicity conditions (pH$_2$ 9.7) genotypes CSR 36 produced highest grain yield followed by CSR 13 (Table 4). However, under partially reclaimed sodic soils (pH$_2$ 9.3 to 9.5) genotype CSR-89IR-8 gave significantly higher yield over rest of the genotypes. CSR-89IR-8 was chosen by majority of the farmers followed by CSR 36 and CSR 2K 262. Based on the preference score and yield performance, six genotypes (CSR-89IR-8, CSR 36, CSR 13, NDR 359, CSR 2K 262 and CSR 2K 239) produced average yield about 5.00 t ha^{-1} which were again evaluated during 2005 at six sodic environments (three on-station and three on-farm) . The data given in Table 7 revealed that genotype CSR-89IR-8 gave highest grain yield (5.12 to 5.23 t ha^{-1}) at all the locations and secured 1st rank due to its earlier mentioned benefits

Table 5. Preference analysis of selected genotypes.

Genotype	Total farmers (42)		Preference score (2002)	Total farmers (36)		Preference score (2003)	Total farmers (30)		Preference score (2004)
	Positive	Negative		Positive	Negative		Positive	Negative	
CSR- 2K 219	1	5	-0.023	1	4	-0.02	0	3	-0.05
CSR 23	3	1	0.011	6	2	0.03	5	1	0.03
CSR- 2K 239	1	9	-0.04	0	8	-0.05	0	8	-0.07
NDR 359	20	2	0.10	15	0	0.10	18	0	0.15
CSR 13	12	3	0.05	14	1	0.09	14	0	0.12
CSR-89IR-8	32	0	0.19	28	0	0.19	28	0	0.23
CSR 27	7	24	-0.10	3	24	-0.14	0	22	-0.18
CSR 36	28	0	0.16	23	0	0.15	26	0	0.22
CSR -2K 262	15	5	0.05	12	3	0.06	5	4	0.01

Correlation between the preference scores of male and female (r=0.91); Correlation between the preference scores of farmers and researchers (r=0.74),

$$\text{Preference score} = \frac{\text{Total positive vote} - \text{total negative vote}}{\text{Total vote casted}}$$

Table 6. Screening, evaluation and selection of rice genotypes across years.

Year	Process	Number of genotypes planted in sodic soil	Number of genotypes selected	Number of trials sites in sodic soil
2001	Screening of genotypes	126 →	18	2
2002	To conduct PVS	18 →	12	5
2003	To conduct PVS	12 →	9	6
2004	To conduct PVS	9 →	6	6
2005	Final selection	6 →	2	6
2006-2007	Up-scaling	2+ 1 (farmer variety) →	1 selected and released as “CSR43”	32

Table 7. Grain yield of selected rice genotypes grown at different locations in kharif 2005.

Genotype	Grain yield (t ha^{-1}) on-station trials			Grain yield (t ha^{-1}) on- farm trials		
	Shivri (pH$_2$ 9.5)	KVK Dhora (pH$_2$ 9.4)	KVK Ainthu (pH$_2$ 9.5)	Dhora (pH$_2$ 9.4)	Mataria (pH$_2$ 9.6)	Kashrawan (pH$_2$ 9.4)
CSR- 2K 262	5.10	5.10	5.04	5.04	4.86	5.10
CSR 13	4.96	5.05	5.00	4.87	4.80	5.10
CSR- 2K 239	4.87	5.00	4.86	4.80	4.75	4.83
CSR-89IR-8	5.20	5.23	5.12	5.12	4.96	5.23
CSR 36	5.10	5.06	5.10	5.00	5.20	5.10
NDR 359	5.00	5.10	5.00	4.91	4.87	4.89
Plot size (m^2)	10.0	12.0	12.0	27.0	12.0	10.0
LSD(P=0.05)	0.16	0.23	0.18	0.12	0.47	0.16

followed by CSR 36.The stability analysis of selected six genotypes across a total of 21 sodicity environments revealed significant differences among genotypes and highly significant interaction between genotypes and environments (Table 8). CSR 36 having regression value 0.384 (<1) and deviation from regression nearly 0 which indicates that it is suitable to the poor environments or high sodicity conditions (>9.6) as shown in Table 9. CSR-

Table 8. Analysis of variance among genotypes and environments for grain yield.

