CPWF Project Report

Development of technologies to harness the productivity potential of salt-affected areas of the Indo-Gangetic, Mekong, and Nile River basins

Project Number 7

Author name: Abdelbagi M. Ismail

International Rice Research Institute

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Project Partners:

NARES

Bangladesh Rice Research Institute, Bangladesh

Central Rice Research Institute, India

Central Soil Salinity Research Institute, India

Narendra Dev University of Agriculture and Technology, India

Cuu Long Delta Rice Research Institute, Vietnam

Rice Research Institute of Iran, Iran

Advanced Research Institutions

Rice Research and Training Center, Egypt

International Rice Research Institute

International Center for Biosaline Agriculture

International Crops Research Institute for the Semi-Arid Tropics

University of California, Davis

Program Preface

The Challenge Program on Water and Food (CPWF) contributes to efforts of the international community to ensure global diversions of water to agriculture are maintained at the level of the year 2000. It is a multi-institutional research initiative that aims to increase the resilience of social and ecological systems through better water management for food production. Through its broad partnerships, it conducts research that leads to impact on the poor and to policy change.

The CPWF conducts action-oriented research in nine river basins in Africa, Asia and Latin America, focusing on crop water productivity, fisheries and aquatic ecosystems, community arrangements for sharing water, integrated river basin management, and institutions and policies for successful implementation of developments in the water-food-environment nexus.

Project Preface

Development of technologies to harness the productivity potential of salt-affected areas of the Indo-Gangetic, Mekong, and Nile River basins

This project emphasized the development and deployment of high-yielding salt-tolerant rice varieties and nonrice crops, together with matching management practices, to enhance and sustain system productivity in coastal and inland salt-affected areas. Integrated and participatory approaches were designed and implemented at the research, delivery, and uptake levels to tackle the enormous complexity of challenges in these areas. More intensive and diversified cropping systems were validated to improve farmers' income and livelihood and preserve the environment. Apparently, tremendous opportunities exist to make use of these marginal resources to meet the rising and pressing demands for food and water.

CPWF Project Report series

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Abbreviations

AICRIP	All India Coordinated Rice Improvement Program
BFRI	Bangladesh Fisheries Research Institute
BRRI	Bangladesh Rice Research Institute
CGIAR	Consultative Group on International Agricultural Research
CLRRI	Cuu Long Delta Rice Research Institute
CNRM	crop and natural resource management
CPWF	Challenge Program on Water and Food
CRRI	Central Rice Research Institute
CSSRI	Central Soil Salinity Research Institute
DAE	Department of Agricultural Extension
DAT	days after transplanting
DNA	deoxyribonucleic acid
DRC	Desert Research Center
DS	dry season
DSW	disappearance of standing water
FGD	focus-group discussion
FVIM	farmers' variety with improved management
FVM	farmers' variety with farmers' management
FYM	farmyard manure
GM	green manure
GO	government organization
GWT	groundwater table
ICARDA	International Center for Agricultural Research in the Dry Areas
ICBA	International Center for Biosaline Agriculture
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IGB	Indo-Gangetic Basin
INGER	International Network for Genetic Evaluation of Rice
INM	integrated nutrient management
IPG	international public goods
IRRI	International Rice Research Institute
IRSTON	International Rice Salinity Tolerance Observation Nursery
IRSSTON	International Rice Soil Stress Observational Nursery
IVFM	improved variety with farmers' management
IVIM	improved variety with improved management
MABC	marker-assisted backcrossing
NARES	national agricultural research and extension systems
NDUAT	Narendra Dev University of Agriculture and Technology
NIL	near-isogenic line
NGO	nongovernment organization
NSB	National Seed Board
OYT	observational yield trial
PRA	participatory rural appraisal
PVS	participatory varietal selection
PYT	preliminary yield trial
QTL	quantitative trait loci
RCBD	randomized complete block design
RDA	Rural Development Academy
RIL	recombinant inbred lines
RRII	Rice Research Institute of Iran
RRTC	Rice Research Training Center, Egypt

SCA	Seed Certification Agency
SES	Standard Evaluation System
SSR	simple sequence repeat
STW	shallow tube well
SYT	secondary yield trial
TE	transpiration efficiency
TP	transplanting
UCD	University of California, Davis
WS	wet season

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RESEARCH HIGHLIGHTS

High salt stress is a major cause of low productivity across large rice-producing inland and coastal areas. Coastal salinity, caused by marine influences, is severe during the dry season (DS), whereas flooding in the wet season (WS) limits cropping to rice. In inland areas, both salinity and sodicity are common and gradually expanding because of improper water management practices. Rice is best suited to revitalize these lands because it can thrive in water and has excellent potential for genetic improvement; however, its productivity is low in these areas. This project attempts to enhance land and water productivity of rice-based cropping systems in salt-affected areas by integrating genetic improvement and management strategies that are environmentally sustainable and socially acceptable. With 11 partners in five countries, the project made considerable contributions through its five activities. A strong partnership and ownership were established and an effective network approach was implemented for the exchange of material and knowledge. Through *socioeconomic and biophysical characterization* of target areas*,* baseline and socioeconomic surveys covered most project sites and data analysis and reports were completed using both primary and secondary data. Synthesis reports on farmers' practices and coping strategies were compiled. Changes in farmers' practices and livelihood were monitored and major shifts in cropping patterns were noted, for example, in southern Bangladesh, Vietnam, and India. These changes became feasible after short-maturity salt-tolerant varieties of rice and other crops became available and best agricultural practices were developed. Synthesis reports showed that adoption of new interventions is increasing among farmers and is associated with higher farmers' income and lower production costs. These studies reflected great potential for improving farmers' livelihoods through improved and more stable rice-based system productivity, lower production and reclamation costs, and better income. They also provided useful information that can help identify technological constraints and gaps, as well as opportunities, for effective interventions. Success stories were documented showing positive changes in farmers' conditions, although in limited areas, reflecting the urgent need for outscaling.

Greater emphasis was devoted to *germplasm enhancement* as an entry point for improving productivity in salt-affected areas. Efforts included (1) developing and using innovative breeding tools, such as marker-assisted backcrossing (MABC), to speed up breeding; (2) strengthening the capacity of local breeding programs; and (3) exchanging and testing new varieties of rice and nonrice crops with farmers. An MABC system was developed and is being used at IRRI and BRRI to introduce *Saltol,* a major DNA locus for salinity tolerance*,* into popular varieties, thus substantially shortening the breeding cycle. New breeding material was also developed and tested by partners and, together with the material being sent regularly via INGER, new lines were selected and are increasingly being used by farmers. Some of these breeding lines were in advanced stages of testing for release. Recently released varieties CSR23, 30, and 36 in India were being outscaled, while others were released through the project, such as BRRI dhan47 for the DS in coastal Bangladesh, showing great impact in increasing the area under DS rice. Excellent progress was made in the collection and evaluation of landraces from salt-affected areas in different countries as potential donors in breeding. ICRISAT identified numerous salt-tolerant varieties of chickpea, pigeonpea, groundnut, sorghum, and millet and began testing them at target sites in India. ICBA identified salt-tolerant grain and forage crops, which are tolerant of salt stress but early-maturing (sorghum, millet, barley, triticale, fodder beet, and rapeseed), and tested them in Egypt and Iran. Seed demand for these crops is increasing and farmer-to-farmer seed exchange is taking place. These nonrice crops facilitated diversity and increased cropping intensity, and hold great promise for outscaling.

Efficient management practices were developed and validated to maximize the performance of tolerant crops and are further being outscaled through PVS trials. Cropping sequences for saline areas were adjusted for duration and to identify the most appropriate crops for the target areas. Options such as direct seeding, nursery management, optimizing seedling age, stage-specific water management, improved irrigation management, liming, low-cost reclamation measures, combining green manures, press mud, and genetic tolerance, and cropping sequences using early-maturing high-value crops are being disseminated. Freshwater harvesting in local canals or in village ponds helped in expanding DS crops. In alkaline soils, the use of cheaper amendments such as press mud, fertilizers, and FYM, in combination with tolerant varieties, reduced gypsum requirements to 25% of the recommended dose for reclamation. In coastal areas, proper nursery practicies coupled with the use of biofertilizers such as *Sesbania* and *Azolla*, and early planting of early-maturing salt-tolerant varieties to avoid high salinity at flowering, were effective and are currently being outscaled through PVS trials. Combining improved varieties with best practicies increased yield by 75–90%. Crop intensification using salt-tolerant rice and nonrice crops (oil, fodder, pulses, vegetables, etc.) and fish/shrimp culture during the DS enhanced food security and provided employment opportunities, especially for women. ICRISAT and ICBA brought new nonrice crops not known to farmers in these predominantly rice areas, which hold great potential for enhancing food security and farmers' income. Interaction with farmers was greatly enhanced through farmers' days, workshops, and fairs. Proper salinity monitoring is in place and extension material in local languages was prepared by several centers. The lack of sufficient high-quality seeds of salt-tolerant varieties and adequate inputs was recognized as the main constraint for successful dissemination. NARES partners' capacity was strengthened through different training activities. The project brought together diverse partners, some of them for the first time, uniting effective teams within and between NARES and advanced research institutes, providing matchless intellectual strength.

EXECUTIVE SUMMARY

High salt stress is an exacerbating problem, resulting in low productivity and land degradation in both coastal and inland areas. Coastal salt-affected areas vary temporally in water availability and salt accumulation, with salinity caused by seawater intrusion and shallow saline water tables. Intrusion is more severe during the DS. In inland areas, both saline and sodic soils are widespread and progressively expanding because of improper water management practices. Rice is suitable for rehabilitating these salt-affected soils because it can grow under flooded conditions and has high potential for genetic improvement for salinity tolerance. In both coastal and inland salt-affected areas, rice productivity is very low and could be raised by 1.5–2.0 t/ha, providing food for millions of the poorest people living off these lands. The ability to produce more food by using land and water resources that are otherwise unusable would reduce pressure on more favorable areas, thereby improving overall water productivity by making use of areas with poor soil and water quality. The goal of this project was to ensure food security and better livelihood of resource-poor farm families through the development and deployment of high-yielding salt-tolerant rice varieties and nonrice crops, with improved crop and natural resource management (CNRM) practices as well as suitable crop diversity options. The project involved 11 participating institutions, including seven NARES in five different countries. A strong partnership and ownership were established and an effective network approach was implemented for the exchange of material and knowledge. Achievements by the participating institutions are briefly summarized here.

Germplasm development for salt-affected areas: IRRI, UCD, ICRISAT, and ICBA

At **IRRI**, several thousand landraces and breeding materials were characterized for their tolerance, and more than 200 of them were characterized for physiological components. New sources of tolerance were identified and are being used in breeding as well as for mapping new genes for tolerance at both the seedling and reproductive stage. Among the new sources are Akundi, Ashfol, Capsule, Jatai Balam, Kuti Patnai, Cheriviruppu, Kalimekri 77-5, TKM6, Bhura Rata, Mushkan 41, Kalarata 1-24, Bhirpala, IR4630-22-2-5-1-3, and Kajalsail. Mapping populations were also developed using several donors. The *Saltol* region was saturated with more than 30 markers and is being introgressed into several popular varieties. UCD made good progress in annotating this locus and in short-listing potential candidate genes, which are currently being analyzed. Substantial progress was also made in understanding the basis of tolerance of salt stress in both rice (IRRI) and nonrice (ICRISAT) crops. Conventional breeding using multiple crosses to combine tolerance traits is being employed at IRRI and several hundred crosses were made each year and advanced for testing and selection. A strong network of partners was established through the International Rice Salinity Tolerance Observation Nursery (IRSTON) as part of the INGER network specifically for sharing and evaluating salt-tolerant germplasm. These efforts culminated in the selection of several breeding lines by each partner institute, of which some were released and others are in the pipeline for release as commercial varieties. At **ICRISAT**, the aim was to identify salt-tolerant nonrice crops to complement rice-based cropping systems during the DS in areas where salinity is too high for rice. Large-scale phenotyping facilities were established and used for screening nonrice crops, allowing much germplasm from reference collections of chickpea, groundnut, and pigeonpea, as well as breeding lines of pearl millet and sorghum, to be tested under saline conditions. Several salt-tolerant accessions within each crop were identified and some were field-tested in Orissa and Uttar Pradesh, India. Significant progress was also made in understanding the physiological basis of tolerance in these crops and mapping populations were developed and are being used for genetic analysis and for breeding. These crops are in high demand as rotation crops with rice, particularly in coastal areas. **ICBA** focused on large-scale screening of field and fodder crops to identify accessions that are highly tolerant of salt stress to fill gaps in rice-based cropping systems in salt-affected areas. A few accessions of sorghum, barley, triticale, fodder beet, forage brassica, pearl millet, and safflower were identified that can perform well under medium and high salt stress. Some of these materials were shared and evaluated by partners in Egypt and Iran. These crops provide options for forage and seed production, most with shorter duration that can fit into current cropping cycles and meet the high demand for forages. Moreover, these forages are highly palatable and nutritious, and can be fed fresh, dry, or as silage.

Coastal India, CRRI.

Soil salinity is a persistent problem in India, resulting in low and unstable crop productivity on more than 6.6 million ha of cultivated lands. Coastal salinity persists in nine states on both the east and western coasts. The east coast accounts for more than 60% of the salt-affected coastal lands, 75% of which are in West Bengal and Orissa. In coastal Orissa, salinity is severe because of seawater intrusion and the rise of shallow saline groundwater, especially during the dry season, but this condition decreases with freshwater flushing in the wet season, limiting cropping mainly to rice. Rice productivity, however, is very low (1.0–1.5 t/ha) due to a lack of suitable varieties, unavailability of good-quality irrigation, and poor management techniques. Other abiotic stresses such as drought, flash floods, and cyclonic disturbances during October-November also contribute to low productivity, and the area is mostly rainfed and monocropped with rice. Drought and salinity at the seedling and reproductive stages and submergence at the vegetative stage are major problems. A benchmark survey was conducted to understand the biophysical aspects of the area and to assess farmers' socioeconomic conditions, existing farming practices, constraints to rice production, and technology needs. This served as the basis for selecting various technology options. Improved salt-tolerant rice varieties, CNRM practices, and rice-based cropping systems were validated through farmers'

participatory research, and then disseminated by conducting farmer-managed demonstration trials, organizing farmers' field days and visits to experimental sites, publishing and distributing extension materials, and using mass media. Finally, impact assessment was made toward the end of the project. Farmers generally grow local rice varieties with low yield potential. In the varietal improvement program, landraces were collected from coastal saline areas and evaluated for salt tolerance at the seedling stage. Some of the tolerant ones were used as donors to transfer the gene(s) into popular high-yielding WS varieties. For the dry season, a few IRRI lines were used as donors. A large number of salt-tolerant rice varieties/elite lines were evaluated in farmers' fields during the wet and dry seasons. The promising ones were selected through participatory varietal selection (PVS) for further testing through the mother-baby trial approach. A few CRRI lines are in advanced stages of testing for release. Efforts were begun to incorporate the *Saltol* QTL into popular varieties through MABC. A poor crop stand and low fertilizer inputs are the main causes of poor and unstable rice yields in coastal saline ecosystems with multiple stresses. Appropriate crop establishment and nutrient management options were validated through participatory on-farm trials. The use of older (40–50-d-old) seedlings raised with good nursery practices and transplanted at closer spacing (15 × 10 cm) in the WS and early planting (1st week in January) in the DS significantly improved crop survival and yield. The use of *Sesbania* as a green manure (GM) for intermediate lowlands (0–50 cm water depth), *Sesbania* + prilled urea (PU), and *Sesbania* + *Azolla* for shallow lowlands (0–30 cm) in the WS, and *Azolla* + PU in the DS, was found promising. In both seasons, the use of improved rice varieties even with farmers' management significantly increased yield, but even more so when combined with best practices where a substantial yield advantage (91% in the WS and 75% in the DS) was achieved. Because of the scarcity of fresh water during the DS, the introduction of less water requiring salt-tolerant nonrice crops is important for increasing cropping intensity as well as land and water productivity. Selected nonrice crops such as sunflower and chilli for high salinity and okra, watermelon, and pumpkin for medium salinity looked promising. Watermelon and pumpkin could also be grown under high salinity when fresh water is available, while a few varieties of sweet potato with good yield potential under medium to high salinity were identified. Lime application (1.0 t/ha) significantly increased the yield of sunflower, watermelon, okra, and groundnut. Marginally saline (2.4–3.1 dS/m) water could be used safely for 2 weeks during the vegetative stage under high salinity. Providing irrigation 2 days after the disappearance of standing water during the vegetative stage produced as much yield as continuous ponding, thus saving fresh water and helping in expanding cropping area. The highest yields of sunflower and groundnut were obtained with 4 cm of irrigation at 15-d intervals. Validated technologies such as improved rice varieties, the use of older seedlings and closer planting (WS), early planting (DS), *Sesbania* green manure (WS), *Azolla* biofertilizer (DS) and promising nonrice crops, lime application for nonrice crops, and technology packages for rice were disseminated through PVS trials. Considerable yield improvements were observed despite the variability in salinity and farmers' practices. Seeds of promising rice varieties and nonrice crops were provided to farmers for dissemination and outscaling. The most prominent achievement of this project was the expansion of DS farming and its contribution to food security in this area, where 4–6 months of hunger were not uncommon in the past. DS rice area increased dramatically from a mere 5% in 2004 to 36% in 2008. Many farmers leased lands for rice cultivation. Farmers now depend more on the less risky DS rice than on WS rice. Area under nonrice crops increased from almost negligible in 2004 to about 10% in 2007. Encouraged by these outcomes, an NGO (World Vision) started a project for constructing irrigation networks to provide fresh river water to these areas. Nearly 90% of the rice area of interviewed farmers was under early planting in 2008. The use of older seedlings, closer planting, *Azolla*, and *Sesbania* green manure is also being adopted and demand for seeds of improved rice and nonrice crops is increasing rapidly.

Shatkhira, coastal Bangladesh, BRRI.

More than 30% of the cultivable land is in the coastal zone and about 0.85 million hectares are salt-affected. The project sites were characterized and socioeconomic data were collected as for other sites. Challenges are similar to those of coastal Orissa, with rainfed rice in the WS and with the area under DS rice expanding where freshwater resources are available. In areas where salinity is high, shrimp culture is being practiced. Extensive efforts and progress were made to develop salt-tolerant high-yielding varieties. Large numbers of crosses were made each year and advanced and selected, and an extensive network of PVS trials was undertaken each year for germplasm evaluation. These efforts culminated in the release of BRRI dhan 47 as the first DS salt-tolerant variety in Bangladesh. This variety resulted in a substantial increase in DS rice, even in areas that have not been used before because of high salinity. Numerous elite breeding lines for both the DS and WS were also in the pipeline for release. In partnership with CN10, effective water management options and cropping sequences were developed that could at least double annual productivity. The soil in this delta seems relatively fertile and the nutrient management options developed for normal soils seem to work well for these saline soils, with little or no benefits from additional fertilizers, except that some response was observed with additional P and Zn. Monitoring of water salinity in nearby rivers suggested great potential for using surface water for a considerable part of the DS. Optimized rice-shrimp systems were demonstrated that can be more stable and profitable. Numerous farmers and other project stakeholders were trained in the relevant fields.

Coastal Mekong Delta of Vietnam, CLRRI.

Without doubt, 2004-08 witnessed significant achievements and valuable products in salt-affected areas of South Vietnam, thanks to the skill and commitment of CP 7. Substantial progress was made through the various project activities. Salt-tolerant improved varieties that suit different ecologies and less favorable areas were developed and several new varieties of rice were released for farmers (OM 4498, OM 5930, OM 5636, OMCS 2008, OM 4668, OM 4900, OM 6073). Other varieties of important crops were also released, such as maize (Bap Nep), peanut (OMDP 13), soybean (OMDN 1, OMDN 29), and mungbean (OMDX 1, OMDX 8). Moreover, additional elite breeding lines are in their final testing, including promising genotypes of mungbean, soybean, and peanut. Other promising rice lines such as OM 4900, OM 6073, OM 6377, and OM 6162 were developed that can yield 4 t/ha in salt-affected areas and are being outscaled; some currently cover more than 20,000 ha. For coastal areas, farmers demanded high-yielding, salt-tolerant, medium- to long-stature, and submergence-tolerant rice varieties and, for these areas, genotypes such as Mot Bui Do, Soc Trang 5, Ham Trau, OM 2395, and AS 996 were introduced that increased the productivity in coastal saline rice lands and farmers' income. Crop and nutrient management options were also developed for these new varieties. New cropping sequences were tested over the past few years. These involved the development of high-yielding, early-maturing varieties of rice and nonrice high-value crops such as soybean and peanut, for areas where water resources are relatively scarce during the dry season in Tra Vinh Province. The model rice-tiger shrimp was considered to be suitable for salt-affected soil, generated good income and social benefits, and increased rice grain yield by more than 20% compared with rice monoculture. Vietnam also sent to Laos and Cambodia 20 rice varieties, 5 soybean varieties, 5 peanut varieties, and 5 varieties of mungbean. Also, 10 new varieties of rice were shared with Indonesia, 33 new early-maturing varieties were sent to IRRI, and 8 of each were sent to Bangladesh and Myanmar. The novel early-maturing high-yielding varieties developed by CLRRI were found to be very useful in these countries to allow improved cropping intensity and diversity and higher annual production. These exchange activities significantly strengthened collaboration and linkages between research institutions of Vietnam and IRRI and with other participating countries.

Nile Delta of Egypt, RRTC, and Caspian Sea, RRII.

Salinity is a constant challenge in Egypt because of the dry climate, and more salt being carried by the Nile River as a result of pollution, water shortage, seawater intrusion, and human practices. More than 0.9 million ha of agricultural lands in Egypt are currently salt-affected, and this area is being targeted for rice production. This is to substitute for the area being forced out of rice in favorable lands of the delta because of water scarcity. Rice is still a major contributor to Egyptian food security and income, as it currently constitutes more than 5% of the country's GDP. Therefore, exploring salt-affected areas is essential to maintain their rice production. Despite the late start of the project in Egypt, significant progress was made under this project via the detailed characterization of salt-affected areas and farmers' strategies, the development and large-scale testing of genotypes suitable for salt-affected areas, and in developing and outscaling water, crop, and natural resource management. Considerable efforts were devoted to site testing and selecting varieties in farmers' fields, together with matching crop and natural resource management (CNRM) practices within a farming systems context, in partnership with men and women farmers and the assistance of extension services. Practices that could further augment rice salt tolerance and grain and water productivity were evaluated, such as the use of biofertilizer, bio-remediation, organic fertilizer management, enhancing seedling vigor, bed-planting methods to save water, as well as proper management and reuse of drainage water or low-quality water for irrigation. Opportunities to extend the duration of freshwater availability were explored to enable cropping intensification and diversification of income-generating activities for improving farmers' livelihoods. Besides rice, new salt-tolerant forage crops were introduced through ICBA for testing as part of the cropping system to enhance intensity and income. Special emphasis was devoted to training farmers and extension personnel in the proper use and management of the new salt-tolerant varieties at target sites. The increase in yield under such areas is expected to exceed 2 t/ha as a consequence of these new interventions, and this will considerably contribute to the country's efforts to enhance farmers' livelihood and alleviate poverty. Assuming that 30% of the area will soon be covered with these new salt-tolerant varieties and best integrated management practices, the potential increase in rice productivity is expected to exceed 400,000 tons of rice.

In the Caspian Sea basin, salinity is becoming a major problem for rice production, particularly in years when irrigation water was not sufficient, resulting in the intrusion of saline water through irrigation canals and the uprise of underground saline water. RRII initiated its breeding program for salt-affected areas through this project, with the main target being Gilan and Mazandran provinces in the north, because they have more than 70% of the rice area in the country. The team completed a baseline study, covering representative villages in the two provinces, and established screening facilities at RRII. Local germplasm was collected and evaluated and a few salt-tolerant genotypes were identified and are being used in breeding. Through INGER, IRSTON nurseries were received and evaluated each season, and nominations from Iran were also included. A large number of crosses was made every year, and segregating materials were advanced and selected. A PVS trial network was established for the first time in these salt-affected areas and used for evaluation of the material generated through the local breeding program or selected through INGER, for evaluation for farmers and for subsequent nomination for release. Through this project, the capacity for research and participatory evaluation was strengthened, and partners participated in several training activities.

Inland sodic soils, CSSRI, Lucknow, and NDUAT, Faizabad

Research focused on developing varieties and management technologies for rainfed inland sodic soils of Uttar Pradesh, India. Developing germplasm for sodic soils was substantially boosted under this project as salt-tolerant varieties constitute an entry point for progress in these areas. Considerable efforts were devoted to breeding salt-tolerant cultivars. The main activities involved evaluating and selecting breeding material shared through the INGER-IRSTON network, evaluating advanced material through PVS mother and baby trials, collecting and evaluating local landraces, and generating segregating material for further selection. Research to improve management practices focused on developing cheap options that can have large effects when combined with suitable varieties. At both centers, socioeconomic studies were completed involving benchmark surveys, outscaling and monitoring, and farmers' feedback. At **CSSRI**, considerable progress was made in breeding and through PVS trials. Several genotypes were identified as suitable for the Lucknow area, including Narendra 359, CSR36, CSR13, and CSR-89-IR-8. The latter is a new breeding line identified in PVS trials and it is preferred by farmers because of its early maturity to allow timely planting of wheat in the DS. Validated management packages include proper nursery, water and nutrient management, and low-cost reclamation methods, particularly technologies that reduce gypsum requirement to only 25% of the recommended dose when combined with salt-tolerant varieties, together with the use of organic amendments, manures, and chemical fertilizers. A few nonrice crops were also tested for the DS, and were found more profitable than wheat commonly grown by farmers. At **NDUAT**, numerous varieties and advanced lines (e.g., NDR 359, Sarjoo 52, Usar Dhan-3, CSR27, CSR30) were selected and were being outscaled in farmers' fields. Best-bet technologies were developed and tested for these varieties on-station and then validated with farmers through PVS trials. These include the development of cheap reclamation and mitigation strategies affordable to farmers such as the use of industrial by-products and green manures, proper nursery management for robust seedlings, and better crop establishment through the use of balanced nutrients, proper spacing and seedling age, proper handling, and root dipping in ZnO. These options were extensively tested in farmers' fields over the past 2–3 years, and they showed consistent and remarkable enhancement of yield in farmers' fields. Combining the best management strategies with genetic tolerance proved to be most effective.

INTRODUCTION

High salt in soils is a persisting problem constraining crop production in more than 20 million ha of saline and sodic lands in Asia. Saline soils have excess neutral soluble salts, and sodic soils have excess carbonates and bicarbonates, producing excess alkalinity upon hydrolysis and causing poor physical properties. In coastal areas, high salinity is caused by marine influences through tidal activities and shallow saline water tables, and it is higher during the DS, but decreases with freshwater flushing in the WS. Sources of alkalinity and primary salinity in inlands are inherent salt deposits or consequences of mismanagement of irrigation and drainage water, and are increasing problems over vast areas such as the Indo-Gangetic Plains of India. Salinization is an insidious problem, steadily leading to soil deterioration until land and water productivity decline to levels that force poor farmers off their lands. Direct interventions to improve water and soil quality in salt-affected areas are costly and require major infrastructure development, with large investments that are beyond the reach of resource-poor communities living in these areas who have no political voice. For most rural poor in these areas, their only hope is to make the best out of their existing water and land resources to meet their food needs. Present rice yields are below 2 t/ha, but can be increased by at least 1 t/ha, providing additional food for millions of needy people.

In both coastal and inland areas, rice is the only crop that can be grown in the rainy season, but the salt remaining at the end of the dry season affects seedling establishment. The limited time period of freshwater supply further constrains increases in cropping intensity and/or diversity during the DS. Improving crop productivity in these areas addresses the primary concern of the poor and mainly subsistence farmers, which is to have assured household food supplies. Putting salt-affected areas into more productive use will improve water productivity for food production. Building on previous progress and using recent advances in knowledge, this project aims to take an integrated systems approach to tackle the various challenges encountered in these salt-affected areas. Characterization of the biophysical, social, and economic conditions of farming communities was found to be helpful to develop a good understanding of the challenges, develop sound interventions, and monitor project progress. The development and deployment of high-yielding salt-tolerant rice varieties and nonrice crops were considered the initial entry point for making progress in these areas. To exploit the potential of these varieties, best agronomic practices were developed and validated, and further disseminated as a package with the varieties in demonstration trials run by farmers, which proved to be extremely successful. Through joint efforts of all partners, it became apparent that significant changes could be made in these areas to enhance water and land productivity and improve farmers' livelihood.

PROJECT OBJECTIVES

The overall objective is to enhance land and water productivity of rice-based systems in salt-affected areas through innovative interventions that integrate genetic improvement and management strategies that are environmentally sustainable and socially acceptable to various resource users. Specific objectives are to

- Develop a systematic understanding of target environments and the livelihood of people as a basis for exploring opportunities for improving water productivity and farmers' livelihood.
- Introduce salinity tolerance into high-yielding rice and nonrice crop varieties that fit into the rice-based farming systems in salt-affected areas.
- Develop farmer-friendly crop and natural resource management options for salt-tolerant varieties to enhance water and land productivity in salt-affected areas.
- Develop strategies for validation and diffusion of new technological interventions through the participation of men and women farmers and local civil societies.
- Enhance the capacity of NARES partners in innovative research and dissemination strategies.

Achievements under each of these objectives are briefly summarized below. More details are provided with the supplementary information through the detailed reports of partners.

1 *Objective 1.* Develop a systematic understanding of target environments and the livelihood of people as a basis for exploring opportunities for improving water productivity and farmers' livelihood

Complete reports on this objective were provided, including detailed data collected from each site. This information is available as individual site reports. Achievements at each site are briefly summarized below.

Coastal Orissa, India (CRRI)

Project sites. The project sites were carefully selected based on areas affected by coastal salinity, physiographical condition, and importance of rice. Selected villages are situated near Paradeep port in Ersama block of Jagatsinghpur District of Orissa. These villages, Chaulia, Kankan, Gangadevi, Patna, Ambiki, and Kimilo, are about 80–95 km away from CRRI, and 4–10 km away from the Bay of Bengal. Jagatsinghpur District falls under the South and Southeastern Coastal Plain agro-climatic zone. Soils are mostly saline and acidic to neutral. Climate is subtropical, hot, and humid. The important rivers, Hansua and Sankha, are directly linked with the sea. Average annual rainfall is 1,558 mm but the entire block is prone to both drought and flood because of variability in monsoon rain during the cropping season. Early and terminal drought, submergence and waterlogging, flash floods, and cyclonic disturbances are frequent. This region is mostly monocropped with rainfed rice grown on 17,859 ha out of the total of 19,365 ha of cultivated area. Farmers are very poor, having marginal to small landholdings. Farming is the main source of livelihood, although a few are also engaged in fishing. Most farmers cultivate their own land, whereas some are engaged in sharecropping. The major constraints to rice production during the wet season are salinity and drought mostly at early seedling and reproductive stages, submergence/waterlogging mostly during the vegetative stage, and crop lodging at the reproductive stage due to strong wind/cyclonic disturbances during October-November. In the dry season, the major constraints to rice production are salinity throughout the season with large spatial and temporal variability, increasing salinity with the progress of the season, scarcity of fresh water for irrigation, and high temperatures at the reproductive stage when planting is late.

Site characterization. A benchmark survey was conducted at the start of the project in 2004 by personal interviews of 50 households from different adopted villages using a pretested structured questionnaire prepared by Dr. Thelma Paris of IRRI's Social Sciences Division. The pro forma questionnaire was designed to collect information regarding socioeconomic status, current farming practices, constraints to rice production, and technology needs. Selected household respondents represented different socioeconomic groups. Participatory rural appraisal (PRA) tools such as focus-group discussions (FGDs) on key topics, a cropping pattern calendar, and pie diagrams were used in collecting village-level information. The information collected primarily included socioeconomic, economic, and biophysical characteristics of the land, land use, varietal use, yields, labor use by source and gender in each crop operation, cost of inputs and returns from rice cultivation, income sources, environmental protection practices, and perceptions on their economic situation. The PRA tools were used in identifying farmers' needs and opportunities for improving the livelihood of the farming households. Qualitative information was gathered through FGDs to understand farmers' attitudes toward the new technologies. Secondary data related to biophysical characterization, institutional and infrastructural settings, and the presence of NGOs were also collected from the Block Development Office and State Agriculture Department.

Characteristics of farm households. The average age of male farmers was 44 years, which implies that farmers were in their active age to engage in labor-intensive activities and had the potential to try new varieties and improve crop management practices. About 53% of the adult population completed secondary education, while 17% completed primary school. Literacy was 80%, with an average of six years of schooling. Adult males had higher literacy (87%) than females (73%). Among the young population (5–15 years old), literacy was 99%, indicating that farmers, irrespective of their socioeconomic status, were aware of the advantages of child education. All girls went to school, whereas 2% of the boys were illiterate,

indicating the greater awareness of parents to educate their daughters, a positive development in terms of reducing the disparity in access to education between boys and girls. Further, 60% of the agricultural workers completed primary school, whereas 12% stopped at the primary level. About 48% of the nonagricultural workers completed primary education, while 20% discontinued at the primary level. About 80% of male adults were directly engaged in farming, whereas 83% of female adults were engaged mainly in household activities. Average household size was six. Patna and Ambiki showed the largest family size (8) while Chaulia had a smaller (5) family size. Other adult male members were engaged in business, private jobs, or services, or they migrated to urban and rural areas on a seasonal or long-term basis. About 52% of the nonworking population consisted of students, unemployed youths, and housewives.

Socioeconomic groups. Almost half (48%) of the sampled farm families are very poor, with less than 1.0 ha of landholding (marginal category), while 40% of them have 1.0–2.0 ha of cultivated land (small). Only 12% of the total farm families have more than 2.0 ha of landholding (medium and large category). These findings indicate that it is difficult for farming households to ensure food security only from their own production. Rice is grown only during the wet season and on limited land. Thus, marginal and small farmers have to diversify their sources of income rather than depend solely on rice. As regards the tenurial system, 94% of the farm families were cultivating their own lands. Share-cropping was adopted by only 1% of farmers (mostly marginal), whereas 5% of them (medium to large) leased their land to other farmers.

Biophysical characteristics. More than half (54%) of the total cultivated area under rice is intermediate lowland (0–50-cm water depth) and prone to submergence and waterlogging. Less than half (45%) of the area used for rice cultivation is medium or shallow lowland (0–30-cm water depth) and prone to both drought and submergence. A negligible proportion (1%) of the total rice-growing area is upland, wherein rice varieties with shorter duration (90–100 days) are generally grown during the wet season. Soil in the major rice-growing belt is sandy-loam (59%) and this is mainly found in the shallow lowlands. About 39% of the total rice-growing area has clay-loam soil, mostly in intermediate lowlands. Only 2% of the total rice area is loamy-sand and this can be found in the uplands. In general, soil salinity is low during the wet season but increases progressively during the dry season, reaching 6-11 dS/m or more. The pH of these soils varies from 5 to 7. About 88% of the total cultivated rice land is not irrigated, specifically in the wet season. However, 10% of the farmers use indigenous irrigation systems to lift harvested rainwater stored in small ponds and ditches while others irrigate their land using high- and low-lift pumps.

Land use. Rice is the main crop grown during the wet season, covering 87% of the total cultivated land. On uplands and homestead lands, farmers grew vegetables on 10% of the cultivated land during the WS. Nearly 3% of the cultivated lands were left fallow, mostly in low-lying areas, because farmers did not have suitable rice varieties or management options for this type of land. Conversely, rice is grown on only 4.5% of the cultivated land in the DS using harvested rainwater, and about 87% of the land is left fallow because of high soil salinity, poor quality and scarcity of irrigation water, and a lack of knowledge on suitable crops. The EC of stored rainwater started increasing in February and, in some areas, water was too saline for irrigation. About 8% of the land was planted with vegetables. Farmers grew perennial crops such as betel vine, cashew nut, coconut, fruits, and other horticultural crops on about 48% of the total noncultivated land. Fish were raised in ponds and small ditches on about 48% of these lands, making fish an alternative income source besides agricultural crops. The rest (4%) of the land is planted to other crops (Table 1.1).

Table 1.1**.** Land use (area in ha) in different seasons in the target villages in Orissa, India.

Type of agriculture	Wet season		Dry season		Both seasons	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Rice	42.73	87.04	2.55	4.53		
Vegetables	5.07	10.33	4.40	7.81		
Potato			0.04	0.07		
Mixed rabi crops			0.61	1.08		
Betel vine					0.46	3.24
Cashew					3.84	27.02
Coconut					1.54	10.84
Fruits					0.57	4.01
Horticulture					0.40	2.82
Others					0.61	4.29
Fish					6.79	47.78
Fallow	1.29	2.63	48.74	86.51		
Total	49.09	100	56.34	100	14.21	100

Farming practices in rice cultivation. About 54% of the total cultivated area under rice was intermediate lowland (flood-prone) and 45% shallow lowland (drought-prone, submergence-prone). Before new technologies are introduced, it is important to understand the farmers' practices and indigenous knowledge. Table 1.2 presents farmers' practices for rice cultivation in normal and saline soils and technologies to

improve these practices. Farmers generally use local rice varieties Bhaluki, Bhundi, Rahspunjar, and Lunabokra. Local landraces have certain advantages over improved varieties: early maturity, better ability to withstand salt stress at early stages, higher tolerance of diseases such as false smut, less grain discoloration, ease of threshing, and less deterioration of seed quality. However, yields are low at 1.5 t/ha. During the WS, farmers generally start seedbed preparation only after the first monsoon rain. In the dry season, the seedbed is normally prepared during late December to early January by puddling the field twice and pregerminated seeds are sown in wet beds. Seedlings aged 25–30 days are transplanted randomly on normal soils, whereas, in saline soils, farmers use 50–60-d-old seedlings. Primary tillage is done during the WS after pre-monsoon rain in June followed by final land preparation after enough rainwater is accumulated in the field during late July or early August. In the dry season, this is done in mid-January. Farmers with marginal to small landholdings usually use a country plow while those with large landholdings use their own or a hired tractor/power tiller for land preparation. Transplanting of wet-season rice is done during late July to mid-August after salinity is sufficiently washed by rainwater to ensure good crop establishment. Growing dry-season rice, which is not a common practice in this area, started as a contingency measure in 2000 after complete loss of the WS crop because of the super cyclone in 1999. The crop often suffers significant yield losses due to water scarcity during flowering/ripening stage and higher soil salinity because of increasing temperatures from March onward. Irrigation is generally at 3–5 days after the disappearance of standing water. The crop is harvested and threshed manually. During the WS, no fertilizers are applied to rice because of low yields and high risks. However, a few farmers apply only N. The rice-fallow cropping sequence is predominant in all villages. However, rice-rice and rice-vegetable cropping sequences were adopted in limited areas under partial irrigation, particularly in the uplands of some villages. In some villages, farmers raised vegetables (potato, chilli, *Basella*), watermelon, and cowpea during the dry season on homestead uplands and some medium lands with partial irrigation.

Labor use in rice production. Small and marginal farming households rely heavily on family labor. To complete rice operations during peak seasons, they exchange labor or hire additional labor. Within a farm household, females and males have assigned tasks, which can be done separately or jointly. Children also help after school. Men are mainly responsible for preparing the land and establishing nurseries, while women do transplanting, weeding, and applying farmyard manure (FYM). Harvesting is done by both men and women and postharvest activities such as threshing and winnowing are mainly done by women. During the WS, men and women contributed 66% and 23% of the total labor input (71 days/ha) in rice production, respectively.

The labor input of females was highest among marginal farming households, indicating that the participation of female family labor increases with poverty. The total labor requirement for different agricultural operations in rice cultivation for marginal farmers was 72 and 85 person-days per ha during the WS and DS, respectively. Marginal farm households usually depend on female members to fulfill the labor requirements in rice production. With the participation of female family members, farming households save on the cost of seedling uprooting, transplanting, weeding, harvesting, and threshing. Women are also mainly responsible for selecting seeds for the next season and storing them as well. Aside from crop production activities, women are engaged in dairy management, particularly collecting fodder and feeding livestock. However, despite their contributions to rice production and postharvest, they lack access to seeds of improved varieties, information on maintaining good-quality seeds, and good crop management practices. Among nuclear households, wives are compelled to make "on-the-spot" decisions when their husbands migrate to urban or other rural areas for nonfarm employment. Thus, women need to be trained not only on improved seed health practices but also on all aspects of rice farming. The engagement of family labor was 58 person-days (82% of the total labor input) during the WS and 83 person-days per ha (81% of the total labor input) during the DS.

Economics of rice cultivation**.** Rice production in these areas is quite risky. Farmers gamble with their limited resources and they have limited marketable surplus. With the increasing cost of inputs such as fuel, labor, and fertilizers, their net returns are gradually declining. Marginal farmers had smaller parcels (0.55 ha) than small farmers (0.87 ha) and medium to large farmers (2.06 ha) during the WS. However, rice productivity was higher (1.96 t/ha) for marginal families than for small (1.78 t/ha) and medium to large (1.63 t/ha) families during the WS. In the DS, parcel area was slightly larger (0.32 ha) for marginal farmers than for small farmers (0.24 ha), but yield was similar (3.2 t/ha). On average, farmers spent Rs. 6,466 per ha for rice production. The highest proportion was spent on labor (78%) and expenditures on seed and seedling establishment (10%), fertilizers (5%), and land preparation (5%) were low. The total cost of inputs during the WS was relatively higher for marginal farmers (Rs. 6,744/ha) than for small (Rs. 6,360/ha) and medium to large (Rs. 5,728/ha) farmers. The total gross returns were Rs. 8,320/ha, 91% of which were obtained from the grain and 9% from the straw. Gross returns were higher for marginal farmers (Rs. 8,889/ha) than for small (Rs. 7,906/ha) and medium to large (Rs. 7,419/ha) farmers. Average net returns from rice cultivation were Rs. 1,854/ha. Among the different landholding categories, marginal farm families earned higher returns (Rs. 2,145/ha) than small (Rs. 1,547/ha) and medium to large (Rs. 1,691/ha) farmers.

Sources of livelihood. Poor farming families diversify their livelihood options to minimize their risks. Animal rearing and fish raising or fishing contributed the highest to total income (42%), followed by cultivation of other crops and vegetables (35%), wherein 13% was contributed by rice and 22% by other

crops. Other income sources are agriculture-related activities (15%) such as selling labor and rental charges for equipment such as power tillers, tractors, and threshers mostly by medium and large farmers. About 8% of total income was generated from other nonfarm sources such as small businesses and services in different sectors. Both men and women from marginal households generally earned the highest proportion of their income (34%) as agricultural laborers in the villages, followed by cultivating rice (23%) and rearing livestock and fish (21%). A significant amount (11%) was also obtained from other nonfarm activities such as running small shops and pulling a rickshaw. For small farm families, livestock and fish rearing and fishing were the highest income earner (51%), followed by the cultivation of perennial crops such as betel vine, coconut, cashew nut (15%), and rice (12%). A similar trend was observed for medium-large farm families. Half of their family income generally came from livestock rearing and fish cultivation. About 36% of the income came from the cultivation of other crops such as betel vine, coconut, cashew nut, banana, and papaya. Only 4% of their total income was generated from rice cultivation, indicating that, when household size increases, dependence on rice cultivation decreases.

***Constraints to crop productivity and livelihood*.** Some 92% of the respondents identified a lack of awareness about suitable technologies and knowledge as the main constraint to improving crop productivity. The region is affected by natural calamities such as flood, drought, and cyclones almost annually, and about 70% of the respondents ranked natural calamities as the second most important constraint to improving their livelihood. The unavailability of salt-tolerant and submergence-tolerant rice varieties (38%) ranked third, while a lack of capital for field operations ranked fourth. Other constraints are a lack of employment opportunities, monocropping of rice, small landholding, poor infrastructure, poor economic conditions, and a low market price for farm outputs. Farmers perceive that the introduction of suitable salt-tolerant rice varieties and other crops in a rice-based production system, the adoption of best management practices, and the use of irrigation facilities for the DS through rainwater harvesting are important for improving their livelihoods and household food security.

***Soil characterization*.** Sixty surface soil (0–15 cm) samples collected from different villages in Ersama block of Jagatsinghpur District, Orissa, during the 2006 DS were analyzed for organic C, total N, and available P. The pH, EC, and ionic composition (Na^+, K^+, and Ca^{2+}) were measured, and wide variability was observed for each. The pH and EC of saturation extract were 5.8–7.0 and 3.4–29.4 dS/m, respectively (Table 1.3). The organic C, total N, and available P were 0.39–1.34%, 0.04–0.14%, and 1.4–10.0 ppm, respectively. The most dominant cation and anion were Na^+ and Cl^-.

