Research Highlights

Annual Research Review 2024-25

Bangladesh Wheat and Maize Research Institute
Nashipur, Dinajpur 5200

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BWMRI
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Preface

Research Highlights 2024–25 of the Bangladesh Wheat and Maize Research Institute (BWMRI) showcases the significant strides made in wheat and maize research to address national food security needs. During this period, wheat production reached 11.11 lakh metric tons from 2.88 lakh hectares, with a notable productivity increase to 3.86 tons per hectare. Maize production also saw a substantial rise, totaling 73.99 lakh metric tons from 6.78 lakh hectares across winter and summer seasons, with productivity increasing to 10.91 tons per hectare, fueled by growing demand for poultry feed, livestock, and processed foods

BWMRI's research this year focused on developing high–yielding, climate–resilient wheat and maize varieties with resistance to abiotic stresses (heat, drought, and salinity) and biotic stresses (diseases). Key collaborations with international partners, including CIMMYT, KSU, CSIRO, ACIAR, and USAID, greatly enhanced our efforts.

The institute also evaluated wheat hybrids from the University of Sydney under the ACIAR–funded project, with promising results for hybrid wheat breeding. Additionally, under the USAID–funded HTMA project, heat–tolerant maize hybrids were tested, and several high–performing varieties were identified for heat–stressed areas. The Bangladesh Coordinated Maize (BCM) Trials, in partnership with private sectors, expanded multi–location testing for maize hybrids across the country.

BWMRI's efforts extended beyond breeding to include the promotion of resource conservation technologies such as zero tillage and bed planting. Research on triticale and durum wheat also progressed, aiming to diversify cereal production for food and feed purposes. This year saw the release of key varieties, including blast–resistant wheat and heat–tolerant maize, contributing to Bangladesh's efforts in enhancing agricultural productivity.

I extend my heartfelt thanks to our collaborators and the dedicated scientists and staff at BWMRI, whose hard work and innovation have made these research achievements possible. This booklet serves as a valuable resource for stakeholders involved in wheat and maize research and development, both in Bangladesh and beyond.

Director General
Bangladesh Wheat and Maize Research Institute (BWMRI)

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1. Wheat variety development

Wheat Breeding Program of the Bangladesh Wheat and Maize Research Institute (BWMRI) has made remarkable progress in developing climate resilient, high–yielding wheat varieties suited to the diverse agro–ecological zones of Bangladesh. In addressing the challenges of climate change and emerging diseases, the program integrates conventional breeding with molecular genetics, physiological screening, speed breeding, and international collaboration. Genetic improvement remains central to the program, focusing on traits such as heat and drought tolerance, salinity tolerance, and resistance to major diseases including spot blotch, rusts, and wheat blast. Early–generation populations are rigorously evaluated in screening nurseries, where lines with desirable agronomic and physiological traits are identified. The best–performing entries are advanced to multi–location yield trials, which assess yield stability, adaptability, and grain quality across contrasting environments and serve for value for cultivation and use (VCU). In addition to the formal breeding pipeline, participatory variety selection (PVS) ensures farmers' involvement in identifying preferred varieties based on performance under real farming conditions. This demand–driven approach accelerates adoption and enhances the impact of released varieties. Maintenance breeding safeguards the genetic purity and integrity of released varieties, while breeder seed production guarantees a sustainable supply of high–quality seed to support national seed systems.

The recent introduction of speed breeding facilities at BWMRI further accelerates generation advancement, enabling faster development of improved varieties. Together, these approaches—from population development, screening nurseries, and yield trials to participatory variety selection, maintenance breeding, seed production, and speed breeding—form an integrated pipeline that ensures the delivery of climate–resilient, farmer–preferred wheat varieties. This report presents the major scientific highlights and achievements of the 2024–25 Rabi season, reflecting BWMRI's commitment to strengthening wheat productivity, food security, and sustainable agricultural practices in Bangladesh.

Figure 1.1. Wheat breeding research field at BWMRI, Dinajpur

1.1 Genetic improvement:

Figure 1.2. Wheat breeder is making crosses in the wheat breeding crossing at the research field of BWMRI, Dinajpur

Hybridization: During 2024–25, a total of 116 genetically diverse wheat genotypes with contrasting agronomic and physiological traits were included in the crossing block. Intensive hybridization was undertaken at BWMRI Headquarters, Dinajpur, and Regional Stations at Rajshahi, Gazipur, and Jamalpur with a focus on developing climate–resilient wheat. The breeding objectives prioritized early maturity, resistance to spot blotch, rusts, and blast, enhanced biomass production with increased grain number and spike density, as well as tolerance to sterility and salinity. In total, 475 single crosses, 72 top crosses, and 20 backcrosses were made, thereby enriching the genetic base and creating novel recombinants for future selection of resilient and high–performing wheat varieties.

Confirmation in F_1 generation: A total of 471 single crosses, 108 top crosses, and 20 backcrosses were confirmed in the F_1 generation through careful phenotypic comparison with their respective maternal parents. The evaluation focused on key morphological traits to distinguish true hybrids from selfed or off–type plants. This confirmation verified hybrid authenticity, ensuring that only true F1s were advanced, thereby maintaining accuracy in trait segregation and genetic analysis in subsequent generations.

Evaluation and selection in segregating generations: Segregating populations from the F_2 to F_6 generations were rigorously evaluated across three research locations—Dinajpur, Gazipur, and Jamalpur. In the F_2 generation, 718 families were assessed, from which 343 promising families were advanced. During the F_3 generation, 179 families were evaluated, leading to the retention of 136 families and the selection of 644 individual plants. At the F_4 stage, 181 families were tested, resulting in the advancement of 106 families; additionally, 101 individual plants were selected at Dinajpur, whereas only families were advanced at the other sites. In the F_5 generation, 108 families were evaluated, from which 92 superior families and 882 plants were selected across locations. These selected plants from F_3 to F_5 generations will be grown in plots in the F_6 generation for consolidation and further evaluation. In the F_6 generation, 812 plots were assessed, and 141 superior lines were advanced for subsequent yield testing. To shorten the breeding cycle and accelerate the delivery of promising lines and varieties, a strategic modification in the selection scheme has been planned from the next season onward. Beginning with the upcoming cycle, individual plants will be selected in the F_3 generation and directly evaluated in plots. Consequently, advancement through the F_4 and F_5 generations will be omitted, thereby reducing the number of years required for line development. The following breeding scheme, illustrated in the figure below, will be revised to enhance selection efficiency and expedite the identification of superior genotypes for subsequent yield trials and variety release.

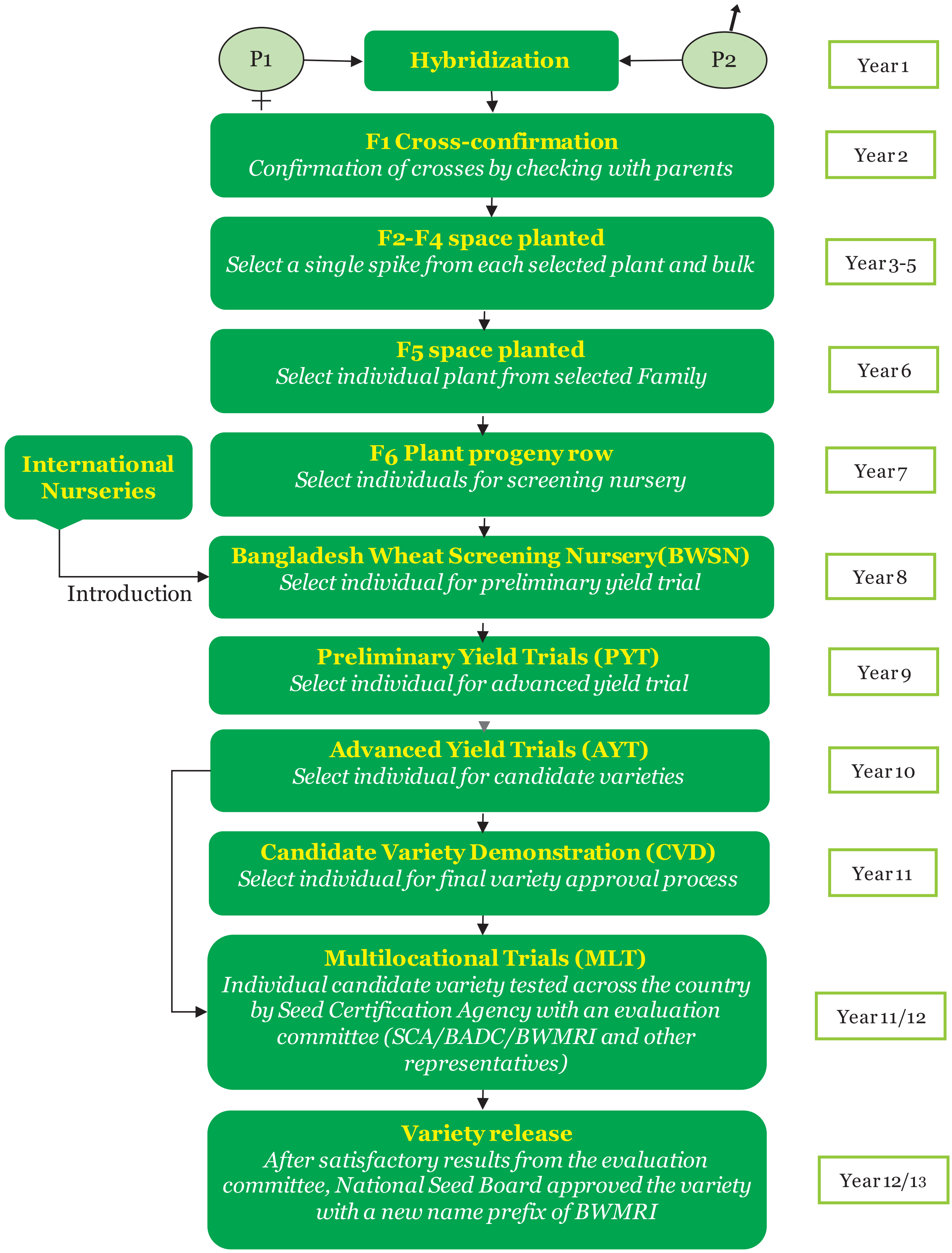


Figure 1.3. Schematic diagram of wheat breeding method in Bangladesh Wheat and Maize Research Institute

1.2. Nurseries and Yield Trials:

Bangladesh Wheat Screening Nursery (BWSN): serves as a critical platform for evaluating selected early–generation breeding lines from national breeding programme and international nurseries across contrasting agroecological environments. Its primary objective is to identify superior genotypes with high yield potential, resilience to abiotic stresses, durable resistance to major diseases, and desirable grain quality, thereby maintaining a strong pipeline of candidate varieties for advancement. The BWSN is structured into three distinct components—BWSN–I, BWSN–II, and BWSN–III—each representing a different stage of germplasm advancement and source of genetic

BWSN–I: This nursery consisted of breeding lines developed through hybridization at BWMRI research stations. These lines were evaluated at three locations—Headquarters (HQ), Dinajpur; Regional Station (RS), Gazipur, and RS, Jashore—under both irrigated timely–sown (ITS) and irrigated late–sown (ILS) conditions. Three checks (BARI Gom 33, BWMRI Gom 2, and BWMRI Gom 4) were included to provide benchmarks for adaptability, yield stability, and stress resilience.

BWSN–II: This nursery comprised of elite genotypes selected from the previous year's international collaborative yield trials, primarily sourced from CIMMYT and other global breeding partners. These were tested at HQ, Dinajpur; RS, Rajshahi, and RS, Jamalpur under both ITS and ILS conditions, using BWMRI Gom 5 as check. This setup facilitated assessment of yield performance and disease resistance across diverse agro–ecological zones.

BWSN–III: This nursery comprised of promising entries originating from international screening nurseries—namely the High Zinc Advance Nursery (HZAN), International Bread Wheat Screening Nursery (IBWSN), and Semi–Arid Wheat Screening Nursery (SAWSN)—which had initially been tested in small–plot (1 m^2) trials. These entries were evaluated in standard research plots under the BWSN–III trial at Dinajpur, with BWMRI Gom 5 as check. This allowed for a more rigorous assessment of their agronomic performance, genetic uniformity, and overall potential before advancing to subsequent yield trials.

Across all three nurseries, genotypes were rigorously assessed for earliness, agronomic architecture (plant height, tillering capacity, spike length), grain quality (size, boldness, and appearance), and yield potential. Based on overall performance, a total of 54 superior genotypes were selected for advancement into the Preliminary Yield Trial (PYT) for multi–location evaluation.

Figure 1.4. Field view of BWSN-III

Preliminary Yield Trial (PYT): The trial represents the first stage of multilocation evaluation for advanced breeding lines selected from BWSN. During the 2024–25 season, 63 advanced lines, along with the check variety BWMRI Gom 3, were evaluated at three research stations—HQ, Dinajpur; RS, Jamalpur, and RS Jashore—under both ITS and ILS conditions. An alpha–lattice design with two replications was employed to ensure precision in yield estimation and minimize experimental error. The genotypes were assessed for grain yield, yield components, phenology, disease resistance, sterility, and grain quality traits. Significant location–wise differences were observed: Dinajpur recorded the highest values for most traits, while Jashore, with lower thousand grain weight (TGW), shorter maturity, and the lowest yield. Jamalpur ranked second in yield, supported by longer maturity and higher TGW. The highest TGW was achieved in BAW 1553, followed by BAW 1555, BAW 1554, and BAW 1550 at Dinajpur. The highest grain yield (6791 kg ha^{-1}) was given by BAW 1557 under ITS at Dinajpur. Yield losses due to late seeding ranged from 0.1% to 48.6%. Based on grain yield, yield–contributing traits, stress resilience, and visual grain quality, a total of 37 promising genotypes— were advanced to the Advanced Yield Trial (AYT) for further evaluation in the following season.

a) Field selection at RS, Jashore   b) Seed selection at RS, Jamalpur

Figure 1.5. Selection team evaluating the performance of advanced wheat lines twice during the 2024–25 Rabi season at each station

Advance Yield Trial (AYT): The trial serves as an important step in validating the performance of elite lines under diverse agro–ecological conditions prior to variety testing. During the 2024–25 season, 22 advanced lines were evaluated against two check varieties, BWMRI Gom 2 and BWMRI Gom 4, across five research stations—HQ, Dinajpur; RS, Gazipur; RS, Jamalpur; RS, Jashore, and RS, Rajshahi—under both ITS and ILS conditions. The trial was laid out in an alpha–lattice design with two replications to improve precision in genotype comparisons. Genotypes were assessed for grain yield, yield components, phenology, disease reaction, and visual grain quality. The effects of sowing time, location, genotype, and their interactions were all significant, reflecting strong genotype × environment (G×E) influences. At the Dinajpur site under ITS conditions, the highest grain yield (7126 kg ha^{-1}) was achieved by BAW 1500, followed by BAW 1503 (6361 kg ha^{-1}) and BAW 1529 (6163 kg ha^{-1}). In contrast, the lowest yields were recorded under ILS conditions at Jashore, with BAW 1505 (625 kg ha^{-1}), BAW 1519 (642 kg ha^{-1}), and BAW 1507 (1007 kg ha^{-1}). TGW varied widely, with the highest recorded in BWMRI Gom 4 (59.5 g) at Dinajpur under ITS, followed by BWMRI Gom 2 (59.0 g) and BAW 1498 (59.0 g) at Jamalpur. The lowest TGW (26.0 g) was observed in BAW 1532 at Jashore under ILS conditions.

Candidate Variety Demonstration (CVD): The Candidate Variety Demonstration (CVD) represents the final stage of pre–release testing, conducted under near–farm conditions to validate varietal performance and farmer acceptability. During 2024–25, twelve advanced lines, along with the check variety BARI Gom 33, were evaluated at Dinajpur and Jashore under both ITS and ILS conditions. The entries were assessed for grain yield, yield components, disease resistance (particularly wheat blast, spot blotch, and rusts), lodging tolerance, and grain quality traits. Based on superior performance and overall adaptability, five elite lines—BAW 1422, BAW 1425, BAW 1433, BAW 1435, and BAW 1439—were selected for on–farm participatory trials and further consideration for release as commercial varieties.

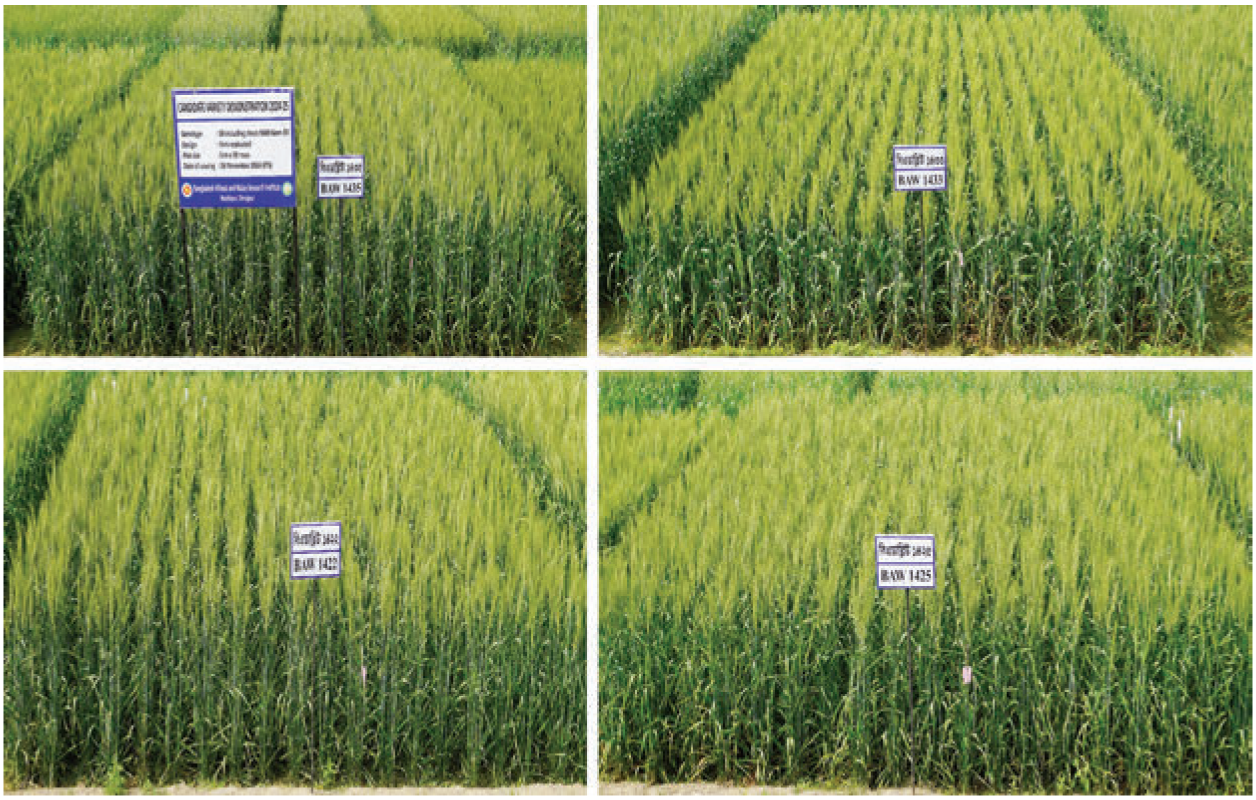


Figure 1.6 Candidate varieties in the research field of BWMRI, Dinajpur

1.3. Molecular Wheat Breeding:

Molecular screening of blast and leaf rust resistance wheat genotypes using molecular markers: A total of 94 wheat genotypes, including entries from Candidate Variety Demonstration (CVD), Advanced Yield Trials (AYT), and Preliminary Yield Trials (PYT), were screened for resistance to wheat blast and leaf rust using seven molecular markers: 2NS (Blast resistance), Lr10, Lr26, Lr34, Lr46, Lr67, and Lr68. These markers are associated with key disease resistance genes, some of which are linked to other disease–resistance genes: 2NS–Lr37–Yr17–Sr38, Lr26–Sr31–Yr9–Pm8, Lr34–Yr18–Sr57, Lr46–Yr29, and Lr67–Yr46–Sr55. The genotypes were grouped based on the number of resistance genes they carry, revealing extensive variation in gene numbers across the collection. BARI Gom 33 carried all seven resistance genes (2NS, Lr10, Lr26, Lr34, Lr46, Lr67, Lr68), representing the maximum gene in the genotype. This variety exhibited high resistance to both wheat blast (Blast Index 4%) and leaf rust (0%), confirming the effectiveness of multiple gene stacking in conferring broad–spectrum resistance. Six genotypes (BAW 1500, BAW 1506, BAW 1510, BAW 1556, BAW 1570, BAW 1576) carried six resistance genes, including key linked clusters such as 2NS–Lr37–Yr17–Sr38, Lr26–Sr31–Yr9–Pm8, and Lr67–Yr46–Sr55. These genotypes also showed very low disease incidence, with Blast Index and Leaf Rust ratings indicating effective resistance. Five genotypes (BAW 1425, BAW 1433, BAW 1435, BAW 1474, BAW 1479) carried five resistance genes, including combinations of 2NS, Lr10, and Lr46, among others. These genotypes exhibited moderate to high resistance levels, illustrating the cumulative effect of gene pyramiding in reducing disease severity. A large number of genotypes carried four genes. While these genotypes showed variable resistance, the presence of linked genes contributed significantly to enhanced resistance against both wheat blast and leaf rust. Genotypes carrying fewer genes (3 or 2) showed moderate to high susceptibility, particularly to wheat blast, highlighting the importance of pyramiding multiple resistance genes to achieve durable and broad–spectrum resistance.

