Bringing Green Revolution to Eastern India: Experiences and Expectations

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Citation

Bringing Green Revolution to Eastern India: Experiences and Expectations. (Ed) Pathak H, Panda BB and Nayak AK (2019). ICAR-National Rice Research Institute, Cuttack, Odisha, 753006, India. pp 62+x.

Published by

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Cover and layout design

Sunil Kumar Sinha

May 2019

Printed by Print-Tech Offset Pvt. Ltd., Bhubaneswar 751 024, Odisha.

त्रिलोचन महापात्र, पीएच.डी.
एफ एन ए, एफ एन ए एस सी, एफ एन ए ए एस
सचिव एवं महानिदेशक
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FOREWORD

Rice is the staple food of around three billion people of the world. The demand of rice is expected to rise globally as the population increases. India currently produces about 112 million tons of milled rice. Country's population is expected to be 1546 million by 2030 and 1824 million by 2050. To meet the demand of the increased population, rice production has to be increased to 123 million tons in 2030 and 140 million tons in 2050. Productivity of rice has to be increased substantially to meet the growing demand of domestic market and export.

The Green Revolution during 1960's transformed Indian agriculture from traditional to intensive practices backed up by modern technologies for increasing the productivity. The Program was mainly designed to meet the food crisis of post-independent India. The area covered under the Green Revolution was, however largely confined to Punjab, Haryana and western Uttar Pradesh. Due to several reasons the program, however, could not have great impact on eastern and north-eastern states of the country. In the year 2010, Govt. of India, on the basis of recommendation of the Planning Commission Task-force, therefore launched the Bringing Green Revolution to Eastern India (BGREI) Program in seven eastern states namely Assam, Bihar, Chhattisgarh, Jharkhand, Odisha, Eastern Uttar Pradesh and West Bengal to augment the productivity of rice and wheat. The Program was implemented successfully with involvement of state departments, research institutes and universities located in the region. ICAR-National Rice Research Institute, Cuttack, Odisha was the nodal Institute to provide technical backstopping to the program.

This technical bulletin on "Bringing Green Revolution to Eastern India (BGREI): Expectations and Experiences" published by ICAR-National Rice Research Institute assesses the impacts of the Program on production and productivity in the region. It also analyses the critical constraints and provide useful suggestions for further improvement of the Program.

I hope the bulletin will be a useful for the policy makers, extension personnel, researchers, scholars and students involved in agricultural development in eastern India. I congratulate the editors and authors for their contributions in bringing out this useful publication.

(**T. Mohapatra**)

PREFACE

The Green Revolution brought a significant increase in the production and productivity of food grains in our country leading to self-sufficiency. Green revolution was a package program that comprised of improved varieties along with enhanced resource or input use particularly water, nutrient and pesticides. However, the fruits of green revolution were mostly restricted to some resource-endowed farmers of the well-irrigated states like Punjab, Haryana and Western UP. Eastern states having tremendous natural resources could not reap the benefits of the package program. Though the food grain production increased many folds and the country harvested more than 110 tons of rice in the initial years of 21st century, occurrence of a massive drought in the year 2009-10 in Eastern Indian states reduced the production and productivity drastically indicating the vulnerability of food production system in the country to natural calamities. On the backdrop of this, Government of India initiated a unique national program "Bringing Green Revolution to Eastern India" (BGREI) to bring in a quantum jump in production, particularly in rice, the staple food of Eastern India. The program was initiated as a part of the RKVY project with the seed capital of Rs. 1000 crores in this year 2010. Since then seven eastern states have been funded through BGREI Program to improve the productivity and bringing stability in production.

The ICAR-National Rice Research Institute was identified by the Government of India as the Nodal Institute and was assigned the duty of providing the technological backstopping and monitoring. The Program was having three major components i.e., block/cluster demonstrations of improved production technologies of rice, asset building and site-specific activities. Initially the cluster demonstrations were conducted based on ecology but subsequently changed to technology-based demonstrations. The new high yielding varieties developed along with the improved production technologies were popularized through the Program. However, in the later part of the Program four new components like seed production and distribution, need based input use, marketing support & post-harvest management and cropping system-based approach was introduced to enhance productivity. In the process, convergence of extension functionaries and research scientists brought a significant change in the implementation of the Program. The Program has made some tangible impact on area, production and productivity in the implementing states. Keeping this in view, the technical bulletin "Bringing Green revolution to Eastern India: Experiences and Expectations" is brought out to share the progress with the stakeholders and policy makers of the BGREI states for further improvement in the Program.

The objectives of the bulletin are to assess the impact of BGREI on 1) state area, production and productivity, 2) improvements in irrigation facility, 3) farm mechanization, 4) Storage structures and marketing facilities developed, and 5) constraints faced and suggestions for further improvement of the program.

This bulletin includes one introductory chapter covering the background and inception of the program and seven chapters on the status of the BGREI program, one each in respective BGREI states. Each of these chapters comprises of a brief agricultural situation of the state, major crop based technological interventions, asset building and site specific activities, coverage of area under demonstration, trends in area, production and productivity in the state, a comparative advantage of BGREI years over pre-BGREI years, a brief analysis of the

results/achievements, limiting factors and suggestion to overcome the constraints for further improvement of the program.

In the course of preparation of this bulletin the authors and editors have received help from different individuals. Authors are extremely grateful to all of them. Authors sincerely thank the guidance and encouragement received from Dr. T Mohapatra, Director General, ICAR and Secretary DARE, Former CSC Member and Director, ICAR – NRRI for proper implementation of the Program. Thanks are due to Shri R Agarwal, Secretary, Dr. B Rajender, Joint Secretary (crops), Dr. SK Malhotra, Agriculture Commissioner, Dr. SS Tomar, Additional Commissioner, Dr. MN Singh, Deputy Commissioner, DAC & FW for their guidance and financial support for execution of the Program. Thanks are also due to the Principal Secretaries, Director of Agriculture of BGREI states Assam, Bihar, Chhattisgarh, Jharkhand, Odisha, Uttar Pradesh and West Bengal for smooth execution of the planned activities in the state. Authors are also grateful to the previous CSC member and Directors of ICAR-NRRI, Dr. TK Adhya, Dr. ON Singh, Dr. AK Nayak who have guided us for proper functioning and technical advancement in the BGREI Program. Authors also thank all the NLMT and DLMT members, scientists, state department officials involved in the Program for providing their inputs for bringing out this technical bulletin.

We hope that this publication would be helpful to the policy makers, planners, researchers, extension functionaries, administrators, farmers and students associated with agricultural development of the BGREI states.

Editors

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Executive Summary

Bringing Green Revolution to Eastern India (BGREI), a mega-Program of Government of India was started in 2010-11 to make short- and medium-term recommendations for efficient management of water, energy and other inputs to maximize agricultural production on a sustainable basis in the seven Eastern Indian states namely Assam, Bihar, Chhattisgarh, Jharkhand, Odisha, Eastern Uttar Pradesh and West Bengal. This Program was intended to address the constraints limiting the productivity of "Rice-based Cropping Systems" in Eastern India and also to enhance and stabilize crop productivity. The farmers were exposed to modern technologies with adequate technical backstopping from research Institutes during this program to attain higher skills and economic empowerment. The Program was implemented by the states with technological support from the ICAR-National Rice Research Institute and State Agricultural Universities for the last eight years and during these years a lot of progress has been made in these states on productivity improvement, creation of irrigation facilities, marketing yards, storage structures and farm mechanization. The achievements of the Program in different states have been summarized in this chapter.

Rice cultivation is the principal activity and source of income for about 2.72 million farm families in Assam. Rice is the dominating crop of the state, which occupies around 89.29 % of the gross cropped area, but productivity is less than the national average. The BGREI Program has been implemented in state of the Assam with an objective to enhance production and productivity of rice along with the cropping intensity in rice mono cropped areas. Interventions like line transplanting, system of rice intensification, stress tolerant varieties (Swarna Sub-1 and Sahbhagi Dhan), hybrid rice (Sahydri 4, NPH-924-1) and rice-pulse cropping system were demonstrated in 47,971 ha area of Assam during 2017-18. Demonstration on hybrid varieties recorded the highest (66.2%) increase in yield against the conventional practice (3.80 t ha^{-1}). About 14.2% of the total rice cultivated area of the state has been covered under the cluster demonstration activity. Rice cultivated area in Assam has shown a slightly declining trend from the year 2009-10 to 2017-18 whereas production and productivity of rice showed an increasing trend during this period. Consequent to implementation of BGREI Program in the state of Assam, the average rice productivity increased from 1.59 t ha^{-1} during pre BGREI period to 2.03 t ha^{-1} during last three years of the Program but the highest productivity of 2.11 t ha^{-1} was achieved in the year 2017-18. Creation of awareness, sensitization, skill improvement and refreshers training for agricultural officers and crop managers with latest innovations for advance planning and timely execution of program at field level help further in brining green revolution in the state of Assam.

In the state of Bihar about 15.7% of the total rice cultivated area has been covered under different demonstrations using various interventions since the inception of the BGREI Program. Rice yield has increased significantly with the implementation of different interventions as compared to the conventional practice. SRI and hybrids performed better with 38.8 and 25.7% increase in the rice yield, respectively, over the farmers' practice. Rice area in the state did not change much during the BGREI Program years; however, there was a wide variation in the production, which is correlated to the occurrence of rainfall in the state. Higher production has mainly achieved due to the productivity enhancement.

The BGREI Program in Chhattisgarh includes cluster demonstration of technologies on rice and wheat, asset building and creation of irrigation facilities with the objective to increase production and productivity of these crops. In rice 14% area has been covered by BGREI demonstrations till date. The BGREI demonstrations have played a major role in improvement

of rice productivity in Chhattisgarh from 1.2 t/ha in 2011-12 to 2.1 t ha^{-1} in 2016-17. Based on the crop cutting data of 2015-16 and 2016-17, higher yield advantage (63.0%) was observed under cropping system based demonstrations compared to the control followed by SRI (31.0%) and direct seeded rice (25.5%). However, SRI and hybrid rice technologies have shown major impact among BGREI components due to the area expansion during the BGREI period. Site specific activities especially check dam and small irrigation ponds built under BGREI Program has brought around 30,000 ha area under irrigation. Hybrid maize technology has been found promising for adaptation in low productive upland rice area of Chhattisgarh. However, the productivity of the state depends more on the rainfall during the crop growth period. The rice yield was reduced significantly in 2017-18 with moisture deficiency in BGREI districts. A state-program on production and distribution of seeds of recommended stress tolerant varieties for unfavorable ecology was suggested to increase the productivity of rice in the state.

Jharkhand was affected by conjugative droughts five times from 2001 to 2010 and food grain productions were low in drought years. The average productivity of paddy, the principal crop of Jharkhand, was 1.4 t ha^{-1} and 1.1 t ha^{-1} in 2004-05 and 2005-06, respectively. The state faced a rainfall deficit of approximately 47 % in 2010 and consequent to that one million hectares of land could not be brought under paddy cultivation and total food grain production decreased by half; average paddy productivity in 2010-11 was 1.5 t ha^{-1}. This added to the food grain deficit, the state faced even during the normal rainfall year. A strategic initiative 'Bringing Green Revolution in Eastern India' (BGREI) to develop high potential Eastern Region of the country for food grain production was initiated in the year 2010-11. The Program has been implemented since then with the objective to increase the productivity of rice based cropping system through promotion of recommended agriculture technology and package of practices by addressing the underlying constraints of different agro-climatic sub-regions. The Program includes a bouquet of three broad categories of interventions, viz., Block demonstrations of rice and wheat, asset building activities for water conservation and utilization. Block demonstration of rice, each of 1000 hectares was suggested to be implemented in five agro-ecological sub-regions namely rainfed uplands, rainfed low lands (shallow low land, medium, deep water) and irrigated rice (traditional, hybrid). The objective of the demonstration was to improve seed replacement rate (SRR), promote line sowing/ planting coupled with promotion of plant nutrient and plant protection technologies.

Rice is the major food crop covering about 63% of the total area under food grains. It is the staple food of almost the entire population of Odisha; therefore the state economy is directly linked with improvements in production and productivity of rice in the state. Rice is grown in all the possible ecologies but having a low productivity due to limitation of many production factors. Bringing Green Revolution to Eastern India (BGREI) program introduced in 2010-11, was implemented in 22 non-NFSM districts to enhance the rice productivity. The state demonstrated different improved production technologies through cluster demonstrations. The state has till date covered 3.95, 33.20, 23.20, 39.0, 32.83 and 23.35 lakh hectares in direct seeded rice (DSR), line transplanting (LT), system of rice intensification (SRI), stress tolerant variety (STV), hybrids and cropping system based (CSB) demonstrations respectively which is about 13.5 % of the total rice area of the state. Improved HYVs i.e., Ranidhan, CR Dhan 601, DRR 42, Sahbhagi Dhan, Swarna sub 1, Varsadhan, MTU 1010, Chandan, Kalajeera, Ketakijoha, DRHR 2, CR Dhan 70, Improved Samba Masuri and hybrids i.e., Ajaya, Arize 6444 have been already popularized. Besides, more than 50,000 Shallow tube wells (STWs), bore wells and dug wells and 122 water harvesting structures and lift irrigations have been created to augment the irrigation facility. Similarly farm mechanization

was advanced in the state by distribution of 16,193 farm machineries among beneficiary farmers. The overall increase in yield was 37.79% in the state by practicing improved production technologies like DSR, LT, STV and CSB Demonstration plots compared to control plots. The Program made a visible impact on the state productivity. The average productivity during the latest three years (1.81 t ha^{-1}) of BGREI Program was 12.65% higher compared to the average productivity of three pre-BGREI years (2007-08 to 2009-10) i.e., 1.60 t ha^{-1}.

Agriculture is the leading occupation in Uttar Pradesh. Uttar Pradesh has accounted for 19 % share in the country's total food grain output. To increase the agricultural productivity in fourteen district of eastern UP, BGREI program was implemented in 2010-11 with cluster demonstrations of improved rice production technologies. Under direct seeded rice 1800 ha, line transplanting 7050 ha, SRI demonstration 300 ha, stress tolerant varieties 7200 ha area has been demonstrated. The hybrid rice demonstration has already been demonstrated in 7067 ha area whereas under cropping system based demonstration, 4473 ha has been demonstrated. The state had also produced 75.0 tons of certified seeds of HYVs not older than 10 years and distributed about 334.7 tons of hybrid seeds and 284.8 tons of certified seeds among farmers. Besides, about 156 pump sets, 104 rotavators, 82 multi crop threshers, 15 pump sets, 46 tractor driven multi crop threshers were distributed to the farmers under asset building activities.

The BGREI Program was also started in West Bengal in 2010-11 to address the constraints limiting the productivity of rice-based cropping system comprising eleven districts. Rice yield and income of the farmers showed an increasing trend since the inception of the BGREI Program. Frequent visits by scientists and extension officers were made and awareness meetings were conducted during implementation of the program, in both the seasons. Under this program, cluster demonstrations on rice was conducted in 8.36 lakh ha area. About 18100 tons of certified HYV Paddy seed was produced. Micronutrients (Zn and B) and bio-fertilizers were distributed for 381438 ha and 226668 ha, area respectively. About 2.53 lakh ha and 2.52 lakh ha area were covered under distribution of plant protection chemicals including bio-pesticides and herbicides, respectively. About 1.95 lakh of different types of farm machineries were distributed to beneficiaries under this program. Regarding site-specific activities, about 10954 nos. of different irrigation related structures/works in target districts and 46758 nos. of different paddy processing yards and grain storage structures were also made. Total 3057 number of cropping system based trainings were organized up to 2017-18 under this program. Since inception of BGREI, almost 100% physical performance has been achieved utilizing 1025.61 crore (99.8% of financial allocation).

All the BGREI states has made a lot of progress in improvement of production and productivity of rice through introduction of improved production technologies, farm mechanization, creation of irrigation facilities and reducing post harvest loss with construction of processing yards and storage structures in the BGREI districts. Though some of the states reached the national average, still other states are lagging behind due to inherent problem of traditional stand establishment methods, poor exploitation of water resources and frequent occurrence of natural calamities like flood and droughts. Therefore, the low productivity eastern Indian states such as Odisha and Chhattisgarh may be given priority for further improvement in the rice productivity in the country.

Bringing Green Revolution to Eastern India: Genesis, Objectives and Implementation

H Pathak, AK Nayak and BB Panda

The National Program of "Bringing Green Revolution to Eastern India (BGREI)" is the outcome of the recommendations of the Task-Force constituted by Government of India in pursuance of the decision taken in the meeting of the Committee of Secretaries held on November 29, 2009 to make short- and medium-term recommendations for efficient management of water, energy and other inputs to maximize agricultural production on a sustainable basis. The Task-Force was *inter-alia* ascribed to assess the existing scenarios of water resources development, utilization and management of foodgrain production in Eastern Indian states namely Assam, Bihar, Chhattisgarh, Jharkhand, Odisha, Eastern Uttar Pradesh and West Bengal. This Program was intended to address the constraints limiting the productivity of "Rice-based Cropping Systems" in Eastern India so that crop productivity is reasonably enhanced and stabilized. The farmers were exposed to nascent technologies through this Program with adequate technical backstopping from research institutes to attain higher skills and economic empowerment.

Accordingly, the "Bringing Green Revolution to Eastern India (BGREI)" Program was initiated in 2010-11 to address the constraints limiting the productivity of rice-based cropping systems in Eastern India comprising of seven states with the following objectives.

1. To increase production and productivity of rice and wheat by adopting latest crop production technologies;
2. To promote cultivation in rice fallow area to increase cropping intensity and income of the farmers;
3. To create water harvesting structures and efficient utilization of water; and
4. To promote post-harvest technology and marketing support.

The following strategies were adopted to achieve the objectives.

1. To promote improved production technologies of rice including popularization of newly released high yielding cultivars and hybrids;
2. To bring rice fallow areas under cultivation through cropping system based approach;
3. To popularize adoption of stress tolerant varieties;
4. To create irrigation structures such as farm ponds and lift irrigation to improve irrigation potential;
5. To promote use of farm machineries and implements suitable for small land holding sizes;
6. To create infrastructure such as go down, procurement centre and marketing infrastructure;

7. To provide technical backstopping by scientists of ICAR-NRRI, SAU and other ICAR institutions to implement the Program.

During 2010-11, major focus of the states was on promotion of improved crop production technologies of major crops, water harvesting measures and their utilization for overall agriculture development. In the subsequent years 2011-12 and 2012-13, the program provided a more focused approach on medium and long-term strategies for asset building activities of water conservation and utilization along with short-term strategies pertaining to transfer of technology of major cereals. During 2013-14, based on the experience of last three years of implementation of the program, marketing support including post-harvest management was included as an intervention. Various improved production technologies were introduced in the subsequent years.

Accordingly, the BGREI comprised of nine broad categories of interventions such as (i) cluster demonstrations of major production technologies like direct-seeded rice, line transplanting, system of rice intensification (SRI), stress tolerant varieties and hybrids and cropping system-based demonstrations in farmers field; (ii) production of certified seeds; (iii) distribution of certified seeds; (iv) nutrient management and soil ameliorants like micronutrients, lime, bio-fertilizers and gypsum to improve the soil fertility; (v) integrated pest management including chemicals and bio-pesticides/bio-agents and herbicides; (vi) asset building activities like construction of shallow tube wells / bore wells / dug wells, pump sets, tractor drawn zero drill seed cum fertilizer drill, threshers, power tillers, cono-weeders, tractors, translators, and threshers; (vii) site-specific activities for facilitating petty works such as construction/renovation of irrigation channels/electricity for agricultural purposes in a cluster approach for convenience and cost effectiveness; (viii) post-harvest management and marketing support including storage, processing, transportation and marketing; and (ix) cropping system-based trainings to enhance the knowledge of the farmers. Under the BGREI Program, adoption of new varieties, farm machines and implements, nutrients, pesticides and knowledge-based interventions are being promoted in different agro-climatic zones of eastern Indian states.

Provision of funds for implementing the Program was made in the Union Budget under *Rashtriya Krishi Vikas Yojna* (RKVY). The approval of action plan of each state is finalized by the GOI in consultation with the states. The action plan so approved by GOI is approved by State Level Sanctioning Committee (SLSC) on the pattern of RKVY for issue of GOI administrative and financial sanction and subsequent release of funds to state.

To review the implementation of the Program at national level a Central Steering Committee was constituted under the Chairmanship of Secretary (A&C) with Deputy Director General, ICAR; Additional Secretary (Seeds and RKVY); Commissioner (Water Resources); Agricultural Commissioner and Director, ICAR-NRRI as members and Joint Secretary (Crops) as Convener. The Committee was mandated to provide suggestion for improvement in the structure of interventions and to resolve various inter-ministerial issues. For each of seven BGREI states, a State Steering Committee (SSC) was set up under the Chairmanship of Agriculture Production Commissioner/Principal Secretary (Agriculture) to review the Program, finalize State Action Plan in consultation with ICAR/SAUs and monitor the progress of technical backstopping by NRRI/SAUs/ICAR Institutes. The function of this committee is to sort out different inter departmental issues affecting crop production. A District Steering Committee is constituted under Chairmanship of District Magistrate/Chief

Development Officer to prepare District Action Plan on the basis of previous experiences, the BGREI guidelines and latest technology, to arrange timely delivery of inputs to the identified beneficiaries of the program, to ensure quality control of inputs, to release incentives to beneficiary farmers and input suppliers, to liaise with NRRI/SAUs for ensuring and facilitating technical backstopping.