***Water characterization*.** Piezometers made of perforated PVC pipes (diameter 5 cm) covered with nylon net sleeves were installed at 1.3–1.5-m depth at nine sites in different villages of Ersama block of Jagatsinghpur, Orissa, during the 2007 DS. Depth to the groundwater table (GWT) was measured periodically, and groundwater samples were collected periodically and analyzed for EC, pH, and ionic composition. The EC of water collected from surface irrigation sources (rivers, creeks, and ponds) was monitored periodically using the same methods used with soil extracts. Table 1.4 summarizes some of the data. The EC of river water before and after the sluice gate was 0.4–0.6 and 11.3–37.3 dS/m, respectively, suggesting that construction of a sluice gate has helped in storing fresh water, which can be used for irrigation during the DS. Groundwater EC at four sites was very high, but DS rice is still possible using creek water with low EC. At two sites, pond-water EC was high but the groundwater EC was relatively low and certain salt-tolerant nonrice crops could be grown. At one site, both surface water and groundwater were highly saline and sunflower grown there did not perform well. At the remaining two sites, surface-water and groundwater EC was low and this water can be used to grow rice and nonrice crops. Strategies to tackle these problems were discussed with different stakeholders and appropriate technologies, such as salt-tolerant rice varieties for both the WS and DS; improved crop, nursery, nutrient, and water management practices; and proper cropping systems involving less water-consuming salt-tolerant nonrice crops, were developed and further validated in farmers' fields.

Lucknow, UP, India (CSSRI)

Categorization of water and soil resources in target areas

Site selection and collection of data. This site represents alkaline inland soils. A reconnaissance survey of various villages covered under the reclamation program by the UP Land Development Corporation was conducted during 1995. Two villages along Pucca Road (Dhora and Mataria) were selected that are more representative of the study area. Both are close to the Krishi Vigyan Kendra (KVK) station, with a mandate for technology transfer. Selection of farmers in each village was based on availability of land, water, other natural resources, socioeconomic conditions, size of landholdings, caste, and religion. Farming is the major source of livelihood in these two villages. The characterization was based on existing farmers' classification and indigenous knowledge on the suitability of rice and wheat varieties in different parcels. Qualitative information from 50 farmers was obtained through interviews and participatory rural appraisal (PRA) tools such as focus-group discussions with key informants. Since women play crucial roles in crop establishment and seed maintenance, they were also asked for their opinions on relevant issues.

Results: transect of villages and irrigation sources. There are three types of land situations in both villages, uplands used for cereals, vegetables, oilseed, and fruit crops, and medium lands and lowlands used for rice during monsoon (July to Oct.) and wheat in winter (Nov. to April). The main source of irrigation is tube wells and rice-wheat is the main crop rotation. About 38% of the farmers have landholdings of <1.0 ha, 30% have 1.0–2.0 ha, and 32% have >2.0 ha of land. The main source of irrigation in the area is tube

wells, which cover about 74% of the total irrigated area. Canal irrigation covers about 24% and the remaining 12% of area is irrigated through wells, tanks, and other sources.

Cropping pattern. The rice-wheat sequence is dominant in both villages. A large number of rice varieties are grown in the area but are dominated by Indrasan and Mussoori. Some farmers started growing salt-tolerant rice varieties rice such as CSR13. The most popular wheat varieties were PBW343, HD2285, and HD2329. Some other crops such as maize during the rainy season and mustard in winter are also grown. The surroundings of the villages are predominantly mango orchards, with some farmers growing mangos within their villages. A small area is grown with mixed crops such as wheat + mustard (4%) during the winter season.

Table 1.2. Current farming practices followed by farmers in rice cultivation and improved practices introduced through the PN7 project during the wet season.

Field operation	Normal soil	Saline soil	Technology being introduced
Land preparation	Plowing after first monsoon shower followed by puddling before transplanting (TP)	Plowing after first monsoon with puddling before transplanting	Summer plowing in Feb.-March, then shallow tillage in May after premonsoon, puddling twice at 7–10-d interval, leveling before TP
Selection of varieties	Long-duration photosensitive high-yielding varieties such as Gayatri, Savitri	Long-duration photosensitive local landraces	Salt-tolerant high-yielding varieties such as SR 26 B and Lunishree in intermediate lowlands and Pankaj in shallow lowlands
Time of sowing in nursery	2nd fortnight of June after the first monsoon rain	2nd fortnight of June after first monsoon	No new technology introduced since sowing time is dependent on rain
Nursery management	Fertilizers not applied	Fertilizers not applied	Apply decomposed FYM at 5 t/ha during land preparation and chemical fertilizers at 10 kg/ha (N, P_2O_5, and K_2O) for healthy seedlings
Seedling age and spacing	25–30-day-old seedlings and random transplanting	50–60-day-old seedlings and random transplanting	30–40-d-old seedlings and planting at 15 × 15-cm spacing for shallow lowlands and 40–50-d-old seedlings and planting at 15 × 10-cm spacing for intermediate lowlands
Planting time	Late July or early August	Mid-August	Late July to early August
Nutrient management	Application of 25–30 kg N/ha as basal or no fertilizer	No fertilizer	*Sesbania* for intermediate lowlands and GM + prilled urea at 20 kg N/ha or GM + *Azolla* for shallow lowlands
Weed management	Hand weeding at 40–50 d after planting or none	No weeding	Mechanical weeding by cono-weeder 25–30 d after planting when possible
Plant protection	No plant protection	No plant protection	Need-based plant protection
Harvesting	Late harvesting	Late harvesting	Harvesting at proper time (75% maturity) to avoid shattering losses
Postharvest operation	Manual or bullock threshing and improper storage	Manual/bullock threshing & storage	Threshing by paddle thresher, proper cleaning, drying, and storage
Cropping system	Rice-fallow or rice-blackgram/ greengram	Rice-fallow	Rice-rice or rice-nonrice crops (sunflower, *Basella*, watermelon, okra, chilli, pumpkin, groundnut)

Table 1.3. Main characteristics of soils (0–15-cm depth) from different villages in Ersama, Orissa.

Parameter	Range	(water-soluble ions)	range (meq/100 g soil)
pH	5.8–7.0	Na^+	2.15–20.90
ECe (dS/m)	3.4–29.4	K^+	0.03–0.38
Organic C (%)	0.39–1.34	Ca^{++}	0.20–1.66
Total N (%)	0.04–0.14	Cl^-	2.2–17.2

Available P (Olsen P; kg/ha)	3–22	SO_4^{--}	0.01–1.85
Available K (kg/ha)	110–950		

Table 1.4. Depth to groundwater table (GWT), pH and EC of groundwater, and EC of surface freshwater sources in Orissa. Values in parentheses are means.

Village	Groundwater EC (dS/m)	Groundwater pH	Depth to GWT (cm)	Surface freshwater EC (dS/m)
Nagari	3.9–8.3 (6.6)	7.2–7.8 (7.5)	41–75 (62)	2.1–2.7 (pond)
Chaulia	2.0–5.3 (3.1)	5.2–7.8 (6.7)	51–106 (71)	0.1–0.4 (pond)
Sarba	15.7–22.0 (17.9)	6.1–8.0 (6.9)	35–88 (64)	0.3–1.4 (creek)
Kankan	4.7–6.5 (5.4)	6.3–7.7 (7.0)	63–100 (80)	1.5–5.6 (pond)
Kankan	10.4–11.8 (11.1)	7.0–7.4 (7.1)	73–102 (91)	2.0–5.5 (pond)
Kankan	3.6–5.4 (4.0)	7.1–7.5 (7.2)	58–87 (76)	1.3–4.8 (pond)
Kimilo	10.2–18.6 (12.8)	5.1–7.5 (6.4)	27–73 (40)	0.3–1.0 (creek)
Kimilo	9.0–11.9 (10.7)	6.7–7.5 (7.0)	28–75 (40)	0.6–1.4 (pond)
Kimilo	15.3–17.4 (16.3)	5.2–6.6 (6.4)	46–82 (59)	0.6–2.9 (creek)

Socioeconomic profile of the families. Data on religion, caste, household size, landholdings, tenure system, major occupation, and employment status were collected from 50 farm families in the two villages. Household size is higher in Dhora than in Mataria because of the high adoption of family planning in Mataria compared with Dhora. About 38% of the households are marginal, 30% are small, and 32% are large farmers. The average age of the household head (husband) in both villages is 51. However, the average age of the wives is 46. Some 49% of the adults above age 16 are literate and 51% are illiterate with schooling of less than 8th standard. About 55% of the males and 40% of the females are literate in both villages. However, more women are illiterate (60%) than men (40%). About 68% of the children between 5 and 15 years of age are literate; however, the rest are illiterate because they either did not attend school from childhood or they could not continue their studies because of financial problems.

Biophysical characteristics of the land. A large part of the land is sandy loam, used for orchards or for a rice-wheat rotation. Salt-affected areas are high in clay and are mainly used for rice cultivation. The study showed that 58% of the total area grown to rice is sandy loam, 22% is clay, and 14% is clay loam. Crops such as oilseeds, maize, sorghum, and berseem are also grown on these soils. The average yield of rice in both villages is 2.8 t/ha and wheat yields only 1.84 t/ha. Total and net returns were higher from rice than from wheat because of the low yield of wheat, which could be replaced by other low-input, more profitable crops.

Costs and returns. The rice-based cropping system is labor-intensive, requiring about 171 person-days, compared with 125 person-days for wheat during the season. About 36% of the total labor requirement for rice and wheat is met by family labor and the remaining from hired labor. About 68% of the hired labor for rice and 65% for wheat is used for weeding, harvesting, and threshing. About 37% of the total input cost of rice cultivation is for labor. Other inputs include hiring of machines for field preparation, seed, fertilizer, insecticides, pesticides, and irrigation. Farmers pay about 26% of the total cost of rice production for fertilizers, 23% for field preparation, and 11% for irrigation. The irrigation cost is much higher for rice than for wheat. For wheat, the cost of fertilizers is about 32.5%, which is more than the labor expenditure. Apparently, the main constraints are the lack of availability of salt-tolerant varieties and inputs/amendments.

Impact of new interventions on livelihood, water productivity, and environment (ex ante). Grain yield of rice increased from 1.64 to 2.74 t/ha after the new interventions, amounting to a 67% increase in grain yield (Table 1.5). During the winter season, grain yield of wheat increased from 1.17 to 2.35 t/ha with the new interventions, showing more than a 2-fold increase. Consequently, farmers' net returns increased from Rs. 5,246 to Rs. 9,792 for rice and from Rs. 5,987 to Rs. 10,907 for wheat (Tables 1.5, 1.6).

Table 1.5. Costs and returns of rice production with and without new interventions during the WS in Uttar Pradesh, India.

Item	Without		Total	With	Level of significance[a]
	Local	Modern		Modern	
Area (ha)	0.79	0.93	0.83	0.79	
Yield (t/ha)	1.67	1.56	1.64	2.74	*
Returns					
Value of production	10,000.00	9,375.58	9,814.36	16,423.76	*
Value of by-products	1,384.80	1,498.87	1,418.71	2,418.84	*
Total returns	11,384.80	10,874.46	11,233.08	18,842.60	*

Costs					
Land preparation cost	1,411.72	1,296.54	1,377.48	2,019.52	***
Seed cost	432.80	362.75	411.98	356.42	
Fertilizer cost	559.34	389.45	508.83	780.72	***
Irrigation cost	1,020.35	686.44	921.08	1,291.47	***
Labor cost	2,861.13	2,545.56	2,767.31	4,601.91	**
Total costs	6,285.34	5,280.75	5,986.68	9,050.05	**
Net returns	5,099.46	5,593.71	5,246.40	9,792.55	**

[a]*, **, *** = significant at *P*<0.05, 0.01, and 0.001, respectively.

Table 1.6. Costs and returns of wheat production with and without new interventions during the rabi season in Uttar Pradesh, India.

Item	Without		Total	With	Level of significance[a]
	Local	Modern		Modern	
Area (ha)	0.63	0.91	0.84	0.84	
Yield (t/ha)	1.10	1.19	1.17	2.35	***
Returns					
Value of production	9,342.86	10,554.29	10,251.43	15,817.62	*
Value of by-products	1,259.47	2,115.31	1,901.35	2,601.38	*
Total returns	10,602.33	12,669.59	12,152.78	18,418.99	*
Costs					
Land preparation cost	1,185.71	1,271.78	1,250.26	1,812.50	***
Seed cost	826.38	955.98	923.58	791.75	
Fertilizer cost	490.02	691.52	641.14	1,032.41	**
Irrigation cost	741.40	692.53	704.75	935.24	
Labor cost	2,318.57	2,755.03	2,645.91	2,939.38	
Total costs	5,562.08	6,366.84	6,165.65	7,511.29	
Net returns	5,040.25	6,302.75	5,987.13	10,907.71	*

[a]*, **, *** = significant at *P*<0.05, 0.01, and 0.001, respectively.

Farmers' conditions before and after the project.
From the survey conducted in both villages, about 70% of the households belong to the poor category. They mentioned a lack of irrigation facilities, small and fragmented landholdings, and unproductive lands as the main cause of poverty. During the interview, farmers also mentioned the problem they have with the current irrigation canal. It is completely filled with weeds such as water hyacinth, and there is no water at the tail end of the canal in both cropping seasons; therefore, they are not getting sufficient water for irrigation. However, 50% of the farmers stated that, although they have irrigation facilities, they still do not get good yields because of poor soil health. About 15% of the area falls under the very poor category. The main causes of poverty were very small landholdings alloted by the government under the poverty alleviation program, lack of capital to purchase agricultural inputs, lack of or ineffective irrigation facilities, and unproductive lands. Only those households with some other businesses and large landholdings were better off. After the project, farmers identified the following changes in their agricultural, economic, social, and general conditions due to the adoption of new technologies: (i) improvement in household status; (ii) increase in rice area for cultivation; (iii) increase in rice yield; (iv) improved knowledge about new technologies and farming practices; (v) more access to basic social services, including meetings and training; (vi) gender equality; and, lastly, (vii) improvement in general well-being.

Faizabad, UP, India (NDUAT)
Categorization of water and soil resources in target areas
Site characterization. This site also represents inland alkaline/sodic soils. In Faizabad District, three villages were selected for the study: Dhamthua, Lodhe Ka Purwa, and Leela Ka Purwa. Research sites were selected based on the extent of sodicity and rice being the major crop grown in the area. The villages were 45–48 km from district headquarters and 5–8 km from the NDUAT campus. Soils are mostly sodic and major areas were affected by severe to moderate sodicity. Agro-climatic conditions are normal with four seasons, summer and rainy (March to October) and winter and spring (November to April). The important cropping seasons are kharif (wet), rabi (dry), and zaid (April-June). Average annual rainfall is <1,000 mm. The selected areas are prone to drought because of the variability of the monsoon rain during the cropping season. Rice and wheat are the major crops cultivated in these areas and more crop diversification is

observed during the rabi season in some pockets where supplementary irrigation is available. Farmers are mostly marginal and small landholders. Cultivation and animal rearing are the main source of livelihood. Most male adult household members were engaged in nonfarm activities in adjacent areas as daily wage laborers (i.e., mechanic, electrician, tailor, construction worker, etc.). Most farmers are own cultivators. Some large landholders and farmers in the upper caste rented out their lands to farmers in the lower castes with small landholdings. This is due to higher input requirements, particularly labor, when their family members are unable to provide. Farmers who purchase irrigation water mostly do not grow rabi-season rice due to high costs and risk of unavailability of water. Only a few farmers owned electric motors. Interviewed farmers were selected based on (a) must have more than 50% (up to 70–80%) of area affected by sodicity; (b) should be owner-cultivator; (c) rice is the major crop grown in kharif season; (d) samples represent different socioeconomic groups and have women family labor in rice-farming activities (as worker or supervisor); and (e) are willing to collaborate in the project.

Data collection. Primary data were collected using a pretested field schedule to 50 households at selected project sites. Both quantitative and qualitative information were obtained through baseline surveys and participatory rural appraisal (PRA) tools such as focus-group discussions with key informants. Aside from households' socio-demographic, economic, and biophysical characteristics, farm characteristics, crop production, and household economic conditions—information on farmer's livelihood strategies, crop management practices, and constraints to crop production under saline conditions and the extension of new technologies were likewise gathered. Some success stories were narrated.

Results: demographic and socioeconomic characteristics. A special family structure called joint family system is still predominant in the villages of eastern Uttar Pradesh. The average household size of respondents is 7, with the upper caste having more family members (8). The average age of the male household head is 47 years while the female is 40 years old. This reveals that both male and female household heads are in their prime age and are still dynamic in farming activities. Women farmers attended only a few years of school, and despite the free education offered to girl children launched by the government in village schools, the percentage of literate girls is still low because of a lack of awareness and work burden in the house and on the farm, and animal management, which are basically done by females. About 85% of adult women were engaged in household activities besides farming activities. It was a normal practice that women actively participate in farming, helping their husbands in all ways they could, especially when the husbands were not around. Women farmers also have the primary responsibility of taking care of their children besides household chores. In eastern Uttar Pradesh, agriculture (60%) remains the core occupation of the majority of the households. At times, where the women actively work on the farm, the men work in either one or two of many nonfarm activities (teachers, drivers, gardeners). A few migrate to distant places in either Delhi or Punjab.

***Biophysical characteristics of the land*.** More than half of the respondents have loamy soil while the rest have sodic soil. Farmers grow rice (kharif season) and wheat (rabi season). In some areas, vegetables, oilseed, maize, and sugarcane are also grown. There is not much difference in land types except that some areas are in lower endowments and are treated as shallow lowland. However, a majority of the cultivated areas are of upland and midland types. Farmers grow the same rice varieties in both land types depending on the availability of supplementary irrigation. Most farmers depend on rainfall so they prefer short- to medium-duration varieties to escape late drought. During the rabi season, farmers grow potato, garlic, berseem, and other early rabi crops such as vegetables and spices in the upper toposequence. In Dhamthua and Leela Ka Purwa, 11.6% and 8.6% of the total area, respectively, is fallowed due to poor soils and lack of irrigation. A majority of the households are owner cultivators (93%), having marginal (57%) and small (35%) landholdings. Many belong to backward castes. Households in the upper caste have large areas, rent out their land to households in the lower caste because of management and labor problems, and have high input and production costs.

Crop management and farming practices. Farmers grow different rice varieties based on land types and water level in the field during the WS. Important considerations for varietal selection are high yield (2.5–3.5 t/ha) and suitable duration (<135 days). Farmers mentioned many positive traits of currently used varieties (Sarju 52, Pant 12, Usar Dhan 3, NDR 359, Mahsuri). Among them are good yield, good straw, medium plant height, medium duration, medium bold grain size, and fertilizer-responsive. Yields averaged 2.5–3.5 t/ha in normal conditions (with timely irrigation and fertilizer application) and about 1.5–2 t/ha in salt-affected areas. In kharif 2005, salt-tolerant varieties performed very well and gave good yield (3.45 t/ha) compared with other existing varieties. The use of press mud as integrated nutrient management and *Sesbania* as a green manure along with salt-tolerant rice varieties substantially increased rice yield.

***Technologies adopted*.** Crop diversity is relatively high during the dry season. Farmers grow peas, lentils, potato, and other vegetables in this season chiefly for consumption purposes because very few crops can withstand high soil sodicity, and new varieties were recently introduced. Table 1.7 shows that 70% of the households adopted a salt-tolerant mustard variety. Mustards are usually grown during the rabi season along with wheat (the second most important crop in UP, after rice). Only 30% adopted salt-tolerant wheat varieties while 56% adopted salt-tolerant rice varieties. Some adopted salt-tolerant rice varieties along with either the application of press mud with zinc sulfate (32%) or *Sesbania* (30%). These technologies increased yields and were being adopted by neighboring farms and other farmers in the nearby villages.

Labor and gender participation. Rice cultivation in target areas is labor-intensive. Most of the farming activities were done by women farmers, either family or hired. Men basically prepare seedbeds, sow seeds,

apply fertilizer, and irrigate, while women handle transplanting, weeding, harvesting, threshing, and postharvest activities. Female labor is expected to be high because most of the labor-demanding tasks are done by female farmers. Aside from rice farming, women are also actively involved in animal rearing and preparing farmyard manure for soil reclamation to cope with the problem of high sodicity.

Impact of new interventions. Labor cost and fertilizer inputs accounted for greater portions of the total costs. Labor cost with and without interventions was 44% and 59%, whereas fertilizer cost was 26% and 31%, correspondingly. It was also found that the use of salt-tolerant varieties (STV) with an application of either press mud or *Sesbania* was highly profitable as indicated by the net returns of Rs. 15,274/ha and Rs. 16,825/ha, respectively, compared with net returns of Rs. 7,849/ha without intervention (farmers' practice). Grain yield increased from 2.51 to 3.44 t/ha (STV + press mud) and to 3.11 t/ha (STV + *Sesbania*), amounting to about a 37% and 24% increase in grain yield, respectively (Table 1.8). This result indicated that intensification and expansion of salt-tolerant rice varieties along with effective nutrient management would reduce crop losses and increase farmers' rice income.

Table 1.7. Proportion of households adopting new varieties and management technologies by 2008 in Uttar Pradesh, India.

Technology	Percent (n = 50)[a]
Use of salt-tolerant rice varieties (STV) only	56
Use of press mud with zinc sulfate and STV	32
Use of *Sesbania* and STV	30
Use of salt-tolerant wheat	30
Use of salt-tolerant mustard	70

[a]There are multiple responses.
Source: Impact assessment survey, CPWF Project, 2008.

Table 1.8. Costs and returns (in Rs.) of rice production with and without new interventions in Uttar Pradesh, India.

Item	Without intervention	With intervention				Total
		Modern variety	Salt-tolerant variety	Press mud + STV	*Sesbania* + STV	
Area (ha)	0.31	0.20	0.10	0.15	0.35	0.18
Yield (t/ha)	2.51	2.32	1.88	3.44	3.11	2.39
Returns						
Value of production	12,566	16,207	13,156	24,045	21,788	16,730
Value of by-products	1,164	599	675	0	2,000	572
Total returns	13,730	16,805	13,830	24,045	23,788	17,302
Costs						
Land preparation cost	–	1,277	1,328	600	–	1,160
Seed cost	367	416	335	335	550	389
Fertilizer cost	1,826	2,193	2,145	2,843	2,138	2,270
Irrigation cost	194	1,071	1,026	1,175	1,250	1,080
Labor cost	3,480	3,467	4,752	3,818	3,025	3,807
Family labor	3,045	2,762	3,529	3,368	3,025	3,034
Hired labor	435	705	1,223	450	–	772
Other cost	14	–	–	–	–	–
Total costs	5,881	8,424	9,585	8,771	6,963	8,706
Net returns	7,849	8,382	4,245	15,274	16,825	8,597

Source: Impact assessment survey, CPWF Project, 2008.

Success stories. Several examples of the many success stories mentioned as a consequence of adopting introduced technologies were from Ram Sawari, Amitendra, and the couple Subedar and Shanti. Ram Sawari had highly sodic land with poor germination of rice seeds. She became involved in the project in 2005, testing salt-tolerant rice varieties on her 1 ha of land. In kharif 2006, she grew CSR23 plus *Sesbania* in one plot and got a yield of 2.3 and 3.3 t/ha in another plot using Usar Dhan 3 plus press mud. In rabi 2006, she planted 3 kg of rice in a small plot and got 45 kg to keep for seeds. The following year, she planted the same rice variety (CSR23) in one plot with press mud and it yielded more than 3.5 t/ha. In another plot, Usar Dhan 3 produced over 3.8 t/ha. In rabi 2007, she grew KRL19 (wheat variety) on 0.2 ha and got a yield of about 2 t/ha on sodic land. In 2008, she continuously grew salt-tolerant varieties. According to her, because of these technologies, her family's social status improved and she became more confident and empowered in making decisions. Amitendra, a resident of Parua Village in Faizabad District, participated in PVS trials and scaling-up of tested technologies in kharif 2006. He grew Usar Dhan 3 on 0.075 ha and got a yield of more than 2.5 t/ha on sodic land. In 2007, he grew the same variety and tried nutrient management technologies (press mud and *Sesbania*) introduced by the CPWF Project and got even better yield (3.5 to 4.5 t/ha). In the rabi season, crops planted in plots where *Sesbania* and press mud were applied during the kharif season also performed well. Subedar and Shanti also used the same technologies and obtained very good yields of rice, mustard, and wheat. According to Shanti, Subedar was able to get his

mortgaged land back because of the increase in his crop production. They were able to grow other rabi crops such as sugarcane, potato, mustard, and peppermint that also gave them good income.

Satkhira, coastal area of southern Bangladesh (BRRI)

Insights from a farm-level survey. In Bangladesh, more than 30% of the cultivable land is in the coastal zone, covering about 2.85 million hectares. Out of this, nearly 0.85 million hectares in 13 southwestern districts are affected by varying degrees of salinity. The coastal area is predominantly rural and agriculture is the main source of people's livelihood. Traditionally the coastal area was monocropped with rice; however, in recent years, visible changes were being observed in land use and management practices of the aforementioned farming communities. Problems of natural hazards, soil and water salinity, traditional farming practices, etc., are hindering the adoption of modern production technologies. In an effort to understand existing practices, and productivity potentials, three villages in Satkhira District were selected for this study. Both a participatory rural appraisal and surveys of farming households were carried out. The analysis revealed that the villages are distinct with respect to degree of salinity and cropping patterns followed by farmers. Ratneswarpur Village is a brackish shrimp area with little or no rice. On the other hand, farmers at Munshiganj grow rice in the rainy season and the fields remain fallow during the DS due to high salinity in both underground and river water. In the boro (dry) season, farmers grow BRRI dhan28 and IET at Gobindapur. However, these varieties are sensitive to salinity, which leads to low productivity and crop loss. The average farm level yield is 4.5 t/ha. In the wet season, BR23 and BRRI dhan41 are grown together with white fish, and this system is gaining popularity. The average yields of BR23 and BRRIdhan 41 are 3.7 and 3.9 t/ha, respectively. This practice has a positive impact on farming households because it provides new sources of income in these saline areas. Furthermore, the high incidence of insects, short seedling height, and low salt tolerance were considered the major constraints to the adoption of available modern rice varieties. Some 60% of the farmers state that inadequate irrigation facilities during the DS contributed to the slow adoption of modern varieties. Developing salt-tolerant varieties, improved crop management options, and good cropping patterns would help enhance the productivity of these deltas.

Farmers' cropping practices. Farmers' practices in salt-affected areas vary based on rice variety, planting method, and harvesting period. In the past, farmers used to practice shrimp culture only. Because of a lack of fresh water, farmers could not grow rice, especially in the dry season (boro). After the installation of shallow tube wells (STW), fresh water became available to their shrimp *gher* (local name for shrimp cultivation area bounded by a polder) in order to grow rice with shrimp in both the dry and wet seasons. The availability of fresh water allowed farmers to introduce boro rice using modern varieties, allowing two seasons per year. Farmers also practice shrimp and freshwater fish cultivation with rice in both the boro and T. aman seasons. The degree of salinity determines the cropping pattern. In the low-salinity areas, boro-T. aman-vegetable and boro + shrimp followed by T. aman are the dominant patterns practiced by the majority of farmers in Shamnagar and Kaliganj. In areas with moderate salinity, boro-T. aman and shrimp + sweetwater fish followed by T. aman are the dominant cropping patterns. However, in high-salinity areas, farmers practice shrimp-shrimp culture in all three study areas.

Farmers' opinions on the advantages of current practices over their traditional practices. Farmers indicated many advantages of current and improved practices over their traditional practices: additional employment, more income, and higher returns from their land through diversification. Farmers' perceptions and demand for MVs for both the wet and dry seasons are shown in Table 1.9. Farmers choose varieties based on their ability to tolerate salinity, yield (better than the yield of varieties they use), and height. BR23 is the dominant variety grown in the wet season in both Kaliganj and Debhata. In Kaliganj, BRRI dhan28 is grown in the boro season and is becoming more popular in the area. According to the farmers, BRRI dhan28 is moderately tolerant of salinity. Since the intensity of salt in both the soil and water is higher during the winter season, farmers prefer a salt-tolerant variety during this season. In the wet season, farmers grow BR23 on a large scale and it is most popular in Kaligonj and Debhata. Farmers believe that BR23 is susceptible to different pests. Moreover, this variety is comparatively short/medium statured. In areas affected by tidal inundation in the T. aman season, BR23 is prone to submergence, resulting in poor plant growth. Therefore, farmers require a high-yielding taller variety. Similarly, BRRI dhan40 is used by some farmers in Kaliganj and Debhata. Farmers observed that this variety can tolerate salinity but it has lower yield. Thus, farmers in these coastal areas want a taller salt-tolerant variety with higher yield.

Table 1.9. Farmers' preferences for rice varieties, Satkhira, 2006.

Season/variety	Characteristics of existing varieties	Characteristics of required variety
1 Winter boro		
BRRI dhan28	Moderately tolerant of salinity, moderate yield	Resistant to diseases, salt-tolerant, has higher yield
2 Wet-season aman		
BR23	Susceptible to stem borer	Taller plants and resistant to pests
BRRI dhan30	Susceptible to insects/pests	Resistant to diseases and tolerant of salt
BRRI dhan40	Comparatively lower yield	Taller plants and higher yield
BRRI dhan41	Lower yield	Salt-tolerant and higher yield

Problems encountered and coping strategies. Several problems were encountered by farmers in shrimp farming. As shown in Table 1.10, farmers use indigenous methods to overcome these problems.

Table 1.10. Problems encountered in shrimp farming and farmers' coping strategies in Bangladesh.

Problems encountered	Farmers' strategies to overcome the problem	Area/site
Shrimp virus	Use lime before releasing prawns. Farmers are not aware of whether viruses are due to source of the prawn or management.	Ratneshawarpur
Lower rain increases salinity and results in lower yield	Use fresh water from adjacent areas when available.	Debhata and Ratneshawarpur
High salinity during crop establishment of T. aman crop	By bringing river water into the *gher* and draining out saline water, salinity decreases.	Debhata
Late shrimp virus diseases	Harvest early before it becomes serious	Debhata
Virus affects the "Baghda" and prawns; however, there is no problem with "Galda"	No solution until now. However, with mixed cultivation (shrimp with white fish), the virus seems to have declined.	Debhata
Fish mortality because of diseases	No solution yet	Kaliganj

*The shrimp cultivation area/plot bounded by a polder is locally called a *gher*.

Farmers identified several constraints to rice production and their perceptions on water quality and environmental issues are shown in Table 1.11. Salinity was mentioned as the major problem. The salinity problem is being tackled by this CPWF project through the development and dissemination of salt-tolerant varieties that match farmers' criteria.

Table 1.11. Farmers' opinions regarding major constraints to rice cultivation in the study areas, Satkhira, 2006.

Constraint	% of farmers' responses		
	Kaliganj	Debhata	Shamnagar
Soil and water salinity	64	88	72
Lack of salt-tolerant rice/variety	56	88	64
Lack of irrigation facility	32	32	64
Drainage problem	4	12	5
High input prices	36	32	32
Disease/pest infestation	8	4	4
Unplanned shrimp culture	4	16	16

Source: Baseline survey, 2005-06.

Mekong Delta of South Vietnam (CLRRI)

The Cuu Long Rice Research Institute conducted surveys in six selected districts in Tra Vinh Province, using a participatory rural appraisal to identify knowledge gaps for crop establishment methods and nutrient management in salt-affected areas. Socio-demographic information and biophysical characteristics were also gathered and constraints to rice cultivation were identified. In addition, baseline surveys were completed. Socioeconomic characterization revealed that

- The majority of farmers belong to the marginal and small holding category.
- More than 70% of the study areas in the districts are severely affected by soil salinity.
- There is a lack of awareness about improved technology for salt-affected soils.
- The average rice yield in salt-affected lands is 3.5 t/ha versus 6–7 t/ha in normal soil.
- Shrimp cultivation hampered rice production due to waterlogging. Shrimp cultivation is a profitable business but risky because of shrimp diseases and viruses.

The livelihood of farm households depends on rice and shrimp cultivation. He Thu (WS rice) is the major crop in Tra Vinh District because of the scarcity of fresh water for irrigation in the DS. Farmers required high-yielding, salt-tolerant, medium- to long-stature, and submergence-tolerant rice varieties. The introduction of salt-tolerant rice such as Mot Bui Do, Soc Trang 5, Ham Trau, and short-duration OM 2395 and AS 996 can increase the productivity of coastal saline rice lands and farmers' income. Shrimp cultivation is a profitable business although shrimp diseases and viruses are major problems. Also, shrimp cultivation hampers rice production due to waterlogging. Based on these findings, several recommendations were made to improve the livelihood of farming communities in Bac Lieu and Tra Vinh regions and to increase farm and water productivity. Information on farmers' practices, innovations in coping with stresses, constraints to the adoption of improved technologies, and technology needs were collected through focus-group discussions, and draft reports were completed. A socioeconomic survey was conducted among 60 farm families in Bac Lieu Province and 35 farm families in Tra Vinh Province to determine current biophysical and socioeconomic characteristics of farm families involved in growing rice and shrimp in the saline areas of Tra Vinh and Bac

Lieu. The information collected included size of landholdings, sources of irrigation, prevailing dominant cropping systems, prevailing crop varieties, cultivation cost, and family income, among others. Major technological constraints/gaps were identified and probable solutions suggested. Opportunities were also identified to help reduce these constraints.

Saline soils of the Nile Delta (RRTC)

The northern Nile Delta in Egypt is an area with extensive saline soils, with high exchangeable sodium that reaches 70% and EC of more than 8 dS/m. Water resources in the northern Nile Delta are less than what is needed to meet domestic, urban, and industrial uses. Recycled wastewater or drainage water is the only source of additional water for agriculture to compensate for the shortage in irrigation water. The objective of this study was to survey soil salinity in the northern part of the Nile Delta close to the sea in the project target areas (Port Said Province and some districts in Kafr El-Sheikh Province). Furthermore, attempts were made to describe crop production problems and determine the optimum cropping patterns and productivity potential of these salt-affected areas. Irrigation water was monitored in Port Said Province, where all lands are affected to some extent by salt stress.

Methods. Port Said and Kafr El-Shiekh provinces were selected based on primary data collected previously in salt-affected areas in northern Egypt. In Port Said, soil samples were collected along El Salam canal starting at 15 km up to its end in a long stretch of 60 km with a width of 5 km. From each km, one sample was taken and a total of 60 soil samples were collected and transferred to the laboratory of the RRTC for analysis. Water samples from the main irrigation canal (El Salam) and its branches were also collected and analyzed at RRTC. The water of this canal is a mixture of agricultural drainage water and fresh water from the Nile. EC, pH, anions, cations, bicarbonates, and carbonates were measured.

Some 100 farmers were selected covering the target area to gather information on cropping patterns, rice production and management practices, and constraints. Questionnaires were distributed to 100 selected farmers by extension workers and the data were summarized. The data included farmers' cultural practices, nutrient management, irrigation and drainage schedules, and the common rice varieties. For Kafr El-Sheikh, coastal districts Sadi Salam, El Reyad, El Hamoual, and Moutobs were selected because they are located near the Mediterranean Sea, and they are more saline due to sea-water intrusion. Ten soil samples were taken from hot spots in each district. Additional information was also collected as in Port Said.

Results: household characteristics. Household family size is about 6 members. Slightly over half of the family members are males (53%). The respondents' ages averaged 57. Only about 33% have actually attended formal schooling. Some 87% of the households covered by this study are involved in farming. About 59% are engaged in farming while others work as livestock raisers. Other households are either involved in business or work as government employees. Men dominate rice farming in the area. Their dominance of rice production is a reflection of the crop's commercial value rather than as a food staple. Rice is considered the second most important export crop after cotton. Wheat is the major winter cereal grain crop and the third major crop in terms of area planted. Maize is the second most important crop, but at least 50% of its production is used for livestock and poultry feed. From the survey, around 33% of the total annual household income comes from rice. Other crops such as wheat share 17% of families' annual income while barley and cotton share 23%. Aside from farming, respondents also get 21% of their annual household income from livestock raising.

***Farming practices*.** Rice is grown under irrigation. Almost all of the farmers (99%) source their water supply from the local irrigation system. Rice lands are affected by different degrees of salinity. Severe salinity occurred 15 years ago as reported by farmers (97%). Right before the project ended, salinity had gone to moderate conditions because of the technologies and change in farming practices adopted by farmers. Land preparation is done mechanically or with animal traction. Before, farmers used to plow twice and dry level the land. Farmers now use improved methods such as laser leveling, subsoiling, and gypsum amendments to reclaim their soils. Transplanting is the most popular method of crop establishment. Moderate to high rates of inorganic fertilizers were used together with rice straw compost. Weeds are controlled with combinations of manual weeding and herbicides. Farmers use salt-tolerant, short-duration, high-yielding varieties such as Giza 177, Giza 178, Sakha 101, Sakha 104, SK2034H, and SK23H.

Yield, rice production, and use. Egypt achieved the world's highest national average rice yield in 2005, with production boosted by hybrids developed locally under an FAO-led project. A yield of 9.5 t/ha was achieved partly through the introduction of newly developed hybrids. In the summer of 2006, farmers' rice yield averaged 6.46 t/ha. Three varieties were planted during this season. Giza 178 is the most commonly used variety, planted on about 82% (102.5 ha) of the total rice area. It yields 6.47 t/ha. Sakha 101 and 104 yield an average of 6.13 and 6.67 t/ha, respectively. In the summer of 2007, Giza 178 was still the dominant variety, planted on about 80% (94.5 ha) of the total rice area. This time, its yield increased to 7.15 t/ha, 10.5% higher than the previous year. Aside from Giza 178, the newly developed hybrid SK2034 was also planted. It was the highest yielding variety during that season, with an average of more than 8.5 t/ha. Because of the exceptionally high rice yield obtained from these varieties, farmers were able to sell an average of about 40% of their total rice production and store 54% to sell later. Only 6% was used for home consumption.

Constraints to crop production and adoption of technologies. There are several constraints to crop production at the project sites The major ones are (i) poor drainage system; (ii) insufficient supply of good-quality seeds; (iii) poor irrigation; and (iv) unstable market, among others. For the adoption of new

technologies, farmers' constraints are (i) the high cost of inputs; (ii) lack of knowledge about new technologies; (iii) unavailability of good-quality inputs (seeds, fertilizers, water, etc.); and (iv) lack of effective communication between farmers and agricultural extension officers. Because of the technologies introduced, farmers were able to obtain high yield and consequently high income that brought a good social life, stability, and gender equality among family members. Farmers in these salt-affected areas practice various cropping patterns (Table 1.12). The predominant pattern in Port Said Province involves rice followed by barley, wheat, or berseem. This project also explored the possibility of introducing a third crop, a short-maturity salt-tolerant forage, using a time window of about 2 months of fallow. Salt-tolerant forage crops introduced by ICBA showed good promise in preliminary testing. Rice varieties grown in these areas are dominated by salt-tolerant Giza 178 (45%), followed by Sakha 104 (30%). However, grain yield in these areas is very low, from 1.2 to 2.8 t/ha.

Table 1.12. Crop patterns in Port Said Province, Egypt (target area).

Common models	Summer	Winter	Percentage
Model 1	Rice	Barley, wheat, or berseem	80
Model 2	Rice	Sugar beet	3
Model 3	Cotton	Berseem	15
Model 4	Maize or sorghum	Berseem or sugar beet	2

Farmers' management practices in salt-affected areas of Port Said, Dakhlia, Beharia, Dammietta, and Kafr El-Sheikh provinces. Apparently, farmers and even extension personnel in these areas often mismanage their crops. This is mainly because of a lack of access to knowledge and poorly trained extension personnel in activities relevant to salt-affected areas. The outcomes of these interviews can be summarized as follows:

- Some farmers still grow salt-sensitive rice varieties such as Giza 177 and Sakha 102.
- Most of these salt-affected areas are not well leveled.
- Use of a high rate of immature farmyard manure with high salinity at the early stages of crop growth.
- High seed rate of up to 250 kg/ha.
- Farmers believe that older seedlings have higher tolerance of salt stress than younger ones, contrary to the recommendations of RRTC, suggesting the use of younger seedlings (25–30 d old) for higher yields.
- Improper sowing date of rice.
- Higher nitrogen and incorrect nitrogen sources and application strategies used for normal conditions.
- Wrong impression about Zn application for rice and subsequent crops, despite the apparent zinc deficiency.
- Farmers not familiar with the benefits and necessity of potassium application for rice grown in salt-affected soils or use of poor-quality water.
- Use of sulfur fertilizers on highly alkaline soils and some fertilizers with high content of sodium.
- Keeping irrigation water in the field for a long time without drainage or clogged drainage canals.
- Lack of proper crop husbandry at early stages and best management practices for saline soils.
- Poor communication between rice farmers and trained extension workers for rice management under poor-quality soil and water, and lack of extension material.
- Difficult communication because most farmers in the newly reclaimed soils (Port Said) are living on their own farms rather than in communities.
- Farmers are ignorant of how to reclaim saline soils or maintain them afterward, and lack good technology transfer programs, for both rice and other crops on saline soils.

Soil analysis showed that soil salinity in the cultivated northern and central parts of the delta in the project area ranged between 4 and 16 dS/m. The soil is clay loam in most areas and could be characterized as saline-sodic. The soils in Port Said are severely deficient in zinc and phosphorus. In most areas, the soil is also deficient in K, whereas, in others, available K is adequate but still extra K is needed because of the high Na in all surveyed areas. Soil in Port Said is high in available nitrogen because farmers there use a rice-fish system with lots of high-protein supplements for fish farming before shifting to field crops.

Irrigation water in the target areas is mostly of low quality. The salinity of the main canal is relatively high (2.0–2.9 dS/m) because of salt intrusion from surrounding fields. Furthermore, a large area is irrigated from the Baher El Baquar drainage canal, which contains municipal, industrial, and agricultural drainage waters with higher salinity and alkalinity as well as heavy metals. Analysis of soil samples collected from the northern districts of Kafr El-Sheikh showed that the soil was heavy clay, and high in both salinity and alkalinity (saline/sodic). In many samples, the concentration of Mg^{2+} was very high, which makes it difficult to reclaim these soils. The dependence on reused drainage water for irrigation in Kafr El-Sheikh aggravated salinity and heavy-metal problems. The soil in this province is also highly deficient in zinc and phosphorus, and farmers mostly face problems similar to those faced in Port Said.

In summary, people living in these salt-affected areas are too poor, with very low productivity and few options. A proper program for agricultural technology transfer for crops grown in these salt-affected areas needs to be in place. Efforts are needed to establish an effective extension program, particularly for rice, as

the most suitable crop for such areas, to ensure better productivity of land and water resources. Dissemination of salt-tolerant varieties of rice and other crops, coupled with training and demonstration on best management practices under conditions of poor soil and water quality, is necessary. All stakeholders, including policymakers, administrators, and researchers have to combine their efforts to develop these unfavorable areas. Current funds are inadequate to cover all salt-affected rice-growing areas in the delta, and these efforts need to be extended to similar areas along the Nile River basin, where most communities are impoverished.

Objective 2. Introduce salinity tolerance into high-yielding rice and nonrice crop varieties that fit into rice-based farming systems in salt-affected areas

The development and deployment of salt-tolerant varieties are the entry point for enhancing productivity in salt-affected areas, mainly because sensitive varieties respond poorly to inputs and mitigation practices. Different approaches were employed, with a major focus on conventional breeding and extensive site-specific testing through participatory approaches using INGER. Modern approaches involving the development and use of marker-assisted backcrossing (MABC), anther culture, and mutant breeding were also explored. Substantial progress was made in tagging a major QTL, *Saltol*, and its introgression into popular varieties through MABC. Large numbers of native landraces were collected from target sites and evaluated for their salinity tolerance, and some of the tolerant lines were physiologically characterized. This information is essential for breeders to select donors for multiple traits and also for further genetic studies. The main achievements are briefly summarized below.

Molecular breeding for tolerance of salt stress

Research into understanding the molecular genetic control of salinity tolerance has led to the identification of tolerant alleles at quantitative trait loci (QTLs) that can be transferred into popular varieties using molecular markers to develop salt-tolerant varieties for the target environments. The specific research activities involved identifying salt-tolerant donors, developing mapping populations, identifying QTLs, developing near-isogenic lines (NILs), fine-mapping, identifying and developing new markers to tag tolerant QTL alleles, validating promising markers in different genetic backgrounds, and using these markers to precisely transfer the QTL into popular varieties through marker-assisted backcrossing (MABC). Although the entire research pipeline for molecular breeding exceeds any single project, key elements of the salinity tolerance marker program were funded by the CPWF Project 7, while additional components were funded by the Generation Challenge Program and the German BMZ/GTZ. A major salt-tolerance QTL on chromosome 1, *Saltol*, previously identified from salt-tolerant landrace Pokkali, was the primary focus of molecular breeding activities such as marker development and MABC. Novel sources of tolerance were also explored, and other QTLs for both seedling- and reproductive-stage tolerance were identified with potential for breeding. This project built the foundation for future activities to combine multiple QTLs to develop higher salt tolerance for different growth stages and environments.

