BANGLADESH RICE RESEARCH INSTITUTE

ANNUAL RESEARCH PROGRAM FOR THE YEAR 2025-2026

PROGRAM AREA 02: CROP SOIL WATER MANAGEMENT

Sub programme **03: Crop Physiology**

Programme performing unit **C: Plant Physiology Division**

Sub-sub-Programme 1: Abiotic stress

Project 1: Salinity Tolerance

Expt.1.1: Screening for Salinity Tolerance of Rice Germplasm at Seedling Stage

Justification: Seedling stage is the most susceptible stage for salinity tolerance of rice. To develop salinity resistant varieties screening of rice at the seedling stage is very crucial. Therefore, the present study was undertaken to screen out of salt tolerant genotypes under high saline condition.

Objective: To screen out tolerant genotypes at seedling stage.

Materials and Method:A total of 500 rice germplasm will be tested at 12 dS/m salinity stress following RCBD design at the net house of Plant Physiology Division. The experiment will be conducted following the method of Gregorio et al., 1997 at seedling stage.

Data collection

- Leaf area damage with SES
- Survival percentage

Expected output: New sources of salt tolerance rice genotypes at seedling stage.

PI: Salma Akter, SSO

CI: Mst. Salma Pervin,CSO and Mir Sharf Uddin Ahmed, CSO (GRSD)

Expt.1.2: Screening for Salinity Tolerance of Advanced Breeding Lines at Seedling Stage

Objective: To screen out tolerant genotypes at seedling stage.

Materials and Method : Advanced breeding lines will be tested at 12 dS/m salinity stress following RCBD design at the net house of Plant Physiology Division. The experiment will be conducted following the method of Gregorio et al., 1997 at seedling stage.

Data collection: Leaf area damage with SES and Survival percentage

Expected output: Salt tolerance breeding lines at seedling stage.

PI: Salma Akter

CI: Mst. Salma Pervin and K M Iftekharuddoula (Plant Breeding).

Expt.1.3: Genotyping and phenotyping of Germplasm against the Traits Related with Salinity Tolerance (LSTD Project)

Objective: To characterize the component traits associated with salinity tolerance.

Materials and Methods: A total of 200 germplasms with tolerant and susceptible check will be characterized at non-saline and 12 dS/m salinity level. Screening will be done following Gregorio et al. 1997 in the Plant Physiology Net house, BRRI during 2025-26.

Data collection

- SES score
- Survival percentage
- Shoot length
- Root length
- Shoot dry weight
- Root dry weight
- Na/K ratio

Expected output: New sources of salt tolerance rice genotypes at seedling stage which may be used to future breeding program.

PI: Salma Akter, SSO

CI: Mst. Salma Pervin,CSO, Md. Akhlasur Rahman,CSO and Md. Abubakar Siddique, SSO

Expt.1.4: Characterization of hybrid varieties for whole growth period at different salinity stress

Objective

1. To identify the level of tolerance of the tested varieties.
2. To estimate the yield and yield components.
3. To know the mechanisms of salinity tolerance.

Materials and Methods:

- ❑ **Plant materials (Boro season):**

- ✓ BRRI hybrid dhan2
- ✓ BRRI hybrid dhan3
- ✓ BRRI hybrid dhan5
- ✓ BRRI hybrid dhan7
- ✓ BRRI hybrid dhan8

❑ **Plant materials (Aman season):**

- ✓ BRRI hybrid dhan4
- ✓ BRRI hybrid dhan6

IR58443-6B-10-3 were used as tolerant check and IRRI154 will be used as susceptible check

Salinity level: 0, 6, 8 10 and 12 dS/m.

Methodology: Soil based methods described by Gregorio *et al.* 1997 will be followed in the Plant Physiology Net house, BRRI.

Data collection

1. Water salinity (every day)
2. Soil salinity during harvest
3. Panicle exertion rate
4. Flowering and maturity date
5. Total dry matter
6. Yield and yield components
7. Na^+ and K^+ content in plant sample

Design: RCBD with four replications.

Date of initiation: 2025

Date of completion: 2026

Location/Site: Net house (Plant Physiology Division)

Principal Investigator: Farzana Akter

Co-Investigator: Dr. Salma Akter,SSO and Dr. Mst. Salma Pervin,CSO

Expected output: Salinity tolerance ability and mechanism of its tolerance will be identified.

Project 2: Submergence tolerance

Expt. 2.1 Exploring new sources of submergence tolerance

Rationale: Submergence is one of the major abiotic stresses and it is a chronic problem for low land rice. BRRI have released three submergence tolerant varieties (BRRI dhan51 and BRRI dhan52, BRRI dhan79) which can survive 2 weeks or more under complete submergence. Submergence conditions are highly variable in terms of frequency, distribution, depth, timing and quality of flood waters. Thus, more varieties needed to address all sorts of submergence environments. However, to develop more submergence tolerant varieties in variable environments, it is necessary to identify donor materials with different physiological mechanisms for future submergence tolerance breeding.

Objectives:

1. To identify tolerant germplasm and advanced breeding lines for 2 weeks or more under complete submergence
2. To observe elongation capacity under complete submergence

Materials and Methods

Plant materials: 181 germplasm from GRS division

Tolerant Check: FR13A and BRRI dhan79

Sensitive check: BR5 and IR42

Methodology: Seedlings will be transplanted 14 days after sowing. After 14 days of transplanting the plants will be submerged for 2 weeks. Then the plants will be de-submerged and the recovery performance will be observed 10 days after de-submergence. The final scoring will be recorded 21 days after de-submergence. During submerged condition, the turbidity of water will be done by diluting mud to the water twice a day. Water temperature, turbidity, light intensity (at different depth), pH and dissolve O_2 will be recorded and measured during submergence period two times a day.

Observations

1. % Survivability
2. % Elongation
3. SES score

Date of initiation:April/2025

Date of completion:July/2025

Location/Site: Plant Physiology Division submergence tank.

Principal Investigator: Sadia Afrin Shupta, SO

Co-Investigators: Dr. Mst. Salma Pervin, CSO

Expected outpu: New sources of submergence tolerant germplasm and advanced breeding lines.

Expt. 2.2 Screening for stagnant flooding tolerance of germplasm/advanced breeding lines

Rationale: Water stagnation is the situation when few cm of standing water persist in the field. During T. Aman season in Bangladesh lower part of arable land goes under water and rice plant are partially submerged for long period and resulted in reduced tillering or partial damage. Genetic variations for water stagnation tolerance are assumed to be present in the rice accessions. Thus, this experiment intends to identify germplasm tolerant to water stagnation.