A National Level Monitoring Team (NLMT) was constituted for each state for monitoring the activities of the Program. The team visited different states at least once in a crop season and submits the report to Agriculture\Production Commissioner of the state; Joint Secretary (Crops) and Director, Directorate of Rice/Development (DRD), Patna. National Consultant (BGREI) was assigned to present the consolidated report to Agriculture Commissioner, GOI. A District Level Monitoring Team was set up under the Chairmanship of District Agriculture Officer. The team visited thrice in a crop season and submits the report including crop-cutting data to Director of Agriculture of respective states.

ICAR-National Rice Research Institute (NRRI), Cuttack is the nodal technical institution to supervise, guide and improve the quality of the interventions. It organizes scientific documentation of various interventions as approved in the strategic action plans. A consolidated report is submitted by ICAR-NRRI by every 1st week of the month and a final quarterly report submitted by them to the CSC following structured proforma. ICAR-NRRI prepared the proposal for mobility, contingencies and other project specific needs by identifying the partner institutions in each BGREI state and its scientists assigned for the project.

The BGREI Program was implemented in 149 districts across seven states in Eastern India till date. From the financial year 2014-15, about 118 non-NFSM districts are being covered under the program in seven states i.e., Assam (14 districts), Bihar (23 districts), Chhattisgarh (14 districts), Jharkhand (20 districts), Odisha (22 districts), Eastern Uttar Pradesh (14 districts) and West Bengal (11 districts). NRRI provides the technological backstopping to the Program involving 127 scientists from 2 ICAR Research Institutes and 11 Agricultural Universities of states. About 497 man-days were spent for technical backstopping of the Program. Rice varieties i.e Swarna sub-1, Sahbhagi Dhan, JKRH-3333, RHR-111, PSC-785, DRRH-7, CRH-5, KRH-7 and NPH-924 in Assam; Rajendra Bhagawati, Arize-6444, 27P31, Sahbhagi Dhan, Rajendra Mahsuri and PHB-71 in Bihar; Swarna Sub-1, Indira Barani dhan-1 Vishnu bhog, Sahbhagi Dhan, CO-4, Arize-6444 Gold, Sayadri-4 and US-312 in Chhattisgarh; IR 64 (DRT 1), PNPH 24, Sahbhagi Dhan and Abhishek in Jharkhand; Swarna Sub 1, Reeta, Naveen, Pratikshya, MTU 1001 in Odisha; NDR 8002, SHIATS Dhan 1, PA 6444, NRR 2064, PHB 71 and RH 1531 in Uttar Pradesh; Swarna sub 1, DRR 42, Sahbhagi Dhan, IR-36, MTU 1010, PD 18, Rajendra Masuri, PAN 802, PAC 8744 in West Bengal has already been popularized under the Program.

The major production technological interventions i.e., direct-seeded rice (50663.6 ha), line transplanting (1.43 lakh ha), system of rice intensification (2.22 lakh ha), stress tolerant varieties (2.65 lakh ha), hybrids (3.85 lakh ha), HYVs (8.18 lakh ha) and cropping system based management (2.14 lakh ha) were made through cluster demonstrations under the program in the seven eastern Indian states from 2010-11 to 2017-18. Likewise about 4.62 lakh ha area was demonstrated with improved management practices under wheat crop. The total area covered under cluster demonstrations of improved production technologies of rice till 2017-18 varied from 7.1% in Eastern UP to 20.4% of the total rice area of the BGREI

states. Total area under demonstration has increased from 0.5-1.0% to 2.5-3.5% in different states by 2017-18.The average yield increase in direct seeded rice, line transplanting, system of rice intensification, cropping system based demonstration, stress tolerant varieties demonstrations were to the tune of 31.28, 24.89, 26.54, 23.35 and 25.94% respectively over farmers practice in Odisha whereas 28.02, 30.09, 34.97, 28.59 and 22.52%, respectively in Chhattisgarh. Besides, about 28.25% yield increase was achieved through demonstration of hybrids in Chhattisgarh.

Integrated pests management activity was taken up in 5.95 lakh ha out of which plant protection chemicals and bio-pesticides/bio-agents in 3.71 lakh ha and herbicides use in 2.24 lakh ha area. Besides, 7.62 lakh ha of rice demonstrations were covered with application of micronutrients in 5.05 lakh ha, lime in 7217 ha, gypsum in 7.69 lakh ha and biofertilizers in 2.42 lakh ha till 2017-18.Under asset building activity, total 7.62 lakh of implements were provided to the beneficiary farmers. About 2721 seed drills, 226 drum seeders, 13655 rotavators, 835 self-propelled paddy transplanter, 2.43 lakh of pumpsets, 39870 cono-weeders, 37 laser land leveler, 334 reapers, 690 MB ploughs, 504 leveler blade, 170676 manual sprayers, 15190 Power knapsack sprayers, 73 power weeder, 5928 paddy thresher, 4087 multi crop thresher, 106 tractors, 18 tractor operated rubber roller sheller, 1275 check dams and Lift Irrigations were constructed, 6666 paddy weeders, 6666 paddy transplanters, 3582 reaper-cum-binder and 5972 8-BHP capacity power tillers were distributed through the program since inception. Besides, 56407 bore wells and dug wells and 131366 shallow tube wells were also created under this activity for irrigating the crop. About 51430 hybrid maize seed minikits were distributed.

Under site specific activities, 164 minor irrigation tanks, 347 water harvesting structures, 428 community cluster bore well, 125 pucca irrigation channels were constructed and 940 pucca check dam were constructed for irrigating the crops. Besides, 2.43 lakh meter of PVC pipes were provided for carrying water to crop fields. Under post-harvest & marketing support, 89 mini rice mills, 2210 godown/storage structures, 519 pucca threshing floors, 1861 house hold level paddy processing yards (HPPU), 2806 community paddy stacking yards, and 51 community drying platforms were constructed. About 7232 cropping system-based training programs were conducted for the farmers in eastern Indian states. These farm equipments have already sown the seeds of revolution for small farm mechanization. This needs to be nurtured in time to come to ensure reducing the cost of production, productivity enhancement and bringing resilience against the climate change. The small mechanization will fuel the growth of rural industry in term of repair maintenance of these machineries ensuring the growth in employment.

Bringing Green Revolution to Eastern India: Experiences and Expectations in Assam

R Bhagawati, K Saikia, KB Pun and N Medhi

Summary

The economy of Assam is mainly agrarian with agriculture and allied activities contributing about 20 percent to the state's net domestic product and providing livelihood support to about 33.82 million rural poor population of the of the region. Though rice is the dominating crop of the state that occupies around 89.29 % of the gross cropped area, productivity is less than the national average. The BGREI Program has been implemented in state of the Assam with an objective to enhance production and productivity of rice along with the cropping intensity in rice mono cropped areas. Cluster demonstrations, production and distribution of rice seeds, nutrient management and soil ameliorations through micro-nutrients and bio fertilizers and integrated pest management were the major component of BGREI program implemented in Assam. Besides these, assistance has been provided for procurement of farm machineries and implements like rotavator, manual and power operated sprayers, power weeder, tractor driven paddy thresher and power tiller to enhance in productivity of rice in the state and modern compact rice mill to improve post-harvest activities and enhance marketing. Community threshing floor with facilities like thresher machine and drier has been given to help farmers in carrying out post-harvest activities easily and quickly. Line transplanting of rice, system of rice intensification, stress tolerant varieties (Swarna Sub-1 and Sahbhagi Dhan), hybrid rice (Sahydri 4, NPH-924-1, RHR-111, Arize 6444, CRHR-5, VNR 2355, NK 5231 and PNPH-24) and rice-pulse cropping system were demonstrated in 47,970.7 ha area of Assam during 2017-18. Demonstration on hybrid varieties recorded the highest 66.17 % increase in yield against the conventional practice (3.80 t ha^{-1}). Other demonstrations like line transplanting, stress tolerant varieties and cropping sequence based demonstration also recorded higher yield as compared to control. The BGREI Program was started in the year 2010-11 and over the years about 14.23% of the total rice cultivated area of the state has been covered under the cluster demonstrations. Rice cultivated area in Assam shown a slightly declining trend from the year 2009-10 to 2017-18 and production and productivity of rice showed an increasing trend during this period. Before implementation of BGREI Program in the state of Assam, the average rice productivity was 1.59 t ha^{-1} and implementing BGREI Program in the state has significantly increased the average rice productivity to 2.03 t ha^{-1} during last three years and recorded the highest productivity of 21.07 q/ha in the year 2017-18. It is felt necessity to create awareness, sensitization, skill improvement and refreshers training courses with latest innovations designed for different levels of Agricultural officers within the state of Assam. Besides, advance planning and timely execution of the program at field level will help in brining green revolution in the state.

1. State background

Assam is an evergreen beautiful state of India. The Brahmaputra and the Barak rivers with 121 small to medium tributaries keep the state fertile. Total geographical area of the state is 78,439 km^2, which is being administrated in 33 districts (Fig. 1). The economy of

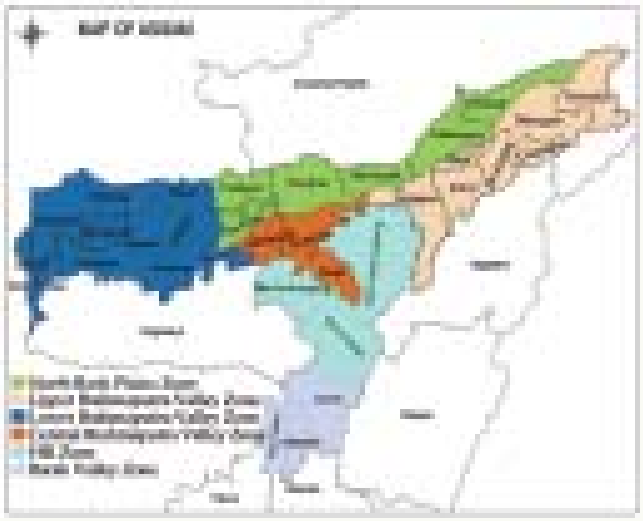

Fig. 1. Map of Assam.

Assam is mainly agrarian with agriculture and allied activities contributing about 20% to the state's net domestic product and providing livelihood support to about 75% of the population of the region. Rice is the dominating crop of the state occupying around 90% of the gross cropped area. Among the cash crops, sugarcane and jute occupy a substantial area. In horticulture, banana, pineapple and citrus are the major fruit crops while potato, various cole crops, cucurbits, okra and diverse leafy vegetables are the major vegetable crops. Productivity of the major crops like rice, pulses, and oilseeds is still much lower in Assam compared to the national average. Agriculture in Assam is characterized by mono-cropping, mostly small holdings low input-low output and subsistence farming systems practiced primarily under rainfed condition.

Assam can be broadly divided into three distinct physiographic units: the plains, the plateau and the hills with the plains of Brahmaputra and Barak valleys being the main area for agricultural development. The typical characteristic feature of Assam soils is its acidity (pH ranging from 4.2 to 5.8). High humidity and seasonal pattern of rainfall and temperature are important features of Assam climate with rainfall being the most important determinant factor for the climate. Rainfall distribution follows a typical monsoon pattern with peak precipitation during monsoon (June-September) and scanty rainfall in winter (December-February). Based on variation in rainfall, physiography and soil characteristics, the state has been divided into following six agro-climatic zones (Table 1).

Table 1. Agro-climatic zones of Assam.

Agro-climatic zones	Districts
North Bank Plains Zone	Darrang, Dhemaji, Lakhimpur, Sonitpur, Biswanath, Udalguri
Upper Brahmaputra Valley Zone	Dibrugarh, Tinsukia, Sivsagar, Charaideo, Jorhat, Majuli, Golaghat
Lower Brahmaputra Valley Zone	Kamrup Metro, Kamrup (Rural), Nalbari, Baksa, Barpeta, Bongaigaon, Chirang, Kokrajhar, Goalpara, South Salmara, Dhubri
Central Brahmaputra Valley Zone	Marigaon, Nowgaon, Hojai
Hill Zone	KarbiAnglong East, KarbiAnglong West, Dima Hassao
Barak Valley Zone	Cachar, Hailakandi, Karimganj

There is a slight variation of climate from region to region within the State. The Lower Brahmaputra Valley Zone of Assam is characterized by plentiful rains and foggy winter. The cold season in this region is from December to February and this is followed by the sand-storms and thunderstorms from March to May. The rainy season, as in rest of Assam begins in late June and continues up to late September. October and November constitute the post-monsoon period. In Lower Brahmaputra Valley Zone of Assam, the day temperatures in April and May are nearly the same as in the monsoon months. The climate of the Barak Valley districts is characterized by abundant rainfall, moderate temperatures and high humidity. The climate of the Central Brahmaputra Valley and North Bank Plain Zone are characterized by the absence of a dry hot summer season, the highest temperature being experienced during the period of south west monsoon along with abundant rains and a humid atmosphere throughout the year. The climate of the Upper Brahmaputra Valley is somewhat identical to North Bank Plains Zone of eastern Assam.

2. Major interventions through BGREI

2.1.1 Cluster demonstrations: Cluster demonstrations, production and distribution of rice seeds, nutrient management and soil ameliorations through micro-nutrients and biofertilizers and integrated pests management were major component of the BGREI Program implemented in state of the Assam to enhance production and productivity of rice. Demonstration on Line transplanting, system of rice intensification, stress tolerant varieties (Swarna Sub-1 and Sahbhagi Dhan), hybrid rice (Sahydri 4, NPH-924-1, RHR-111, Arize 6444, CRHR-5, VNR 2355, NK 5231 and PNPH-24) and rice - pulse cropping system were the major interventions in the state to enhance production and productivity of rice along with the cropping intensity in rice mono-cultured areas.

Asset building and site-specific interventions: Asset building intervention includes assistance for procurement of farm machineries & implements like rotavators, manual and power operated sprayers, power weeder, tractor driven paddy thresher and power tiller. Assistance has been provided for procurement of Power tiller (8 BHP and above) under the component of Site Specific Activities to SC, ST, small and marginal and women farmers of Assam with the objective of enhancing the productivity of rice in the state. Modern compact rice mill with a milling capacity of 300-500 kg/hour (7-10 HP motor) has been provided with a financial assistance of 60% of the cost limited to 1.5 lakh to improve post-harvest activities and enhance marketing. Community threshing floor with facilities like thresher machine and drier has been created to help farmers in carrying out post-harvest activities easily and quickly.

3. Areas of demonstrations

The BGREI Program was started in the year 2010-11 and over the years about 14.23% of the total rice cultivated area of the state has been covered under the cluster demonstration activity.

Table 2. Rice area of Assam State vis-à-vis area covered in the BGREI.

Rice area (lakh ha)	Area covered under BGREI demonstration (lakh ha)							Cumulative BGREI demonstration area (lakh ha)	Area covered under BGREI demonstration (%)
	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18		
24.51	0.41	0.56	0.38	0.72	0.41	0.53	0.48	3.49	14.23

4. Trends in area, production and productivity of rice since 2009-10

Rice cultivated area in Assam has shown a slightly declining trend from the year 2009-10 to 2017-18 (Fig. 2). Production of rice in the state showed an incremental trend during this period. Rice productivity of the state was 1.74 t ha^{-1} in 2009-10 and showed an increasing trend in the successive years and recorded the highest productivity of 2.11 t ha^{-1} in the year 2017-18

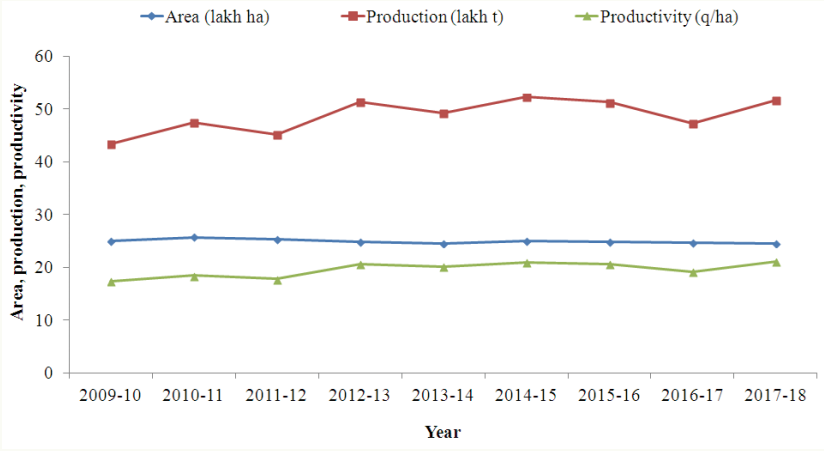

Fig. 2.Trend in area, production and productivity of rice from 2009-10 to 2017-18.

5. Effects of the BGREI interventions

Interventions *viz.*, line transplanting, SRI, stress tolerant varieties, hybrid varieties and productive cropping systems were demonstrated in 47,970.7 ha area under BGREI in Assam during 2017-18. Effects of the technologies on the yield of the rice crop were evaluated through crop cuttings in the demonstration and control plots under the

conventional practice in the farmer's fields. Demonstration on hybrid varieties recorded the highest 66.17 % increase in yield against the conventional practice (3.80 t ha^{-1}) (Table 3). Other demonstrations like line transplanting, stress tolerant varieties and productive cropping systems also recorded higher yield compared to control.

Table 3. Performance of interventions in Assam (2017-18).

Name of the demonstration	Area covered (ha)	Yield in demonstration plot (q/ha)	Yield in control plot (q/ha)	Increase in yield (%)
Line transplanting	3682	49.99	41.39	20.77
SRI	1413	-	-	-
Stress tolerant varieties	16153	51.78	40.96	26.39
Hybrids	6069	63.13	37.99	66.17
Cropping system based interventions	20654	48.58	43.00	12.99

6. Production and Productivity Comparison of BGREI and Pre BGREI Years

Before implementation of BGREI Program in the state of Assam the average rice productivity was 15.93 q/ha and implementing BGREI Program in the state has significantly increased the average rice productivity to 20.28 q/ha during last three years.

Table 4. Area, production and productivity of rice in Assam during Non-BGREI and BGREI years.

Parameters	Non-BGREI years (2007-08 to 2009-10)	BGREI years (2015-16 to 2017-18)
Area ('000 ha)	2434.3	2467.7
Production ('000 t)	3887.3	5005.4
Productivity (t ha^{-1})	1.59	2.03

Assam receives around 1500 mm of annual rainfall and rainy season mark the most of the months of a year (Table 5). Rain showers erratically in the summer months between March and June. However, the state witnesses exceptionally higher monthly rainfall of 437.4 mm in the month of April in the year 2017 (Fig. 5). Monsoon arrives in the later part of June month and the intensity of rainfall usually crosses the extent and leads to natural catastrophes like floods in the state. Such heavy precipitation lasts till the month of September. From late-October to late-February, winter season exists in the state marked by low temperature and scanty rainfall. Spring and autumn seasons continue to carry moderate temperatures and less rainfall in Assam.

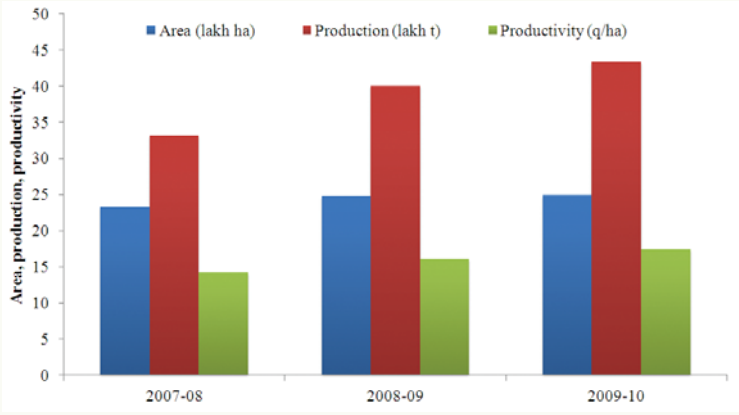

Fig. 3. Area, production and productivity of rice in Assam in pre-BGREI period.

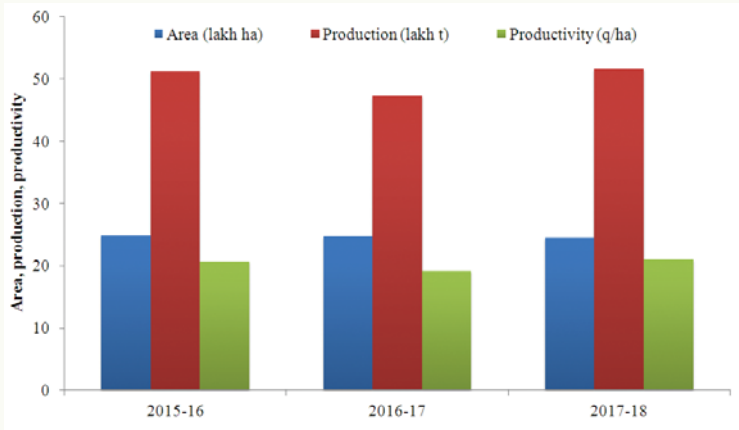

Fig 4. Area, production and productivity of rice in Assam during BGREI period.

Table 5. Rainfall pattern of Assam during the last ten years.

Month	Rainfall (mm)	Rainy days (No.)
January	6.70	1
February	13.44	1
March	56.66	4
April	229.88	11
May	251.71	13
June	317.05	11
July	182.73	10
August	209.21	9
September	165.11	7
October	58.99	2
November	3.82	0
December	4.51	1
Total	**1499.81**	**70**

7. Suggestions

- Proper planning and timely formulation of action plan and its implementation.
- Seeds should be distributed well ahead of the season. Late receipt of seed resulted in less adoption of demonstration.
- Varieties for demonstration should be selected as for land situation based on State Seed Sub Committee recommended. Swarna sub-1 should not be grown in all ecologies.
- Measures need to be taken for utilization of perennial water streams for irrigation in *rabi* rice.
- In villages three phase electricity connection is rare, hence in place of electrical rice mill diesel operated mill may be provided.
- Awareness, sensitization, skill improvement of agricultural officers through refreshers training courses with latest innovations should be designed within the state.