The identification of these genotypes provides a valuable resource for molecular breeding programs, enabling breeders to develop new varieties with durable disease resistance. Moreover, linked resistance genes can be effectively utilized in marker–assisted selection (MAS) to accelerate breeding for multiple disease resistance. The data also reveal that even genotypes with four genes can provide meaningful resistance, offering flexibility in breeding strategies where maximum gene pyramiding may not be feasible. Overall, this study provides a comprehensive overview of resistance gene distribution in Bangladeshi advanced line and highlights promising candidates for future breeding programs aimed at enhancing food security through disease–resilient wheat varieties.

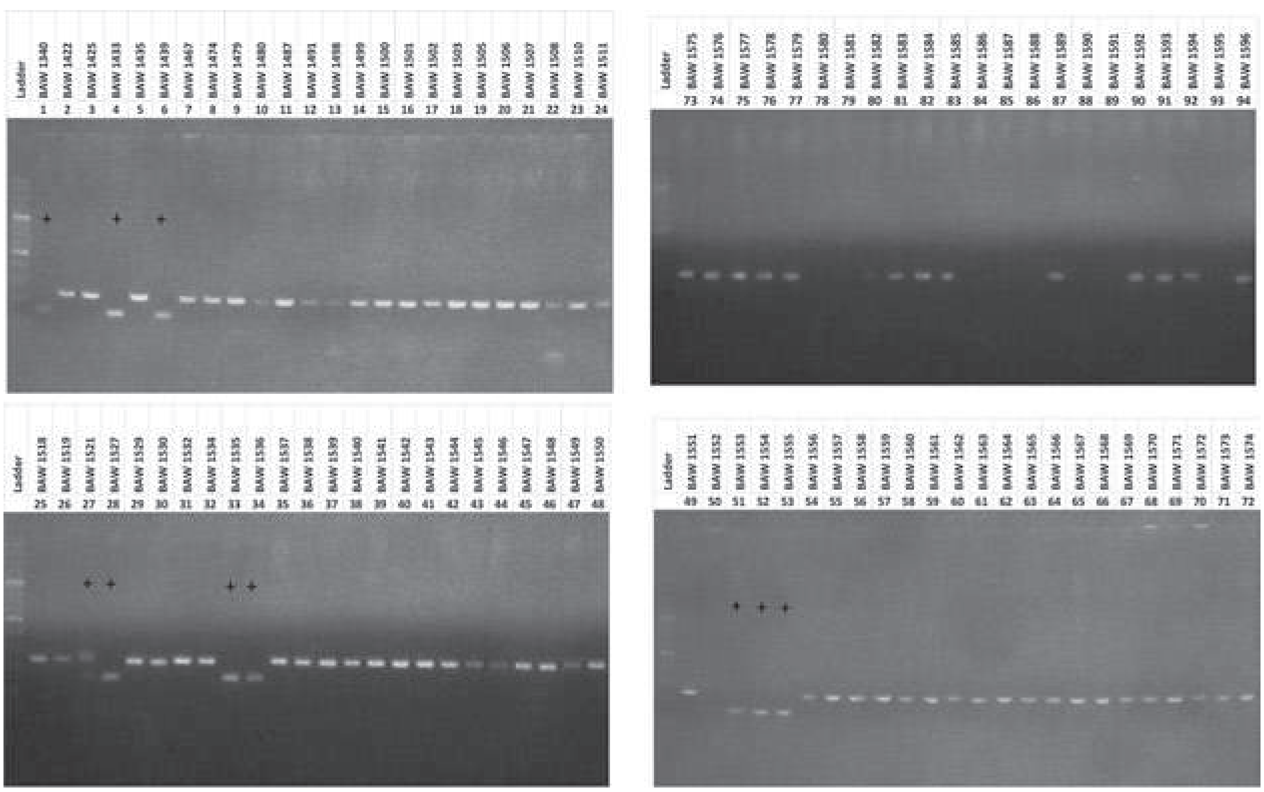


Figure 1.7. Gel picture of genotypes from CVD, AYT and PYT for the primer CsLV34.

Table 1.1: Gene Cluster Composition and Distribution in Wheat Genotypes

Gene Cluster	Cluster Composition	Genotypes
6–Gene Cluster	*2NS–Lr37–Yr17–Sr38, Lr10, Lr26–Sr31–Yr9–Pm8, Lr34–Yr18–Sr57, Lr46–Yr29, Lr67–Yr46–Sr55*	BAW 1500, BAW 1506, BAW 1510, BAW 1556, BAW 1570, BAW 1576
5–Gene Cluster	*2NS–Lr37–Yr17–Sr38, Lr10, Lr26–Sr31–Yr9–Pm8, Lr34–Yr18–Sr57, Lr46–Yr29*	BAW 1425, BAW 1433, BAW 1435, BAW 1474, BAW 1479
4–Gene Cluster	Most linked genes plus one independent gene	BAW 1501, BAW 1503, BAW 1507, BAW 1508, BAW 1511, BAW 1518, BAW 1519, BAW 1521, BAW 1527, BAW 1529, BAW 1530, BAW 1532, BAW 1534, BAW 1535, BAW 1536, BAW 1537, BAW 1538, BAW 1539, BAW 1540, BAW 1541, BAW 1544, BAW 1545, BAW 1546, BAW 1547, BAW 1548, BAW 1549, BAW 1550, BAW 1551, BAW 1552, BAW 1553, BAW 1554, BAW 1555, BAW 1557, BAW 1560, BAW 1563, BAW 1569, BAW 1574, BAW 1580, BAW 1581, BAW 1592, BAW 1594
3–Gene Cluster	Partial pyramiding: few linked genes	BAW 1422, BAW 1439, BAW 1467, BAW 1480, BAW 1487, BAW 1491, BAW 1498, BAW 1499
2–Gene Cluster	Minimal pyramiding: only 2 linked genes	BAW 1542, BAW 1543, BAW 1584, BAW 1585, BAW 1586, BAW 1587, BAW 1588, BAW 1589, BAW 1590, BAW 1591, BAW 1593, BAW 1595, BAW 1596

Genome–wide association study for identifying SNPs associated with phenology, physiology and yield contribution traits for Bangladeshi wheat panel: A genome–wide association study (GWAS) was conducted on a panel of 450 spring wheat genotypes representing diverse Bangladeshi and international germplasm during the 2024–25 season at BWMRI, Dinajpur. Phenotypic data were recorded for phenology, physiology, and yield–contributing traits under standard field conditions. Genotyping–by–sequencing using ddRAD–Seq generated 12,790 high–quality SNPs after filtering. Population structure, phylogenetic tree analysis, and PCA confirmed substantial genetic diversity within the panel. GWAS was performed using a mixed linear model (MLM) in TASSEL v5.2, resulting in several significant marker–trait associations (MTAs) across multiple chromosomes for the studied traits. A major genomic region on chromosome 5A was consistently associated with booting, heading, anthesis, and maturity, with the strongest signal detected at Chr5A_590164722 ($p = 9.40 \times 10^{-9}$ for heading date). These findings provide valuable insights into the genetic architecture of adaptive and yield–related traits and identify candidate SNP markers for accelerating marker–assisted breeding of high–yielding and climate–resilient wheat varieties in Bangladesh.

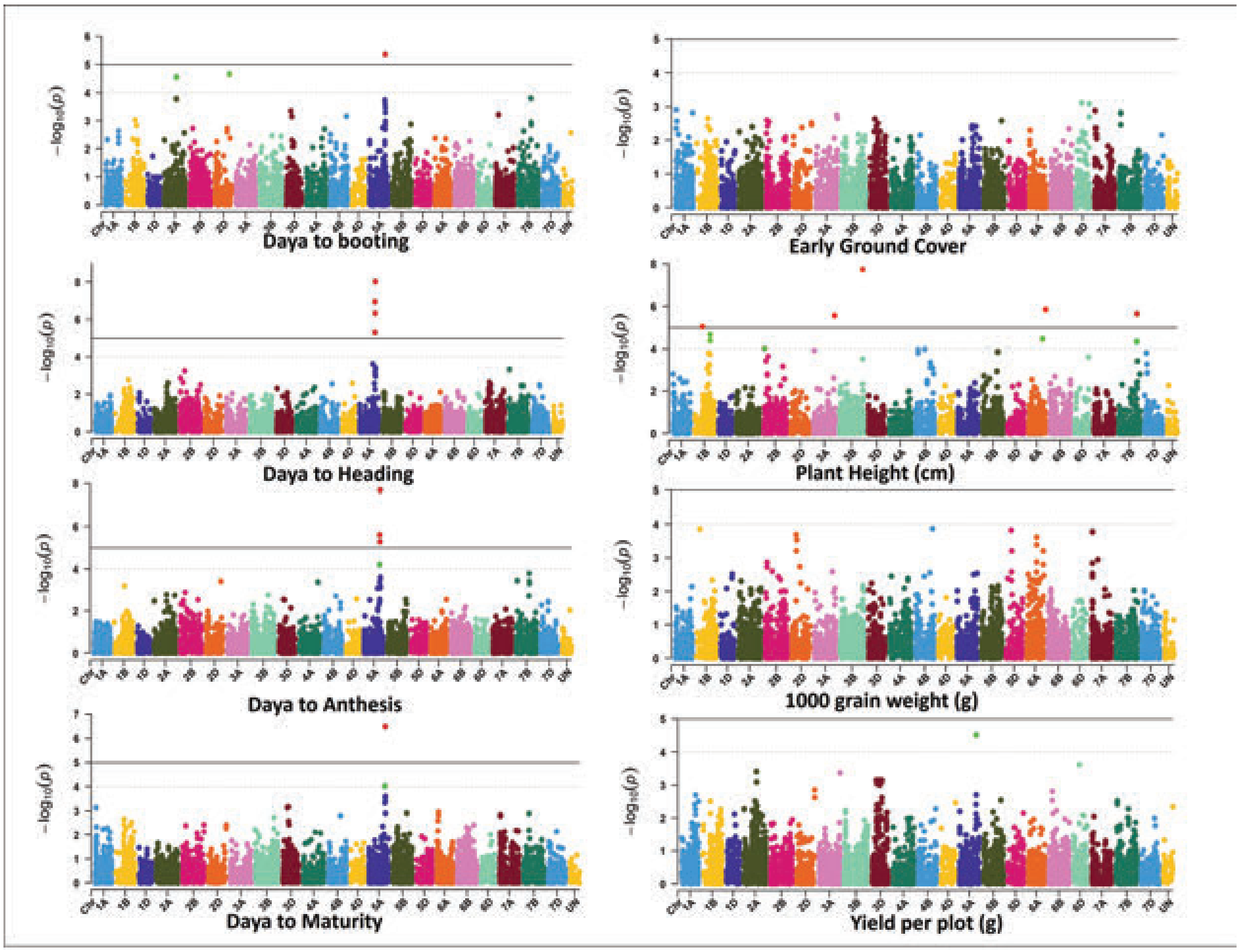


Figure 1.8. Manhattan plots for phenological and yield–contributing traits.

1.4. Development of heat tolerant wheat genotypes:

Early Heat–Tolerant Wheat Screening Nursery (14th EHTWSN): The expansion of short–duration rice varieties allows wheat sowing from last week of October to 1st week of November; however, high temperatures during this period can negatively impact germination and early crop establishment, leading to juvenile heat stress. This stress reduces biomass accumulation, tillering, and spike development, often shortening the vegetative period and reducing grain number per spike. Farmers typically prefer to sow wheat early to avoid leaving land fallow, which increases the risk of early heat stress. The experiment aimed at identifying spring wheat genotypes capable of withstanding early–season heat stress during the 2024–25 Rabi season. Five high yielding spring wheat genotypes including check varieties BWMRI Gom 5 were evaluated under early sowing conditions. Significant variation was observed for plant stature, phenology, and grain characteristics. Based on these evaluations, four genotypes (BAW 1486, BAW 1494, BAW 1506 and BAW 1531) further evaluation for advanced yield trial in the next year. Among the entries BAW 1494 and BAW 1531 were found top emerging as the top yielders. These genotypes demonstrated strong potential to enhance wheat adaptation across varying sowing windows, contributing to the development of heat–resilient varieties critical for climate–adaptive wheat production in Bangladesh.

1.5. Development of salinity tolerant wheat and maize varieties

Screening of wheat and maize genotypes under artificial salt stress condition: Soil and water salinity is a major constraint limiting crop productivity, particularly in South Asia, threatening food security and agricultural sustainability. The development of salt–tolerant wheat and maize genotypes is essential for maintaining yields in saline–prone areas. Controlled artificial salt stress screening was conducted at BWMRI to evaluate germination, early growth, and adaptability under salinity. These studies provide information for selecting genotypes suitable for breeding programs targeting saline environments.

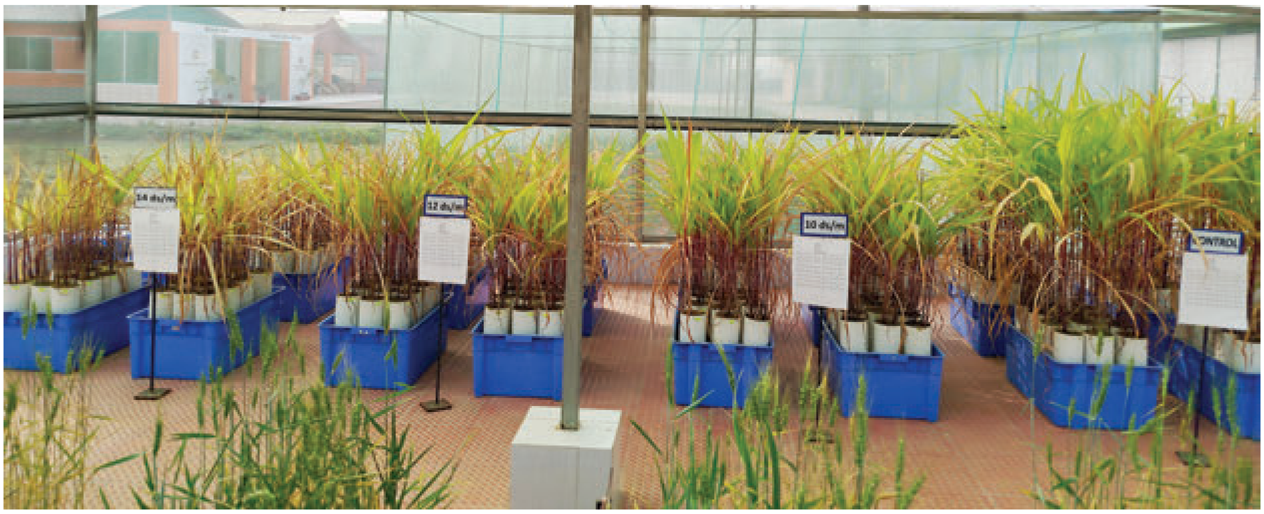


Figure 1.9. Screening wheat genotype in artificial saline stress condition at BWMRI, Dinajpur

Figure 1.10. Secretory, Ministry of Agriculture visited the artificial saline screening of wheat at BWMRI Dinajpur

Fifty wheat genotypes were screened from 15–30 November 2024 under four salinity levels: control (tap water), 10, 12, and 14 dS m^{-1}, using sodium chloride solutions. A completely randomized design (CRD) with two replications was employed. The results showed wide variation in germination and survival, highlighting differential responses to salt stress. Based on overall performance 6 wheat genotypes were identified as salt–tolerant: BAW1472, BAW1500, BAW1502, BAW1507, BAW1519, BAW1521, BAW1527, BAW 1539. These genotypes provide valuable resources for breeding programs focused on salinity tolerance in wheat.

Fifty maize genotypes were evaluated under the same salinity levels (control, 10, 12, and 14 dS m^{-1}) using a CRD with two replications. Significant variation in germination and survival rates was observed, indicating differential salt tolerance. Based on overall performance 6 maize genotypes were identified as salt-tolerant: PINA 14 × VL 1110502, PVA 9 × KL 153092, TITAN 16 × BIL 79, TITAN 27 × BIL 79, PINA 10 × BIL 28 and 981–26 × BIL 28. These genotypes represent critical breeding material for the development of salt-tolerant maize varieties suitable for saline-affected regions.