Objectives:

1. To identify tolerant germplasm for water stagnation condition.
2. To observe tillering ability under water stagnation conditions.

Materials and methods

Plant Materials: Total 100 local germplasm and advance breeding lines.

Check varieties: Tolerant Check BR10, BR23, BRRI dhan30

Methodology: Twenty days old seedlings will be transplanted using 20 cm x 20 cm in a concrete tank. The water pressure of 30 cm will be applied just after transplanting. After that @ 5 cm/week water pressure will be started from 7 days after transplanting and will be continued up to 60 cm. The stagnant water will be maintained up to maturity. Data of the plant height, tiller number, yield (at 14 % moisture) and survivability will be taken from average of 5 hills.

Observations

- Survival percentage
- Plant height (cm)
- Tiller/hill
- Yield/hill

Date of initiation: June/2025

Date of Completion: December/2025

Location/Site: Submergence Tank, Plant Physiology Division, BRRI, Gazipur-1701

Principal Investigator: Sadia Afrin Shupta, SO

Co-Investigators: Dr. Mst. Salma Pervin, CSO

Expected output: Identification of medium stagnation of tolerant genotypes.

Exp.2.3: Evaluation for elongation ability of different genotypes under deep flooding condition

Objectives: To observe the elongation ability of tested genotypes under deep flooding condition

Materials: 23 local germplasms and 59 advanced lines

Ck varieties: Lakshmi digha, BRRI dhan71, BRRI dhan111, BR5, FR13A

Methods: 5 seedlings (5 hills/row) with 20 cm x 20 cm spacing of twenty days old for each line were transplanted in a concrete tank. Two weeks after transplanting water level was increased @2 cm per day and stopped when the water level was up to 1.5 m.

Data collection

Plant height (cm), Culm length (cm), Internode length (cm), Tiller number/Hill, Kneeing ability, Elongation ability and Survivability (%), Grain Yield/Hill.

Starting date: June/2025

Ending date: July/2026

Duration: 2025-26

Status: New

Location: Deepwater tank, Plant Physiology Division, BRRI, Gazipur

PI: Sadia Afrin Shupta, SO

CI: Dr. Mst. Salma Pervin, CSO

Project 3: Drought Tolerance

Expt. 3.1: Confirmation of performance for advanced breeding materials under drought stress at reproductive phase

Objective: To evaluate of advanced breeding materials (RYT materials) under control drought condition in the net house

Materials: 12 RYT materials supplied by Plant Breeding Division, 10 materials from Biotechnology Division with BRRI dhan71 and IR64 as tolerant and sensitive check respectively will be evaluated.

Methodology: Plants will be grown in aluminium drum in the rain out shelter. Two sets of experiment will be conducted where

i) 1st set will be grown in well-watered conditions

ii) 2nd sets under drought stress condition at reduction division stage

Data to be collected:

1. Water table depth, Soil water tension & Soil moisture,
2. Plant height, Tiller no.
3. Date of flowering,
4. Yield and Yield components.

Locations: Rain-out shelter, Plant Physiology Division

Principal Investigator: Dr. Mst. Salma Pervin, CSO

Co-Investigator: Mst. Jinnurain Jannati, SO and Ratna Rani Majumdar,SSO (Plant Breeding Division)

Status of the Experiment: New

Starting date: July/2025

Expected ending date: February/2026

Expt. 3.2: Screening germplasm for drought tolerance at reproductive phase (PARTNER Project)

Objective: To identify rice germplasm tolerant to drought stress at reproductive phase.

Materials: Some total of 340 germplasm with tolerant and susceptible ck.

Methodology: Field-managed screening protocol will be followed (IRRI, 2008).

Field–managed drought screening protocol is as follows (IRRI 2008):

- ❖ Treatments: Two (drought and well-watered)
- ❖ Design: Alpha lattice
- ❖ Replication: Two
- ❖ Plot Size: 3 m X 3 m
- ❖ Standard agronomic management practices will be followed in both stress and control plots.
- ❖ For inducing drought at reproductive stage, the plots used for drought treatment will be drained out in 4 weeks after transplanting.
- ❖ A ground-water tube were used to monitor the level of water table.

- ❖ The field will be re-irrigated when the water table tube will be empty (1 m below the surface) or the drought-sensitive checks would be wilt and show severe stress symptoms.
- ❖ After a flush re-irrigation the field will be drained out again, and successive drying cycles will be repeated until harvest to manage the drought as per treatment.

Data to be collected:

1. Water table depth
2. Soil moisture
3. Plant height
4. Tiller no.
5. Date of flowering
6. Yield and Yield component
7. Drought tolerance index

Status of the Experiment: New

Starting date: July/2025

Expected ending date: March/2026

Location: Farmers field, Giolmary, Razabari Hat, Godagari, Rajshahi

Principal Investigator: Dr. Mst. Salma Pervin

Co-Investigator: Dr. Abdul Kader, M. Khalequzzaman, Dr. M. Hossain (In-charge R/S Rajshahi)

Expected output: The best tolerant germplasm to be further used as donor parent for developing future drought tolerant varieties.

Expt. 3.3: Evaluation of previously selected germplasm under drought stress at reproductive phase in the rain-out shelter

Objectives: To find out the correlation of field performance of tested genotypes with the performance under control drought condition in the rain-out shelter

Materials: Previously tested 34 germplasm with BRRI dhan71 and IR64 as tolerant and sensitive check respectively.

Methodology: Thirty-day old seedlings will be transplanted at a spacing of 20 cm x 20 cm. For inducing drought at reproductive stage, irrigation water will be withheld in 4 weeks after transplanting. The plot will be irrigated when the water tube would be empty.

Data to be collected:

1. Water table depth & Soil moisture,

2. Plant height,

3. Tiller no.

4. Date of flowering,

5. Yield and Yield component.

Data analysis: Correlation will be done by using R software

Location: Rainout shelter, Plant Physiology Division, Gazipur

Status: New

Starting date: July, 2025

Expected ending date: December, 2025

Principal investigator: Dr. Mst. Salma Pervin, CSO

Co-Investigator: Mst. Jinnurain Jannati, SO

Expt. 3.4: Physiological and biochemical characterization of advanced breeding lines under drought stress at reproductive phase

Objective:

1. To assess the effect of drought stress on growth and yield of the tested genotypes

2. To identify the physiological traits associated with drought tolerance.

Materials: Most tolerant advanced genotypes identified from previous studies were taken with BRRI dhan71 and IR64 as tolerant and sensitive check respectively.