Average productivity of rice was 1.60 t ha^{-1} before implementation of the BGREI Program in the state of Assam but significantly increased to 2.02 t ha^{-1} (latest three years) on implementation of the BGREI Program. Demonstration on hybrid varieties recorded the highest (66.17%) increase in yield against the conventional practice (3.70 t ha^{-1}) in the state. Seeds should be distributed well ahead of the season as rainfall starts early in the state. Further, as three phase electricity connection is rare in the villages, in place of electricity, diesel operated mill may be provided through the program.

Bringing Green Revolution to Eastern India: Experiences and Expectations in Bihar

Md. Shahid and BB Panda

Summary

Eastern region is rich in natural resources conducive to higher productivity. However its potential could not be exploited for improving agricultural productivity, poverty alleviation and livelihood improvement. The BGREI Program came into inception to address the constraints limiting the productivity of "rice-based cropping system" in Eastern India comprising seven states which includes Bihar. The major focus is on the promotion of improved crop production technologies, water harvesting measures and efficient management of natural resources for overall agriculture development. Major interventions under BGREI are system of rice intensification, direct seeded rice by zero tillage/seed drill/drum seeder, cropping system-based demonstration, stress tolerant varieties, zero tillage wheat, distribution of seeds (HYVs and Hybrids), asset building and site-specific activities (includes assistance for farm machineries & implements). Since the inception of the BGREI Program in Bihar state about 15.7 per cent of the total cultivated area has been covered under different demonstrations using various interventions. Rice yield with different interventions increased as compared to the conventional practice. Rice area in the state didn't change much during the BGREI Program years; however, there is wide variation in the production, which ranged from 3.11 Mt in 2010-11 to 8.24 Mt in 2016-17. As there was less variation in the area, higher production is mainly attributed to the increase in the productivity.

1. State background

Bihar with a geographical area of about 94,200 km^2 is divided by the river Ganges into two parts, the north Bihar with an area of 53,300 km^2 and the south Bihar having an area of 40,900 km^2. Based on soil characterization, rainfall, temperature and terrain, four main agro-climatic zones in Bihar have been identified i.e., Zone-I: North Alluvial Plain; Zone-II: North East Alluvial Plain; Zone-III A: South East Alluvial Plain and Zone-III B: South West Alluvial Plain (Fig. 1). Zone I and II are flood prone whereas Zone III is drought prone. All these three zones have vast untapped potential for increasing the productivity of crops. The details of the agro-climatic zones are given in Table 1.

Fig. 1. Agroclimatic zone map of Bihar (Source: www.krishi.bih.nic.in).

Table 1. Name of the districts under each agro-climatic zone and important physiographic features.

Agro-climatic zones	Districts	Soil	pH	Total rainfall (mm)	Temperature (°C) Max.	Min.
Agro-climatic zone I (Northern West)	West Champaran, East Champaran, Siwan, Saran, Sitarnarhi, Sheohar, Muzaffarpur, Vaishali, Madhubani, Darbhanga, Samastipur, Gopalganj and Begusarai	Sandy loam, Loam	6.5-8.4	1040-1450 (1245)	36.6	7.7
Agro-climatic Zone II (Northern East)	Purnea, Katihar, Saharsa, Supaul, Madhepura, Khagaria, Araria and Kishanganj	Sandy loam, clay loam	6.5-7.8	1200-1700 (1450)	33.8	8.8
Agro-climatic Zone III A (Southern East)	Sheikhpura, Munger, Jamui, Lakhisarai, Bhagalpur and Banka	Sandy loam, clay loam	6.8-8.0	990-1240 (1115)	37.1	7.8
Agro-climatic Zone III B (Southern West)	Rohtas, Bhojpur, Buxar, Bhabhua, Arwal, Patna, Nalanda, Nawada, Jehanabad, Aurangabad and Gaya	Sandy loam, clay loam	6.8-8.0	990-1240 (1115)	37.1	7.8

Rainfall varies from 990 to 1700 mm in the state. Most of the rain is received during the month of July to September. There are three crop seasons: Kharif, Rabi and Zaid. Rice, wheat and pulses are grown in all the districts. Bihar has three types of soil i.e., montane, alluvium and marshy/ swampy soil of Tarai. Soil texture varies from sandy loam to heavy clay. However, the majority type belongs to loam category which is good for crop. Soil pH varies from 6.5 to 8.4. Being located between 25 to 27° North latitude, the climate of Bihar is of mostly sub-tropical. Nevertheless region close to Tropic of Cancer experiences tropical climate during summer. Bihar reels under hot summer season during months of March to June with average temperature are 35-40° C. April to June is the hottest months of the year. December to January is the winter season in Bihar. The winter in Bihar is mild with average temperature 5 to 10°C. Bihar gets its maximum rainfall during South-West monsoon season which prevails from June to September. Average rainfall of Bihar is around 1200 mm.

Bihar is endowed with rich natural resources: fertile soil, adequate water, both surface as well as ground, and favourable climatic conditions which offer opportunities for growing, variety of crops viz. grains, fruits, vegetables etc. These factors are also crucial higher productivity. In spite of these endowments; Bihar also suffers from certain problems- high population density, small farm holdings, poor input and output marketing infrastructure, poor access to new technologies and frequent climatic aberrations (flood & drought). Small farm holding sizes, increasing energy & input prices and shortage of labours force farmers to

adopt sub-optimal and inadequate management practices which end up with lower efficiency of resource use, low productivity and profitability. This contradiction accounts for the low productivity of agriculture.

Bihar accounts for 8.6% of India's population while its share of geographical area is meagre 2.85% of the country putting a stress on natural resources. The share of agriculture and animal husbandry sector to the state GSDP is 18.3%. About 97% of holdings fall under small and marginal categories with average holding size of 0.39 ha. This type of holding pattern does not incentivize farmers to make investments and to adopt modern crop production technology. Poor credit base of farmers further worsens the situation. Poor adoption of modern crop production technology coupled with weather aberrations leaves a wide gap between potential and actual productivity of crops.

Agriculture is the mainstay of economy of Bihar as more than 70% of the population derives their livelihood out of it. The agricultural economy of Bihar is skewed in favour of subsistence sector, since the acreage under food grains, even after a decrease in recent years, is more than 90%. Post bifurcation, Bihar is left with meagre mineral resources and poor industrialization. For a state like Bihar, where over 85% people live in villages and one way or other depend on agriculture and allied activities, the development of agriculture is not only desirable but also inevitable. Without increasing the output in agriculture, growth benefit may not reach the vast majority. The state government appreciates the fact that rural prosperity shall remain a distant dream until agriculture and allied sector is imparted a growth impetus.

Eastern region is rich in natural resources conducive to higher productivity. However, its potential could not be exploited for improving agricultural productivity, poverty alleviation and livelihood improvement. Government of India realised the importance of hidden opportunities got the impression if second green revolution has to come, it has to come from eastern states wherein lay a vast gap between potential and actual productivity.

The BGREI Program came into inception to address the constraints limiting the productivity of "rice-based cropping system" in Eastern India comprising seven states which includes Bihar. The major focus is on the promotion of improved crop production technologies, water harvesting measures and efficient management of natural resources for overall agriculture development.

2. Major interventions with BGREI

2.1.1. Custer demonstrations

a) System of rice intensification: System of Rice Intensification (SRI) was found a significantly superior crop establishment method for irrigated well-drained land. This is a technique for transplanting 10 days old rice seedling with single seedling per hill in wider spacing (25 x 25 cm) having specific nutrient, water and weed management.

b) Direct-seeded rice by zero tillage/seed drill/drum seeder: The yield potential of direct seeded rice (DSR) is high due to wider spacing and increased activity of soil biota. The technology is found feasible and economically viable. It requires less labour and there is no need to prepare nursery. The crop matures 7 to 10 days earlier facilitating timely

sowing of wheat. It requires less water, makes better use of resources and is cost effective. It allows line sowing and facilitates weed control between rows. DSR ensures better crop establishment resulting into higher yield. It is a climate resilient technology.

c) Cropping system-based demonstration: Demonstration on rice transplanting by transplanter in kharif followed by zero tillage wheat sowing in rabi is being taken up. Rice transplanter helped in timely transplanting of rice with its harvest on time. This facilitated timely sowing of wheat, which helped to utilize residual moisture for wheat sowing. This increased the agricultural output and better utilization of land, which used to be fallow in rabi.

d) Stress tolerant varieties (STV): Bihar has twin problems of flood and drought. Stress tolerant varieties like Swarna sub-1 and Sahbhagi Dhan have been a great help to farmers in such areas and farmers have been able to raise good paddy crop. Other interventions like seed distribution, distribution of seed based input have popularized the use of micro nutrient, bio-fertilizers, plant protection mean uses and raise the varietal replacement rate.

e) Zero tillage wheat: In Bihar paddy grown in lowland is harvested late which delays the sowing of wheat till end of December and in some cases till first week of January. Late sown wheat suffers from terminal heat during grain-filling phase, which results in shriveled grains and low yield. Zero tillage ensures timely sowing of wheat because time for field preparation is saved. Zero tillage makes effective use of receding moisture, facilitates time sowing and better management of crop with less cost and efficient and sustainable use of natural resources. This saves wheat from impact of terminal heat and gives higher yield. Cost of cultivation is less, which gives higher income to farmers.

f) Distribution of seeds (HYVs and Hybrids): The distribution of seeds of the high yielding varieties and hybrids have also included in the BGREI program for their popularization and higher yield.

2.1.2 Asset building and site-specific activities

The asset building intervention includes assistance for farm machineries & implements like manual/power sprayer, drum seeder, seed drill/zero-till seed drill, power weeder, self-propelled paddy transplanter, rotavator, multi crop thresher irrigation pipes and pump set. The component of site-specific activities has been provided to induce flexibility in the program to take up the activities not covered under other components of the program which contribute in productivity of rice and wheat. Assistance for activities that would help in enhanced procurement, creation of storage facility, marketing and value addition is also included. These activities will include promotion/creation of primary processing facilities (drying, grading, par-boiling of paddy and bagging, etc.) including farm level storage, institution building, linkage for procurement operations/ marketing.

3. Areas of demonstrations

The BGREI Program was started in the year 2010-11 and over the years about 15.7% of the cultivated area of the state has been covered under the cluster demonstration activity.

Table 2. Rice area of Bihar State vis-à-vis area covered in the BGREI.

Rice area (lakh ha)	Area covered under BGREI demonstration (lakh ha)							Cumulative BGREI demonstration area (lakh ha)	Area covered under BGREI demonstration (%)
	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18		
32.33	0.36	0.78	1.02	0.82	1.01	0.70	0.39	5.08	15.7

4. Trends area, productivity, production of rice and wheat since 2009-10

The trends of rice area and production are described in (Fig. 2). The rice area in Bihar state varied in the range of 2.84 to 3.34 Mha for the period 2009-10 to 2017-18. However, there is wide variation in the production, which ranged from 3.11 Mt in 2010-11 to 8.24 Mt in 2016-17. As there is less variation in the area, higher production is mainly due to the increase in the productivity, which ranged from 1.07 t ha^{-1} in 2010-11 to 2.47 t ha^{-1} in 2016-17.

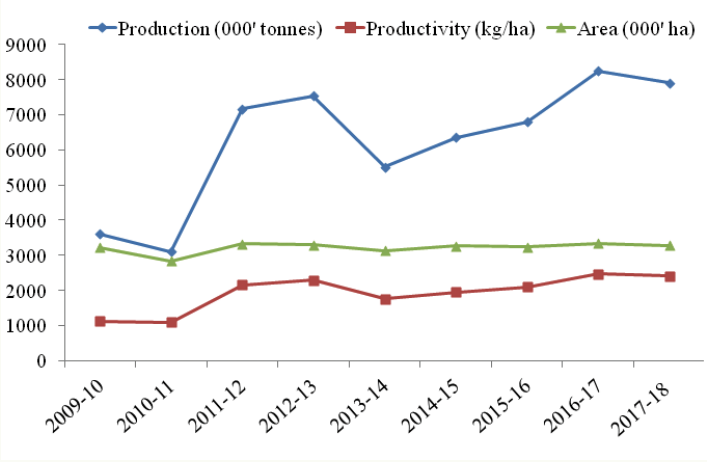

Fig. 2.Trend in area, production and productivity of rice from 2009-10 to 2017-18.

5. Effects of interventions of BGREI

To assess the effects of the technologies on the yield of the rice crop, crop cuttings are done in the demonstration plots along with the conventional practice under different interventions during 2017-18. Based on the cropping cutting data, it is observed that under SRI demonstration highest increase in yield is there i.e., 38.8% over the conventional practice. Other demonstrations like STVs, Hybrid and DSR also recorded higher yield as compared to control; whereas under paddy transplanter a slight decrease in yield was observed.

Table 3.Performance of Interventions in Bihar (2017-18).

Name of the demonstration	Total no. of crop cuttings	Avg. Yield in Demonstration Plot (q/ha)	Increase in yield over control (%)
Control	2672	44.3	–
SRI	2765	61.5	38.8
Stress Tolerant Varieties	591	52.2	17.8
Hybrid	2569	55.6	25.7
Paddy Transplanter	361	44.1	-0.4
DSR	1611	48.7	9.9

6. Production and Productivity during BGREI and Pre-BGREI Years

There has been a significant jump in the productivity of rice from an average of 1.4 t ha^{-1} in pre-BGREI year (2007-2009) to an average of 2.3 t ha^{-1} during last three years (2015-2017). Despite drought and rainfall deficiency in intermittent years the yield of rice has been maintained above 2.0 t ha^{-1} during post BGREI years.

Rainfall has direct effect on the overall productivity of a crop under rainfed agriculture. In the year 2009, 2010 and 2012 the Bihar state suffered from slight drought and during 2013 and 2015 state suffered moderate drought. During the drought year's yield of the rice crop decreased. During the years of normal rainfall a higher productivity is obtained particularly in the year 2016-17.

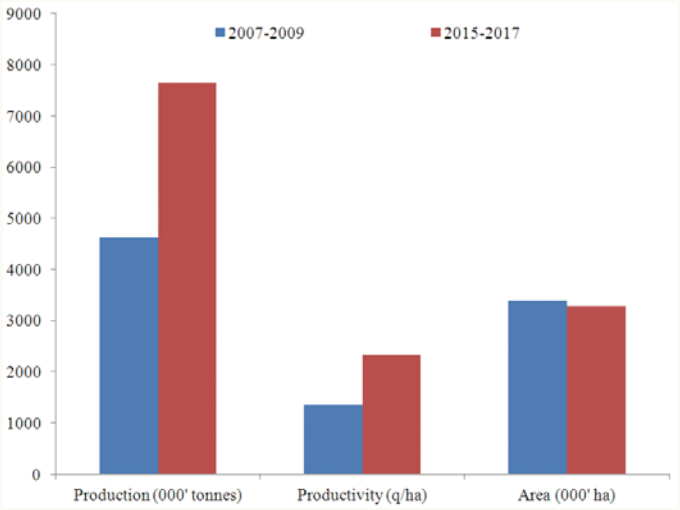

Fig. 3 Comparison of pre-BGREI (2007-2009) and BGREI years (2015-2017) in terms of production, productivity and area of rice in Bihar.

Table 4.Productivity of rice for different years along with the rainfall deficiency.

Year	Productivity (t/ha)	Rainfall Deficiency (%)	Remarks
2009-10	1.13	—	-
2010-11	1.09	-22	All 38 districts drought affected
2011-12	2.15	3	-
2012-13	2.28	-20	-
2013-14	1.76	-30	33 districts out of 38 districts drought affected
2014-15	1.95	-17	Due to hailstorm & cyclone, production of wheat is less than normal.
2015-16	2.02	-27	Deficient rainfall in some districts resulted less yield than previous year.
2016-17	2.47	-5	Being normal year yield increase over last year
2017-18	2.41	8	-

7. Suggestions

- SRI and stress tolerant variety demonstrations should be separated. SRI should be restricted to well drain irrigated areas with hybrids or HYVs. Cono-weeders may be supplied to the SRI demonstration farmers along with the seed and other inputs. Swarna sub 1 (flood tolerant variety) should be grown in flash flood areas with normal spacing and 20 - 25 days old seedling.
- In the upland and drought affected areas short duration varieties with drought tolerance trait such as Sahbhagi Dhan should be demonstrated.
- Timely availability of good quality seeds should be ensured.
- RiceXpert app launched by NRRI can be used by the extension workers and the farmers to get the answers of their queries.
- Village agricultural meets may be arranged once during vegetative stage and once at harvesting in demonstrating villages inviting non beneficiary farmers of the village and cross site visit of beneficiary farmers may be arranged at different stages of the demonstration.
- The BGREI Program is running successfully in the state with the participation of the farmers, state government machinery, state agricultural universities and ICAR institutions. For effective implementation of the program, there must be high synergy in all the stakeholders. The ground staffs who are involved in the implementation of this program need to be updated with the new technologies through trainings Programs.
- In mechanized transplanting of rice with transplanter, trainings on technique of nursery raising may be given priority. Along with the polythene sheet, wooden/iron frame or tray may be provided for better mat nursery. Farmers may be encouraged to purchase

more number of rice transplanters under the BGREI program, so that the felt shortage can be overcome.

- Farmers and the ground staff have limited knowledge on improved production technologies of rice and wheat. Therefore, ground level workers such as Agricultural coordinator and farmers may be trained on the latest technologies for effective implementation of the programme. Further the ground level staff should be provided with necessary logistics such as digital weighing balance, measuring tape, tirpal etc. for proper crop cutting activities.

Productivity of rice has shown a significant increase from an average of 1.4 t ha^{-1} in pre-BGREI year (2007-2009) to an average of 2.3 t/ha during last three years (2015-2017). Despite drought and rainfall deficiency in intermittent years the yield of rice has been maintained at above 2.0 t ha^{-1} during post BGREI years. From different interventions adopted through the program, it was observed that SRI demonstration has highest increase in yield i.e. 38.8% over the conventional practice based on the crop cutting data. Short duration variety like Sahbhagi Dhan with drought tolerant trait may be provided to the farmers for the upland and drought affected areas. Timely payment for the kits may be provided to the farmers to conduct the demonstrations.

Bringing Green Revolution to Eastern India: Experiences and Expectations in Chhattisgarh

K Chattopadhyay, M Din and R Lakpale

Summary

The BGREI Program in Chhattisgarh includes cluster demonstration of technologies on rice and wheat as well as building assets and irrigation facilities with the objective to increase production and productivity of these crops. In rice 14 % area has been covered by BGREI demonstrations till date. BGREI demonstrations has played a major role in improvement of rice productivity in Chhattisgarh from 1.2 t/ha in 2011-12 to 2.1t/ha in 2016-17. Based on the crop cutting data of 2015-16 and 2016-17, highest yield advantage (63%) has been found in the cropping system based demonstration over the control followed by SRI (31%) and direct seeded rice (25.5%). SRI and hybrid rice technologies have highest impact among BGREI components based on the expansion of area over the period. Site-specific activities especially check dam and small irrigation pond built under BGREI Program brought around 30000 ha area under irrigation. However the area of upland rice in this state is still very high and due to its low productivity, the estimated value of overall rice productivity is comparatively lower than the other BGREI states. Hybrid maize technology is showing increasing adaptation in Chhattisgarh. If some of the upland areas can be replaced by the hybrid maize, mean productivity of rice in the state will be improved. On the other hand, due to water deficiency in BGREI districts the productivity has come down significantly in 2017. A state sponsored program for seed production and distribution of recommended stress tolerant varieties for unfavourable ecology are suggested to increase the productivity of rice in the state.

1. State background

Chhattisgarh is the tenth largest state in India with an area of 135,190 km^2. Chhattisgarh is primarily a rural state with only 20 per cent of population residing in urban areas. Agriculture has major share in economic growth of Chhattisgarh (Table 1). The growth rate of agriculture can be increased by adopting the new technology. The BGREI Program has been launched in the State to enhance rice productivity in the state. Therefore, BGREI was in operation initially in 08 non-NFSM districts and later it was extended to 14 districts of Chhattisgarh (Fig. 1).

Table 1. Particulars of Chhattisgarh state.