Figure 1.11. Targeted Population Environment Trial 2 (TPE–2) at BWMRI Dinajpur

1.6. Collaborative Studies with International Organizations:

BWMRI continued its active collaboration with leading international organizations, notably CIMMYT, Mexico, and ICARDA, Morocco, during the 2024–25 Rabi season. Through these partnerships, a wide range of international nurseries and yield trials were evaluated across multiple agro ecological zones of Bangladesh to strengthen the breeding pipeline for high–performing wheat germplasm. The collaborative studies were broadly categorized into: (i) yield potential trials, including the Elite Spring Wheat Yield Trial (ESWYT) and the International Bread Wheat Screening Nursery (IBWSN), as well as physiologically improved materials such as the Wheat Yield Consortium Yield Trial (WYCYT) and the Stress Adaptive Trait Yield Nursery (SATYN), aimed at identifying high–yielding lines suitable for local environments; (ii) stress tolerance trials, comprising the High–Temperature Wheat Yield Trial (HTWYT), the Semi–Arid Wheat Yield Trial (SAWYT), and the Semi–Arid Wheat Screening Nursery (SAWSN), which targeted adaptation to heat, drought, and other abiotic stresses; and (iii) grain quality and biofortification trials, including both normal and early–maturing sets of the High–Zinc Wheat Yield Trial (HZWYT), along with the High–Zinc Advanced Nursery (HZAN), designed to enrich grain micronutrient content. In addition, complementary trials provided by ICARDA, notably the Elite Spring Bread Wheat Yield Trial (ESBWYT) and the Heat and Drought Tolerant Spring Bread Wheat Observation Nursery, further broadened the scope of adaptive breeding under Bangladeshi agro ecological conditions. Alongside these efforts, BWMRI is also implementing Targeted Population of Environments (TPE) trials in collaboration with CIMMYT. This transformative approach groups trial sites into zones with shared environmental characteristics—defined by climate, soil, biophysical constraints, and farmer practices—to better capture genotype–by–environment interactions (GEI). By tailoring selection to the environments where wheat is expected to be grown, TPE trials accelerate the development of resilient and farmer–relevant varieties for Bangladesh's diverse and vulnerable agro ecological zones, including coastal saline areas and the Barind tract. Furthermore, BWMRI has initiated a collaborative program on hybrid wheat breeding with the University of Sydney, Australia, focusing on the development and evaluation of hybrid germplasm suited to South Asian growing conditions, with the long–term goal of achieving yield breakthroughs and production stability under changing climates.

Table 1.2. Collaborative yield and screening trials with CIMMYT and ICARDA, 2024–25 Rabi season

Sl No	Trial Name	Trial Design	Location	Genotype	
				Tested	Selected
CIMMYT Collaboration					
1	Elite Spring Wheat Yield Trial (45th ESWYT)	Alpha Lattice with 2 reps	Dinajpur	49	14
2	High–Temperature Wheat Yield Trial (23rd HTWYT)	Alpha Lattice with 2 reps	Dinajpur Gazipur Rajshahi	49	13
3	Semi–Arid Wheat Yield Trial – Early Maturing (2nd SAWYT–EM)	Alpha Lattice with 2 reps	Dinajpur Rajshahi	49	16
4	High Rainfall Wheat Yield Trial (32nd HRWYT)	Alpha Lattice with 2 reps	Dinajpur	49	8
5	High–Zinc Wheat Yield Trial (15th HZWYT)	Alpha Lattice with 2 reps	Gazipur	49	14
6	High–Zinc Wheat Yield Trial – Early Maturing (4th HZWYT–EM)	Alpha Lattice with 2 reps	Dinajpur	49	11
7	Stress Adaptive Trait Yield Nursery – Heat (14th SATYN–HEAT)	Alpha Lattice with 2 reps	Dinajpur	36	6
8	Wheat Yield Consortium Yield Trial (12th WYCYT)	Alpha Lattice with 2 reps	Dinajpur	39	6
9	Semi–Arid Wheat Screening Nursery (42st SAWSN)	Non replicated with check in regular interval	Dinajpur Rajshahi	198	13
10	High–Zinc Advanced Nursery (16th HZAN)	Non replicated with check in regular interval	Dinajpur Gazipur	169	25
11	International Bread Wheat Screening Nursery (57th IBWSN)	Non replicated with check in regular interval	Dinajpur	221	19
12	Targeted Population–Environment (TPE–2) Trials	Alpha Lattice with 2 reps	Dinajpur Jamalpur	168	31
13	Targeted Population–Environment (TPE–1 & TPE–3) Trials	Alpha Lattice with 2 reps	Jamalpur	336	30
ICARDA Collaboration					
14	Elite Spring Bread Wheat Yield Trial (25th ESBWYT)	Alpha Lattice with 2 reps	Rajshahi	49	3
15	Heat and Drought Tolerant Spring Bread Wheat Observation Nursery (25th HT & DT SBWON)	Non replicated with check in regular interval	Dinajpur	295	10

Hybrid Wheat Development: The hybrid wheat breeding program at BWMRI, in collaboration with the University of Sydney, continued in 2024–25 using the two–line Blue Aleurone (BLA) system. Forty–three F_1 hybrids were evaluated at Dinajpur and Rajshahi along with two checks. The highest yield gain was 4% over BARI Gom 33 at Dinajpur, while E–28 (BLA#4/BARI Gom 21) and E–41 (BLA#6/BARI Gom 21) outperformed BWMRI Gom 2 by 8% and 13% at Rajshahi, respectively. Both crosses also showed tolerance to spot blotch and leaf rust. These hybrids have been advanced for seed increase and multi–location trials.

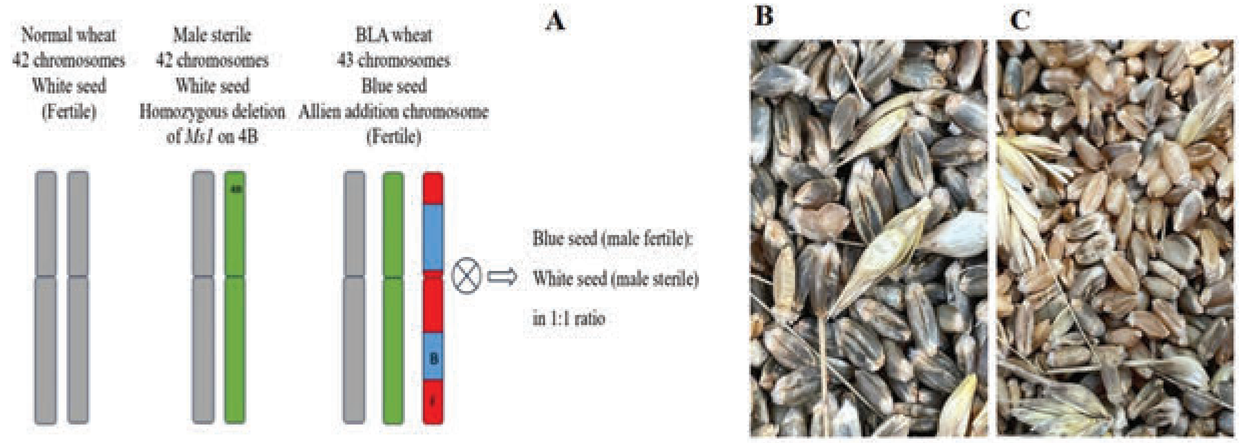


Figure 1.12. A). Two–line BLA technology; B. The deep blue fertile seeds (DBGMF); C. Mixture of light blue fertile (LBGMF) and white sterile seeds in 1:1 ratio.

Figure 1.13. Hybrid wheat production using BLA technology at BWMRI research field, Dinajpur

For hybrid seed production, five BLA male–sterile lines were crossed with 11 adapted varieties, producing 55 cross combinations. Outcrossing rates ranged from moderate to high, with effective seed set between 58–96%. Twenty–eight promising crosses were selected for further yield evaluation. Additionally, 50 single crosses were initiated to convert elite lines into the BLA system, targeting yield potential, stress tolerance, and disease resistance.

To strengthen hybrid seed supply, five promising F_1s were multiplied, producing sufficient seed for farmer–level demonstration trials across environments. Maintenance of five BLA lines at Dinajpur ensured genetic stability, with 55.5 kg of seed preserved. Overall, the program identified promising hybrids, established a pipeline of BLA–converted lines, and demonstrated the potential of hybrid wheat to improve productivity and food security in Bangladesh.

1.7. Germplasm Maintenance:

A total of 213 wheat genotypes were maintained in observation nurseries, representing diverse germplasm from both national and international sources. These nurseries serve as a genetic reservoir, safeguarding allelic diversity critical for future breeding programs. Systematic maintenance ensures the availability of elite and exotic lines for crossing, selection, and evaluation, supporting the development of varieties with improved yield, stress resilience, and adaptability to emerging environmental and agronomic challenges in Bangladesh.

1.8. Variety Maintenance and Breeder Seed Production:

Maintenance of First– and Second–Year Lines of Recommended Wheat Varieties: During the 2024–25 Rabi season, eight bread wheat varieties—BARI Gom 30, BARI Gom 32, BARI Gom 33, BWMRI Gom 1, BWMRI Gom 2, BWMRI Gom 3, BWMRI Gom 4, and BWMRI Gom 5—were maintained at the Bangladesh Wheat and Maize Research Institute (BWMRI), Dinajpur, to ensure high–quality seed availability for subsequent seasons.

First–Year Line Maintenance: Each variety was grown in plots of 200 rows, from which 50 superior rows were selected based on plant vigor, seed quality, and uniformity. The selected rows were individually harvested and threshed to propagate the best–quality seeds for the second–year lines, ensuring varietal purity and preservation of desirable agronomic traits. Maintenance of BWMRI Gom 1 was reduced to half as compared to other varieties.

Second–Year Line Maintenance: Second–year lines were grown in 100 rows per variety, with 25 rows selected for individual harvesting. The number of plots for BWMRI Gom 1 was reduced to half and selected accordingly. The second–year lines of BWMRI Gom 5 will be established next season. From the plots, 2,624 kg of seeds were harvested across the other seven varieties. These seeds will serve as breeder seed for the 2025–26 season, covering approximately 20 hectares. Seeds from non–selected rows (1513 kg) will be used for truthfully labelled seed (TLS) production, supporting commercial seed multiplication and farmer distribution.

1.9: Breeder Seed and Truthfully Labelled Seed Production of Recommended Wheat Varieties:

Figure 1.14. Breeder seed production plot at Seed Production Station (SPS) of BWMRI, Debiganj, Panchagar

Breeder Seed Production: During the 2024–25 Rabi season, breeder seed of seven wheat varieties was produced across multiple BWMRI stations under the direct supervision of wheat breeders to ensure genetic purity and seed quality, resulting in a total production of 62,113 kg. The station–wise contributions were: Nashipur, Dinajpur – 14,628 kg (BARI Gom 30, BWMRI Gom 3); Debiganj, Panchagarh – 42,315 kg (BARI Gom 32, BARI Gom 33, BWMRI Gom 2); and Thakurgaon – 5,170 kg (BWMRI Gom 1, BWMRI Gom 4). The produced breeder seed will be supplied to stakeholders, including BADC and private seed companies, for foundation and certified seed multiplication, thereby ensuring the timely availability of newly released varieties in the seed market.

Seed Distribution: In November 2024, 42,750 kg of breeder seed from the 2023–24 season were distributed to the Bangladesh Agricultural Development Corporation (BADC) and private seed companies. Additionally, 19,144 kg of TLS were produced at BWMRI stations during 2024–25, and 56,227 kg of seed from nine wheat varieties were distributed to farmers, ensuring access to high–quality seed for increased wheat productivity.

1.10. Participatory Variety Selection (PVS) of Wheat: Mother Trials

Participatory wheat variety evaluation was conducted across Dinajpur, Panchagarh, Rajshahi, and Jamalpur, engaging local farmers through mother trials (MTs) under farmer–managed conditions. Two MTs per village were established on two farmers' fields, evaluating six wheat genotypes (BAW 1422, BAW 1425, BAW 1433, BAW 1435, BAW 1439, and the check variety BWMRI Gom 2) in a randomized complete block design (RCBD) with two dispersed replications. Plot size was 20 m². Data collection was carried out by researchers, who facilitated farmer scoring during physiological maturity and postharvest stages.

Farmer Evaluations: At physiological maturity, BAW 1433 received the highest average preference score (9.1) due to short stature, high tillering, long spikes, disease tolerance, and predicted yield though similar average preference score was received by the check variety BWMRI Gom 2. BAW 1425 and BAW 1435 (average score 8.8) were the second preferred genotypes mainly for their early maturing habit along other with average performance in respect of other traits. After postharvest evaluation, BAW 1425 emerged as the most overall preferred genotype (average score 9.6) across locations for its bold, shiny grain, low black–point incidence, and high yield. BAW 1433 along with BWMRI Gom 2 (average score 9.1) were the second most preferred genotypes in final evaluations over locations.

Similar results in both physiological maturity and post–harvest stage were obtained in the last year evaluation at five locations. In the present 2024–25 growing season, BAW 1425 and BAW 1433 were also among the entries which were selected by the wheat breeders from the Candidate Variety Demonstration (CVD). Therefore, based on the preference of both the wheat breeders and the farmers, the promising lines BAW 1425 and/or BAW 1433 may be proposed to release as variety (ies) this year.

Figure 1.15. Evaluating advanced line in the field of Bajnahar, Birol, Dinajpur

1.11. Special Breeding Activities:

Accelerating wheat breeding program through cutting edge genomics and phenotypic technologies: Yield is the ultimate target of any breeding program. Prediction of wheat yield using secondary traits is very important as is enhances the selection accuracy. The objective of TPE/GS study was to monitor wheat growth and predict grain yield in wheat using high–density temporal proximal sensing measurements and yield components under extreme terminal heat stress that is common in Bangladesh. We analyzed normalized difference vegetation index (NDVI) and CT measurements in two sets of 540 advanced breeding lines collected from the International Maize and Wheat Improvement Center (CIMMYT) at the BWMRI, Regional Station, Jamalpur. To optimize use of the phenotypic datasets, several variable reduction and regularization techniques followed by using a cross–fold validation approach was explored to predict grain yield. The multivariate models gave higher prediction accuracies for grain yield than the univariate models. Stepwise regression performed as well or better in predicting grain yield than other models which was 0.79 for 2024–25 growing season Figure 1.15. Our results showed that the optimized phenotypic prediction models can leverage secondary traits to deliver highly accurate prediction of wheat grain yield, allowing breeding programs to make more robust and rapid selections.

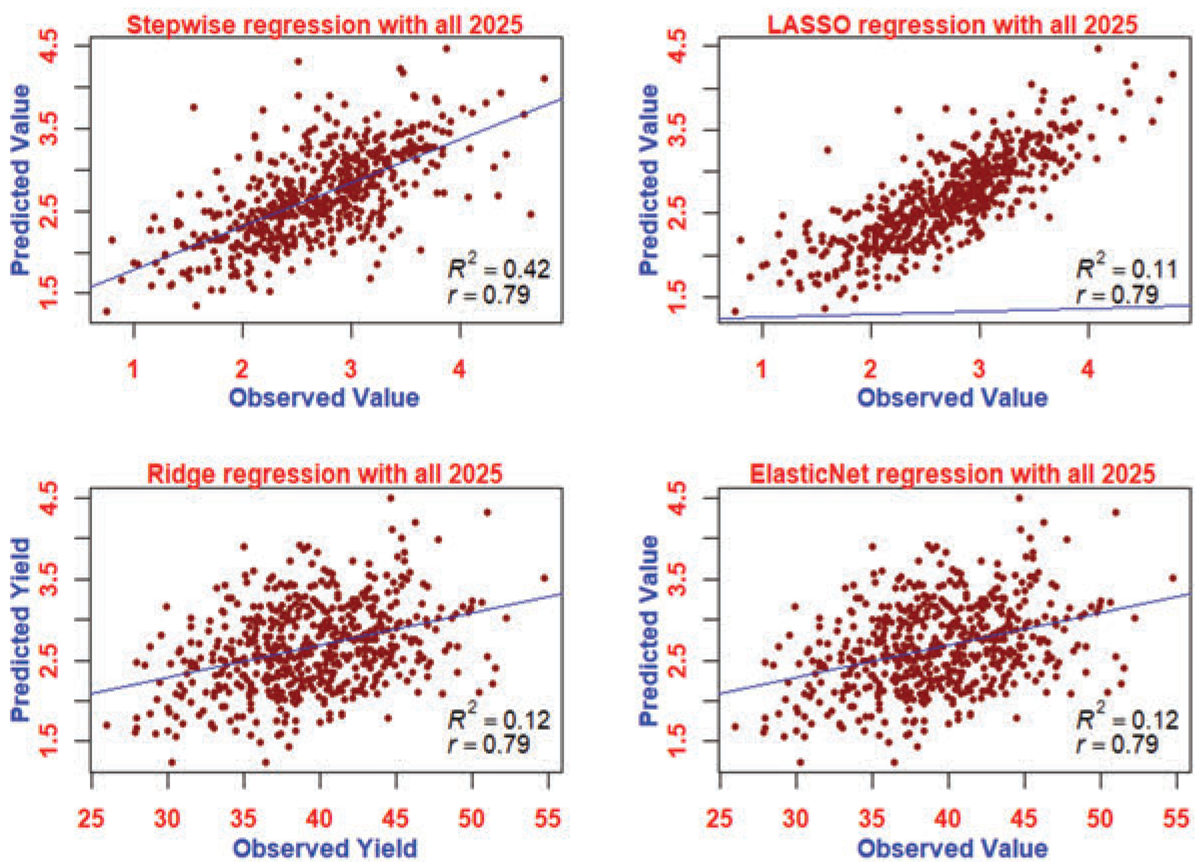


Figure 1.16. Wheat yield prediction using secondary traits with four shrinkage models leveraging a prediction accuracy of 0.79.

2. Maize variety development

Maize (*Zea mays L.*) is the second most important cereal crop in Bangladesh after rice, and it leads in production per unit area with a yield of 10.91 t ha^{-1}. While it is grown in both kharif and Rabi seasons, the highest yields are achieved during the Rabi season due to the use of irrigated fields and hybrid maize varieties with advanced production technologies. Since the early 2000s, maize cultivation has expanded rapidly, driven by the poultry feed industry's demand, with nearly 100% of the cultivated area now planted with hybrids. In 2024–25, maize was cultivated on 6.78 lakh hectares, producing 73.97 lakh tons of grain, meeting the national demand of 7 million tons. Maize research in Bangladesh began in the 1950s with a focus on composite popcorn and sweet corn varieties. Initially, open–pollinated varieties (OPVs) were prioritized for their easier seed multiplication. However, since the early 1990s, research shifted towards hybrid development. Programs have focused on developing inbred lines from hybrids and OPVs, with promising single crosses recycled to extract superior inbred lines. This approach has led to the release of 20 hybrid varieties between 2000 and 2024. The Bangladesh Wheat and Maize Research Institute (BWMRI) has also collaborated with CIMMYT and private partners (BRAC, ACI Ltd., Lal Teer Seed Ltd.) to test exotic hybrids through international trials, aiming to identify hybrids suited for stress–prone areas. Current breeding objectives include developing high–yielding hybrids for field corn and specialty corn, such as popcorn, sweet corn, and baby corn. Efforts are also underway to breed for stress tolerance (heat, salinity, and drought) and create location–specific varieties for challenging regions like haor, char, and hilly areas. Public–private partnerships have been instrumental in scaling up seed production and ensuring the widespread adoption of these hybrids, contributing to the continued growth of maize cultivation in Bangladesh.

2.1. Germplasm collection, characterization and maintenance

Maintenance and characterization of locally developed inbred lines of maize (10 sets): Maize inbred lines are essential for hybrid development due to their adaptation and desirable agronomic traits. This study evaluated 134 locally developed inbred lines comprising field corn, sweet corn, and popcorn during the rabi season of 2024–25 at Dinajpur. Lines were maintained through removal of off–types and manual self–pollination, and characterized for phenology, plant architecture, and selfed seed yield. Popcorn types flowered earlier, while field corn and sweet corn types were taller and later maturing. The results highlight the importance of genetic maintenance and phenotypic evaluation for effective use of inbred lines in maize breeding programs.