Methodology: Plants will be grown in aluminium drum in the rain-out shelter. Two sets of experiment will be conducted:

i) 1^{st} set will be grown in well-watered condition and

ii) 2^{nd} sets under drought stress condition at reduction division stage

Data to be collected:

1. Water table depth & Soil moisture,

2. Plant height, Tiller no. ,

3. Date of flowering,

4. Yield and Yield components,

5. Proline and CHO content

6. GST, Gly1, CAT, SOD etc

Location: Rain-out shelter, Plant Physiology Division

Principal Investigator: Dr. Mst. Salma Pervin, CSO

Co-Investigator: Mst. Jinnuraine Jannati, SO

Status of the Experiment: New

Starting date: July/2025

Expected ending date: March/2026

Expected Output: Mechanism of tolerance of tested genotypes will be determined.

Expt. 3.5: Characterization of Aus Rice under low water condition at vegetative and reproductive phase.

Objective: To characterize of aus rice under different water levels.

Materials and Method : Four aus rice genotypes as BRRI dhan98, BRRI dhan106, BRRI hybrid dhan7 and Hashikalmi will be considered for this study. The experiment will be conducted under different water regimes as well watered condition, saturated condition, 75% water of saturated and 50% water of saturated condition following RCB design with four replications.

Data collection

- Sterility percentage
- Tillering pattern
- Dry matter production
- Yield and yield component
- Deep rooting ability

Expected output: Characteristics of aus rice will be identified under low water condition.

PI: Salma Akter,SSO

CI: Mst. Salma Pervin, CSO

Project 4: Heat Tolerance

Expt. 4.1: Screening of rice genotypes for high temperature tolerance at flowering stage

Rationale: Heat stress, particularly during critical growth stages such as flowering and grain filling, can lead to significant yield losses, reduced grain quality, and lower overall productivity. Screening of rice germplasm and lines for heat tolerance is a crucial step in identifying genetic resources that can be utilized in breeding programs with improved physiological, biochemical, and agronomic responses to heat stress.

Objective: To identify new heat tolerant donor and advanced breeding lines.

Materials and methods

Plant materials: 57 advanced breeding lines and 30 hybrid rice parental lines along with Check: N22 and BRRI dhan28

Methodology: Germinated seeds will be sown directly in the pot at normal condition of Plant Physiology Division, BRRI, Gazipur. There will be 2 plants per pot and 6 pots will be maintained for each genotype. All pots will be placed in natural condition until heading with recommended management practices. During heading 2 pots from each genotype will be placed in controlled glass house at high temperature (35 ± 3^0) and high humidity (75±5%) for seven days and one set will be in natural condition. After 7 days of heat treatment and completion of flowering each of the pots will be returned to natural condition and kept until maturity.

Observations

1) Sterility percentage
2) SES Score

Design: RCBD

Date of initiation: March' 2024

Investigator: Dr. Mst. Salma Pervin, CSO and Farzana Akter, SO

Location/Site: Plant Physiology Division

Expected Output: New sources of heat tolerant donor for high temperature stress (35-38 ˚C) during flowering can be identified and breeding lines will be selected for future program.

Project 5: Cold Tolerance

Expt. 5.1: Exploring new sources of cold tolerance from BRRI Genebank Collection at seedling stage

Rationale: Cold stress causes significant yield losses through seedling mortality and spikelet sterility. Identification of new genetic sources of cold tolerance is very important to enable rice breeders to develop cold-tolerant rice cultivars.

Objective: To identify rice genotypes which can tolerate low temperature at seedling stage.

Materials and methods

- 600 rice Gene Bank germplasm of BRRI will be tested in cold water tanks.
- CK.: BRRI dhan28, BRRI dhan36, Bhutan and HbjB-VI

- Leaf discoloration score will be recorded when susceptible cheek BRRI dhan28 died and scored 9 in cold water tank.

Design: RCBD

Location/Site: Plant Physiology Division

Principal Investigator: Farzana Akter

Co-Investigator: Dr. Mst. Salma Pervin, CSO, Scientist from GRSD

Expected output: Identification of new sources of cold tolerant germplasm

Expt. 5.2: Screening of advanced breeding lines for cold tolerance at reproductive phase

Objectives: To identify cold tolerant advanced breeding lines for whole growth period.

Materials and methods

- Advanced breeding lines supplied from Plant Breeding Division
- CK.: BRRI dhan28 and BRRI dhan67
- Sprouted seeds of the genotypes will be shown in the puddle seedbed on 15 October, 01 November and 15 November 2025
- Forty days old seedlings will be transplanted.

Data to be collected

- Visual cold tolerance score at different stages of rice plant
- Plant height, days to first heading, flowering (initiate, 50% and 100%), growth duration
- Panicle per hill, panicle emergence, panicle length
- Last internode length, last flag leaf sheath length
- Degeneration of spikelets
- Spikelet fertility
- Grain yield and yield components

Design: RCBD

Location/Site: Plant Physiology Division

Principal Investigator: Dr. Mst. Salma Pervin

Co-Investigator: Mst. Jinnurine Jannaty, SO and Dr. P S Biswas, CSO (Plant Breeding Division)

Date of initiation: October/2025

Date of Completion: May/2026

Expected output: Identification of cold tolerant advanced breeding lines.

6: Growth Studies and yield potential

Exp.6.1: Morpho-biochemical and anatomical characterization for lodging resistant BRRI varieties at T. Aman season

Justification: Lodging of rice plants is caused mainly by action of wind. Culm of rice plants becomes weakened under heavy rainfall or natural calamities. Another reason of lodging application excess nitrogenous fertilizers dense planting, deep submergence and sunlight deficiency Kono (1995).But Varietal characters has some positive and negative impact on this. Lodging tends to vigorously growing plants after heading, when ripening progresses and panicle drop. Lodging prior to harvest results in appreciable losses in both quality and quantity of rice Chang (1964). Internodes thickness is one of the most important characters of a rice variety for lodging resistance. Culm strength is an inherent character and it has positive impact on lodging resistance. Droopy leaves collect more raindrops overloading the culm and thereby rice plants lodged Yoshida (1981).