Particulars	Status		
Population (crore)	2.56 (male-1.29, female-1.28)		
Population growth (%)	22.61 in 2011		
Farm families (Nos.)	37.46 lakhs (80% small and marginal farmers)		
Forest village	74		
Revenue districts (Nos.)	27		
Block / Janpad Panchayat (Nos.)	146		
Village Panchayat (Nos.)	10971		
Tehsil (Nos.)	150		
Total Village (Nos.)	20273		
KrishiUpaj Mandi (Nos.)	73		
Annual Rainfall (ave.)	1296 mm (september, 2017 µ 877.90 mm)		
Land Use Pattern (Area : Lakh ha)	**Agricultural Land Use**		**(Area-Lakh ha)**
Geographical Area	138	Net sown area	47.75
Cultivable Area	57.28 (41.53%)	Double cropped area	10.47
Forest Area	63.15 (45.80%)	Gross cropped area	65.25
Land under non-agricultural use	10.30 (7.46%)	Kharif area	47.75
Permanent Pastures	5.25 (3.80%)	Rabi area	17.5
Cultivable Wasteland	3.51 (2.55%)	Cropping intensity	137%
Barren and uncultivable land	8.88 (6.43%)		
Current Fallows	2.67 (1.93%)		
Irrigation	**(Area : Lakh ha)**	**Source of irrigation**	**(Area : Lakh ha)**
Net irrigated area	14.68	Canals	9.03 (61.55%)
Gross irrigated area	17.87	Tanks	0.43 (2.93%)
Rainfed area (to cultivable area)	39.41 (69%)	Open wells	0.20 (1.37%)
		Bore wells/ Tube wells	4.28 (29.17%)
		other sources	0.73 (4.98%)
		Total Irrigated Area	14.67
Soil Type			**(Area-Lakh ha)**
Alluvial soil (Kachhar)	1.38 (2.7%)	Inceptisols (Matasi)	13.54 (26.9%)
Entisols (Bhata)	10.02 (20%)	Vertisols (Kanhar)	11.43 (22.8%)
Alfisols (Dorsa)	13.82 (27%)	Land Classif. Total	50.19
Major Agricultural Crops			
Kharif	Paddy, Pigeonpea, Soyabean, Maize, Mung, Urd, Kulthi		
Rabi	Wheat, Gram, Mustard, Safflower, Lathyrus, Field pea, Lentil, Linseed, Groundnut		

(*Source- ENVIS, Center of M.P. State)

2. Major interventions through the BGREI

2.1. Cluster demonstrations

BGREI Program was started in 2010. In the initial years upto 2014-15 the components of cluster demonstration like Rainfed upland rice, Shallow lowland rice, Irrigated variety and Irrigated- hybrid variety has been demonstrated. From 2015-16 the cluster demonstrations like Cropping system based, Direct seeded rice, Hybrid rice, Line transplanting, SRI and Stress tolerance variety has been started.

2.2. Asset building and site-specific activities

The Asset building intervention includes assistance for farm machineries & implements like manual/power sprayer, drum seeder, seed drill/zero-till seed drill, power weeder, self propelled paddy transplanter, rotavator, multi crop thresher irrigation pipes and pump set. The component of Site Specific Activities has been provided to induce flexibility in the program to take up the activities not covered under other components of the program, which contribute in productivity of rice and wheat. Assistance for activities that would help in enhanced procurement, creation of storage facility, marketing and value addition is also included. These activities include promotion/creation of primary processing facilities (drying, grading, par-boiling of paddy and bagging etc) including farm level storage, institution building, linkage for procurement operations/ marketing. A total 1707 number of check dam which have the potentiality to irrigate 22657 ha area and 287 small irrigated ponds which have the potentiality to irrigate 7155 ha land have been constructed under BGREI Program in the state (Table 2).

Table 2. Site-specific activity specially check dam and small irrigated pond under BGREI (from 2011 to 2018).

Year	Check Dam		Small irrigated pond	
	No.	Irrigated land (ha)	No.	Irrigated land (ha)
2010-11	224	2972	100	2500
2011-12	158	2097	32	800
2012-13	273	3625	103	2575
2013-14	236	3131	20	500
2014-15	359	4777	8	200
2015-16	268	3550	15	375
2016-17	111	1470	5	125
2017-18	78	1035	4	80
Total	1707	22657	287	7155

3. Areas of demonstrations

In Chhattisgarh 14 % area under rice has been covered by BGREI demonstration till date. The details of the year-wise demonstration area are presented in Table 3. In last three years (2015-2018) around 2 lakh ha area in the state was demonstrated with different components under BGREI Program (Table 4).

Table 3. Area under BGREI demonstration in Chhattisgarh.

Total rice area	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	BGREI demo area
37.73	0.39	0.87	1.14	1.07	0.70	0.74	0.49	5.40

Table 4. Demonstration area (ha) under different components in the BGREI program.

Different components	Year		
	2015-16	2016-17	2017-18
Direct Seeded Rice	5000	5000	1000
Line Transplanting	5000	5000	1000
SRI	5000	5001	2000
Stress Tolerant Varieties	21860	21266	15000
Hybrid Rice	18412	25000	15000
Cropping System Based	14900	13000	15136
Sub Total Rice	70172	74267	49136

4. Trends area, productivity, production of rice and wheat since 2009-10

The trends of rice area and production are described in (Fig 2). The rice area in Chhattisgarh state varied in the range of 3671-3830 thousand hectares for the period 2009-10 to 2017-18. However, there is wide variation in the production which ranged from 4.11 Mt in 2010-11 to 8.05 Mt in 2016-17. As there was less variation in the area, higher production is mainly due to the increase in the productivity, which ranged from 1.12 t ha^{-1} in 2009-10 to 2.10 t ha^{-1} in 2016-17 (Table 5).

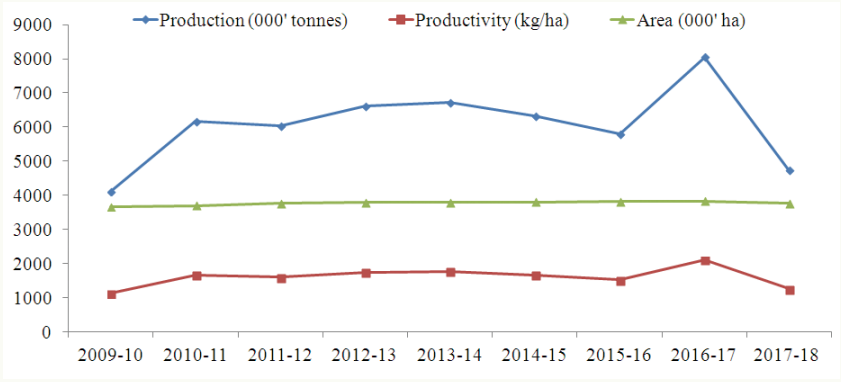

Fig. 2. Trends of area, production and productivity of rice in Chhattisgarh.

5. Effects of BGREI interventions

The BGREI Program started in 2010-11. Until 2014-15 the components of rice demonstration were rainfed upland rice, shallow lowland rice, irrigated variety and irrigated hybrid. The average yield advantage based on crop cutting data from 2012 -13 to 2014-15 is presented in Table 6. The average yield advantage of all these components was around 20-21%. Since 2015-16 BGREI demonstration components were revised. The average crop cutting data of 2015-16 and 2016-17 revealed that the highest yield advantage was achieved in cropping system based demonstrations (67%) followed by SRI demonstration (31%) and direct seeded rice (25.5%) (Table 7).

Table 6. Yield advantage of BGREI demonstrations based on the average value of the years, 2012-22013, 2013-14, 2014-15.

Components	Yield of demonstration plot (t ha^{-1})	Yield in control plot (t ha^{-1})	Yield increase (%)
Rainfed upland rice	4.21	3.49	20.10
Shallow low land rice	4.46	3.72	20.08
Irrigated traditional variety	5.10	4.21	21.28
Irrigated hybrid	5.41	4.50	20.20

Table 7. Average yield of demonstration plot, control plot and yield advantage over the control plot (Based on crop cutting data of 2015-16 and 2016-17).

Demonstration	Area (ha)	Cluster (Nos.)	Crop cutting result (Demonstration plot)		Crop cutting result (Control plot)		Yield advantage (%)
			No. of cutting (total)	Production (q/ha)	No. of cuttng (total)	Production (q/ha)	
Cropping System Based	22310	261	7162	56.46	7139	34.47	63.80
Direct Seeded Rice	8800	114	2439	33.33	2422	26.55	25.51
Hybrid	38299	474	12559	53.59	11990.67	44.25	21.11
Line Transplanting	9700	115	2872	39.75	2818	33.14	19.94
SRI	9501	120	3091	43.57	2851	33.21	31.19
Stress Tolerance	38234	502	11751	37.40	11283	31.18	19.96

The overall impact of BGREI Program in Chhattisgarh state as realized from the percent of area increased under different technologies (Table 8) can be summarized as follows.

SRI and hybrid rice technologies have higher impact. The area can be increased under such technology to get better productivity

Application of herbicide & line sowing in direct seeded rice should be higher to get better productivity in upland and medium land areas

Upland rice is low productive. If some of the area is replaced with hybrid maize, the mean productivity of rice can be improved for the state

Seed treatment package and regular training to farmers can reduce crop loss and increase productivity

Some new rice varieties including stress tolerance varieties and hybrid are adopted in the state (Table 9, Fig. 4)

Table 8. Impact of technologies under BGREI Program in increasing area

Transfer of technology	Area (ha)		Increase (%)
	2012	2017	
SRI	20944	54200	159
Seed treatment	2374131	2920382	23
Line sowing	226660	275392	22
Intercropping	173353	184913	7
Bund farming (Pigeon pea/sesame)	219953	223788	2
Hybrid rice	157486	433370	175
Hybrid maize	62108	161285	160
Weedicide	879806	1152917	31

Table 9. Varieties adopted under rice demonstration in 2017 in Chhattisgarh

Rice demonstration in different ecosystem	Variety under demonstration	Area under demonstration (ha)
Direct Seeded	Chandrahasini, Rajeshwari, Maheshwari	5000
Line Transplanting	Durgeshwari, PKV HMT, Pusa 5, HMT, Samleshwari	5000
SRI	PKV HMT, Durgeshwari, Maheshwari, Swarna Sub-1	5000
Stress Tolerent Variety	Swarna Sub 1, Karmamasuri, Rajeshwari, OP Bio-226, IGKVR-1	24860
Hybrid Rice	US-382, JKRH-401, CORH-3, K-371, VNR-2245	18173
Cropping system based	Durgeshwari, DRH-775, Chandrahasini, Karma Masuri, CORH-3, US-382, K-371, Arize Tej, DRRH-02	14900

Fig. 4. Under BGREI, Hybrid paddy (cv. US-382) demonstration in Kondagaon district was monitored by national level monitoring team in 2018.

6. Production and Productivity Comparison of BGREI and Pre-BGREI Years

There has been a significant increase in the production of rice from 4110 thousand tonnes (2009-10) to an average 6187 thousand tonnes in last three years (2015-18). Despite low production in previous year due to rainfall deficiency there has been significant increment in the productivity from an average of 1.1 t/ha in pre-BGREI year (2009-10) to an average of 1.6 t/ha during last three years (2015-2018) (Fig. 5).

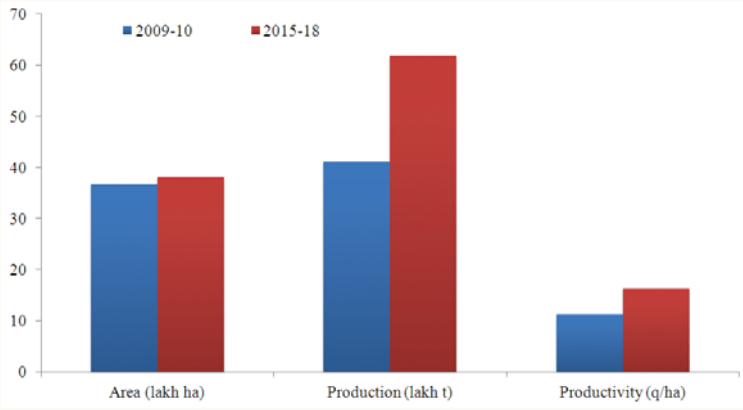

Fig. 5. Comparison of pre-BGREI and BGREI years in terms of area, production and productivity of rice in Chhattisgarh.

Rainfall pattern in 2016-17 and 2017-18 is presented below. In 2017-18, in most of the BGREI districts rainfall was deficit (Table 10). Therefore, the productivity in the state that was steadily going up over the years came down to 1.2 t ha^{-1}.

Table 10. Rainfall deficiency in 2017 as compared to 2016.

Name of district	Rainfall (cm)(June to November)		Deficit/Excess
	2016	2017	
Gariyaband	141.67	102.42	-11%
Mahasamund	135.76	100.66	-8%
Dhamtari	155.34	89.13	-19%
Durg	141.04	69.09	-36%
Bemetara	105.62	75.3	-29%
Balod	154.99	101.27	-6%
Janjgir	144.51	83.67	-33%
Sarguja	136.52	116	-13%
Surajpur	141.49	107.79	-9%
Balrampur	211.19	152.2	27%
Kanker	222.65	111.9	-10%
Narayanpur	191.46	109.28	-17%
Jagdalpur	204.44	149.2	16%
Kondagaon	199.64	130.13	3%

7. Suggestions

- Inclusion of preferred high yielding varieties/hybrids of the farmers in this program.
- Giving seed indent for seed production of the newly released high yielding stress tolerant and nutrient rich varieties. New rice varieties with their suitability in the context of food and nutritional security and changing scenario are suggested as follows.
- High yielding varieties with high nutrient (Protein, Fe, Zn) content is required to cultivate in large scale to achieve the food and nutritional security. Presently high yielding varieties with high nutrient content are available. CR Dhan 310 (with high protein content), DRR Dhan 45 (with high Zn content) and Chattrisgarh Zinc rice 1 (with high Zn content) can be incorporated under BGREI Program.
- Rainfall deficiency is becoming a frequent event in many BGREI districts under changing climatic scenario. Therefore, drought tolerant variety in IR 64 background, DRR Dhan 42 (IR 64 Drt 1), another rice variety DRR Dhan 44 with drought tolerance and CR Dhan 801 in Swarna background is suggested to incorporate in BGREI Program. Apart from this many aerobic rice varieties have been released as a part of the water saving technology. Long slender grain aerobic rice varieties such as CR Dhan 203 and CR Dhan 201 also can also be adapted in BGREI demonstrations.
- Varieties are being grown since long are subjected to high incidence of insect-pests and diseases. Samba Mahsuri is one of the popular varieties are being cultivated in Chattrisgarh for its good grain quality. But this variety has been notified more than 10 years and susceptible to pest and diseases such as bacterial blight. This can be replaced by Improved Samba Mahsuri (RP Bio-226), a high yielding rice variety with major bacterial blight resistance genes Xa21, xa13 and xa5. CR Dhan 800 (CRMAS 2232-85) in 'Swarna' background showed ssignificantly higher level of Bacterial blight resistance than Swarna. This variety also can be taken in Chhattisgarh for this Program.
- Cluster demonstrations using more than one rice varieties in catchment areas of check dam, build under BGREI Program.
- Regular monitoring of BGREI cluster demonstrations and submission of reports to the Nodal officers from NRRI, Cuttack and IGKV on quarterly basis.
- Non Supply/ Poor supply of quality seeds of paddy, including the varieties and hybrids by the state seed corporation is another major area of concern, needing immediate attention of State govt. Indent of breeder seeds of new recommended varieties (by NRRI, IGKV) by state agricultural department is required for adaption of new rice varieties with high yield, quality and stress tolerance.
- Delayed/incomplete supply of inputs under *cafeteria* needs immediate attention of the State nodal agency i.e., SSC or an alternate mechanism such as decentralized supply of inputs may be decided at level of state headquarters.

The BGREI demonstration and other intervention helped in improvement of rice productivity in Chhattisgarh from 1.2 t ha^{-1} in 2011-12 to 2.1 t ha^{-1} in 2016-17. However, the productivity was very poor in 2017 due to moisture deficiency in most of the rice growing districts as well as the BGREI districts. More interventions of climate change adaptation and mitigation technologies are required in future for getting sustainable production and profitability of rice cultivation. Line transplanting can be incorporated under SRI, hybrid rice and cropping system-based research and area can be increased for getting better productivity. A state-program for seed production and distribution of stress tolerant varieties for unfavourable ecology can increase the productivity of rice in the state.

Bringing Green Revolution to Eastern India: Experiences and Expectations in Jharkhand

A Poonam, S Bhagat, Y Kumar and VD Shukla

Summary

Jharkhand has been affected by conjugative droughts five times from 2001 to 2010 and food grain productions were low in drought years. Paddy, which is the principal crop of Jharkhand, had average productivity of 1.4 t ha^{-1} and 1.1 t ha^{-1} in 2004-05 and 2005-06 respectively. The state faced a deficit of rainfall by approximately 47% in 2010 and consequent to that 1 Mha of land could not be brought under paddy cultivation and total food grain production decreased by half; average paddy productivity in 2010-11 was 1.5 t ha^{-1}. This added to the food grain deficit the state faced even during the normal rainfall year. A strategic initiative 'Bringing Green Revolution in Eastern India' (BGREI) to develop high potential Eastern Region of the country for food grain production has been initiated since 2010-11. The Program is being implemented with the objective to increase the productivity of rice based cropping system through promotion of recommended agriculture technology and package of practices by addressing the underlying constraints of different agro-climatic sub-regions. The Program included a bouquet of three broad categories of interventions, viz., Block demonstrations of rice and wheat, asset building activities for water conservation and utilization. Block demonstration of rice, each of 1000 hectares was proposed to be implemented in five agro-ecological sub-regions namely rainfed uplands, rainfed low lands (shallow low land, medium, deep water) and irrigated rice (traditional, hybrid). The objective of the demonstration was to improve seed replacement rate (SRR), promote line sowing/planting coupled with promotion of plant nutrient and plant protection technologies.

1. State background

Jharkhand state was created in November 2000 through the reorganization of erstwhile Bihar. Comprising of the Chhotanagpur, Santhal Parganas and Hazaribag divisions of the undivided Bihar, this state has a total geographical area (TGA) of 79,714 km^2. Jharkhand is landlocked and is an integral part of the north-eastern portion of the Peninsular Plateau of India. The state is divided into three agro climatic subzones, namely Zone IV (Central and North Eastern Plateau), Zone V (Western Plateau) and Zone VI (South Eastern). Sub-zones IV, V and VI are characterized by humid and sub-humid tropical, sub-humid to sub-tropical and humid to sub-tropical respectively. Broadly, the region represents an undulating

plateau dotted by hills and mountains. The reduced number of perennial rivers, depleting forest due to mineral and industrial exploitation is a matter of concern.

Agriculture is the principal source of livelihood in the state with 66 % of the people engaged in farming. Land-use statistics suggest that in spite of large cultivable area (52%) only 22% is under cultivation, which is below the national average of 47%. The state receives an average annual rainfall of about 1200 mm, mainly from the south-west monsoon. However, only about 25% of the water is retained and utilized and the remaining is lost through run-off. Irrigated area is only 10% of the net sown area making the rainfed mono-cropping zone to cover ~85%. The overall cropping intensity is 114%. Jharkhand has notified 23,605 km^2 area (~30%TGA) under forests. In addition to agriculture, forests continue to be an important supplemental source of livelihoods for the rural communities.

Table 1. Agro climatic division with broad characteristics.

Zones	Agro-climatic regions	Districts	Total geographical area (m ha)	Net cultivated area (%)	Irrigated area (%)
Zones-IV	Central Eastern	North Chatra, Koderma, Plateau Godda, Hazaribag Bokaro, Ramgarh, Ranchi Khunti, Giridih Dhanbad Deoghar, Pakur, Dumka Sahebjunj, Pakur, Jamtara	4.1	55	6.58
Zones-V	Western Plateau	Garhwa, Palamau, Lohardaga, Gumla, Latehar and Simdega	2.5	24	9.65
Zones-VI	South Eastern	Purbi Singhbhum, Paschimi Singhbhum and Saraikela	1.3	31.6	4.54

The major area of the state is dominated by sandy loam to loamy acidic soils (pH 4.5–6.5) showing low productivity. The average land holding in Jharkhand is 1.58 ha and is slightly higher than all-India average of 1.57 ha. The land surface is rugged and undulating, ranging from flat lands to almost steep slopes. Rice area in Jharkhand is only 4% of total 44.0 Mha which is 1.62 Mha with a production of 3.33 Mt and productivity of 2.02 t ha^{-1}.

2. Major interventions with BGREI

The major interventions in Jharkhand were crop-based interventions, asset building, site specific activities, marketing support and capacity building.

2.1.1. Cluster Demonstration

Under crop-based interventions, quality seeds of HYVs (Naveen, Shahbhagidhan, Abhishek, IR 64 improved, IR 36 and Lalat) and hybrids (KRH 2, PHB 71, DRRH 3, Arize 6444) of rice were distributed to the farmers for enhancing the seed replacement rate in the state. Besides,

the ecology based cluster demonstration of improved production technologies of rice i.e. medium land and shallow low land rice were conducted to enhance the productivity of the crop. The activities under cluster demonstrations were deep ploughing, line sowing / planting, seed / seedling treatment, green manuring, soil health card-based nutrient application, pre- emergence herbicide application, need-based plant protection and harvesting and storage at right moisture. But later on since 2015-16, emphasis was given on cluster demonstration of five improved production technologies.