Figure 2.1. Maize breeders are crossing to improve maize germplasms at Dinajpur

Maintenance of exotic inbred lines of maize (2 sets): A total of 91 exotic field corn inbred lines 51 orange grained and 40 yellow grained introduced from CIMMYT were maintained and characterized during the rabi season of 2024–25 at Dinajpur. Each line was grown under uniform management and manual self–pollination performed to ensure genetic purity. Data on phenology, plant height, ear height, and selfed seed weight revealed substantial variation among lines, indicating their potential as breeding resources. Early and late maturing types were identified for specific environmental adaptation, and high–yielding lines showed strong promise as hybrid parents. A total of 34.6 kg of selfed seed was harvested and stored in cold storage for use in future maize improvement programs.

Figure 2.2. Monitoring of generation advancing plot at Dinajpur

2.2. Development of source population and inbred lines

Seven sets of generation advancement were carried out during the Rabi season of 2024–25 at BWMRI, Dinajpur, involving field corn, popcorn, and sweet corn lines. Balanced bulk seeds from selfed ears were planted and managed under standard agronomic practices. Healthy, true to type plants were self pollinated to maintain genetic purity and progress lines toward homozygosity. The work advanced both early and late generation lines, ensuring a balance between refining elite inbreds and preserving genetic diversity for future breeding. A total of 376 maize lines were advanced, supporting a strong pipeline of parental materials for hybrid development.

2.3. Evaluation of single cross hybrids

Performance trial of released, promising, and commercial hybrids across diverse locations: A multi–location trial was conducted during the rabi season of 2024–25 at Dinajpur, Gazipur, Jamalpur, and Jashore to evaluate seven released, six promising, and three commercial maize hybrids.

Figure 2.3. Visiting of performance trial site at Dinajpur

The objective was to assess yield potential, stability, and adaptability across diverse environments. Significant variation was observed among genotypes and locations for phenology, plant height, ear height, and grain yield. Early flowering was more common in Jamalpur and Jashore, while later–maturing hybrids, such as BWMRIHM 2 and BMS 349, performed well in longer–season conditions. Plant and ear height varied by environment, with taller plants recorded in Dinajpur and shorter in Jamalpur. Grain yield ranged from 8.94 to 13.31 t ha^{-1}, with BWMRIHM 2, BMS 349, and P–3355 showing consistently high performance across locations. The results highlight these hybrids' adaptability and potential for wider cultivation, underscoring the value of multi–location testing in identifying stable, high–yielding varieties.

Validation of promising hybrids of maize at different regions of Bangladesh: A multi–location validation trial was conducted during the rabi season of 2024–25 in five regions of Bangladesh Dinajpur, Thakurgaon, Rajshahi, Manikganj, and Sherpur to evaluate ten maize hybrids, including eight BWMRI–developed promising lines, one internal check, and one commercial check (P3355). Grain yield varied significantly across locations, indicating strong genotype × environment interactions. Among the tested hybrids, BMS 355 (14.28 t ha^{-1}) achieved the highest mean yield with consistent performance across all sites, followed by BMS 349 (13.44 t ha^{-1}) and BWMRI HM 2 (13.21 t ha^{-1}). The commercial check P 3355 also performed well (13.01 t ha^{-1}), confirming its adaptability. The results highlight BMS 355, BMS 349, and BWMRI HM 2 as high yielding, stable, and well adapted hybrids with strong potential for wider adoption. Promoting such locally developed hybrids could reduce dependence on imported seed and enhance maize productivity in Bangladesh.

Figure 2.4. Validation of promising hybrids and field day at Bankali, Sadar, Dinajpur

Evaluation of field corn single cross hybrids for adaptability and yield stability: Sixty promising maize hybrids, along with five check varieties (BWMRI Hybrid Maize 2, DKC 9217, P3355, Juboraj and Early king) were evaluated across four locations (Dinajpur, Jashore, Gazipur, and Jamalpur) during the Rabi 2024–25 season, using an alpha lattice design with two replications. The combined ANOVA revealed highly significant effects of environments, genotypes, and genotype × environment (G×E) interactions for all measured traits, highlighting strong environmental influence and the need for multi–location testing.

Genotypic performance showed wide variation, with means ranging from 7.82 to 13.37 t ha^{-1}. Several hybrids showed high yield with stability, notably Titan 34×BIL 28 (13.29 t ha^{-1}), Titan37×BIL 28 (12.33 t ha^{-1}), Titan 6×BIL 28 (13.36 t ha^{-1}) and Titan 10 × BIL 28 (12.21 t ha^{-1}). While hybrids like Titan 35×BIL114 (13.37 t ha^{-1}), Titan17×BIL 28 (12.96 t ha^{-1}), and Titan 10 × BIL 114 (12.80 t ha^{-1}) also exhibited higher yield but they are responsive to specific environment.

Figure 2.5. Selection of promising hybrids by maize breeders at Dinajpur

Comparative yield trial of imported and local maize hybrids: This study evaluated the genotype × environment interaction (GEI) for grain yield and other key traits of twenty maize hybrids across four locations in Bangladesh during the Rabi 2024–25 season. The analysis of variance revealed significant variations for genotypes (G) environments (E) and their interaction (G×E) for all traits. This indicates that hybrid performance was strongly influenced by specific environmental conditions. Among the test locations, Dinajpur was the most suitable for maize cultivation, followed by Gazipur, while Jamalpur and Jashore were less favorable. Based on mean yield, AMMI Stability Value (ASV), Genotypic Selection Index (GSI), and AMMI biplot analysis, several hybrids were identified as superior. BWMRI HM 2, Titan 34 × BIL 28, and DKC 9217 exhibited the highest mean yields, but their performance was more responsive to specific, favorable environments, indicating a lack of broad stability. In contrast, Palowan 9120, NH 7720, Early King, 984 Gold and P–3355 demonstrated stable performance with above average yields, making them well suited for a wider range of growing conditions.

Evaluation of locally developed popcorn hybrids: A total of 67 locally developed popcorn hybrids, along with five commercial checks, were evaluated during the rabi season of 2024–25 at the Bangladesh Wheat and Maize Research Institute, Dinajpur, to assess their agronomic performance and yield potential. Significant variation was observed in phenology, plant height, ear height, and grain yield, indicating substantial genetic diversity among the tested entries. Days to pollen shedding ranged from 90 to 100 days, while plant height varied from 116 cm to 224 cm. Grain yield differed significantly, with the highest–performing local hybrids PCB–13–1×T–17–2 (8.51 t ha^{-1}), PCB–13–1×T–17–1 (8.43 t ha^{-1}), and SPC–24×SPC–10 (8.22 t ha^{-1}) showed comparable yields of top commercial checks such as BRAC Super Pop (8.88 t ha^{-1}) and Rafiq Seed (8.60 t ha^{-1}). The promising popcorn hybrids were also impressive for popping capacity and quality. Several hybrids from the PCB and SPC series demonstrated high yield potential, desirable plant architecture, and appropriate maturity, making them strong candidates for further multi–location testing and potential release.

These findings highlight the potential of locally bred popcorn hybrids to reduce dependence on costly imported seed and enhance domestic production.

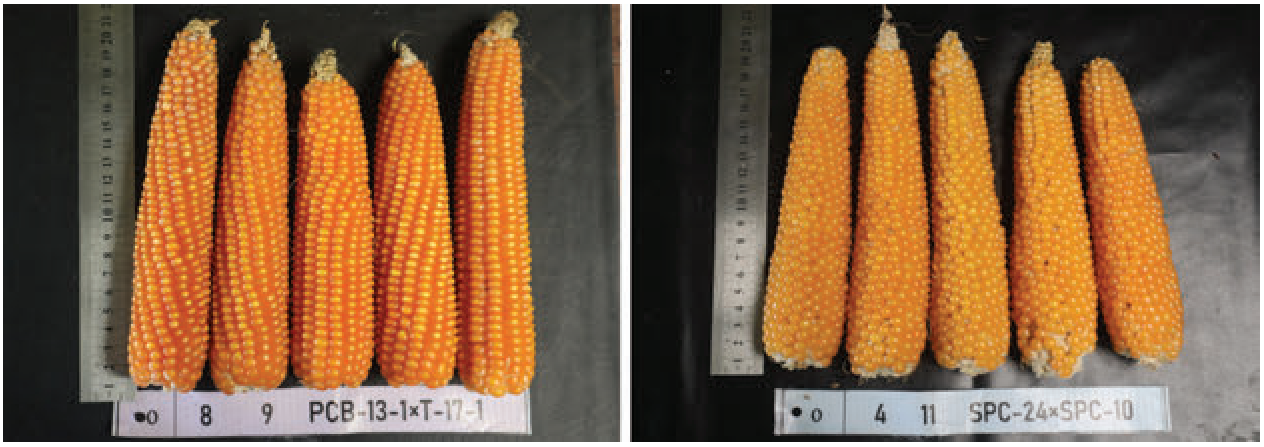


Figure 2.6. Selected locally developed popcorn hybrids

2.4. Abiotic Stress Breeding

Evaluation of selected HTMA hybrids during kharif season: Bangladesh is highly vulnerable to climate change, making the development of stress–resilient maize hybrids essential. Eight heat–tolerant hybrids from the Heat Tolerant Maize for Asia (HTMA) project, along with two commercial checks, were evaluated during the kharif season of 2025 at Dinajpur and Gazipur using a randomized complete block design (RCBD) with three replications. Data were collected on flowering traits, plant height, ear height and grain yield. Significant effects of genotype, environment, and their interactions were observed for all traits. Flowering was earlier in Gazipur, while taller plants and higher ear placement were recorded in Dinajpur. Grain yield was higher in Dinajpur (11.42 t ha^{-1}) than in Gazipur (9.45 t ha^{-1}). Pioneer 3376, Pacific 339, VH 19488 and ZH 17362 were the top yielders, while ZH 22692 consistently performed poorly. Some genotypes like ZH19940, ZH159 exhibited the high yield potential with stability, suggesting their suitability for sustainable maize cultivation under heat stress environments in Bangladesh.

Figure 2.7. Salinity screening of maize hybrids at Dinajpur

Screening of maize genotype under artificial salt stress condition: Maize is the third most important cereal crop in Bangladesh, but its expansion into saline–prone areas is constrained by its moderate salt sensitivity. This study aimed to screen 50 maize genotypes under artificial salinity stress in a hydroponic system using a Completely Randomized Design (CRD). Seedlings were exposed to three salinity levels (10, 12, and 14 dS m^{-1}) along with a control, and survival percentage was recorded after 25 days. Results revealed that, at 10 dS m^{-1}, genotype G24 maintained high tolerance, while nine entries, including G2, G6, G7, and G18, showed moderate tolerance (60–79%). At 12 and 14 dS m^{-1}, survival declined sharply, with only G2 retaining moderate tolerance; most genotypes showed poor survival (<40%), and several suffered complete mortality. The study highlights G24 and G2 as promising candidates for developing salinity–resilient maize hybrids, through further validation under natural saline field conditions.

2.5. Production of new hybrids

The study was conducted at Dinajpur, Thakurgaon, and Debiganj to produce seeds of 120 newly developed field corn hybrids under isolation using six designated testers. Isolation, staggered planting of male parents, detasseling, and rigorous rouging were implemented to ensure genetic purity. Fertilizers were applied following recommended rates, and standard agronomic practices were followed. At maturity, selected ears from female rows were harvested, dried, and processed, with final seed lots stored in a cold room to maintain quality. A total of 510 kg of hybrid seed was successfully produced, ensuring adequate seed supply for further evaluation, distribution, and potential commercial release.

2.6. Maintenance and seed increase of parental/inbred lines

Five parental lines (BIL 28, BML 264, BIL 157, VL109501, and CML 582) of released and candidate maize hybrids were grown during Rabi 2024–25. Total 1580 kg seeds were obtained from five parental inbred lines and stored for distribution and seed production in the next Rabi season.

Figure 2.8. Seed production of parental lines of BWMRI Hybrid Maize 2

Figure 2.9. Detasseling during hybrid seed production

2.7. Seed production of different released hybrids

Seeds of three BWMRI and BARI released hybrids (BARI Hybrid Maize 9, BARI Hybrid Maize 17, and BWMRI Hybrid maize 2) were produced in isolation at three different BWMRI research stations during Rabi 2024–25. Total 5440 kg hybrid seeds (F1) were obtained and stored for distribution and experimental use in the next Rabi and kharif season.

2.8. Maintenance and seed production of open–pollinated varieties

Four composite maize varieties viz. Popcorn, BARI Sweet corn 1, BARI Maize 7 and Barnali were grown in isolation at four different locations of BWMRI research stations during Rabi 2024–25 and a total amount of 950 kg seeds were obtained and stored for maintenance and distribution in the next Rabi season.

2.9. Bangladesh Coordinated Maize (BCM) trial

BCM trial during rabi season: The Bangladesh Coordinated Maize (BCM) trial was conducted during Rabi 2024–25 at four locations (Dinajpur, Jashore, Sherpur, and Jaldhaka) to evaluate 20 maize hybrids, including entries from BWMRI and BRAC, two internal checks (BWMRI HM 2 and Juboraj) and two commercial checks (DKC 9217 and P–3355). Significant genetic variability and strong genotype × environment interactions were observed for flowering, plant height, ear height, and yield. The environment of Dinajpur was highly favorable followed by Sherpur (Bogura) and Jaldhaka for hybrid maize cultivation. Considering the yield potentiality, it is concluded that three genotypes BWMRI Hybrid Maize 2 (15.0 t ha^{-1}) Titan37×BIL28 (14.56 t ha^{-1}) and Titan–6×BIL28 (14.80 t ha^{-1}) exhibited the highest average yield, but they are responsive to specific environment. On the other hand, based on stability parameter and AMMI biplot genotypes Titan–31×BIL28 (13.19 t ha^{-1}), BRAC 5 (12.69 t ha^{-1}) and 9120–20×BIL28 (11.84 t ha^{-1}) are stable across different environment and showed moderate yield performance. The results highlight the importance of multi–location trials in identifying both broadly adapted and location–specific hybrids to strengthen Bangladesh's maize seed system.

Figure 2.10. Field visit and selected hybrid of BCM trial at Dinajpur

BCM trial during Kharif season: The Bangladesh Coordinated Maize (BCM) trial during Kharif 2025 evaluated 20 maize hybrids across five locations, including entries from BWMRI and BRAC, with internal checks (BARI Hybrid Maize 17, King Corn) and commercial checks (Pac 339, P–3376). This study assessed the genotype × environment (GEI) effects on grain yield, pollen shedding, silking, plant height, and ear height. Analysis of variance revealed highly significant effects of genotype, environment, and GEI for yield, confirming strong environmental influence. Based on mean yield, regression (bi), deviation from regression (S^2di), and AMMI biplot analysis, distinct response patterns were observed. BRAC 3 (11.15 t ha^{-1}) recorded the highest yield but showed specific adaptation, while BRAC 2 (10.61 t ha^{-1}), BRAC 4 (10.23 t ha^{-1}), and Titan–37×BIL 28 (9.56 t ha^{-1}) also outperformed the trial mean. In contrast, BARI Hybrid Maize 17, Titan–16×BIL 28, and BRAC 7 produced moderate yields but exhibited stable performance across environments. These results highlight the potential of specific hybrids for broad adaptation, while others may be targeted for environment–specific cultivation strategies.

3. Crop and Soil Management

3.1. Crop management

This section covers various agronomic practices aimed to improving crop productivity, weed management and economic returns for maize and wheat crops. The trials were carried out during the 2024–25 growing seasons at the headquarters and different regional stations of BWMRI, Dinajpur. The experiments were designed to evaluate the impact of different agronomic treatments on the grain yield, forage yield and weed control efficiency of maize and wheat.

3.1.1. Evaluation of pre-emergence herbicide to control weeds in wheat

The experiment was conducted at the research field of Bangladesh Wheat and Maize Research Institute, Nashipur, Dinajpur during Rabi season of 2023-24 and 2024-25. The experiment was laid out in Randomized Complete Block Design with three replications. The unit plot size was 4m × 4m and the variety was BWMRI Gom 3. Seeds were sown on 26 November, 2023 and 04 December, 2024 with a spacing of 20 cm apart from rows followed by continuous seeding. Eight different treatments were employed in this study viz. 1) Panida 33 EC @ 2.5 L ha^{-1}, 2) Fist 33 EC @ 3.0 L ha^{-1}, 3) Clear up 33 EC @ 2.5 L ha^{-1}, 4) Pendulam 33 EC @ 2.0 L ha^{-1}, 5) Dafa 33 EC @ 1.0 L ha^{-1}, 6) Kri Stop 33 EC @ 2.0 L ha^{-1}, 7) Hand weeding at 25 DAS, 8) Weedy check (Control).

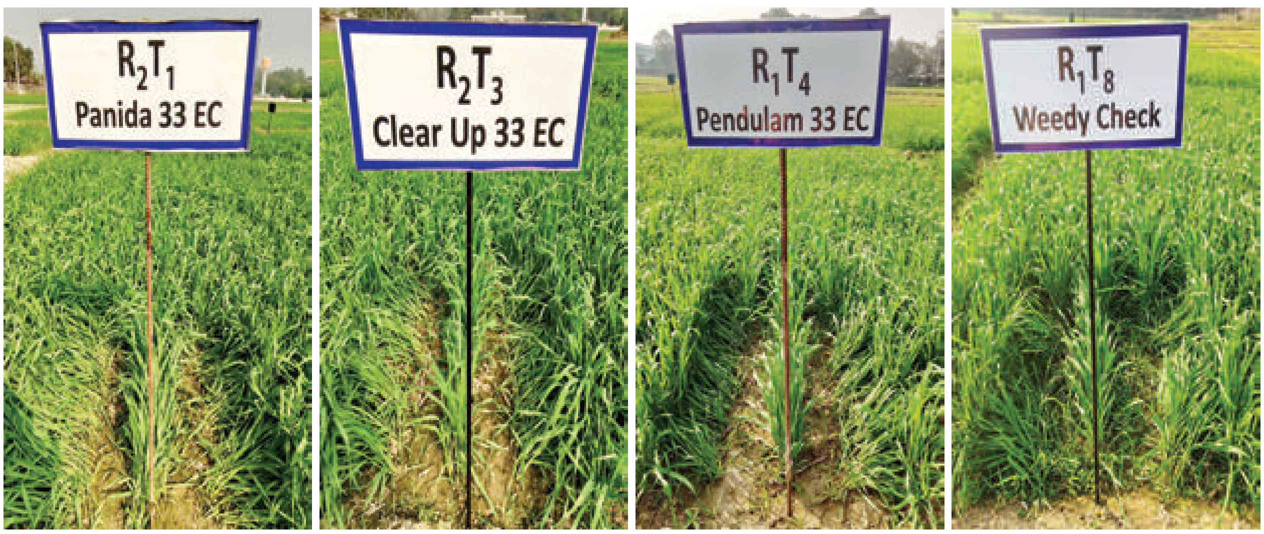


Figure 3.1. Effect of pre-emergence herbicides on weed control in wheat at 35 days after sowing (DAS)

Among the weed species *Scroparia dulcis, Cynodon dactylon, Chenopodium album, Physalis heterophylla, Enhydra fluctuans, Echinochloa colona, Echinochloa crussgalli* were the most dominating weed species in the experimental field. No phytotoxic effect of herbicide was observed in the experimental plot. Based on the two years results, it was found that pre-emergence herbicide Panida 33 EC showed highest weed control efficiency (83.84% and 85.54%) in 2023-24 and 2024-25 at 25 DAS. All other pre-emergence herbicides also control weed effectively than control and hand weeding. The highest grain yield (4.30 t ha^{-1} and 4.34 t ha^{-1}) was recorded in Panida 33 EC in 2023-24 and 2024-25 and the lowest grain yield (3.40 t ha^{-1} and 3.32 t ha^{-1}) was recorded in Weedy check (control) treatment in both the years. All other herbicides also gave statistically identical grain yield. The highest gross return (188190 Tk ha^{-1}) and BCR (2.34) was found in Panida 33 EC and the lowest (146775 Tk ha^{-1} and 1.92) was found in Weedy check (control). All other herbicides also provided higher BCR than hand weeding.