Source of variation	D.f.	Sum of squares	Mean Squares	F. Ratio	Probability
Genotypes	5	1.92205	0.38441	31.989	0.00000***
Env.+ (Geno.* Env.)	120	8.17273	0.06811	5.667	0.00000***
Environments	20	5.59786	0.27989	23.291	0.00000***
Geno.* Env.	100	2.57487	0.02575	2.143	0.00005***
Environments (Lin.)	1	5.59786	5.59786	465.829	0.00000***
Geno.* Env.(Lin.)	5	1.20494	0.24099	20.054	0.00000***
Pooled Deviation	114	1.36994	0.01202	1.000	0.50000
Total	125	10.09479	0.08076		

D.f. : degree of freedom, Env.: Environments,*** significant at 1% level of significance.

Table 9. Estimation of mean and stability parameters of genotypes.

Genotype	Grain yield		
	μ (Mean)	Bi (Regression)	S^2Di (Deviation)
CSR- 2K 262	4.897	1.74	0.01
CSR 13	4.902	1.07	0.01
CSR -2K 239	4.810	1.39	0.01
CSR-89IR-8	5.167	0.85	0.01
CSR 36	5.096	0.38	0.01
NDR 359	4.932	0.57	0.02
Population mean 4.967	4.967		

Table 10. Sensory analysis of three rice genotypes in 2005.

Genotype	Acceptability		Rank *		
	Yes	No	Female (n=26)	Male (n=21)	All farmers (n=47)
CSR 36	29	18	3	3	3
CSR-89IR-8	28	19	2	2	2
Sambha Mahsuri	44	3	1	1	1

*1: best, 2: very good, 3: good.

89IR-8 yielded second highest and exhibited higher deviation from regression which indicated that this variety is more suitable for moderate sodic soils or partially reclaimed sodic soils. Due to early maturity and good grain quality, farmers' preference for the CSR-89IR-8 genotype has increased remarkably. It matures about 20 days earlier than the local varieties which enable it to fit in very well in crop rotation for higher overall economic benefits and less water consumption.

Sensory analysis of cooked rice

To know the cooking quality and taste of the salt tolerant as well as local varieties, a sensory analysis consisting of two highly preferred salt tolerant (CSR-89IR-8 and CSR 36) genotypes and one local variety (Sambha Mahsuri) was conducted during 2005. Forty seven farmers including 26 women and 21 man participated in this exercise. Based on farmers' ranking (1 excellent, 2: very good, 3: good) for the taste, aroma, color of the cooked rice and non-cohesiveness, Sambha Mahsuri a local variety was highly preferred by the farmers followed by CSR-89IR-8 (Table 10).This shows that genotype CSR-89IR-8 was also accepted well by farmers as well as consumers due to impressive grains and better cooking quality.

Farmers' managed baby trials

The data of farmers' managed baby trials conducted

Table 11. Comparative performance of CSR 36, CSR-89IR-8 genotypes and farmer's own variety under farmers managed baby trials in 2006.

Location	Soil pH_2 (0-15 cm)	Grain yield (t ha^{-1})		
		CSR 36	CSR-89IR-8	Farmer's own variety
1	9.35	4.52	4.77	4.31
2	8.99	5.03	5.24	4.32
3	9.21	4.35	5.02	5.00
4	9.40	4.65	4.93	4.32
5	9.37	4.54	4.86	4.21
6	9.68	4.55	4.32	4.02
7	10.30	0.86	0.42	0.23
8	10.19	1.01	0.62	0.32
9	10.16	1.11	0.53	0.21
10	10.55	0.20	0.10	0.08
11	9.48	4.21	4.75	4.05
12	9.76	4.12	3.82	2.90
13	9.42	4.62	5.02	4.25
14	9.29	5.02	5.04	4.80
15	8.97	5.20	5.45	5.04
16	8.99	5.00	5.22	5.00
Mean	9.56	3.68	3.75	3.31

Table 12. Comparative performance of CSR 36, CSR-89IR-8 and farmers own variety under farmers managed baby trials in 2007.

Location	Soil pH_2 (0-15 cm)	Yield (t ha^{-1})		
		CSR 36	CSR-89IR-8	Farmer's own variety
1	9.4	4.22	4.51	4.12
2	9.6	3.34	3.14	2.80
3	9.5	4.13	4.50	3.80
4	10.0	1.12	0.86	0.14
5	9.7	3.84	3.14	2.16
6	9.4	4.32	4.74	4.15
8	9.8	2.89	1.14	0.14
9	9.6	4.24	3.94	3.12
10	9.5	4.25	4.83	4.12
11	9.2	5.50	6.20	4.62
12	9.2	5.20	5.84	4.62
13	9.7	4.48	4.07	3.36
14	9.8	3.21	1.34	0.21
15	9.6	4.25	4.14	3.84
16	9.4	4.52	5.10	4.42
Mean	9.56	3.96	3.83	3.04