Population development and QTL mapping

IRRI. To identify novel sources of tolerance of salt stress, a set of 53 landraces and 9 modern varieties from Bangladesh and 10 checks from other countries was screened at the seedling stage at IRRI to characterize them physiologically for the basis of salt tolerance. Measurements were made on overall phenotypic performance (SES score), Na^+ and K^+ concentration in leaves, plant vigor, and chlorophyll content. Several landraces from Bangladesh were highly salt tolerant and excellent Na^+ excluders (e.g., Akundi, Ashfol, Capsule, Jatai Balam, Kalarata, Kuti Patnai), providing novel sources of tolerance for future breeding. An F_2 mapping population between Capsule and BR29 was developed. In addition, eight accessions of Pokkali were screened for tolerance and genotyped with 78 SSR markers to analyze the relationships between the different Pokkali landraces. Significant genetic and phenotypic variation was detected, revealing the extensive diversity across the different Pokkali accessions. Additional markers were also added to the IR29/Pokkali QTL map to better define QTLs on other chromosomes (besides *Saltol*) to provide more QTL targets for seedling-stage tolerance.

In parallel efforts from 2005 to 2008, several thousand accessions, especially from IRRI's Genetic Resources Cnter (GRC), were screened to identify novel sources of salt tolerance in addition to traditional sources such as Pokkali and Nona Bokra, the two most widely used donors of salt tolerance. To identify more sources of salt tolerance, reportedly tolerant genotypes from the GRC and elsewhere were collected and screened for salinity tolerance at the seedling stage at IRRI under an Ec of 12 and 18 dS/m. The following genotypes were identified as tolerant and they are potential donors for breeding: Cheriviruppu (IRGC 19928), Kalimekri 77-5 (IRTP 14213), TKM6 (IRTP 11703), Bhura Rata (IRGC 28590), Mushkan 41 (IRGC 6828), Kalarata 1-24 (IRGC 26913), Bhirpala (IRGC 37015), IR4630-22-2-5-1-3 (IRGC 72958), Kajalsail, IR69502-6-SRN-3-UBN-1-B (TON4222 I), IR65483-118-25-31-7-1-5 (TON4244 I), IR65483-141-2-4-4-2-5 (TON4245 I), IR77298-14-1-2 (TON4263 I), IR63262-AC201-1-7-2 (TON4266 I), and IR73689-76-2 (TON4281 I). Some of these genotypes had multiple accessions, of which usually only one was tolerant. One outstanding genotype was from Sri Lanka, AT 401 (Acc. 9105), which showed tolerance comparable with that of FL478, the highly tolerant recombinant inbred line (RIL) derived from Pokkali. Other accessions identified with high salinity tolerance were CI0022 (IRGC 249) and Akundo (IRGC 36968) that were used as

parents for crossing. Another improved variety from India, CSR28, also exhibited high salinity tolerance comparable with that of FL478. SSR markers combined with selective genotyping were used for mapping QTLs for salt tolerance in rice at CLRRI, Vietnam. The salt-tolerant cultivar AS 996 was crossed with IR50404 and 229 RILs were produced by single seed descent. In addition, an IR64/OMCS 2000//IR64 backcross population was developed and 217 BC_2F_2 lines were analyzed. Regression analyses based on SSR allele class differences were performed. Highly significant associations were detected at the SSR locus RM223 on chromosome 8. To examine the power of the identified SSR marker in predicting the phenotype of the salt-tolerance locus, the genotypes of 93 improved varieties at locus RM223 were determined. The results indicated an accuracy of more than 95% in identifying resistant plants. Results of a germplasm survey on OM 4498 and OM 5900 will be useful for the selection of parents in breeding programs aimed at transferring these genes from one varietal background to another and using them in marker-assisted selection.

Molecular marker development and validation. The IR29/Pokkali QTL map was updated using a larger number of RILs (140) and 100 SSR markers to confirm the location of *Saltol* and to identify additional salt-tolerance QTLs. NIL populations were also used to more precisely define the *Saltol* QTL to a 1.2-Mb region on chromosome 1 (11 to 12.2 Mb on the rice physical map). Twenty new polymorphic SSR markers were identified in the *Saltol* region, and these were used for further genotyping of BC populations. Graphical genotyping showed that FL478, the highly tolerant RIL currently being used as a donor for *Saltol* in MABC, had a small Pokkali introgression at the *Saltol* QTL region. Following fine-mapping and annotation of the *Saltol* region, numerous genes were identified in the locus that are likely to be involved in salinity tolerance based on converging evidence from expression data and physiological studies. At first, comparative sequence analysis of annotated genes in this region combined with DNA microarray data identified 8 promising candidate genes in the *Saltol* region that were up-regulated by salinity stress: pectinesterase, serine threonine kinase, phospholipase D, a Myb transcription factor, a Sec A transport factor, an unknown cDNA, a peroxidase, and a sugar transporter. Subsequently, additional candidate genes were identified that had predicted functions relating to salinity tolerance: *SKC1* (of the HKT gene family) that was cloned and identified to be a K transporter by another group (Ren et al 2005), a chloride-cation co-transporter recently cloned (E. Blumwald, UCD), and the previously characterized *SalT* gene. Gene-based insertion/deletion (indel) markers were then developed at four genes: the chloride-cation co-transporter, *SKC1*, pectinesterase, and *SalT*, and these markers were genotyped in the fine-map and MABC populations.

To further test the *Saltol* QTL effect using different donors and genetic backgrounds, three F_2 breeding populations derived from the crosses BRRI dhan40 (sensitive)/IR61920-3B-22-2-1 (tolerant), BRRI dhan28 (sensitive)/IR50184-3B-18-2B-1 (moderately tolerant), and Kajalsail (tolerant)/IR52713-2B-8-2B-1-2 (tolerant) were tested with 20 SSR and two EST markers across the *Saltol* region. The *Saltol* QTL was detected only in the population derived from BRRI dhan40/IR61920-3B-22-2-1 with the SSR marker RM8094 as the most significant (P<0.001) in comparison with four other significant markers, RM1287, RM3412, RM493, and CP03970 (P<0.05). An F_3 population of this cross was used to reconfirm these results. Interestingly, the tolerant parent (IR61920-3B-22-2-1) was unrelated to Pokkali used for the original mapping studies, showing that multiple alleles may provide tolerance at the *Saltol* QTL. However, the fact that no QTL was detected at the *Saltol* locus in the other two populations indicates that other QTLs are involved in salt tolerance.

Fine-mapping of the Saltol QTL and diversity analysis. Four BC families were selected at the BC_3F_1 of IR29/Pokkali, and 25 heterozygous individuals at loci RM140 and RM24 were derived from three backcrossed families and advanced to BC_3F_3. BC_3F_4 seeds were grown to generate 10,000 NILs. Graphical data of 25 individuals derived from the three families showed heterozygous SSR loci of RM140 and RM24 that flanked *Saltol*, indicating recombination in the region. Seven polymorphic markers (RM8094, RM3412, RM493, CP06224, CP03970, AP3206, and RM140) were identified and used to genotype two families of 2,000 BC_3F_4 plants. Based on interval analysis, two peaks were observed, at the RM140 locus and at the region flanked by markers CP03970 and CP6224, with LODs of 5.02 and 3.34, respectively. The peaks suggested two possible QTLs. A possible location of one QTL associated with the trait was between markers RM493 and RM8094 at a maximum distance of 0.6 cM. Moreover, single-marker analysis was done to determine the significant association of the individual markers with the trait, which confirms that marker CP6224 was highly associated with salinity tolerance at the seedling stage. In this study, 8% of the NILs had the introgressed segment of Pokkali. Most introgressed segments were in the region of the QTL.

Validation of SSR markers and haplotype diversity at the Saltol locus on chromosome 1 in rice. In another study, 115 diverse genotypes together with 7 Pokkali accessions were analyzed for diversity at the *Saltol* region from 10.8 to 13.7 Mb (58.1 to 66.5 cM) on chromosome 1. Seven SSR and EST markers were used. A total of 7 haplotypes were identified among the 115 genotypes. One haplotype was identified in five tolerant genotypes with high tolerance of salt stress. The other six haplotypes seem to be associated with moderate tolerance. Different accessions of Pokkali also seem to have different haplotypes, and accessions with tolerant alleles were identified for use in breeding.

***Marker-assisted backcrossing for improved salinity tolerance*.** An MABC system involving foreground (specific to the target QTL allele), flanking (recombinant), and background (recurrent parent-specific) markers was developed to transfer the Pokkali-derived *Saltol* QTL allele into popular but salt-sensitive varieties. Polymorphism surveys using SSR and gene-based indel markers were completed for a number of different popular varieties to identify markers that can be used in different populations. Crosses were made

with the *Saltol* donor FL478 (IR66946-3R-178-1-1) to recurrent parents BRRI dhan28 (a dry-season Bangladeshi variety), BR11 (a wet-season Bangladeshi variety), IR64 (a widely popular irrigated rice), and Swarna and Samba Mahsuri (popular in India). Through this project, two populations underwent marker-assisted selection in several backcross generations: FL478/BRRI dhan28 and FL478/IR64, were brought to an advanced stage, and are being continued through other projects to test the effectiveness of *Saltol* under field conditions. Furthermore, training for molecular marker techniques with NARES partners was pursued to help build their capacity for marker-assisted breeding.

Further studies on Saltol at UCD. The significant contribution of *Saltol*, as the major QTL of Na^+/K^+ discrimination during salt stress in rice, was determined by characterizing the ability of the parental lines Pokkali and IR29 and their progenies (RIL FL478 and NILs 30, 17, 23, 24, and 35) to maintain ion homeostasis. The eight genotypes rank from tolerant to sensitive as follows: Pokkali, FL478, NIL30, NIL17, NIL23, NIL24, NIL35, and the most sensitive, IR29. Data on Na^+ and K^+ concentrations, damage scores, and dry matter production agreed with this classification. Pokkali, FL478, NIL30, and NIL17 had the lowest damage scores, higher dry matter production, and lower Na^+ concentration in roots and shoots. Genotypes that display the lowest Na^+ concentrations produced the greatest dry matter and had fewer dead and injured leaves.

Genes in the *Saltol* region were annotated, and some of them were selected for further analysis based on converging evidence from physiological, positional, and global gene expression analysis. Transcript levels of selected candidate genes (cation chloride co-transporter, *SKC1*, *SEC A,* and serine threonine kinase) were up-regulated in roots and shoots of Pokkali, suggesting that these genes might be involved in the tolerance of Pokkali. The expression of ion transporter *SKC1* and cation chloride co-transporter was up-regulated only in the roots of NIL30 and IR29. But the expression of *SKC1* in the roots was very low in the two lines. Moreover, genes involved in vesicular trafficking (*SEC A and SEC 23/24*) were induced in the roots of IR29 under saline conditions. Only the cation chloride co-transporter and *SEC 23/24* were up-regulated in roots of NIL17 under salt stress. The expression of SAM synthetase is regulated in a tissue-specific manner in all genotypes. Apparently, it seems difficult to make definite conclusions from these data on the responses of candidate genes to salt stress among these lines, as the expression of these genes could not differentiate tolerant lines from sensitive lines. However, the induction in expression of genes such as cation chloride co-transporter, *SKC1, SEC A*, and serine threonine kinase in the roots and shoots of Pokkali suggests a possible role of these genes in tolerance. The existence of another cation chloride co-transporter *in planta* is confirmed by isolating the gene from Pokkali. Cloning of this gene will help verify its function and determine the significance of these cation chloride co-transporters in ion homeostasis. Further analysis of this gene as well as others in the *Saltol* region is ongoing.

Physiological basis of tolerance of salt stress in rice. Salt stress is a major constraint to cereal production worldwide, and particularly for rice grown in coastal areas under marine influence, or even in some inland areas where excessive irrigation results in a buildup of harmful salts. Rice is particularly sensitive to salt stress, but it is the only cereal that has been recommended during initial reclamation of salt-affected soils because of its ability to grow well under flooded conditions (Ismail et al 2008). Rice is peculiar in being relatively tolerant of salt stress during germination, active tillering, and maturity, but sensitive during the early seedling and reproductive stages. The physiological bases of tolerance during seedling stage are fairly well understood; key traits are high seedling vigor, salt exclusion at the root level, compartmentation of ions in roots and older tissues, high tissue tolerance, responsive stomata, and a sensitive antioxidant system, particularly the ascorbate/glutathione pathway of oxidative stress tolerance (Moradi and Ismail 2007, Ismail et al 2007). Growth and physiological responses during reproduction were investigated using genotypes contrasting in tolerance at both stages. Salt stress affects almost all aspects of vegetative and reproductive growth. It reduces survival and growth, delays flowering, hinders neck node elongation and panicle extrusion, reduces spikelets per panicle and pollen viability, and causes high panicle and spikelet sterility. Tolerant cultivars strongly exclude salts from the flag leaf and developing panicles, maintain their stomatal conductance and photosynthesis, particularly that of the flag leaf, and maintain the activity of enzymes involved in ROS-scavenging systems.

Most of these mechanisms are effective during both the seedling and reproductive stage. These traits are mostly independent, but none of the known salt-tolerant landraces combine favorably more than a few of them, with considerable variation in the extent of expression of particular traits among cultivars, suggesting the likelihood of identifying even better donors and combinations of alleles at useful genes. Salinity tolerance at the seedling and reproductive stages is only weakly associated; hence, pyramiding of contributing traits at both stages is needed for developing resilient salt-tolerant cultivars. Based on these studies, we hypothesize that salinity tolerance can be improved substantially by using donors superior in particular traits and eventually through mapping and combining favorable alleles. We collected and characterized large sets of landraces from target areas as well as varieties and breeding lines developed for salt-affected areas. Most of this material was characterized for major physiological mechanisms. This information is useful for breeders to select suitable donors for particular traits.

A large number of landraces were collected by partner institutions (India, Bangladesh, Vietnam, Egypt, Iran) and inventories of these lines as well as of tolerant rice varieties were submitted to IRRI. Some of these lines were evaluated for specific mechanisms. For example, out of a set of 384 salt-tolerant elite lines, 11 lines were grouped as high Na^+ excluders (<0.06 mM/g/day), while 86, 63, 95, and 129 lines were

categorized as excluders (0.06–<0.1 mM/g/day), intermediate excluders (0.1–<0.2 mM/g/day), accumulators (0.2–<0.5 mM/g/day), and high accumulators (>0.5 mM/g/day) for Na^+ uptake. Based on Na/K ratio, 69 elite lines had a very low (≤0.2) ratio, whereas 37 had a very high (>1.0) ratio. Na uptake and Na/K ratio were negatively correlated with visual symptoms (SES score). Another set of 75 lines was analyzed for physiological mechanisms for seedling-stage tolerance. This set included 33 tolerant (SES ≤ 5), 21 intermediate (SES >5 and <7), and 21 susceptible (SES ≥ 7) varieties. Measurements were made on leaf-to-leaf compartmentation, vigor, chlorophyll concentration, SES scores, and Na/K concentration in the roots and shoots at 10 and 25 days after the start of the stress treatment. Visual evaluation of seedling tolerance (SES score) was highly correlated with % Na^+ in shoots (R^2 = 0.82), with % leaf chlorophyll (R^2 = 0.77), and with Na/K ratio in shoots (R^2 = 0.72), but had less correlation with vigor (R^2 = 0.50), % Na^+ in roots (R^2 = 0.29), leaf-to-leaf compartmentation (R^2 = 0.28), and Na/K ratio in roots (R^2 = 0.11) (Moradi and Ismail 2007, Ismail et al 2007).

Besides the work at IRRI, material collected at various centers was also classified for important traits such as visual symptoms (SES) and salt uptake and compartmentation. A good example is the work conducted at CSSRI using artificially salinized water tanks (125 mM NaCl). In this, entries IR63731-1-1-4, IR65192-4B-3-2, IR65195-3B-6-3, IR67075-2B-2-2, and BW 267-3 exhibited very low Na uptake(<0.60 mmol/g dry wt.) and therefore could be considered potential Na excluders. Similarly, IR9884-54-3-1E, IR51500-AC-11-1, IR55182-3B-10-3, IR72046-B-R-7-3-1, IR1829-3R-82-1, IR72048-B-R-2, and IR72046-B-R-8 exhibited low Na uptake, and IR51491-AC10, IR63275-B-1-1-3, IR63311-B-3R-B, IR64197-3B-17-2, IR65196-3B-10-2-3, and IR70865-B-P-16-2 accumulated higher K (>1.0 mmol/g dry wt.). In another set, IR65209-3B-1-2-1, Nona Bokra, IR65575-4B-10-1-2, IR63731-1-1-4-3, IR65196-3B-20-2-2, and IR65192-4B-4-2 were identified as high K accumulators (>1.5 mmol/g dry wt.). At RRII, a set of 75 lines from Iran was assembled and multiplied in normal paddy fields and characterized for salt tolerance at 0, 4, and 8 dS/m. Traits evaluated at the seedling stage were tolerance index (1–9), root dry matter, shoot dry matter, root/shoot length, Na and K concentrations, and Na/K ratio, among others. Rice genotypes were classified into tolerant, medium, and susceptible.

Physiological basis of tolerance of salt stress in nonrice crops (ICRISAT)

Methods. Experiments involving peanut and pigeonpea genotypes contrasting in salinity tolerance, based on first-year data, were conducted at ICRISAT to investigate the response of transpiration to salt application. The background hypothesis is that salinity would decrease transpiration and thus reduce photosynthesis and biomass accumulation. In this case, we can hypothesize that "successful" genotypes would be able to maintain a relatively higher rate of transpiration, while being efficient at using water to produce biomass (high water-use efficiency, WUE). However, maintaining a high rate of transpiration under salinity may also allow a larger amount of salt to be loaded in the xylem stream, unless plants can exclude salt from being loaded via roots. We investigated three aspects: (i) the relative reduction in transpiration rate of tolerant and sensitive genotypes, (ii) the relation between WUE and biomass accumulation under salt stress, and (iii) the apparent xylem Na concentration in plants treated with salt.
Results. In groundnut, transpiration decreased fairly rapidly after imposing the salt treatment. Although we could not assess transpiration on the first two days after salt treatment, it was very clear that, by day 5 after stress imposition, groundnut reached a fairly constant relative rate of transpiration compared with the control. Other experiments using a similar protocol have been carried out in pearl millet and showed a similar pattern, that is, a rapid decrease in transpiration after salt treatment and a fairly constant transpiration rate afterward. In contrast, the response of pigeonpea was very different. As in groundnut, transpiration decreased very rapidly, as shown by the lower rates achieved after treatment. However, the relative rates of transpiration continued to decrease steadily in the following 10 days, with several plants reaching less than 20% of the control.

Genotypes of groundnut and pigeonpea varied markedly in percentage decrease in transpiration. One groundnut genotype maintained a transpiration rate at 90% of the control, whereas others had transpiration rates as low as 60% of the control. In pigeonpea, the rate of decrease was also different. Since that rate continued to decrease steadily, we compared genotypes based on average relative transpiration rates and found a good relation between the average rate of decrease and the degree of sensitivity of pigeonpea to salinity, as measured in the previous screening. The main conclusion of this study is that tolerant pigeonpea genotypes maintain higher relative transpiration than sensitive ones under salt stress, and that salinity decreased the transpiration of sensitive genotypes, resulting in a dramatic decrease in biomass accumulation. In groundnut, transpiration efficiency (TE) did not vary much among genotypes under a control treatment, and only ICG4955 had a lower TE, but large variation was observed under salinity. ICG4890 had the highest TE and ICG6022 the lowest. The ratio of biomass accumulation correlated with TE under salinity (R^2 = 0.42). In pigeonpea, very little difference in TE was also found under control conditions, except for two wild accessions that had higher TE. The relative decrease in dry weight under salt stress correlated with TE (R^2 = 0.59). In contrast, salinity stress decreased TE dramatically, with large variation across genotypes. The relative decrease in dry weight under salt stress correlated significantly with TE (R^2 = 0.71), suggesting a role of TE in tolerance.

Xylem Na concentrations were high in groundnut, with substantial genetic variation, for example, genotype ICG11144 had 4.9 mg Na/kg water, whereas ICG4998 (tolerant) had only 2.72 mg Na/kg of water. The ratio of biomass increase correlated with xylem Na (R^2 = 0.53). Pigeonpea also showed large differences in xylem Na concentration. Xylem Na appeared to be higher than in groundnut, which might explain the higher sensitivity of pigeonpea to salinity than groundnut. Wild relatives of pigeonpea had much lower xylem Na accumulation (24–45 mg Na/kg water) than cultivated pigeonpea (43–105 mg Na/kg water). Except for two genotypes that showed large variation in their xylem Na concentration, we found a good relation between the ratio of shoot biomass under salinity and xylem Na concentration (R^2 = 0.51).

After repeated screening of the groundnut mini-core collection in 2006 and 2006-07, we selected five tolerant genotypes and five susceptible genotypes for evaluation of TE and Na accumulation, particularly at the reproductive stage, with the hypothesis that, as in chickpea, reproduction might be more sensitive to salt stress in groundnut. Salt treatment was applied at either sowing or flowering time, and several biochemical indicators (ABA, proline, protein profiling, etc.), leaf gas exchange (transpiration and leaf conductance), and TE were measured. Salinity at the reproductive stage was applied when 50% of the plants had at least one flower. Differences between genotypes for pod yield under saline conditions were confirmed in a glasshouse environment for 4 out of 5 tolerant or sensitive genotypes. Tolerant genotypes showed a larger drop in transpiration rate upon salt treatment than the sensitive ones. On average, the relative transpiration of the sensitive group was about 60–80% of the control, whereas the relative transpiration of the tolerant group was as low as 40% of the control. No major differences between genotypes were observed in apparent xylem Na concentration. Using a parallel set of plants kept through maturity, no relation was observed between stem, leaf, and shoot Na concentration and pod yield, suggesting that the extent of Na accumulation in shoots was not directly responsible for the effect on pod yield under salt stress. This confirmed the lack of a relationship between shoot Na concentration and seed yield that we found in the large salinity screening of 2006.

Discussion. After several years of evaluation involving a large number of germplasm accessions of chickpea and groundnut, it appears that the tolerance of these two crops of salinity had no relation with the Na concentration in shoot tissues, which is contrary to that observed in pigeonpea, in which salt tolerance correlated negatively with Na accumulation in the shoot. In fact, the high concentration of Na in salt-sensitive genotypes was simply related to their lesser growth, and did not necessarily imply that the lesser growth was caused by Na itself. Therefore, these results contradict the prevalent idea that salt stress is due to Na toxicity. In chickpea and groundnut, the relation between biomass and yield under salt stress was very weak or inexistent, and the major effect of salt stress was likely to be on the reproductive stage rather than on growth per se. More recent work has been done in which we followed the number of buds, flowers, and pods to assess whether any of these stages are particularly sensitive to salt stress using several contrasting lines of chickpea. Results indicated that the yield differences between tolerant and sensitive genotypes were explained by differences in the number of flowers that were produced under control conditions. Among these legumes, groundnut appeared to be the most tolerant of salt stress, followed by chickpea. Pigeonpea was extremely sensitive to salinity and has a limited chance to become an option in saline areas despite some genetic variability.

Generation of breeding lines and strategy to combine tolerance of multiple abiotic stresses at IRRI

Salt stress invariably occurs with other abiotic stresses and tolerance traits for these stresses are controlled by numerous genes, so a breeding strategy to combine multiple stresses is needed. A modified diallel selective mating system (DSMS) was followed to develop genotypes with high yield and tolerance of multiple abiotic stresses. A large number of single, 3-way, 4-way, and multiple crosses (>1,850) were made in both the wet and dry season using diverse donors for salt and associated abiotic stresses during the project's timeline. Crossing aimed to break linkage blocks and integrate important traits to increase adaptability and productivity in salt-affected areas. The specific traits considered in selecting parents for crosses were salt tolerance; high yield; long slender, medium slender, long bold, and medium bold grains with good cooking quality; resistance to important diseases (rice tungro); and tolerance of other stresses such as zinc deficiency, iron toxicity, heat, and submergence. The objective of this breeding strategy was to increase the frequency of desirable alleles in the population, thus intermating only selected alleles based on phenotyping and also MABC to increase the probability of desirable recombinants and further improve popular rice varieties lacking specific tolerance.

Donor parents were selected and F_1s were again intercrossed to develop F_1 diallel series. To accommodate more diverse genotypes in the crosses, a partial diallel was used. It is difficult to make many crosses in self-pollinated rice, so a half diallel was made without reciprocals ($n \times (n - 1)/2$). The major donors for various traits involved in the basic series in successive cycles are as follows:

- Salt tolerance: IR66946-3R-178-1-1 (FL478), Cheriviruppu, Kalimekri 77-5, CSR11, IR4630-22-2-5-1-3, IRRI 128 (PSBRc 88 or CSR23), AT401, CSR28 TKM 6, Akundo, Bhirpala, C10022, Pokkali, Nona Bokra
- Submergence tolerance: IR82809-237 and IR82810-407
- Zn deficiency tolerance: A69-1
- Fe toxicity tolerance: Suakoko 8, IR61640-3B-14-3-3-2
- Good grain quality: OM 4498, PSBRc 82

- Acid soils: AS 996
- Good plant type with high yield (from the irrigated breeding program): IR71701-28-1-4, IR74963-262-5-1-3-3

This is a long-term breeding strategy for generating novel recombinants for tolerance of multiple abiotic stresses and it envisages breaking the stubborn linkage blocks that are characteristics of self-pollinated species. So, the advantage of this series is expected to be harnessed beyond the timeline of the project.

Screening, field evaluation, generation advancement, and dissemination of tolerant rice genotypes. More than 26,500 genotypes were screened in the IRRI phytotron for seedling-stage salinity tolerance and were advanced during the project duration. Screening was done using 120 mM of NaCl in modified Yoshida culture solution and buffer-based culture solution. Advanced breeding lines, selected based on seedling-stage salinity tolerance score and morphological acceptance, were further evaluated at a natural field site at Ajuy, Iloilo, during the wet season, with salinity of 12 to 15 dS/m, before final selection and seed multiplication. About 3,050 genotypes were selected during various cropping seasons and advanced. Stabilized genotypes were clustered into different modules specific for the different target areas based on specific plant- and grain-type requirements.

The project included partners from both coastal and inland salt-affected areas. Coastal sites had two seasons, the WS and DS, whereas in others, rice was mostly grown only during the WS. During the project, each coastal site received 8 seed sets totaling 300 genotypes, while other sites received 6 seed sets comprising 242 genotypes through both regular and special sets of the International Rice Soil Stress Observational Nursery (IRSSTON). Additional germplasm was also provided based on specific requests. Breeding lines were screened and selected and promising lines were tested further with farmers through PVS trials. Examples of selected lines were IR59443-B-7-3-2, IR61919-3B-18-3, IR50184-3B-18-2B-1, IR51499-2B-29-2B-1-1, IR61919-3B-7-2, IR64197-3B-14-2, IR72593-B-19-2-3-1, and IR72046-B-R-3-3-3-1. NARES also used selected materials as donors in their national breeding programs. Some lines are nominated for release such as IR72046-B-R-3-3-3-1, selected for coastal areas of eastern India, and CSR-89-IR-8, selected for inland sodic soils of northern India. Another IRRI breeding line, IR63307-4B-4-3, was released as BRRI dhan47 for the saline areas of coastal Bangladesh.

Adjusting screening techniques for seedling-stage salinity tolerance. Screening for seedling-stage salinity tolerance used to be conducted in phytotrons under 29/21 °C day/night temperature and 70% relative humidity (RH). But many entries identified as tolerant at the seedling stage performed poorly in many locations in both coastal (Orissa, India, and Satkhira, Bangladesh) and inland (Lucknow, India) areas as most of the target environments of NARES are hotter, especially at the early seedling stage. To mimic this temperature regime, the ambient temperature of the phytotron was readjusted to 35/25 °C day/night and RH kept at 70%. Higher day temperature increases salt uptake by enhancing transpiration, which subjects seedlings to more severe stress. Temperatures of up to 40 ºC are often encountered in coastal and inland salt-affected areas during the main rice season, whereas low RH is observed in inland salt-affected areas.

Coastal saline Bangladesh (BRRI)

BRRI followed a comprehensive approach to develop varieties adapted to the coastal saline areas of Bangladesh. Numerous activities were undertaken every year over the duration of the project. These activities are briefly summarized below. Further details and the data generated became available as part of the data files submitted with this report and also in a paper published in the proceedings of the "International Conference of Delta 2007."

Generation of new crosses and generation advancement. Numerous crosses were made every year for both irrigated (dry-season) and rainfed lowland (wet-season) ecosystems. During 2006-08, a total of 137 crosses were made for both irrigated (73) and rainfed (64) ecosystems. These crosses were then grown with their respective parents in subsequent years in hybridization blocks to confirm the F_1 hybrids. Confirmed hybrids were then used for generation advancement. For the dry season, the use of BRRI dhan28 and 29 as recipient parents was emphasized because of their popularity among farmers. Selected F_2 populations (2,000–3,000 plants per population) were grown every year and used for selection within each population. Selected plants were then grown in bulks (F_3–F_4) in saline areas such as Sonagazi and Satkhira together with standard checks for the selection of pedigree progenies and bulk populations. This process continued until fixed lines with good yield and grain quality and with reasonable tolerance of salt stress were identified (F_6–F_7 generation). Selected lines were then evaluated in observational yield trials (OYT). These trials combined lines from INGER-IRSSTN nurseries, PVS trials, and selected breeding lines, as well as germplasm introduced from elsewhere, such as the six varieties introduced from South Vietnam for the dry season. These trials were mostly nonreplicated, with plot size of 5.4 m by 10 rows, 25 cm apart. Selections were then made based on duration, plant type, and salt tolerance. Tolerant lines were then re-evaluated in replicated trials in the greenhouse of the plant physiology section of BRRI to confirm their tolerance. These OYT were conducted every year throughout the project and selected genotypes were either re-evaluated in a subsequent OYT or entered into preliminary yield trials (PYT).

Preliminary yield trials were conducted throughout the project duration, from 2005 through 2008. Breeding lines developed through conventional methods, anther culture, or somaclonal variation were evaluated in yield trials with 2–4 replications. Lines were evaluated for morphological traits, duration, farmers'

preference, tolerance of salt stress, and resistance to prevailing diseases and pests as well as grain yield. Numerous breeding lines were evaluated against salt-tolerant checks each season and superior lines were selected and re-evaluated through PVS trials. For example, during the last year of the project (2007-08), a total of 42 breeding lines were evaluated at the BRRI regional station in Satkhira, with BRRI dhan40 and 41 as tolerant checks, and 17 genotypes were selected for further testing during the WS. During the dry season of the same year, 8 breeding lines were evaluated with BRRI dhan47 as the tolerant check, but none of them outyielded BRRI dhan47.

Genotypes selected from PYT were then evaluated in secondary yield trials (SYT). These trials normally involve fewer breeding lines but they are evaluated using the same methods described for PYT. BRRI dhan40 and 41 and BR11 were used as checks during the WS, and BRRI dhan28 and 47 were used during the DS. Numerous superior genotypes were selected during this process for both the WS and DS. Of particular importance are crop duration, plant height, grain quality, nonshattering, and grain yield. Selected genotypes are further tested in farmers' fields through PVS trials for final evaluation and selected lines are promoted for national testing and release as commercial varieties. BRRI dhan47 (IR63307-4B-4-3) was released through this process in 2006, and a few more lines are now in the final stages of testing.

International Rice for Soil Stress Tolerance Nursery (IRSSTN). *I*RSSTN is the INGER nursery specific for salt-affected and other problem soils. Each country receives a set of genotypes through this network for evaluation under local conditions. Standard procedures are used across countries for evaluation and data collection. More than 160 breeding lines for the WS and 140 lines for the DS were evaluated between 2005 and 2008 in Bangladesh. During each season, selections were made relative to local high-yielding varieties and selected lines then went through the evaluation process described above.

Germplasm evaluation for salt tolerance. This evaluation was performed under greenhouse conditions at BRRI, using culture solutions and the standard method developed at IRRI. Breeding lines selected from OYT, SYT, PVS, and IRSSTN trials were all evaluated for their salinity tolerance and selected lines were further tested for agronomic and quality traits. For example, during 2005-06, 170 IRRI lines, 57 landraces, 5 PVS lines, 19 IRSSTN materials, and 2 checks, Pokkali (tolerant) and IR29 (sensitive), were evaluated. In 2006-07, an additional 110 lines were evaluated and another set of 75 lines was evaluated in 2007-08. Tolerant lines were selected based on their overall performance using the standard IRRI SES scoring, with 1 being normal and 9 as dead or dying. Another set of trials was also conducted for evaluating breeding lines for tolerance of salt stress during the reproductive stage. The method used involved growing plants in perforated pots filled with fertilized soil. The pots were then bathed in saline water (6–8 dS/m), from a few days before panicle initiation until harvest. Tolerant lines were identified based on a set of traits, including the extent of panicle exsertion, fertility, overall health, and grain yield. These lines were then evaluated for other traits under field conditions.

Coastal saline areas of Orissa, India (CRRI)

Farmers in the target areas mostly grow low-yielding local rice varieties during the wet season. In the dry season, a limited area is grown with high-yielding rice varieties, which are intolerant of salt stress and do not perform well under saline conditions. The development and deployment of suitable salt-tolerant varieties are essential for enhancing and stabilizing crop yields in these areas. In this project, local landraces from coastal saline belts were collected, evaluated for their salinity tolerance at the seedling stage, and then used as donors for developing improved varieties. In addition, advanced breeding lines and existing varieties received through the project's germplasm testing network were evaluated in farmers' fields and promising ones were selected through farmers' PVS trials. Seeds of selected genotypes were multiplied and provided to farmers for further testing and adoption.

Collection and evaluation of rice germplasm. Forty-five rice landraces were collected from coastal saline areas of Orissa and West Bengal. They were evaluated for salinity tolerance at the seedling stage following the procedure developed by IRRI. Scoring for visual symptoms of salt injury was done at least twice during 8–16 days of growth at EC of 12 dS/m depending on environmental conditions and level of injury. Tolerant genotypes were re-evaluated in three replications to confirm their reaction. Nine lines were identified as tolerant (Kamini, Talmugra, Rahspanjar, Ourmundakan, Nangalmutha, Paloi, Marisal, Rupsal, and Ravana), with an SES score of 3. Some of these genotypes are now being used as donors in breeding programs.

Development and evaluation of salt-tolerant rice varieties**.** Crosses were made using popular high-yielding varieties Savitri, Gayatri, Swarna, Mahsuri, and Jaya as female parents and salt-tolerant donors Ourmundakan, Kalapanka, Rahspanjar, Bhurarati, Pokkali, and Patnai 23 as male parents for developing varieties for the WS. For the DS, high-yielding short-duration varieties Khandagiri, Parijat, and CR Boro Dhan 2 were used as female parents and the salt-tolerant donors IR73571-3B-2-1, IR72402-B-P-25-3-1, and NSICRC 106 as male parents. Elite breeding lines were evaluated along with existing salt-tolerant varieties, popular landraces, and elite lines from IRRI in on-farm trials during 2004-08 in RCBDs with three replications. The soils for these trials were sandy loam to clay loam, with pH of 5.5–6.6, organic C of 0.61–0.94%, total N of 0.06–0.09% and available P of 10–16 kg/ha. The most promising genotypes were re-evaluated in subsequent years to test their yield stability.

Out of 12 genotypes evaluated during the 2004 wet season, CR2093-7-1 produced the highest grain yield (6.4 t/ha), followed by Lunishree, Sonamani, CR2094-46-3, SR26B, and CR2096-71-2 (4.5–6.0 t/ha). The yields recorded in 2004 for most genotypes were relatively high, possibly because salinity was low (soil ECe of 2.4–6.6 dS/m and field water EC of 1.0–4.8 dS/m) and no drought owing to well-distributed rainfall. In the 2005 wet season, 13 genotypes were evaluated at two sites. Patnai 23 gave the highest grain yield (4.7 t/ha), followed by SR26B, CR2096-71-2, and CR2070-52-2 (3.6–3.8 t/ha) at site I (soil ECe of 3.9–10.4 dS/m and field water EC of 0.7–3.5 dS/m), and Lunishree, SR26B, CR2096-71-2, and CR 2093-7-1 (2.3–2.6 t/ha) at site II (soil ECe of 3.9–14.3 dS/m and water EC of 0.6–1.2 dS/m). Both sites were subject to early-season salinity followed by submergence twice during the active tillering stage. At site II, there was heavy infestation of leaf folder, resulting in lower yields.

In the 2006 wet season, 14 genotypes were evaluated at two sites but the crop at one site was badly damaged by complete submergence for about 10 days soon after transplanting. Although the crop at the other site (soil ECe of 4.6–9.0 dS/m and field water EC of 1.2–5.5 dS/m) was also submerged for a few days, most of the genotypes survived and produced good yields. SR26B gave the highest grain yield of 3.6 t/ha, followed by Lunishree and CR2093-7-1 with a similar yield of 3.3 t/ha. Patnai 23 also had good yield. During the 2007 wet season, 14 genotypes were evaluated at two sites but most of them suffered heavy damage from drought and salinity at the seedling stage and unusually prolonged submergence after transplanting following heavy rainfall and blockage of the river mouth with sand deposits. Some of them even could not survive. Nevertheless, Lunishree, SR26B, Patnai 23, and CR2095-181-1 performed better at both sites and produced grain yields of 0.75–1.15 t/ha.

Based on the results of these multisite and multilocation trials, SR26B, Patnai 23, Lunishree, CR2093-7-1, CR2096-71-2, and CR2070-52-2 were selected for the WS, and CSR4, Annapurna, IR72046-B-R-3-3-3-1, IR72593-B-19-2-3-1, CR2473-7-169-1, CR2073-33-155-2, CR2473-9-136-1, CR2472-1-6-2, and CR2485-7-3-45-1 were selected for the DS as potential commercial varieties. The CRRI lines CR2096-71-2, CR2070-52-2, and CR2093-7-1 were nominated in 2005 for multilocation testing under the All India Coordinated Rice Improvement Program (AICRIP), and were found promising. Seeds of promising varieties/lines were multiplied and distributed to farmers of the target sites for testing in baby trials in their own fields each year.

Salt-affected soils at Lucknow, Uttar Pradesh, India (CSSRI)

Evaluation of rice genotypes for sodicity tolerance through participatory varietal selection. PVS is an important tool for disseminating technology. We used this approach for validating and outscaling both salt-tolerant high-yielding varieties and management and mitigation practices.

Methodology. PVS trials involving rice genotypes 2K219, CSR23, 2k239, NDR359, CSR13, CSR-89-IR-8, CSR30, CSR36, and 2K228 were conducted in farmers' fields with soil pH of 8.9 to 9.4 at Dhora Village, Unnao District, Uttar Pradesh, during the WS of 2006. Seedlings (35-d-old) were transplanted at 20 × 15-cm spacing with four replications in 12-m^2 plots. The recommended doses of fertilizer (150 N:60P:25 $ZnSO_4$) were applied uniformly in all plots.

Results. Narendra 359 had the highest grain yield (5.55 t/ha), followed by CSR36 (5.43 t/ha), CSR13 (5.11 t/ha), CSR-89-IR-8 (5.13 t/ha), and 2k239 (5.12 t/ha) at soil pH of 8.9. In fields with higher pH of 9.4, CSR13 had the highest yield (4.75 t/ha), followed by CSR-89-IR-8 (4.7 t/ha), CSR36 (4.7 t/ha), and Narendra 359 (4.2 t/ha). On the basis of these trials, it is also observed that genotype CSR-89-IR-8 matured about 10–20 days earlier than the other genotypes screened in the trials. These results suggested that adaptation of these varieties is site-specific based on the extent of stress, and that PVS is a good method for selecting varieties that can meet local adaptive and preference requirements.

Rice genotypes identified for sodicity tolerance from international sources. A total of five genetically diverse germplasm entries, including three check varieties developed by CSSRI, were evaluated in highly sodic soils (pH 9.8) at the regional research farm, Shivari. The results indicated that entries CSR36 and IR70023-4B-R-12-3-1 developed by CSSRI and IRRI performed better than the other entries, with grain yield of 2.0 t/ha. Other promising entries were IR64419-3B3-2 (1.8 t/ha) and IR51491-AC10 (1.5 t/ha).

Breeding for alkaline soils of Uttar Pradesh, India (NDUAT)

***Screening of IRSSTN germplasm for soil sodicity tolerance*.** IRSSTON entries and checks were screened every year for the project duration and selected lines were field-tested in PVS trials and used in breeding. In 2008, 40 entries and 2 checks (CSR30 and Narendra Usar Dhan 3) were evaluated in replicated trials at pH 10.5 during the WS. Entries were grown in 2-row plots of 5 m length using 20 × 15-cm spacing during transplanting of 35-d-old seedlings. Plant height (cm), days to heading, phenotypic acceptability, tillering ability, spikelet fertility (%), tolerance scores, yield, and disease and pest scores were evaluated using the SES. Monthly weather data indicate that total rainfall was high during the first week of August and declined progressively toward the end of the WS. Entries showed wider variation in all traits evaluated; 10 entries were selected for subsequent evaluation.

Evaluation of promising lines for high sodicity tolerance. Twenty lines selected in previous years were evaluated for sodicity tolerance and zinc efficiency at pH 9.5 and 10.5 in two different sets, using an RCBD

with three replications. Wide genetic variability was observed for yield and its attributes in both sets. The best entries at both pH are IR66946-3R-178-1-1 (FL 478), 507 (EC 541934), and IR75395-2B–B-19-2-1-2. These entries will be multiplied, promoted for validation in PVS field trials, and used for hybridization.

Generation and evaluation of segregating populations and evaluation of local material. This activity began from the start of the project to generate new material. Each season, segregating F_2s and advanced populations were evaluated in alkaline fields at pH 9.5. Selections were made and backcrossed, whereas topcrosses were purified for evaluation at higher sodicity. In addition, every year a few single crosses were made using local material, including landraces, to widen the genetic variability for further selection. Local landraces were also being collected every year and evaluated for tolerance. For example, in 2008, 19 traditional and improved genotypes collected from several districts of eastern Uttar Pradesh during 2006 and 2007 were evaluated and characterized for growth, phenology, and yield, and 6 genotypes (Amghaur, Gujrat 70, Kalanamak, Pusa Basmati1, NDR 359, and Sarjoo 52) were selected and used as donors for hybridization and for field testing.

Cuu Long Delta, South Vietnam (CLRRI)

The past two decades witnessed substantial growth in agricultural production in Vietnam, with considerable improvement in farmers' livelihoods. However, most farmers living in coastal salt-affected areas of the Mekong Delta have not benefited sufficiently from these developments owing to the low productivity of these areas caused by persistent rapid population growth, diminishing agricultural land due to industrial expansion, land degradation, and persisting abiotic stresses such as salinity, toxicities to high Al and Fe, and low pH. Crop yields in these areas are generally low and are progressively decreasing, particularly in saline areas where farmers still use traditional varieties and practices. The project helped in introducing measures that can help enhance and stabilize productivity in these areas, through the introduction of salt-tolerant varieties adapted to these areas, best agricultural practices, and better cropping patterns. New salt-tolerant rice varieties adapted to the Mekong Delta region are being developed using both conventional and modern approaches such as anther culture, mutation, and marker-assisted breeding. Numerous short-maturity varieties such as Tam Xoan-93, Tep Hanh, Mot Bui Do, OM 4498, OM 5900, and AS 996 were developed that can yield 4 to 5 t/ha under salt stress of 6.0 to 9.0 dS/m, and they are now being outscaled. Most of these achievements were published in the Proceedings of the International Conference Delta 2007: Managing the Coastal Land-Water Interface in Tropical Delta Systems, and the *CGIAR Challenge Program on Water and Food 2nd International Forum on Water and Food*.

Collection and evaluation of local germplasm. Over the past four years, about 200 local landraces were collected; 65 of them were identified for analysis of different adaptive and agronomic traits. Considerable variation was observed in grain yield and yield attributes, as well as in growth and phenology. Molecular analysis using 34 polymorphic SSR markers indicated significant genetic diversity among the 65 traditional varieties, with 6 distinct clusters.

Breeding strategies**.** Different approaches are being followed at the Cuu Long Delta Rice Research Institute (CLDRRI) to develop salt-tolerant varieties of rice, including conventional methods involving crosses with salt-tolerant donors and subsequent selection for agronomic and adaptive traits over several generations. Moreover, modern breeding tools such as mutation breeding, anther culture, and molecular markers are being implemented to accelerate progress in breeding salt-tolerant varieties. Our phenotyping system follows the screening methods developed at IRRI using the Standard Evaluation System for rice.