Objectives: To know the morpho-biochemical and anatomical characters of lodging resistant varieties.

Materials: Seventeen latest T. Aman BRRI varieties along with BR11 (tolerant ck) and BRRI dhan32 (susceptible ck)

Methodology: This experiment will conducted at Westbyde, Plant Physiology research field, Gazipur during T. Aman season. Seventeen latest T. Aman BRRI varieties along with BR11 (tolerant ck) and BRRI dhan32 (susceptible ck) will be tested to determine the morpho-biochemical and anatomical characters of the rice genotypes. Thirty days old seedling will be transplanted . Urea will be applied in the three equal splits. Other fertilizer such as TSP, MP, gypsum will be applied in three basal dose and intercultural operation will be maintained properly by time to time monitoring. At hard dough stage 3 randomly selected plants from each replication will be cut at culm base. They will put into the bucket dipping base into water to restore the turgidity and then various morphological data will be recorded. Plant height (cm), culm length (cm), visible internode length (cm) (3^{rd} and 4^{th}), fresh weight (gm) of above ground part, shoot dry weight (gm) will be measured by using measuring scale. Visual observation of wrapping score will be recorded. Flag leaf angle (degree), panicle exertion (cm), panicle length (cm) and weight (gm) will measured at maturity. Anatomical data will be collected at dough stage and biochemical analysis like lignin content will be recorded also.

1. According to Hoshikawa and Wang (1990) bending moment (gm.cm) will be calculated as a product of total fresh weight of above ground part and culm length.
2. Stem density (mg/cm) will be recorded in terms of dry weight (mg) per unit length of total culm length (cm) (Rao *et. al.,* 2017)
3. The visual lodging rate will be measured at maturity stage using the formula: Visual lodging rate = (Lodged area in plot / total plot area) x 100% as reported by (Lu et al., 2014).

Data analysis: Done by CropStat 7.2 and R Package

Spacing: 20 X 20 cm

Replication: Three

Design: RCBD

Location: BRRI west byde field (Plant Physiology division)

Duration: 2025-26

Status: Old

Date of initiation: July/2025

Date of Completion: June/2026

Principal Investigator: Sadia Afrin Shupta, SO

Co-Investigator: Mst. Salma Pervin , CSO

Expected Output: Lodging resistant capacity of the tested genotypes will be known.

Exp.6.2: Screening for lodging tolerant of advanced breeding lines at Boro season

Objective: To determine the visual lodging rate of supplied advanced breeding lines

Materials: Supplied advanced breeding materials

Check variety: BRRI dhan28 and BRRI dhan29 for Boro

Methodology: Transplanted the seedling with three replications with RCBD design. At hard dough stage 3 randomly selected plants from each replication will be cut at culm base. They will be put into a bucket dipping bases into water to restore the turgidity and then various morphological like plant height (cm), culm length (cm), wrapping score, lower internodes length (cm) and stem bending strength by culm strength tester. Visual lodging rate will be monitored time to time at different growing stages.

Spacing: 20 X 20 cm

Replication: Three

Design: RCBD

Location: BRRI west byde field (Plant Physiology division)

Duration: 2025-26

Status: Old

Date of initiation: January/2026

Date of Completion: December/2026

Principal Investigator: Sadia Afrin Shupta, SO

Co-Investigator: Dr. Mst. Salma Pervin , CSO

Expected Output: Lodging tolerance of the tested genotypes will be known.

Expt.6.3: Photoperiod sensitivity test of different rice genotypes

Rationale: Knowledge of photoperiodic requirements of rice useful to the farmers, when flood force them to replant later than the usual time i.e. a particular variety could be grown in a much shorter time, secondly, by inducing early maturity, it could escape adverse conditions like drought and thirdly, early harvesting would leave sufficient time for the preparation of fields for the crops following in rotation. The present investigation aims at studying the response of some local germplasm with four BRRI released varieties and check of T. Aman varieties to photoperiodic treatments.

Objectives: To know the photosensitive response of advanced lines

Materials

- 191 advanced breeding lines
- Check variety: Nizersail and Gainza

Methods: Seeds of advanced lines shown in the puddle seedbed on 10 April 2025. Line to line spacing was 15 cm*15 cm and two replications with RCBD design. One set was growing under natural condition. Another set was growing under confined area where plants were covered by black cloth and was disclosed for 10 hours a day from 7 am to 5 pm.

Design: RCBD

Replication: 2

Date of initiation: April/2025

Date of completion: June/2026

Status: Old (New materials)

Duration: 2025-2026

Location: Plant Physiology Division

Data Collection:

- First heading heading

Principal investigator: Sadia Afrin Shupta,SO

Co-Investigator: Dr. SM Hisam-Al-Rabbi, SSO and Dr. Mst. Salma Pervin, CSO

Expected output: Photoperiod sensitivity of the tested sample

Exp.6.4: Investigating the combined impact of Growing Degree Days and photosensitivity on the growth and development of rice

Objectives: To know the correlation of GDD and photoperiod sensitivity of tested genotypes

Materials: Strong Photoperiod sensitive: BR22, Nizersail,Weakly Photoperiod sensitive: BR11, BRRI dhan30 and Insensitive: BRRI dhan71, BRRI dhan75.

Replication: 2

Design: CRD

Temperature: 1st set 25^{0}C and 35^{0}C and 2nd set 22^{0}C and 32^{0}C for day time temperature, Night time temperature: 20^{0}C

Relative humidity: Night time 75% and day time 70%

- Data Collection
- Calculation of GDD
- Panicle Initiation date
- Heading date
- 50% Flowering
- 100% Flowering
- Plant height, Tiller Number
- Spikelet fertility and sterility (%)
- Yield and Yield components

Date of initiation: July/2025

Date of completion: June/2026

Status: New

Duration: 2025-2026

Location: Plant Physiology Division, BRRI, Gazipur-1701

Principal investigator: Sadia Afrin Shupta,SO

Co-Investigator: Dr. SM Hisam-Al-Rabbi, SSO and Dr. Mst. Salma Pervin, CSO

Expected Output: Effect of GDD on different sensitivity level of tested rice varieties

Exp. 6.5: Introgression of Strong culm genes for improvement of lodging tolerance of BRRI dhan87 (LSTD project)

Objective: To improve lodging resistance of BRRI dhan87 through introgressing *SCM1* and *SCM2*

Rationale: Although SD1 has been used to develop rice, lodging has happened in several semi-dwarf types when strong winds, notably tropical depressions, strike during the flowering to grain-filling stages of rice. New methods for enhancing lodging resistance in rice must be developed in order to generate high-yielding varieties. Habataki has been found to have two QTLs, SCM1 and SCM2, for thick and strong culms. These QTLs also have pleiotropic effects on increasing spikelet and grain quantities.