across 2 years revealed that genotype CSR-89IR-8 and CSR 36 gave higher yield over the farmers' own variety at almost all the locations (Tables 11 and 12). CSR-89IR-8 yielded more than CSR 36 and farmer's own variety where pH_2 was < 9.6. However, CSR 36 gave higher yields where pH_2 exceeded 9.6. After two years of farmers managed baby trials, a household level feedback survey was conducted during 2008 which revealed that the adoption rate of CSR-89IR-8 increased from 22.09% in 2007 to 36.36% in 2008 (Table 13). However, the adoption rate of traditional variety NDR 359 reduced from 34.25 to 26.18%.The reason behind fast adoption rate of

Table 13. Adoption of rice varieties in sodic soils from a survey of 181 and 298 farmers in 2007 and 2008, respectively.

Genotypes	Number of adopters		Adoption percentage of total farmers surveyed	
	2007	2008	2007	2008
Narendra 359	62	72	34.25	26.18
Sona Mahsuri	32	44	17.67	16.00
Pant 12	27	32	14.91	11.63
CSR 13	20	40	11.04	9.81
CSR-89IR-8	40	100	22.09	36.36
Total farmers	181	298		

genotype CSR-89IR-8 is its higher yield in sodic soils due to genetic tolerance, medium dwarf stature to combat lodging, better grain quality and early maturity for beneficial crop rotation than the traditional varieties which could help in timely sowing of succeeding wheat crop as reported by 100% responding farmers. Because of its early maturity, about Rs. 2400 ha^{-1} (about US $ 60 ha^{-1}) could be saved on account of 2 to 3 additional irrigation otherwise required for growing of long duration traditional rice varieties. Our survey also revealed that 23% farmers emphasized to grow green manuring crop in between rice and wheat crops for additional benefits in terms of saving of about 40 kg N ha^{-1} in wheat. In addition, due to attractive appearance and shape of the grain, farmer's and traders perception on market price of the variety has remarkably changed. During 2008 market acceptability of genotype CSR-89IR-8 was higher than the traditional varieties like Sona Mahsuri and Narendra 359 grown in sodic areas because of its long slender attractive grains suiting to puffed rice making.

Up-scaling and adoption of salt tolerant genotypes

Based on the performance of the promising selected genotypes in different trials conducted in sodic soils, farmers liking and market rate, the adoption of genotype CSR-89IR-8 in sodic areas increased remarkably year after year through "seeing is believing" approach. Consequently about 40 farmers covering about 20.0 ha area planted CSR-89IR-8 during 2007 in adopted villages where PVS trials were conducted. During 2008, the adoption of the genotype increased to 98.35% over 2007. On the contrary, the adoption rate of highly popular variety 'Narendra 359' which has been recommended for normal high yielding environments got reduced to 23.55% over the previous year in target sodic areas. During 2007, one farmer Mr. Daya Ram produced about 1.2 ton seed of genotype CSR-89IR-8 and sold to 40 farmers through inter-farmer seed dissemination mechanism at $260 t^{-1}. Anticipating its popularity in the succeeding year Mr. Daya Ram grew this genotype in about 1.0 ha land and produced 5.2 ton seed. He sold 4.2 tons seed to the farmers during 2008. By the end of 2008, this genotype got disseminated to 100 farmers covering 60 ha sodic soil. By this time he had become a promising seed producer whose per hectare net income increased from $260 to $580 ha^{-1}. Keeping in view the performance in terms of grain and straw yield, farmer's preference, adoption rate and market prices, a proposal was submitted to government of Uttar Pradesh in 2011 to release this genotype (CSR-89IR-8) as variety "CSR 43". The government has accepted the proposal and released it as CSR 43.

DISCUSSION

Participatory variety selection is becoming quite popular and relevant in enhanced adoption and crop productivity. Witcombe (2002) has discussed and highlighted the concept of Mother and baby trial in rice. Farmer's Participatory varietal selection is reported to be a rapid, cost-effective and reliable way of identifying farmer-preferred cultivars (Joshi and Witcombe, 1996; Witcombe et al., 1996). Its effectiveness identifies the need to organize outreach research on participatory lines. It contributes not only to the dissemination of farmer-preferred varieties through farmer-to-farmer networks but also to the up scaling of locally adapted and suitable technologies through a decentralized technology testing process (Joshi et al., 1997).