3.1.2. Evaluation of different herbicides to control weeds in maize field in kharif season

Figure 3.2. Effect of different treatments on weed control in maize: 23 days after spraying and hand weeding, and 48 days after sowing in control

An experiment was conducted at the Research field of Bangladesh Wheat and Maize Research Institute, Nashipur, Dinajpur during Kharif season of 2023-24 and 2024-25 to find out the proper agronomic management along with post emergence herbicides to reduce the costs and risks of intensive weed control in Kharif maize. The experiment was laid out in Randomized Complete Block Design with three replications. The unit plot size was 4.2m × 4m and the variety was BARI Hybrid Maize 17. Seeds were sown on 29 April, 2024 and 16 April, 2025 with a spacing of 60 cm apart from rows and 20 cm from seed to seed. The selected herbicide treatments were 1) Calaris Xtra 27.5 SC @ 3.0 L ha^{-1}, 2) Maize Clean 55 SC @ 2.0 L ha^{-1}, 3) Bajna 55 SC @ 3.0 L ha^{-1}, 4) Mesotin 50 WP @ 1.8 kg ha^{-1}, 5) Mingto 38 SE @ 3.0 L ha^{-1}, 6) Triozine 55 SC @ 2.0 L ha^{-1}, 7) Prism 27.5 SC @ 2.0 L ha^{-1}, 8) Mia Bhai 55 SC @ 2.0 L ha^{-1}, 9) Hand Weeding at 25 DAS and 10) Control (no weed control). Among the weed species *Digitaria sangunalis, Echinochloa colonum, Cyperus rotundus, Eleusine indica* were the most dominant weed species in the experimental field. No phytotoxic effects of herbicides were observed in the experimental plot. Based on the two years result, it was found that Calaris Xtra 27.5 SC @ 3.0 L ha^{-1} and Mesotin 50 WP @ 1.8 kg ha^{-1} recorded the highest WCE (81.39% and 88.15%) and (86.05% and 84.33%) in 2023-24 and 2024-25, respectively. All other herbicides also performed better in controlling weeds than hand weeding. The highest grain yield (9.30 t ha^{-1}) was obtained from Triozine 55 SC @ 2.0 L ha^{-1} in 2023-24, while in 2024-25, the highest yield (7.53 t ha^{-1}) was recorded in Calaris Xtra 27.5 SC @ 3.0 L ha^{-1}. All other herbicides also recorded identical grain yield in both the years. The lowest grain yield (7.01 t ha^{-1} and 5.05 t ha^{-1}) were obtained in control treatment in 2023-24 and 2024-25, respectively. The highest gross return (204125 Tk ha^{-1}) and BCR (2.50) was obtained in Calaris Xtra 27.5 SC @ 3.0 L ha^{-1} followed by Triozine 55 SC @ 2.0 L ha^{-1}, Mesotin 50 WP @ 1.8 kg ha^{-1} and Bajna 55 SC @ 3.0 L ha^{-1} and the lowest (150750 Tk ha^{-1} and 1.92) in control treatment. Considering economic performance, it can be concluded that application of Calaris Xtra 27.5 SC @ 3.0 L ha^{-1}, Triozine 55 SC @ 2.0 L ha^{-1}, Mesotin 50 WP @ 1.8 kg ha^{-1} and Bajna 55 SC @ 3.0 L ha^{-1} were more beneficial than other treatments.

3.1.3. Effect of different spacing and nitrogen levels on green cob and forage yield of baby corn

Figure 3.3. Effect of different treatments on weed control in maize: 23 days after spraying and hand weeding, and 41 days after sowing in control

The experiment was conducted at the research field of Bangladesh Wheat and Maize Research Institute, Nashipur, Dinajpur during Rabi season of 2024-25 to study the effect of planting spacing and nitrogen levels on yield performance of Baby corn. The unit plot size was 3m × 3m and the variety was BWMRI Hybrid Baby corn 1. Seeds were sown on 08 December 2024. The experiment was conducted in a split-plot design with three replications. Five Nitrogen doses viz. F_1 = BWMRI recommended dose; $F_2 = F_1$ + 10% of N; $F_3 = F_1$ + 20% of N; $F_4 = F_1$ - 10% of N; $F_5 = F_1$ - 20% of N were employed in main plot and five planting spacing's S_1 = 35cm × 20cm; S_2 = 40cm × 20cm; S_3 = 40cm × 15cm; S_4 = 45cm × 20cm; S_5 = 45cm × 15cm were employed in sub-plot. The highest cob length and cob weight was recorded in F_3 nitrogen level and the lowest in F_5 nitrogen level. The highest forage yield was recorded in S_3 spacing and the lowest in S_4 spacing. The highest cob yield without husk (6.06 t ha^{-1}) was recorded in F_3S_3 and the lowest (3.79 t ha^{-1}) in F_1S_4 followed by F_5S_5 (3.81 t ha^{-1}) treatment combination. The highest gross return (322770 Tk ha^{-1}) and BCR (2.45) was found in F_3S_3 treatment combination and the lowest (202670 Tk ha^{-1} and 1.64) in F_1S_4 followed by F_5S_5 (206160 Tk ha^{-1} and 1.64) treatment combination. From 1st year result, it can be concluded that increasing nitrogen level up to 20% is economically profitable. So, for the final recommendation, the experiment will be continued next year.

Figure 3.4. Effect of different treatments on response of newly evolved maize varieties to fertilizer

3.1.4. Response of newly evolved maize varieties to fertilizer

The objective of this study was to recommend fertilizer doses for achieving higher economic returns for newly evolved maize varieties. A field experiment was conducted at the Regional Station of Bangladesh Wheat and Maize Research Institute, Jamalpur during the Rabi season from November to May, 2023–24 and 2024–25. The experiment was comprised with four treatments viz. F_1 : STB doses, F_2 : STB + 10% NPKS, F_3 : STB + 20% NPKS, F_4 : STB + 30% NPKS along with two varieties viz V_1 : BWMRI Hybrid Maize 1 and V_2 : BWMRI Hybrid Maize 2.

Varieties were in main plots and fertilizers were in sub plots in a split–plot design. The results revealed that variety V_2 (BWMRI Hybrid Maize 2) produce higher yield (14.5 t ha^{-1} in 2023–24 season and 13.2 t ha^{-1} in 2024–25 season) than V_1 (BWMRI Hybrid Maize 2) (11.0 t ha^{-1} in 2023–24 and 10.0 t ha^{-1} in 2024–25 season) and fertilizer dose for Rabi i.e., treatment F_3 produced the highest grain yield (14.3 t ha^{-1} and 13.0 t ha^{-1}) followed by the treatments F_4 (13.1 t ha^{-1} and 12 t ha^{-1}) and the lowest grain yield was recorded from the treatment F_1 (11.5 t ha^{-1} in 2023–24 and 8.4 t ha^{-1} in 2024–25 season). The maximum grain yield (15.0 t ha^{-1} and 13.7 t ha^{-1}) was recorded from V_2F_4 treatment combination followed by V_2F_3, V_2F_2, V_2F_1 treatment combination in 2023–24 and 2024–25 season. The lowest grain yield (9.2 t ha^{-1} and 8.4 t ha^{-1}) was recorded from V_1F_1 treatment combination. The highest gross return (330807 Tk ha^{-1}) was recorded from V_2F_4 treatment combination followed by V_2F_3 treatment combination. Gross margin was also highest from V_2F_4 (157653 Tk ha^{-1}) treatment combination followed by V_2F_3, V_2F_2 treatment combination. On the other hand, the lowest gross return (218020 Tk ha^{-1}) and gross margin (50720 Tk ha^{-1}) was obtained from V_1F_2 treatment combination followed by V_1F_1 where fertilizer used only STB and STB + 10% NPKS dose. This result indicate that V_2F_4 treatment combination showed better result over other treatment.

3.1.5. Effect of different post–emergence herbicides to control weeds in wheat

The objective of this study was to identify the most effective post–emergence herbicide for controlling weeds in wheat. A field trial was conducted at Regional Station, Jamalpur, during the Rabi season of 2023–24 and 2024–25 following Randomized Complete Block Design with three replications. Seven treatments viz. T_1 : Hammer 24 EC @ 104 ml ha^{-1}, T_2 : Amily 48 SL @ 2.0 L ha^{-1}, T_3 : Fielder 48 SL @ 2.8 L ha^{-1}, T_4 : Sunrise 150 WP @ 100 ml ha^{-1}, T_5 : Council 15 WG @ 150 ml ha^{-1}, T_6 : Hand Weeding at 25 DAS and T_7 : Control were

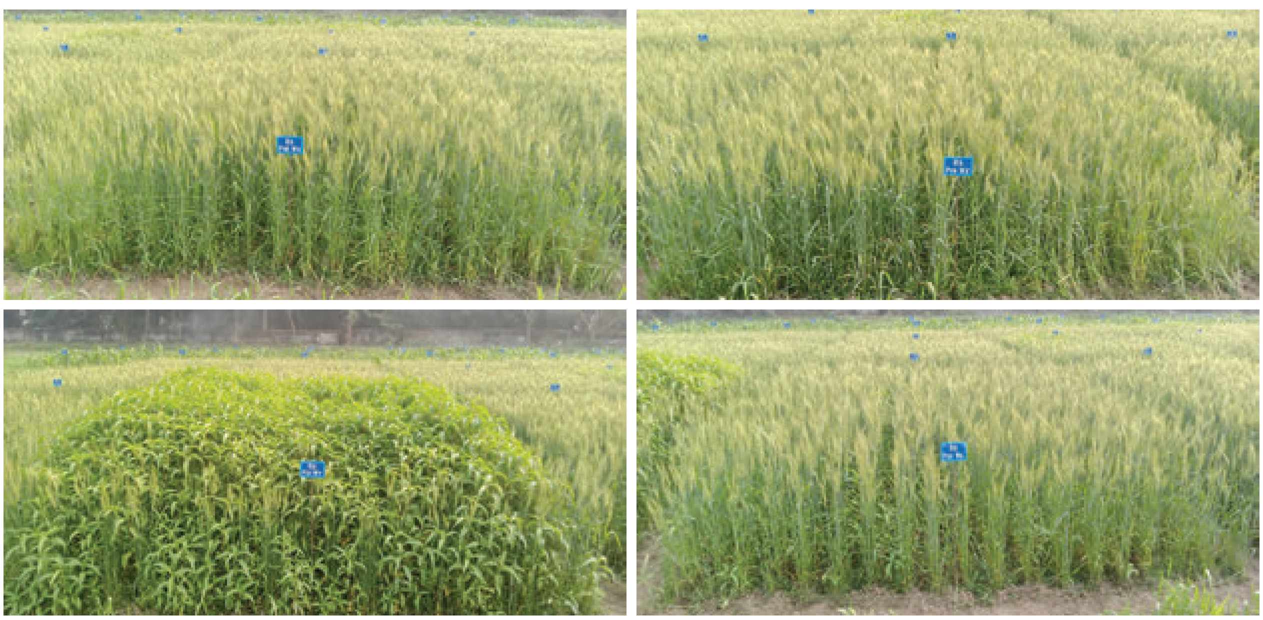


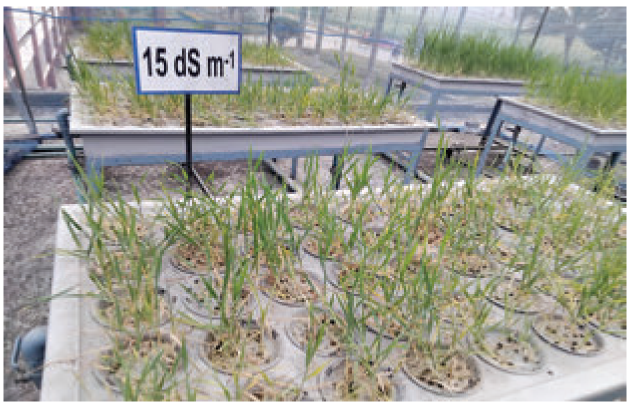
Figure 3.5. Effect of post–emergence herbicides to control weeds in wheat.

applied in variety BARI Gom 32. Seven major weeds namely Bothua, Biskatali, Helencha, Susnishak, Paperonia, Maloncha and Foska begun were observed in the experimental field. Different treatments were significantly influenced on grain yield and yield components of wheat. The highest grain yield (3.8 t ha^{-1} and 4.3 t ha^{-1}) was recorded from T_1 treatment followed by T_3 and T_6.

This higher yield might be due to less weed–crop competition resulting higher absorption of nutrients and sufficient interception of sunlight. The lowest grain yield was observed from T_7 treatment. Among the herbicidal treatments Hammer 24 EC @ 104 ml ha^{-1} (T_1) showed higher weed control efficiency (70.6% and 81.6%) in 2023–24 and 2024–25 season followed by Fielder 48 SL @ 2.8 L ha^{-1} (T_3) (65.5% and 82.6%) in 2023–24 and 2024–25 season. Economic performance within the treatments, the maximum gross return (151520 Tk ha^{-1} and 170880 Tk ha^{-1}) and gross margin (73620 Tk ha^{-1} and 92980 Tk ha^{-1}) was found from T_1 treatment due to lower weeding costs and higher grain yield, making it the most effective post–emergence herbicide under the tested conditions.

3.1.6. Identification of salt–tolerant wheat genotypes through combined field and hydroponic evaluation

To identify salt–tolerant wheat genotypes for future breeding and cultivation in coastal areas, two complementary experiments were conducted. A field trial was established during the 2024–2025 rabi season at Sekandarkhali, Kolapara, Patuakhali, using fifty wheat genotypes in a randomized complete block design with three replications under naturally saline soil conditions (average salinity ≈ 11 dS m^{-1}at 60 DAS). In parallel, a hydroponic trial was conducted at the Regional Station of BWMRI, Gazipur, following a split–plot completely randomized design with four replications, using the same fifty wheat genotypes with two salinity treatments (control and 15 dS m^{-1}salt solution, prepared from diluted seawater). Data on growth, biomass partitioning, and ion regulation (Na^+, K^+, and K^+/Na^+ ratio) were recorded in hydroponics, while yield and associated traits were measured in the field. Analysis of variance revealed significant effects of salinity, genotype, and their interaction on most traits in both environments.



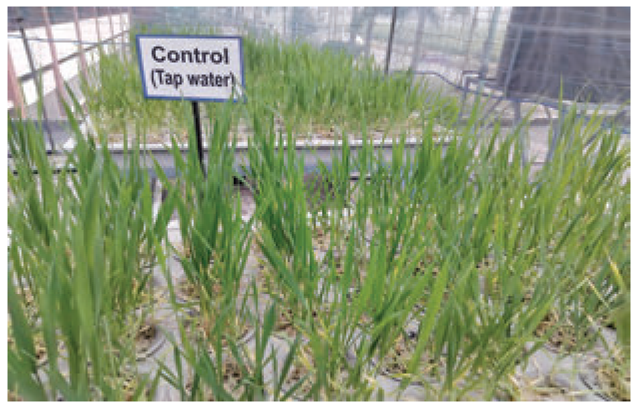


Figure 3.6. Lab view of the experiment on salt–tolerant wheat genotypes through combined field and hydroponic evaluation.

Hydroponic screening proved effective in differentiating genotypes under uniform stress, while field evaluation validated performance under heterogeneous saline soil conditions. Hierarchical clustering grouped genotypes into five clusters in each trial, separating tolerant and susceptible entries. Among the selected genotypes, five promising genotypes from the hydroponic trial (BAW 1467, BWSN 1–16 (23–24), BAW 1516, BAW 1510, BAW 1532) and five from the field trial (BWSN 1–8 (2023–24), BWSN 1–21 (2023–24), BWSN 1–18 (2023–24), BAW 1511, BAW 1513) were highlighted for their superior performance. Integration of both datasets enabled the selection of 15 tolerant genotypes, including five common across both trials (BWMRI Gom 4, BWSN 1–13 (2023–24), BAW 1508, BAW 1514, BAW 1526), and one susceptible check (BAW 1524). These tolerant genotypes combined superior biomass, yield potential, and a favorable K^+/Na^+ balance, confirming their potential for direct use and as breeding materials. This integrated approach demonstrates that combining hydroponic and field screening enhances confidence in identifying stable salt–tolerant wheat genotypes. The selected genotypes represent a valuable resource for breeding and varietal development to expand wheat production in the coastal areas of Bangladesh, thereby contributing to reducing the national wheat production gap.

Figure 3.7. Field view of the experiment on integrating agronomic and physiological traits for selection of salt-tolerant wheat genotypes in coastal Bangladesh

3.1.7. Integrating agronomic and physiological traits for selection of salt-tolerant wheat genotypes in coastal Bangladesh

This study aimed to evaluate 16 contrasting wheat genotypes for their yield performance and physiological responses under natural saline field conditions, and to establish a framework for reliable selection using adjusted analyses. Field experiments were conducted in a randomized complete block design under coastal conditions, where soil electrical conductivity (ECe) was monitored at sowing, 30, 60 days after sowing (DAS), and harvest. Grain yield and agronomic traits (spikes m^{-1}, grains $spike^{-1}$, 1000-grain weight, biological yield, harvest index), physiological parameters (relative water content, SPAD chlorophyll, proline), and ionic traits (Na^+, K^+, K^+/Na^+ ratio) were measured. Regression analyses revealed that salinity at 60 DAS (mean ECe = 11.72 dS m^{-1}, R^2 = 0.47) explained the maximum variability in yield. Therefore, analysis of covariance (ANCOVA) was applied using 60 DAS salinity as a covariate to adjust trait values, thereby correcting for field heterogeneity. A composite Performance Index (PI), integrating yield and seven physiological traits, was also calculated to rank genotypes more comprehensively. Results indicated wide genotypic variation in tolerance. Based on ANCOVA-adjusted yield, BAW 1435, BAW 1433, BAW 1425, and BAW 1430 were the highest yielders (>3.3 t ha^{-1}), supported by favorable biomass, RWC, SPAD, and K^+/Na^+ balance. In contrast, BARI Gom 25, BARI Gom 33, and BAW 1422 were the most susceptible (<3.0 t ha^{-1}), characterized by high Na^+ accumulation and poor sink strength. The PI-based approach emphasized the multi-trait superiority of BAW 1425 and BAW 1433 (PI > 0.60), while several genotypes including BWMRI Gom 4, BAW 1439, and BAW 1340 were placed in the moderate category. In conclusion, combining ANCOVA-adjusted yield with PI classification provided a robust and integrated framework for identifying salt-tolerant wheat. BAW 1425 and BAW 1433 were confirmed as the most promising genotypes for deployment and breeding in coastal saline areas, with several moderate lines offering secondary options. This dual evaluation approach strengthens confidence in genotype selection and supports the expansion of wheat cultivation in saline-prone environments of Bangladesh.