Mutation breeding. New breeding lines of known varieties were developed through radiation and chemical mutagenesis. An example is the development of Tam Xoan-93 from the Vietnamese variety Tam Xoan, a traditional variety from northern Vietnam that is tall, has low yield, but has good grain quality and reasonably high tolerance of acid sulfate soils. Seeds of Tam Xoan were gamma-irradiated and the generated plantlets were advanced and screened for salinity tolerance in each generation. Tam Xoan-93 was subsequently identified with superior agronomic and quality traits: it matures earlier, is shorter, has more tillering capacity and higher harvest index, and yields more than 3 times the original variety, coupled with its high tolerance of salt stress. This new variety was released to farmers during 2004-05 and is being outscaled through this project; it already covered more than 500 ha by 2006.

Anther culture. This is a quick method for developing homozygous salt-tolerant lines. We are now using this method to breed salt-tolerant varieties adapted to the salt-affected soils of the Mekong Delta. Six crosses involving high-yielding varieties × salt-tolerant donors were made and their progeny cultured and advanced after selection each year. Some 26 derived lines were selected that are salt-tolerant and they were being further evaluated for both seedling- and reproductive-stage salinity tolerance, as well as for other agronomic traits in the greenhouse of CLDRRI. The best selected lines will enter into yield trials in subsequent years for field evaluation and potential release as varieties. This demonstrated the effectiveness of anther culture in breeding.

Use of DNA markers to accelerate progress in breeding for salt tolerance. We developed several mapping populations using salt-tolerant and sensitive genotypes and used them for mapping QTLs associated with salinity tolerance during the seedling stage. Two QTLs with relatively large effects were identified, one on chromosome 1 and the second on chromosome 8. Microsatellite markers closely linked to these loci were identified, such as RM215 associated with the QTL on chromosome 1 and RM223 associated with the QTL on chromosome 8. These markers were further evaluated for their effectiveness in selection using a set of 24 improved varieties, including tolerant (Pokkali) and sensitive (IR28) checks. The results

indicated an accuracy of more than 95% in identifying tolerant cultivars, which indicated the usefulness of these markers in parental surveys and in identifying tolerant lines from segregating populations; however, further tests are needed to confirm their effectiveness in different genetic backgrounds. More efforts are needed to develop markers closely linked to these two QTLs to be used in MABC.

Evaluation of rice breeding lines received from IRRI through INGER. Lines received through INGER together with local checks were evaluated regularly during both the wet and dry seasons each year during this project. These lines were evaluated in farmers' field trials as well as at the CLDRRI station. Different traits were assessed, including crop duration, plant height, grain setting and fertility, quality traits, and salinity tolerance. Lines that are early maturing (90–110 days), semidwarf (90–110 cm), with a medium number of panicles/hill (8–10), a high number of grains/panicle (80–100), and high tolerance of salinity were selected for further testing in rice-rice cropping patterns. Examples are IR73571-3B-9-3 and IR73571-3B-9-3 selected for salt-affected areas of Long Xuyen square and Ca Mau Peninsula. Some lines were also identified that have high salt tolerance but relatively longer duration such as IR73571-3B-9-2 (114 days) and IR73571-3B-5-1 and IR73055-8-3-1-3-1 (113 days), and these lines will be suitable for the rice-shrimp cropping pattern in Ca Mau Peninsula and other salt-affected areas. Selected lines will be further tested in subsequent years. A few salt-tolerant breeding lines were being tested in farmers' fields in Tra Vinh and some short-maturity lines (<100 d) were selected from IRRI breeding material that yield reasonably higher than the check AS 996. Lines such as OM 6043, OM 6036, OM 6040, and OM 6038 yielded significantly higher than the check variety and are considered candidates for release in areas where up to three crops can be grown each year. Besides the progress discussed above, the following activities were also undertaken by CLRRI:

- Screened more than 350 genotypes, bulk populations, and observational nurseries under saline acid field conditions at Tra Vinh (Cau Ngang) during the 2006 WS.
- Screened 72 lines from IRRI and 15 lines from CLRRI in observational nurseries in saline fields at Cau Ngang during the 2006-07 WS.
- Conducted a replicated yield trial at Cau Ngang, Chau Thanh, and Cau Ke, with 15 tolerant lines and checks.
- Made 189 crosses during 2005, 2006, and 2007, involving diverse sources for tolerance of salinity and good grain type in diallel and partial diallel schemes to generate material for tolerance of multiple abiotic stresses.
- Identified breeding lines such as OMCS 2000 (tolerant) and OM 576 and OM 1490 (moderate) from greenhouse screening at EC of 10–12 dS/m. This material will be tested in the field.
- Selected 512 progenies and 96 bulk populations from F_3–F_7 generation based on salinity tolerance and adaptability in salt-affected areas.
- Selected 21 moderately tolerant and 35 tolerant genotypes from observational trials for further evaluation; one somaclonal line, OM 5930, selected based on yield and phenotypic acceptance; two advanced lines, OM 2428 and OMCS 2009, were chosen by farmers for the rice-shrimp system for their earliness.
- Following extensive field testing, recommended about 10 lines for national testing and release as new varieties. About 70 lines from IRRI were moderately tolerant to tolerant. Some lines were selected for Tra Vinh and Bac Lieu provinces: IR73055-8-3-1-3-1, IR73571-3B-5-1, and IR73571-3B-9-2 because of their high yield, tolerance of bacterial leaf blight and brown planthopper, and adaptation to salt-affected areas. Three lines were also approved as new rice varieties for rice-shrimp systems in the Mekong Delta. IR73055-8-3-1-3-1 and IR73571-3B-5-1 were selected by farmers and will be further evaluated in subsequent years.

Multilocation yield trials. (i) In 2005, 22 elite breeding materials and five salt-tolerant and sensitive high-yielding check varieties (OM 4495, OM 4498, OM 5240, OM 5439, OM 5976) were evaluated in Tra Vinh and Bac Lieu in six farmers' fields each with salinity of 6–7 dS/m in microplots in an RBD with three replications. OM 4498 and OM 4495 consistently ranked the best in almost all PVS trials in the field; (ii) in 2006, 10 lines (OM 4498, OM 5900, OM 4900, OM 5625, OM 4412, OM 5936, OM 6073, OM 2513, OM 2488, and AS 996) were evaluated at Tra Vinh and Bac Lieu in six farmers' fields each with salinity of 6–7 dS/m, as in 2005, and AS 996 and OM 5900 were selected; (iii) in 2007, 9 elite breeding materials (HG1, OM 4498, OM 4900, OM 5936, OM 5930, OM 5625, OM 2513, OM 5636, AS 996) and five high-yielding checks were evaluated at Tra Vinh and Bac Lieu, again in six farmers' fields each with salinity of 6–7 dS/m, and OM 4900 was selected for the WS; (iv) in 2008, 22 elite breeding materials and five high-yielding checks were evaluated as in the two provinces in previous years, and two lines, HG2 and OM 6073, were consistently the best. Material identified through these trials is being further validated through PVS trials before recommendation for national testing and release.

Salt-tolerant varieties for the Nile Delta (RRTC)

Identification of new salt-tolerant rice genotypes. RRTC succeeded in developing some salt-tolerant rice varieties such as Giza 178, Sakha104 and 224, and SK2034H hybrid. During this project, an attempt was made to identify new elite breeding lines with higher salinity tolerance. Zinc deficiency also emerged as an alarming problem in salt-affected areas in Egypt and efforts were also made to screen genotypes that are more efficient in Zn uptake from salt-affected soils. Some 111 entries from different sources were selected and evaluated for tolerance of salinity and zinc deficiency during two successive seasons of 2007 and 2008.

These lines were evaluated at the agricultural farm of the El Sirw Agricultural Research Station located in the northern part of the delta in Dammietta Province. This research station has a mandate to conduct research on salt-stress tolerance in various crops. A trial was irrigated with a mixture of fresh and saline water, with salinity ranging from 1.5 to 2.1 dS/m throughout the season. Each entry was grown in seven rows, 5 m each, with spacing of 20 × 20 cm. Soil samples were taken from each plot and analyzed at the RRTC laboratory for salinity and soil Zn concentration. Sowing was on 20 April in both years and transplanting was done 30 days after sowing. Data on heading and tolerance of salt stress and Zn deficiency were collected. At harvest, ten plants from each entry were randomly taken to estimate yield components. Panicles per plant, plant height, and panicle length were also measured. The inner five rows of each plot were harvested, threshed, dried, and used for determining grain yield. Cultural practices were followed using recommendations from RRTC.

Results and discussion. Some genotypes showed high tolerance of salt stress comparable with that of Giza 178. Based on the two years of data, Giza 178, IET 1444, GZ5121-5-1-2, IR75395-2B-B-19-2-1-2, IR63307-4B-9-2, IR72593-B-3-2-3-8, IR72593-B-3-2-3-13, and IR75395-2B-B-19-2-1-2 were the most salt-tolerant entries, and, among these, the highly preferred entries were IR75395-2B-B-19-2-1-2, Giza 178, IR75395-2B-B-19-2-1-2, and IR63307-4B-9-2. These genotypes were selected based on their grain quality and tolerance of both salinity and Zn deficiency. Selected genotypes are further being disseminated to farmers in target areas.

Apparently, new elite high-yielding genotypes with higher tolerance of salt stress were identified in these studies. These genotypes could be considered for release as commercial varieties after further evaluation of their grain quality. These genotypes are also being tested in other regions with similar soil problems for evaluation by farmers in PVS trials. Selected genotypes can also be used in breeding as donors for salt tolerance. Interestingly, this is the first time that screening for zinc deficiency was carried out, and the selected genotypes are important for breeding and further studies. Another important aspect of this study is the realization that selection for higher tolerance of salt stress and Zn deficiency could be carried out simultaneously at hot spots; however, more resources are needed to continue these efforts.

Breeding for salt-affected areas of the Caspian Sea basin (RRII)

Research on salinity at the RRII, Iran, began with this project, after recognition of the escalating salt damage around the Caspian Sea, particularly in years when fresh water in irrigation canals was low, resulting in salt intrusion and sometimes forcing farmers to use saline underground water late in the season, with devastating effects. Baseline socioeconomic surveys were conducted at target sites to understand the challenges and farmers' coping practices.

Germplasm development. More than 50 native materials were collected from different provinces of Iran, and seeds were multiplied for evaluation of their salinity tolerance as well as for other agronomic traits. Screening of local material identified some lines that are tolerant such as Shiroodi, Shahpasand, Neda, Ahlami-tarom, Rashti, Abji-boji, Hasani, Dorfak, and Ghas-ol-dashti. RRII participated regularly in nominating breeding material and released varieties for sharing and testing in other countries through INGER, for example, genotypes Nemat, Sang-tarom, Hasani, Dasht, and Hashemi were nominated in 2008. Since the start of the project, new crosses were being made every year and segregating material selected and advanced for testing in farmers' fields.

***Testing of the identified new salt-tolerant materials in salt-affected farmers' fields*.** Fourteen selected salt-tolerant rice genotypes, together with Pokkali and IR29 as checks, were tested in farmers' fields in 2008. Three lines (Binam, SAL23, and SAL28) showed better performance and were selected for further tests in farmers' fields. In 2008, the numerous populations developed in past years were tested for salinity tolerance at seedling and reproductive stages. These populations are (1) BC populations (Spidroud/Ahlami-tarom)//Ahlami-tarom, (Neda/Ahlami-tarom)//Ahlami-tarom, and (2) $F_{2:3}$ populations (RILs): Khazar/ Tarom-mahali (about 160 F_4s). These populations are being advanced for selection in subsequent seasons. Segregating populations developed each year were tested in salt-affected fields in Ghajarkheil District in Mazandaran. PVS trials were also instituted in both Gilan and Mazandran, the main rice-producing northern provinces, and seeds of selected genotypes from mother trials were increased each year and distributed to farmers for further testing before nomination for release.

Nonrice crops. Seeds of accessions of five crops—rapeseed (7 acc.), fodder beet (8), barley (17), pearl millet (45), and sorghum (13)—were sent by ICBA to Iran in October 2007. Seeds of three crops (rapeseed, fodder beet, and barley) have been sown in salt-affected lands as a second crop in rotation with rice. Two other sets were not sown as they are summer crops. Based on preliminary analysis, four cultivars of canola (Hyola-60, Hyola-401, Hyloa-405, 98-d), two barley cultivars (86/2 A, 58/1 A), and one fodder beet (acc. # Magnum) showed good performance in the first year of testing. These crops provide an option for farmers to grow another crop during the winter season, when lands are normally left fallow.

Evaluation and selection of salt-tolerant nonrice crops

Progress at ICRISAT

***Choice of plant species*.** The project activities at ICRISAT center on identifying nonrice crop species with tolerance of salinity. The major focus is on finding tolerant legumes suitable for saline soil, as a way to fit in

fallows after WS rice, particularly in areas where freshwater resources are limited. After contacting the different partners in India and Bangladesh early in the project, we decided to work on chickpea, pigeonpea, and groundnut, which are also ICRISAT's mandate crops. There was also some interest in black gram and green gram, but the lack of direct access to germplasm made us leave these species aside. We also considered pearl millet and sorghum as possible fodder sources in India and Bangladesh. Peanut was considered a good commodity for salt-affected areas, with potential use in India, Bangladesh, and Vietnam.

Setup protocol for salinity screening. At the beginning of the project, we first established a protocol to assess response to salinity across a range of crops. We initially used pigeonpea, groundnut, black gram, and green gram, using a few accessions for each species. The basic purpose was to define one salt treatment for which plant growth would be decreased by about 50% compared with a control. The screening setup for each crop species would then be used later on to screen a larger number of accessions. Plants were grown in 6-inch pots, filled with 2.3 kg of Alfisol. Three salt treatments were applied, 50, 100, and 150 mM NaCl. The treatments involved applying a salt solution on dry soil and then saturating it to field capacity (more or less 20% of the soil weight) with the respective salt concentrations. These treatments corresponded to an application of 0.58, 1.17, and 1.75 g NaCl/kg of soil. Similar experiments were done to determine an adequate salt concentration to screen for salinity tolerance in chickpea, using a Vertisol, and the adequate treatment appeared to be 1.17 g NaCl/kg Vertisol, that is, the application of 80 mM NaCl solution in sufficient amount to saturate the Vertisol (25% w/w).

Protocols to screen for tolerant groundnut and pigeonpea were set up. After two repeated experiments, it was found that 100 mM NaCl (1.17 g NaCl/kg Alfisol) was suitable for screening in groundnut, whereas an application of 75 mM NaCl (approximately 0.88 g NaCl/kg Alfisol) was suitable in pigeonpea. Pigeonpea was indeed a lot more susceptible than groundnut to salt stress. We initially applied the salt treatment once only at sowing time, by saturating the soil with the salt solution. However, we found that this had a deleterious effect on early seedling development, except in chickpea. Therefore, to prevent a possible osmotic effect at germination stage, the salt application was split into three staggered applications in all subsequent experiments, performed within the first 2 weeks after sowing, by applying one-third of the dose at each application. The pots were sealed so that no salt could leach out. Watering was done daily to keep pots close to field capacity and prevent building up of salt, thus also avoiding waterlogging.

Salt response was initially evaluated based on the biomass produced at about 50 days (vegetative stage). However, we soon realized that biomass under salt stress had little relation to yield under stress conditions. Therefore, most subsequent evaluations focused on yield. The protocols developed were set up in outdoor conditions, using large pots that allowed yield evaluation in a way similar to field conditions. This outdoor facility was equipped with portable rainout shelters to cover the crop in case of rain. Pots of 28 cm diameter were used, with 4 plants per pot for chickpea and 2 plants per pot for pigeonpea, groundnut, pearl millet, and sorghum.

Screening of the chickpea mini-core collection**.** Plants were grown under saline and nonsaline conditions in 27-cm diameter pots containing 7.5 kg of Vertisol soil taken from the ICRISAT farm. The experiments were carried out between November 2004 and March 2005 at ICRISAT headquarters (Patancheru, Andhra Pradesh, India) in an open-air facility equipped with a rainout shelter. The average maximum temperatures ranged between 29.7 and 32.6 °C and minimum temperatures ranged between 15.4 and 16.1 °C. A similar experiment was repeated between November 2005 and March 2006. Salt-stress treatment was applied as an 80-mM solution of NaCl in a sufficient volume to wet the soil to field capacity. Two experiments were planted side by side: one for the evaluation of biomass at 50 DAS, the other for seed yield, with an RCBD in each experiment with two factors (salt and control) and three replications. A total of 263 genotypes were tested, including 211 accessions from the mini-core collection of ICRISAT (10% of the core collection, 1% of the entire collection), chickpea lines reported as tolerant of sodicity, popular cultivars and breeding lines, and one cultivar previously released by CSSRI for salinity tolerance (CSG8962). Both *kabuli* (58) and *desi* types (192) were included in the study.

Screening of the groundnut reference collection. A total of 288 groundnut genotypes were screened, including the 189 accessions of the mini-core groundnut collection of ICRISAT, some breeding lines from the groundnut breeding group, and genotypes selected based on their passport data (origin in the Chaco area of northern Argentina, western Paraguay, and southeastern Bolivia, an area supposedly affected by salinity). Three trials were conducted: in 2005, between mid-April and mid-June; in 2006, between mid-April and the end of August; and one between November 2006 and March 2007. In the first trial, plants were grown for 60 days, corresponding to the pod development stage in most entries, under either control conditions (fresh water) or salinity (1.17 g NaCl/kg of soil applied in three splits doses, at sowing and in the initial 2 weeks afterward). In the second and third trials, plants were also grown under both saline and control conditions, and grown up to maturity. At harvest, shoot biomass, total pod weight, weight of mature pods, and number of total and mature pods were recorded.

Screening of the pigeonpea mini-core collection. A large set of 300 accessions of pigeonpea has been screened. Of the 300 accessions 150 genotypes were from the mini-core collection of ICRISAT's genetic resource unit, 68 were different wild accessions, 69 were accessions selected from salt-affected areas worldwide (Bangladesh, Taiwan, Ethiopia, Indonesia, Argentina, Iran, and Brazil), and 13 genotypes were from breeding material (breeding lines and cytoplasmic male sterile lines; derivatives of different wild species), along with a few pigeonpea hybrids. Three trials were performed. The first was planted on 31 July 2005 under a rainout shelter in an alpha lattice design (30 × 10) in three replications with two treatments

(0.88 g NaCl/kg of Alfisol and a control). The experiment was repeated in 2006 during the summer season but failed because all plants in the stress treatment died after salt treatment. We attributed this effect to the much higher vapor pressure deficit prevailing at the time of this experiment (March), with a consequent high salt uptake. A third trial was successfully repeated in 2007, during the rainy season also (planting in July and harvest at 60 DAS). At harvest, plants were separated into leaves and stems. There was very little flowering and pod setting, except for short-duration pigeonpea genotypes, so that pods were not considered for statistical analysis. Among the crops tested, pigeonpea was the only one in which only biomass was evaluated, rather than yield as in other crops. The reason was that pigeonpea seems more sensitive to salt stress and tolerance was initially dependent on survival under salinity, whereas, in the other legumes, most germplasm survives well under salt-stress conditions and genotypic differences in tolerance were reflected in grain yield.

Results: screening protocols and relative tolerance of several legume species. Preliminary results showed great variation between species for salinity tolerance. Pigeonpea appeared to be the most sensitive to salinity, but also showed large variations, with some accessions dying at stress (0.88 g NaCl/kg Alfisol), whereas some genotypes were more tolerant. Groundnut appeared to have fairly good tolerance, even at 1.75 g NaCl/kg Alfisol. Black gram and green gram had intermediate tolerance between groundnut and pigeonpea, and showed a fairly large growth reduction at 150 mM, although they survived. From the preliminary experiments, we chose the range 1.17–1.46 g NaCl/kg Alfisol to screen for salinity tolerance in groundnut, and the 0.58–0.88 g NaCl/kg Alfisol range for pigeonpea. A treatment of 1.17 g NaCl/kg Vertisol was previously identified as suitable for screening for salinity tolerance in chickpea. Although the treatments for chickpea and groundnut were the same, we argue that groundnut is probably more tolerant than chickpea because the high organic matter content of Vertisol likely "buffered" part of the salt effect. Indeed, we also developed another protocol for screening for salinity tolerance in Alfisol in chickpea, through another project, and found that the seed yield under salt stress in Alfisol (under 0.94 g NaCl/kg Alfisol) was a little over 40% of that in Vertisol (1.17 g NaCl/kg Vertisol).

Screening of the chickpea mini-core collection. Very large variation for yield response was observed, ranging from 2 to 12 g/pot under stress. Three findings were noteworthy: (i) 5–6 genotypes yielded better than a previously released salinity-tolerant variety (CSG6982); (ii) two parents of an existing RIL population fell at the extreme ends of the ranking, which opened up the possibility of finding QTLs for salinity tolerance in chickpea (this RIL population was phenotyed with support from another project); (iii) there was no relation between seed yield obtained under salt stress and biomass at 50 days after sowing. These studies further showed that earliness was an important characteristic of salt-tolerant chickpea, and that salt-tolerant chickpea is an Na excluder. Data from the early harvest showed that chickpea accumulated considerably less Na in shoots (0.1–0.5%) than sorghum (0.4–1.0%) or pearl millet (0.7–2.5%).

Seed yield was related to the capacity of tolerant genotypes to keep a relatively large number of filled pods compared with sensitive genotypes. In contrast, seed yield under stress was not related to relative 100-seed weight (relative to a control). These data show that the reproductive stage rather than seed-filling differences accounted for the differences in salt tolerance between genotypes. The trial was repeated in 2005-06 and largely confirmed the results of the first trial. From this repeat experiment, crosses were made between contrasting genotypes (tolerant ICC1431 × ICC 6263 (sensitive) and tolerant JG11 × ICCV2 (sensitive)). Because phenology appeared to also interact with salinity tolerance, genotypes with similar duration used in the crossing program were chosen. These populations are now being descended under another project supported by the Australian Research Council. Data from the first year have been published in *Field Crops Research* (Vadez et al 2007). Data from 3 years of trials (2004-07) are being synthesized into a manuscript.

Screening of the groundnut mini-core collection. From the screening carried out in the first year (2005), we found very limited variation for biomass under salt-stress conditions. In contrast, variation in number of pods and pegs at harvest was relatively high. From there on, and based on the lack of a relation between biomass at the vegetative stage and seed yield in chickpea (see above), we decided to assess groundnut pod yield in subsequent screenings. We carried out two such screenings, in April-August 2006 and November 2006-March 2007, in order to test genotype response in two different seasons.

In 2006, the range of variation for pod yield under salinity was about 6–7-fold between the most and the least tolerant genotypes. Unlike previous findings in chickpea, we found no relation between pod yield under salinity and pod yield under a control, meaning that salinity tolerance for pod yield production under salinity was not related to the yield potential of groundnut. Again, contrary to previous findings in other crops, we found a modest relation between the ratio of pod yield (salinity/control) and the ratio of shoot biomass at maturity, suggesting that selection for biomass under salinity could improve grain yield. However, that relation was not confirmed in 2006-07. The number of pods per plant decreased by 50% under salt stress and pod weight was only 30% of that under a control. This suggested that both ability to produce pods and the ability to fill them are important under salt stress. The third screening (2006-07) revealed a fivefold range of variation in pod yield under salt stress (treatment of 1.46 g/kg soil was used, instead of 1.17 g/kg in 2006), ranging from 6.5 to 35 g/pot, with a large G × E interaction between the two years. Combined analyses of the data from both years identified 14 tolerant and 16 sensitive genotypes under salinity stress. In 2006-07, pod weight was less affected by salinity than in 2006, being 52% of the control, probably because of lower evaporative demand during the reproductive stage in 2006-07 compared with that in

2006. More details are discussed in a manuscript prepared for the IDCC conference (Alexandria, Egypt, 7-11 November 2008).

Diversity analysis of contrasting lines in groundnut. A total of 31 groundnut genotypes contrasting in salinity tolerance were used to study the molecular diversity among them. Twenty-one primer pairs of groundnut SSR markers were selected on the basis of size differences, and DNA fragments were denatured and size-fractioned using capillary electrophoresis on an ABI-3100 automatic DNA sequencer. Of the 31 lines analyzed, 18 showed polymorphism. Diversity analysis was carried out to assess the genetic distance between lines and to identify pairs of contrasting parents for both phenotypic and genotypic analysis. Data are now available to identify pairs of parents that contrast both genetically and phenotypically. Publication of the work is planned and a PhD thesis is almost finalized on that screening and diversity analysis work. Interestingly, we found that genotype JL24 (sensitive) contrasted with ICG (FDRS) 10 (tolerant) across seasons. Genotype CSMG 84-1 (sensitive) also contrasted with genotypes ICGS44 and ICGS76 (tolerant). RIL populations from ICGS44 × CSMG 84-1 and ICGS76 × CSMG 84-1 have been developed for TE in past years and are now at F_8. These three populations are available for mapping of tolerance of salt stress. Contacts were made with Tamil Nadu Agricultural University and with NRCG, Junagath, Gujarat, to further evaluate these lines at their locations. Current plans are to confirm the previous contrast identified in these lines and multiply these lines for field testing in salt-affected areas.

Screening of the pigeonpea mini-core collection. In pigeonpea, assessment was made based on percent relative reduction under saline conditions compared with a control and the salinity susceptibility index by using the formula SSI = (1 – YSS/YNS)/SII, where YSS and YNS are the mean biomass of a given accession in saline and nonsaline conditions, respectively. SII (salinity intensity index) was calculated as SII = 1 – XSS/XNS, where XSS and XNS are the means of all accessions under salinity-stressed and nonstressed environments. Genotypes with <50% relative reduction and with SSI between 0 and 0.75 were considered tolerant. Genotypes with 50–70% relative reduction and SSI of 0.76 to 1.05 were considered moderately tolerant, and those with relative reduction of 70–90% and SSI of 1.06–1.37 were considered moderately susceptible. Others with higher values are considered highly sensitive. A very large range of variation for percent relative reduction in biomass (2–100%) was observed, with ICPW 87 and ICPW 94 as the most tolerant. Both genotypes belong to *C. scaraboides*. One accession (ICPW 68) of *C. platycarpus* also had a low SSI of 0.37 and only 24.3% relative reduction in biomass. Among the wild accessions, ICPW 87 and ICPW 94 were the most tolerant of salinity, with SSI of 0.03 and 0.28, and their relative biomass reduction was small (2.0% and 18.6%). Both genotypes belong to *C. scaraboides*. One accession (ICPW 68) of *C. platycarpus* also had a low SSI (0.37) and only a 24% reduction in biomass. In the set originating from areas putatively affected by salinity, ICP 13991, 14974, 13997, and 11412 were tolerant and ICP 13625, 13996, 14175, 11414, and 11420 showed high susceptibility. In the mini-core collection, 13 genotypes were considered tolerant (ICP 8860, 7803, 7260, 6815, 10654, 3046, 2746, 7426, 10559, 7057, 6049, 6859, and ICP 7), whereas three (ICP 15493, 15382, 1071) were considered susceptible.

For the accessions selected from different areas putatively being affected by salinity, the variation ranged from 42% to 100% for relative reduction in biomass and from 0.64 to 1.52 for SSI, which also shows a very large genotypic variation to identify contrasting entries for salinity tolerance. In this set, ICP 13991, 14974, 13997, and 11412 were tolerant and ICP 13625, 13996, 14175, 11414, and 11420 showed high susceptibility. Among the mini-core collection of pigeonpea, the range of variation for biomass relative reduction was 15–100% and for SSI 0.23–1.52. These data show that the mini-core collection contained genotypes having higher salinity tolerance than in the group of genotypes putatively originating from salinity-affected areas. Out of 150 genotypes of the mini-core, 13 were considered as tolerant (ICP 8860, 7803, 7260, 6815, 10654, 3046, 2746, 7426, 10559, 7057, 6049, 6859, and ICP 7) and four (ICP 15493, 15382, 1071, and 6739) as salinity susceptible. Finally, for the set of wild derivatives of pigeonpea, the range varied from 42% to 84% for biomass relative reduction and 0.75–1.52 for SSI. Out of these, ICPB 2051, 2030, and 2039 were tolerant.

***Testing of pearl millet, sorghum, and groundnut in a farmer's field of Orissa*.** Ten genotypes each of pearl millet and sorghum were tested in a farmer's field of Orissa as potential forages in saline soils. Three genotypes of groundnut were also tested but salinity was probably too high and the crop failed to establish. Sorghum and pearl millet seem to be promising in these areas where some accessions of both crops produced more than 1 t/ha of fodder yield in saline fields in several cuttings. Tolerant lines of groundnut and sensitive checks (total of 11) were also sent to CRRI for further testing in 2008-09.

In summary**,** after the 4 years of this project, we identified several highly tolerant genotypes of groundnut, chickpea, and pigeonpea based on large-scale assessment of the mini-core collections of these crops. These trials were carried out at least twice, with a focus on grain yield as a measure of genetic tolerance, contrary to many previous studies. Genotypes identified in these studies are now being used by breeders and for developing mapping populations for the identification of QTLs for salinity tolerance. This germplasm is also being tested in multilocation trials. The project also helped develop large-scale phenotyping facilities allowing the evaluation of a large number of entries and breeding lines. The contrasting germplasm identified is being used for studying mechanisms of tolerance of salt stress. Contrary to prevalent knowledge, Na accumulation in shoots has little relation with grain yield under stress in chickpea, groundnut, sorghum, and pearl millet, an important finding for effective breeding strategies and for studying their mechanisms of adaptation to salt-affected areas. Apparently, the extensive work done on the role of Na exclusion from plant tissue might have little relevance for chickpea and groundnut. The project has also

been the basis for several peer-reviewed publications and two PhD theses (one currently submitted and two others in progress: one on pearl millet, one on chickpea).

Progress at ICBA

Rice-based cropping systems in the Nile River and Caspian Sea basins are affected by salinity, particularly late in the season. In addition, a fallow period exists between rice and the following crop. Existing crops are usually not profitable in salt-affected areas, but prospects are good for the introduction of new, more tolerant crops and varieties. Short-duration crops with sufficient salt tolerance are needed to provide alternatives for farmers so they can select material suitable for their conditions and use. The availability of salt-tolerant field and forage crops such as pearl millet, sorghum, barley, triticale, safflower, etc., would be of great benefit to these farmers, particularly when using effective and affordable management measures, as forage shortage is a major constraint in salt-affected areas. This component of the project focused on selecting promising crop genotypes that are salt tolerant and fast growing to be used as gap-filling crops within rice-based rotations. A large number of genotypes of numerous summer and winter crops were screened at salinity levels commonly experienced in farmers' fields. Many genotypes were selected with stable yield under moderate to high salt stress.

Rice is grown from May to September in the Nile Valley and the Caspian Sea basin. Farmers grow several traditional crops in between two cropping cycles to maximize farm productivity. However, salinity in rice fields increases with excessive irrigation and the use of saline/brackish water. We attempted to identify crop species that are more tolerant of salt stress and adapted to conditions of rising salinity. Two types of crops were attempted: (a) fast-growing forages that can be planted in September and harvested in late November before the winter crops are sown and (b) salt-tolerant crops that fit the whole period between two cycles. For this purpose, ICBA started genetic improvement of barley, triticale, fodder beet, forage brassica, pearl millet, sorghum, and safflower for high yield under saline environments. These crops are the main source of winter and summer forages, except safflower, which is a valuable cash crop. Large numbers of genetically diverse accessions of these crops were screened at low, medium, and high salinity (5, 10, and 15 dS/m). Screening trials were conducted using pots to select a smaller number of promising genotypes for eventual field testing. High-yielding salt-tolerant genotypes (25 to 30) of each crop were identified and nurseries were assembled. These nurseries were evaluated under field conditions at three salinity levels and promising lines were used for seed multiplication. The seed was then distributed to NARES and farmers in the targeted regions for evaluation to select the best-performing genotypes under their growing conditions.
More than 2,300 accessions of barley were evaluated at ICBA and other locations in West Asia and North Africa (WANA) regions. In addition, 64 barley varieties supplied by ICARDA were evaluated under field conditions. Similarly, more than 1,000 accessions of triticale were screened in pots at 10 dS/m. About 150 genotypes with variable seed type and forage type were selected for further evaluation. Biomass and seed yield of some accessions were in an acceptable range, even at higher salinity. As expected, yield decreased by 28% and 13% at high and medium salinity, respectively; however, genotypes with high salt tolerance and yield were identified. Overall dry matter and seed yield of barley varied between 12.9 to 4.5 t/ha and 5.6 to 0.3 t/ha, respectively. Varieties Saida, Australian, Badia, Giza-125, and Manel had the highest dry matter and seed yields under control conditions and at high salinity. Moreover, five international barley nurseries were also screened at ICBA. These nurseries were developed for specific agro-climatic conditions for barley cultivation. A wide range of genetic variability within and among genotypes was observed. Promising genotypes were selected from each nursery and assembled for further evaluation in saline fields.
Most of the triticale genotypes showed high biomass and seed production, and genotypes were subsequently grouped into forage types and seed types. Fifteen fodder beet (*Beta vulgaris*) and seven forage rape/canola (*Brassica napus*) varieties were also evaluated for salt tolerance at ICBA and in other countries. Fodder beet varieties had good germination and establishment at all salinity levels and a few varieties were selected, such as Blaze, Blizzard, Interval, and Hobson. Most of the fodder beet varieties maintained higher biomass production at medium and high salinity and aboveground biomass yield decreased by a maximum of 31% under high salinity. Aboveground green forage yield varied from 26 to 41 t/ha and fresh tuber yield ranged from 74 to 95 t/ha. Beet varieties Turbo, Blaze, Blizzard, Tintin, Kyros, and Magnum produced higher aboveground green forage (up to 41 t/ha) and tuber yield (up to 95 t/ha) across the salinity levels tested. The yield of brassica varieties was also acceptable, although their yield declined with increasing salinity. Rape variety 98-D produced the highest green forage yield. The use of highly saline water reduced green forage and dry matter yield by up to 44% and 47%, respectively.

Around 600 safflower accessions were screened in pots, and 273 accessions were identified and re-evaluated. Subsequently, 60 elite accessions were selected for field evaluation in 2007-08. The average number of heads/plant varied from 1.2 to 16. Biomass production (dry matter) varied from 2.6 to 4.6 t/ha and seed yield varied from 0.8 to 4.6 t/ha. Genotypes PI243070, PI250924, PI251267, PI167390, and PI251291 maintained high and stable yields. For pearl millet and sorghum, ICRISAT supplied 36 pearl millet B-lines and 65 diverse genotypes, along with 46 sorghum genotypes for screening at ICBA during 2007-08. Dry matter yield of pearl millet accessions was higher than that of elite genotypes, hybrids, and early-maturing progenies. Pearl millet genotypes IP6106, IP13150, HHVBCTall, ICMS7704, MC94C, and ICMV155Brist showed high and stable yield across different salinity levels. Hybrids ICMA95333 × ICMP451

produced the highest dry matter yield among ICRISAT and commercial hybrids. Dry matter production of sorghum genotypes SP39053, NTJ2, GD65008 (brown), SP39007, SPV1022, and A2267-2 reached 28 t/ha across salinity levels. These genotypes were able to maintain a consistently higher yield at higher salinity, confirming their suitability for areas highly affected by salt stress.

During 2006-08, ICBA supplied seeds of barley, pearl millet, sorghum, fodder beet, rape/canola, and sorghum to two institutes in Egypt, the Desert Research Center (DRC) and Rice Research and Training Centre (RRTC), and to the Rice Research Institute in Iran (RRII) for testing under their local conditions. At DRC, crops were planted under two water salinities (6.25 and 11 dS/m) using two irrigation systems (drip and gated pipes). Several farmers participated in the evaluation of the selected crops. Based on results at DRC and farmers' evaluation, promising barley varieties were identified for low and medium salinity. The performance of pearl millet and sorghum was promising and higher yield was achieved across salinity levels. Both fodder beet and rape varieties also showed good performance. Drip irrigation proved better than the gated-pipes irrigation system. Farmers were able to select genotypes capable of maintaining high yields under their local saline conditions. Demand for seeds of the various crop genotypes is very high. ICBA in collaboration with partner institutes is working on developing a work plan for in-country and on-farm seed production of the selected genotypes. This component still needs further support and backup to bring it to fruition.

The work of ICBA and NARES demonstrated great potential for these crops for forage and seed production at medium and high salinity. Selected material also has shorter duration so that it can fit into current cropping cycles and meet the high demand for forages in these areas. Selected varieties are well suited for use in a rice-based system to fill the gap between two cropping cycles or as rotational crops, under both normal conditions and salt-affected areas. Moreover, these forages are highly palatable and nutritious and can be fed fresh, dry, or as silage. Research findings of this project will have a great impact on rice-farming communities, particularly in coastal areas where forages are usually in high demand. Inclusion of these crops will enhance farm productivity and eventually improve the livelihood of poor farmers in rice-growing areas. Seeds of these crops should be multiplied and distributed for other salt-affected areas of Asia.

Objective 3. **Develop farmer-friendly crop and natural resource management options for salt-tolerant varieties to enhance water and land productivity in salt-affected areas.**

The productivity of salt-affected areas is very low because of a lack of suitable varieties and proper management practices. This activity focused on developing integrated nutrient, water, and soil management options for the newly developed salt-tolerant rice varieties, considering the socioeconomic status of target farmers. On-station and on-farm trials were conducted in different countries and selected options were subsequently validated in participatory farmer-managed trials throughout the project duration. A brief summary of these options is provided below; more details are published elsewhere (Ismail et al 2008) and additional information is provided as a supplement with data submitted with this report.

Coastal Orissa (CRRI)

Nursery management for better crop establishment. Poor crop stand is the main reason for low and unstable rice yields in saline areas because of the high sensitivity of rice at this stage. Crop establishment during the wet season can be improved by using healthy and robust seedlings. On-farm trials were conducted during the 2004 and 2005 WS to evaluate the effect of different fertilizer treatments applied in a nursery on seedling vigor and grain yield of rice using variety SR26B. In 2004, seedlings raised with the recommended NPK (10 kg/ha each of N, P_2O_5, and K_2O) in combination with *Azolla* compost and vermi-compost at 5.0 t/ha were more vigorous (61.2% and 93.2% higher biomass) and produced significantly higher (8% and 10%) grain yield of 5.4 and 5.5 t/ha, respectively. Application of a double dose of NPK alone or in combination with organic manures further improved seedling vigor but had little effect on grain yield. In 2005 also, seedlings raised with the same amount of NPK, alone or in combination with organic manures (5.0 t/ha), were more vigorous (15–63% higher biomass) and produced significantly higher (29–43%) grain yield than unfertilized seedlings. Increasing the fertilizer dose from 10 to 20 kg/ha N, P_2O_5, and K_2O did not improve seedling vigor or grain yield. Combining 20 kg/ha each of N, P_2O_5, and K_2O with organic manures increased seedling dry weight by 20–38%, but with no significant increase in grain yield.

Seedling age and spacing. Survival and productivity in saline soils can also be improved through the use of older seedlings and closer planting. The effects of seedling age (30, 40, and 50 days) and spacing (15 × 10, 15 × 15, and 15 × 20 cm) on grain yield of SR26B were evaluated during the 2004 and 2005 WS in a CRBD with three replications. Transplanting at 15 × 10 cm resulted in the highest grain yield in both years (Fig. 3.1). However, the differences between 15 × 10 and 15 × 15 cm or 15 × 15 and 15 × 20 cm spacing were not significant. The 50-d-old seedlings produced significantly higher grain yield than 40-d-old seedlings in 2005 but not in 2004, possibly because of severe submergence stress in 2005. The differences between 30-d-old and 40-d-old seedling treatments were not significant. The higher grain yield with older seedlings and closer planting was mainly due to the greater survival under stress and consequently more panicles per unit area. The crop suffered from submergence during the early vegetative stage and drought coupled with salinity during the reproductive stage in 2004, and submergence after transplanting, than during the reproductive stage in 2005.

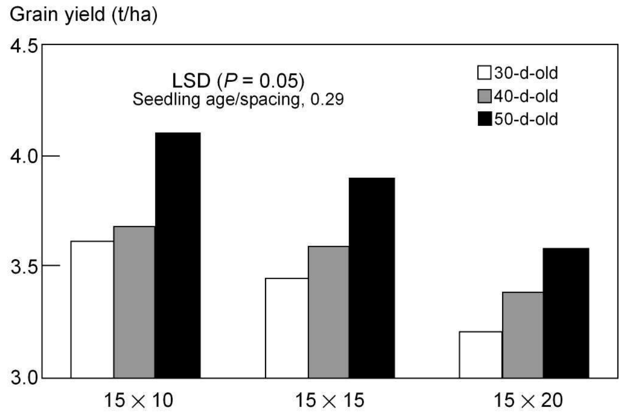


Fig. 3.1. Effect of seedling age and spacing on grain yield of rice variety SR26B during the WS of 2005.

Nutrient management and seedling age. During the 2007 wet season, an on-farm trial on nursery fertilization (unfertilized and fertilized with 10 kg/ha each of N, P_2O_5, and K_2O + FYM at 5.0 t/ha) vs. seedling age (30, 40, and 50 d) was conducted using SR26B in a CRBD with three replications. The 40-day-old and 50-day-old seedlings again showed better survival under severe stresses and produced significantly higher grain yield than 30-d-old seedlings. Fertilized seedlings also had higher survival and grain yield irrespective of seedling age.

Date of transplanting. Salinity during the dry season increases as the season progresses because of water scarcity and increasing evaporative demand with rising temperature. A delay in planting causes a significant yield reduction, particularly during the reproductive stage. On-farm trials were conducted at two sites in the 2005 and 2006 DS to set the optimum time of planting, using a CRBD with three replications. Transplanting on 8 January produced the highest grain yield, except at one site in 2006, where yield was highest from 18 January planting (Fig. 3.2). However, differences between the two planting dates were not significant at this site in both 2005 and 2006. Later planting progressively resulted in a gradual reduction in yield. Transplanting after 28 January at site II in 2005 was damaged completely because of high salinity (ECe of 8–12 dS/m at planting). Furthermore, the groundwater table was nearer to the surface with even higher salinity, particularly for February plantings. This land was used for cropping in the dry season for the first time. In 2006, the gradual reduction in grain yield with a delay in planting at site II was significant because of the higher water table and groundwater EC than site I. The problem was further aggravated due to the scarcity of water toward the reproductive stage for later plantings.

During the wet season, the effect of nursery fertilization on grain yield was more pronounced in 2005 than in 2004. However, rainfall distribution in 2005 was erratic and the crop suffered from submergence stress during the vegetative stage, leading to lower yield. Similarly, older seedlings and closer planting had greater effects on grain yield in 2005 than in 2004. These findings suggest that the use of robust, older seedlings and closer planting is particularly advantageous under stress conditions. In 2007, the crop suffered initially from salinity stress and later from prolonged submergence and waterlogging. Thus, yield declined drastically. Under such severe stresses, the use of older seedlings and closer planting was effective in increasing rice grain yield. During the DS, the crop transplanted in the first fortnight of January produced the highest grain yield because of relatively lower soil and irrigation water salinity, which increased gradually with increasing temperatures as the season progressed. Further, crops planted later would have experienced higher temperatures during the reproductive stage, resulting in a yield loss. Thus, almost normal yields could be achieved simply by early planting, even under high salinity.

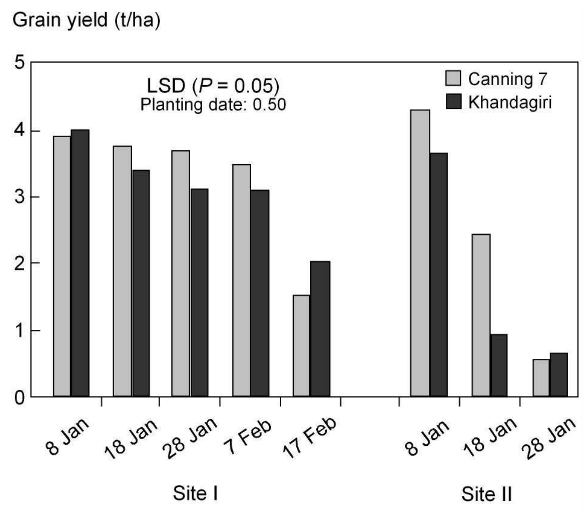


Fig. 3.2. Effect of different dates of transplanting on grain yield of rice varieties Canning 7 and Khandagiri during the dry season of 2005.

These results showed that tremendous progress can be made in salt-affected areas through proper crop and nutrient management in the nursery. Options include adjusted sowing date, proper nutrition, the use of older seedlings and proper seeding rate, and transplanting of older seedlings at closer spacing. The use of earlier maturing varieties during the WS will ensure early transplanting; however, their use is even more important during the DS to ensure maturity before salinity becomes too high, fresh water runs out, or the temperature becomes too high during reproduction**.**

Management options for nonrice crops in the DS (e.g., sunflower). Farmers usually sow sunflower with very close spacing. An on-farm trial on the effect of different spacing (30 × 30, 30 × 25, and 30 × 20 cm) and fertilizer (recommended NPK and NPK + FYM at 5.0 t/ha) treatments was conducted during the 2007 DS using an RCBD with three replications. Seed yields in 30 × 30- and 30 × 25-cm spacing were comparable (2.06 and 1.92 t/ha) and significantly higher than that in 30 × 20-cm spacing (1.72 t/ha). Application of FYM increased average yield by 14%. Yield of sunflower could therefore be increased by using 30 × 30-cm spacing and applying FYM along with a recommended dose of NPK fertilizer.