Materials and methods

Plant materials: Habataki and BRRI dhan87 will be hybridized to introgress *SCM1* and *SCM2*.

MAS breeding scheme: Marker survey for *SCM1* and *SCM2* between Habataki and BRRI dhan 87. F1 will be tested with linked markers for hybridity and introgression of *SCM1* and *SCM2* into BRRI dhan87. Backcrossing of the QTLs and lines with BRRI dhan87.

Present Status: The parental lines, BRRI dhan87 (recurrent parent) and *Habataki* (donor parent) were sown and transplanted in three sequential sets at 10 days interval. This sequential planting ensured the synchronization of flowering between the two varieties, ultimately facilitating successful hybridization. Manual hybridization was performed between BRRI dhan87 (♀) and *Habataki* (♂). Successful hybridization generated **F_1 seeds**, which were harvested, dried, and stored for sowing.

Expected outputs: Lodging resistance version of BRRI dhan87

PI: Mst. Jinnuraine Jannaty, SO

CI: Dr. Jannatul Ferdous,SSO, Dr. Shahanaz Sultana, CSO, (Biotechnology Division), Dr. Mst. Salma Pervin, CSO

Expt. 6.6: Phenotyping of collected materials for association study in relation lodging resistant characteristics.

Objectives:

i. To generate phenotypic data for GWAS analysis
ii. To unveil the morpho-physiological parameters associated with lodging resistance

Plant material and field management

The purified plant material will be grown in a randomized complete block design (RCBD) in three replications for 2 consecutive years. Three lines of 1 m length for each genotype will be grown in 20 × 20 cm spacing in heavily nitrogen reached soil. Sampling and phenotyping will be performed on randomly selected three plants from each line. The average value of three replicated plants from each block during 2 years will be used for analysis. The standard cultural practices as per local area requirements will be kept constant.

Measurement of Mechanical Lodging Resistance Traits

At 2 weeks after heading, three plants of each line will be selected to investigate the lodging resistance traits. The stem diameter (SD) of the fifth internode from the top of each selected plant will be measured using an electronic Vernier caliper in the field. Stem length of the internode (SL) from the top will be measured from the ground to the base of the panicle. The breaking strength (BS), a parameter for the physical strength of the stem, will be measured at the last internode of the plants using a plant lodging tester (YYD-1A, Zhejiang TOP Instrument Co., Ltd., China).

The lodging resistance of three randomly selected plants from each line will be calculated by the standard lodging resistance parameters, including section modulus (SM), pushing resistance (PR) and bending moment at breaking (M).

SM was measured in cubic-millimeters (mm^3) by the formula (Ookawa et al., 2010):

The whole plant's pushing resistance (PR), also known as bending stress at breaking (BnS), was measured in grams per centimeter-square (g/cm2) with a lodging meter at the maturity stage, according to a method reported previously (Kashiwagi and Ishimaru, 2004). The bending moment (M) of the basal internode at breaking (g/cm) was calculated as follows as previously described (Ookawa et al., 2016):

M = Section Modulus(Z) × BendingStress (BnS).

$$Z=\frac{\Pi(a_1^3\, b_1-a_2^3 b_1)}{32a_1}$$

Where, M is the bending moment at breaking, Z is the section modulus. a_1 is the outer diameter of the minor axis in an oval cross-section, b_1 the major axis in an oval cross-section, a_2 is the outer diameter of is the inner diameter of the minor axis in an oval cross-section, and b_2 is the inner diameter of the major axis in an oval cross-section. Z was measured in cubic-millimeters (mm3) by the formula (Ookawa et al., 2010).

The degree of leaf sheath reinforcement was calculated using the following equation

$$\alpha = \frac{M_{with} - M_{without}}{M_{without}}$$

where α is the degree of leaf sheath reinforcement, M_{with} is the bending moment at breaking with leaf sheaths, and $M_{without}$ is the bending moment at breaking without leaf sheaths.

After the measurement, the dry weight of the basal internodes was recorded, and the culm tissue density was calculated by the following formula (Chigira et al., 2020).

$$D = \frac{W_d}{\pi(a_1 b_1 - a_2 b_2)}.$$

D is the culm tissue density, and W_d is the dry weight of the basal internodes. (The basal internode was defined as the internode positioned at the bottom of the culms but had a length over 4 cm.)

Besides this, several lodging resistant parameters will also be measured

1. Lodging coefficient= $\frac{Weight\ of\ the\ plant\ top}{Strenth\ of\ culm}$

(Here, Loading the weight, with which the culm base is broken when the culm is fixed at 10cm upper part of the culm base)

2. Logding index= $\frac{(Cum\ length)^2 \times Total\ fresh\ weight\ pertiller}{Culm\ dryweight\ per\ tiller} \times Bending\ Moment\ at\ breaking$

(Oda et al. 1966)

3. Index related to lodging $= \frac{\text{Height of the centre of gravity}}{Breaking\ strenght\ of\ culm\ with\ leaf\ sheath}$ (Hitaka, 1968)

Several morphological lodging resistant parameters will be taken. Such as-

1. Plant height
2. Wrapping Score

3. Culm length
4. Culm fresh and dry weight
5. 4th and 5th Internode length and fresh and dry weight
6. Stem strength
7. Point of breaking
8. Stem density
9. Panicle length
10. Panicle weight (fresh and Dry)
11. Total carbohydrate and Lignin content of stem

Location: Plant Physiology Division, BRRI, Gazipur

Starting Date: June 2025

Ending date: December 2027

PI: Tuhin Halder, SSO

CI: Dr. Mst. Salma Pervin,CSO, Dr. KMI Iftekharudaulla, CSO and Prof. Dr. Md. Anwar Hossain (BAU)

Expt.6.7: Analysis of lodging-resistant characteristics of rice grown under different nitrogen and potassium management.

Objectives:

1. To observe changes in morphological & anatomical features of lower internodes underdifferent nitrogen and potassium managements
2. To determine changes in mechanical properties of lower internodes in relation to lodging resistance of rice

Materials: BRRI dhan100

Methodology: Four different nitrogen and potassium rate will be applied.