1. Line transplanting (Manual and Mechanized): The traditional way of random transplanting is labour intensive and involves drudgery and plant population is low. Line transplanting (Manual and Mechanical) helps in maintaining an optimal plant population. Mechanical rice transplanting is cost effective and operation friendly and helps in maintaining soil physical properties and considered to be a better option from crop management and productivity point of view. In Line transplanting the seed rate is low and provides the opportunity for use of implements and machineries for intercultural operations.
2. Direct seeded rice (DSR): In Jharkhand still a majority portion of the area is under broadcasted DSR where maintenance of optimal plant population is difficult. The seed rate in traditional DSR is very high leading to high population of plants which often results in higher level of competition at early stage but lower population after beushening. Besides, weed is a major problem in traditional DSR which leads to decrease in yield. In modern DSR line sowing is practiced followed using a seed cum fertilizer drill and application of pre emergence herbicide for controlling the weeds. The seed rate and weed population in modern DSR is low compared to traditional DSR with option of using mechanical weeder.
3. Stress tolerant variety: Rice production and productivity is severely affected by the increasing impact of abiotic stress factors such as drought, flood, salinity etc. Jharkhand is frequently affected by drought. The production and productivity was reduced drastically due to moisture stress. The stress tolerant varieties for moisture deficient condition with the appropriate production technology can be a great promise.
4. Cropping system based production technologies: Rice monocropping is the major activity in Jharkhand. Rice followed by other dry crops is grown in rainfed areas using residual soil moisture. However some areas remain fallow owing to low productivity or abiotic and biotic stresses to the sequence crop in the system. Introduction of short duration and stress tolerant pulses can maintain the soil fertility and increase the pulse production. Deep rooting, nitrogen fixation, leaf shedding ability and mobilization of insoluble soil nutrients are some of the unique characteristics of pulses which substitutes the requirements of nutrients for the next season.
5. System of rice intensification (SRI): System of Rice Intensification (SRI) is a combination of several practices which include nursery management, time of transplanting, water and weed management. It is a unique package to improve productivity by transplanting 8-12 days old seedling at spacing of 25 x 25 cm, about 16 plants per square meter with use of organic manures, mechanical weed control through cono-weeder and alternate wetting and drying method of water management. The water requirement in SRI is quite less as compared to other practices and thus was demonstrated in irrigated medium lands for enhancing the productivity of small and marginal farmers.
6. Popularization of Improved HYVs and Hybrids: The HYVs and the hybrids released under the last 10 years were demonstrated under the cluster demonstration. Good quality

seeds of these varieties along with micronutrients and soil ameliorants like zinc, gypsum and bio fertilizers were supplied to the demonstrating farmers for yield improvement. Similarly need based plant protection measures were taken up in the cluster demonstrations. The following varieties have been currently recommended ecology wise for promotion under the Program.

Table 2. Rice varieties recommended for Jharkhand.

Ecologies	Recommended for promotion under BGREI
Irrigated	Abhishek, CR Dhan 305, Arize Tej, DRH 775
Aerobic	CR Dhan 202, CR Dhan 204
Rainfed Upland	Sahbhagi Dhan, CR Dhan 40, Birsa Vikas Dhan 111, Birsa Vikas Dhan 203
Rainfed Shallow Lowland	Improved Samba Mahsuri

2.1.2. Asset building and site-specific activities

Asset building activities were taken up for improvement of the irrigation facilities and farm mechanization in the program areas. The state has created water conservation structures through 175 Birsa Pucca Check Dams (BPCD), 167 Loose boulder check Dam (LBCD) and 450 lift irrigation facilities from rivulets, 12305 pump sets were distributed to strengthen irrigation by carrying water from the source to its destination in rainfed rice area. Similarly a total of 2458 farm machineries were distributed among beneficiary farmers which includes 24 seed drills, 1336 cono weeder, 229 rotavators, 1 self propelled paddy transplanters, 300 threshers and 1214 sprayers. Under Post harvest and marketing support 85 mini rice mill, 5 marketing shed, 13 (100 tons capacity) godown, 7 pre-fabricated storage godown, 12 weighing machine/moisture meter/ portable bag closing machine each were provided.

3. Areas of demonstrations

The state of Jharkhand implemented the BGREI Program in 20 non NFSM districts namely Bokaro, Chatra, Dhanbad, East Singhbhum, Garhwa, Giridih, Jamtara, Latehar, Pakur, Palamu, Sahebganj, Simdega, Ranchi, Koderrna, Ramgarh Godda, Dumka, Hazaribag Deogarh Khunti. The state has demonstrated different improved production technologies through cluster demonstrations. The state has till date demonstrated line transplanting, system of rice intensification (SRI), stress tolerant variety, HYV, hybrids and cropping system-based demonstrations.

Table 3. Targets for Block Demonstration on Rice in Jharkhand (2010-11 to 2018-19).

Cluster Demonstration	Target area (ha)	Achieved area (ha)
DSR	97840	90567
Line transplanting	9200	9120
SRI	12495	12075
Stress Tolerant Variety	20400	19435
Hybrids	69450	67141
HYVs	87413	53426
Cropping system	15320	15292
Total	312118	267056

*The data of 2015-16 is not included

4. Trends in area, productivity, production of rice and wheat since 2009-10

In 2011-12, there is marked increase in production (103.52%) in Jharkhand due to the favourable rainfall year. Yield and production decrease in the year 2015-16 due to occurrence of drought and the production range varied from 15.0-87.3% across the state.

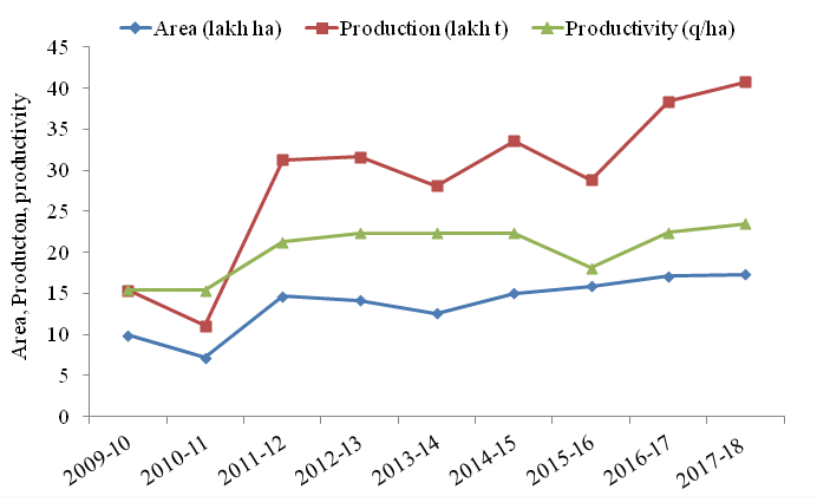

Fig 1. Trends of area, Production and productivity of rice from 2009-10 to 2017-18.

5. Effects of BGREI interventions

Improved HYVs i.e., Sahbhagi Dhan, MTU 1010, Lalat, IR 36, IR 64, Abhishek, Naveen and hybrids i.e., KRH 2, PHB 71, Arize 6444, DRRH 3 have been already popularized. In the year 2017-18, the average yield of demonstrated plot under HYVs and stress tolerant rice varieties were was 4.67 to 5.44 t/ha and that of hybrid been 6.77 t/ha in the good rainfall years. Hybrids have been popular for low seed requirement and higher grain yield, in the medium lowlands where rainwater accumulates being lowest lands in terrace land. Stress tolerant variety Sahbhagi Dhan has also been popular in most of the blocks for its drought resistance. Significant positive effect of BGREI Program in Jharkhand has been recorded. The technical interventions like block/cluster demonstrations, cropping system based demonstration, seed production, seed distribution, asset building & site specific works and creation of storage structures and marketing facilities has tremendous effect on increasing rice production and productivity at highest level as well as reducing the storage losses. The BGREI farmers have adopted new proven technology with high production and productivity of rice and thereby, these technologies are being adopted by the non-BGREI farmers.

6. Production and Productivity Comparison of BGREI and Pre BGREI Years

The area has increased from 1.68 to 1.73 Mha from 2008-09 to 2017-18, which is the only 2.98% over the last nine years whereas the increase in production is 16.14% and increase in productivity is 13.62%. The area, production and productivity is lower during 2009-10 is due to the declared drought year. The increase in area from the non-BGREI years (average of 2007-08, 2008-09, 2009-10) to BGREI years (average of 2015-16, 2016-17, 2017-18) was 23.22% (Fig. 2). The increase in productivity from the non-BGREI years (average of 2007-08, 2008-09, 2009-10) to BGREI years (average of 2015-16, 2016-17, 2017-18) productivity was 12.21%.

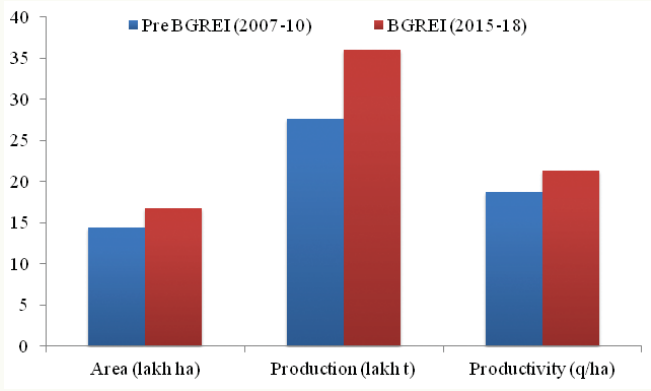

Fig. 2. Comparison of area, production and productivity of rice in Jharkhand in pre-BGREI and BGREI years.

The annual average rainfall in the state is about 1386 mm, which occurs mainly during in four months (June-Sept) Out of that, 80-85% received in 3½ months, from 15th June to 30th of Sept, 10-15% from October to January and very few rainfalls received in rest of the period .Out of total rain, 60% is used to be waste due to surface run-off and leaching. Therefore, only 40% rain remains left for crop use. Despite of having an average rainfall of 1400 mm, only an average of 10 to 12% of the net sown area is under irrigation against the national average of 40 per cent and the remaining almost 90% of cultivable area is dependent on rain. In the recent years due to the unprecedented successive drought, which largely hampers kharif prospects, paddy need to be taken in only those areas where water accumulates in low rainfall conditions.

Table 1. Meteorological fetures of different agro-ecological zones of Jharkhand.

Months	Rainfall (mm)		
	Zone IV	Zone V	Zone VI
June-September	1098 (82.4%)*	1174 (83.3%)	1053 (80.6%)
October-November	90 (6.0%)	96 (6.7%)	69 (5.3%)
December-February	54 (4.1%)	71 (5.0%)	58 (4.4%)
March-May	88 (6.1%)	68 (4.8%)	122 (9.4%)

*Percent of annual rainfall

7. Suggestions

- Irrigation infrastructure is very poor in Jharkand which need to be strengthen immediately for higher productivity of rice as the crop production during *kharif* season largely depends on rainfed.
- Strengthen regular monitoring and progress meeting and capacity building for Block level Agril. Officers, other field functionaries and farmers
- Timely supply of inputs like fertilizer, herbicide and pesticide etc. with good coordination among the state officials.
- Beneficiary selection for hybrids must be done based on availability of irrigation facility and shorter duration rice varieties need to be promoted to avoid problems from late onset and early withdrawal of monsoons
- Zero tillage/fertilizer cum seed drills and wheel hoes/finger weeder and spraying equipments needs to be provided to accelerate adoption of DSR in drought prone areas

Agriculture in Jharkhand is largely rainfed, practiced in the undulating topography with a meager irrigated area of only 10%, even the most proven technology fails to show its potentiality. However, implementation of the BGREI Program has definitely made a difference by increasing the area, production and productivity of Jharkhand state. Further strengthening of irrigation facilities at appropriate locations will further improve the total productivity of the state.

Bringing Green Revolution to Eastern India: Experiences and Expectations in Odisha

BB Panda, AK Nayak, PK Roul and A Ghosh

Summary

Rice is the major crop covering about 63% of the total area under food grains. It is the staple food of almost the entire population of Odisha; therefore the state economy is directly linked with improvements in production and productivity of rice in the state. The annual normal rainfall of the state is 1451.2 mm. The rainfall pattern is highly unpredictable in timing, amount, and distribution and therefore the state suffers from either drought or flood. Rice is the major crop of the state grown in all the above ecologies but having a low productivity due to limitations posed by many production factors. Bringing Green Revolution to Eastern India (BGREI) program was introduced in 2010-11 to enhance the productivity in the state. The Program was implemented in 22 non NFSM districts that are major rice producing districts of the state. The state demonstrated improved rice production technologies through cluster demonstrations. The state has till date covered 3.95, 33.20, 23.20, 39.0, 32.83 and 23.35 lakh hectares in direct seeded rice (DSR), line transplanting (LT), system of rice intensification (SRI), stress tolerant variety, hybrids and cropping system based (CSB) demonstrations respectively which is about 13.5% of the total rice area of the state. Improved HYVs i.e., Ranidhan, CR Dhan 601, DRR 42, Sahbhagi Dhan, Swarna sub 1, Varsadhan, MTU 1010, Chandan, Kalajeera, Ketakijoha, DRHR 2, CR dhan 70, Improved Samba Masuri and hybrids i.e., Ajaya, Arize 6444 have been popularized. Besides, more than 50,000 shallow tube wells, bore wells and dug wells and 122 water harvesting structures and lift irrigations have been created to augment the irrigation facility. Similarly farm mechanization was advanced in the state by distribution of 16,193 farm machineries among beneficiary farmers. The overall increase in yield was 37.79% in the state by practicing improved production technologies like DSR, LT, STV and CSB demonstration plots compared to control plots. The Program made a visible impact on the state productivity. The average productivity during the latest 3 years (18.05 q/ha) of BGREI Program was increased by 12.65% compared to the average productivity of 3 pre-BGREI years (2007-08 to 2009-10) i.e., 16.03 q ha^{-1}. However, the productivity of the state is the lower than the national average and main factor dragging back the productivity of the state is attributed to the higher area under broadcasted rice and less use of herbicides for controlling weeds in broadcasted fields and frequent occurrence of natural calamities. Therefore, efforts may be made to convert all broadcasted rice areas into line sown DSR with use seed drills and herbicides; creating irrigation facilities in rainfed rice areas and diversifying the upland rice areas into horticultural crops.

1. Background

Agriculture in Odisha to a considerable extent means growing rice. Rice covers about 69% of the cultivated area and is the major crop covering about 63% of the total area under food grains. It is the staple food of almost the entire population of Odisha; therefore the state economy is directly linked with improvements in production and productivity of rice in the state. Odisha's share in the country's rice production was more than 11% in the pre-HYV period which gradually declined to 7.9% in 2008-09. Odisha falls under Agro-Climatic Zone

VII as per the classification of planning commission for India. Further, the state of Odisha has been divided into 10 Agro-Climatic sub-Zones based on soil structure, humidity, elevation, topography, vegetation and rainfall.

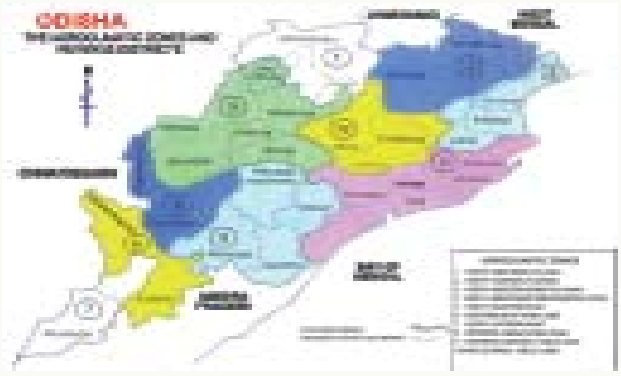

Fig. 1. Agro-climatic zones of Odisha.

Odisha is located in the subtropical belt in eastern India. The State broadly falls under hot and dry sub-humid, warm and humid, hot and humid, and hot and moist sub-humid regions. Odisha is broadly divided into two agro-climatic zones i.e., Plateau Region and Coastal alluvial plain. The Mountain range separates the eastern part of the state, which is a coastal belt with 482 km of coastline, and the western part, which is an extensive plateau. The coastal region contains about 15% of the geographical area of the state contributing 1.70 Mha of rice land

Table 1. Physiographic features of various agro-climatic zones of Odisha.

Agro-Climatic Zone	Climate	Soil type	Rainfall (mm)	Temp (°C) Min	Max
North Western Plateau	Hot & moist sub-humid	Red, Brown Forest, Red & Yellow, Mixed Red & Black	1600	15.0	38.0
North Central Plateau	Hot & moist sub-humid	Lateritic, Red & Yellow, Mixed Red & Black	1534	11.1	36.6
North Eastern Coastal Plain	Moist sub-humid	Red, Lateritic, Deltaic Alluvial, Coastal Alluvial & Saline	1568	14.8	36.0
East & South Eastern Coastal Plain	Hot & Humid	Saline, Lateritic, Alluvial, Red & Mixed Red & Black	1577	11.5	39.0
North Eastern Ghat	Hot & moist, sub-humid	Brown Forest, Lateritic Alluvial, Red, Mixed Red & Black	1597	10.4	37.0
Eastern Ghat High Land	Warm & humid	Red, Mixed Red & Black, Mixed Red & Yellow	1522	7.5	34.1
South Eastern Ghat	Warm & humid	Red, Lateritic & Black	1710	13.2	34.1
Western Undulating Zone	Hot & moist sub-humid	Red, Mixed Red & Black and Black	1352	11.9	37.8
Western Central Table Land	Hot & moist sub-humid	Red & Yellow, Red & Black, Black, Brown Forest & Lateritic	1614	12.4	40.0
Mid Central Table Land	Hot & moist sub-humid	Alluvial, Red, Lateritic, Mixed Red & Black	1421	14.0	38.7

constituting about 38% of the total rice area. The plateau region has 2.75 Mha of rice land constituting about 62% of the total rice area of the state. The soils of Odisha are mostly red lateritic and acidic in nature leading to seepage/deep percolation of water and thus demanding more water usage. The southwest monsoon enters the state during the second half of June and continues up to first week of October. The annual normal rainfall of the state is 1451.2 mm. The rainfall pattern is highly unpredictable in timing, amount, and distribution and therefore the state suffers from either drought or flood. The mean maximum temperature is 32°C in the coastal districts and can increase upto 42°C in hilly areas. The relative humidity varies from 36 to 98% in the state. The deltaic alluvial soils are generally fertile but low in N and P.

Table 1: BGREI Districts covered under various Agro-climatic zones of Odisha.

Agro-Climatic Zone	Area (%)	Districts	Districts covered under BGREI
North Western Plateau	10.00	Sundargarh, parts of Deogarh, Sambalpur & Jharsuguda	Sundargarh, Sambalpur
North Central Plateau	11.50	Mayurbhanj, major parts of Keonjhar, (except Anandapur subdivision)	Mayurbhanj
North Eastern Coastal Plain	6.00	Balasore, Bhadrak, parts of Jajpur & Anandapur Sub-Division of Keonjhar	Balasore, Bhadrak, parts of Jajpur
East & South Eastern Coastal Plain	13.00	Kendrapara, Khurda, Jagatsinghpur, part of Cuttack , Puri, Nayagarh & part of Ganjam	Kendrapara, Khurda, Jagatsinghpur, part of Cuttack , Puri, Nayagarh & part of Ganjam
North Eastern Ghat	15.00	Kandhamal, Rayagada, Gajapati, Part of Ganjam & small patch of Koraput	Rayagada, Gajapati, Part of Ganjam & small patch of Koraput
Eastern Ghat High Land	8.00	Major parts of Koraput & Nabarangpur	Major parts of Koraput & Nabarangpur
South Eastern Ghat	4.50	Malkangiri & part of Koraput	Malkangiri & part of Koraput
Western Undulating Zone	7.50	Kalahandi & Nuapada	Kalahandi
Western Central Table Land	16.00	Bargarh, Bolangir, Boudh, Sonepur and parts of Sambalpur, Deogarh & Jharsuguda	Bargarh, Bolangir, Boudh, Sonepur and parts of Sambalpur
Mid Central Table Land	8.50	Angul, Dhenkanal, parts of Cuttack & Jajpur	Dhenkanal, parts of Cuttack & Jajpur

Rice is grown in different ecologies i.e. irrigated *kharif* (27.4%), rain-fed upland (19.1%), medium land (12.4%), shallow lowland (22.5%), semi-deep (7.9%), deep (3.4%) and irrigated *rabi* (7.4%). The upland ecosystem is mostly drought prone area whereas the medium land is fairly stress free. The shallow water, semi-deep water and deep water ecologies are flood prone and water logged. Rice is the major crop of the state grown in all the above ecologies but having a low productivity due to many production factors. Bringing Green Revolution to Eastern India (BGREI) program was introduced in 2010-11 to enhance the productivity in the state.

2. Major Interventions with BGREI

Major interventions in Odisha were crop-based interventions, asset building, site specific activities, marketing support and capacity building.

2.1.1. Cluster Demonstration

Under crop-based interventions, quality seeds of HYVs and hybrids of rice were produced and distributed to the farmers for enhancing the seed replacement rate in the state. Besides, the ecology based cluster demonstration of improved production technologies of rice i.e. upland, medium land and shallow low land rice were conducted to enhance the productivity of the crop. The activities under cluster demonstrations were deep ploughing, line sowing / planting, seed / seedling treatment, green manuring, soil health card-based nutrient application, pre- emergence herbicide application, need-based plant protection and harvesting and storage at right moisture. But later on since 2015-16, emphasis was given on cluster demonstration of five improved production technologies.

1. **Line transplanting (Manual and Mechanized):** The traditional way of random transplanting is labour intensive and involves drudgery and plant population is low. Line transplanting (Manual and Mechanical) helps in maintaining an optimal plant population. Mechanical rice transplanting is cost effective and operation friendly and helps in maintaining soil physical properties and considered to be a better option from crop management and productivity point of view. In Line transplanting the seed rate is low and provides the opportunity for use of implements and machineries for intercultural operations.
2. **Direct seeded rice (DSR) using seed cum fertilizer drill:** In Odisha still a majority portion of the area is under broadcasted DSR where maintenance of optimal plant population is difficult. The seed rate in traditional DSR is very high leading to high population of plants which often results in higher level of competition at early stage but lower population after beushening. Besides, weed is a major problem in traditional DSR which leads to decrease in yield. In Line sown DSR line sowing is practiced followed using a seed cum fertilizer drill and application of pre emergence herbicide for controlling the weeds. The seed rate and weed population in line sown DSR is low compared to traditional DSR with option of using mechanical weeder. Line sown DSR has a great potential in Odisha.
3. **Stress tolerant variety:** Rice production and productivity is severely affected by the increasing impact of abiotic stress factors such as drought, flood, salinity etc. Odisha is frequently affected by natural calamities i.e. drought and flood almost every year. The production and productivity was reduced drastically due to these events. The stress tolerant varieties like Sahbhagi Dhan for moisture deficient condition and Swarna sub 1

for moisture excess/ flood prone condition with the appropriate production technology can be a great promise.