Nutrient management for rice. Farmers in coastal saline areas generally do not apply fertilizer for rice during the WS and resort to an indiscriminate use of fertilizer during the DS. INM combining chemical fertilizers with organic manures and biofertilizers is important for realizing the yield potential of improved salt-tolerant varieties. Site-specific on-farm trials were conducted during 2004-06 to evaluate selected INM practices for both the wet and dry seasons in three separate trials, two in the WS under shallow (0–30-cm water depth) and intermediate (0–50 cm) lowland conditions and one in the DS under irrigated conditions, using an RCBD with 4, 5, and 3 replications, respectively.

In the WS, rice varieties Pankaj (shallow lowlands) and Lunishree (intermediate) were used, whereas Canning 7 and Annapurna were grown in the DS. About 40 kg/ha P_2O_5 and K_2O were used in all experiments. Soil and field water salinity was higher in 2005 than in 2004 because of lower rainfall during August-September. In the DS trial, the depth to the groundwater table and groundwater EC were 0.67–0.95 and 0.46–1.04 m and 3.6–10.5 and 2.0–9.9 dS/m in 2005 and 2006, respectively. Salinity in the DS was higher in 2005 than in 2006. A terminal drought during October-November in the 2004 WS was responsible for the greater salinity buildup in the 2005 DS, whereas high rainfall during October 2005 led to lower salinity in the 2006 DS. Apparently, salinity during the WS varied mainly based on the rainfall pattern and land situation, whereas, during the DS, it depended on the depth of the groundwater table, groundwater EC, temperature, and rainfall pattern in the preceding WS.

In shallow lowlands, *Sesbania* GM + prilled urea (PU) (20 kg N/ha), *Azolla* + PU (30 kg N/ha), and *Sesbania* GM + *Azolla* were as effective as PU at 60 kg N/ha in increasing grain yield of rice in the 2004 and 2005 WS, with a yield advantage of 30–40%. The *Sesbania* GM + *Azolla* is of special interest because it does not need any inorganic N fertilizer. In intermediate lowlands, rice grain yields obtained under *Sesbania* GM and urea supergranules (USG) (45 kg N/ha) were comparable in 2004 but not in 2005, because *Sesbania* growth was poor due to early drought coupled with high soil salinity (8–11 dS/m). The FYM + PU treatment was not effective in 2004, possibly because of the slower decomposition of FYM under excess soil moisture conditions. However, in 2005, it significantly increased the grain yield (57%) over the no-N control and was on a par with the other treatments, possibly because of the favorable soil moisture conditions and residual effects of FYM applied in 2004. The yield advantage of USG and *Sesbania* over a control was 52% and 52% in 2004 and 68% and 27% in 2005, respectively. In a shallow lowland trial, yields were higher in 2004 than in 2005 because of prolonged waterlogging in 2005. A similar effect was not observed in intermediate lowlands, where a taller variety with better tolerance of waterlogging was used.

In the DS, *Azolla* + PU resulted in significantly higher yields than the application of PU at 80 kg N/ha, with about 15% higher grain yields in both. This finding suggests that *Azolla* saved 30 kg N/ha of chemical fertilizer, besides improving rice yield. The yield advantage of *Azolla* + PU over the no-N treatment was 114% in 2005 and 91% in 2006. Grain yield in all treatments was higher in 2005 than in 2006, possibly due to lower ambient temperatures during grain filling, with an average of 28.6 °C in 2005 and 29.7 °C in 2006. In 2005, soil salinity was high toward maturity but remained below 6 dS/m during most of the season, and might not have affected grain yield. Yield enhancement under different nutrient management practices in both years was associated with higher panicle number per unit area and more grains per panicle. Results of these studies clearly suggest that *Sesbania* is promising during the WS in both shallow and intermediate lowlands. In intermediate lowlands, application of PU is not very effective due to frequent waterlogging, and *Sesbania* provides a good option to improve N supply. Although USG is equally effective, it is not readily available and its application has practical problems. Similarly, FYM is often available in small quantities and is mostly used for vegetables on homestead land. *Azolla* is a promising biofertilizer for the DS and can also be used successfully in shallow lowlands during the WS provided there is no drought or flood. Farmers can produce *Azolla* inoculums at low cost in ponds and ditches that are common in coastal areas. It seems that *Sesbania* and *Azolla* offer considerable opportunities to improve soil quality and enhance and sustain crop productivity in coastal saline soils, despite some limitations.

Mitigating salinity through liming in rice. An on-farm trial on the effect of liming on rice yield was conducted during the 2008 DS, involving no lime (control), lime at 100 kg/ha in a nursery, lime at 1.0 t/ha in the main field, and lime in both a nursery and main field. Two rice genotypes, Khandagiri and IR72046-B-R-3-3-3-1, were used in an RCBD with three replications. The soil was sandy clay loam, with pH of 5.7, organic C of 0.71%, total N of 0.07%, and available P of 10 kg/ha. Data showed that lime had no significant effect on grain yield, suggesting that these soils probably have adequate calcium.

Effect of liming on nonrice crops. The effect of an application of lime at 1.0 t/ha on the yield of sunflower, watermelon, groundnut, and okra was evaluated in farmers' fields during the 2005 and 2006 DS using an RCBD with three replications. Liming significantly increased the growth and yield of all crops in both years, with a yield advantage in the range of 36% (sunflower) to 57% (watermelon and okra) in 2005. The response was relatively less in 2006, possibly because of residual effects from 2005. These findings *suggest that liming could be recommended for enhancing the productivity of these crops in the DS.*

Water management for rice. Rice is the main crop during the WS in coastal saline areas. In the DS, limited areas are planted to rice using harvested rainwater, which is important for food security. To expand rice area in the DS, optimizing the use of fresh water and using it in conjunction with saline water at relatively tolerant growth stages are important. Two on-farm trials were conducted during 2005-08. In the first experiment, five treatments involving irrigation with fresh water throughout (control), irrigation with marginally saline (MS) water for 1 week during 41–48 days after transplanting (DAT), irrigation with MS water for 2 weeks during 34–48 DAT, irrigation with MS water for 3 weeks during 27–48 DAT, and irrigation with MS water for 4 weeks during 20–48 DAT were evaluated with two rice varieties (Annapurna and Canning 7) in 2005 and 2006, in a split-plot design with three replications. In the second experiment, four treatments, continuous ponding (control), irrigation 2 days after the disappearance of standing water (DSW), irrigation 4 days after DSW, and irrigation 6 days after DSW, were compared with rice variety Annapurna in 2007 and Annapurna and IR72046-B-R-3-3-3-1 in 2008. An RCBD with four replications was followed in both years.

The EC of irrigation water and groundwater in the first experiment was 2.4–3.1 and 5.8–7.4 dS/m in 2005 and 2.4–4.8 and 4.2–6.1 dS/m in 2006, respectively. Depth to the groundwater table was 50–80 cm in 2005 and 45–78 cm in 2006. Irrigation with saline water for 1–4 weeks during the vegetative stage (20–48 DAT) in 2005 did not reduce grain yield. In 2006 also, irrigation with saline water for 2 weeks had no significant effect on grain yield, but saline water irrigation for 3 or 4 weeks decreased yield by nearly 40%. This was mainly because of the higher salinity of irrigation water than in 2005, particularly during the reproductive stage. In the second trial, the EC of groundwater and depth to the groundwater table were 9.2–14.8 dS/m and 27–43 cm, respectively. Grain yield was highest under continuous shallow flooding. Providing freshwater irrigation 2 days after DSW during the vegetative stage (10 DAT-PI) did not significantly decrease yield. However, irrigation 4 and 6 days after DSW decreased grain yield by 30% and 48%, respectively, due to the higher soil and field-water salinity. In 2008, irrigation 6 days after DSW was not included because it caused a drastic reduction in grain yield. Here again, grain yield of both varieties was the highest when the crop was subjected to continuous flooding. The average grain yield of the two varieties in treatments receiving irrigation 2 d after DSW (5.0 t/ha) was comparable with that with continuous flooding (5.3 t/ha). However, irrigation at 4 d after DSW decreased yield by 23%. IR72046-B-R-3-3-3-1 produced 28% higher grain yield than Annapurna. The study indicated that marginally saline water could be used safely for 2 weeks during the vegetative stage without a significant reduction in rice grain yield under high salinity. Furthermore, irrigation with fresh water 2 d after DSW during the vegetative stage produced yield similar to that of continuous ponding of water. These approaches would help in substantially saving precious fresh water and expanding the cropping area, leading to enhanced land and water productivity.

Water management for nonrice crops. Two on-farm trials evaluated the effects of irrigation frequency (10- and 15-d intervals) and depth (2, 4, and 6 cm) on the performance of sunflower and groundnut during the 2006 DS using a CRBD with three replications. Depth to the groundwater table at this site was 60–100 cm. The initial soil ECe was 6–8 dS/m. For sunflower, seed yield was significantly higher with irrigation at 15-d intervals than at 10-d intervals, and with 4-cm irrigation depth than with 2- or 6-cm irrigation depth. For groundnut, irrigation at 15-d intervals resulted in higher pod yield when 4 and 6 cm of irrigation was applied but not with 2 cm of irrigation water. The depth had no significant influence when irrigation was provided at 10-d intervals, but yield was higher with 4-cm than with 2- or 6-cm irrigation depth when irrigation was provided at 15-d intervals. The highest yields of both sunflower and groundnut were obtained with 4 cm of irrigation at 15-d intervals. The higher yields with irrigation at 15-d intervals than at 10-d intervals suggest contributions from shallow groundwater.

Best-bet management. Integration of improved management practices with high-yielding salt-tolerant varieties is important for enhancing productivity and ensuring household food security in these unfavorable areas. On-farm trials on the use of salt-tolerant rice varieties with improved management practices were conducted in different villages during the 2005 WS and 2006 DS. Four treatments—farmers' variety with farmers' management, improved variety with farmers' management, farmers' variety with improved management, and improved variety with improved management—were evaluated under intermediate lowlands using a CRBD with three replications. Farmers grew rice variety Bhaluki during the wet season and Khandagiri during the dry season. In the WS, farmers used random transplanting at wider spacing (>20 cm) using 35–40-d-old unfertilized seedlings with little or no fertilizer and pesticides in the field. During the DS, they followed random and late (3rd week Jan-1st week Feb) transplanting using 30–35-d-old unfertilized seedlings. The improved varieties used in the trials were SR26B during the WS and Annapurna/CSR 4 during the DS. The improved management package for the WS included the use of robust fertilized seedlings (NPK at 10 kg/ha each + FYM/*Azolla* compost at 5.0 t/ha), older seedlings (50 d old), closer planting (15 × 10 cm), and *Sesbania* as green manure. During the DS, improved management practices used fertilizer in the nursery as in the WS, early planting (January, 1st fortnight) with 30-d-old seedlings at 15 × 15-cm spacing, and *Azolla* + 50 kg N/ha (30 kg as basal and 20 kg at tillering). P and K were used at 30 (WS) or 40 (DS) kg/ha. Grain yield during both the 2005 WS and 2006 DS was the lowest under the farmers' variety and management (Fig. 3.3). Improved variety with farmers' management increased grain yield by 48% and 23% during the WS and DS, respectively. Similarly, the farmers' variety with improved management produced 24% and 46% higher grain yield in the WS and DS, respectively. The greater yield advantage from an improved variety in the WS was because the farmers' variety was a traditional one with low yield potential. However, the yield advantage due to improved management was higher during the DS, possibly because the farmers use a high-yielding input-responsive variety. Combining improved variety with improved management resulted in a yield advantage of 91% during the WS and 75% during the DS.

Economic analysis showed that the benefit-cost (B:C) ratio was 26.4 and 13.5 for an improved variety with farmers' management during the 2005 WS and 2006 DS, respectively. Very high B:C ratios in this treatment were mainly because of the significant yield advantage with little additional cost for seed. The corresponding B:C ratios for improved management with a farmers' variety were 0.7 and 1.4. The low B:C ratio with improved management, particularly during the WS, was expected with the farmers' variety that was tall, was susceptible to lodging, and had a low response to nutrients. The B:C ratio for an improved variety with improved management was 2.7 and 2.4 during the 2005 WS and 2006 DS, respectively. Clearly, the introduction of high-yielding salt-tolerant varieties with improved management practices can substantially increase rice yield in the coastal saline ecosystem during both the wet and dry seasons with good benefits to farmers. These varieties have potential to increase yield significantly even under farmers' management with little additional cost, but improved management will ensure yield sustainability. These studies confirm that management packages developed through this project are, in fact, very effective under actual farmers' field conditions. However, more resources and efforts are required to disseminate these practices in these coastal saline areas as well as in similar ecosystems facing similar challenges.

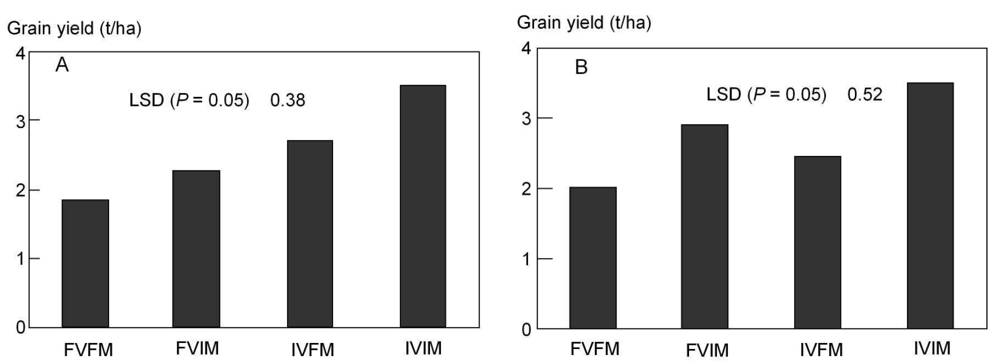


Fig. 3.3. Grain yield of rice during the 2005 wet season (A) and 2006 dry season (B) using a farmers' variety with farmers' management (FVFM), farmers' variety with improved management (FVIM), improved variety with farmers' management (IVFM), and improved variety with improved management (IVIM).

Rice-based cropping systems. Coastal saline areas are normally monocropped with rice grown during the WS because of the lack of freshwater resources during the DS coupled with high salinity. The introduction of less water-consuming salt-tolerant nonrice crops for the DS is important for better land and water productivity. On-farm trials were conducted in Ersama block of Jagatsinghpur District, Orissa, India, during 2005 and 2006 to evaluate the performance of selected nonrice crops in the DS. In 2005, sunflower, *Basella*, watermelon, chilli, pumpkin, peanut, tomato, bitter gourd, and okra were evaluated under medium salinity (ECe of 4–7 dS/m) and high salinity (ECe increasing from 10 to 15 dS/m) in sandy loam soils. In 2006, watermelon, chilli, sunflower, pumpkin, *Basella,* okra*,* and peanut were grown under medium salinity (*Basella;* ECe of 2–6 dS/m except during the latter part of the season) and high salinity (okra and peanut; ECe of 4–8 dS/m, increasing to 16–26 dS/m toward the end of the season) at two locations with sandy loam and clay loam soils. In 2005, all crops performed well under medium salinity, whereas only sunflower and *Basella* produced reasonable yields under high salinity. The other crops failed because of high soil and water salinity during the early crop growth stages. In 2006, all crops performed well, but with variable yield except for sunflower and chilli. The yields of watermelon and pumpkin were especially dependent on irrigation-water quality. Across seasons and salinity levels, watermelon, chilli, pumpkin, and sunflower were the best crops based on rice yield equivalent, net returns, B:C ratio, and water productivity. Okra was the most profitable under medium salinity, although its water productivity was lower than that of watermelon and pumpkin in some cases. These crops offer considerable opportunities for diversification in coastal saline areas. Detailed data were summarized in a paper presented at the Delta 2007 international conference held in Bangkok in November 2007, and also as a supplement to the data provided with this report.

Apparently, salinity during the DS is affected by rainfall in the preceding WS, among other factors. Certain crops, such as sunflower and *Basella*, are more tolerant of salinity than other crops. Analysis of benefits and costs showed that, under medium salinity, watermelon produced the highest rice equivalent yield, net returns, and B:C ratio, followed by chilli, okra, pumpkin, and sunflower. The rice equivalent yield of okra, pumpkin, and sunflower was comparable, but the B:C ratio was lower for sunflower because of the higher cultivation costs. In 2006, rice equivalent yield and net returns were the highest for chilli, followed by sunflower and watermelon at one site; at another site, all crops, with the exception of sunflower and chilli, achieved much higher rice equivalent yields and net returns were highest for watermelon, followed by pumpkin and chilli. The B:C ratio of all crops in the high-salinity fields ranged from 2.0 to 6.9, with the highest value for chilli and watermelon. The B:C ratio across crops under medium salinity was 2.5–9.5, with the highest B:C value for okra.

Water productivity. Water availability and quality are the main determinants of DS cropping in coastal saline regions. Crop-specific water productivity expressed as kg rice equivalent yield per m^3 water applied was determined for comparisons. In 2005, water productivity in medium-saline fields was the highest for watermelon, followed by pumpkin, chilli, and bitter gourd. Water productivity of watermelon was very high (more than 80 kg rice equivalent/m^3 of water), possibly because of its high yield. Obviously, rather low water productivity was achieved in high-salinity fields during 2005, when only sunflower and *Basella* succeeded. In 2006, water productivity in high-salinity fields was highest for watermelon, followed by chilli, pumpkin, and sunflower. Watermelon, chilli, pumpkin, and sunflower were promising for medium- and high-salinity conditions based on rice equivalent yield, B:C ratio, and water productivity. Under high salinity, watermelon and pumpkin performed better when fresh water was available. Okra was the most remunerative crop under medium salinity, although its water productivity was in some cases lower than that of watermelon and pumpkin. Sunflower and chilli yields were relatively consistent across locations and they were preferred by farmers for their own consumption needs and for their better storage characteristics. These studies showed considerable potential for nonrice crops in these highly saline areas during the DS.

Evaluation of sorghum and pearl millet for green fodder. The cattle in this area are fed mainly with rice straw and no alternative green fodder is available. To ensure fodder supply during the DS, 11 sorghum genotypes and 12 pearl millet genotypes obtained from ICRISAT were evaluated in a farmer's field using an RCBD with three replications on a sandy loam soil. The crop was grown with the recommended dose of fertilizers and 2–3 light irrigations were provided using pond water. Green fodder was cut 2–3 times. For sorghum, S 35 produced the highest fodder yield of 11 t/ha and ICSV 112, ICSV 406, ICSR 170, and ICSV 93034 were comparable with fodder yields of more than 9 t/ha. Some cultivars of pearl millet also produced comparable yields of about 10 t/ha (HHVBC Tall). Others such as Raj 171, IP 6105, IP 6106, and IP 19586 produced more than 8 t/ha. Those data showed considerable scope for these fodder crops in coastal areas; however, farmers are still reluctant to use them and they prefer growing food crops to ensure their own food security. These crops could probably prevail after farmers first secure their food supply.

Evaluation of sweet potato varieties. Sweet potato can serve as the main food when WS rice is not sufficient. We tested 15 sweet potato varieties under medium and high salinity during the 2007 and 2008 dry seasons in an RCBD with three replications in sandy loam soils. The trial was conducted in collaboration with the Regional Station of the Central Tuber Crops Research Institute, Bhubaneswar, Orissa. Soil salinity at planting in 2007 and 2008 was 5.9–17.5 and 4.2–5.9 dS/m at the medium-salinity site, and 8.7–22.6 and 4.9–8.7 dS/m at the high-salinity site, respectively. Variety CIP 440127 produced the highest tuber yield of 17 and 23 t/ha at the medium-salinity site and 9 and 12 t/ha at the high-salinity site during 2007 and 2008, respectively. CIP 440038 also produced good yields under both conditions and in both years. Samrat, Sree Bhadra, and Kisan performed well under both salinity levels in 2007, but their tuber yields under high salinity were much lower in 2008. Pusa Safed produced high yields under medium salinity but

not under high salinity. The yields at the medium-salinity site were higher in 2007 than in 2008, possibly because excess rain and prolonged waterlogging in the 2007 WS lowered the salinity in the 2008 DS. These studies showed that sweet potato varieties CIP 440127 and CIP 440038 are the most promising for coastal saline areas in both medium- and high-salinity conditions. Apparently, there is good scope for root crops during the DS in these coastal areas, with light soils, especially when fresh water could be provided either through harvested rainwater or from surface-water resources, with considerable impact on food security.

Management practices for inland alkaline/sodic soils of Lucknow, UP (CSSRI)

Water-saving techniques during seedling stage. During May, farmers in western UP, India, face water shortage because electricity is not available or diesel cost is too high. This study aims to establish the optimum seedling age for survival and water savings in sodic soils using salt-tolerant varieties.

Methods. Experiments were conducted at the CSSRI-RRS experimental farm, Shivari, Lucknow, in sodic soils (pH of 9.36) using 20-, 30-, and 40-d-old seedlings, in an RCBD with four replications. Recommended doses of fertilizer were applied in all the treatments. Salt-tolerant variety CSR23 was transplanted on 13 and 14 July in 2005 and 2006, respectively. The crop was harvested on 18 to 28 October during the respective years. Yield attributes (grain and straw yield) were recorded at maturity, and water use was measured during the seedling stage in the nursery. Results indicated that rice grain yield increased with older seedlings but yield was similar from 30- and 40-d-old seedlings in both years. Based on yield and water savings, 30-d-old seedlings seem to be optimum for the salt-tolerant variety used in this study.

Integrated water, soil, and nutrient management strategies to mitigate the effect of salt stress. The development of salt-tolerant varieties will enable more use of sodic land and water, while varieties with increased tolerance of short-term or medium-term water deficits, and of shorter duration, will help in saving water under irrigated conditions. The high early seedling vigor and harvest index of modern varieties also help in increasing water productivity over that of traditional varieties.

Effect of water stress on different growth stages of salt-tolerant rice varieties in sodic soils. This trial aimed at developing alternative water management strategies for using less water. The objectives were to (i) optimize irrigation requirements of salt-tolerant varieties of rice, (ii) assess the effect of water stress on growth, yield, and water productivity, and (iii) monitor changes in soil properties. An experiment was conducted during 2006, 2007, and 2008 at the CSSRI-Regional Research Station using two varieties, CSR23 and NDR-359, under seven different levels of water stress at three growth stages in a split-plot design with four replications. Seedlings were transplanted at 20 × 15 cm on 21 July and harvested from 27 to 31 October each year. Another experiment was conducted with early-maturing breeding line CSR-89-IR-8 and Samba Mahsuri (local variety) under four water stresses in sodic soils during 2007 and 2008 at the CSSRI experimental farm, Shivari, also using a split-plot design with four replications.

Results. Grain yield of both varieties was higher when adequate irrigation was given during all stages and decreased progressively with decreasing water input. Under the most severe water-stress treatment (irrigation after 7 d of water disappearance), grain yield of CSR23 decreased by 28% and 20% during 2006 and 2007, respectively. Similarly, grain yield reductions in NDR359 were 32% and 23% under water-stress conditions during the respective years. The reduction in yield was more in NDR359 than in the salt-tolerant CSR23. In the second experiment, grain yield of CSR-89-IR-8 is higher than that of Samba Mahsuri in all treatments and CSR-89-IR-8 saved 155 mm of water because it matures earlier. Grain yield of both varieties was higher with adequate irrigation during all stages and the reduction under stress was greater in Samba Mahsuri than in CSR-89-IR-8. This showed that the use of salt-tolerant early-maturing varieties is more effective in reducing water use and increasing water productivity in salt-affected soils.

***Optimizing nitrogen for salt-tolerant varieties*.** Sodic soils are highly deficient in organic matter and crops invariably suffer nutritional disorders. Press mud improves the organic matter and time in reclaiming sodic soils. Fertility status of these soils is generally poor, with high pH, excess of exchangeable sodium, low available N, and poor physical properties. This trial attempts to optimize nitrogen recommendations for salt-tolerant varieties. The trial was conducted on reclaimed sodic soil (pH 9.2) at the CSSRI-Regional Research Farm. N treatments were a control (0 N), 50, 100, 150, and 200 kg/ha N with two varieties, CSR23 and CSR13, using a split-plot design with N as the main plot and varieties as subplots with four replications. The crop was transplanted on 19 July and 21 July in the respective years and harvested on 27 and 29 October, respectively. Half of N was given at transplanting and the rest equally split at 35 and 50 d after transplanting. Grain yield of CSR13 and CSR23 increased progressively with increasing N. Grain yield of CSR23 was highest at 200 kg N/ha, whereas that of CSR13 increased significantly up to 150 kg/ha. The data suggest a substantial response to N in these sodic soils.

***Modeling yield and water balance in sodic soils using ORYZA2000*.** The objective was to explore the possibility of applying the ORYZA200 model to simulate yield and water balance during the rice-growing season under well-watered and water-stress conditions in sodic soils. The model was calibrated with two varieties (salt-tolerant and intolerant) using field data collected over 2006 and 2007. The ORYZA2000 model seemed to work well as reflected by the close matching of the simulated and measured crop growth and yield data together with water-balance components. Application of this model is possible for predicting yield, yield gaps, and water productivity under these environments, and can help in developing strategies to optimize irrigation water use. For a given environment, this model can help envisage the effects of changes in morphological and physiological characteristics of rice to predict its adaptation to specific conditions, which is valuable for breeding.

Feasibility of direct-seeded rice in partially reclaimed sodic soil. Transplanting is the most common method of crop establishment in salt-affected areas, but high labor input is needed, which is mostly not available during transplanting in July and labor is expensive. Transplanting in puddled soil reduces soil permeability and helps in controlling weeds, but repeated puddling aggravates soil dispersion in sodic soils. This trial attempted to test the feasibility of direct seeding in partially reclaimed sodic soil. Trials were conducted in 2005 (15 cultivars) and 2006 (4 cultivars), using either (i) transplanting of 8-week-old seedlings in puddled soil or (ii) direct seeding after dry plowing. Direct seeding was the same for both field and nursery. In the first year, eight genotypes produced more than 4 t/ha: CSR23 (5.1 t/ha), NDR 359 (4.8 t/ha), IET-18710 (4.7 t/ha), CST-7-1 (4.6 t/ha), Swarna Mahsoori (4.5 t/ha), IET-18708 (4.3 t/ha), Sarjoo-52 (4.2 t/ha), and IET-18702 (4.1 t/ha). In 2006, grain yield was significantly higher under direct seeding (3.6 t/ha) than under transplanting (3.4 t/ha). NDR-359 had the highest yield (4.2 t/ha), followed by CSR23 (4.1 t/ha), and these two lines had higher yield under direct seeding than under transplanting and were harvested 18 d earlier when direct seeded, which is desirable for the subsequent wheat crop. Plant height, panicle length, and 1,000-grain weight were considerably higher under direct seeding, but tillers per plant were lower.

Salt-tolerant varieties help reduce gypsum requirement for reclaiming sodic soils. Farmers of UP have poor resources and can afford only low-cost technologies for reclaiming their sodic soils. The objectives were to find alternatives that can help reduce the recommended doses of gypsum. Trials were conducted in farmers' fields in Dhora Village, Unnao District, and Shakra Village in Hardeo District, on barren sodic soils, with pH of 9.76 and 10.06, respectively. The gypsum requirement (GR) at Dhora was 10.8 t/ha and the corresponding value of Shakra fields was 13.3 t/ha. Salt-tolerant CSR13 was planted on 17 July and recommended fertilizers were applied with control plots representing farmers' local practices. Treatments at Dhora included a control (no gypsum + local varieties of rice and wheat), 25% GR+ salt-tolerant varieties (CSR13 of rice and KRL 19 of wheat), and 50% GR+ salt-tolerant varieties. At Shakra, treatment combinations were 25% GR + salt-tolerant varieties, 50% GR + a salt-tolerant variety, and 25% GR + press mud at 5 t/ha + salt-tolerant varieties. At Dhora, CSR13 has better growth and yield than the local variety Pant 4. Grain yield of tolerant rice varieties with 25% and 50% GR were 4.2 and 4.4 t/ha, respectively. Corresponding wheat yields were 2.47 and 2.75 t/ha. The benefit of additional yields of rice and wheat from 50% GR was about Rs. 2,836, but the cost of additional gypsum is Rs. 7,200. At Shakra, 25% GR + press mud resulted in 5.6 t/ha when farmers obtain only 2.8 t/ha. The addition of press mud improved the organic carbon of the soil and had a residual effect on the succeeding wheat crop. Application of gypsum at 25% GR and the use of salt-tolerant varieties could therefore be used for reclaiming sodic soils when the pH is not too high; however, the addition of organic industrial by-products such as press mud will be useful in highly alkaline soils. With such reduced costs, sodic soils that had never been used for crop production could be completely reclaimed and used for both rice and wheat within 2–3 years.

***Cropping patterns: diversification of cropping system in partially reclaimed sodic soils*.** Rice-wheat is the predominant cropping system in reclaimed sodic soils, occupying about 60–70% of the area. Wide adoption of this system is due to its high productivity and less risk. But this created many serious ecological problems such as exhaustion of underground water and other adverse effects on soil conditions, crop yield, and factor productivity, thus increasing the cost of production and weed infestation in the wheat crop. A field experiment was conducted to explore more profitable alternatives to this system. Trials were conducted in farmers' fields during 2004-05 and 2005-06 on partially reclaimed sodic soil, with pH of 9.2, EC2 of 1.43 dS/m, and organic carbon of 0.10%. Four cropping systems were tested, rice-wheat (cereal-based), sorghum-berseem (fodder-based), sweet basil (tulsi)–matricaria (medicinal and aromatic crop-based), and chilli-garlic (spices-based). Pant 10, SSG-59-3, Sim somya, and LCA-235 of rice, sorghum, sweet basil, and chilli were grown during the rainy season and PBW 343, JB-2, vallary, and local varieties of wheat, berseem, matricaria, and garlic were grown during the winter season. Sorghum and berseem fodder yields were calculated on the basis of two and four cuttings each, respectively. The prevailing market prices of rice, wheat, sorghum, berseem, chilli, and garlic, and those of sweet basil oil and matricaria flowers, were used for economic analysis of different systems. Tulsi-matricaria is highly profitable compared with rice-wheat, sorghum-berseem, and chili–garlic, with a higher rice equivalent yield (14.2 t/ha), followed by chilli-garlic and sorghum-berseem, and the lowest was the rice-wheat system. The higher rice equivalent yield in sweet basil-matricaria cropping was because of the high market price of sweet basil oil (Rs. 500/L) and matricaria flowers (Rs. 52.5/kg) for medicinal and aromatic uses. There is good potential for alternative cropping patterns to replace the traditional rice-wheat system, given a stable market price.

Management practices for inland alkaline/sodic soils, Faizabad, UP (NDUAT)

The target area is inland sodic soils of UP, with a focus on development and validation with farmers of affordable management technologies for reclaiming these soils and improving productivity. Technologies include the use of industrial by-products such as press mud from the sugarcane industry, the use of green manures and chemical fertilizers, and proper nursery management.

Validation of press mud technology for improving rice yield and health of sodic soil. Experiments were conducted during 2006-08 using Usar Dhan-3 and Sarjoo-52 in 2006, with CSR30 added in 2007 and 2008. Treatments involved a control, press mud (PM), and PM + $ZnSO_4$ at 10 t/ha and 20 kg/ha, respectively. PM was incorporated 10 d before transplanting, while $ZnSO_4$ was added just before puddling. 35-d-old seedlings were transplanted in soil with pH of 9.5. Growth and yield parameters were better under

PM and PM + Zn, with a yield increase of 23–40% in 2006 and 29.5–31% in 2007. However, the yield advantage in 2008 was much higher (36% to 55%). These data clearly showed the advantage of using this technology in reclaiming and enhancing productivity in sodic soils, which are normally low in available Zn. PM is an organic by-product of sugar factories rich in S, Zn, and Ca. PM is a cost-effective and easily accessible technology within the reach of rice farmers and it can effectively be used to improve the productivity of sodic soil when integrated with salt-tolerant rice varieties, thus eliminating the need for expensive gypsum.

Validation of PM technology for improving yields in farmers' fields. This technology was validated over 3 years in farmers' fields using 10 t/ha of PM and 20 kg/ha of $ZnSO_4$. In 2006, PM technology was evaluated by 10 farmers in 3 villages of Faizabad District. The soil pH was between 9.5 and 10.2. PM + $ZnSO_4$ increased plant height, tillering, and grain yield of Usar Dhan-3 in all farmers' plots, with a yield advantage of 31% to 67%, averaging about 47%. In 2007, PM technology was validated in Faizabad and Sultanpur districts of eastern UP, in 10 farmers' fields with soil pH of 9.6 to 10.2. Application of PM with $ZnSO_4$ substantially improved growth and increased the yield of Usar Dhan-3, CSR27, Sarjoo-52, and NDRK-5083, with a yield advantage of 11% to 56%, and with better responses in soils with higher pH. In 2008, 19 farmers were involved in three villages with soil pH of 9.3 to 10.2. Yield advantages in NDRK-5083, Usar Dhan-3, Sarjoo-52, NDR-359, and CSR27 were 33.3–37.5%, 16.7–62%, 50–86.7%, 28.5–66.7%, and 33–60%, respectively, again with greater responses at higher sodicity. These trials clearly demonstrated the dramatic and consistent benefits of using this relatively cheap technology when combined with salt-tolerant varieties and it should be outscaled to benefit more farmers who experience a severe yield reduction due to soil alkalinity in UP and elsewhere.

Evaluation of green manure technology for yield improvement of rice in farmers' fields. Green manures (GM) are known to help improve soil health and reduce pH in alkaline soils. A series of trials were conducted with farmers during 2006-08 to validate and quantify its benefits against farmers' practices. In 2006, six farmers were involved in Faizabad and Sultanpur districts, using a combination of *Sesbania* as GM and Usar Dhan-3 as a salt-tolerant variety, under farmers' management practices. Soil pH varied from 9.5 to 9.8. The yield advantage over farmers' practices ranged from 31% to 60% in different farmers' fields. In 2007, trials were conducted in the same districts using Usar Dhan-3 and Sarjoo-52 with 7 farmers and soil pH of 9.3 to 9.8. Again, GM increased plant height and effective tillers. Grain yield of Usar Dhan-3 increased by 25–31% and that of Sarjoo-52 by 23–50%. In 2008, four varieties, Usar Dhan-3, NDRK-5083, NDR-359, and Sarjoo-52, were used by 11 farmers in three villages with soil pH similar to that of 2007 villages. Application of *Sesbania* as GM increased the grain yield of all varieties at all sites. The yield increase of Usar Dhan-3 ranged from 16.7% to 86.7%, NDRK-5083 from 37.9% to 50.0%, NDR-359 from 37.9% to 40.6%, and Sarjoo-52 from 28% to 75%. As with press mud, the yield advantage of GM was progressively higher with increasing soil pH.

Nutrient management in the nursery for rice yield improvement in sodic soil. Poor crop establishment because of high seedling mortality is a major reason for low yield in sodic soils. These soils are also inherently poor in available nutrients. This set of trials tested proper nursery management options that reduce seedling mortality upon transplanting in sodic soils. Nursery treatments were either a control or the addition of a combination of chemical fertilizers and FYM (N:P:Zn:FYM at 60:40:20 kg/ha:10 t/ha). All nutrients were applied just before sowing except FYM, which was incorporated in the seedbed 10 d earlier in normal soils. After 35 d, seedlings were transplanted in an RCBD with three replications. In 2006, Usar Dhan-3 was used. The application of nutrient in the nursery increased grain yield by about 17% over the control. In 2007, Usar Dhan-3 and CSR30 were used, and nutrient application in the nursery again showed a significant impact on growth and yield. Usar Dhan-3 produced higher yield (2.83 t/ha) than CSR30 (1.9 t/ha) but the yield advantage over the control was more in CSR30 (27%) than in Usar Dhan-3 (21%). The addition of FYM and chemical fertilizers is therefore recommended for transplanted rice in sodic soils. This improved seedling health and showed carryover effects in sodic farmers' fields. This is cost-effective given the small nursery area that the farmers had to manage.

Optimizing ZnO root dipping to improve rice yield in sodic soil. Sodic soils are inherently deficient in zinc and farmers have to apply 20–30 kg/ha of $ZnSO_4$ every season, which is expensive and sometimes not available with a reasonable quality. As a micronutrient, Zn is required in small quantities; thus, these trials tested the effectiveness of applying Zn in the nursery, or by just dipping roots in slurry of zinc oxide, on growth and yield after transplanting. Two experiments were conducted in 2006-07 involving Usar Dhan-3 and Sarjoo-52, and four treatments—control, $ZnSO_4$ at 20 kg/ha (basal), and dipping of seedling roots in either 15% or 20% solution of ZnO for 20 min, then drying in the shade for 30 min before transplanting of 35-d-old seedlings in the field (pH 9.5). An RCBD with three replications was used. In both years, dipping roots in 15% ZnO was more effective, and increased grain yield by 20–24% in 2006 and by 18–26% in 2007. This practice could effectively replace field application of $ZnSO_4$, with substantial savings to farmers.

Management practices for salt-affected areas of coastal Bangladesh (BRRI)

Nutrient management for boro rice in salt-affected soil. Boro (DS) rice is being practiced on a large scale in southern Bangladesh, particularly with the availability of short-maturity and salt-tolerant varieties. This study aimed to establish nutrient management recommendations for this system and to test whether requirements in these saline areas could vary from recommendations for normal soils. BRRI dhan28 (sensitive), PVS-B3, PVS-B8, and PVS-B19 (tolerant) were subjected to six treatments as follows: T_1 =

recommended dose (65-8-30-0.5 kg NPK-Zn/ha); T_2 = T_1 + 0.1% ($FeCl_2$ $MnCl_2$, and $CuSO_4$ spray) at 15 days after transplanting; T_3 = T_1 + 0.1% ($MnCl_2$ $CuSO_4$ spray) at 15 days after transplanting; T_4 = T_1 + 0.1% $FeCl_2$ spray at 15 days after transplanting; T_5 = T_1 except for K as ash at 3.0 t/ha (before transplanting); and T_6 = soil test-based N, P, and Zn, and K as per basic cation saturation ratio (no need for fertilizer). A split-plot design with four replications was used, with variety as the main plot and nutrient treatment as the subplot. Forty-day-old seedlings were transplanted at 25 × 15 cm with 3 seedlings per hill. Seeding and transplanting were done, respectively, in mid-November and mid-December 2005. Nutrient and EC levels of the soil were determined before transplanting. The soil is saline (4–4.8 dS/m) but available P, K, Ca, Mg, and organic matter were at normal levels. Leaf nitrogen concentration was the lowest in T_6, which received no N fertilizer. The application of Fe, Mn, or Cu did not significantly affect N concentration. Phosphorus, K, Ca, and Mg composition in leaves was similar in all genotypes and treatment effects were not significant. Similarly, Na concentration in all genotypes and treatments was similar. The ratio of K/Ca in PVS-B19 was greater than in other varieties, but ratios of other cations were similar in all genotypes and were not affected by any treatment. BRRI dhan28 was damaged during the early growth stage. The treatment effect was insignificant for plant height, tillers/m^2, panicles/m^2, and grain yield and significant genotypic effects were observed in plant height and panicles/m^2. Based on these data and on soil analysis, it seems that micronutrient deficiency is probably not a major problem in these soils; however, the large variability in the data might have masked the genotype and treatment effects and the experiment needs to be repeated before solid recommendations can be made.

Crop and nutrient management in saline soil (irrigated, 2006-07). On-station and on-farm trials were conducted at the BRRI regional station, Satkhira, and in a farmer's field at Tala. Soil salinity at the BRRI farm and at Tala was 4.96 and 4.50 dS/m at the start of the experiment. Two rice varieties, BRRI dhan28 and BRRI dhan47, were tested with four fertilizer management practices: T_1 = recommended dose of N, P, K, and Zn (120-8-30-0.5 N-P-K-Zn kg/ha); T_2 = T_1 + additional 50 kg K/ha; T_3 = T_1 + additional 5 t ash/ha at 15 days after transplanting; and T_4 = T_1 + additional 20 kg N/ha. The design was an RCB with three replications. Nitrogen, P, K, and Zn were applied as urea, triple superphosphate, muriate of potash, and zinc sulfate, respectively. Fifty-two-day-old seedlings were transplanted at the BRRI farm, Satkhira, and 53-day-old seedlings were transplanted in a farmer's field at Tala on 7 and 8 January 2007, respectively. P, K, and zinc sulfate were applied during final land preparation in the respective plots. For T_2, one-half of K was applied during final land preparation and the rest was applied at PI stage. Ash in T_3 was applied at 15 DAT. Nitrogen was applied at 15, 30, and 45 days after transplanting. Field soil and water salinity was measured from 15 to 90 DAT. Salinity in the irrigation water was also measured fortnightly.

Results. Irrigation water salinity at the BRRI farm, Satkhira, was 3.0 dS/m at 15 DAT and declined progressively with time to about 1.5 dS/m at 90 DAT. The treatment effect on water salinity was not significant. Soil salinity was slightly lower than water salinity at the first sampling date, but increased gradually and stayed slightly higher than water salinity. Treatment effects on plant growth and yield were not significant, but the varietal effect was prominent in plant height, tiller and panicle production, sterility, and grain yield. BRRI dhan47 outyielded BRRI dhan28 at both locations. At the BRRI RS farm, the yield of BRRI dhan28 was 6.12–6.47 t/ha, while the yield of BRRI dhan47 was 6.53–6.82 t/ha, and in farmers' fields was 6.18–6.53 and 6.35–6.64 t/ha, respectively. Soils of both locations had good supplying capacity of inherent N and K, which might have obscured the effect of additional K, ash, or N on rice. Further nutrient management studies in coastal saline areas need to be done in areas where farmers face difficulties with P and Zn deficiencies and iron toxicity. Investigation on soil characterization is needed in areas where farmers grow neither rice nor nonrice crops during the dry season.

Monitoring river-water salinity. The Betna River is adjacent to the BRRI farm in Satkhira. A major interest is to use river water for irrigation in the dry season from November to April. Water samples were collected during high- and low-tide periods at the sluice gate point of the BRRI farm from the river. Figure 3.4 shows the weekly trend in water salinity from June 2006 to April 2007. River water becomes unsuitable for irrigation in March (>5.0 dS/m) when farmers start using brackish water for raising shrimp. River-water salinity was also monitored in the 2007-08 DS in both the Betna and Kopotaksho rivers and similar results were observed for the Betna River; however, Kopotaksho water is usable until May. It is evident that Betna River water can be used until the end of February, and for the whole DS from the Kopotaksho River. Water salinity of high tide is much more important for irrigation using tidal force.

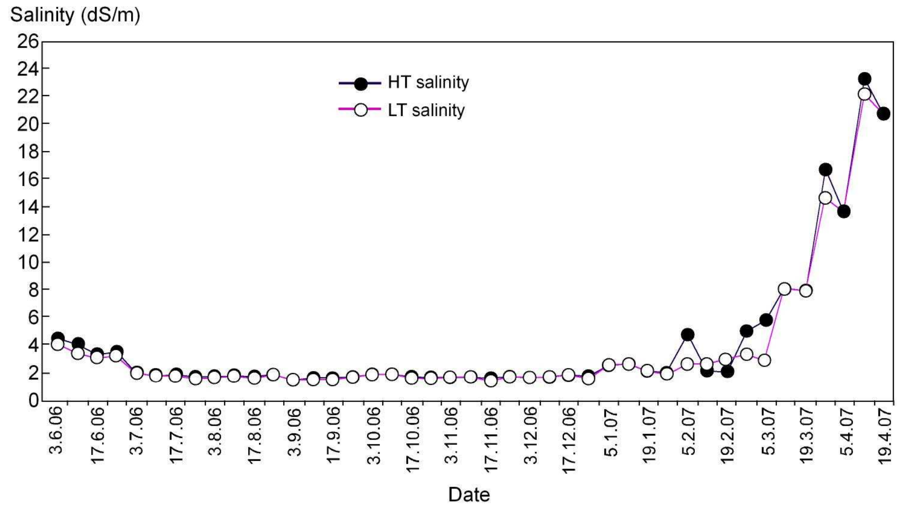


Fig. 3.4. High-tide (HT) and low-tide (LT) water salinity of the Betna River at the sluice gate point of the BRRI farm, Satkhira, from June 2006 to April 2007, CP-7 site.