3.2. Soil management

3.2.1. Effect of Rhizoflo Premium biofertilizer on growth and yield of maize

This study evaluated the effect of Rhizoflo Premium biofertilizer on the growth, biomass, and yield of maize through both on–station and on–farm trials. The trials were designed to assess the potential of enhancing maize productivity while optimizing fertilizer usage. Five treatments were applied: T_1 (100% chemical fertilizer), T_2 (100% chemical fertilizer + Rhizoflo Premium at 5 ml kg^{-1} seed + 1 spray at 3 ml L^{-1} at 15 DAS), T_3 (75% chemical fertilizer + Rhizoflo Premium at 5 ml kg^{-1} seed + 1 spray at 3 ml L^{-1} at 15 DAS), T_4 (50% chemical fertilizer + Rhizoflo Premium at 5 ml kg^{-1} seed + 1 spray at 3 ml L^{-1} at 15 DAS), and T_5 (control). Key parameters measured included plant biomass, plant growth, shoot and root development, SPAD value, agronomic traits, and yield components. The on–station trial demonstrated that T_2 (100% chemical fertilizer + Rhizoflo Premium) consistently outperformed other treatments across most growth and biomass parameters. This treatment (T_2) also exhibited the highest plant growth (47.195 cm), shoot growth (25.945 cm), and root biomass (2.2750 g), leading to significantly highest yield (7706.7 kg/ha) than other treatments; indicating the beneficial effects of Rhizoflo Premium in promoting maize productivity under the tested fertilization protocol. In the on–farm trial (farmer's field), T_2 also resulted in the highest values for growth and biomass, including plant (106.13 g) and shoot biomasses (101.90 g). Moreover, T_2 yielded the highest maize yield (11750 kg/ha) than all other treatments. T_5 (control) consistently underperformed in both growth and yield, confirming the advantages of using Rhizoflo Premium for sustainable maize production. It is important to note that BWMRI Hybrid Maize 2 variety has high yield potential and greater nutrient uptake, as recommended by BWMRI. However, in this trial, the fertilizer protocol was followed, which recommend lower fertilizer amounts than those suggested by BWMRI for this variety. As a result, T_2 performed best under the trial conditions. Additionally, crop lodging caused by wind and adverse weather conditions significantly affected the yield, leading to lower–than–expected results. Future trials will strictly adhere to BWMRI's fertilizer recommendations to ensure more accurate and reliable results, optimizing conditions for the maize crop.

Figure 3.8. Field view of experiment on effect of Rhizoflo Premium biofertilizer on growth and yield of maize at farmers' field

Figure 3.9. Field view of experiment on effect of Rhizoflo Premium biofertilizer on growth and yield of maize at BWMRI research field

3.2.2. Effect of phosphate solubilizing bacteria on the phosphorus availability and productivity of wheat in the acid soil of north–western Bangladesh

Phosphate solubilizing bacteria (PSB) are recognized for their ability to increase phosphorus (P) availability in soils, which is especially important in acid soil, particularly north–western part of Bangladesh, where P is often locked in unavailable forms both in high and low pH also.

Research consistently shows that PSB inoculation can significantly enhance both P availability and wheat productivity, offering a sustainable alternative to reduce chemical fertilizers. Considering the burning issues, an experiment was conducted during Rabi season of 2024–25 at the research field of BWMRI, Dinajpur, using a split plot design where three types phosphate solubilizing bacteria (Pseudomonas putida, Bacillus subtilis, Serendipita indica) were used in main plot and four different levels of phosphorus fertilizers (i.e., P_1= Control (STB based NPKZnBS fertilizers), P_2= Without P + NKZnBS (STB) fertilizers, P_3= 50% P (STB) + NKZnBS (STB) fertilizers; P_4= 75 % P (STB) + NKZnBS (STB)) were established in sub–plot with three replications. Data on spikes /m2, plant height (cm), grains/spike, spikelets spike^{-1}, spike length (cm), biological yield (t ha^{-1}), 1000–grain weight and grain yield revealed the maximum grain yield (4.73 t ha^{-1}) in the plot were phosphate solubilizing bacteria Serendipita indica was used at 50% P (STB) + NKZnBS (STB) fertilizers. The phosphorus level provided the highest net return (117024 Tk ha^{-1}). The finding of the study suggested that phosphate solubilizing bacteria along with chemical fertilizers can enhance wheat productivity with the highest economic return, since the combination of both organic and inorganic fertilizers is in an environmentally friendly way for sustainability of crop production.

Figure 3.10. Effect of phosphate solubilizing bacteria on the phosphorus availability and productivity of wheat

3.2.3. Effect of nano (liquid) urea on phenology, growth and yield of wheat

This study aimed to evaluate the effect of nano–urea (liquid) on the growth, phenology, and yield of wheat through foliar application and seed nitrogen level. The experiment was conducted during two consecutive wheat seasons of 2023–24 and 2024–25 at the research field of BWMRI, Dinajpur, using a randomized complete block design with five levels of nitrogen (N). Variety BARI Gom 33 was used as experimental material. The nitrogen levels included varying combinations of basal N application in the form of urea and nano–urea foliar sprays applied at the crown root initiation (CRI) and booting stages. Key growth parameters such as SPAD value, plant height, number of spikes per m², grains per spike, 1000–grain weight, and yield were measured. The results revealed that the split application of urea in combination with nano–urea applied as foliar spray significantly

Figure 3.11. Effect of nano (liquid) urea on phenology, growth and yield of wheat

enhanced plant growth leading to enhance the total productivity of wheat. The T_2 N level, which involved BWMRI– recommended fertilizer application with split urea doses, produced the highest yield (4.54 t ha^{-1} and 4.41 t ha^{-1}), followed by T_3, which included 50% basal urea and two foliar sprays of nano–urea (4.17 t ha^{-1} and 4.34 t ha^{-1}) in both seasons. Economic analysis also showed that T_2 provided the highest net return (139,895 Tk ha^{-1} and 121388 Tk ha^{-1}) in both seasons. The findings of the study suggested that through nano–urea can enhance wheat productivity, but the BWMRI– recommended N dose is still appropriate to get the potential yield for wheat variety BARI Gom 33 and economic return under the given conditions.

Figure 3.12. Effect of nano (liquid) urea on phenology, growth and yield of maize

3.2.4. Effect of nano urea (liquid) on growth and yield of maize

Nano urea is a nano technology based liquid formulation containing (4% nitrogen) alternative to conventional urea now–a–days. Optimal dose of nano urea and application timing may vary due to maize variety and local conditions. In the context, a nanotechnology–based experiment was conducted at the research field of BWMRI–Dinajpur to evaluate the effects of nano–urea on the growth, phenology, and yield of BWMRI Hybrid Maize 2 through foliar application and seed nitrogen level. The experiment was carried out in two consecutive rabi season of 2023–24 and 2024–25 at BWMRI, Dinajpur, using a randomized complete block design. The N fertilizers were in four doses T_1: Zero urea + other RF fertilizers during final land preparation T_2: BWMRI Recommended fertilizer (1/3 urea as basal + other recommended fertilizers during final land preparation) + top dressing of rest 2/3 urea at 30 DAS and 80 DAS T_3: 1/2 urea + other RF fertilizers during final land preparation + two foliar sprays of nano urea @ 3 ml L^{-1} at 30 DAS and second one at tasseling stage (80 DAS) T_4:

No basal urea + other RF fertilizers during final land preparation + three foliar spray of nano urea @ 3 ml L^{-1} at 30 DAS and second one at tasseling stage (80 DAS) and third one at grain formation stage (115 DAS). The findings revealed that treatment T_2 resulted in the highest SPAD value, grain weight/cob (g), 1000–grain weight (g), yield (14.13 t ha^{-1} and 14.72 t ha^{-1}) followed by T_3 (13.45 t ha^{-1}, 13.73 t ha^{-1}), which was significantly higher performance than other treatments. So, it can be said that split application of urea fertilizer and foliar applications of nano–fertilizers not only improve the yield but also have a better economics of crop.

3.2.5. Effect of different levels of NEB (Nitrogen Efficiency for Bioavailability) on the growth and yield of maize

Figure 3.13. Effect of different levels of NEB on the growth and yield of maize

Nitrogen Efficiency for Bioavailability (NEB) is now applied to maximize its uptake and decrease environmental impact by decreasing usage of urea fertilizer. It is a blend of natural root exudates, which helps to increase microbial activities in the soil. Using NEB, plants get more N for longer period of time which helps to optimum growth of plants leading to improve the crop productivity. An experiment was conducted in two consecutive rabi maize seasons of 2023–24 and 2024–25 at the research field of BWMRI, Dinajpur (AEZ–1) to find out the appropriate dose of NEB for maximizing the yield of maize. There were five treatments T_1: NEB control; T_2: Seed treatment with NEB @ 6ml kg^{-1} seed + NEB @1.5ml L^{-1} or 750mL foliar application at 35 DAS; T_3: Seed treatment with NEB @6mL kg^{-1} seed + 1mL L^{-1} or 500mL foliar application at 35 DAS; T_4: Seed treatment with NEB @6mL kg^{-1} seed + 1mL L^{-1} or 500mL foliar application at 35 DAS + at 71 DAS; T_5: Seed treatment with NEB @ 6ml kg^{-1} seed + NEB @1.5ml L^{-1} or 750mL foliar application at 35 DAS + at 71 DAS. BWMRI Hybrid Maize 2 was used as experimental material. The experiment was set up in a randomized complete block design (RCBD) with three replications. Two years observation revealed that NEB treatments significantly affected the growth and yield contributing characters (i.e., plants per unit area, cobs/plant, grains/cob, grain weight/cob, 1000–grain weight), ultimately significantly affected the grain yield of maize. The highest grain yield in both years (17.72 and 16.66 t ha^{-1}) was recorded in T_5 (Seed treatment with NEB @ 6 seed + NEB @1.5ml L^{-1} or 750mL foliar application at 35 DAS + at 71 DAS) treatment, and the lowest grain yield in both seasons (13.79 t ha^{-1}, 12.83 t ha^{-1}) was recorded in T_2 treatment. Grain yield increased by 17.43% and 15.34% in T_5 treatment compared to NEB control plots during both seasons. T_5 treatment also gave maximum economic outcome in both seasons. This result suggests that seed treatment with NEB @ 6 ml kg^{-1} seed + NEB @1.5ml L^{-1} foliar application at 35 DAS and 71 DAS is the appropriate dose for achieving higher yield of maize and reducing environmental hazards by limiting inorganic fertilizers levels.

4. Pest management

4.1. Disease management

Diseases are one of the major constraints to wheat production in Bangladesh. Among them, Bipolaris leaf blight (spot blotch) caused by *Bipolaris sorokiniana* (Sacc.) Shoemaker is most important. The second most important disease is leaf rust caused by *Puccinia triticina* Eriks. The disease usually appears in mid–February under the agroclimatic conditions of Bangladesh. Wheat blast (WB), a devastating wheat disease caused by *Magnaporthe oryzae* pathotype Triticum (synonym *Pyricularia oryzae* Cavara) emerged for the first time in 2016 in several south–western and southern districts of Bangladesh. In 2016, the disease was limited to eight districts but now it has been established and found in 36 districts. However, major wheat growing areas of Bangladesh i.e. north–western parts still remain free from wheat blast. Stem rust caused by *P. graminis Pers. f. sp. tritici* Eriks. & Henn. was observed in 2014 in the rust trap nurseries after three decades, but no Ug99 was detected. Yellow rust caused by *P. striiformis* occurs occasionally with low to moderate severity. Fusarium head blight (FHB) is an emerging fungal disease of wheat in Bangladesh caused by the species *Fusarium graminearum*. Other diseases of regular occurrence are seedling blight caused by *B. sorokiniana,* foot and root rot caused by *Sclerotium rolfsii* Sacc., head blight caused by *B. sorokiniana* and black point incited mainly by *B. sorokiniana* and *Alternaria alternata* (Fr.) Keiss. Now–a–days, a number of maize diseases are frequently observed in most of the farmers' fields with different levels of severity. Leaf blight, caused by *Exserohilum turcicum* and *Bipolaris maydis* are more common in most of the fields with varying level of infection. Leaf rust caused by *Puccinia sorghi* is also observed frequently in the cultivated varieties. Fusarium stalk rot, an emerging threat for maize cultivation in Bangladesh is caused by several species of Fusarium. It not only damages the maize plant and reduces its yield and nutritional values but also imposes threats to human life through mycotoxin development. The incidence and severity of the diseases were found higher in Kharif season compared to Rabi. This section focuses on the development and implementation of comprehensive disease management strategies for wheat and maize in Bangladesh, targeting key pathogens that significantly impact crop yields.

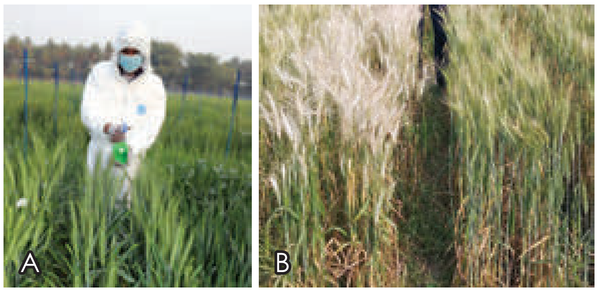


Figure 4.1. Germplasm screening against wheat blast under inoculated conditions; (A) Magnaporthe spore inoculation on advanced genotypes and (B) response of resistant and susceptible lines to wheat blast

4.1.1. Evaluation of wheat germplasm against wheat blast under inoculated field conditions

A cohort of 330 entries were screened against wheat blast under inoculated conditions at Regional Station, Bangladesh Wheat and Maize Research Institute (BWMRI), Jashore and field conditions at BWMRI, Dinajpur during 2024–25 crop growing season. Among the entries evaluated, 13 lines were selected based on blast disease index, 1000–grain weight, grain yield and other agronomic characters. Blast severity was recorded only at Jashore. The percentage of disease index of the selected lines ranged from 0 to 23.6% while those of the susceptible check BARI Gom 26 displayed 78.2%, and resistant varieties BWMRI Gom 3 was close to 10% and BARI Gom 33 completely free from disease infection. Grain yields of the selected entries varied from 600 to 985 g/plot.

4.1.2. Evaluation of elite wheat genotypes for resistance to wheat blast under inoculated field conditions

Wheat blast has been considered one of the main biotic stresses to food security in the world. The experiment was aimed to evaluate the resistance of advanced wheat genotypes to the disease at reproductive stage. A bunch (40) of elite bread wheat genotypes from diverse sources including susceptible/resistant checks were evaluated under inoculated conditions at Regional Station, Jashore during 2024–25 cropping season. From the results, the genotypes demonstrated varying levels of severity against the disease. Out of 40 genotypes, 29 genotypes were found resistant (0–10% Disease Index) to wheat head blast. The resistant varieties BARI Gom 33 and BWMRI Gom 3 displayed highly resistant reaction (disease free), while the susceptible variety BARI Gom 26 demonstrated the highest disease severity (95%). Resistance will be confirmed under greenhouse conditions in the coming days and after confirmation to be used as source of resistance in the wheat breeding program.

4.1.3. Efficacy of foliar fungicides in controlling wheat blast

Wheat blast caused by the fungus Magnaporthe oryzae (MoT), establishes one of the major obstacles to the expansion of wheat production in Bangladesh. In absence of resistant variety, fungicide control is the first–hand effort. Therefore, the efficiency of ten (10) fungicides was tested for the control of wheat blast at Regional Station, BWMRI, Jashore during 2024–25 cropping season. The experiment was conducted under late sowing conditions. Our results demonstrated that eight chemical fungicides (Nativo 75 WG, Amister Top 325 SC, Tilt 250 EC, Bactrol Plus 80 WP, Isobin 25 WP, Shahzole 28 SC, Beena 28 SC and Sainik 75 WP) except the bio-fungicides (Bio Tilis 40 WP and Shornali 1.5 WP) can control the disease effectively (82–92%). The fungicide Nativo 75 WG was found the utmost effective in controlling wheat blast with least disease index (8%). Application of chemical fungicide can increase grain yield upto 46%.

Figure 4.2. Efficacy of fungicide in controlling wheat blast; (right) Nativo 75 WG sprayed plot and (left) unsprayed plot

4.1.4. Surveillance of rusts and blast diseases of wheat in Bangladesh

A total of 164 farmers' field and trial sites were surveyed during 2024–25 crop growing season in 49 districts across the country to know the current status of rusts and blast diseases in the cultivated wheat field. The survey was conducted following BGRI protocols developed for cereal rust assessment. Disease severity was estimated using 0–100 scale and the modified Cobb scale for blast and rust diseases, respectively. Our field visit demonstrated that around 52 fields (32%) out of the 164 had leaf rust with low to high level of infection. Among the infected fields, 79% showed low (<20%) level of severity, 6% moderate (20–40%) and 15% high (more than 40%). Regarding varietal response, the older varieties like BARI Gom 24 and BARI Gom 26 were found higher levels of incidence and severity with susceptible reaction but the latest varieties BWMRI Gom 3, BWMRI Gom 4 and BWMRI Gom 5 with low incidence or free from rust and the reaction was resistant. Yellow rust or stem rust infection was not noticed. While for wheat blast, twenty districts have been identified with wheat blast having low to high level of incidence and out of them, 7 were newly affected (Bandarban, Chandpur, Cumilla, Coxsbazar, Kishoreganj, Sherpur and Sylhet). Among the new affected districts, Bandarban, Coxsbazar and Sylhet are the non–traditional areas for wheat cultivation. Infected fields of southern and south–western districts were found with higher levels of blast infection in the late planted fields. However, overall blast incidence throughout the country was very low.

Figure 4.3. Survey and monitoring of wheat diseases in Bangladesh; (left) investigation of wheat blast and rust incidence in field and (right) Bangladesh map showing field surveillance areas with blast incidence

4.1.5. Determination of sporulation capacity of Magnaporthe oryzae (MoT) in different culture media and identifying virulent isolate

The experiment was conducted under laboratory and greenhouse conditions at BWMRI, Dinajpur during 2024–25 crop cycle. Our results demonstrated that the most suitable sporulating medium was Oat Meal Agar (OMA) followed by Wheat Leaf Agar (WLA). Among seventeen evaluated isolates, the isolates HAB240002, MEH240001, CHU240001 and GAZ240001 were found high sporulating as compared to others. Variations in morphological characters was observed among the isolates cultured on Potato Dextrose Agar (PDA) medium. The front colony for most of the isolates was black to gray or brown to gray colored, but for some of them had different color.

The colony surface of different isolates varied from smooth flattened and fluffy mycelia, and some were with the presence of concentric rings. On the other hand, the present investigation revealed that the isolates with high virulence was prevalent in the studied M. oryzae populations. The isolates HAB240001, HAB240002, CHU240001 and FAR240002 were identified more virulent as compared to others.

4.1.6. Development of differential lines against wheat blast

Wheat blast (WB) caused by Magnaporthe oryzae pathotype Triticum (MoT) is an important fungal disease in tropical and subtropical wheat production regions. Genetic resistance is only the durable way to get crop free from disease. So far, 2NS is the only the stable source for blast resistance. From our study, 14 genotypes have been identified with high level of resistance under greenhouse conditions. Molecular analysis will be performed for the presence of new genes or stable resistance sources to the coming year.

4.1.7. Evaluation of wheat germplasm against Bipolaris leaf blight under field conditions

Bipolaris leaf blight (BpLB) caused by Bipolaris sorokiniana, is a growing concern for wheat production due to changes in cropping systems, particularly in regions with high temperatures and high humidity. In this study, we have evaluated around 50 wheat genotypes under field conditions across three locations (Dinajpur, Jamalpur and Jashore) during 2024–25 crop cycle to identify lines with resistance to BpLB. Disease severity was assessed using the area under the disease progress curve (AUDPC), alongside agronomic traits such as plant height, 1000–grain weight, and grain yield. According to field experimentation, ten (10) lines were selected based on their superior performance. Notably, Entry 1 exhibited the highest yield (516g/m²) and the lowest AUDPC (91), demonstrating its strong resistance and high productivity. These findings underscore the potential of these 10 lines as promising candidates for breeding programs aimed at improving disease resistance and yield stability in wheat.