The Nitrogen dose will be

N_0 = Control

N_1 = 120 kg/ha

N_2 = 180 kg/ha

N_3 = 240 kg/ha

The potassium dose will be

K_0 = Control

K_1 = 60 kg/ha

K_2 = 120 kg/ha

K_3 = 180 kg/ha

Phosphorus and Gypsum will be applied @45 kg and 38 kg/ha (As per fertilizer recommendation guide 2014, BARC). Except Nitrogen all the fertilizers will be applied at basal dose and Nitrogen fertilizer will be applied at 10, 25 and 40 days after transplanting. Split plot design with three replications will be followed, where Potassium will be allotted in main plot and Nitrogen will be allotted in subplot.

Data to be taken: The length of each node, panicle length, plant height, and center of gravity height (the distance from the base of the stem to the horizontal balance fulcrum of the single stem of rice) will be measured with a steel ruler. After removing leaf sheath, the 4^{th} internodes will be cut and the inner and outer diameters of the stem were measured via vernier caliper to calculate the stem diameter and wall thickness.

Determination of Lodging Index

For non-destructive sample

A lodging tester YYD-1A (Topyunong Science and Technology Co., Ltd. Hangzhou, Zhejiang, China) was held to the plants at a height of 20 cm above the bottom of stem and slowly pushed vertically, the pushing resistance force was recorded when the plants were leant at 45°. Then these plants were harvested to measure plant height (H), fresh weight, and then fresh weight per tiller (M) and pushing resistance force per tiller (F) were calculated. Lodging index was calculated by following formula:

lodging index (LI_{nd} = (M × H/F) × 100. (Liu et al. 2020)

For destructive sample

Logding index (LI_d)

$$= \frac{(Cum\ length)^2 \times Total\ fresh\ weight\ pertiller}{Culm\ dryweight\ per\ tiller} \times Bending\ Moment\ at\ breaking$$

(Oda et al. 1966)

Where, the bending moment (M) of the basal internode at breaking (g/cm) was calculated as follows as previously described (Ookawa et al., 2016):

M = Section Modulus(Z) × Bending Stress (BnS).

(To measure BnS, Loading the weight, with which the culm base is broken when the culm is fixed at 10cm upper part of the culm base)

Fifteen (15) days after heading dissection of 4^{th} internode will be done and observed under compound microscope. At maturity stage, yield of 5 m^2 will be measured and converted to ton/ha. Rice plants in each plot will be sampled and N and K accumulation in the aboveground tissues was calculated according to the methods described by Pan et al. (2016). Total amount of soluble sugar in culms or leaf sheaths will be measure according to Yoshida et al. (1971).

Location: Plant Physiology Division, BRRI gazipur

Starting Date: November/2025

Ending date: April/2026

PI: Tuhin Halder, SSO

CI: Dr. Mst. Salma Pervin,CSO, Dr. KMI Iftekharudaulla, CSO and Prof. Dr. Md. Anwar Hossain (BAU)

Expt.6.8: Dormancy and viability test of BRRI varieties grown in Aus, Aman and Boro season.

Objective: To determine the dormancy and viability period of rice varieties in Aus, Aman and Boro season.

Materials and Method: For dormancy test, germination test will be done at the date of harvest and then at an interval of 7 days until the dormancy is broken. For viability test, when germination percent was 80% or above seeds will be preserved in refrigerator, cold room, polythene packet and gunny bag. These seeds will be used for viability test. The viability test will be done at an interval of 30 days beginning from the date of broken dormancy.

Data collection

- Days to 80% germination
- Days to remain 80% germination

PI: Salma Akter, SSO

CI: Dr. Mst. Salma Pervin, CSO

Expected output: Dormancy and viability period of these varieties would be identified.

Expt.6.9: Screening of Advanced Breeding Lines for Pre-harvest Sprouting (PHS)

Justification: Pre-harvest sprouting (PHS) of rice reduces grain yield and quality, which can cause significant economic losses for farmers. In ripening phase of T. Aus rice, heavy rainfall may occur frequently which creates favorable climatic conditions for pre-harvest sprouting. However, genotypes having no or less pre-harvest sprouting characters are needed for farmers and breeders remaining grain quality and yield.

Objective: To screen out pre-harvest sprouting resistant genotypes.

Materials and Method

Materials: Advanced breeding lines.

Replication: Three

Design: RCBD
Duration: 2025-2026.
Data collection: Sprouting percentage at 80% maturity

PI: Salma Akter, SSO

CI: Mst. Salma Pervin,CSO, and K M Iftekharuddoula, CSO (Plant Breeding).

Expected output: Genotypes having no or less pre-harvest sprouting characters will be identified.

Expt.6.10: Screening of Regeneration Ability of Aus Rice Germplasm.

Objectives: To identify the Aus rice germplasm having regeneration ability or faster vegetative growth with higher yield.

Materials and Method

A sum of 100 Aus rice germplasms with tolerant check from BRRI Genebank will be used for this study. Seeds will be sown directly in lines during 2025-26 in the west byde, BRRI, Gazipur. Plants of one row will be mowed after 30 days of sowing to observe the tillering ability after breaking the apical dominance.

Data collection

- Different Flowering Date
- Grain filling period
- Dry matter production
- Yield and Yield components

PI: Salma Akter, SSO

CI: Mst. Salma Pervin, CSO, One scientist from GRSD.

Expected output: New sources of aus germplasm with higher regeneration capacity.

Expt.6.11: Phenological development of newly released three BRRI varieties in Boro season

Justification: Crop phenology is important for choosing cultivars with an appropriate growth period and for determining the timing of management practices such as planting, fertilizer application and harvesting. During crop growth period, the occurrence of various phenological events can be estimated by computing accumulated growing degree days. In this study, we investigated the responses of rice phenology and yield to the change in day length as well as growing season.

Objectives:

1. To observe the phenological development of rice varieties

2. To investigate the duration of different developmental stages of rice varieties when seeded at different time

3.To find out the required degree-days for developmental phase of rice.