Management practices for salt-affected areas of the Mekong Delta (CLRRI)

Improved cropping patterns. A set of 10 mungbean and 14 soybean varieties was evaluated for its yield after rice in the dry season. Substantial genetic variability was observed and a few superior varieties were selected from each crop for further testing. New cropping sequences were tested, involving the development of high-yielding short-maturity rice varieties for less saline areas with ample fresh water; nonrice high-value crops such as soybean and peanuts, for areas where freshwater resources are relatively scarce during the DS; and rice-aquaculture systems for areas where salinity is high during the DS, as in Tra Vinh Province. Results of these studies were presented in part in the proceedings of the Delta 2007 international conference.

The rice–tiger shrimp system was suitable for salt-affected soil, can generate good income and social benefits, and can increase rice grain yield by up to 22% compared with mono rice culture. Demonstrations of the model of using salt-tolerant modern rice varieties followed by shrimp culture with proper management were substantially profitable and sustainable at our pilot site at Tra Vinh. In 2004, the farmer adopting our model obtained 4 t/ha of rice and 1,000 kg/ha of shrimp with a gross income of 78 million VND (net profit of 38 million VND). In 2005, the same farmer following this system obtained even better yields of rice (4.3 t/ha) and shrimp (1,200 t/ha), with a net profit of more than 50 million VND. Neighboring farmers using their traditional systems were unsuccessful because of the late start of the shrimp season and poor management. Introduction of this modern rice-shrimp system in Tra Vinh is profitable and results will be further outscaled. However, over the years, it seems that farmers tend to diversify their system from rice-shrimp to rice-fish because of the uncertainties in shrimp cultivation. In another trial at He Thu in 2007, involving rice–tiger shrimp on 3 ha, four new varieties of rice were tested at three sites. The results showed that AS 996 and OM 6073 were suitable for this system at all sites, with a rice yield of 4.4 t/ha and shrimp yield of 0.7 t/ha. This clearly demonstrated the feasibility of this system in areas where salinity is too high during the DS, but proper techniques should be followed to ensure system sustenance.

Integrated water, soil, and nutrient management strategies to mitigate salt stress. Because nutrient recommendations for favorable conditions might not be applicable in stressful environments, a series of trials was conducted in salt-affected areas. Some of these involved omission trials, to establish which elements were deficient at a particular site. In another set of trials, responses of five modern rice varieties during the WS to variable amounts of N (0, 30, 60, 90, 120 kg N/ha) and another set of five varieties for the dry season (0, 40, 80, 120, 160 kg N/ha) were evaluated. For the WS, all genotypes showed a positive response to applied N up to 90 kg/ha, whereas, in the DS, the response was up to 80 kg/ha. Significant variation was also observed among genotypes, with some being more responsive than others.

Management options for irrigated rice in the Nile delta (RRTC)

Maximizing rice productivity in poor water and soils was the main objective of these studies. A series of trials was conducted to improve crop nutrient management of rice under saline soil, and to optimize the amount and application time, particularly for N and K. In addition, different fertilizer sources were tested as rice straw compost, FYM, and *Azospirillum* as biofertilizer under the wheat-rice cropping system. The project also helped in disseminating some options developed before, including proper nitrogen amounts for rice for saline soil (165 and 180 kg N/ha for inbred and hybrid rice, respectively). Nitrogen splitting into four parts with a small dose at booting stage under saline soil was found to be effective, and basal application of nitrogen is not recommended. Optimum sowing date is 20 April–5 May, for both direct-seeded and

transplanted rice. Seedling age at transplanting is 25–30 d. Zinc and phosphorus applications were recommended as in the normal soil. Broadcasting pregerminated seeds is recommended using 50–75 kg seed/acre, based on salinity level. K enhances salinity tolerance and grain yield in salt-affected soil and this was confirmed in this project. Four trials were conducted.

Role of K in productivity of inbred and hybrid rice in newly reclaimed saline soils. Two field experiments were conducted at the El Sirw Agricultural Research Station in Dammiatta, Egypt, during 2005 and 2006 seasons, to investigate the effect of K rates, 0, 24, 48, and 72 kg K_2O/ha, on growth; Na and K in leaves and their ratio at heading; grain yield; and yield components of three hybrids, SK2034H, SK2046H, and SK2058H, and three inbreds, Giza 177, Giza 178, and Sakha 104. Soil was clayey with an Ec of 8.5 and 8.7 dS/m in the first and second seasons, respectively. A split-plot design was used with four replications, with varieties in the main plots and K treatments as subplots. Plant height, tiller number, panicle number per hill, panicle length, filled grains per panicle, % sterility, and 1,000-grain weight were determined on five random plants. Grain yield was determined on a 5-m^2 area and adjusted to 14% moisture content. Grain yield and panicle weight responded significantly to K application up to 72 kg K_2O/ha in both seasons. Hybrid rice cultivar Sk2034H showed the highest yield and Giza 177 was the poorest because of its sensitivity to salt stress. The interaction between rice varieties and K was significant because responses were better in tolerant varieties. The study suggested the importance of using higher K in saline soils, with a consequent increase in tolerance of salt stress and yield.

***Effects of irrigation interval and K splitting in newly reclaimed saline soils*.** Two field experiments were conducted at the El Sirw Agricultural Research Station during the summers of 2005 and 2006 on clay soil with pH of 8.15 and 8.07, $CaCo_3$ of 2.3% and 2.35%, organic matter of 0.85% and 0.89%, exchangeable sodium percentage of 8.96 and 8.73, and Ece of 6.0 and 5.53 dS/m in the first and second seasons, respectively. Giza 178 (salt-tolerant) was grown in a split-plot design, with four replications. The main plots were irrigation intervals, 3, 6, and 9 d, and subplots as K applied as basal (B), 1/2 B + 1/2 at maximum tillering (MT), 1/2 at tillering (T) + 1/2 at panicle initiation (PI), and 1/3 B + 1/3 MT + 1/3 at PI. A K rate of 57 kg K_2O/ha was used. About 165 kg N and 50 kg P_2O_4/ha were applied as urea and calcium superphosphate, respectively, and were applied as recommended for saline soils. Thirty-d-old seedlings were transplanted at 15 × 15 cm with 4 seedlings/hill. Irrigation water was measured using a cut flume of 20 × 90 cm. Five plants were randomly harvested at maturity to determine plant height, tiller and panicle numbers per hill, panicle length, field grains per panicle, % sterility, and 1,000-grain weight. Grain yield was estimated from a harvested 5-m^2 area and adjusted to 14% moisture content.

Irrigation intervals significantly affected yield and its attributes. Water stress significantly reduced growth, spikelet fertility, and grain yield. The irrigation interval of 6 d did not significantly reduce grain yield in this experiment. Potassium splitting significantly improved LAI, dry matter, chlorophyll content, and N and leaf K^+ content at heading, and enhanced grain yield in both seasons. Interestingly, K application as basal did not increase grain yield or enhance other attributes; however, triple splitting of 1/3 B + 1/3 MT + 1/3 PI resulted in better tolerance of both water and salt stress and subsequently improved rice growth and grain yield. The irrigation interval of 3 d resulted in the highest evapotranspiration (ETa), percolation, and water use in both seasons. The irrigation interval of 6 d resulted in the highest water productivity measured on the basis of water requirements and total water applied, and also in better returns. Thus, watering every 6 d could be sufficient in these soils.

***Organic and biofertilizer management of rice-wheat cropping system in newly reclaimed saline soil**.* Field experiments were conducted at the El Sirw Agricultural Research Station during 2007 and 2008 to establish the proper combination of organic, inorganic, and biofertilizers applied either directly before rice or before the previous wheat crop, and to analyze rice yield in the rice-wheat cropping system. Treatment combinations are presented in Table 3.1. Giza 178 and SK2034H hybrid, together with wheat variety Sakha93, were used. The soil was clayey and salinity ranged from 7 to 8 dS/m. At harvest, 5 random plants were used to determine plant height, tiller number, panicle number per hill, panicle length, filled grains per panicle, sterility %, and 1,000-grain weight. Grain yield was determined on a 5-m^2 area and adjusted to 14% moisture content.

The hybrid rice variety significantly outyielded Giza 178 under all treatments, suggesting that this hybrid will be extremely useful in salt-affected areas of the delta, and should be outscaled. N application at 165 kg/h gave the highest grain yield, similar to that obtained under 5 t FYM + 83 kg N/ha, 5.0 t RCS +83 kg N/ha, and *Azospirillum* + 83 kg N/ha, particularly when organic fertilizers were applied to the preceding wheat crop. This suggest that chemical N fertilizer could be reduced by half in saline soils through the application of 5 t of rice straw compost and FYM or using bacteria *Azospirillum* inoculation. Applications of these organic fertilizers over several years might further reduce the need for chemical fertilizers. Results are being validated this year.

Table 3.1. Grain yield of two rice varieties as influenced by organic fertilizer and biofertilizer applied before preceding wheat or directly before rice.

Treatments	Applied before wheat (t/ha)	Applied before rice (t/ha)
Giza178	5.39	4.20

SK2034H	6.28**[a]	4.99**
Treatments	-	-
Control	3.50	3.4
165 kg N/ha	6.60	6.40
7.5 t FYM + 83 kg N/ha	6.40	5.50
5.0 t RCS + 83 kg N/ha	6.50	5.53
Azospirillum + 83 kg N/ha	6.50	6.00
7.5 t FYM + 5.0 RCS + *Azo*	5.80	5.40
LSD 0.05	0.60	0.70
ECe dS/m	7.50	8.0

[a]** = significant at $P < 0.01$.

In summary, in salt-affected areas of the Nile Delta, grain yield of rice seems to respond to K application for up to 72 kg K_2O_5/ha. K splitting into three doses (one-third each as basal, at active tillering, and at PI) is more effective than a single basal application, and can significantly enhance tolerance and grain yield. The use of chemical nitrogen fertilizer could be reduced by 50% in saline soils by applying 5 t of rice straw compost and FYM or by using bacteria *Azospirillum* inoculation. The application of organic manures seems to be more effective for rice if applied on the preceding wheat crop.

Objective 4. **Develop strategies for validation and diffusion of new technological interventions through the participation of men and women farmers and local civil societies**

CRRI, India

Technology demonstration and dissemination. Promising salt-tolerant varieties and validated management technologies were disseminated mainly through on-farm demonstration trials conducted in different villages during the wet and dry seasons. Farmers' field days and field visits to experimental sites were organized to facilitate technology dissemination. An extension bulletin on "Improving rice productivity in salt-affected coastal soils" was published in both English and the local language and distributed to farmers and extension personnel. Mass media such as TV and local newspapers were also used for technology dissemination and to generate awareness.

Salt-tolerant rice varieties. About 2,670 kg of seed of salt-tolerant rice varieties selected through farmers' PVS trials was multiplied in farmers' fields and distributed to farmers during 2006 and 2007. Farmers reported appreciably higher yields with these varieties. In the DS, one of the IRRI lines, IR72046-B-R-3-3-3-1, performed well even under high salinity, with yields of 3.2–4.8 t/ha (mean of 4.2 t/ha) compared with 2.5–3.0 t/ha yields of farmers' varieties.

Demonstration of the effect of nutrient management in the nursery. In the 2006 WS, demonstration trials on transplanting of seedlings fertilized with the recommended dose of NPK (10 kg each of N, P_2O_5, and K_2O/ha) and NPK + FYM/*Azolla* compost (5.0 t/ha) were conducted at eight sites. Seedlings fertilized with NPK and NPK + FYM/*Azolla* compost produced grain yields of 2.1–3.8 t/ha (mean 2.7 t/ha) and 2.4–3.9 t/ha (mean 2.9 t/ha), respectively, as against yield of 1.6–3.2 t/ha (mean 2.2 t/ha) with the farmers' practice (Fig. 4.1), with a yield advantage of 8–39% and 12–62%. In the 2007 WS, demonstration trials with unfertilized and fertilized (NPK + FYM/*Azolla* compost) seedlings were planted at 10 sites, but the crop was badly damaged at seven sites because of repeated prolonged submergence following unprecedented heavy rainfall and blockage of the river mouth due to sand deposits. At the remaining three sites, yields were relatively poor compared with those of 2006. Nevertheless, transplanting with fertilized seedlings produced 10–35% higher grain yield than with unfertilized seedlings.

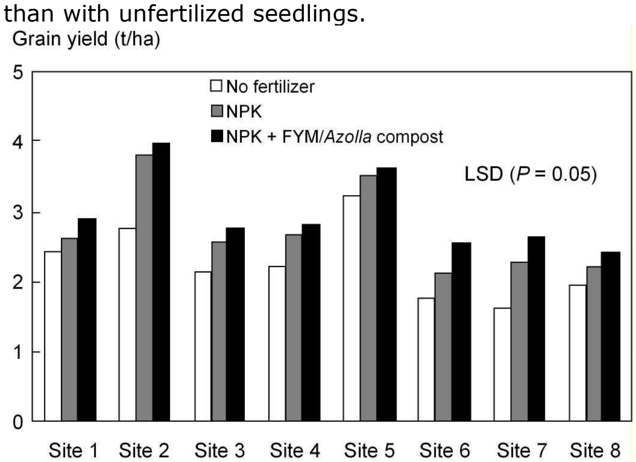


Fig. 4.1. Effect of nursery nutrient management (NPK and NPK + FYM/*Azolla* compost) on grain yield of rice (cv. SR26B) during 2006 wet season in India.

Improved methods of transplanting in saline soils. On-farm demonstration trials on an improved method of transplanting (50-d-old seedlings and line planting at a closer spacing of 15 × 10 cm) vis-à-vis the farmers' method (30–40-d-old seedlings and random planting at wider spacing) were conducted under an intermediate lowland situation (cv. SR26B) during the WS at 10 sites in different villages. However, all the trials in 2007 suffered heavy crop damage due to repeated prolonged submergence while in 2006 only one trial was damaged. In the 2006 trials, the improved method of transplanting had grain yields of 1.9–3.7 t/ha (mean 2.9 t/ha), against 1.7–3.0 t/ha (mean 2.1 t/ha) with the farmers' practice, giving a yield advantage of 13–69% (Fig. 4.2).
Early transplanting in the DS. Demonstration trials on early planting were conducted at eight sites during the 2007 dry season and at 10 sites during the 2008 dry season. Early planting (January, 1st wk) was compared with the farmers' practice of late planting (January, last wk). Average grain yield with early planting was 4.79 t/ha but only 3.5 t/ha in 2007, and 4.75 t/ha and 3.9 t/ha, respectively, in 2008, corresponding to a yield advantage due to early planting of up to 60% in 2007 and 29% in 2008. The yield increments in 2008 were relatively less than in 2007 because farmers planted earlier than in 2007 as they became aware of the advantage.

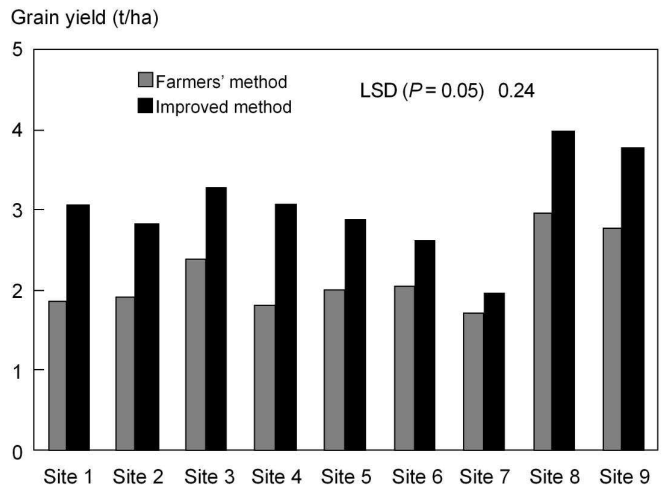


Fig. 4.2. Effect of improved method of transplanting (50-d-old seedlings and 15 × 10 cm spacing) vis-à-vis farmers' method (random planting at wider spacing) on grain yield of rice during the 2006 wet season.

Nutrient management. Demonstration trials on promising nutrient management practices for WS rice were conducted in 2006 and 2007 and for DS rice in 2007 and 2008. In shallow lowlands, grain yields (cv. Pankaj) with *Sesbania* green manure (GM) and *Sesbania* GM + *Azolla* were 2.7–3.3 (mean 2.89) and 2.93–3.70 (mean 3.32) in 2006, and 1.09–1.41 (mean 1.20) and 1.37–1.65 (mean 1.52) in 2007, as against 2.0–2.77 (mean 2.37) and 0.7–1.0 (mean 0.88) t/ha in the unfertilized control (farmers' practice), respectively. The two treatments gave a yield advantage of 12–40% and 19–77% in 2006 and 17–59% and 54–96% in 2007, respectively. In intermediate lowland trials during 2006, the grain yield of rice (cv. Lunishree) without and with *Sesbania* GM averaged 2.64 and 3.30 t/ha, respectively. The yield advantage due to *Sesbania* GM was 8–50%. The grain yield of rice (cv. Annapurna/Canning 7) in no-*Azolla* and *Azolla* treatments averaged 3.6 and 4.4 t/ha in 2007, and 3.9 and 5.1 t/ha in 2008, respectively. The yield advantage due to *Azolla* application was on average 24% and 31% in 2007 and 2008, respectively. *Sesbania* growth was poor in sandy loam soils with low fertility, whereas it grew well and produced more biomass in sandy clay loam soils with a better fertility and moisture status.
Best-bet management. The performance of improved rice varieties with improved management (IVIM) vis-à-vis farmers' varieties with farmers' management (FVFM) practices was evaluated during the 2006 and 2007 WS and 2007 and 2008 DS for technology demonstration and dissemination. In the 2006 and 2007 WS, the grain yield under farmers' varieties with farmers' management at different sites averaged 1.6 and 0.61 t/ha, respectively, but increased to 2.7 and 1.0 t/ha due to the combined use of improved varieties and improved management. In the 2007 and 2008 DS, average grain yield under IVIM was 4.4 and 5.0 t/ha, compared with 3.3 and 3.5 t/ha under FVFM, respectively. The yield advantage due to improved varieties with improved management was 36–47%, 12–90%, 10–70%, and 34–94% during the 2006 WS, 2007 WS, 2007 DS, and 2008 DS, respectively. Apparently, combining modern salt-tolerant varieties with best be management practices significantly improved productivity, an example is shown in Figure 4.3.

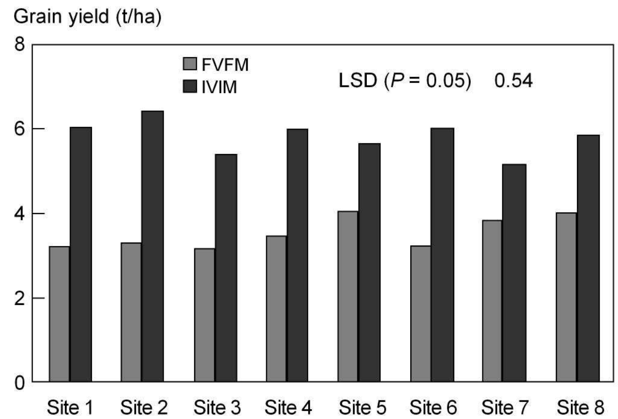


Fig. 4.3. Grain yield of rice under farmers' varieties with farmers' management (FVFM) and improved varieties with improved management (IVIM) during the dry season of 2008.

Nonrice crops. Encouraged by the crop performance and farmers' response, seeds of sunflower, watermelon, chilli, and okra were provided to nearly 170 and 230 farmers from 11 and 10 sites in the 2007 and 2008 DS, respectively. Sunflower and watermelon produced 1.2 and 15.6 t/ha in 2007 and 0.9 and 11.8 t/ha in 2008, respectively. Although chilli and okra were badly damaged by mid-season rainfall and waterlogging in 2007, they still produced 0.8 and 11.4 t/ha yield, respectively. Farmers' response to adoption of these nonrice crops is encouraging and seed demand is increasing rapidly in this area. This would strongly contribute to crop diversification as well as livelihood improvement of the poor farming communities. On-farm trials on liming for groundnut (cv. AK 12-24) and sunflower (cv. KBSH 1) were conducted at four sites during the 2007 DS and eight (groundnut)) and 12 (sunflower) sites during the 2008 dry season. Lime was applied at 0.5 t/ha in furrows before sowing. The seed yield of sunflower in no-liming and liming treatments was 1.20–2.06 and 1.57–2.23 t/ha in 2007 and 0.6–2.25 t/ha and 0.8–2.41 t/ha, while the pod yield of groundnut in the two treatments was 0.79–1.87 and 1.05–2.50 t/ha in 2007 and 0.48–1.56 and 0.64–1.68 t/ha in 2008, respectively. Liming increased the yield of sunflower in 2007 and 2008 by 7.8–30.8% and 5.1–36.4% and that of groundnut by 18.7–57.8% and 4.2–63.6%, respectively.

These demonstration trials were managed by farmers and there was considerable variability in the observed yields and yield advantages due to improved technologies depending on the amount of management and differences in soil texture, soil fertility and salinity status, depth of groundwater table, and hydrological situation (WS). Nevertheless, there was significant yield improvement in almost all the trials. The purpose of conducting demonstration trials on component technology is to provide different options to farmers, particularly for those who cannot afford the adoption of complete technology packages. Some of the improved technologies such as improved salt-tolerant rice varieties in both the wet and dry seasons, the use of older seedlings and closer planting of rice in the wet season, and early planting of rice, *Azolla*, and the cultivation of nonrice crops (sunflower, watermelon, chilli, and okra) in rice fallows during the DS are being widely adopted by farmers. Although *Sesbania* is also promising, farmers are somewhat skeptic about its use because of uncertain establishment of the green manure in the event of early drought. The adoption of salt-tolerant rice varieties with matching improved management practices as a complete package showed considerable potential for doubling yield in both the wet and dry seasons. Rainwater harvesting also proved to be effective in expanding dry-season crops, and 12 existing small ponds in six villages were renovated to increase their water holding for irrigating nonrice crops.

Farmers' training on rice seed health management and seed multiplication. The production of healthy seed and its proper storage are very important in coastal environments due to the prevalence of high temperature and humidity. A farmers' training on "Rice seed health management" was organized in 2005, in which 25 men and women farmers from different adopted villages participated. Hands-on training was given on the selection of healthy seeds from rice fields, cleaning and grading of harvested seeds, and seed processing and safe storage. Seeds of promising improved rice varieties in large quantities were produced by the trained farmers under the supervision of CRRI scientists and these seeds were bought back for distribution to other farmers. This has greatly helped in disseminating the improved varieties.

***Farmers' field days and field visits*.** Farmers' field days were organized every year to discuss the major constraints to agricultural productivity in the target areas and possible technology options for improving land and water productivity in salt-affected coastal soils. Men and women farmers from different villages participated in the meetings. Experiences and success stories of farmers about improved technologies were also discussed. In addition, field visits to the experimental sites were organized during both the wet and dry season to create awareness about improved technologies. This has greatly helped in disseminating the improved technologies.

***Extension bulletins and media*.** A bulletin on "Improving rice productivity in salt-affected coastal soils" was published in English and the local language (Oriya) and distributed to farmers and extension personnel at both project sites and in neighboring districts. Several short documentaries on problems of coastal

salinity and strategies for improving the land and water productivity of salt-affected soils were recorded and telecast through ETV during 2005-07. In addition, a special documentary on the prospects of using *Azolla* biofertilizer for improving rice productivity was telecast in 2006. The documentary in 2005 was mostly on the development of coastal saline areas and possible remedial measures through the deployment of salt-tolerant crops and varieties and soil, water, and nutrient management options. In subsequent years, discussion focused on promising technologies validated under this project. Also, proceedings of the farmers' field days were published in local newspapers to create greater awareness among the farming communities facing similar challenges.

Qualitative impact assessment. Farmers in this region used to experience about 4 to 5 months of food shortage annually. A qualitative impact assessment was conducted by an anthropologist from IRRI, Philippines, in November 2006 through four focus-group discussions (FGDs) involving 15–20 farmers in each group. Separate FGDs of men and women farmers were conducted in each village. The farmers acknowledged that the adoption of improved salt-tolerant rice varieties and management technologies increased their yields in the WS and allowed expansion of rice area in the DS, leading to surplus rice production, enhanced farmers' income, and better food security. There is farmer-to-farmer exchange of improved rice seeds. Validated management technologies such as improved method of transplanting in the WS, early planting in the DS, and integrated nutrient management practices in both the wet and dry seasons are being widely accepted. Farmers reported that they had observed good crop growth and yield by using inputs and improved transplanting methods. Sunflower is well accepted by farmers as an option for diversification. The demand for seeds of salt-tolerant rice varieties and nonrice crops has increased substantially.

Quantitative impact assessment. This was conducted in 2008 by interviews with 100 farmers from 11 villages using a structured questionnaire. Nearly half of them were also interviewed during the benchmark surveys conducted in 2004. The study showed a progressive increase in DS rice area from almost nil to 16.63, 34.82, and 48.20 ha in 2006, 2007, and 2008, respectively, out of a total landholding of 134.96 ha. The DS rice area of respondent farmers increased gradually in most villages, except in Kankan and Patna, where adequate irrigation water was not available, and area expansion was more extensive in villages having adequate irrigation water. The farmers now depend more on DS than WS rice for their food security. Encouraged by this spectacular outcome, an NGO (World Vision) has begun a project of making a network of irrigation channels for providing fresh river water to these areas. This would greatly help in further expanding dry-season rice. The area under nonrice crops after WS rice for the respondent farmers also increased from almost negligible in 2004 to 9.5% in 2007. However, the area declined slightly to 7.2% in 2008. The decline was noticed in four villages that have adequate fresh water for growing rice. In four villages with less fresh-water availability, the area under nonrice crops increased during 2008. On the other hand, information collected from the key informants for these villages indicated that total nonrice crop area had actually increased in 2008 (35 ha) compared with 2007 (30 ha). Among the CNRM technologies introduced through this project, early planting for dry-season rice has been most widely adopted by farmers, and area under early planting for interviewed farmers was 73.8%, 81.6%, and 89.7% during 2006, 2007, and 2008, respectively. This simple technology was readily accepted by the farmers in 2006 and its adoption has remarkably helped in improving the productivity of DS rice.

CSSRI, India

Adaptive trial for evaluating the production potential of salt-tolerant varieties of rice and wheat with a reduced dose of gypsum in salt-affected soils. To validate the low-cost technology for the reclamation of sodic soils developed at Lucknow by reducing the gypsum requirement from 50% to 25% with the introduction of sodicity-tolerant varieties, an adaptive trial was conducted in farmers' fields in Dhora and Mataria villages, Unnao District. The initial pH of the experimental soil (0–15 cm) at Dhora and Mataria was 10.6 and 10.3, and the Ec was 2.3 and 11.5 dS/m. The gypsum requirement (GR) of the respective sites was 16 and 15 Mg/ha. Two gypsum levels were used, 25% and 50% GR. One salt-tolerant variety of rice (CSR 13) and wheat (KRL 19) and intolerant varieties of rice (Pant 4) and wheat (PBW 343) were tested with four replications at Dhora. At Mataria, genotypes 2K219, 2K262, IRRI-2K8, CSR23, CSR30, CSR36, and CSR27 were compared in a split-plot design under two amounts of gypsum (25% and 50% GR) with three replications. A total of 24 farmers participated in ranking these varieties under field conditions at maturity at Mataria. Under 50% GR, 24% of the farmers preferred CSR30, whereas CSR27 and IRRI-2K8 scored 21% of the votes. Under 25% GR, 35% of the farmers preferred 2K219, whereas CSR30 and 2K262 scored 30% and 25% of the votes, respectively. A group of 19 rice farmers, including two women with sodic lands, participated in the varietal selection at Dhora. Based on the number of votes, 2K219 had the highest score, followed by CSR23 and IRRI-2K8.

Scaling up of salt-tolerant, high-yielding, and early-maturing rice genotypes. A PVS trial with 7 genotypes, 2K219, CSR-89-IR-8, IRRI-2K8, CSR23, CSR30, CSR36, and CSR27, was conducted in farmers' fields having pH 9.2 in Dhora Village, Unnao District, during kharif 2005-06. The trial was evaluated by 19 farmers at maturity and CSR-89-IR-8 was selected as the best for cultivation under alkali soil conditions. During 2006-07, the same genotype was scaled up on about 2.0 ha by the farmers. It also showed a yield advantage of 7.0% to 31% over local varieties Narendra 359 and Sona mansoori, respectively, and matured 14 and 21 days earlier than the respective varieties. With the introduction of this genotype, farmers can save one to two irrigations and prepare their fields in time for sowing wheat.

Dissemination of integrated nutrient management techniques in the rice-wheat cropping sequence on partially reclaimed sodic soil. Sodic soils are highly deficit in organic matter and crops invariably suffer nutritional disorders. Sulficated press mud improves organic matter and enhances the reclamation of sodic soils. Therefore, adoptive research began in 2005 to (i) compare new integrated nutrient management options with the farmers' practice and the recommended chemical fertilizer alone in the rice-wheat cropping system, and (ii) identity any constraints to the adoption of these technologies in farmers' fields.

Methodology. Field trials were conducted at three villages with initial soil pH2 of 9.0, 9.4, and 9.0 for Kashrawan, Hardoi, and Todarpur villages, respectively. The treatments included four nutrient management practices: T1 = farmers' practice (conventional rice-wheat system, rice seedling transplanting in puddled soil without basal NPK and Zn, and only nitrogen at 110 kg/ha was applied in three splits at 20-d intervals after transplanting. Irrigation was applied after 4 to 5 d after the disappearance of ponded water; T2 = 100% N and P (recommended) only; T3 = 50% of T2 + sulficated press mud at 10 Mg/ha; and T4 = T2 + sulficated press mud at 10 Mg/ha. Two rice genotypes were used: one was salt-tolerant and the other was high-yielding and intolerant. The experiment was continued in the rabi season using two wheat varieties.

Results. The application of 100% NP along with press mud increased yield by 40% and 84% for rice and wheat, respectively. The application of 50% NP together with press mud also significantly increased rice and wheat grain yields and saved 50% N. Yield of Narendra-359 (rice) and PBW 343 (wheat) was lower than that of salt-tolerant varieties CSR13 (rice) and KRL19 (wheat) at higher pH under conventional practices. The application of press mud improved the availability of micronutrient and hydraulic conductivity of surface soil.

Empowering tools, workshops, and technology demonstrations to facilitate farmers' adoption of new technologies. A "Kisan Gosthi" or farmers' fair was organized on 18 October 2005 at Mataria Village, Unnao District. Shri S.P. Dixit (IAS), special secretary (home), government of Uttar Pradesh, inaugurated this program. About 400 male and female farmers participated in this Gosthi and scientists of various institutes interacted with the farmers. Important national and international research projects on the management of salt-affected soils using participatory approaches were undertaken in this village. Special emphasis was given to different newly emerging techniques for the reclamation and management of sodic soils. The information on important salt-tolerant varieties released by CSSRI—CSR13, CSR23, CSR27, and CSR30 (basmati)—was made available. Field visits were conducted to show the performance of these varieties on highly sodic soils. In addition, several other technological aspects such as methods of application of amendments such as gypsum and pyrite were shared with farmers during field visits. In a structured question-answer session, various issues raised by farmers related to sodic land reclamation and management were addressed by specialists. Another farmers' fair was organized on 26 September 2006 at Krishi Vigyan Kendra Dhora Village, Unnao District, and about 120 male and female farmers participated.

A "farmers' meet" was organized on 27 April 2007 at Krishi Vigyan Kendra Dhora Village, Unnao. About 80 male and female farmers participated. Dr. A.K.Biswas, president, Third World Center for Water Management, Mexico; Dr. Jonathan Woolley, program coordinator, CPWF, IWMI; and Dr. A.K. Sikka, basin coordinator of IGB, were present. Scientists from various institutes interacted with the farmers of the region. Special emphasis was also given to newly emerging techniques for the reclamation and management of sodic soils.

Preparation of communication materials for use by extension agents for broader accessibility. Two bulletins, "Soil Sodicity Test: A Field Kit" in English and "Mirda Chhariayata: Janch kit" in Hindi, were published for use by extension personnel and farmers.

NDUAT, UP, India

Evaluation of promising salt-tolerant rice varieties in PVS trials with farmers. Seven promising varieties selected from previous mother trials were evaluated in baby trials by six farmers whose land had soil pH of 9.5 to 9.8. The following varieties showed considerable advantages over those being used by farmers: Sarjoo-52 (8–56%), CSR27 (40–49%), CSR30 (11–30%), NDRK-5089 (15–48%), CSR23 (21–43%), NDRK-5083 (54%), and NDRK-5050 (30%). In 2007, 11 genotypes were evaluated by 15 farmers on sodic soils (pH of 9.2–9.8). All varieties showed considerable advantages over the farmers' cultivars, but with considerable variation based on soil pH and farmers' management. NDRK-5083 was consistently ranked the best, with a yield advantage of 36–66% over the farmers' own varieties, followed by Sarjoo-52 (30–61%), Usar Dhan-3, IR67519-3R-994-2B-2-1, and NDRK-5089. In 2008, seven genotypes were evaluated by 20 farmers in two villages. Again, the new salt-tolerant varieties were considerably better than farmers' varieties in all trials, with a yield advantage of 20–75%. The best varieties were Usar Dhan-3, NDR-359, Sarjoo-52, NDRK-5083, NDRCP-8, CSR30, and CSR23. Across all trials, Usar Dhan-3 and NDR-359 ranked the highest among farmers. These trials demonstrated the advantages of replacing farmers' traditional varieties with these new salt-tolerant high-yielding varieties, which are also more responsive to inputs.

BRRI, Bangladesh

Evaluation of rice genotypes for brackish shrimp–rice system, WS, 2005-06. *T*wo PVS-T lines and two standard varieties were evaluated along with popular landraces in coastal areas after harvesting of shrimp in the T. aman season. Seedlings (35–40-d-old) were transplanted at 2–3 seedlings at 25 × 15-cm spacing in plots of 5 m × 10 m. The fertilizer dose was 80:60:40 kg NPK/ha. Gypsum and $ZnSO_4$ were applied at 100

and 10 kg/ha, respectively. N was applied in three splits. The total amount of P, K, gypsum, and $ZnSO_4$ was applied at final land preparation. Other cultural management practices were as farmers' practices. The field was washed at least twice with rain/high tide before transplanting. The trial was conducted in 8 professional brackish-water shrimp-culture fields. A farmer participatory approach was followed in collaboration with the NGO Sushilan. Two advanced lines, PVS-T2 and PVS-T5, were 1–3 wk earlier than the standard and local checks but with yield similar to that of the standard varieties. The earliness is important for preparation of the shrimp field. Therefore, farmers have chosen these lines for the rice-shrimp system.

DS, 2005-06. Three PVS-B lines and a standard check variety were grown in seven farmers' fields, including the BRRI farm at Satkhira. These materials were selected through PVS "mother and baby" trials. An RCB design with three replications was used, and 40–45-d-old seedlings were transplanted at 2–3 seedlings per hill spaced at 25 × 15 cm in plots with 5.1 × 8 rows with NPKSZn at 100:60:40:18:2 kg/ha. The trials were conducted in cooperation with the Department of Agricultural Extension (DAE) and two NGOs, Gurpukur and Shushilan, at Satkhira. A formal application was made to the National Seed Board (NSB) for conducting a field evaluation at heading and ripening stages for recommendations of varieties for release. NSB evaluated the trials at flowering stage at seven locations and showed satisfaction with the uniform heading of the proposed lines. The crop matured in late April 2006. The NSB team visited the fields again and the evaluation team cut the crop across the locations. Evaluating the distinctness, uniformity, and yield, the team recommended PVS-B3 (IR63307-4B-4-3) to the Technical Committee to consider releasing it as a commercial variety for salt-affected areas in the boro season (yield advantage of more than 1.5 t/ha over BRRI dhan28). The Seed Certification Agency (SCA) completed tests and BRRI is preparing details for submission to the Technical Committee.

Evaluation of rice genotypes in brackish-water shrimp fields during 2006-07. Two PVS-T lines were evaluated at 16 locations in fields where the previous crop was brackish shrimp. BR23 and BRRI dhan41 were used as standard checks. Also, a popular landrace was used as a check per site. Cultural practices were similar to the trials above. Among the 16 locations of the experimental plots, only four locations survived and the rest were damaged by high tidal inundation and waterlogging along with submergence for 10–15 days, a common risk in coastal areas. PVS-T2 and PVS-T5 lines were 10–15 days earlier and 10–15 cm shorter than the check varieties, making them tolerant of lodging. These advanced lines showed a 0.2–0.25 t/ha yield advantage over the local check. Water salinity ranged from 2.0 to 3.5 dS/m. PVS-T2 yielded higher than other varieties for all the locations except location 3, where PVS-T5 had a higher yield. Therefore, these two lines became more promising than others for the brackish shrimp–rice system.

Upscaling of BRRI Dhan47 in Satkhira region in 2006-07. BRRI dhan47, previously called PVS-B3, was released by the NSB in January 2007. We distributed 4 kg of its seeds to each of 60 farmers in November 2006. The farmers were from Satkhira Sdar, Tala, Ashashuni, Debhata, Kaliganj, and Shyamnagar upazillas of Satkhira District. They followed their own practices. At maturity, A. Ismail and M.A. Salam participated in farmers' field days and evaluation at some of the sites. Among the 60 farmers, yield varied from 4.2 to 7.5 t/ha and averaged 6.1 t/ha. Farmers who have higher salinity in their irrigation water showed the highest satisfaction with BRRI dhan47. The release and outscaling of this variety are a major milestone for this project, as this is the first salt-tolerant variety to be released for the DS in coastal Bangladesh. Farmers are continuously demonstrating satisfaction with its performance and demand for seeds is increasing every year. Farmers were able to grow rice in areas that have not been productive over several years in the past. Extension services such as DAE, NGOs, and private farms are currently involved in the rapid dissemination of the variety in subsequent seasons.

Evaluation of rice genotypes in brackish-water shrimp fields in 2007-08. Two PVS-T lines were evaluated at ten locations in fields where the previous crop was brackish shrimp. BR23 and BRRI dhan41 were used as standard checks and similar cultural practices were followed as in previous years. The crop condition was excellent at the beginning, but, because of cyclone Sidr, all the trials were damaged and no further data were collected. This is another case of vulnerability of this ecosystem to frequent natural disasters.

Participatory varietal selection, 2007-08. Both mother and baby trials were conducted during the DS. The mother trial used 13 genotypes, including three popular varieties (BRRI dhan28, BRRI dhan29, and BRRI dhan47), five advanced lines, and four lines from Vietnam. The experiment was conducted at five locations in the Satkhira region named Satkhira Sdar, Shyamnagar, Kaliganj, Ashashuni, and Tala, using similar practices as in previous years. Water and soil salinity was monitored weekly; at maturity, farmers were gathered to select their favored lines. Yield at the sites depends on the amount of salinity. A few lines were identified that were earlier than BRRI dhan28, the earliest variety in the region, and these were BR7084-3R-39 and OM 1490 (from Vietnam). Overall, BRRI dhan47 was the best, followed by BR7084-3R-39, OM 4498, and OM 2718. Most farmers voted for BRRI dhan47, followed by BR7084-3R-39 and BRRI dhan29-SC3-27. Selected genotypes will enter baby trials in subsequent years.

Further upscaling of BRRI Dhan47 at Satkhira in 2007-08**.** A package of 5 kg of seeds was distributed to more than 300 new farmers in early November 2007 at Satkhira Sdar, Tala, Ashashuni, Debhata, Kaliganj, and Shyamnagar upazillas of Satkhira District. In addition, seeds of BRRI dhan47 were distributed in three other locations in the Barisal region for demonstration. Trials were managed by farmers and monitored by the PN7 team to provide advice as needed. At crop maturity, the project team, led by M.A. Salam, visited several farmers' fields and conducted field days with farmers, scientists from BRRI and DAE, and NGO representatives.

CLRRI, Vietnam

Focus-group discussions and farmers' field visits were conducted to enhance farmers' knowledge and encourage their adoption of new technologies. In addition, field days were organized at Cau Ngang, Chau Thanh, and Cau Ke, Bac Lieu, to provide first-hand information to the farmers about technologies available for sodic soil. Scientists, local government personnel, and CLRRI were regularly contacted for further information about technology adoption by the farmers. Seed production and seed health management training were organized in two provinces in collaboration with CLRRI.

Training workshops and scientific research visits. A total of 21 classes, from 2 days to 5 days of training on the selection of salt-tolerant varieties and seed production and management of these varieties, were conducted during 2004, 2005, 2006, 2007, and 2008 in cooperation with the Rural Development Province (RDP) and center of extension in Tra Vinh Province. About 600 farmers attended the training and at least 2% were women. In a 7-day training at Bac Lieu, 60 farmers participated in 2007, wherein they learned about the details of a complete package of management techniques for brackish-shrimp farming and new salt-tolerant rice varieties for rice-shrimp systems. These training activities were mostly conducted by specialists from CLDRRI. At the Plant Breeding Division, Pham Thi Xim conducted MSc studies on the "Application of molecular markers in selection of salt-tolerant rice varieties through pollen tissue culture" under this project at Can Tho University. Three BSc students conducted their thesis research on salinity tolerance under this project also: Nguyen Hoang Minh, at Da Nang University, and two students from An Giang University. Scientists from IRRI (Ismail, Singh, and Paris) participated in a training course on the "Application of participatory approaches to agricultural research and extension and a participatory approach to PSV," conducted at Tra Vinh during 2006 and 2007.

Training of farmers and local government agents. Field days were organized twice a year at least at two sites each year throughout the project duration. About 100 to 1,200 farmers, including men and women, participated in these workshops and they evaluated the new varieties at each site. Farmers were involved in ranking varieties from researcher-managed (mother) trials as well as in evaluating PVS entries during field days. They were also trained in seed cleaning, roguing, and selecting healthy panicles for pure healthy seeds. CLRRI shared its technical expertise, including seed production and handling of the new salt-tolerant varieties with partner institutions. A series of training activities on seed health and management was completed involving farmers and researchers in a few villages every year. In addition, CLRRI also shared seeds of its newly developed salt-tolerant short-maturity varieties with other partners, and some of them are expected to be released as commercial varieties as in Bangladesh and Indonesia. CLRRI also organized regular meetings with provincial staff at project sites to discuss issues relevant to rice-based system productivity and challenges.

RRTC, Egypt

Based on the previous survey for target salt-affected areas in the Nile basin at the commencement of the project and previously identified challenges in these areas, plans were prepared for tackling such problems and to further develop these areas under this project. These plans focused on disseminating best-bet technologies for rice cultivation in salt-affected areas, as rice is the main crop representing around 75–80% of these areas. Several strategies were followed throughout the project duration to ensure effective technology transfer:

- Extension lectures for women and men farmers in their own villages and towns: In three successive years, 102 lectures about the best-bet rice cultivation technologies for salt-affected soils were delivered to farmers. A total of 1,020 men and women farmers benefited from these lectures, representing the villages located in the target areas. In addition, extension workers in these areas were also involved to ensure further outscaling.
- Two training courses were also conducted to increase the awareness of farmers and extension personnel on the challenges of salt-affected soils and their proper management and use for agricultural production. This also included proper technology for mitigation and reclamation and proper cultural practices and crop husbandry and protection for effective rice-based systems. Some 32 extension workers and field technicians were also trained through these workshops.
- Booklets with packages of recommendations for proper rice cultivation in saline soil were also published in the local language and distributed to extension workers and farmers, including women and men.
- Demonstration fields: About 25–30 extension fields were developed in saline areas and farmers were regularly invited to observe modern technologies demonstrated through these farms. Field days were also organized at harvest and various stakeholders, including policymakers, local government officials, and farmers, participated. In these extension fields, new varieties and management practices were demonstrated against farmers' practices. Rice grain yield in these extension fields exceeded that of the adjacent field by around 1.0 t/ha, suggesting that these new technologies will significantly contribute to national productivity. The large gap between these fields and farmers' fields suggested that more work is needed to bridge this gap. This is particularly important for Egypt, with limited land and water resources and the dire need to increase productivity from existing marginal resources, as yield from favorable areas already reached its plateau.

***Objective 5.* Enhance the capacity of NARES partners in innovative research and dissemination strategies**

Numerous capacity-strengthening activities were undertaken under this project involving degree and nondegree training as well as workshops on specific topics. These activities were also summarized in the capacity-building section of the final report document submitted with this report. A total of seven MSc students (one at CLRRI, two each at CRRI, ICRISAT, and IRRI) and five PhD students (one at RRTC and two each at CLRRI and NDUAT) received support during their degree training through this project. One postdoc was also involved at IRRI. Several additional training activities were presented below.

CRRI, India. Two scientists from CRRI, Cuttack, participated in two training workshops on "Advances in marker-assisted breeding" and "Application of participatory approaches to agricultural research and extension" held at IRRI, Philippines, during 21-28 February and 21 November-2 December 2005, respectively. One scientist attended training on "Rice seed health management" organized by IRRI and held at NDUAT in 2006.