Importantly, participatory programme conducted in sodic soil environment through IRRI-India collaboration and described in this paper has confirmed the relevance and utility of participatory approaches to such disadvantaged environments as well. On-station conventional testing of large number of genotypes helped to find out the suitable rice germplasm for stress environment. We started our program with the screening of large number of rice germplasm and breeding lines under moderate sodicity stress. Selection of promising salt tolerant genotypes during first stage of screening was followed by their evaluation at on-station and on-farm conditions. Farmers were involved throughout the cropping period to assess the worth of the genotypes across the locations and stresses and to elicit their response. Based on four years of PVS studies, it was observed that there was a differential response of the genotypes for various attributes which starts diminishing when grown under higher stress conditions. Preference analysis to rank the varieties was based on the liking of both men and women farmers. Upon analysis, it was revealed that farmers considered various growth and yield attributing traits like plant vigour, plant height, number of tillers, flowering duration, length of panicle and grain type and grain yield etc during variety ranking. Based on the preference score given to the individual genotype by the different category of farmers CSR 43 (Earlier 'CSR-89IR-8') was ranked as 1st choice in most of the cases. The present studies revealed that, farmers generally preferred sodicity tolerant, short duration rice varieties for early harvesting near festival season and also because of timely sowing of succeeding crop like wheat etc. The CSR 43 genotype matured about 20 days earlier than the local late varieties which could be helpful in timely sowing of succeeding wheat crop and saving water for irrigation. It was estimated that because of early maturity, about Rs. 2400 ha^{-1} (about US $ 60 ha^{-1}) could be saved on account of 2 to 3 additional irrigation required for growing local varieties. Moreover, such water saving alternatives could be extremely useful to ward off the problems of depleting water table in such regions. However, it is suggested to conduct further precise studies to quantify the impact of early duration sodicity tolerant rice varieties in conferring advantages in sodic soils of higher rice yield, water saving and elevated yield of succeeding crop due to timely sowing etc.

In India, of the approximate 3.8 million hectare land affected by sodicity or poor quality ground water, about 1.29 million hectare falls in the state of Uttar Pradesh only (Sharma et al., 2004) where present variety interventions were introduced. The socio-economic situation in such unfavorable environments in the eastern Indo-Gangetic plains is mostly characterized by resource poor farmers with small land holdings. These mostly represent economically disadvantaged section of society having little access to chemical amendments like gypsum to restore and normalize their lands affected with sodicity. To restore the agricultural potential of these areas and to cater to specific needs of such production systems, previous works on varietal improvement for salt affected soils have amply demonstrated the potential of salt tolerant varieties in alleviating the stress problems effectively and economically with minimum investments on chemical amendments (Singh et al., 2004; Gautam et al., 2010; Singh et al., 2009). Moreover, with the onset of reclamation and cultivation of rice in sodic lands, soils tend to become "normal" after 3 to 4 years (Chhabra and Abrol, 1977; Tyagi, 1998; Swarup, 2004) thus giving place to other high yield potential varieties. Thus growing of sodicity tolerant rice varieties is crucial during initial 3 to 4 years of land reclamation particularly for resource, scare farmers primarily due to two reasons. Firstly, reclamation becomes economically feasible due to less gypsum requirement for getting more yields from sodic lands and secondly more roots and plant biomass hastens the reclamation process.

Recently, the adoption rate in terms of number of farmers growing CSR 43 and area under this variety is increasing over the years than the other prevailing varieties. Nevertheless, area is a more erratic variable because, even when a farmer has decided to adopt a variety, the area in which it is cultivated is determined by availability and severity of sodic land per household and this differed within and among villages. The severity of sodicity is also reduced due to cultivation of rice especially with salt tolerant varieties (Tyagi, 1998; Chhabra and Abrol, 1977).

Farmer-to-farmer seed dissemination of new rice variety "CSR 43" provides an example of the magnitude of the spread that can take place through farmers' networks in sodicity stressed areas. A few kilograms of seed given to farmer Mr. Daya Ram for PVS purpose elicited great interest and response among several farmers of nearby areas. Expecting good performance, he produced several hundred kilograms seed within two seasons and sold to about 100 farmers. The observations on yield data and feedback about CSR 43 were obtained across villages from even other adjacent districts of the UP state over years in CPWF-IRRI project areas.

It is also further added that CSR 43 was also nominated in the National trials on Salinity and Sodicity simultaneously and was tested for four years across states; however it was found quite promising only in the sodic soils of UP state. Therefore, CSR 43 was included in the PVS trials in the state wherein it received good response.