Materials and methods:

Plant materials: Three newly released Boro rice varieties: BRRI dhan105, BRRI dhan107 and BRRI dhan108

Date of seeding: Five different sowing date at 15 days interval like 15th November, 2. 30th November, 3. 15th December, 4. 30th December and 5. 15th January

Data collection: Plant height, No. of panicle/m2, No. of filled grain/panicle, 1000-grain weight (gm), Grain yield (ton/ha), Sterility (%), Panicle initiation (PI) date, Days to 50% flowering, Maturity date, Growth duration, Growing Degree Days (GDD)

Design: RCBD

Date of initiation: November/2025

Principal Investigator: Farzana Akter, SO

Co-Investigator: Dr. Mst. Salma Pervin, CSO
Location/Site: Plant Physiology Division

Expected Output: Appropriate sowing time for the rice varieties will be identified for future program.

Expt.6.12: Phenological development of some BRRI varieties affected by sowing time in T. Aman season

Rationales: Phenological development of rice is important because it gives foremost information about major growth stages that occur. Phenomenological analysis is essential for evaluating responses of rice yield to change in day length as well as growing season. This information helps to adjust planting, irrigation, fertilization, pest control, and harvesting practices to maximize crop yield and adjust to changing environmental factors like climate variations.

Objectives:

1. To observe the phenological development at different growing season.
2. To investigate the duration of different developmental stages of rice varieties when seeded at different times.
3. To find out the degree-days for developmental phase of rice.

Materials and methods

Plant materials: BRRI dhan110, BRRI hybrid dhan4, BRRI hybrid dhan6

Sowing dates: 7th July, 22nd July, 6th August, 21st August

- ❑ 30days seedlings will be transplanted
- ❑ Single seedling/hill at 20*20cm spacing
- ❑ Plot size: 3*6 m^2

Design: RCBD

Replication: 3

Date of initiation: July, 2025

Date of completion: December, 2025

Location: West byde, Plant Physiology Division

Data collection: Plant height, Number of panicle, Number of filled grain, Number of unfilled grain, 1000 grain weight, grain yield, days to PI, days of flowering, days to 50% flowering, days to maturity, Growing degree days etc.

PI: Mst. Jinnuraine Jannaty, SO

CI: Dr. Mst. Salma Pervin, CSO

Expected output: Phenology of selected rice cultivars.

Expt.6.13: Reduction of pre-harvest sprouting of rice through chemical spraying

Rationale: Pre-harvest sprouting (PHS) is a critical phenomenon involving the germination of seeds in the mother plant before harvest under relative humid conditions and reduced dormancy (Sohn, S.-I., et al., 2021). The preharvest sprouting of rice seeds is closely related to the extent of dormancy, an adaptive trait that prevents seed germination in favorable environmental conditions (Gu, X.Y. et al.,2011). A high level of dormancy in cereal seeds can lead to unfavorable outcomes, such as uneven and delayed postharvest germination. Maintaining an optimal level of seed dormancy is essential for enhancing the yield and quality of cereal crops (Gao, F. & Ayele, B.T., 2014). PHS reduces both grain yield and quality, leading to significant economic losses for farmers. Sprouted grains often exhibit decreased milling recovery, poor cooking quality, and lower market value. In addition, PHS compromises seed viability and storability, making it unsuitable for use as seed in the next season.

In rice (Oryza sativa L.), Wan et al. (2006) reported substantial yield losses due to sprouted grain with prolonged rain close to harvest. Low-lying area of southern part are likely to be inundated more frequently as heavy rainfall events and tropical cyclones increase throughout the 21st century (IPCC, 2013), resulting in increased likelihood of damage to rice crops.

Among the regulators of dormancy, ABA plays a positive role in inducing and maintaining dormancy. Foliar application of exogenous ABA has been shown to enhance resistance against PHS by reinforcing dormancy signaling pathways. Paclobutrazol (PBZ) can be used to induce dormancy in plants by inhibiting gibberellin biosynthesis, a hormone crucial for cell elongation and shoot growth. Paclobutrazol is one of the growth retardants that has been effective in controlling plant size and increasing in compactness (Banon et al., 2002), reducing water use (Hickman, 1986; Ahmad et al., 2014) and reducing abiotic stresses (Whipker, 2013).

Molybdate is crucial for plants because it forms the molybdenum cofactor (Moco) needed for enzymes like aldehyde oxidase, which synthesizes abscisic acid (ABA) (Ralf R. M & Robert

Hänsch, 2002). Supplementing with molybdate increases internal ABA production, leading to stronger plant dormancy and making the plants less susceptible to sprouting.

Molybdenum (Mo) has been reported to enhance seed dormancy. Tanner (1978) discovered Mo involvement in reducing pre-harvest sprouting in maize (Zea mays L.). In wheat (Triticumaestivum L.), Mo sprays at the flag leaf stage inhibited germination whilst dormancy increased with dose rate (0-600 mg Mo L-1 as sodium molybdate) (WalkerSimmons, 1987; Modi and Cairns, 1994). Walker-Simmons (1987) also showed that endogenous abscisic acid (ABA) in embryos increased with molybdenum dose rate. The plant hormone ABA is associated with seed maturation and embryonic dormancy (Bewley and Black, 1994; Leung and Giraudat, 1998; Finkelstein et al., 2002; Hilhorst, 2007; Bewley et al., 2013), with the balance between ABA and gibberellic acid regulating seed dormancy and germination; GA is antagonistic to ABA and promotes germination.

Therefore, the exogenous application of ABA, paclobutrazol, and molybdate offers a promising chemical approach to mitigate PHS in rice by reinforcing seed dormancy and reducing premature germination under humid field conditions.

Objectives: To determine the effect of chemical spraying for reducing the pre-harvest sprouting of spikelet in rice panicle.

Plant Materials: BRRI dhan86 (PHS-prone), BRRI dhan89 (PHS-prone) and BR16(PHS resistant)

Treatment:

1. Five foliar spray treatments of Mo @ 100, 600 or 3000 mg L^{-1} (as sodium molybdate (VI) dihydrate (Acros Organics, New Jersey, USA)
2. ABA (grade ≥ 98%, Sigma Aldrich, UK) @ 150, 200 & 250 mg/L
3. Combination of 1 and 2
4. Paclobutrazol @ 125, 200 & 250 ppm

Spraying the chemical at time of Flag leaf appearance. Each treatment solution included 1% Tween 20 (Thermo Scientific, UK) as a surfactant to improve adherence to leaves.

For inducing artificial pre-harvest sprouting panicle of three randomly selected plants were gently bent to standing water at 23, 30, 37 and 44 days after flowering for 24 hours. Then the panicles kept within a water-soaked cloth bag enclosed in a polythene bag for 6 days. Both ends of the bag were tied to prevent the cloth bag from drying. The plants were kept upright with a bamboo stick.