CSSRI, India. Dr. Gurbachan Singh, director of CSSRI, visited IRRI, Philippines, for discussion on IRRI-CSSRI research programs. Dr. D.K. Sharma also visited IRRI for training on the application of the ORYZA2000 model, Dr. R.K. Gautam for training on marker-assisted selection in rice, and Dr. Y.P. Singh also attended hands-on training in data entry and analysis. IRRI resource persons (Drs. Ismail, Mackill, Wissuwa, R.K. Singh) and CPWF Theme 1 leader and IGB coordinator visited the project activities and shared experiences and views with CSSRI scientists. CSSRI also shared its technology expertise, including seed of salt-tolerant varieties, with partner institutions, for example, NDUAT, Faizabad, and CRRI, Cuttack, as well as others through INGER. A series of training activities on seed health and management was completed in UP involving farmers, scientists, and extension personnel.

***BRRI, Bangladesh.* rice seed health improvement training.** The use of good-quality seed can increase grain yield by more than 10%. A 4-d training was conducted in cooperation with the Rural Development Academy (RDA) at Bogra from 11 to 14 May 2005. A total of 30 participants, including farmers, field staff, NGOs, and DAE representatives, attended. Participants were able to have hands-on experience with best practices for better seed production, preservation, and health management.

Training on brackish-shrimp farming. This project attempted to introduce a rice crop in brackish-shrimp fields to maximize the use of land and water during the WS and reduce pollution and diseases caused by shrimp culture. Numerous trials were conducted during the WS involving salt-tolerant varieties grown in shrimp fields, which encouraged farmers to adapt rice production in the T. aman season in these fields after harvesting brackish shrimp. Eighteen farmers interested in growing rice after the harvesting of shrimp were trained in proper practices for brackish-water shrimp farming in collaboration with the Bangladesh Fisheries Research Institute (BFRI). The training was held in December 2005 at the premises of the NGO Shushilan, Kaliganj. The IRRI project leader (A. Ismail) and coordinator (M.A. Salam) also participated. During the meeting, farmers requested full-course training at BFRI, Paikgachha. Subsequently, a 3-d training course was conducted at BFRI, Khulna, for the same farmers during December 2005, at which farmers received a complete package of management for brackish-shrimp farming and learned how to maintain a healthy system for both rice and shrimp.

Capacity strengthening of BRRI. Two BRRI students were able to pursue their degree training at IRRI under this project: Dr. Md. Rafiqul Islam, senior scientific officer, Plant Breeding Division, completed his PhD, while Mr. Akhlasur Rahman, senior scientific officer, Plant Breeding Division, is still pursuing his PhD, anticipating completion within one year.

CLRRI, Vietnam. CLRRI conducted numerous in-country training workshops for farmers and other stakeholders (e.g., seed production, seeding rate, nutrient management, seedling handling and multiplication, integrated pest management) as summarized under activity 4. Numerous scientists also participated in short-term on-the-job training as well as workshops held at IRRI, on various techniques of phenotyping (seedling and reproductive stages) and the use of SSR markers, mapping, and marker-assisted selection. Varieties developed in Vietnam were also shared with other countries, including Cambodia (20 rice, 5 soybean, 5 peanut, and 5 mungbean varieties); Indonesia (10 new varieties); IRRI (33 new varieties); Bangladesh (7 varieties); and Myanmar (8 new varieties). Linkages were also strengthened with IRRI and other countries.

RRTC, Egypt. Two training courses were conducted to enhance the capacity of extension workers in knowledge of managing saline soil. Sixty field extension trials were conducted during 2007-08. In addition, recommendation packages on integrated crop and nutrient management for saline soils were developed.

IRRI. At IRRI, 29 staff from NARES institutions involved in the project participated in training workshops: (1) Marker-Assisted Selection Workshop, 21-24 February 2005; and (2) Workshop on Project Management Tools, 28 February 2005. Representatives of participating centers also participated in the rice breeding course held annually at IRRI.

OUTCOMES AND IMPACTS

This portion of the study focuses on the outcomes and impact of the CPWF PN#7 on Development of Technologies to Harness the Productivity Potential of Salt-Affected Areas of the Indo-Gangetic Plains, Mekong Delta, and eastern India.

2 Pro forma

Summary Description of the Project's Main Impact Pathways

Actor or actors who have changed at least partly due to project activities	What is their change in practice?, i.e., what are they now doing differently?	What are the changes in knowledge, attitude, and skills that helped bring this change about?	What were the project strategies that contributed to the change? What research outputs were involved (if any)?	Please quantify the change(s) as far as possible
IRRI-CPWF, NARES partners - plant breeders, crop physiologists, agronomists – men and women farmers at salt-affected research sites in eastern India	*Before*, plant breeders conducted their varietal trials on-station without farmer participation. *Now*, plant breeders conduct their trials on-station and in farmers' fields that represent salt-affected areas. *Before*, plant breeders followed the conventional "top-down" approach in plant breeding. *Now*, plant breeders together with crop physiologists, agronomists, and social scientists use the protocol of participatory varietal selection (researcher-managed and farmer-managed trials). *Before,* farmers were not involved in the early evaluation of new rice lines (unreleased); thus, farmers' opinions did not matter. *Now*, farmers are asked to select which rice lines they like and dislike and their opinions are considered in plant breeding objectives. *Before*, scientists talked to men only; *now*, scientists also ask the opinions of women who are actively engaged in farming, particularly	- Greater understanding of farmers' circumstances, coping mechanisms, farming practices, and criteria for varietal selection. - Knowledge that crop performance depends on both a suitable variety and best crop and natural resource management practices. -Knowledge that men and women have distinct roles and responsibilities in farming, which also influence their criteria for varietal selection and technology adoption. - Change in attitudes among scientists that they know best, to farmers know their needs, environments, and constraints to increasing rice yields. - Change in attitude among scientists that they need to spend more time in the field and interact with farmers. - Improved skills in interacting with	- Participation of scientists in IRRI-sponsored training courses on the Impact of Plant Breeding and Participatory Approaches in Research and Extension. - Involving all stakeholders/ partners in almost all meetings - Formation of a multidisciplinary team at each site. - Development of standard methods of data collection and analysis. - Following the established protocol for a participatory approach, that is, PVS at all sites. - Most of the experiments were done in farmers' fields with farmer participation. - Strong partnership with extension agents, GOs, NGOs, and farmer-to-farmer dissemination. - Organized farmers' days every year. -Farmer field visits in both the wet and dry season. RESEARCH OUTPUT: High-yielding	* Increased rice yields: Orissa: from 1.75 to 2.49 t/ha on average. Faizabad: from 2.6 to >3 t/ha. Lucknow: from 1.64 to 2.74 t/ha. * Increased income - farmers sell rice surplus and cash crops in local markets. - farmers are able to grow more rabi crops and sell some of them. - farmers in Orissa were able to grow rice during the DS and sell some of the produce. * Increased livelihood opportunities * Orissa: increased food security (95%), improved financial status/financial condition (56%), able to send children to school (44%), and increased purchasing power (31%), among others. * Faizabad: increased confidence among family members

	on postharvest, and eating and cooking quality of rice and nonrice varieties. *Before*, plant breeders were the main actors in rice varietal improvement. *Now*, plant breeders, crop physiologists, agronomists, and social scientists (including sociologists, anthropologists, and gender specialists) work as a team and have a strong interaction with farmers. *Before*, women farmers were reluctant to interact with scientists due to lack of confidence. *Now*, after giving them access to seeds and information and as partners in farmer-managed trials, they are more confident in expressing what they want in terms of varietal traits. *Before,* Scientists perceived women's roles as housewives who do not know anything about rice farming. *Now*, scientists consider women farmers as decision-makers whose opinions matter. *Before*, hungry months were common, as in coastal Orissa; *now*, farmers involved said they no longer warry about food and looking into other opportunities. *Before*, large areas were not being used for faming, especially in the DS; *now*, some of these areas are being/could be exploited as in Orissa and UP, India, and southern Bangladesh.	farmers. - Change in scientists', managers', and farmers' perception on the potential capacities of women to be agents of change, and they are also farmers. - Change among scientists' mode of working—from a single discipline to multidisciplinary approach and as a team, which fosters teamwork. - Changes in perception of managers and policymakers for the potential of salt-affected marginal areas and their possible role in food security.	varieties with reasonable salt tolerance and quality and techniques to improve crop-water-nutrient management (promising nursery establishment and crop and nutrient management packages for new salt-tolerant varieties) remain the main thrusts of the project.	(70%), more pro-active (52%), improved social status and well-being (50%), and increased women's participation (54%), among others.

Of the changes listed above, which have the greatest potential to be adopted and have impact? What might the potential be for the ultimate beneficiaries?
The *products* that have the greatest impact to be adopted are early planting for dry-season rice, early-maturing and high-yielding salt-tolerant rice and nonrice varieties, salt-tolerant varieties and associated nutrient management techniques, cheap soil amendments, and the use of salt-tolerant varieties for early rice planting to enable farmers to grow another rice crop. New cropping systems such as rice-sunflower have a high potential for adoption. New breeding tools and optimized phenotyping protocols could speed the varietal development process.
New practice and knowledge: Participatory varietal selection (PVS) for rice varietal improvement and participatory experiments on new farming practices, especially water management and nutrient management. These will all have a positive impact on the lives of the poor living in salt-affected areas. Lands that were barren/fallow before are now grown with rice and other crops, thus increasing crop productivity and cropping intensity, ensuring household food (rice) security, enabling farmers to have a marketable surplus, and providing additional income. Moreover, farmers were taught how to produce their own seeds while maintaining quality. The ultimate beneficiaries are men and women from poor farming households who grow rice and other crops in salt-affected areas.

What still needs to be done to achieve this potential? Are measures in place (e.g., a new project, ongoing commitments) to achieve this potential? Please describe what will happen when the project ends.
This project has been very successful in developing and validating effective interventions; however, these technologies were demonstrated in limited areas, and some will need further validation with farmers, such as new breeding lines. Much more needs to be done in scaling out and scaling up, particularly in the dissemination of new rice varieties and management packages. Although there is increased demand for salt-tolerant seeds, supply is short. Thus, more efforts are needed to strengthen seed systems to give farmers better access to these seeds. However, seed distribution is not enough. New information with regard to the crop management techniques associated with the seeds should be provided to farmers. Innovative strategies are needed to give farmers access to affordable inputs to improve the nutrient requirements of the crops. Need-based training for researchers and farmers in all aspects of the project still need to cover target sites and strengthen the outscaling process.
After the project ends: The project will benefit from a second phase to be supported by the CPWF, but with emphasis on validation and outscaling of technologies developed through the first phase, and further quantification of impacts. A lot needs to be done in a second phase to organize policy dialogues to bring these developments to the attention of governments and policymakers to solicit further support and make greater impact. More pilot demonstrations need to be made at additional sites within the project areas, for example, the IGB, for greater impact.

Each row of the table above is an impact pathway describing how the project contributed to outcomes in a particular actor or actors. Which of these impact pathways were unexpected (compared to expectations at the beginning of the project?)

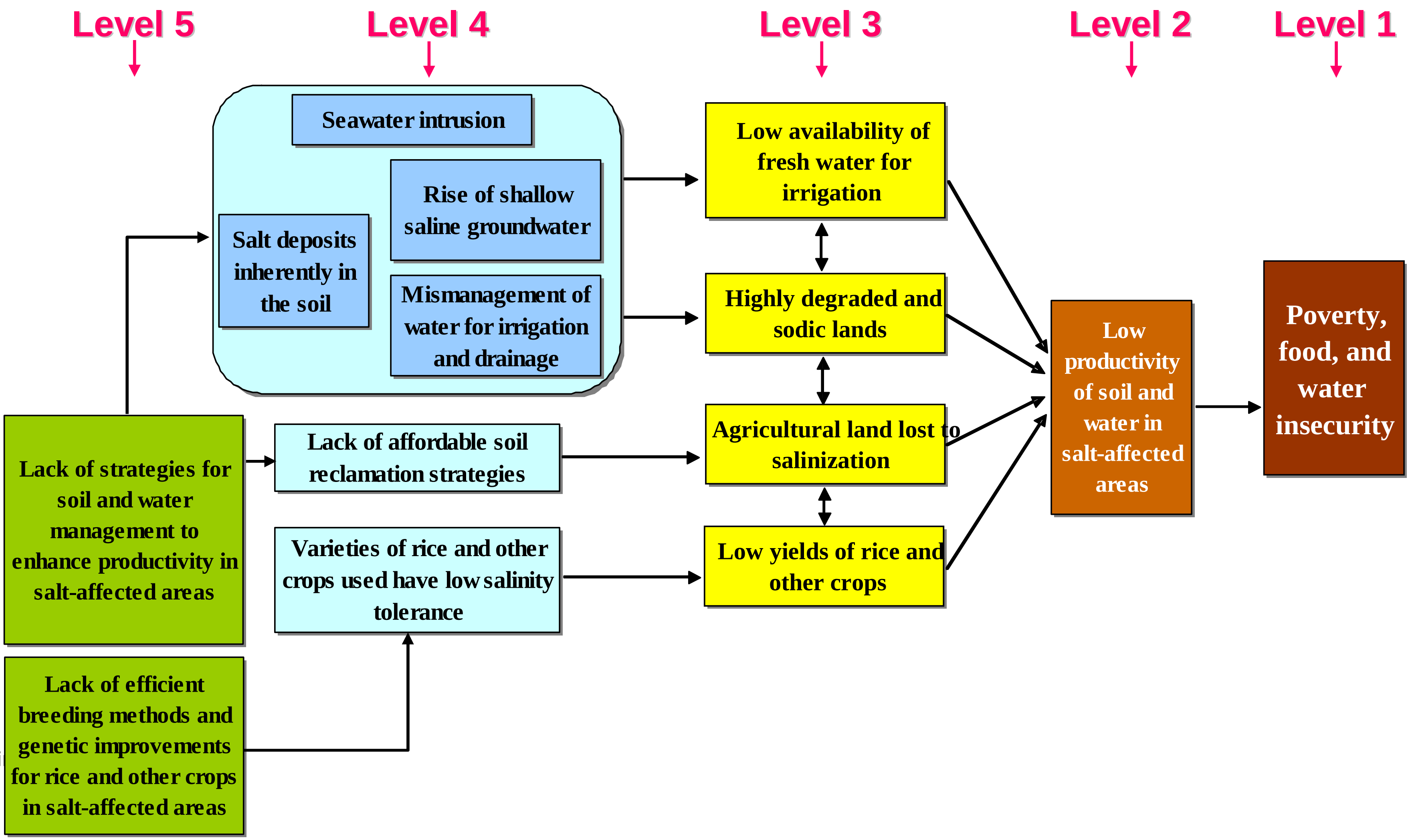
- The proportion of dry-season rice area increased remarkably during the project period in Orissa and southern Bangladesh; in addition, farmers started leasing new lands when they discovered the benefits.
- The area under noncrops increased from almost negligible in 2004 to 10% in 2007; in villages with less fresh water, the area under nonrice crops increased during 2008.
- Considerable benefits from inputs once salt-tolerant varieties became available, and resilience of the farmers to adopt new changes.
- Change of attitudes at the policy level toward the value of these marginal resources that were seemingly neglected in the past.

Why were they unexpected? *How was the project able to take advantage of them*?
Unexpected because some of them involved dramatic changes in farmers' practices, and that seems to start relatively fast, as adoption normally takes a long time to occur in farmers' fields. Also encouraged by the spectacular changes, local governments, for example, in Tra Vinh, and other organizations, for example, World Vision (an international NGO), tapped in with additional resources to implement and facilitate these changes. World Vision is developing an irrigation system to provide fresh water for DS crops in coastal Orissa after it witnessed the impacts on the few farmers involved in the project. The project facilitated this involvement, but more resources are needed to bring further attention and support to these interventions.

What would you do differently next time to better achieve outcomes (i.e., changes in stakeholder knowledge, attitudes, skills, and practice)?
- Focus on additional areas but with more resources to have quicker impact
- Include more social scientists, and women, especially on the research team and in the outscaling process
- More resources and trained people to increase farmer/community participation

- Provide new seeds to involve more farmers in farmer-managed trials
- Sensitize senior staff and NARES research managers on the importance of participatory approaches and encourage younger research staff to participate in project activities
- Involve more women farmers in project activities and strengthen seed systems
- More degree training to fill in gaps on research teams at NARES

Problem Tree



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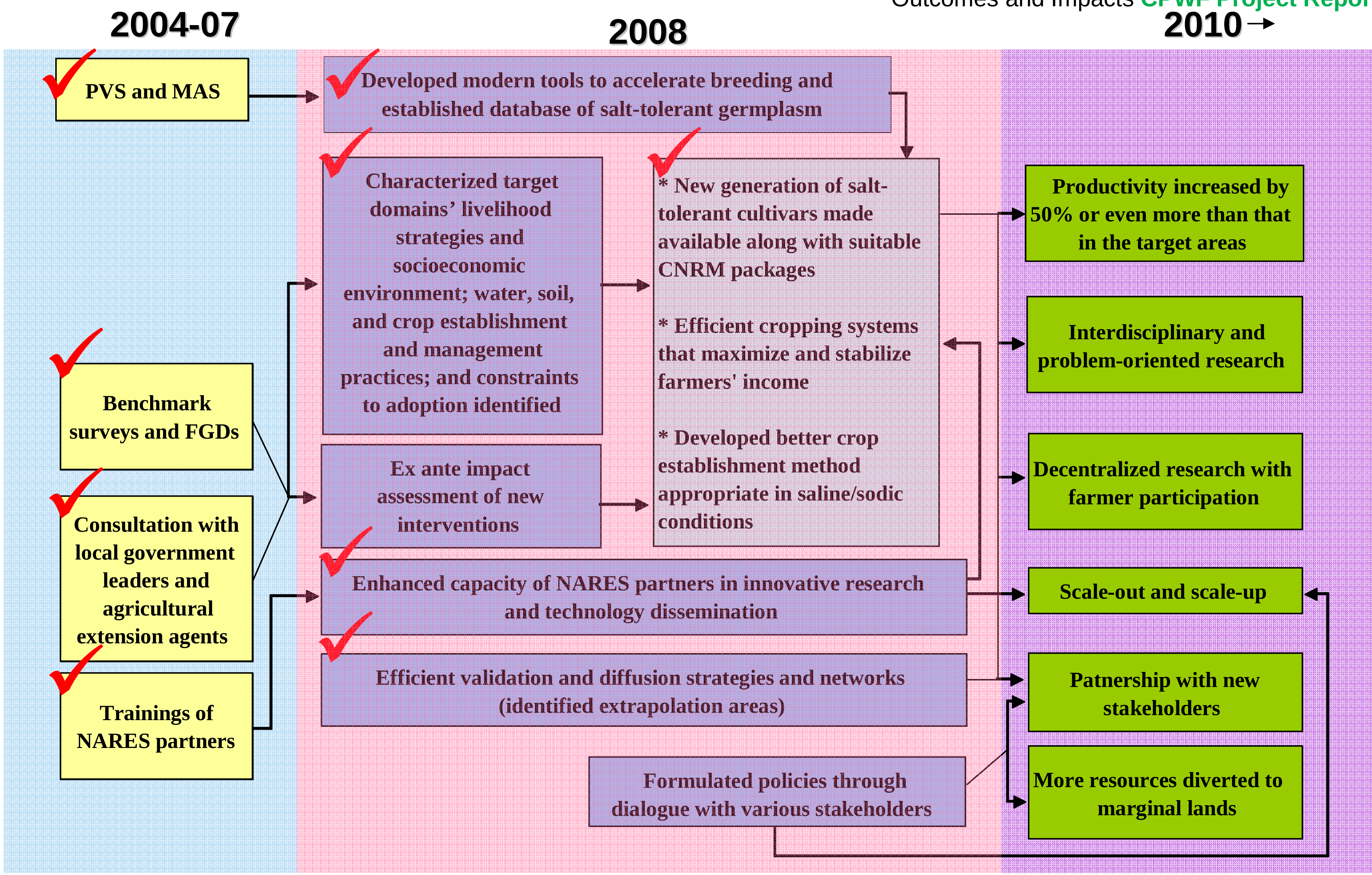
2004-07
2008
2010
PVS and MAS
Developed modern tools to accelerate breeding and established database of salt-tolerant germplasm
Characterized target domains' livelihood strategies and socioeconomic environment; water, soil, and crop establishment and management practices; and constraints to adoption identified
* New generation of salt-tolerant cultivars made available along with suitable CNRM packages
* Efficient cropping systems that maximize and stabilize farmers' income
* Developed better crop establishment method appropriate in saline/sodic conditions
Productivity increased by 50% or even more than that in the target areas
Interdisciplinary and problem-oriented research
Benchmark surveys and FGDs
Ex ante impact assessment of new interventions
Decentralized research with farmer participation
Consultation with local government leaders and agricultural extension agents
Enhanced capacity of NARES partners in innovative research and technology dissemination
Scale-out and scale-up
Efficient validation and diffusion strategies and networks (identified extrapolation areas)
Patnership with new stakeholders
Trainings of NARES partners
Formulated policies through dialogue with various stakeholders
More resources diverted to marginal lands

3 International Public Goods

The project produced a number of IPG that will have impact beyond the project target sites. These include tools and structured formats developed and used in the collection of data from socioeconomic surveys and feedback from different stakeholders, varieties released or in the pipeline of both rice and nonrice crops that are salt-tolerant, knowledge on best management practices, affordable mitigation and reclamation options for sodic/alkaline soils, and water harvesting. All these options will be useful in areas facing similar challenges worldwide. Landraces collected and evaluated are important for future studies and for preservation; those landraces identified with high tolerance could be used in breeding elsewhere.

3.1 Tools and methodology

A number of tools were developed that will be extremely valuable for users beyond this project, including structured questionnaires and pro forma for surveys and feedback, advanced tools for accelerated breeding, large sets of DNA markers and protocols for MABC, efficient screening protocols for rice (IRRI) and nonrice crops (ICBA and ICRISAT), and established protocols for participatory evaluation of breeding material involving all stakeholders (researcher- and farmer-managed trial networks). Some kits were developed (CSSRI) that can help monitor soil alkalinity in the field. Extension material in local languages was also prepared and this will be available for large-scale distribution in similar areas.

3.2 Project insights

Many of the project outputs will show greater impact after large-scale dissemination if sufficient resources are made available. Many breeding lines were developed and are at different stages of testing. Some of these will be future varieties in some countries. Management strategies, including water harvesting, affordable reclamation and mitigation strategies, coupled with profitable cropping sequences, will help transform the life of farmers in many salt-affected areas. Some of these changes are already being seen at some of the project sites but will need to be outscaled to reach the vast majority of farmers who need them most.

4 Partnership Achievements

A unique feature of this project is the strong sense of ownership and partnership that developed among participants. Eleven institutions are involved, including seven NARES institutes in five countries, two CG centers, and two advanced research institutes. This allowed the development of a strong network of interdisciplinary teams with expertise across different ecosystems. Some of these institutions entered into partnership with IRRI for the first time. The project also facilitated stronger linkages between institutes even within each country as in the case of India and Bangladesh. The considerable diversity in expertise among partners allowed a holistic systems approach to be employed to provide sound solutions to the common problem of salt stress. Expertise included social scientists, economists, gender specialists, agronomists, soil scientists, water engineers, fisheries specialists, physiologists, breeders, molecular geneticists, and molecular biologists working together, and this provided unprecedented intellectual strength and diversity to the project. Building such a strong network also provided a lasting foundation for future collaboration and joint activities. These kinds of linkages were not possible in the past.

5. Recommendations

Through the different activities and outputs of the project, several technologies were developed and validated, and a considerable amount of scientific knowledge was accumulated. However, more efforts are needed for up- and outscaling to reach the ultimate beneficiaries; some of these are summarized below:

On research:

- Increase investments in research on salt-affected areas, at both the national and international level, as these areas are currently extremely underused but hold great potential for contributing to food security. These areas have been largely neglected in the past, with the notion that little could be achieved.
- Make greater efforts to establish accurate databases on the extent and severity of salt-affected lands, crop losses, and coping mechanisms. This information is needed in defining recommendation domains for technology targeting.
- Build on indigenous knowledge in traditionally salt-affected areas and understand the interface between the biophysical and socioeconomic circumstances of targeted communities for effective development and dissemination of technology options and policy formation.
- Increase efforts for the collection, evaluation, and preservation of native germplasm from habitually salt-affected areas, as this material constitutes precious sources of diversity and adaptation, and is useful for current and future breeding programs.
- Understanding that high-yielding salt-tolerant varieties of rice and upland crops constitute an entry point for progress in these areas, but with considerable synergy when combined with best management practices. Farmers also showed the will to invest more in inputs for the new varieties. Greater efforts are needed to develop varieties with higher tolerance and proper management packages adjusted for these varieties.
- Give special emphasis to crop establishment as most crops are more sensitive during this stage. Increasing seedling-stage tolerance, together with best management practices, is particularly important. Proper nursery management is needed for transplanted crops as rice is important and less costly.
- Use a systems approach in addressing the needs and constraints of poor farming families who spread risks by resorting to various livelihood strategies. This will require a dedicated multidisciplinary team to

develop/identify appropriate crops and varieties as well as best practices for their management. However, transformation of farmers' livelihood is foreseeable.

On extension:

- Involve farmers in each step of the adaptive research process from needs and opportunities assessment, and on-farm testing and validation, to evaluation and dissemination. Both men and women actively engaged in rice farming should be involved in testing new varieties as well as management options in their own fields using their own skills. This gives the farmers a sense of ownership and confidence and speeds the adoption process.
- Ensure that men and women have access to new seeds as well as knowledge on crop management requirements specific for these unfavorable areas. Management is mostly as important as genetic tolerance, and neither of them could be effective on its own.
- Consider farmers' available resources and capacities to absorb new knowledge (proper timing, rates of input use, etc.) when recommending alternative options over their traditional practices.
- Increase the number of women extension workers who can work with women farmers.
- Use diverse extension and communication strategies to accelerate dissemination and outscaling.
- Tap entrepreneurs and service providers to enable farmers to have easy access to inputs and engage in agri-business ventures, for example, the use of stress-tolerant nonrice crops that are more profitable when fresh water is scarce, the use of alternative organic fertilizers when available, etc.

On policy:

- Develop infrastructure and marketing opportunities that can provide incentives to farmers to intensify and diversify their cropping systems.
- Relax the varietal release regulations, for example, by considering the data obtained through PVS trials in farmers' fields as part of the varietal release process. This will speed the commercialization of new varieties to help reach their target beneficiaries. In many countries, subsidies could be provided to farmers only on seeds of released varieties.
- Provide credit at low interest to farmers who want to invest in seeds and other inputs such as machinery and irrigation facilities, and to enable farmers to apply inputs as recommended.
- Provide farmers access to high-quality seeds of stress-tolerant varieties at lower cost.
- Researchers at NARES should be encouraged and supported to write proposals to their national programs to strengthen their local research output. For example, use of molecular breeding technologies will require a steady source of funding for these activities.

On institutions:

- Given the extreme diversity, severity, and complexity of abiotic stresses encountered in salt-affected areas, extensive site-specific evaluation is inevitable. The PVS system developed through this project needs to be institutionalized and sustained, and information and feedback gathered from farmers, both men and women, during evaluation should be carefully considered during the process of commercial release of new varieties.
- NARES laboratories need to be equipped to incorporate modern breeding tools in their conventional breeding to streamline germplasm development. After the molecular laboratories are established, additional technical backstopping is initially required to ensure that the labs are running effectively. Ultimately, these labs should become self-sustainable and independent through NARES support.
- NARES should encourage interdisciplinary research, with teams representing different disciplines but addressing a common problem. There is also a dire need for interinstitutional linkages within NARES.
- National programs still lack the critical mass to undertake serious research and development activities targeting unfavorable areas in general and problem soils in particular. Investment is needed to strengthen human capacity in research and delivery, including degree training, building of proper screening facilities, and capacity for on-farm participatory evaluation and adaptive research.
- Need for trained social scientists, particularly women, who can work with biophysical scientists in the development and dissemination of technologies and for incorporating farmers' perceptions and feedback.

6. Publications

A summary of project publications was provided in the Excel spreadsheet of the project report (CP7 Publications updated 20 May 2009.xls).

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8. PROJECT PARTICIPANTS

International Rice Research Institute (IRRI), Philippines
Abdelbagi M. Ismail, Thelma B. Paris, Glenn B. Gregorio, Michael J. Thomson, R.K. Singh, Stephan M. Haefele, Edilberto Redoña

Central Rice Research Institute (CRRI), Cuttack, India
Devendra Pratap Singh, A.K. Nayak, Kantiranjan Mahata, Purushottam Sen, Sanjoy Saha, J.N. Reddy, Rajshree Biswal

Central Soil Salinity Research Institute (CSSRI), Karnal, India
Gurbachan Singh, R.K. Gautam, D.K. Sharma, S.K. Sharma, P.C. Sharma, Neeraj Kulshrestha, Y.P. Singh, B.K. Bandopadhyay (CSSRI West Bengal), Ranbir Singh

Cuu Long Delta Rice Research Institute (CLRRI), Vietnam
N.T. Lang, Bui Chi Buu

Narendra Dev University of Agriculture and Technology (NDUAT), India
P.C. Ram, Abha Singh, P.N. Singh, Om Prakash Verma, Ram Pratap Singh, Uma Singh, Vijai Narain Singh, Jagdish Singh

Bangladesh Rice Research Institute (BRRI), Bangladesh
M.A. Salam, Rumen Yasmeen, Md. Atiqur Rahman Bhuiyan, M. Shahe Alam, Md. Rafiqul Islam, Mohammad A. Saleque, K.M. Iftekharuddaula

Rice Research and Training Center (RRTC), Egypt
Abdel Salam E. Draz, Bassuni A. Zayed

Rice Research Institute of Iran (RRI), Iran
Faramarz Alinia, Ali Moumeni

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India
Vincent Vadez

University of California, Davis, USA
Eduardo Blumwald, Ellen Tumimbang

International Center for Biosaline Agriculture (ICBA), Dubai, UAE
John Stenhouse, Abdullah Dakheel

9. APPENDICES

Appendix A. List of publications under the project

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
PAPERS									
Papers - National seminar/ conference/ workshop									
	Paper - International seminar/ conference/ workshop	A "SNAP" technique in screening rice for salinity tolerance at seedling stage (Annex 7)	The Philippine J. Crop Sci. 30:54 Abstracts, 18th Conference of the Federation of Crop Science Society of the Philippines	2-6 May 2005	DL Adorada, G Gregorio, P Jose, A Santos, RD Mendoza	2,3	IRRI	1	
	Paper - National seminar/ conference/ workshop		CSSP Conference, 8-12 May 2006	May 2006	Rafiqul Islam et al	2	IRRI	2	
	Paper - National seminar/ conference/ workshop	Application to Rice breeding Populations and Haplotype Diversity of Molecular markers for Salinity tolerance in Chromosome 1	CSSP Conference, 8-12 May 2006	May 2006	M.R. Islam, G.B. Gregorio, B.C.Y. Collard, E. Tumimbang-Raiz, D.L. Adorada, R.D. Mendoza, M.A. Salam, and L. Hassan	2	IRRI	2	
	Paper - National seminar/ conference/ workshop	Molecular mapping and Marker-assisted selection for salt tolerance in rice	Omon rice		Nguyen Thi Lang, B.C. Buu, A. Ismail	2	CLRRI	4	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
Papers - International seminar/ conference/ workshop									
	Paper - International seminar/ conference/ workshop	Getting closer to the salt tolerance gene	Plant & Animal Genomes XIII Conference, San Diego, California, USA, page 288.	15-19 January 2005	EB. Tumimbang, DL Adorada, J Niones, F Elahi, Z Seraj, J Dvorjak, GB. Gregorio	2	IRRI	1	
	Paper - International seminar/ conference/ workshop	Enhancing and stabilizing productivity of rice based cropping system in salt-affected areas of Indo-Gangetic region through improved germplasm and management strategies	World Rice Research Conference "Rice is Life" Tokyo and Tsukuba, Japan. Abstract # 753, Page 323.	4-7 November 2004	RK Singh, AM Ismail, G Gregorio, DK Sharma, RK Gautam, CL Verma, YP Singh, R. Singh AK Nayak	Whole project	IRRI, CSSRI	1	
	Paper - International seminar/ conference/ workshop	QTL mapping and marker-assisted backcrossing for improved salinity tolerance in rice	In: Proceedings of BioAsia 2007: 6th Asian Crop Science Association Conference and 2nd International conference on rice for the future, Bangkok, Thailand, 5-9 November, 2007, pages 6-12	2007	Thomson, M.J., De Ocampo, M., Egdane, J., Katimbang, M., Rahman, M.A., Singh, R.K., Gregorio, G.B. and Ismail, A.M.	2	IRRI		
	Paper - International seminar/ conference/ workshop	Networking Asia and Africa to validate and disseminate improved rice germplasm for salt tolerance	INGER Technical Advisory Meeting, Bangkok, Thailand, 8-11 May 2007	2007	Rakesh Kumar Singh		IRRI		
	Paper - International seminar/ conference/ workshop	Breeding rice varieties with tolerance to salt-stress	International Symposium on Management of Coastal Ecosystem: Technological advancement and livelihood security" Science City, Kolkata, India, 27-30 October	2007	Rakesh Kumar Singh		IRRI		

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
			2007						
	Paper - International seminar/ conference/ workshop	Standardization of a Screening Technique for Salinity Tolerance in Groundnut (Arachis hypogaea) and Pigeonpea (Cajanus cajan)	International Food Legume Research Conference, Delhi, October 2005	2007	Namita Srivastava, V. Vadez*, L. Krishnamurthy, K. B. Saxena, S.N. Nigam and A. Rupakula	2	ICRISAT	2	
	Paper - International seminar/ conference/ workshop	Tapping the large genetic variability for salinity tolerance in chickpea	Australian Society of Agronomy, Canberra	September 2006	V Vadez*a, L Krishnamurthy a, Pooran M Gaur a, Hari D Upadhyaya a, David A Hoisington a, Rajeev K Varshney a, Neil C Turner b, Kadambot HM Siddique b	2	ICRISAT	2	
	Paper - International seminar/ conference/ workshop	Screening for salinity Tolerance in Groundnut (Arachis hypogaea) and Pigeonpea (Cajanus cajan)	Proceeding of the Fourth International Food Legumes Research Conference (IFLRC-IV) October 18-22, 2005, New Delhi - India M.C.Kharkwal (ed.), Copyright©2007, ISGPB, New Delhi-India.	2007	Namita Srivastava, V. Vadez, L. Krishnamurthy, K. B. Saxena, S.N. Nigam and A. Rupakula	2	ICRISAT	4	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	Paper - International seminar/ conference/ workshop	Crop and resource management for high and stable productivity in coastal saline areas	Proceedings of CURE's Special Workshop: Natural Resource Management for Poverty Reduction and Environmental Sustainability in Fragile Rice-Based Ecosystems. Dhaka , Bangladesh , March 8-9, 2006 (in press)	2008	Mahata KR, Singh DP and Ismail AM	4	CRRI		
	Paper - International seminar/ conference/ workshop	Coastal saline ecosystem in India	Proceedings of CURE's Special Workshop: Natural Resource Management for Poverty Reduction and Environmental Sustainability in Fragile Rice-Based Ecosystems. Dhaka , Bangladesh , March 8-9, 2006 (in press)	2008	Saha Sanjoy, Singh DP and Mahata KR	4	CRRI		
	Paper - International seminar/ conference/ workshop	Water management for dry season rice in salt affected coastal soils	International Symposium on Management of Coastal Ecosystem: Technological Advancement and Livelihood Security, Kolkata, India; 23-27 Oct, p.71	2007	Mahata KR, Singh DP, Saha Sanjoy & Ismail AM	4	CRRI	4	
	Paper - International seminar/ conference/ workshop	Crop establishment strategies for enhancing rice yield in coastal saline ecosystem.	International Symposium on Management of Coastal Ecosystem: Technological Advancement and Livelihood Security,	2007	Sanjoy S, Mahata KR, Singh DP & Ismail AM	Crop establishment strategies	CRRI	4	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
			Kolkata, India; 23-27 Oct, p.14-15						
	Paper - International seminar/ conference/ workshop		International Symposium on Management of Coastal Ecosystem: Technological Advancement and Livelihood Security	2007	Sanjoy S, Singh DP, Sinhababu DP, Mahata KR, Behera KS & Pandey MP	5	CRRI	4	
	Paper - International seminar/ conference/ workshop	Development and evaluation of salt tolerant rice genotypes for coastal saline areas of eastern India	International Symposium on Management of Coastal Ecosystem: Technological Advancement and Livelihood Security, Kolkata, India; 23-27 Oct, p.10	2007	Sen P, Mahata KR & Singh DP	3	CRRI	4	
	Paper - International seminar/ conference/ workshop	Enhancing rice productivity in coastal saline ecosystem through use of salt tolerant varieties and improved crop management	International Symposium on Management of Coastal Ecosystem: Technological Advancement and Livelihood Security, Kolkata, India; 23-27 Oct, p.14	2007	Singh DP, Mahata KR, Saha Sanjoy & Ismail AM	4	CRRI	4	
	Paper - International seminar/ conference/ workshop	Phenotypic and physiological tolerance of rice genotypes to saline and sodic soil environments	In Proceedings: 2nd International Rice Congress, New Delhi, 9-13 October 2006, Abstract (ID 5026) pp 246-247	2006	Gautam, R.K., Singh, R.K., Chauhan, M.S. and Ismail, Abdelbagi M.		CSSRI	3	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	Paper - International seminar/ conference/ workshop	Evaluation of Iranian Rice genotypes under Saline condition and path Coefficient analysis for yield	Proceeding of 5th International Rice Genetics Symposium and 3rd International Rice Functional Genetic S Symposium. 19-23 November 2005. International Rice Research Institute. Manila, Philippines	19-23 November 2005	Sabouri, H., A. Rezaei, A. Moumoni, A.F. Mirlohi, F. Alinia, M. Allahgholipur		RRII	3	
	Paper - International seminar/ conference/ workshop	The role of Potassium application on productivity of some inbred and hybrid rice varieties under newly reclaimed saline soils.	8 African Crop Science Society Conference, 27-31 October 2007, El-Minia, Egypt, Vol 1, pp (55-60).	2007	Zayed, B.A., W.M. Elkhoby, S.M. Shehata and M.H. Ammar		RRTC	4	
	Paper - International seminar/ conference/ workshop	Designing Resilient Rice Varieties for Coastal Deltas Using Modern Breeding Tools	Delta 2007: Managing the coastal land-water interface in tropical delta systems, 7-9 November 2007, Bangsaen, Thailand	2007	Ismail, A. M.; Thomson, M. J.; Rahman, M. A.; De Ocampo, M; Egdane, J.; Katimbang, M.; Singh, R. K.; Gregorio, G. B.; Mackill, D. J.		IRRI		
	Paper - International seminar/ conference/ workshop	Right Rice in the Right Place: Systematic Exchange and Farmer-centered Evaluation of Rice Germplasm for Salt-affected Areas	Delta 2007: Managing the coastal land-water interface in tropical delta systems, 7-9 November 2007, Bangsaen, Thailand	2007			IRRI		
	Paper - International seminar/ conference/ workshop	Productivity Potentials of the Salt Affected Delta Areas of Bangladesh: Insights from Farm Level Survey	Delta 2007: Managing the coastal land-water interface in tropical delta systems, 7-9 November 2007, Bangsaen, Thailand	2007	M. Shahe Alam		BRRI		

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	Paper - International seminar/ conference/ workshop	Soil Characteristics of Saline and Non-saline Deltas of Bangladesh	Delta 2007: Managing the coastal land-water interface in tropical delta systems, 7-9 November 2007, Bangsaen, Thailand	2007	Mohammad A. Saleque		BRRI		
	Paper - International seminar/ conference/ workshop	The Trail of Rice Varietal Development with Crop Management for the Coastal Wetlands of Bangladesh	Delta 2007: Managing the coastal land-water interface in tropical delta systems, 7-9 November 2007, Bangsaen, Thailand	2007	Rafiqul Islam		BRRI		
	Paper - International seminar/ conference/ workshop	Strategies for Improving and Stabilizing Agriculture and Food Productivity in the Meking Delta	Delta 2007: Managing the coastal land-water interface in tropical delta systems, 7-9 November 2007, Bangsaen, Thailand	2007	Nguyen Thi Lang		CLRRI	4	
	Paper - International seminar/ conference/ workshop	Boro Rice for Food Security in the Coastal West Bengal	Delta 2007: Managing the coastal land-water interface in tropical delta systems, 7-9 November 2007, Bangsaen, Thailand	2007	S.K. Bardhan Roy				
	Paper - International seminar/ conference/ workshop	Improving Rice Productivity in Coastal Saline Soils of the Mahanadi Delta Through Integrated Nutrient Management	Delta 2007: Managing the coastal land-water interface in tropical delta systems, 7-9 November 2007, Bangsaen, Thailand	2007	Kantiranjan R. Mahata		CRRI		
	Paper - International seminar/ conference/ workshop	Crop Intensification for Improving Water Productivity and Rural Livelihood in Coastal Saline Soils of the Mahanadi Delta	Delta 2007: Managing the coastal land-water interface in tropical delta systems, 7-9 November 2007, Bangsaen, Thailand	2007	Devendra Pratap Singh		CRRI		

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	Paper - International seminar/ conference/ workshop	Assessing the Needs, Constraints and Livelihood Opportunities in Coastal Salinity Environments: A Case in Orissa, India	Delta 2007: Managing the Coastal Land-Water Interface in Tropical Delta Systems	2007	Paris TR, Saha Sanjoy, Singh DP, Mahata KR, Delos Reyes-Cueno A, Zolvinski S & Ismail AM	1	CRRI	4	
	Paper - International seminar/ conference/ workshop		Delta 2007: Managing the Coastal Land-Water Interface in Tropical Delta Systems	2007	Mahata KR, Singh DP, Saha S, Ismail Abdelbagi M & Haefele S	4	CRRI	4	
	Paper - International seminar/ conference/ workshop		Delta 2007: Managing the Coastal Land-Water Interface in Tropical Delta Systems	2007	Singh DP, Mahata KR, Saha S & Ismail AM	5	CRRI	4	
	Paper - International seminar/ conference/ workshop		Delta 2007: Managing the Coastal Land-Water Interface in Tropical Delta Systems	2007		3	CRRI	4	
PowerPoint Presentations									
	PowerPoint Presentation	CPW&F Project 7: Development of technologies to harness the productivity potential of salt-affected areas of the Indo-Gangetic, Mekong, and Nile river basins" an opportunity to build on PETRRA achievements.	Presented during PETRRA SP1300 meeting on "Development of high yielding varieties for coastal wetlands of Bangladesh", Dhaka, Bangladesh	28-29 April 2004	Abdelbagi M. Ismail	Whole project	IRRI	1	
	PowerPoint Presentation	Linkages between CN7 and CN10 in Bangladesh and Vietnam:	Short presentation during the review and planning meeting of Project 10 in Bac Lieu, Veitnam	4 March 2005	Abdelbagi M. Ismail	Whole project	IRRI	1	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	PowerPoint Presentation	Improving productivity of salt affected areas-What can we achieve through the CPW&F project #7	Cuu Long Delta Rice Research Institute, Vietnam	7 March 2005	Abdelbagi M. Ismail	Whole project	IRRI	1	
	PowerPoint Presentation	Progress of Salinity Tolerance Work in Legumes	Meeting in Karnal (Partners)	April 2006	Vadez et al	2	ICRISAT	2	
	PowerPoint Presentation	Developing Cropping Sequence Options for Rice-based Production Systems	Meeting in Karnal (Partners)	April 2006	A. Dakheel	2 & 3	ICBA	3	
	PowerPoint Presentation	Development of technologies to harness the productivity potential of salt-affected areas of the Indo-Gangetic, Mekong and Nile River Basins	Annual Planning and Review Meeting CPWF Karnal, April, 2006	April 2006	P. C. Ram	Whole project	NDUAT	3	
	PowerPoint Presentation	Abiotic stress tolerance in Plants: Challenges and opportunities	National Seminar on Plant Physiology: Physiological and Molecular approaches for the Improvement of Agricultural, Horticultural and Forestry Crops", Kerala Agricultural University, Thrissur, Kerala, India, 28-30 Nov 2006	29 November 2006	P.C. Ram	Whole project	NDUAT	3	
	PowerPoint Presentation	Developing new salt tolerance	Meeting at Tra Vinh	May 2006	Lang et al	2	CLRRI	3	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
Abstracts									
	Abstract	Enhancing and stabilizing productivity of rice based cropping system in salt-affected areas of Indo-Gangetic region through improved germplasm and management strategies	World Rice Research Conference 2004 "Rice for Life". 5-7 November, 2004. Tsukuba international Congress Centre, Tsukuba, Japan. Abstract # 753, page 323.	2004	Singh RK, Ismail AM, Gregorio GB, Sharma DK, Gautam RK, Verma CL, Singh YP, Singh R, Nayak AK		IRRI		YES
	Abstract	Molecular markers to salt tolerance in rice: Is it working?	In: Abstract, 5th International Rice Genetics Symposium, IRRI, Manila, Philippines. pp 115-116	2005	Islam, M.R., G.B. Gregorio, M.A. Salam, L. Hassan, E. Tumimbang-Raiz, D.L. Adorada and R.D. Mendoza		IRRI		
	Abstract	A "SNAP" technique in screening rice for salinity tolerance at seedling stage	The Philippine Journal of Crop Science, Vol. 30, Supplement No. 1, May 2005; 18th Scientific Conference of the Federation of Crop Science Societies of the Philippines, Lapasan, Cagayan de Oro City, Philippines	2005	Adorada DL, Gregorio GB, Santos PJA, Mendoza RD		IRRI		YES
	Abstract	Getting closer to the salt tolerance gene	Plant & Animal Genomes XIII Conference, 15-19 January 2005, San Diego, California, USA, page 288.	2005	Tumimbang ET, Adorada DL, Niones J, Elahi F, Seraj ZI, Dvorjak J, Gregorio GB		IRRI, UCD		YES
	Abstract	Development of Technologies to Harness the Productivity Potential of Salt-Affected Areas of the Indo-Gangetic River Basins: Socio Economic			delos Reyes-Cueno A, Paris T, Singh A, Singh YP, Saha S		IRRI		YES