4. **Cropping system based production technologies:** Rice Based Cropping System is the major cropping system in Odisha. Rice double cropping is generally practiced in the irrigated areas of the state but rice followed by the dry crops is grown in rainfed areas using residual soil moisture. However some areas remain fallow owing to low productivity or abiotic and biotic stresses to the sequence crop in the system. Introduction of short duration and stress tolerant pulses like Greengram or Blackgram can maintain the soil fertility and increase the pulse production. Deep rooting, nitrogen fixation, leaf shedding ability and mobilization of insoluble soil nutrients are some of the unique characteristics of pulses which substitutes the requirements of nutrients for the next season.

5. **System of rice intensification (SRI):** System of Rice Intensification (SRI) is a combination of several practices which include nursery management, time of transplanting, water and weed management. It is a unique package to improve productivity by transplanting 8-12 days old seedling at spacing of 25 x 25 cm, about 16 plants per square meter with use of organic manures, mechanical weed control through cono-weeder and alternate wetting and drying method of water management. The water requirement in SRI is quite less as compared to other practices and thus was demonstrated in irrigated medium lands for enhancing the productivity of small and marginal farmers.

6. **Popularization of Improved HYVs and Hybrids:** The HYVs and the hybrids released under the last 10 years were demonstrated under the cluster demonstration. Good quality seeds of these varieties along with micro nutrients and soil ameliorants like zinc, gypsum and bio fertilizers were supplied to the demonstrating farmers for yield improvement. Similarly need based plant protection measures were taken up in the cluster demonstrations. The following varieties have been currently recommended ecology wise for promotion under the Program.

Table 1. Rice varieties recommended for Odisha.

Ecology	Variety/Hybrid
Irrigated	CR Dhan 304, CR Dhan 307, CR Dhan 310, CR Dhan 907, Arize 6444 Gold
Aerobic	CR Dhan 203, CR Dhan 205, CR Dhan 209
Boro	CR Dhan 601
Rainfed Upland	Sahbhagi Dhan, Satyabhama, Mandakini, Jyotirmayee
Rainfed Shallow Lowland	CR Dhan 800, CR Dhan 701, Swarna sub1, Reeta, Rani,
Rainfed Semi deep & Deep Lowland	CR Dhan 409, CR Dhan 500, CR Dhan 505
Coastal Saline	Luna Sankhi , Luna Barial, Luna Suvarna , Luna Sampad

2.1.2. Asset building, site specific activities & marketing support

Asset building activities were taken up for improving the water availability and irrigation facilities as well as farm mechanization in the Program areas. The state has already created 45,805 dug wells and bore wells, 4,999 shallow tube wells, 87 water harvesting structures, 35 river lift irrigation systems. The state has also provided 80,331 pump sets and 7.89 lakh meters of PVC pipes for carrying water from the source to its destination. Similarly a total of

16,193 farm machineries were distributed among beneficiary farmers which includes 1,052 seed drills, 1,936 cono-weeder, 5,060 rotavators, 757 self propelled paddy transplanters, 6,964 threshers, 14 drum seeders, 14 land leveler and 296 sprayers. Under Post harvest technologies, 277 threshing floor yard, 60 paddy seed cleaner cum grader, 144 pucca threshing floor. Besides 2018 cropping system trainings were also provided to the farmers regarding improvement in the crop production.

2.2. Monitoring procedure

The ICAR-NRRI as the nodal organization was involved in providing technical backstopping and monitoring of the program. The Program was planned by the department in discussion with scientists from ICAR-NRRI and OUAT, Bhubaneswar. The Program was monitored at national level by a national level monitoring team constituting members from NRRI Cuttack, Directorate of rice development, Patna and state agricultural department, Bhubaneswar. At district level the Program was monitored by a district level monitoring team where a scientist from ICAR-NRRI or OUAT is the member. The district level monitoring team (DLMT) used to visit 3-4 times during the crop growth period to ascertain the scientific way of executing the cluster demonstrations. In case of any deviation in implementing/executing the interventions were advised then and there to make necessary corrections. For example in case of insect, pest and disease attack the solutions were provided to the farmers. The scientists observed that the department after planning the activities during May/June conducts an orientation training Program of the departmental staffs as well as the farmers of respective clusters where they were explained about the rice varieties and their improved production technologies to be demonstrated under the Program. Under the cropping system based training Programs the farmers were trained 4 times during a year i.e. in May/June and November/December for Kharif crop and January/February and March/April for Rabi crops. The inputs required for the cluster demonstrations were purchased and supplied to the farmers by the state department in the initial period of the BGREI Program. However, currently "Surabhi stores" have been opened in different blocks by the agro industries department of the state where the identified farmers are purchasing the inputs on subsidy. Similarly the state follows online direct benefit transfer (DBT) system for asset building, site-specific activities and marketing support. Finally at the time of harvest, crop cutting experiments and field days were organized to assess the yield advantage achieved in the demonstrated varieties and production technologies.

3. Areas of demonstrations

The state of Odisha implemented the BGREI Program in 22 non-NFSM districts namely Balasore, Baragarh, Bhadrak, Cuttack, Dhenkanal, Mayurbhanj, Kendrapada, Gajapati, Jagatsinghpur, Jajpur, Kalahandi, Khurda, Koraput, Puri, Rayagada, Sonepur, Bolangir, Boudh, Ganjam, Nabarangpur, Nayagarh and Sambalpur. The state has demonstrated different improved production technologies through cluster demonstrations. The state has till date covered 0.40, 0.33, 0.23, 0.39, 3.28 and 2.34 Mha in direct-seeded rice (DSR), line transplanting, system of rice intensification (SRI), stress tolerant variety, hybrids and cropping system based demonstrations, respectively which is about 13.5% of the total rice area of the state.

4. Trends in Area, Production and Productivity of rice since 2009-10

The rice area in the state was 4.36 Mha in the pre BGREI year of 2009-10 out of which 0.69 Mha was under autumn rice and 3.41 Mha under winter rice and 0.26 Mha under summer rice. The area under rice showed a declining trend during the BGREI period. The average area of rice during the BGREI period was 4.03 Mha, which was decreased by 8.09% from the pre BGREI year 2009-10. The rice area coverage was 3.70 Mha in the year 2017-18, which is 15.3% lowered compared to the year 2009-10. The rice production of the state was 6.92 Mt in the year 2009-10 which was varied to a great extent depending upon the occurrence and magnitude of natural calamities in the state. However the productivity of rice showed an increasing trend during the Program period.

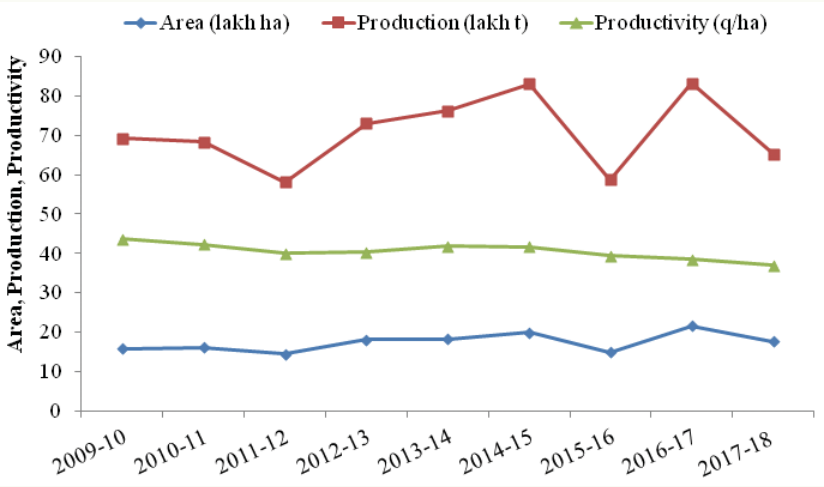

Fig. 2. Trends in area, production & productivity of rice in Odisha during the BGREI period.

5. Effects of the BGREI Interventions

Improved HYVs i.e., Ranidhan, CR Dhan 601, DRR 42, Sahbhagi Dhan, Swarna sub 1, Varshadhan, MTU 1010, Chandan, Kalajeera, Ketakijoha, DRHR 2, CR Dhan 70, Improved Samba Masuri and hybrids i.e., Ajaya, Arize 6444 have been already popularized. In the year 2017-18, the average yield of control plot was 3.79 t ha but the average yield of demonstrated plot under DSR technology was 4.67 t ha^{-1}, which was 23.42% higher than the yield of control plot. The highest percentage increase in yield was found in Khordha district under DSR with 40.37% more than the control plot. Under line-transplanted plot, the average yield of control plot was 3.73 t ha^{-1} whereas the average yield of demonstrated plot was 4.68 t ha^{-1} leading to 25.48% higher yield than the control plot. The highest percentage increase in yield (52%) was found in Bolangir district under this technology. The average yield of control plot was 3.83 t/ha whereas the average yields of demonstrated plot having stress tolerant varieties were 4.69 t/ha resulting in 22.58% higher yield than the control plot/farmers practice. The highest percentage increase in yield was found in Khordha district having stress tolerant varieties whereas highest percentage increases in yield was found in Bolangir district in cropping system based demonstrations. The overall increase in yield was 37.79% in the state by practicing improved production technologies like DSR, LT, STV and CSBD as compared to control plots.

Highest average paddy yield recorded in demonstrated plot of system of rice intensification (SRI) was 5.94 t/ha which was 26.5% higher than the average yield in control plot when pooled over 2 years. The results also indicated that stress tolerant varieties also producing similar yield as of line transplanting however in DSR plots comparatively lower yield is recorded in demonstrated plot. However, the control plot yield around the stress tolerant varieties plot recorded similar yield as the other control plots indicating that the area was neither not subjected to moisture stress or wrong selection of location for the stress tolerant varieties.

Table 2. Performance of Interventions in Odisha (pooled over last 2 years).

Name of the demonstration	Area covered (ha)	No. of crop cutting	Avg. yield in demonstration plot (q/ha)	Avg. yield in control plot (q/ha)	Increase in yield (%)
Line Transplanting	34843	6446	50.3	40.2	25.2
SRI	2400	299	59.4	46.9	26.5
Stress tolerant	36900	6480	50.7	40.9	24.1
DSR	6750	1695	47.2	38.0	24.2
CSBD	29522	5175	49.8	40.3	23.6

6. Production and Productivity Comparison of BGREI and Pre BGREI Years

Average rice production during the BGREI period was 7.01 Mt with an increase by 2.23% from the year 2009-10. The production was decreased by 5.6% resulting in 6.53 Mt for the year 2017-18. The state experienced reduction in production in the year 2011-12, 2015-16 and 2017-18 whereas more than 20% yield increase was recorded in the years 2014-15 and 2016-17.

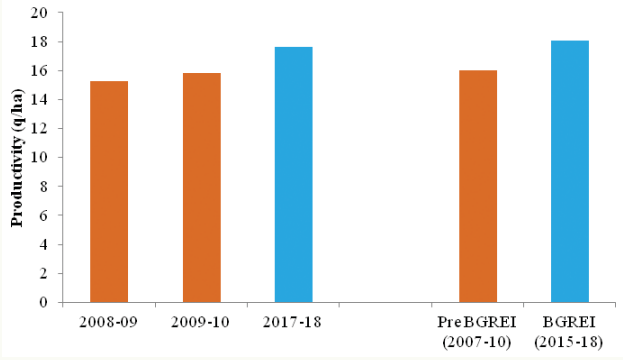

Fig. 2. Comparison of rice productivity in Odisha during the pre-BGREI and BGREI periods.

Productivity of rice increased by 11.4% to 1.76 t ha^{-1} for the year

2017-18 as compared to 1.58 t ha^{-1} in the year 2009-10. The average productivity during the latest 3 years of BGREI Program was 1.80 t ha^{-1}, which is 12.65% higher than the average productivity of 3 pre-BGREI years (2007-08 to 2009-10) i.e., 1.60 t ha^{-1} (Fig. 3).

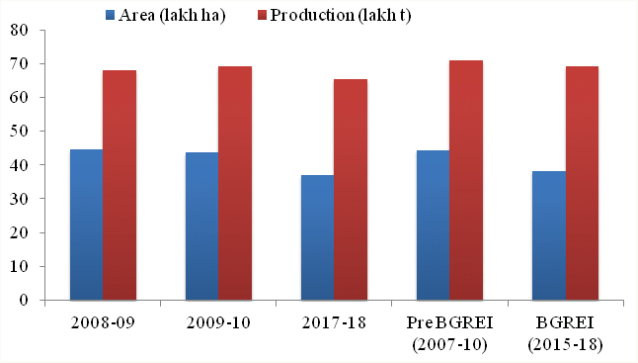

Fig. 3. Comparison of rice area and production of rice in Odisha during the pre-BGREI and BGREI periods.

Productivity of rice was 1.6 t ha^{-1} in the pre BGREI years. The rice productivity of the state increased by 12.46% during the BGREI period which may be attributed to the adoption of new HYVs and improved rice production technologies demonstrated through the program as there was on an average 23-26% increase in paddy yield in the demonstrated plots compared to control/farmers practice (Table 2). BGREI was the major program of the state on rice and implemented in 22 most important rice producing districts out of the 30 districts of the state. The state has already covered 13.5% total rice area under cluster demonstrations during the BGREI Program. Therefore, BGREI may be the key factor behind the increase in rice production and productivity of the state. However, decrease in yield in the year 2011-12 and 2015-16 compared to 2009-10 may be attributed to the natural calamities faced by the state. The state

Table 3. Rainfall pattern in Odisha during the Pre-BGREI and BGREI period.

Year	Normal rainfall (mm)	Actual rainfall (mm)	Deficit/ excess (%)	Natural calamity (Flood/ drought	Districts affected (No.)	Crop area damaged (ha)
2008-09	1473	1553.0	5.43	Flood	20	3,82,080
2009-10	1473	1407.4	-4.43	Flood	17	2,399
				Drought	18	60,913
2010-11	1479	1341.8	-9.25	Flood	6	30,212
				Drought	17	10786 villages
2011-12	1461	1334.1	-8.65	Flood	21	2,60,256
				Drought	21	7,04,718
2012-13	1461	1382.3	-5.35	Flood	5	1061
				Drought	4	314 villages
2013-14	1461	1644.9	12.63	Flood	18	5,61,590
2014-15	1461	1539.2	5.39	Flood	27	3,97,538
2015-16	1461	1210.4	-17.12	Flood	14	46,135
				Drought	27	14,92,565
2016-17	1461	1234.9	-15.45	Flood	6	-
				Drought	4	22658
2017-18	1461	1341.6	-8.14	Drought	15	3,15,000

faced four phases of floods during 2011 in which 21 districts were severely affected. The 1st and 2nd phases of flood occurred in the months of June and August respectively and floods in both 3rd and 4th phase were experienced in the month of September, 2011. In total about 2.60 lakh hectares of kharif crop sustained crop loss of more than 50% due to floods leading to a decline in productivity compared to pre BGREI year 2009-10. Similarly the state also faced both drought and flood in the year 2015-16. The erratic and deficient rainfall during the South West Monsoon-2015 was the main reason for the drought situation and particularly the continued moisture stress during the flowering and grain filling period reduced the rice productivity. Besides drought, the rice crop was also affected because of flood in Jajpur and Bhadrak district leading to 5.9% reduction in the yield compared to 2009-10. The yield decline was minimal during the BGREI period though the state was visited with frequent flood and drought, which may be ascribed to adoption of stress tolerant varieties in later part of the BGREI period.

7. Constraints

Major constraints affecting the rice production in Odisha include frequent occurrence of drought and flood, low irrigated areas, low exploitation of ground water and low and imbalanced nutrient use. Farmers do not have much flexibility in making management adjustments in rice cropping due to the frequent occurrence of drought and erratic rainfall regarding choice of variety, sowing time, and method of crop establishment and they mostly follow a standard set of practices which does not meet their needs during changing climatic situations such as delayed monsoon, early drought, and continuation of stress for a longer period resulting in poor yield. Besides, non-availability of quality seeds and fertilizers are also a reason behind low productivity. Majority of farmers are small and marginal and unable to bear the input cost. The state has a substantial area under rainfed broadcasted direct seeded rice where optimum plant population is not maintained. The knowledge on the insect, pests and dieses is very poor among the farmers. However, while implementing the BGREI Program in Odisha, the following issues aroused and constraints experienced which needs to be addressed of.

- Herbicides use is not popular for weed control in Direct seeded rice as timing of supply and application could not be maintained
- Bund planting of red gram is not successful in low land areas because of very small and narrow bunds
- Non availability of seeds lead to mismatched selection of stress tolerant varieties and location for demonstration
- Use of rotavators and seeding with seed drill/ drum seeder is limited
- Unavailability of high yielding YMV tolerant improved green gram/black gram varieties

8. Suggestions

Though there is substantial increase in the production and productivity of rice, for further enhancement of the rice productivity in the state, the following activities may be introduced/ up scaled in the state under BGREI Program.

- Creation of irrigation facility through cluster bore well/shallow tube wells particularly in rainfed broadcasted rice areas.

- Converting the broadcasted rice areas to drill sown DSR with use of herbicides.
- Planned production and distribution of good quality seeds of HYVs/Hybrids by producing truthful leveled seeds at district level involving Krishi Vigyan Kendras.
- Enhancing/optimizing fertilizer consumption in the state through real time nutrient management i.e. customized leaf colour chart (CLCC).
- Upscaling mechanized transplanting/SRI in irrigated medium land areas.
- Timely identification of insect pest and disease through e-pest surveillance and supply of pesticides.
- Converting the un-bunded uplands to horticultural (fruit) crops.
- Bringing rice fallow under cultivation by promoting cold/heat/YMV tolerant, green gram/ black gram and other low water required oilseed and spices.

The BGREI program could improve production and productivity of rice in state of Odisha. It also increased the farm mechanization activity in the state. Adoption of stress tolerant varieties and the site specific activities like creation of irrigation facility substantial reduced the effect of natural calamities like drought and flood and maintained the production of in the state even if in severe drought and flood occurred during the BGREI period.

Bringing Green Revolution to Eastern India: Experiences and Expectations in Uttar Pradesh

R Tripathi and ON Singh

Summary

Agriculture is the leading occupation in Uttar Pradesh. Uttar Pradesh has accounted for 19% share in the country's total food grain output. To increase the agricultural productivity in eastern part of ten states, BGREI program was implemented in 2010-11 through cluster demonstrations of improved rice production technologies i.e. direct seeding; Line transplanting, SRI, Stress tolerant varieties, Hybrids rice production and cropping system based demonstrations. The hybrid rice demonstration has already been demonstrated in 7067 ha area whereas under cropping system based demonstration, 4473 ha has been demonstrated. The state also produced 750q of new certified seeds of new varieties, which are not older than 10 years and about 3346.7q of hybrid seeds and 2848.5q of certified seeds have already been distributed among farmers. 156 pump sets, 104 rotavators, 82 multi crop threshers, 15 pump sets, 46 tractor driven multi crop threshers were distributed to the farmers under asset building activities.

For proper implementation of the activities and cluster demonstrations, there should be proper monitoring of cluster demonstrations by the university staff at regular interval, which is most of the time lacking. KVK scientists must visit the demonstration and advise the right pesticide and dose as and when required. The of BGREI beneficiary farmers should be made aware about the technologies to be demonstrated in their field under cluster demonstrations and the benefits associated while following these scientific practices. Farmer's meet at regular interval may be conducted in the village by State agricultural department Officials along with KVK scientists.

1. State background

Uttar Pradesh, one of the most populous states in the country, is the fifth largest Indian state with an area of 2,43,286 sq km, situated between 23°52' and 31°28' N latitudes and 77°3' and 84°39' E longitudes. It can be divided into three distinct regions, Himalayan region in the North which is highly rugged and varied terrain, Gangetic plain in the centre which is highly fertile, flat topography broken by numerous ponds, lakes and rivers and the Vindhya Hills and plateau in the south. The climate of Uttar Pradesh can also vary widely, with

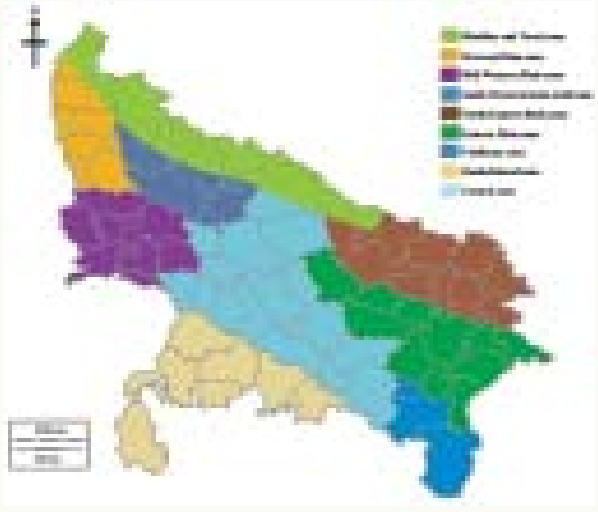

Fig. 1. Agro climatic zones of Uttar Pradesh.

temperatures varying from 47 °C in summer, to as low as -1°C in winter. The state has three distinct seasons, winter season from October to February; summer season from March to mid-June and the rainy season from June to September. The state has 75 districts.