4.1.8. Evaluation of wheat genotypes for resistance to Bipolaris leaf blight under inoculated field conditions

An effort was made to evaluate the reactions of 56 wheat genotypes including advanced lines and check varieties against Bipolaris leaf blight under inoculated field conditions during 2024–25 crop season at BWMRI, Dinajpur. The evaluated lines/varieties showed different levels of resistance against the disease and were graded into different resistance categories.


Figure 4.4. Bipolaris leaf blight resistance in wheat genotypes under inoculated conditions; (left) Bipolaris spore inoculation in screened materials and (right) disease reaction in the advanced genotypes

Among them, one genotype was found resistant, two moderately resistant, 11 moderately susceptible, 39 susceptible and 3 as highly susceptible. These resistant lines will be used in the breeding program for developing disease resistant wheat variety.

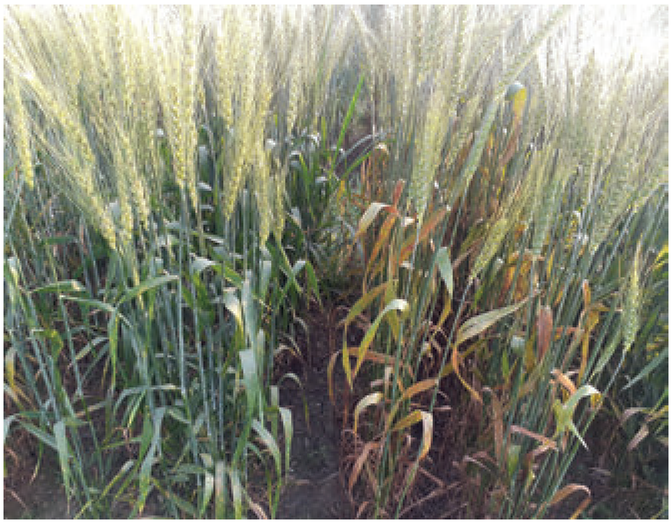


Figure 4.5. Leaf rust resistance in susceptible (right) and resistant (left) cultivars

4.1.9. Evaluation of wheat genotypes for resistance to leaf rust under inoculated field conditions

Eighty (80) wheat genotypes were screened against leaf rust to find out resistance sources under inoculated field conditions conducted during 2024–25 cropping season at BWMRI, Dinajpur. Disease assessment was made following modified Cobb scale. From the study, 72 lines/varieties were found resistant to the disease and among them, 13 lines were completely free from leaf rust infection. Our latest varieties BARI Gom 33, BWMRI Gom 2, BWMRI Gom 3, BWMRI Gom 4 and BWMRI Gom 5 were showed resistant reaction with low severity (<10%) while >70% severity was observed in susceptible cultivars Morocco and Prodip.

4.1.10. Efficacy of fungicides in controlling Bipolaris leaf blight of wheat

Bipolaris leaf blight (BpLB) caused by Bipolaris sorokiniana, a major wheat disease in Bangladesh that can reduce grain yield by up to 50% under certain conditions. In this study, 10 fungicides including standard checks were tested for their efficacy in controlling BpLB under field conditions at Bangladesh Wheat and Maize Research Institute, Dinajpur during 2024–25 cropping cycle. The evaluated fungicides were Nativo 75 WG, Amister Top 325 SC, Tilt 250 EC, Isobin 25 WP, Sainik 75 WP, Shahzole 28 SC, Beena 28 SC, Bactrol Plus 80 WP, Bio Tillis 40 WP and Shornali 1.5 WP. Results showed that all fungicides significantly controlled the disease (>70%) except Sainik 75 WP and Bactrol Plus 80 WP. New fungicides Shahzole 28 SC and Beena 28 SC demonstrated the highest yield increase (17–18%) over control treatment. Further evaluation of the new fungicides is needed before going to recommendation for the farmers.

4.1.11. Efficacy of fungicides in controlling leaf rust of wheat

Leaf rust caused by Puccinia triticina, is a major threat to wheat production worldwide, often resulting in significant yield losses. Considering this issue, a study was undertaken to test the efficacy of ten fungicides including standard checks in controlling leaf rust of wheat under field conditions at Bangladesh Wheat and Maize Research Institute, Dinajpur during 2024–25 crop cycle. The evaluated fungicides were Nativo 75 WG, Amister Top 325 SC, Tilt 250 EC, Isobin 25 WP, Sainik 75 WP, Shahzole 28 SC, Beena 28 SC, Bactrol Plus 80 WP, Bio Tillis 40 WP and Shornali 1.5 WP. Our field results demonstrated that three new fungicides Shahzole 28 SC, Shornali 1.5 WP and Beena 28 SC including checks Amistar Top 325 SC, Nativo 75 WG and Tilt 250 EC can control the disease close to 100% with significantly increase in grain yield (up to 29%) over control treatment.

This finding indicate that timely application of effective fungicides can substantially reduce leaf rust severity and improve wheat productivity.

4.1.12. Helminthosporium leaf blight screening nursery

A field experiment was conducted to screen 52 bread wheat lines including checks against Helminthosporium leaf disease under natural field conditions of disease development in three different locations (Dinajpur, Jamalpur and Jashore) of Bangladesh during 2024–25 cropping cycle. Among the entries evaluated, eight lines were selected based on AUDPC (BpLB), disease index (Blast), 1000–grain weight, grain yield and other agronomic characters assessed over locations. The AUDPC of the selected lines ranged from 176 to 326, while those of the check varieties 238 and 338. Grain yields of the selected entries varied from 308 to 584 g/plot, whereas 247 and 408 g/plot were obtained from the checks. Blast severity of the selected entries recorded at Jashore varied from 0 to 1.0%. Days to heading, plant height and 1000–grain weight of the selected lines were within the acceptable range.

4.1.13. Stem rust resistance screening nursery

A nursery from CIMMYT–Mexico having 103 wheat entries including local checks were evaluated for their response to stem rust under field conditions in three different locations (Dinajpur, Jamalpur and Jashore) of Bangladesh during 2024–25 cropping cycle. Among the entries evaluated, seven lines were selected based on Bipolaris leaf blight severity, blast disease index, grain yield and other agronomic traits assessed over locations. Stem rust was not noticed over the locations. The area under disease progress curve (AUDPC–BpLB) of the selected lines ranged from 162 to 239 while the check varieties showed 127 to 245. Grain yields of the selected entries varied from 461 to 561 g/plot, whereas 347 to 564 g/plot found in check varieties. Blast severity of the selected entries recorded at Jashore varied from 0 to 0.2%. Days to heading, plant height and 1000–grain weight of the selected lines were within the acceptable range.

4.1.14. Fusarium head blight screening nursery

A nursery from CIMMYT–Mexico with 52 wheat entries including local checks was evaluated for their response to Fusarium Head Blight (FHB) under natural conditions during 2024–25 cropping season in two locations– Dinajpur and Jashore. Among the entries evaluated, five lines were selected based on area under disease progress curve (AUDPC) of Bipolaris leaf blight, 1000–grain weight, grain yield and other agronomic characters. The incidence of FHB was not observed in the screened materials over locations. The AUDPC of the selected lines ranged from 193 to 317 while the check varieties 316 and 340. Grain yield of the selected entries varied from 516 to 621 g/plot whereas 359 and 552 g/plot were obtained from the checks. Days to heading, plant height and 1000–grain weight of the selected lines were within the acceptable range.

4.1.15. Determining status of seed–borne fungi including Magnaporthe oryzae causing wheat blast

An effort was made to determine the incidence of Magnaporthe oryzae and other seed–borne fungi associated with wheat seeds of eight varieties collected from five different locations of Bangladesh. The name of the varieties is BARI Gom 26, BARI Gom 32, BARI Gom 33, BWMRI Gom 1, BWMRI Gom 2, BWMRI Gom 3, BWMRI Gom 4 and BWMRI Gom 5 while the locations are Dinajpur, Jamalpur, Rajshahi, Gazipur and Jashore. Pathogen identification was done at BWMRI Plant Pathology Laboratory during June to

August 2025. Results showed that seed–borne prevalence of Magnaporthe oryzae and other fungi varied over locations, varieties, and sowing time. A total of 17 fungi were identified from the seed samples of different locations. Seed–borne incidence of blast pathogen was recorded only in Jashore location seeds. The overall incidence of M. oryzae was estimated very low (0.4%). The highest incidence of M. oryzae was observed in the seeds of BARI Gom 26 and the lowest in BARI Gom 32 and BWMRI Gom 1 (0.2%). The latest blast resistant wheat varieties BWMRI Gom 3 and BWMRI Gom 5 seeds were free from M. oryzae incidence. Other major seed–borne pathogens like Bipolaris sorokiniana was found higher in the BWMRI Gom 3 seeds, reaching around 20.1% while Curvularia spp. of about 12.9% in BWMRI Gom 1. Considering location, the overall maximum incidence of B. sorokiniana were observed in Jamalpur followed by Dinajpur but incidence of Curvularia spp. was found higher in Gazipur followed by Jashore. Incidence of different pathogens always higher in late planted wheat seeds compared to optimum.

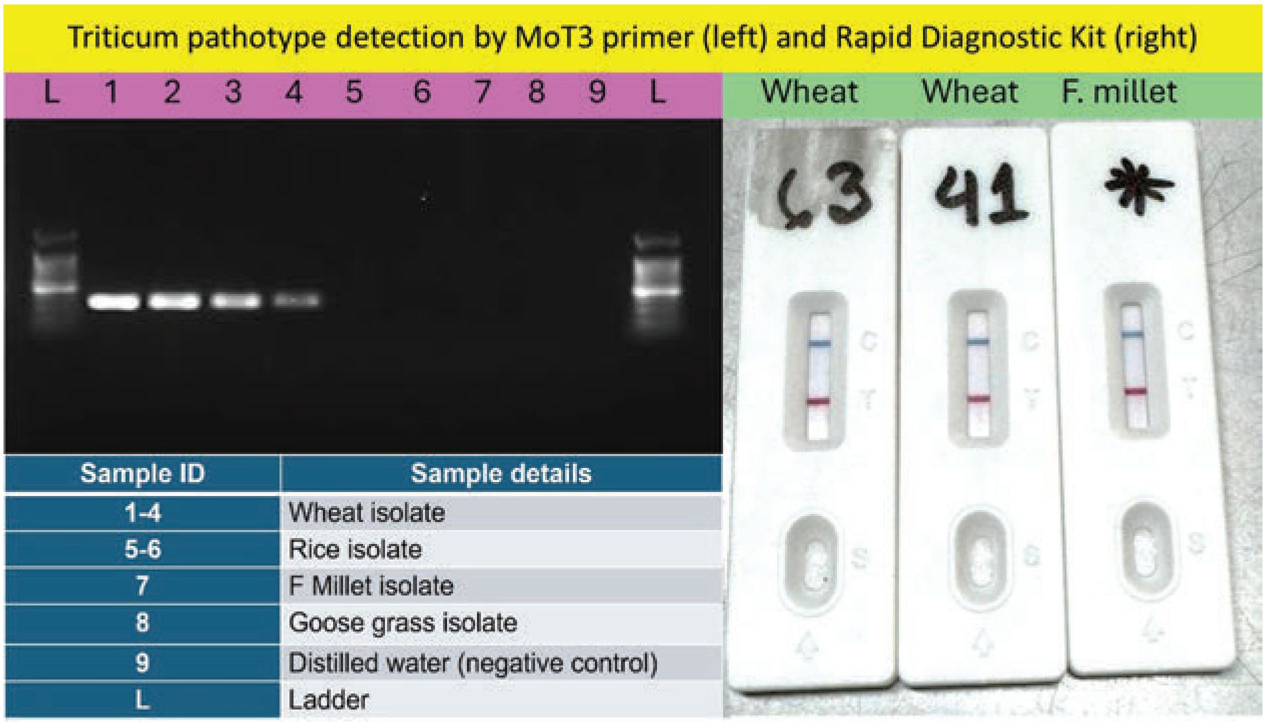
4.1.16. Wheat Blast: Precision Phenotyping Platform

Four thousand six hundred sixty–three (4663) wheat genotypes (bread wheat, synthetics, winter wheat, wild relatives, land races) along with susceptible/resistant checks were evaluated against wheat blast under inoculated field conditions at Regional Station, Jashore during 2024–25 crop growing season. The main aim of the study was to identify resistance sources for developing blast resistant wheat variety. The materials were planted under lates seeding conditions, 1st and 3rd week of December 24. Favorable conditions for disease development were created by providing mist irrigation and hand inoculation of *Magnaporthe* spores to the materials at anthesis. Disease note was taken on percentage of spike infected and percentage of diseased area on infected spike. As per the results obtained, varying levels of disease severity was recorded among the lines evaluated. Out of 4663 screened genotypes, 1076 (23.06%) lines were graded as resistant and 714 (15.31%) lines moderately resistant. Among 1076 resistant lines, 311 (6.66%) entries were found completely free from blast infection. These resistant lines will be used in the crossing block for making durable resistance in the advance genotypes or cultivars. The resistant variety BARI Gom 33 demonstrated resistant reaction (<7% disease index) to the disease while the susceptible variety BARI Gom 26 >80% infection.

Figure 4.6. Germplasm screening against wheat blast at PPP Jashore under inoculated conditions; (left) misting of germplasm at precision phenotyping platform and (right) response of elite lines to the disease

4.1.17. Molecular detection of wheat blast pathogen Magnaporthe oryzae pathotype Triticum (MoT) using MoT3 assay and Rapid Diagnostic Kit

Wheat blast is a devastating disease persistent in South America, South Asia and Africa, and now becoming a global concern. *Magnaporthe oryzae* is a fungal plant pathogen causing blast disease in several species of the Poaceae family. It includes several genetic lineages, including one that is pathogenic on wheat and belongs to the *Triticum* lineage of *M. oryzae*. Confirmation of plant pathogen can be done by various way and among them, molecular testing is one of the best. During July to August 2025, a total of 28 isolates were successfully amplified by the MoT3 markers confirming as *Triticum* pathotype of wheat blast. Beside this, pathotype of the wheat blast fungus was also confirmed using Rapid Diagnostic Kit.



Sample ID	Sample details
1-4	Wheat isolate
5-6	Rice isolate
7	F Millet isolate
8	Goose grass isolate
9	Distilled water (negative control)
L	Ladder

Figure 4.7. Detection of *Triticum* pathotype of *Magnaporthe oryzae* using MoT3 primer (left) and Rapid Diagnostic Kit (right)

4.1.18. In vitro inhibitory effect of fungicides and bio–agents on morpho–physiological characters of Fusarium species, the cause of Fusarium stalk rot of maize

Fusarium stalk rot is a significant disease in maize caused by various Fusarium species, leading to yield losses worldwide. In absence of resistant cultivars, the disease needs to be controlled by chemical fungicide. For this reason, four chemical fungicides viz. Indofil M–45, Autostin 50 WDG, Tilt 250 EC and Amistar Top 325 SC at four different level of concentrations i.e. 50, 100, 150 and 200 ppm, and one bio–control agent viz. Trichoderma spp. were tested in–vitro against the pathogen Fusarium spp. under laboratory conditions at BWMRI, Dinajpur. All the chemical fungicides except Indofil M–45 effectively inhibited the mycelial growth (92–96%) of Fusarium at all concentrations. The biocontrol agent also performed better which inhibited the mycelial growth by 91%.

4.1.19. Isolation and identification of the causal agent of Bacterial stalk rot of maize

Bacterial stalk rot of maize caused by Dickeya zeae, is a highly destructive disease that significantly affects maize yield, particularly in regions with warm and humid climate. The disease manifests as soft rot, primarily targeting the stalks and leading to plant decay and lodging. In this study, we aimed to isolate and identify the causal agent of bacterial stalk rot from infected maize samples. The serial dilution method followed by plating on nutrient agar was employed to obtain bacterial colonies, which were further characterized using the morphological characteristics of the bacterial colony. Two bacterial isolates resembling Dickeya zeae were obtained and preserved for additional biochemical and molecular identification. This experiment lays the foundation for future research on bacterial characterization and disease management strategies.

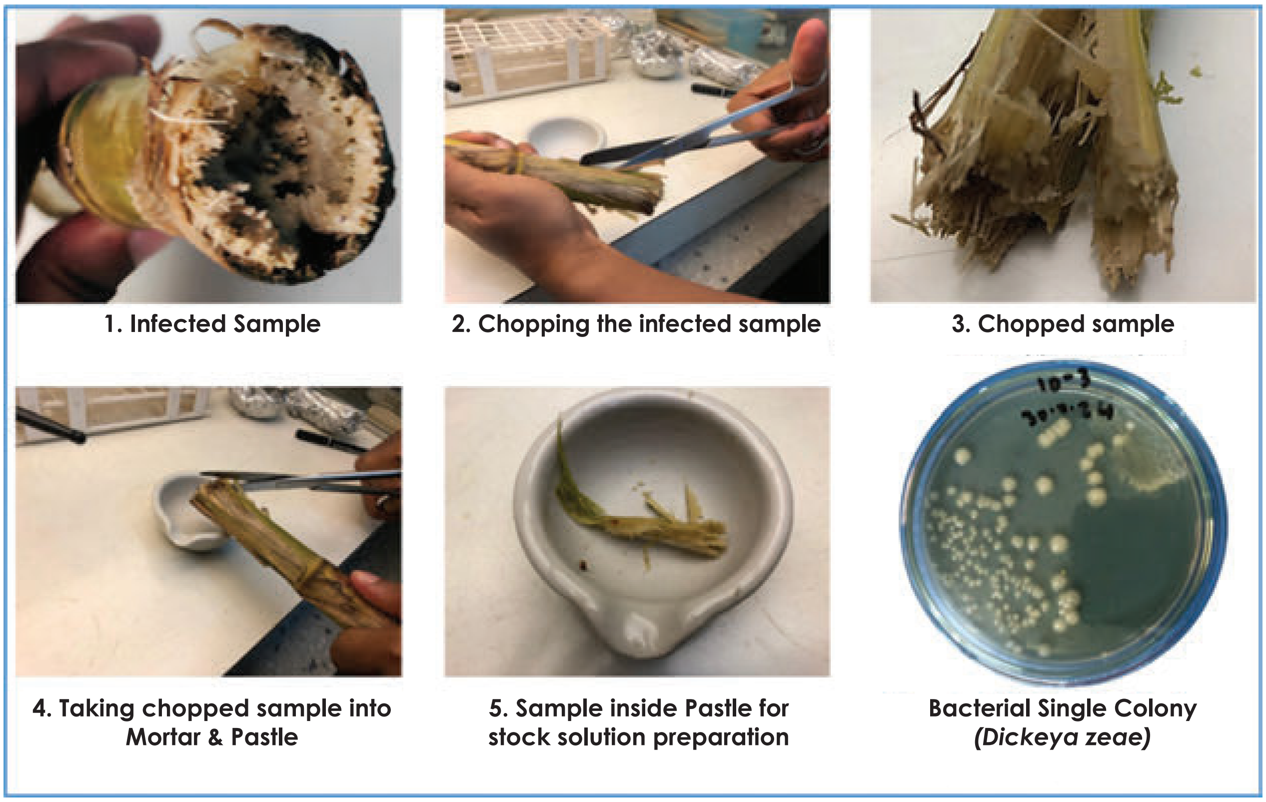


Figure 4.8. Sample preparation and isolation procedure of Dickeya zeae from the infected maize samples

4.1.20. Surveillance and monitoring of maize diseases in Bangladesh

Surveillance of maize diseases involves monitoring, identifying, and tracking the occurrence and spread of diseases affecting maize crops. This is crucial for effective disease management, helping to prevent yield losses and maintain food security. During 2024–25, around 50 maize fields and trial sites from 10 districts throughout the country were surveyed in Rabi and Kharif seasons. A total of eight diseases has been recorded in different maize fields. Among the diseases, leaf blight was found most common in 47 fields (94.0%) with low to medium severity. Leaf rust and sheath blight were observed in 16 fields (32.0%) and 31 fields (62.0%), respectively with varying level of severity. The emerging disease, Fusarium stalk rot (FSR) was recorded in 20 fields (40.0%) mostly with low level of incidence (<1%).