The performance data of national trials conducted within UP state complimented with PVS mother and baby trials data across years were used to prepare the release proposal. Judging its overall performance across years and locations and keeping in view stakeholders' enormous response, the proposal of CSR 43 (the name CSR89-IR8 before release) was prepared and submitted to UP State Variety Release Committee which approved it in 2011 for general cultivation in sodic areas of the U.P. State.

Sensing the uptake potential of this genotype among end users, it was considered imperative to offer this product to the public system through its release and inclusion in the official seed chain, because in India the final approval of release ensures the eligibility of variety for its notification in the national gazette of varieties. Resultantly, the new variety finds place in the official seed chain of Breeder to Foundation to Certified seed. The government departments, different state agencies and NGO's are working for the reclamation of sodic soils in the state through which indent for the breeder seed of sodicity tolerant varieties is mobilized every year for meeting the larger requirement and variety spread. It is also emphasized here that for the release of new varieties, testing of new genotypes in national or state variety trials under researcher managed conditions and farmers' participatory variety selection trials should not be mutually competitive but complementarily between two should be promoted for the larger success of released varieties, because the former approach ensures systematic evaluation under standard agronomic recommendations across wider locations, whereas the later elicits the specific preference requirements of the beneficiaries under their own management. Our experience in sodic soils has shown that most of the tolerant germplasm of rice survives and gives satisfactory yield up to pH~9.5, however quite few genotypes give satisfactory performance between narrow range of pH~9.6 to pH~10.0 because with every decimal increment from pH~9.6, survival and yield are noticeably reduced. The variety CSR36 gives best yield advantage when soil pH exceeds 9.6 whereas CSR43 imparts yield superiority upto pH~9.6 as shown in Tables 9 and 10, besides its other important attributes of early maturity, lodging resistance due to semi-dwarf stature and better grain quality due to very long slender grains. Therefore, the two varieties CSR43 and CSR36 derived from crosses KDML 105 / IR 4630-22-2-5-1-3/ IR 20925-33-3-1-28 and CSR13/IR36/Panvel-2, respectively are not mutually competitive but are suited to specific sodicity regimes plausibly due to their different genetic mechanisms of tolerance imparted by different genic combinations. CSSRI, Karnal is now producing Breeder seed of CSR 43 for meeting the requirements of various stakeholders in sodic areas. Further up-scaling of the CSR 43 is being done through more demonstration trials conducted by the nearby Farm Science Centre (*Krishi Vigyan Kendra*) which facilitates the dissemination of the sodic land reclamation technologies in the target areas. Similarly, Witcombe et al. (1999) reported that seed distribution of upland rice in eastern India was higher from a non-project village than from the project villages. This is an important finding, since the less-intensive system promoted greater self-reliance on seed production and dissemination than favorable environments. The findings of our experience indicate that there is emerging need of understanding farmers' preference for variety selection and considering PVS results in the official system of variety release process. This is required more so in the resource scarce situations of marginal farmers under salt stressed environments where variety technology offers cheap and economically viable solutions.

Conclusions

Development of varieties for unfavorable sodic environments through farmers' participatory varietal selection strategy was first attempt of this kind under CSSRI-IRRI collaborative projects. This gave opportunities to the farmers to pick up varieties suiting to their specific needs through their own selections made at their own field and management. It also provided good opportunities to the researchers to contribute and subject their breeding materials and varieties to farmers' selection for harnessing the benefits of biological tolerance under salt affected areas where livelihoods of most families depend on rice. The results from this study are being used to build a large communication strategy to motivate farmers for selecting the suitable variety to increase farm yields. Our experience showed that development and selection of variety through PVS is the most effective and reliable approach which can be organized by the researchers , government extension agencies and NGOs in salt affected areas which are mostly inhabited by resource poor farmers. After selection and identification of potential variety, the major challenge will be reforming the policies and guidelines so that appropriate weightage of participatory results could be officially incorporated into varietal testing, release and extension systems. More germplasm and varieties need to be evolved on the basis of participatory data to cater to the diversity of niches found in salt affected environments. Such policy changes are quite important because the yield gains from varietal replacement in salt affected environment although are likely to be lower in percentage terms than those found in more productive agricultural environments, but can contribute to higher absolute gains in yield per unit area. The successful results and achievements of PVS in release of CSR 43 and large scale adoption of CSR 43 rice variety in sodic expanse of eastern Indo-Gangetic region can be potentially quite useful in translating the gains of salt tolerance into reaping higher rice productivity under stress environments on sustainable basis. Our experience suggests that appropriate weightage of farmers 'preference and rating should be incorporated in the process while considering approval of new varieties for release for disadvantaged salt stressed and resource scarce conditions.

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