It offers diverse agro climatic conditions, which are conducive for agricultural production. The major crops grown in the state are paddy, wheat, sugarcane, potato, mustard, gram, pea, groundnut and lentil. The total cultivated area of the state is 16.68 Mha and the gross cropped area is 25.52 Mha. The cropping intensity in the state is 153%. Nine agro-climatic zones identified in the state are depicted in Fig. 1 and the districts falling in these agro-climatic zones along with soil and climatic characteristics is given in Table 1.

The largest Gangetic plain region is in the north includes the Ganges, Yamuna, Doab and the Ghaghra plains. The smaller Vindhya Range includes plateu region is in south. The bhabhar tract gives place to terai area. The entire alluvial plain is divided into three sub regions i.e. the eastern tract consisting of 14 districts. The flood and drought are common phenomena of this tract. The highest density of population is also found in this tract. On account of highest density of population, the per capita availability of land is very low in comparison to other tracts of the state. The state has more than 32 large and small rivers, of them, the Ganges, Yamuna, Saraswati, Sarayu, Betwa and Ghaghara are larger rivers of the state.

The economy of Uttar Pradesh is based mainly on Agriculture and 65% of the total population is dependent on agriculture. According to the survey of 2014-15, approximately 16.60 Mha (68.7%) land is used for cultivation. According to Agriculture survey 2011-12, there are 233.25 lakh farmers in the state. In the year 2015-16, food grain production was 43.95 Mt against the target of 62.66 Mt out of which production in Kharif were 15.91 Mt and

Table 1. Districts of Uttar Pradesh under different Agro-climatic Zone.

Agro-climatic Zone	District
Bhawar and plain, tarai plain	Parts of different district Saharanpur,Bahraich, Bareilly
Western Plain Zone	Shaharanpur, Muzzaffar nagar, Baghpat
Mid western plain zone	Bijnore, Moradabad, Rampur, Bareilly, Badaun, Pilibhit and Shahjahanpur (7 district)
Western sub tropical zone	Aligarh, Mathura, Agra, Firozabad, Etah, Mainpuri (6 districts)
Mid plain zone	Farrukhabad, Kannauj, Etawah, KanpurNagar, KanpurDehat, Unnao, Hardoi, Khiri, Sitapur, Lucknow, Raebareilly, Fatehpur, Pratapgarh and Allahabad (14 districts)
Bundelkhand Zone	Lalitpur, Jhansi, Jalaun, Hamirpur, Banda and Chitrakott (7 districts)
North Eastern Plain Zone	Behraich, Balrampur, Gonda, Siddharthnagar, Basti, Maharajganj, Kushinagar and Deoria (9 districts)
Eastern Plain Zone	Barabanki, Faziabad, Sultanpur, Jaunpur, Azamgarh, Mau, Ballia, Ghazipur, Varanasi and Sant Ravidasnagar (10 districts)
Bindhya Zone	Mirzapur and Sonbhadra (2 Districts)

Table 2. Soil and climatic characteristics of the Agro-climatic Zones of Uttar Pradesh.

Agro climatic zone	Tempera-ture (°C) Min	Max	Average annual rain fall (mm)	Irrigated Area (%)	Soil
Bhawar and	5.5	38.4	1400	73.29	Minimum to medium in Alluvial plain, tarai plain phosphorous Medium to high in potassium and organic matter in high quantity.
Western Plain Zone	1.5	43.3	795	89.23	Alluvial, pH- normal to alkaline and organic matter minimum to medium quantity
Mid western plain zone	4.5	45.4	1032	83.21	Mostly alluvial, $_{P}$H Normal to slightly alkaline and organic matter in medium quantity.
Western sub tropical zone	4	47	662	75.52	Alluvial and aravali
Mid plain zone	5.5	45	863	66.41	Alluvial, PH Normal to slightly alkaline and organic matter in medium quantity.
Bundelkh and Zone	3.0	47.8	867	38.65	Rakar, Parwa, Kabar and Mar
North Eastern Plain Zone	4.9	44.2	1240	48.24	Alluvial and calcarious soil
Eastern Plain Zone	5.7	41.4	803	69.43	Alluvial , sodic and diara soil
Bindhya Zone	5.0	45.2	1134	52.85	Black heavy, Red granular and Alluvial soil in plains

Rabi 28.04 Mt. Production of oil seed crops was 0.85 Mt against the target of 1.30 Mt. In the year 2016-17, 6.69 Mt fertilizer was distributed for achieving the higher yield by application of balanced nutrition. To achieve the desired production and maintain the soil health, special efforts were made for use of phosphorous and potash along with nitrogen.

2. Major interventions through BGREI

2.1.1. Cluster demonstrations

1. System of Rice Intensification: System of Rice Intensification (SRI) is a better rice cultivation practice where irrigation and drainage facilities are available. In this technique 8-10 days old rice seedling are transplanted with wider spacing (25 x 25 cm). Generally one seedling per hill is planted and need based water management is practiced.
2. Direct Seeded Rice: Since labour shortage during peak time of transplanting is a major problem, direct seeded rice is helpful in those areas.

3. Cropping system based demonstration: There is a need to utilize the land and increase the cropping intensity for profit maximization. Hence, cropping system based demonstrations were taken up which also helps in utilization of residual moisture. This also helps in crop diversification and ensures the better soil condition for next crop.
4. Stress Tolerant Varieties (STV): There are problems of both drought and flood in different areas of eastern UP. To reduce the impact of adverse environmental situation like uneven and less rainfall, stress tolerant varieties like swarna sub-1 and Sahbhagi Dhan were introduced. But these varieties should be recommended only for those areas where there is need for stress tolerant varieties.
5. Distribution of seeds (HYVs and Hybrids): For increasing the productivity of rice, hybrid seeds of were distributed. In some areas Arize 6444, performed better under water shortage conditions where there was less rainfall than normal.
6. Line transplanting: Line transplanting was promoted for increasing the yield by facilitating the intercultural operations to perform easily.
7. Strategies for bringing rice fallow area under cultivation under BGREI:

To bring rice fallow areas under cultivation cropping system based approach was followed by creating irrigation facilities like small boring, lift irrigation point, etc to improve irrigation potential. Farm machineries and implements suitable for small farmers were promoted.

2.1.2. Asset building, site specific activities & marketing support

Different asset building activities were taken up to encourage farm mechanization and use of improved agricultural implements to enhance the farm activity in the BGREI period i.e., 80038 shallow tube wells were established, 266 drum seeder and cono-weeders, 1619 zero till seed drills, 7094 rotavators, 28912 pump sets, 211 manual sprayers, 1914 power knapsack sprayers, 5 power weeders, 1184 paddy threshers, 35 laser land levelers, 70 power tillers and 726 power sprayers were provided to the farmers. About 36 self propelled power reapers, 9 self propelled paddy transplanters, 28 straw reaper cum binders and 41 tractor drawn zero drill seed cum fertilizer drills were distributed among the beneficiary farmers. About 35.18 lakh meters of water carrying PVC pipes were provided, 1.95 lakh kilograms of bio-fertilizers were provided to increase the availability of nutrients to the soil and plant and 9 mini combined harvesters were provided under site-specific activities. To develop marketing support activities, 530 community-drying platforms were constructed in this Program.

3. Areas on demonstration

Bringing of Green Revolution to Eastern India (BGREI) Program started in 2010-11 to address the constraints limiting the productivity of "Rice based cropping systems in eastern U.P comprising of 14 districts under Prayagraj, Kaushambi, Varanasi, Chandauli, Sonbhadra, Bhadohi, Maharajganj, Kushinagar, Basti, Siddharthnagar, Ayodhya, Ambedkarnagar, Sultanpur, Gonda rice crops and 5 districts Bhadohi, Maharajganj, Siddharthnagar, Ambedkar nagar and Sultanpur under wheat crops.

4. Trends in area, production and productivity of rice since 2009-10

The trends of rice area, production and productivity for Eastern Uttar Pradesh (Fig. 2) and Uttar Pradesh (Fig. 3) showed that rice area in the entire state varied from 5.19 to 5.99

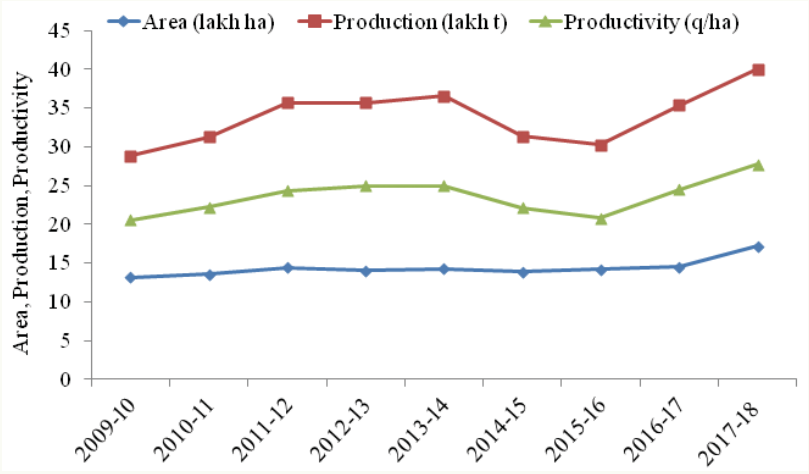

Fig. 2. Trends in area, production and productivity of rice in Eastern Uttar Pradesh before and after implementation of the BGREI program.

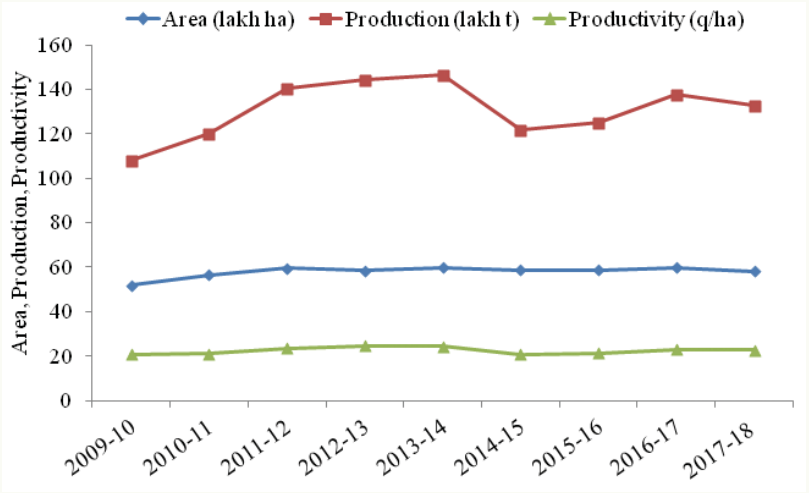

Fig. 3. Trends in area, production and productivity of rice in Uttar Pradesh before and after implementation of the BGREI program.

Mha during 2009-10 to 2017-18. Rice production was 10.81 Mt in 2009-10 before implementation of BGREI, which increased to 14.64 Mt in 2013-14. Rice production enhanced by 9.5% was recorded in the year 2017-18 (2.46 t ha^{-1}) over the year 2009-10.

5. Effects of BGREI Interventions

There was a visible increase in rice productivity after implementation of the BGREI programme. There was 25.6% increase in rice productivity in 2017-18 compared to 2009-10. Similarly rice production was 29% higher in 2017-18 compared to 2009-10 whereas no major change in rice area was recorded. There was 14.8% increase in productivity of rice in BGREI demonstration plots as compared to control plots.

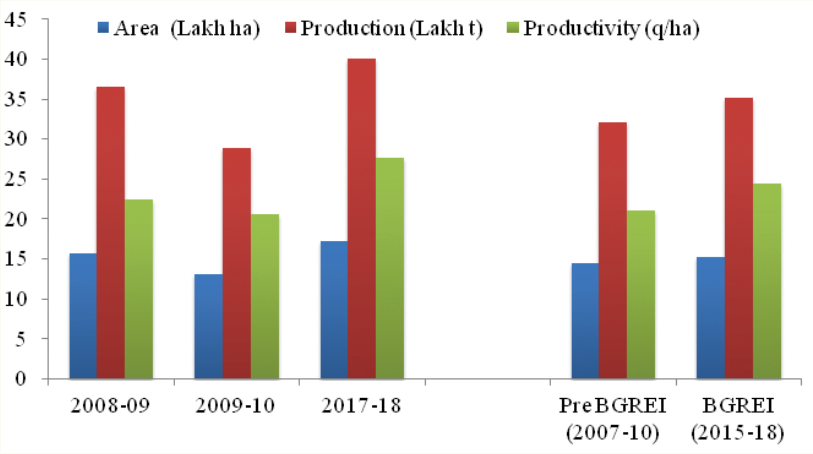

Fig. 4. Impacts of the BGREI implementation in BGREI districts of Uttar Pradesh on area, production and productivity of rice.

6. Production and Productivity Comparison of BGREI and Pre BGREI Years

Impacts of BGREI Program can be assessed by comparing the production and productivity of crops before and after the implementation of the BGREI programme. In Eastern UP, the productivity of rice was 2.19 t ha^{-1} in the pre BGREI year 2009-10 and in 2017-18 it was 2.33 t ha^{-1}, which is 6.39% higher than the pre BGREI year. The average productivity during the last 3 years of BGREI Program was 2.30 t ha^{-1}, which was 3.60% higher than the average productivity of three pre-BGREI years (2007-08 to 2009-10) i.e., 2.22 t ha^{-1} (Fig. 5).

Rice production during the BGREI period 2017-18 was 4.0 Mt, which is 38.88% higher than production of the year 2009-10 i.e., 2.88 Mt. The average production of last three BGREI years was 10.57 Mt, which is 9.65% more than the average production of last three years of pre BGREI period i.e., 9.64 Mt.

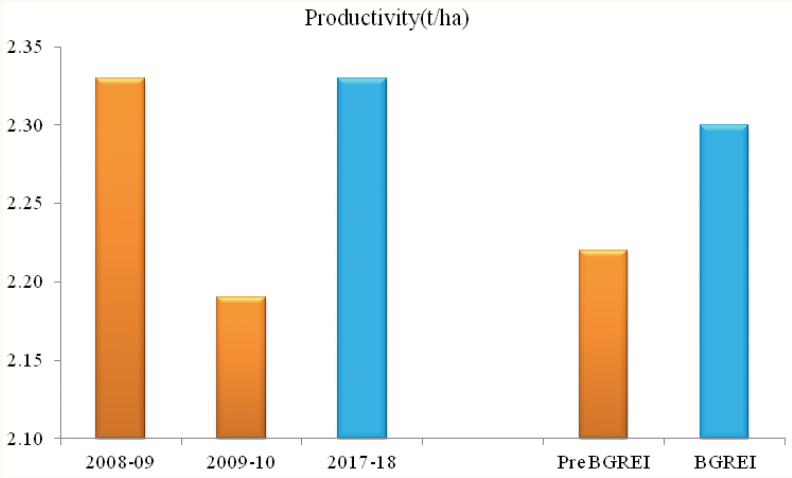

Fig. 5. Comparison of Pre BGREI & BGREI Rice Productivity in Eastern Uttar Pradesh.

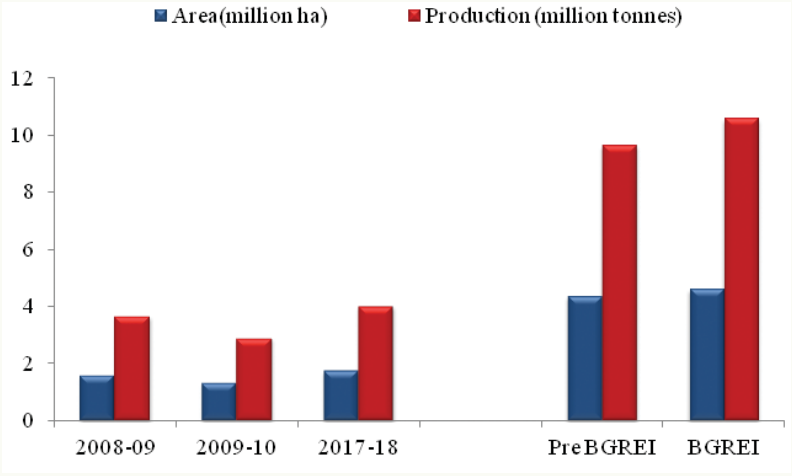

Fig. 6. Comparison of Pre BGREI & BGREI Rice Area & Production in Eastern Uttar Pradesh.

Table 3. Area, Production and Productivity of Rice in BGREI Districts.

Year	Area (Mha)		Production (Mt)		Productivity (t ha^{-1})	
	U.P.	BGREI District	U.P.	BGREI District	U.P.	BGREI District
2009-10*	5.60	1.42	11.74	3.11	2.10	2.19
2014-15	5.84	1.39	13.24	3.13	2.27	2.26
2015-16	5.84	1.42	12.43	3.03	2.13	2.14
2016-17	5.97	1.45	14.40	3.54	2.41	2.44
2017-18	5.90	1.46	15.44	4.00	2.62	2.75

*Base Year

There was significant impact of BGREI demonstrations. Rice Productivity increased 0.56 t ha^{-1} (25.67%) in 2017-18 as compared to base year.

Table 4. Area, production and productivity of wheat in BGREI districts.

Year	Area (MHa)		Production (Million ton)		Productivity (t/ha)	
	U.P.	BGREI District	U.P.	BGREI District	U.P.	BGREI District
2009-10*	9.73	0.64	27.78	1.73	2.86	2.71
2014-15	9.85	0.59	20.06	1.36	2.04	2.34
2015-16	9.64	0.59	26.87	1.78	2.79	3.03
2016-17	9.89	0.57	34.97	2.07	3.54	3.61
2017-18	9.75	0.59	35.65	2.28	3.66	3.89

*Base Year

There was a 43.5 % increase in average wheat productivity in 2017-18 compared to 2009-10 in BGREI districts. Inspite of wheat area reduced in 2017-18 compared to 2009-10, there was 31.8% higher production in 2017-18 compared to 2009-10.

Average annual rainfall of Eastern UP is 902.3mm. In the year 2017-18, there was 932.7 mm of rainfall where the actual rainfall was 989.7mm i.e., an excess of 6.1% rainfall was recorded in Eastern UP (considering pre-

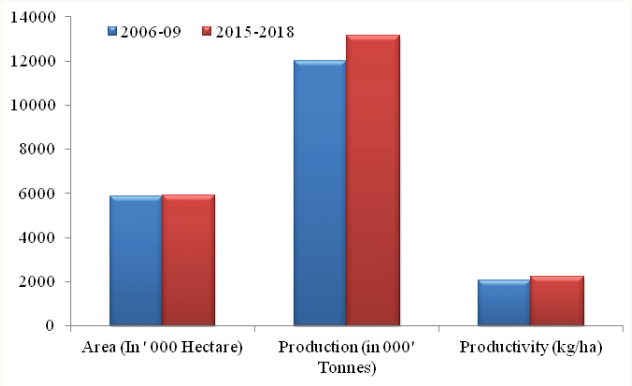

Fig. 7. Average change in area production and productivity in rice from 2006-09 to 2015-18 in Uttar Pradesh.

Table 5. Rainfall pattern in Eastern Uttar Pradesh during pre-BGREI and BGREI period.

Years	Normal rainfall (mm)	Actual rainfall (mm)	Deficit/ excess (%)	Natural calamity (Flood/ drought)	Districts affected (No.)	Crop area damaged (in lakh ha)
2006-07	767.0	1009.0	31.5	Flood	12	-
2007-08	812.0	1009.0	24.3	Flood	20	4.33
2008-09	1100.0	1009.0	-8.27	Flood	25	4.98
2009-10	694.6	1008.6	45.2	-	-	-
2010-11	742.3	1002.9	35.1	Flood	33	7.00
2011-12	864.7	989.7	14.4	Flood	36	3.96
2012-13	817.5	989.7	21.1	-	-	-
2013-14	975.6	989.7	1.4	Flood	40	797.50
2014-15	627.6	989.7	57.6	-	-	-
2015-16	569.3	989.7	73.8	-	-	-
2016-17	863.8	989.7	14.5	Flood	31	5.96
2017-18	932.7	989.7	6.1	Flood		

monsoon, monsoon and post-monsoon) in that year. The number of districts affected and crop area damaged due to flood is mentioned below (Table 5). In Uttar Pradesh, around 40 districts were affected by flood in 2013-14. In the same year, 797.5 lakh ha crop area was affected due to flood which was the highest ever recorded.

7. Suggestions

- KVK scientists must visit the demonstration patches and advise the right pesticide and dose as and when required. Farmers may purchase these pesticides from the certified Agriclinics and Agri-junctions in consultation with agriculture department for which payment can be made through DBT on production of authentic bills to Agriculture department.
- It was found that most of the farmers under cluster demonstration don't prefer line transplanting due to higher labour charges. It was suggested that a kishan goshthi or Krishak sammelan may be organised for farmers so that they can be informed about the benefits of line transplanting
- DLMT member from universities should regularly visit the cluster demonstrations. Proper monitoring of BGREI cluster demonstrations need to be done and DLMT members should visit the demonstrations at important growth stages of crop and technical backstopping may be provided along with monitoring.
- Light traps are not utilized efficiently for pest control. Since, majority of the farmers are not having electricity connection. Hence solar light traps may be better option for these areas.
- Distribution of mini kit containing seed, micro-nutrients, herbicides, sprayers in one time well before start of monsoon may save the time of both farmers and government employees. It makes verification and processing of bill much easier.
- Customized leaf colour chart (CLCC) developed by NRRI, Cuttack may be used for efficient nitrogen management in rice.
- Demonstrations must be expanded for more number of districts.
- Farmer's perception and preference about consumption and marketing should also be considered while recommending a variety for a particular location.