Data to be taken: Yield components and Germination percentage

Status: New
Date of initiation: November/2025
Location/Site: Plant Physiology Division
PI: Mst. Jinnuraine Jannaty, SO

CI: Dr. Mst. Salma Pervin, CSO

Location/Site: Plant Physiology Division
Expected Output: PHS preventing technology will be developed.

Project: 7 Genome editing
Expt. 7.1: CRISPR-Cas9 mutagenesis of the OsRR22 gene for improving salinity tolerance of rice
Objectives: To improve salinity tolerance in rice genotypes

Rationale: The CRISPR/Cas9 genome editing system, developed in 2013, is proving to be an effective technology for generating targeted mutations in a wide array of cells and organisms. CRISPR/Cas9 dramatically increases the potential to improve traits in crops. Importantly for crop improvement, homozygous pyramiding of genes of interest into elite germplasm can be carried out within a single generation. Using CRISPR/Cas9 technology possible to rapid and straightforward determination of the function of different coding and non-coding DNA sequences in plants. The main advantages of the CRISPR/Cas9 system are its ability to genetically modify an organism without leaving any foreign DNA behind and its versatility and simplicity of programming. Current scientific advancements show that CRISPR is not only an extremely versatile technology; it's proving to be precise and increasingly safe to use. Thus, the CRISPR/Cas9 technology plays a vital role by improving crops.
Gene of interest:

1. *OsRR22* gene for improving salinity tolerance in rice (Background: BRRI dhan81, BRRI dhan92)

Methodology:

- Guide RNA design and primer synthesis

- Vector construction
- Agrobacterium-mediated rice transformation
- Mutant identification from regenerated plants
- Selection of T-DNA free mutants
- Transcriptome analysis
- Morphological characterization
- Field validation etc.

Date of initiation: June/2020

Location/Site: Plant Physiology Division

Principal Investigator: Dr. Hirendra Nath Barman, PSO

Co-Investigator: Dr. Md. Sazzadur Rahman,CSO, Mst.Jinnuraine Jannaty,SO, Dr. Mst. Salma Pervin, CSO

Expected output: New traits will be developed for salinity tolerance, male sterile line for two-line hybrid system and semi-dwarf plant in rice.

Project 8: Crop Weather Information

Expt. 8.1: Automatic weather station data collection and storage

Objective: Weather data collection, delivery, reporting, and storage for automatic weather stations.

Materials: Collection of all kinds of weather data recorded by 7 Vantage Pro2 automatic weather stations established 2 in BRRI HQ and 11 in different regional stations (Rangpur, Rajshahi, Satkhira, Habiganj, Gopalganj, Barishal, Bhanga, Shirajganj,Cumilla, Kustia and Sonagazi).

Methods: All types of weather data will be collected based on available sensors attached to the stations via supplied cable and software, and all will be saved on a removable hard drive for future use.

Observations

1) Air temperatures,
2) Relative humidity,
3) Solar radiation,
4) Rainfall,
5) Wind speed and direction
6) Evapotranspiration

Status: On-going

Date of initiation: 2012

Location/Site: Plant Physiology Division

Principal Investigator: Sadia Afrin Shupta,SO

Co-Investigator: Dr. Mst. Salma Pervin,CSO

Expected output: Archiving of digital weather data from BRRI headquarter and different regional stations.

Expt. 8.2: Manual weather station data collection and maintenance

Objectives: Data collection, delivery, reporting, and storage of weather variables

Methods: All types of weather data will be collected from different stations and all will be stored in removable hard drive for future use.

Weather variables: Air temperature, Humidity, Rainfall, Sunshine hour and Evapotranspiration.

Observations:

1) Air temperature
2) Humidity
3) Solar radiation
4) Rainfall
5) Evapotranspiration

Status: On going

Location/Site: BRRI Gazipur, BRRI R/S Rangpur, Rajshahi, Cumilla, Bhanga, Barishal, Habiganj and Sonagazi.

Principal Investigator: Farzana Akter , SO

Co-Investigator: Salma Akter, SSO and Mst. Salma Pervin, CSO

Expt. 8.3: Development of Crop-Weather Calendar for Rice Crop in Bangladesh

Justification: In Bangladesh there is no rice-based crop calendar for region specific. We have enough opportunities to develop a crop weather calendar for rice.These calendars are useful for crop planning, irrigation scheduling and plant protection measures, which are vital importance for effective crop planning and for maximizing and stabilizing food production in the country. This single sheet of paper, if used judiciously, will help him prepare not only a value based advisory with all the relevant messages with respect to weather crop - pest /

disease but also save his valuable time. By developing a weather calendar, we can easily disseminate region specific information about rice production.

Objective: The aim of the study is to develop a crop-weather calendar that guides rice farmers in Bangladesh through a climate-resilient, optimized agricultural schedule.

Materials and Methodology: To achieve the objectives, the study will employ a mixed-method approach, integrating climate data analysis, field trials, and feedback from farmers and agricultural experts.

Season: Crop weather calendar for Boro season

Duration of rice: Long, medium and short duration

Data collection:

Climate Data: Historical (minimum 30 years) and forecasted climate data (temperature, rainfall, humidity, sunshine hour and solar radiation) will be sourced from Bangladesh Meteorological Departments

Crop Growth Data: Information on growth stages and critical thresholds for rice varieties commonly grown in Bangladesh will be collected from BRRI and literature

Farmer Practices: Surveys and interviews will be conducted with farmers to understand their current practices, timing of activities, and weather-related challenges

Date of Initiation: July/2025

PI: Sadia Afrin Shupta, SO

CI: Rumana Akter,SO, Tanjina Islam, SO, ABM Anawar Uddin,PSO, Niaz Md. Farhat Rahman, PSO, Md. Abu bakar Siddique,SSO, ABM Zahid Hossain,SSO, Mst. Salma Pervin,CSO, Md. Rafiqul Islam,DR, Mohammad Khalequzzaman,DG.

Expected Outcomes:

1. A scientifically validated crop-weather calendar for rice that aligns rice cultivation practices with weather forecasts, reducing risks associated with climatic variability
2. Enhanced awareness and preparedness among farmers to adapt their practices to anticipated climate conditions, improving resilience to weather extremes.
3. A potential increase in rice productivity and resource efficiency, contributing to food security and sustainable agriculture in Bangladesh.