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
		Component							
	Abstract	Molecular and morphological variability for salinity tolerance at reproductive stage in rice			Mohammadi-Nejad G, Singh RK, Rezai AM, Arzani A, Adorada DL, Melgar RJ, Gregorio GB		IRRI		YES
	Abstract	Molecular and morphological characterisation of 30 rice genotypes using microsatellite markers for the reproductive stage salinity tolerance	Abstract proceedings of 36th Crop Science Society of Philippines, Palawan, 8-12 May 2006; Abstract no. PBG-084. page 108	2006	Melgar, R.J.; Singh, R.K.; Gregorio, G.B.; Adorada, Dante; Nejad, G.M.		IRRI	3	
	Abstract	Physiological and molecular characterization of the elite salt tolerant rice genotypes using microsatellite markers for the seedling stage salinity tolerance	Abstract proceedings of 36th Crop Science Society of Philippines, Palawan, 8-12 May 2006; Abstract no. PBG-092. page 112	2006	Ramos, L.; Singh, R.K.; Gregorio, G.B. and Adorada, Dante		IRRI	3	
	Abstract	Designing abiotic stress-tolerant rice varieties for the rainfed lowlands of sub-Saharan Africa	Presentation /Abstract Proceeding of the African Rice Congress, Dar es Salaam, Tanzania, 31 July – 4 August 2006	2006	Gregorio,GB, M Sie, M-N Ndjiondjop, H Tsunematsu, M Wissuwa, DS Brar, RK Singh, J Bennett, AM Ismail, DJ Mackill		IRRI	3	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	Abstract	Molecular Breeding strategy to combine multiple abiotic stress tolerance in rice	Abstract proceedings of International Plant Breeding Symposium, Mexico, 20-25 August 2006; page 101	2006	Singh, R.K.; Gregorio, G.B.; Mackill, DJ; Adorada, D.; Mendoza, R. and Sajise, A.G.		IRRI	3	
	Abstract	Salinity, submergence and nutrient deficiency in rice: bases of tolerance and progress through breeding	Abstract proceeding of 2nd International Rice Congress held in New Delhi, 9-13 October 2006; Abstract ID: 5343. Page 15	2006	Ismail, AM; Wissuwa, M; Gregorio, GB; Thomson, M; Singh, RK; Heuer, Sigrid and Mackill, DJ	3,4	IRRI	3	
	Abstract	Application to rice breeding population and haplotype diversity of molecular markers for salinity tolerance in chrom 1	The Philippine Journal of Crop Science. 31: 17	2006	Islam, M.R., G.B. Gregorio, B.C.Y. Collard, E. Tumimbang-Raiz, D.L. Adorada and R.D. Mendoza, M.A. Salam and L. Hassan	2	IRRI, BRRI	3 & 4	
	Abstract	Graphical Genotyping of Salt-tolerant Lines of Rice and Comparison of Allelic Variation in Different Pokkali Accessions	In abstract: Proceedings of the 19th FCSSP Scientific Conference, 13-15 June 2007, Development Academy of the Philippines, Tagaytay City, Philippines.	2007	De Ocampo M, Thomson MJ, Egdane JA, Katimbang MLB, Zantua R, Rahman MA, Ismail AM		IRRI	3	
	Abstract	QTL Mapping and Marker-assisted Backcrossing for Improved Salinity Tolerance in Rice	In abstract: Plant and Animal Genome XV Conference	2007	Thomson MJ, De Ocampo M, Egdane J, Katimbang M, Rahman MA, Singh RK, Gregorio GB, Ismail AM		IRRI	3	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	Abstract	Molecular markers to salt tolerance in rice: Is it working?	In: Abstract, 5th International Rice Genetics symposium. IRRI. Manila, Philippines. Pp 115-116	2005	Islam, M.R., G.B. Gregorio, M.A. Salam, L. Hassan, E. Tumimbang-Raiz, D.L. Adorada and R.D. Mendoza	2	BRRI	3 & 4	
	Abstract	Validation of SSR markers and haplotype diversity at the SalTol locus on chromosome 1 of rice	In: Abstract, 26th International Rice Research Conference and 2nd International Rice Congress, 9-13 October 2006, New Delhi, India. p. 172	2006	Islam, M.R., G.B. Gregorio, M.A. Salam, B.C.Y. Collard, G. Mohammadi-Nejad, R.K. Singh and L. Hassan	2	BRRI	3 & 4	
	Abstract	QTL mapping for salinity tolerance of rice at seedling stage	In: Abstract, 26th International Rice Research Conference and 2nd International Rice Congress, 9-13 October 2006, New Delhi, India. p. 171	2006	Islam, M.R., M.A. Salam, L. Hassan, B.C.Y. Collard, R.K. Singh and G.B. Gregorio	2	BRRI	3 & 4	
	Abstract	Molecular diversity of stress tolerant rice genotypes using SSR markers	In: Abstract, 26th International Rice Research Conference and 2nd International Rice Congress, 9-13 October 2006, New Delhi, India. p. 174	2006	Islam, M.R., R.K. Singh, G. Mohammadi-Nejad, M.A. Salam, L. Hassan and G.B. Gregorio	2	BRRI	3 & 4	
	Abstract	Validation of molecular markers and haplotype diversity at the SalTol locus on chromosome 1 of rice	In: Abstract, 2nd International Conference on Plant Molecular Breeding, 23-27 March 2007, Sanya, Hainan, P.R. China	2007	Islam, M.R., G.B. Gregorio, M.A. Salam B.C.Y. Collard, R.K. Singh and L. Hassan	2	BRRI	3 & 4	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	Abstract	Application of molecular markers to rice breeding population and haplotype diversity for salinity tolerance in chromosome 1	In: Abstract, Conference on Promotion of Biotechnology in Bangladesh: National and International perspectives, 6-8 April 2007, Dhaka, Bangladesh. p. 40	2007	Islam, M.R., G.B. Gregorio, B.C.Y. Collard, E. Tumimbang-Raiz, D.L. Adorada, R.D. Mendoza, M.A. Salam and L. Hassan	2	BRRI	3 & 4	
	Abstract	QTL mapping of rice for salinity tolerance at seedling stage	In: Abstract, 7th Biennial conference of Plant Breeding and Genetics Society of Bangladesh (PBGSB), 26 May 2007, Gazipur, Bangladesh. p. 55	2007	Islam, M.R., M.A. Salam, L. Hassan, B.C.Y. Collard, R.K. Singh and G.B. Gregorio	2	BRRI	3 & 4	
	Abstract	Introgression of Saltol QTL into Bangladeshi mega rice variety BR11 and BRRI dhan28 through marker assisted backcrossing	In: Abstract, Plant tissue culture and Biotechnology conference held in 11-13 April 2008, University of Dhaka, Bangladesh. P. 28	2008	Rahman, M S, M R Islam, S Rahman, A Ferdousi, R Malo, M J Thomson, M A Salam, A M Ismail and Z I Seraj	2	BRRI	4	
	Abstract	Integrated nutrient management for enhancing rice productivity in coastal saline soils of eastern India	Abstract proceeding of 2nd International Rice Congress held in New Delhi, 9-13 October 2006; Abstract ID: 497. Page 369-370	2006	Mahata, K.R.; Singh, D.P.; Saha, Sanjoy; Ismail, Abdelbagi M.	4	CRRI	3	YES
	Abstract	Including gender analysis in assessing the needs, constraints and opportunities for improving the livelihoods of farming households in the coastal saline areas of Orissa	Abstract proceeding of 2nd International Rice Congress held in New Delhi, 9-13 October 2006; Abstract ID: ____. page 42	2006	Saha S, Paris T, Singh DP, Mahata KR, Delos Reyes-Cueno A, Sharma SG	1	CRRI	3	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	Abstract	Identification of suitable salt tolerant rice genotypes for coastal saline areas of Eastern India	Abstract proceeding of 2nd International Rice Congress held in New Delhi, 9-13 October 2006; Abstract ID: 544. page 222-223	2006	Sen, P., Mahata, K.R., Singh, D.P. and Singh, R.K	3	CRRI	3	
	Abstract	Crop diversification options for rice-based cropping system for higher land and water productivity in coastal saline areas of eastern India	Abstract proceeding of 2nd International Rice Congress held in New Delhi, 9-13 October 2006; Abstract ID: 496. Page 475	2006	Singh, D.P., Mahata, K.R., Saha, Sanjoy, Haefele, S., Ismail, Abdelbagi M.	5	CRRI	3	YES
	Abstract	Phenotypic and physiological tolerance of rice genotypes to saline and sodic soil environments	Abstract proceeding of 2nd International Rice Congress held in New Delhi, 9-13 October 2006; Abstract ID: 5026. Page 246	2006	Gautam, R.K., Singh, R.K., Chauhan, M.S. and Ismail A.M	3	CSSRI	3	YES
	Abstract	Phenotypic evaluation of rice genotypes under saline and sodic soils			R.K. Gautam, R. K. Singh 1 M. S. Chauhan and Abdelbagi M. Ismail 1		CSSRI		YES
	Abstract	Identification of salt tolerant and adaptable genotypes of rice and wheat for sodic lands of Indo-Gangetic plains	Abstract proceeding of 2nd International Rice Congress held in New Delhi, 9-13 October 2006; Abstract ID: 5147. Page 248	2006	Singh, Y.P., Singh, K.N., Singh, R.K. and Gautam, R.K		CSSRI	3	
	Abstract	Improving health and productivity of sodic soils of Indo Gangetic Plains	Abstract proceeding of 2nd International Rice Congress held in New Delhi, 9-13 October 2006; Abstract ID: 5197. Page 349	2006	Singh PN, Singh N, Singh RP, Singh U, Ismail A, Ram PC		NDUAT	3	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
1	Invited oral presentations	Salinity tolerance in rice: integration of QTL, expression analysis, and breeding	Proceedings of the Plant and Animal Genome Conference XIV. Jan. 14-18, 2006. San Diego CA, USA. Abstract no. W262, *http://www.intl-pag.org/14/abstracts/PAG14_W262.html*	2006	Ismail AM, Gregorio G, Thomson M, Tumimbang E, Walia H, Blumwald E, Wilson C, Close T	2	IRRI	3	
PUBLICATIONS									
Journal Article									
	Journal Article	CSR 23 : a new salt-tolerant rice variety for India	International Rice Research Notes. 31(1): 16-18	June 2006	Singh, RK, Mishra, B. and Gregorio, G.B		IRRI	3	YES
	Journal Article	CSR30 : first basmati rice variety for sodicity stress	Indian Farming. 56(1): 3-6	April 2006	Singh, RK and Mishra, B		IRRI	3	YES
	Journal Article	Salinity, Submergence, and Nutrient Deficiency in Rice: Bases of Tolerance and Progress Through Breeding	IRC 06	2006	AM Ismail, M Wissuwa, GB Gregorio, MJ Thomson, RK Singh, S Heuer, DJ Mackill		IRRI		YES
	Journal Article	Salinity, Submergence, and Nutrient Deficiency in Rice: Bases of Tolerance and Progress Through Breeding	IRC 06	2006	AM Ismail, M Wissuwa, GB Gregorio, MJ Thomson, RK Singh, S Heuer, DJ Mackill		IRRI		YES
	Journal Article	Response to salinity in rice: Comparative effects of osmotic and ionic stresses	Plant Production Science Vol 10, No. 2, p. 159-170	2007	Castillo, E.G., Tuong T. P., Ismail, A.M., Inubushi K		IRRI	3	YES

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	Journal Article	Responses of Photosynthesis, Chlorophyll Fluorescence and ROS-Scevenging Systems to Salt Stress During Seedling and Reproductive Stages in Rice	Annals of Botany 99: 1161-1173, 2007	Received: 29 September 2006, Returned for revision: 30 October 2006, Accepted: 7 February 2007, Published electronically: 11 April 2007	Foad Moradi, Abdelbagi M. Ismail		IRRI		YES
	Journal Article	Genetic and genomic approaches to develop rice germplasm for problem soils	Plant Mol Biol (6007) 65:547-570	Received: 29 April 2007, Accepted: 22 July 2007, Published online: 17 August 2007	AM Ismail, S Heuer, MJ Thomson, M Wissuwa		IRRI		YES
	Journal Article	QTL Mapping for Salinity Tolerance in Rice	Physiol. Mol. Biol. Plants (2007), 13(2): 87-99	2007	RK Singh, GB Gregorio, RK Jain		IRRI		YES
	Journal Article	Diversity analysis of rice varieties differing in salt-tolerance.	Egyptian Journal of Plant Breeding. 11(2): 543-550.	2007	Ammar, MHM; Monir, Samah; Singh, RK; Mohapatra, T and Singh, NK.		IRRI		

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	Journal Article	Genome-wide transcriptional analysis of salinity stressed japonica and indica rice genotypes during panicle initiation stage	Plant Molecular Biology Vol.63, No.5, p.609-623	2007	Walia, H., Wilson C., Zeng, L., Ismail A.M., Condamine P., Close T. J.		UCD, IRRI	3	YES
	Journal Article	Array-based genotyping and expression analysis of barley cv. Maythorpe and Golden Promise	BioMed Central Genomics 8:87	2007	Walia H, Wilson C, Condamine P, Ismail AM, Xu J, Cui X, Close TJ		UCD, IRRI		YES
	Journal Article ?	Standardization of a protocol to screen for salinity tolerance in groundnut	International Arachis Newsletter	2005	V Vadez*, N Srivastava, L Krishnamurthy, A Rupakula and SN Nigam	2	ICRISAT	2	
	Research Paper/ Peer reviewed paper/ Journal Article	Screening technique for salinity tolerance in groundnut (Arachis hypogaea) and pigeonpea (Cajanus cajan)	Indian Journal of Crop Science	2007	Namita Srivastava, V. Vadez*, L. Krishnamurthy, K. B. Saxena, S.N. Nigam and A. Rupakula	2	ICRISAT	3	
	Journal Article	Salinity in groundnut and pigeonpea; Standardization of a screening technique for salinity tolerance in groundnut (Arachis hypogaea) and pigeonpea (Cajanus cajan)			Namita Srivastava, V Vadez, L Krishnamurthy, KB Saxena, SN Nigam, A Rupakula		ICRISAT		YES
	Journal Article	Screening for intra and inter specific variability for salinity tolerance in pigeonpea (*Cajanus cajan*) and its related wild species	Electronic Journal of SAT Agriculture Research 2: p12	2006	Namita Srivastava, V. Vadez, H.D. Upadhyaya, and K.B. Saxena		ICRISAT	3	YES

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	Journal Article	Large variation in salinity tolerance in chickpea is explained by differences in sensitivity at the reproductive stage	Field Crops Research (104) 2007, p.123-129	2007	Vadez, A., Krishnamurthy, L., Serraj, R., Gaur, P.M., Upadhyaya, H.D., Hoisington, D.A., Varshney, R.K., Turner, N.C., Siddique, K.H.M.		ICRISAT	3	YES
	Peer reviewed paper/ Journal Article	Large variation in salinity tolerance in chickpea is explained by differences in sensitivity at the reproductive stage	Field Crop Research	2007	V. Vadez*a#, L. Krishnamurthy a, R. Serraj, P.M. Gaur a, H.D. Upadhyaya a, D.A. Hoisington a, R.K. Varshney a, N.C. Turner b, K.H.M. Siddique b		ICRISAT	3	
	Research Paper/ Journal Article	Large variation in salinity tolerance in chickpea is explained by differences in sensitivity at the reproductive stage	Field Crop Research (in press)	2007	V Vadez*a, L Krishnamurthy a, Pooran M Gaur a, Hari D Upadhyaya a, David A Hoisington a, Rajeev K Varshney a, Neil C Turner b, Kadambot HM Siddique b	2	ICRISAT	3	
	Paper - National seminar/ conference/ workshop/ Journal Article	Genetic diversity in salt tolerant rice (*O. sativa*)	Journal of Plant Breeding and Genetics 19(1), 35-40.	2006	Islam, M.R., Faruquei, M.A.B., Salam, M.A.	2, 3	BRRI	3 & 4	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	Journal Article	BRRI Dhan47: A salt tolerant variety for the Boro season	International Rice Research Notes, IRRI, Philippines, Vol. 32, No. 1, p. 42-43	2007	Salam, M A, M A Rahman, M A R Bhuiyan, K Uddin, M R A Sarker, R Yasmeen and M S Rahman	2, 3	BRRI	3 & 4	YES
	Journal Article	Participatory variety selection for salt tolerant rice	Intl. J. BioRes. 4 (3): 21-25	March 2008	Islam, M.R, M A Salam, M A R Bhuiyan, MA Rahman and GB Gregorio	2	BRRI	4	YES
	Journal Article	Improvement of rice genotypes for salt affected areas of Bangladesh	Intl. J. BioRes. 4 (5): 81-85	May 2008	Islam MR, MA Salam, TL Aditya, MAR Bhuiyan, MA Rahman, MS Rahman, S Khatun, HU Ahmed	2	BRRI	4	YES
	Journal Article	BRRI Dhan 47: A salt tolerant rice variety for Boro season isolated through participatory variety selection	Intl. J. BioRes 5(1):1-6	July 2008	MR Islam, MA Salam, MAR Bhuiyan, MA Rahman, R Yasmeen, MS Rahman, MK Uddin, GB Gregorio, AM Ismail		BRRI		YES
	Journal Article	Coastal Saline Environment and Rice Variety Development in Bangladesh	Eco-friendly Agril. J. 1(1):37-47, 2008 (August)	Accepted 26 August 2008	M R Islam, M S Rahman and M A Salam		BRRI		YES
	Journal Article	Rice varieties for salt-affected soils: development and deployment	Rice India, 17(5): 28-32	2007	Gautam, RK; Singh, RK; Singh, KN; Mishra, B and Singh GB		CSSRI, IRRI		

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	Research Paper/ Journal Article	Alkalinity induced changes in mobilization efficiency, seedling vigour, L-amylase and protease activities in rice genotypes	Annals of Agri-Bio Research 12 (2): 133-138	2007	Bindu Prasad, Uma Singh, P.C.Ram, G.S. Chaturvedi		NDUAT	4	YES
	Journal Article	Rice breeding for salt tolerance in the Mekong delta	Mekong rice Vietnam	2005	Bui Chi Buu and Nguyen Thi Lang	2	CLRRI	3	
	Journal Article	Appraisal of saline tolerance of some short growth duration rice varieties	Journal of Agriculture and Rural Development	December 2006	Nguyen Thi Lang et al	2	CLRRI	3	YES
	Journal Article		VietNam Journal of Agriculture and Rural Development		Nguyen thi lang, Nguyen thi Xim, Trinh Hoang Khai, Bui Chi Buu	Selection of salt tolerance by gamaeclone	CLRRI	3	
	Journal Article		Omon rice, VietNam Journal of Agriculture and Rural Development		Nguyen thi Lang et al 2006, 2007	Salt tolerance, new varieties, evaluated salt tolerance	CLRRI	3	
	Journal Article	Genetic variability to salt stress	Science and Technology Journal of Agricultural & Rural Development: 24: 32-36. 2006 Omon rice 15: 179-183		Nguyen Thi Lang, Mai Thai Binh		CLRRI	4	
	Journal Article	Application of microsatellite to salt tolerance in rice			Nguyen Thi Lang, Hoang Thi Minh Nguyen Thach Can		CLRRI	4	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	Journal Article	Identification of some promising rice varieties for saline soil and phosphorous deficient areas in the Mekong Delta	IRRI –Japan		Nguyen Thi Lang, Dang Minh Tam, Bui Chi Buu		CLRRI	4	
	Journal Article	Invitro selection of somaclonal and gametoclonal variants for salt tolerance in rice Rice breeding for salt tolerance in the Mekong delta	IRRI –Japan		Bui Chi Buu and Nguyen thi Lang		CLRRI	4	
	Journal Article	Evaluation of Iranian rice genotypes under salinity condition in seedling stage A: Compare mean and sensitive and tolerance index	Iranian Journal of Agricultural Sciences: Tehran University. In Press (Abs. in English)	2006	Sabouri, H., Rezai, A. , Moumeni, A.		RRII	3	YES
	Journal Article	Evaluation of Iranian rice genotypes under salinity condition	Journal of Sciences and Technology of Agriculture and Natural Resources: Isfahan University of Technology. In Press. (Abs. in English)	2006	Sabouri, H., Rezai, A. , Moumeni, A., Mirlohi, A., Kavousi. M		RRII	3	
	Journal Article	Evaluation of Iranian rice genotypes under salinity condition in seedling stage B: Multivariate analysis.	Iranian Journal of Agricultural Sciences. (In Press)		Sabouri, H., Rezai, A., Moumeni, A., _____.		RRII		YES
	Journal Article	Effect of Reuse Drainage Water Management on Rice Growth, Yield and Water Use Efficiency under Saline Soils of Egypt	Asian Journal of Plant Sciences 5(2): 287-296	2006	Zayed BA, WH Abou El Hassan, Y Kitamura, SM Shehata, Zahor Ahmed and Faridullah		RRTC		YES

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	Journal Article	Role of pottasium application on the productivity of some inbred and hybrid rice varieties under newly reclaimed saline soils	African Crop Science Conference Proceedings, Vol. 8 pp. 53-60	2007	BA Zayed, WM Elkhoby, SM Shehata, MH Ammar		RRTC		YES
Working Paper									
	Working Paper	Research Paper Rice and Water Productivity As Affected By Irrigation Intervals And Potassium Splitting Under Newly Reclaimed Saline Soil.	J.Agric.Res.Kafer Elsheikh Univ., 33(4):807-823.(2007).	2007	Zayed, B.A., S.M.Shehata, W.M.Elkhoby and E.E.E.Kafaga		RRTC	4	
Research Paper									
	Research Paper	Alkalinity induced changes in mobilization efficiency, seedling vigour, amylase and protease activity in rice genotypes	Indian Journal of Plant Physiology	December 2007	Uma Singh, P.C Ram, S.P. Singh, Bindu Prasad, G.S. Chaturvedi and P.N Singh		NDUAT	2	
	Research Paper	QTL for salt stress in F8 in rice	Science and Technology Journal of Agricultural & Rural Development 139-163				CLRRI	4	
	Paper	Genetic diversity of salt tolerance rice landraces in Mekong delta			Nguyen thi Lang, Pham thi Be Tu, Bui thi Duong Khuyeu, Nguyen Chi Thanh, Bui Chi Buu, A.Ismail		CLRRI		YES
	Paper	Study on Maize varieties supplying to Mekong Delta			Nguyen Thi Lang, Tran Anh Nguyet, Nguyen Thuy Kieu Tie, Bui Thi Duong Khuyeu, Nguyen thi Thu Huong, Bui Chi Buu,		CLRRI		YES

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					A.Ismail				
	Paper	Breeding and selecting for salt tolerance in rice in Vietnam			Nguyen Thi Lang, B.C. Buu, A.Ismail		CLRRI		YES
	Paper	In vitro selection of somaclonal for salt tolerance in rice			Nguyen Thi Lang, Tran Thi Thank Xa, Bui Chi Buu		CLRRI		YES
	Paper	Selecting the rice varieties for soil conditining in Mekong Delta			Nguyen Thi Lang, Trinh thi Luy, Nguyen Thach Can, Bui Xuan Ky, Bui Chi Buu and A.Ismail		CLRRI		YES
Policy paper/ brief									
1	Policy paper/ brief		Rural Development		Nguyen thi Lang and Bui Chi Buu	Release new salt tolerance	CLRRI	3	
Book/ Monograph									
Chapters in books/ proceedings									
	Chapters in books/ proceedings	Breeding for Abiotic Stress Tolerance in Rice	In: Abiotic stresses; Plant resistance through breeding and molecular approaches" ed M. Ashraf and PJC Harris. Food Product Press, Inc. New York. pp 513-534	2005	Gregorio GB, Cabuslay G	2, 3	IRRI	1	YES
	Chapters in books/ proceedings	CSR 30 : First basmati rice variety for salt affected soils	In: Scented Rice of Uttar Pradesh and Uttaranchal; pp 75-84	2005	Singh, R.K.; Mishra, B and Sharma DK; Eds: Singh RK and Singh US. Kalayani		IRRI	3	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
					publishers, New Delhi, India				
	Chapters in books/ proceedings	Approaches to Enhance Salt Tolerance in Crop Plants: Progress and Prospects	Crop Improvement: Strategies and Applications. Editors: RC Setia, Harsh Nayyar, Neelam Setia, IK International Publishing House Pvt. Ltd., New Delhi, pp. 179-205	2008	PC Sharma, RK Singh		IRRI		YES
	Chapters in books/ proceedings	Development of drought and salinity tolerant crops	In: Food and Water Security in Developing Countries. Taylor & Francis (U.K.) publishers, U. Aswathanarayana (ed)	2007	Vincent Vadez	2	ICRISAT	3	
	Chapters in books/ proceedings		Proceedings of CURE's Special Workshop: Natural Resource Management for Poverty Reduction and Environmental Sustainability in Fragile Rice-Based Ecosystems.	2008	Mahata KR, Singh DP & Ismail AM	4	CRRI	4	
	Chapters in books/ proceedings		Proceedings of CURE's Special Workshop: Natural Resource Management for Poverty Reduction and Environmental Sustainability in Fragile Rice-Based	2008	Saha Sanjoy, Singh DP & Mahata KR	Ecosystem characterization	CRRI	4	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
			Ecosystems.						
	Chapters in books/ proceedings	Approaches to enhance salt tolerance in crop plants: progress and prospects	In: Crop Improvement: Strategies and Applications. . Eds: R.C. Setia; Harsh Nayyar and Neelam Setia. I.K. International Publishing House Pvt. Ltd., New Delhi. pp 179-205.	2008	Sharma, P.C. and Singh, R.K.		CSSRI, IRRI		
	Chapters in books/ proceedings	Physiological and molecular basis of abiotic stress tolerance in Plants.	Title of the book: Plant Adaptation and productivity under stress environments: Physiological and Molecular approaches. (Eds. P. C. Ram and G.S. Chaturvedi)	October 2008	P.C. Ram , P. N. Singh, V.N. Singh, N. Singh, Punam, Abdelbagi Ismail and R. K. Singh		NDUAT	4	
	Chapters in books/ proceedings	Physiological mechanism of salinity alkalinity tolerance in crop plants.	Title of the book: Plant Adaptation and productivity under stress environments: Physiological and Molecular approaches. (Eds. P. C. Ram and G.S. Chaturvedi)	October 2008	S. K. Sharma and P. C. Ram		NDUAT	4	
Other									

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
		A draft review paper is being prepared with the tentative title "Recent advances in breeding for salt tolerance in tropical rice-based cropping systems"		2005-2006		2, 3	IRRI	1	
	Peer reviewed paper	Rice response to salinity: Comparative effects of osmotic and ionic stresses	Plant Production Science (in press)	2006	Castillo, E.G., Tuong T. P., Ismail, A.M., Inubushi K		IRRI		
	Review paper	Abiotic stress tolerance in tropical rice: progress and future prospects	Oryza, Vol. 43 No. 3, 2006 (171-186)	2006	HR Lafitte, A Ismail, J Bennett		IRRI		YES
TRAINING MATERIALS									
Course Materials									
	Course Material	Course materials on Marker-Assisted Section Workshop, 21-24 February 2005	Project Partners	21-24 February 2005	Various international resource persons, trainers/ facilitators	2	IRRI	1	
	Course Material	Course materials on Project Management Tools, 28 February 2005	Project Partners	28 February 2005	Shire, D, Bell, MA, Lapitan, J	7	IRRI	1	
	Course Material	Breeding for salt-tolerance in rice – for the Plant Breeding Training Course	Participants of Plant Breeding Training Course	2006	Singh, R.K.	2	IRRI	3	
	Course Material	Breeding for salt-tolerance in rice	In e-learning module developed by IRRI	2006	Singh, R.K.	2	IRRI	3	
	Course Material	Course material on training for farmers: development of new varieties, IPM, nutrient	CLRRI	November 2005	Nguyen thi Lang, Cao Van Phung, Luong Minh Chau	2, 3	CLRRI	3	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
		management in salt tolerance							
	Course Material	Seed technology and protect BpH and mangene for nutrient some salt stress			Nguyen thi Lang, Cao van Phung, Luong Minh Chau		CLRRI		
SURVEY MATERIALS									
Survey proforma									
1	Survey proforma	Survey proforma for socio economic baseline surveys		2004-2005	Thelma Paris	1	IRRI	1	
Analysis proforma									
PROJECT INFORMATION MATERIALS									
Web site									
1	Web site	CP7 web under construction				Whole project	IRRI		
Posters									
	Poster	Project Outline	Presented at Nairobi and South Africa meetings	A copy of it was already submitted to the CP Secretariat	Abdelbagi M. Ismail	Whole project	IRRI	1	
	Poster	Development of Technologies to Harness the Productivity Potential of Salt-Affected Areas of the Indo-Gangetic, Mekong and Nile River Basins			A. Ismail, T. Paris, G. Gregorio, D. singh, R. Singh, P. Ram, M. Salam, R. Seraj, B. Buu, E. Blumwald, F. Alinia, J. Stenhouse, A. Draz	Whole project	IRRI		YES

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	Poster	Getting Closer to the Salt Tolerance Gene	Plant and Animal Genomes XIII Conference, 15-19 January 2005, Town & Country Convention Center, San Diego, CA	2005	Ellen T. Tumimbang, Dante L. Adorada, Johnathan Niones, Fazle Elahi, Zeba I. Seraj, Jan Dvorjak, Glenn B. Gregorio		IRRI		YES
	Poster	A "Snap" Technique in Screening Rice for Salinity Tolerance	18th Scientific Conference of the Federation of Crop Science Societies of the Philippines, Lapasan, Cagayan de Oro City, Philippines		Dante L. Adorada, Glenn B. Gregorio, Primitivo Jose A. Santos, and Rhulyx D. Mendoza		IRRI		YES
	Poster	Isolation and characterization of IR64 knockout mutants with altered responses to salt stress in rice	Proceedings of the Int. Rice Genetics Symposium and the 3rd Int. Rice Functional Genomics Symposium. Nov. 19-23, 2005. Manila, Philippines. P 158	2005	Nakhoda B, Ismail AM, Leung H, Egdane J		IRRI	3	
	Poster paper	Phenotypic analysis of rice knockout mutant lines with altered response to salt stress	Proceedings of the 36th Crop Science Society of the Philippines Scientific Conference. May 8-12, 2006, Puerto Princesa, Palawan, Philippines. The Philippines J. Crop Sci. 31(Supl. 1): P 71	2006	Nakhoda B, Ismail AM, Leung H. Egdane J		IRRI	3	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	Poster paper	Seedbed management strategies for enhanced rice crop establishment, growth characteristics and grain yield in coastal saline areas of the Philippines	Proceedings of the 36th Crop Science Society of the Philippines Scientific Conference. May 8-12, 2006, Puerto Princesa, Palawan, Philippines. The Philippines J. Crop Sci. 31(Supl. 1): P 125	2006	Azhiri-Sigari A. Ismail AM, Sebastian LS, Montiel ZOP, Cardenas CC, Guzman ED			3	
	Poster	Mimicking the iron toxic environment in culture solution for efficient rice screening	CSSP Conference, 8-12 May 2006	2006	V. Elec, R.K. Singh, ES.E. Johnson, R. Mendoza,and D. L. Adorada	2	IRRI	2	
	Poster	Genetic Variability for Salinity Tolerance at Reproductive Stage in Rice	CSSP Conference, 8-12 May 2006	2006	Ghasem Mohammadi-Nejad1, J.Melgar1, R.K. Singh1, D. Adorada1, A.M.Rezai2, A. Arzani 2and G.B. Gregorio	2	IRRI	2	
	Poster	Fine mapping of the salinity tolerance gene in Chromosome 1 of Rice (Oryza sativa L.) using near-isogenic lines	CSSP Conference, 8-12 May 2006	2006	J.M. Niones, G.B. Gregorio, E.T. Taiz, D.L. Adorada, and J.E. Hernandez	2	IRRI	2	
	Poster	Physiological and molecular characterization of the elite salt-tolerant rice (Oryza sativa L.) genotypes using microsatellite markers for the seedling stage salinity tolerance	CSSP Conference, 8-12 May 2006	2006	L. Ramos, R.K. Singh, G.B. Gregorio, and D.L. Adorada	2	IRRI	2	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
	Poster	Temperature and relative humidity affect salinity tolerance in rice	CSSP Conference, 8-12 May 2006	2006	R.K. Singh, D.L. Adorada, C. Magsino, Z. Roque, N. Tamayo, A. Sajise, and G.B. Gregorio	2	IRRI	2	
	Poster paper	Morphological, physiological and biochemical evaluation of IR64 mutant lines under salinity and normal conditions	Abstract in Proceeding of 2nd International Rice Congress held in New Delhi, 9-13 October 2006; Abstract ID: 2592. Page 244	2006	Nakhoda B, Leung H, Egdane J, Mohammadi-Nejad G, Ismail AM		IRRI	3	
	Poster	Helping poor women farmers improve their livelihoods in rice areas suffering from sodicity: a case in eastern Uttar Pradesh	Abstract in 2nd International Rice Congress, 9-13 October 2006, New Delhi, 548p.	2006	Paris, T., Singh A.J., Delos Reyes-Cueno A., Singh, R.P., Jadish, Ram, P.C.	1	IRRI	3	
	Poster	Breeding strategy to develop rice populations/genotypes with multiple abiotic stress tolerance		2005	RK Singh, GB Gregorio, DJ Mackill, D Adorada, R Mendoza, AG Sajise		IRRI		YES
	Poster	Integrating salinity and submergence in one genetic background through MAS in rice (*Oryza sativa L.*)			SZM Thein, JE Hernandez, TH Borromeo, AG Sajise, R Mendoza, LC Refuerzo, GB Gregorio, DJ Mackill, RK Singh		IRRI		YES
	Poster	New major QTL for salinity tolerance in rice			G Mohammadi-Nejad, AM Rezai, A Arzani, AG Sajise, GB		IRRI		YES

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					Gregorio, RK Singh				
	Poster	Temperature and Relative Humidity Affect Salinity Tolerance in Rice			RK Singh, DL Adorada, C Magsino, Z Roque, N Tamayo, GB Gregorio		IRRI		YES
	Poster	Genomic comparisons between barley and rice in relation to salt adaptation and heritable salt tolerance	Proceedings of the Int. Rice Genetics Symposium and the 3rd Int. Rice Functional Genomics Symposium. Nov. 19-23, 2005. Manila, Philippines. P 28	2005	Close TJ, Walia H, Wilson G, Condamine P, Liu X, Ismail AM, Zeng L, Wanamaker SI, Mandal J, Xu J, Cui X		UC, IRRI	3	
	Poster	Genomic comparison between barley and rice in relation to salt adaptation and heritable salt tolerance	Proceedings of the Plant and Animal Genome Meeting XIV. Jan. 14-18, 2006. San Diego CA, USA. Abstract no. P784, P 296	2006	Walia H, Wilson C, Condamine P, Liu X, Ismail A, Zeng H, Wanmaker S, Mandal J, Xu J, Cui X, Close T		UC. IRRI	3	
	Poster	Validation of SSR markers and haplotype diversity of the *Saltol* locus on chromosome 1 of rice			MR Islam, GB Gregorio, MA Salam, BCY Collard, RK Singh, L. Hassan		BRRI		YES
	Poster	Molecular diversity of stress tolerant rice genotypes using SSR markers			MR Islam, RK Singh, G Mohammadi Nejad, MA Salam, L. Hassan, GB Gregorio		BRRI		YES

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	Poster	QTL Mapping for Salinity Tolerance of Rice at Seedling Stage			MR Islam, MA Salam, L Hassan, BCY Collard, G Mohammadi-Nejad, RK Singh, GB Gregorio		BRRI		YES
	Poster	Molecular Markers for Salt Tolerance in Rice: Is It Working?			MR Islam, GB Gregorio, MA Salam, L Hassan, E Tumimbang-Raiz, DL Adorada, RD Mendoza		BRRI		YES
	Poster	Coastal Saline Environment and Rice Variety Development in Bangladesh			MA Salam, MR Islam, MS Rahman		BRRI		YES
	Poster	Participatory Variety Selection for Salt Tolerant Rice			MR Islam, MA Salam, MAR Bhuiyan, MA Rahman, GB Gregorio		BRRI		YES
	Poster	Environmental characterization of waterlogged sodic soils and technology validation for mitigating adverse effects of waterlogging on wheat	National Seminar on Plant Physiology: "Physiological and Molecular approaches for the Improvement of Agricultural, Horticultural and Forestry Crops", Kerala Agricultural University, Thrissur, Kerala, India, 28-30 November 2006	Abstract Published November 2006	N.Singh, P.C. Ram, P.N.Singh, Mamta Singh, Subhash Kumar, B.N.Singh, B.B.Singh and T.L.Setter.	Whole project	NDUAT	3	

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	Poster	Improving health and productivity of sodic soils of Indo Gangetic plains	2nd International Rice Congress, 2006, New Delhi, India, 9-13 October 2006	Abstract published October 2006	P. N. Singh, N.Singh, R.P.Singh, Uma Singh, A. Ismail and P.C. Ram	2, 4	NDUAT	3	
	Poster paper	Farmers' participatory varietal selection on unfavorable flood prone rice in Eastern Uttar Pradesh: A case study	Abstract in Proceeding of 2nd International Rice Congress held in New Delhi, 9-13 October 2006; Abstract ID: 1768. Page 236	2006	Dwivedi JL, Ismail A, Mackill DJ, Sigh RK, Ram PC		NDUAT	3	
	Poster	Beneficial effects of pressmud application on growth and yield of rice in sodic soil	National Seminar on Plant Physiology Physiological and molecular approaches for increasing yield and quality of Agricultural, Horticultural and Medicinal Plants under changing environment) (29-30th November and 1st December, 2007)	2007	Singh, P.N., Singh, N., Srivastava, A, Ram, P. C. and Abdelbagi Ismail	4	NDUAT	4	
	Poster	Efficacy of zinc oxide root dipping treatments for rice yield improvement under sodic soil	National Seminar on Plant Physiology Physiological and molecular approaches for increasing yield and quality of Agricultural, Horticultural and Medicinal Plants under changing environment) (29-30th November	2007	Singh, N., Singh, P.N., Singh, S.P., Ram, P. C. and Abdelbagi Ismail	4	NDUAT	4	

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			and 1st December, 2007)						
Brochure									
1	Brochure	Usar Bhumi ki utpadakta badhane ki aadhunik takneekiyan	Farmers/ Seed growers	September 2007	P.C Ram et al.	Whole project	NDUAT	3	
2	Brochure	Growing Rice for Salt-affected Soils					IRRI	2	
Newsletters									
	Newsletter								
Others									
1	Report		Report on IRSSTON (last 25 years) : IRSSTON Revisited		R.K. Sing et al	2, 3	IRRI	2	
2	Report	Production Systems, Constraints and Research Priorties in Salt-Affected Rice Villages in eastern Uttar Pradesh: A synthesis of findings			Paris TR, Cueno A, Saha S, Singh YP and Singh A	1	IRRI	3	
3	Report	Production systems, Constraints and Research Priorities in Salt -Affected Rice Villages in Coastal Orissa, India			Saha Sanjoy, Mahata, KR, Singh DP, Paris TR and Cueno delos Reyes A.	1	IRRI	3	
4	Report	Production systems, Constraints and Research Priorities in Salt -Affected Rice Villages in Sodic Soils in Eastern Uttar Pradesh			Singh Abha, Jagdish Singh, Paris, TR and Cueno delos Reyes A	1	IRRI	3	

No.	Type	Title	Name of Journal/Main User of Materials	Date (expected date) of Publication	Author/s	Related to which output/s	Center	Reported in CPWF Annual Report No.	Electronic copy available
5	Report	Production systems, Contraints and Research Priorities in Salt-Affected Rice Villages in Salt-Affected Rice Villages in Unnao, Lucknow district			Singh YP, Paris TR and Cueno delos Reyes A	1	IRRI	3	
6	Guidelines	Guidelines for participatory tools			Thelma Paris	1	IRRI	1	
7	Guidelines	Guidelines for Plant Varietal Selection (PVS) trials			Thelma Paris	1	IRRI	1	
8	Technology bulletin (English and Oriya)	Rice varieties and CNRM practices	Improving rice productivity in salt-affected coastal soils. CURE and CPWF Project Bulletin No. 1	2008	Sanjoy Saha, KR. Mahata, P Sen, RC Dani, BC Marandi & D. P. Singh	4	CRRI	4	
9	Farmers' extension bulletin	Modern Techniques for Enhancing Productivity of Salt Affected Areas		2008	P.C. Ram/NDUAT	6	NDUAT		
Any other written materials that do not fall under the above categories									
1	Concept note	Consortium for crop improvement for abiotic stresses: sodicity, salinity, waterlogging and microelement toxicities & deficiencies.	"National Agricultural Innovation Project" Concept Note for Component 4, ICAR New Delhi, India	30 November 2006	P. C. Ram	Whole project	NDUAT	3	
2	Magazine article	Opposites attract…attention	GCP				IRRI		YES
3	Media article	Evolve tech to fight salinity problem; Minister urges scientists	The Daily Star, Dhaka, Bangladesh	April 2005					YES
	Media article/ briefing kit	Boro rice in saline soil	Media attending the 1st Annual Review and Planning Meeting, April 2005, Dhaka, Bangladesh	April 2005					YES

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	Media article	Scientists from eight countries gathered to combat salinity problem: They discussed from Nile river basin to Gangetic basin problems in Karnal	Punjab Kesari Ambala Edition 26 April 2006: (section page number).	April 2006					YES
	Media article	Eight countries' scientists hold intensive discussion: How to increase production in salt-affected soils	Dainik Bhaskar 26 April 2006: (section page number)	April 2006					YES
	Media article	Area of salt-affected soils increasing—scientists from the world discussed intensively	Dainik Jagran Haryana Edition 26 April 2006: 5	April 2006					YES
	Media article	About world's one billion area is under salt-affected soil: International workshop on enhancing the production—65 scientists from eight countries participating	Amar Ujala 26 April 2006: 9	April 2006					YES
	Media article	Campaign to save freshwater	Amar Ujala 26 April 2006: 9	April 2006					YES
	Media article	Workshop on technologies for increasing productivity on salt-affected soil opened	Daily Tribune, Chandigarh 26 April 2006: (section page number)	April 2006					YES
	Media article	Hope of green in barren soils: Second of three-day workshop at CSSRI	Karnal Jagran 27 April 2006: 13	April 2006					YES
	Media article	Work together in agriculture (to get maximum benefits): India has advanced technology and resources for agriculture	Dainik Bhaskar 27 April 2006: (section page number)	April 2006					YES

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	Media article	CSR30—will give pride to the province: Aromatic, better quality, high yield and boon for sodic soils and saline water areas	Dainik Bhaskar 26 April 2006: (section page number)	April 2006					YES
	Media article	Farmers should use hybrid seeds to grow crops	Karnal Jagran 28 April 2006: 15	April 2006					YES
	Media article	Farmers will have to raise production: Workshop involving scientists from eight countries concluded at CSSRI	Dainik Bhaskar Karnal Edition 28 April 2006: (section page number)	April 2006					YES
	Media article	Scientists discussed intensively: Program on reclaiming salt-affected areas continues until 2008	Punjab Kesari Haryana Ambala Edition 28 April 2006: (section page number)	April 2006					YES