The productivity of rice in Eastern UP has increased significantly from 2006-07 to 2017-18 and this improvement could be possible due to different interventions i.e. SRI, direct seeded rice, line transplanting and stress tolerant varieties, which are introduced to the beneficiary farmers through BGREI Program. Different useful farm machineries and implements were provided to the farmers through this Program, which helped in capacity building and encouraging to adopt modern techniques. Kishan goshthi or Krishak sammelans may be organised at regular intervals for creating awareness about the Programs and other interventions for benefit of farmers.

Bringing Green Revolution to Eastern India: Experiences and Expectations in West Bengal

S Saha

Summary

The BGREI program in West Bengal is implemented in eleven districts viz., Siliguri Sub-division (Darjeeling), Dakshin Dinajpur, Malda, Murshidabad, Nadia, North 24-Parganas, Hooghly, Burdwan, Bankura, Birbhum and Paschim Medinipur. Rice yield and income of the farmers showed an increasing trend since the inception of the Program due to introduction of several interventions, regular visits by scientists and extension officers and awareness meeting. Since inception, cluster demonstrations on rice was conducted in 8.359 lakh ha area. About 18100 tons of certified HYV paddy seed was produced. Micronutrients (Zn and B) was distributed in 0.38 Mha area of BGREI Cluster. Bio-fertilizers was distributed for 2.27 lakh ha area. About 0.25 Mha area each were covered under distribution of Plant Protection Chemicals including Bio-pesticides and herbicides, respectively. About 1.95 lakh of different types of farm machineries were distributed to beneficiaries under this program. Regarding Site Specific Activities, about 10954 different irrigation related structures/works like Check Dam, Pucca Irrigation channels, water harvesting structures, transmission channel treatment, stream bank erosion control, etc. were constructed in target districts and 46758 different structures / works like paddy processing yards for sun drying, manually operated grain drier, low cost paddy & grain storage structures, etc. were also created since till last year. Total 3057 cropping system based trainings were organized up to 2017-18 under this program. Since inception of BGREI to 2017-18, almost 100% physical performance has been achieved utilizing 1025.61 crore (99.8% of financial allocation).

1. State Background

West Bengal is located between 21p 31'& 27p14' North Latitude and 85p91' & 89p53' East Longitude. The tropic of Cancer passes through the middle of the state covering the district in the East, Nadia and Bardwan and in the West Bankura and Purulia. The state has occupied a geographical area of about 88,75,200 hectares. Based on soil characterization, rainfall, temperature and terrain, six main agro-climatic zones in West Bengal have been identified (Fig. 1). These are: (i) Hill Zone, (ii) Terai Zone, (iii) Old Alluvial Zone, (iv) New Alluvial Zone, (v) Red and Laterite Zone & (vi) Coastal and Saline Zone . Across the state there is variety of soil.

The State is broadly divided into six Agro-climatic Zones, which fall within three Agro-climatic Regions (Eastern Himalayan Region, Lower Gangetic Plain Region, Eastern Plateau& Hill Region) out of total 15

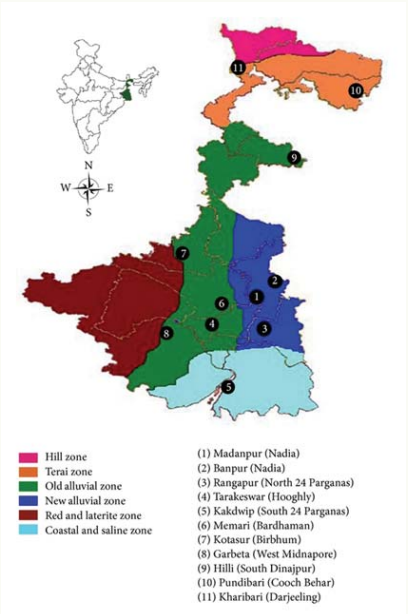

Fig. 1: Agro-climatic Zones of West Bengal

regions in India, as classified by the planning commission, Govt. of India. The state has occupied a geographical area of about 88,75,200 hectares sharing 2.7% land of the country but producing more than 8% of country's food production and providing space 7.6% of the country's population. Total cultivable area of this state is about 5.6 Mha which is 63% of its geographical area and having 62% irrigation area of Net cropped area. Gross cropped area is 9.46 ha with cropping intensity (2012-13) of 182%.

West Bengal ranks first in production of rice, jute and vegetables. Production of different crops under food grains in the state has recorded significant growth, which is recognized by GOI through awarding "KRISHI KARMAN" 3 times in a row during 2011-12, 2012-13 & 2013-14.

There are 71.23 lakh farm families of whom 96% are small and marginal farmers. The average size of land holding is only 0.77 ha. However, the State is bestowed with diverse natural resources and varied agro-climatic conditions, which support cultivation of a wide range of crops. West Bengal ranks first in paddy and vegetable production in the country. It stands second in potato production (after Uttar Pradesh). It is also the leading producer of jute, pineapple, litchi, mango and loose flowers. Cultivation of pulses, oilseeds and maize is also picking up fast.

Table 1. Districts under each Agro-Climatic Zone in West Bengal.

Agro-Climatic Zone	District
1. Northern Hill Zone (Eastern Himalayan Region)	Part of Darjeeling & Jalpaiguri
2. Teesta-Tarai Alluvial Zone (Eastern Himalayan Region)	Coochbehar, Part of Darjeeling, Jalpaiguri& U. Dinajpur
3. Gangetic Alluvial Zone (Lower Gangetic Plain Region)	D. Dinajpur, Malda, Nadia, Part of U. Dinajpur, Murshidabad, N. 24 PGS, S. 24 PGS, Howrah, Hoogly & Birbhum
4. Vindhyan Alluvial Zone (Lower Gangetic Plain Region)	Part of Murshidabad, Howrah, Hoogly, Burdwan, Birbhum, Bankura, Paschim & PurbaMedinipur
5. Coastal Saline Zone (Lower Gangetic Plain Region)	Part of N. 24 PGs, S. 24 PGS, Howrah &Purba Medinipur
6. Red & Laterite Zone (Eastern Plateau & Hill Region)	Purulia, Part of Burdwan, Birbhum, Bankura & Paschim Medinipur

The major soil types are laterite and lateritic soils, red soils, alluvial soils, coastal soils, Terai soil, Colluvial and skeletal soils 7. Transition soils. The annual rainfall varies in the different parts of the state. North Bengal receives the highest rainfall, 2000 to 4000 mm. In the coastal areas rainfall is about 2000 mm, in the Ganga plain and in the central part of the state rainfall is about 1500–2000 mm and in the western plateau region the amount of rainfall received is about 1000 to 1250 mm. Drought is a common phenomenon in Bankura and Purulia districts. Rainfall that occurs in the Summer months often bring about heavy storms called Kalbaishakhi. Adequate rainfall in the plains of West Bengal influences crop production. The hot wet climate is good for the production of rice and jute. Higher rainfall received in the northern mountainous region is favourable for the production of tea, which is popular all over the world. Pulses and oilseeds are also produced in large quantities. Soil

pH varies from 5.8-6.8. The Tropic of Cancer passes 6 km north of Nabadwip, so, according to latitude, the northern part of the state falls in the temperate belt and the southern part fall in the tropical belt. But the southern part receives adequate rainfall and because of maritime influence is not severely hot. Barring the mountainous parts of Darjeeling and Jalpaiguri, the entire state experiences a warm wet tropical monsoon climate. Regional differences are visible in the climate. In the western plateau region, rainfall is low and variations in temperature are more common; maritime influence in the coastal region makes the climate here moderate and pleasant. The summer temperatures in the state ranges between 26 °C (79 °F) and 43 °C (109 °F) while the winter temperatures range from 10 °C (50 °F) to 19 °C (66 °F). The detailed description about the agro climatic zone is as follows:

Table 2. Important physiographic features of the Agro-climatic Zone.

Agro-climatic Zone	Soil type	Area (Mha)	Annual rainfall (mm)	Maximum & minimum temperature (^{0}C)
1. Northan Hill Zone (Eastern Himalayan Region)	Brown Forest & Tarai Soil	0.37	2500-3500	19.5 & 4.8
2. Teesta-Tarai Alluvial Zone (Eastern Himalayan Region)	Tarai Soil	1.15	2000-3000	32.3 & 12.8
3. Gangetic Alluvial Zone (Lower Gangetic Plain Region)	Ganga Alluvial	2.08	1350-1650	35.0 & 15.6
4. Vindhyan Alluvial Zone (Lower Gangetic Plain Region)	Vindhyan Alluvial	1.77	1500-2000	35.5 & 15.1
5. Coastal Saline Zone (Lower Gangetic Plain Region)	Coastal Saline	1.32	1600-1800	34.0 & 16.0
6. Red & Laterite Zone (Eastern Plateau & Hill Region)	Red Soil	1.99	1100-1400	37.0 & 14.8

The net cropped area is 5.20 Mha which comprises 68% of the geographical area and 92% of arable land. The cropping intensity is 184%. However, as the State is located in the humid tropic and the Bay of Bengal is close-by, it has to often face vagaries of nature like flood, cyclone, hailstorm etc. Though the state has a surplus production of rice, vegetables and potato however a huge gap exists between the requirement and production of pulses, oilseeds and maize. Deterioration of soil health due to imbalance in the use of chemical fertilizers, paucity of suitable improved varieties of seed, inadequate farm mechanization, unorganized marketing structure etc. are major challenges to agricultural growth.

2.Major interventions through BGREI

2.1.1. Cluster demonstrations:

Major interventions under BGREI program in the state are given below:

- Cluster Demonstrations: It includes i. Direct seeded rice; ii. Line transplanting; iii. SRI; iv. Stress tolerant varieties; v. Hybrid rice (during dry season); vi. Cropping system based demonstrations viz., *Kharif* rice – Coarse cereals (Hybrid Maize); *Kharif* rice – *rabi* pulses (Lentil) and *Kharif* rice – rabi oilseeds (Mustard/Hybrid mustard).

- Production of seeds – It includes hybrid rice seed production and ii. Certified seeds production (for varieties less than 10 years)
- Nutrient Management and Soil Ameliorant
- Integrated Pests Management
- Post Harvest& Marketing Support
- Cropping System Based Trainings

2.1.2. Asset building and site-specific activities

It includes construction of check dam on community basis, construction of pucca irrigation channels on community basis (100 x 0.45 x 0.5 m) and excavation of water harvesting structure on community basis

3. Areas of demonstrations

The Agriculture Department of the State is working closely with the agri-allied departments viz. Animal Resources Development, Fisheries, Agri. Marketing, Horticulture, Cooperation, Water Resources Investigation Development, Irrigation & Waterways, Forest, Sericulture, Food & Supplies and WBCADC under the P&RD Department to achieve the above objectives. During the recent years, the focus has been on helping small and marginal farmers in their endeavor to get better returns from farming through an improved package of practices, quality inputs, crop diversification, front-ended subsidy for farm mechanization, augmenting irrigation facilities through water conservation and watershed management and by providing market intelligence; the betterment of farmers belonging to SC, ST and backward classes; empowerment of women in agriculture; fostering Public Private Partnership involving the FPOs and NGOs etc. The Department has also launched an ICT based agri-extension portal, MATIR KATHA, which provides a dynamic platform to disseminate crop solution to farmers at farm-gate level. Eleven districts are covered under this Program. It includes Siliguri Sub-division (Darjeeling), Dakshin Dinajpur, Malda, Murshidabad, Nadia, North 24-Parganas, Hooghly, Burdwan, Bankura, Birbhum, PaschimMedinipur.

4. Trends area, productivity, production of rice and wheat since 2009-10

The trends of rice area and production are described in (Fig. 3). It is seen that the rice area in West Bengal varied in the range of 49.4 to 5.63 Mha for the period 2009-10 to 2017-18. However, there is slight variation in the production, which ranged from 13.05 Mt in 2010-11 to 15.95 Mt in 2015-16. As there was less variation in the area, higher production is mainly due to the increase in the productivity, which ranged from 2.55 t ha^{-1} in 2009-10 to 2.92 t ha^{-1} in 2017-18.

5. Effects of interventions of BGREI

From rice productivity trend (Fig. 3), it was found that the productivity of rice showed a sharp increasing trend due to the impact of BGREI interventions from 2010-11 to 2017-18 and it varied from 2.64 to 2.92 t ha^{-1}. There was 10% enhancement in rice productivity due to the imposition of BGREI interventions. From the crop cutting results of kharif rice during 2011-12 to 2013-14 under BGREI, it was found that the average yield of cluster demonstration increased from 3.27 to 4.63 t/ha. The percentage increase in yield over Non- BGREI plots varied from 8.4 to 22.7% (Table 3).

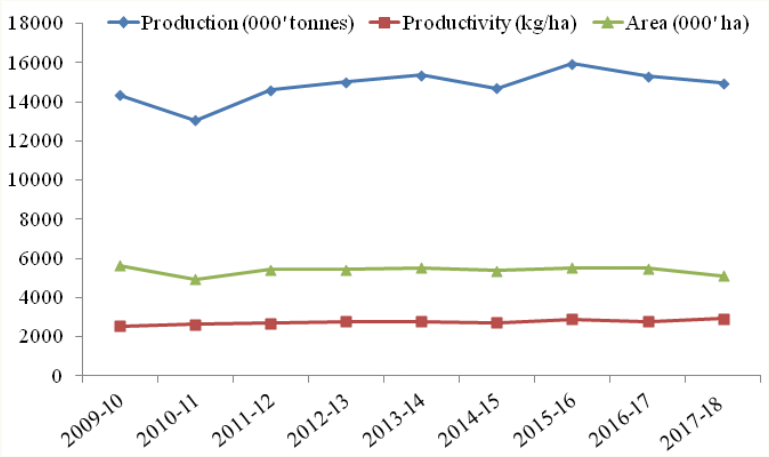

Fig. 3. Trends in area, productivity, production of rice during 2009-10 to 2017-18.

Table 3. Crop cutting results of Kharif paddy under BGREI for West Bengal.

Year	Yield of BGREI plots (t ha^{-1})	Yield of non-BGREI plots (t ha^{-1})	Increase (%)
2011-12	3.27	2.73	16.5
2012-13	4.40	3.40	22.7
2013-14	4.63	4.24	8.4

Table 4. Yield of paddy under cluster demonstration (2017-18).

Crop	Yield of BGREI plots (t ha^{-1})	Yield of non-BGREI plots (t ha^{-1})	Increase (%)
Kharif HYV paddy	4.81	4.42	8.9
Boro HYV paddy	5.55	4.98	11.5
Rice hybrid (boro)	6.98	6.01	16.1

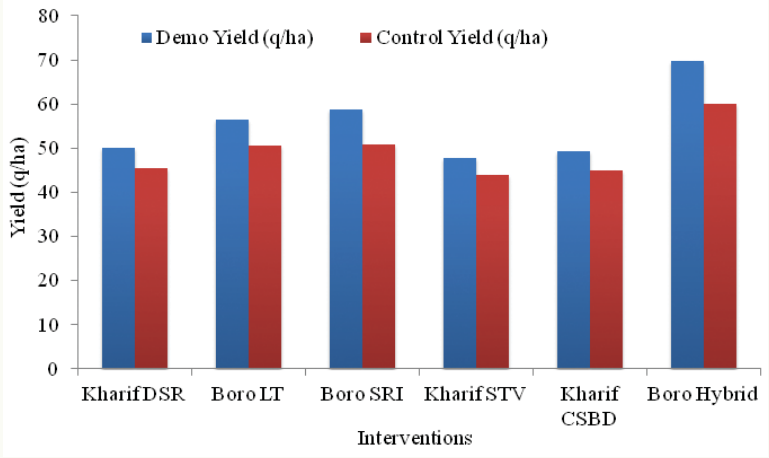

Fig. 4. Intervention-wise yield in BGREI program (2017-18).

Status of Implementation of major components of BGREI since inception

- Cluster Demonstrations on Rice conducted in 8.36 lakh ha areas.
- Cluster Demonstrations on Wheat conducted in 8.86 lakh ha areas.
- Certified HYV Paddy Seed Production of 18100 mt.
- Distribution of Micro-nutrients for 3.81lakh ha areas.
- Distribution of Bio-fertilizers for 2.27 lakh ha areas.
- Distribution of P.P.Chemicals & Bio-pesticides for 2.54 lakh ha areas.
- Distribution of Weedicides for 2.52 lakh ha areas.
- Distribution of 1.95 lakh of different types of farm machineries.
- 10954 Nos. of different irrigation related structures / works like Check Dam, Pucca Irrigation Channels, Water Harvesting Structures, Transmission Channel Treatment, Stream Bank Erosion Control etc.
- 46758 Nos. of different structures / works like paddy processing yards for sun drying , manually operated grain drier , low cost paddy & grain storage structures etc.
- Organised 3057 cropping system-based trainings.
- Since inception of BGREI to 2017-18, almost 100% physical performance has been achieved utilizing 1025.61 crore (99.81% of financial allocation).

6. Production and Productivity Comparison of BGREI and Pre BGREI Years

The benchmark yield of rice was 2.65 t ha^{-1} during 2010-2011 and it was enhanced to 3.26 t ha^{-1} during 2014-2015 and there was a sharp increase in rice yield from 2010-2011 to 2014-2015 due to the interventions followed under the BGREI program.

Annual mean rainfall data (1901-2000) showed that Jalpaiguri district has received highest rainfall (2306 mm ± 25.18 mm) whereas Purulia district has received lowest rainfall (854 mm ± 16.78 mm). The highest pre-monsoon rainfall was found in Cooch Bihar district (111.86 mm. ± 31.467 mm) and lowest was in Purulia district (37.152 mm. ± 18.69 mm). During the

monsoon period, maximum rainfall was recorded in the Jalpaiguri district (1465 mm. ± 66.69 mm.) and minimum occurred in the South 24 Parganas district (1262 mm. ± 54.619 mm.). During the post-monsoon period, it also varied from highest rainfall in the North 24 Parganas and lowest in the Puruliya district. In the winter season, rainfall in the whole state has decreased considerably. But still among the districts, Purulia has received maximum rainfall (17.241 mm. ± 11.012 mm.) and Jalpaiguri has received minimum rainfall (7.732 mm± 5.004 mm.). So, the changing monsoonal rainfall trend is the highly significant factor of determining economic behavior of the districts. Therefore, from this long-term rainfall distribution pattern analysis in the districts of West Bengal one can say that Purulia is a drought prone district.

Annual average rainfall most of the districts have a definite trend except Birbhum, Malda and UttarDinajpur districts. During pre-monsoon, rainfall is increasing in the North Bengal and it is decreasing in the South Bengal except Purulia and it is completely reversed during post-monsoon period. During winter season, the entire Bengal has a downward trend of rainfall except the hilly northern districts and two 24 Parganas.

Rainfall has strong relation with other hydrological parameters. There is a negative co-relation between rainfall and temperature, rainfall and potential evapo-transpiration as well as reference crop evapo-transpiration in one hand and positive co-relation between rainfall and wet-dry frequency. During pre-monsoon, rainfall is increasing in the North Bengal whereas it is decreasing in the South Bengal. So, it could be understood that Boro cultivation will be preferable in the North Bengal than the South Bengal. In the fertile plains of South Bengal, irrigation facility must be provided in this season. In case of annual average rainfall trend, Malda is a district of showing no such significant trend.

7. Constraints

- State own seed production is not sufficient to meet up the total requirement of 17094.06 MT seed of Boro HYVs notified within last 10 years
- Restriction on use of HYVs notified beyond 10 years results non-availability of seeds of new varieties.
- Lack of availability of slender grain HYVs parallel to Satabdi and MTU-1010 as per farmers choice.
- Farmers rely on tested varieties only. Not responsive to subsidy sale of newly released varieties.
- Incapability of NSC and West Bengal State Seed Corporation to supply suitable newly released HYVs.

8. Suggestions

- Farmers desire new rice variety (100-110 days) with long slender grain and high yield potential as substitute of Satabdi - SSC (WB). CR Dhan 203 performed well in Multi-locational trials and could be a substitute for Satabdi.
- Crop establishment (D-DSR) with zero tillage seed drill with herbicide-based weed control performed very well in different districts need to be further expanded. Farmers preferred this technology as it reduces cost of cultivation up to 32%.

- Stress tolerant varieties, Sahbhagi Dhan, DRR Dhan 42 and Swarna Sub 1 performed well in different districts and accepted by farmers may be taken up in large scale.
- Farmers preferred rice varieties of grain quality like Swarna as it is easily acceptable by millers.
- Variety MTU 1010 is accepted by the farmers during dry season for its higher yield and grain quality.
- Approval of three years Annual Action Plan enabling the States to draw up seed rolling plan in advance.
- Age relaxation of varieties up to 15 years for paddy and 20 years for pulses & oilseeds instead of 10 years.
- Distribution of certified seed of more than 10 years variety may be allowed to the tune of 50% of total allocation for seed distribution.
- Tentative allocation for BGREI may be given by GOI within January / February so that AAP to be prepared & approved by SLSC during March followed by final approval from GOI within Mid-April.
- Lump sum fund may be approved for intervention 'Asset Building' irrespective of specific implements to be proposed so that farmers could choice their implements out of approved fund outlay as per SMAM guideline.

Rice yield and income of the farmers showed an increasing trend since the inception of the BGREI Program due to implementation of rice interventions, regular visits by scientists and extension officers and awareness meeting which are conducted regularly under this program during both the seasons. The above suggestions may be considered to strengthen the BGREI program in West Bengal.