The disease leaf blight had common occurrence irrespective of growing seasons while leaf rust and Fusarium stalk rot were mostly found in Rabi season at the reproductive stage of the crop. Samples of FSR were collected from infected fields for isolation and further investigation.

Figure 4.9. Survey and monitoring of maize diseases in farmer's field; (left) investigation of maize diseases and (right) dried–up maize stalks affected by the pathogen Fusarium spp.

4.1.21. Efficacy of fungicides in controlling leaf blight of maize

Leaf blight of maize is an important disease affecting maize crop in Bangladesh. This disease causes considerable losses in maize crop every year. To avoid this loss, a study was conducted to check the efficacy of seven fungicides against leaf blight disease of maize. The experiment was conducted in the field of Plant Pathology Division, Dinajpur during Kharif 2025 season. The tested fungicides were Amistar Top 325 SC, Tilt 250 EC, Nativo 75 WG, Compline 75 WP, Maya Pyrox 35 SC, Aztech 28 SC and Piper 28 SC. The result showed that Amistar Top 325 SC (75.6%) was the most effective fungicide to control leaf blight of maize followed by Compline 75 WP (73.3%), Tilt 250 EC (71.1%) and Nativo 75 WG (71.1%). Further evaluation is needed to confirm their efficacy in the coming season.

4.1.22. Evaluation of maize genotypes against Fusarium stalk rot under field conditions

This study was undertaken to evaluate the resistance of 15 maize genotypes—including BWMRI and BARI hybrids, commercial varieties, and imported lines—under field conditions at BWMRI, Dinajpur during the Rabi season 2024–25. The experiment was conducted in a randomized complete block design (RCBD) with two replications. Disease incidence was recorded, and genotypes were categorized based on resistance levels. Results revealed that all the screened genotypes fell within the resistant category (0–10% incidence), where PAC 164, BARI Hybrid Maize 14, and Nayak showing complete resistance (0% incidence). Other genotypes such as BARI Hybrid Maize 13, BARI Hybrid Maize 17, Gourob 99, and KB 39 exhibited very low disease incidence (1%), reinforcing their suitability for resistance breeding. These findings underscore the availability of strong genetic resources for FSR resistance and highlight several genotypes as promising candidates for future breeding programs. Further screening under artificial inoculation is recommended to validate field–level resistance and assess stability across environments.

4.1.23. Evaluation of maize genotypes against Bacterial stalk rot under field conditions

Bacterial stalk rot (BSR) caused by Dickeya zeae, severely affects maize crop in humid and warm regions, leading to yield loss and poor grain quality. Chemical control is ineffective, making resistance breeding the preferred strategy. This study screened 15 maize genotypes at BWMRI, Dinajpur during the 2024–25 Rabi season. Six genotypes showed strong resistance (0–3% DI), while six others had slightly higher but acceptable incidence (4–6%). These resistant genotypes need to require further evaluation. The results support the use of resistant genotypes in breeding programs to improve BSR tolerance.

4.1.24. Efficacy of fungicides in controlling leaf rust of maize

Common leaf rust caused by Puccinia sorghi, is prevalent disease in most of the maize field of Bangladesh. Six fungicides viz., Amistar Top 325 SC, Tilt 250 EC, Nativo 75 WG, Compline 75 WP, Maya Pyrox 35 SC, Aztech 28 SC and Piper 28 SC along with checks were evaluated during Kharif 2025 at BWMRI Dinajpur field against leaf rust of maize. Our results demonstrated that all the evaluated fungicides were found effective for controlling the disease. Among the fungicides, Piper 28 SC (94.9%) was the most effective followed by Amistar Top 325 SC (92.0%) and Aztech 28 SC (87.4%).

Figure 4.10. Efficacy of fungicide in controlling leaf rust of maize;
(left) unsprayed plot and (right) Piper 28 SC sprayed plot

4.1.25. Efficacy of seed treating fungicides in reducing prevalence of seed–borne pathogens and control of seedling diseases of wheat and maize

Eight seed treating fungicides (four chemical and four biocontrol) viz. Provax 200 WP, Thiraxin 75 WP, Agrovac 750 DS, Maya Carbo 75 WP, Tricost 1% WP, Trichomax, Lykomax and Dynamic for wheat and five seed treating fungicides (three chemical and two biocontrol) viz. Provax 200WP, Figure seed care 35 FS, Advance 62.5 FS, Trichomax and Lykomax for maize were evaluated to test their efficacy in controlling seed–borne pathogens as well as seedling diseases under laboratory and field conditions, respectively. In both cases, Provax 200 WP was used as standard check. The experiment was laid out in the laboratory of Plant Pathology Division and field of BWMRI Dinajpur during 2024–25. Both for wheat and maize seeds, all the chemical fungicides can eradicate fungal incidence (100%), while biocontrol agents could not control in laboratory conditions. Seedling diseases was not observed in the field for both crops. In case of wheat field, all the fungicides except Trichomax and Dynamic significantly increased the plant populations. While for maize, all the fungicides except Lykomax significantly increased germination percentages in field. There were not significant variations in other traits like seedling height, average fresh and dry weight with application of the fungicides.

4.2. Insect management

This project focuses on developing eco–friendly and effective strategies for managing insect pests of maize and wheat crops in Bangladesh. The research addresses critical challenges posed by various insect pest species that threaten food security and agricultural productivity by reducing both yield and quality. Our activities include extensive field surveys to identify major insect pests and their natural enemies using both morphological and molecular identification techniques. Based on these findings, integrated pest management (IPM) approaches are being developed and disseminated to farmers. These strategies combine biological control agents, cultural and agronomic practices, and the judicious use of new molecules, less–toxic insecticides to suppress pest populations while ensuring environmental sustainability. Field trials are conducted to evaluate the effectiveness of different management practices, including pheromone traps, biopesticides, cultural and agronomic interventions, and optimized spray schedules of safer insecticides. The project also prioritizes farmer participation and capacity–building by raising awareness of pest dynamics and promoting the adoption of sustainable IPM practices. By strengthening the resilience of maize and wheat production systems against insect pests, this research aims to enhance crop yields, reduce economic losses, and contribute to environmentally sound and sustainable agricultural development in Bangladesh.

4.2.1. Insect diversity and population dynamics in Rabi maize fields under a pesticide–free ecosystem

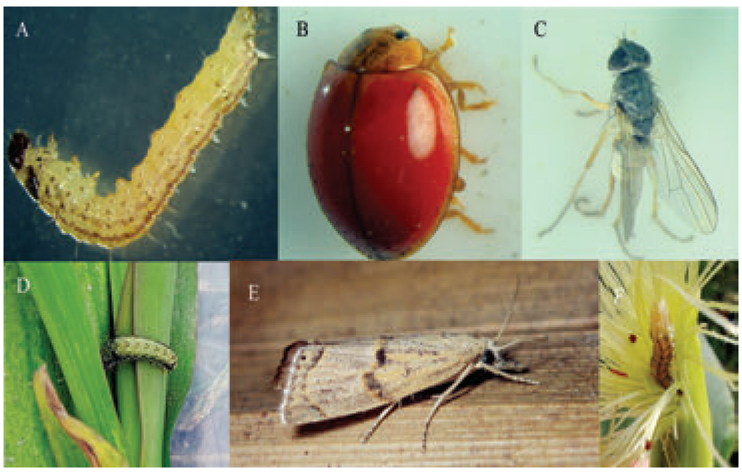


Figure 4.11. Major insects and other arthropods were identified in the maize field under a pesticide–free ecosystem (A) *C. auricilius* (B) *Coleoptera* (C) *Diptera* (D) *S. litura,* (E) *Moth M. separata* (F) *H. zea*

This study aims to determine the insect diversity and insect population dynamics associated with maize fields under a pesticide–free ecosystem. The study was conducted at the Entomology Research Field of BWMRI, Dinajpur, during the Rabi season of 2024-25. The study field was divided into 18 equal plots, and insect data were recorded through direct eye observation from emergence (VE) to silking (R1) and sticky trap sampling from four leaf (V4) to tasselling (VT) plant growth stages. A total of seven types of major pests were identified from field observations, including *Mythimna separata, Chilo auricilius,* grasshoppers, *Spodoptera frugiperda, Sesamia inferens,* Spodoptera litura, and Aphids. Population trends varied significantly across growth stages, with *M. separata, C. auricilius,* and grasshoppers dominating the early vegetative phase, S. frugiperda prevailing during mid to late vegetative stages, and aphids peaking at tasseling and reproductive stages. Statistical analysis through ANOVA and Tukey's HSD test confirmed significant stage–wise variation in pest abundance ($P < 0.001$). Sticky trap sampling recorded 977 arthropod individuals and 655 insect individuals of 28 different species, belonging to three orders: Coleoptera, Diptera, and Hymenoptera, where Diptera and Hymenoptera were the dominant groups. Diversity analysis indicated a Shannon–Wiener index (H') of 2.02, Simpson index (D) of 0.79, showing moderate dominance, and Margalef's richness index (R) of 4.32, reflecting a moderately diverse insect community. Species–level identification is ongoing; unidentified species were coded & stored for morpho–molecular study. Overall, the findings highlight that maize fields supported a dynamic assemblage of pests and non–pest insects, underscoring the need for stage-specific pest management while acknowledging the unexplored biodiversity that may be beneficial or contribute to ecosystem services and sustainable production.

4.2.2. Insect diversity and population dynamics in wheat fields under different sowing times

The study investigated the population dynamics and diversity of insect communities in wheat across three sowing times (optimum, late, and very late) at the Entomology Research Field of BWMRI, Dinajpur, during the Rabi 2024–25 season. A total of 12 equal plots (4 × 4 m) in each sowing were monitored through visual observations from tillering to hard dough stages, along with sticky traps installed at tillering, stem elongation/heading, and soft dough stages. Visually, 10 different insect pests were observed, in which aphid was the dominant one, particularly during the reproductive stage, while natural enemies such as syrphid flies, lady beetles, and rove beetles appeared earlier and increased with pest outbreaks, indicating a strong predator–prey relationship. Importance Value Index (IVI) confirmed aphid as most important in optimum (66.9) and late sowings (68.9), whereas predators (Syrphid 44.2, Lady beetle 12.7) and termites (28.1) gained higher importance in very late sowing. Sticky trap captures were dominated by Hymenoptera and Diptera, with a sharp emergence of Thysanoptera under the later reproductive stage. Diversity indices showed that late sowing supported the highest richness and evenness (Shannon = 2.19, Simpson = 0.99, Margalef's = 4.33), compared to moderate diversity in optimum sowing and lower balance in very late sowing. Overall, the results indicate that sowing time strongly influences insect incidence and diversity, with late sowing favoring greater ecological balance, while optimum sowing enhances pest buildup. The findings highlight the importance of beneficial insects in maintaining ecological balance within wheat production systems.

Figure 4.12. Research field view and major insects identified in the wheat field (A) *Termites* (B) *Aphids* (C) *Research field view* (D) *M. separata*

4.2.3. Assessment of stemborer dynamics and their bio–rational management strategies in maize

This study evaluated the efficacy of different bio–rational options to control stem borer in maize in the Rabi season and their effects on yield attributes. The hybrid maize variety BWMRI Hybrid Bhutta–2 was cultivated under a Randomized Complete Block Design with five treatments and four replications. Treatments included seed treatment with Cyantraniliprole, foliar applications of *Bacillus thuringiensis, Celastrus angulatus,* and *Metarhizium anisopliae,* as well as a combination of effective chemical insecticides (Chlorantraniliprole and Spinosad), alongside an untreated control. Infestation data were recorded from emergence (VE) to the five–leaf (V5) growth stage, while yield attributes were measured at maturity. Plant damage peaked during the early stages (V1 and V2) and declined significantly at later stages (V4 and V5), coinciding with a reduction in stem borer activity. Regression analysis revealed a statistically significant ($P < 0.05$) but weak relationship (low R^2) between temperature and percentage plant damage, suggesting that temperature influenced infestation patterns in a non-linear manner. Biopesticide–based treatments performed comparably to chemical controls in reducing damage and sustaining yield, particularly during periods of naturally low pest pressure. These findings highlight the potential of biopesticides as effective components of sustainable stemborer management in maize and the population dynamics of stemborer in maize. Further multi–location studies are required to validate the potential of biopesticides and better understand the population dynamics of stemborers in maize.

Figure 4.13. Stemborer-infested maize plants (A) Stemborer infestation at VE stage (B) Stemborer infestation at V2 stage

4.2.4. Field evaluation of conventional and IPM-compatible strategies against stem borer in maize

A field trial was conducted in a farmer's maize field during the 2024–2025 Rabi season to evaluate Integrated Pest Management (IPM) compatible strategies for controlling Stem borer (mainly *Chilo auricilius*), an insect pest, that infests maize seedlings. The experiment compared three management packages: (P1) conventional practice (farmer's practice– usually cypermethrin, chlorpyrifos application), (P2) seed treatment with cyantraniliprole followed by biopesticide applications (*Bacillus thuringiensis* and *Celastrus angulatus* extract), and (P3) basal application of chlorantraniliprole combined with the foliar spray with less toxic insecticide 'Spinosad'. Results indicated that both P2 and P3 significantly reduced early plant damage at the V_1 stage compared to P1 and improved plant stand, cob number, and yield. Cob damage remained minimal across treatments, reflecting the pest's biology, as C. auricilius does not attack mature maize plants or cobs. The findings suggest that replacing conventional broad–spectrum insecticides with IPM–compatible options can provide effective early–stage stemborer suppression and support sustainable maize production.

4.2.5. Genetic diversity and morpho–molecular identification of aphids attacked in wheat crops in Bangladesh

Wheat aphids are significant pests that cause substantial yield losses and economic damage in wheat crops worldwide. Infestation of aphids in Bangladesh wheat crops also impacts farmers substantially. Accurate identification of aphid species is essential for effective pest management strategies. This study integrates molecular and

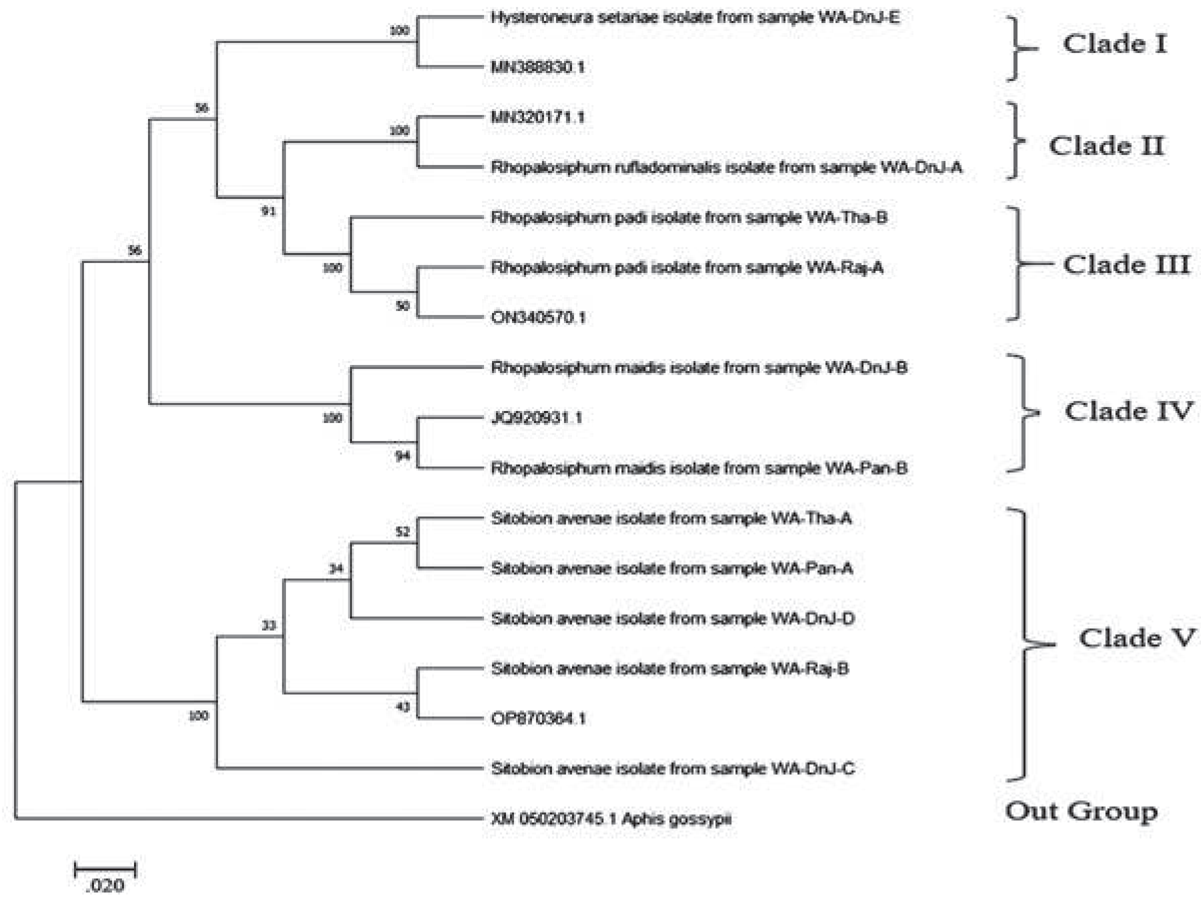


Figure 4.14. Maximum Likelihood (ML) tree based on partial COI sequences of Aphids from selected wheat growing districts in Bangladesh.

morphological techniques to identify and characterize wheat aphid species collected from various distinct wheat–growing regions. Morphological identification was conducted using taxonomic keys based on physical characteristics such as body size, color, cornicle shape, cauda size, siphunculi, and antenna length, leading to the characterization of five aphid species: *Rhopalosiphum maidis, Rhopalosiphum rufiabdominalis, Rhopalosiphum padi, Sitobion avenae* and *Hysteroneura setariae*. Molecular identification involved DNA barcoding of the mitochondrial cytochrome oxidase subunit I (COI) gene to confirm species delineation and resolve ambiguities in morphological classification. The results demonstrate the advantages of integrating both approaches, with molecular methods providing high–resolution species discrimination where morphological traits overlap or vary. Genomic DNA was extracted, and PCR amplification of the COI gene was successfully performed, followed by agarose gel electrophoresis confirmation and sequencing.

A BLAST search of the obtained sequences identified eleven samples as the aforementioned species, demonstrating the utility of genetic analysis in distinguishing morphologically similar aphids. A comparative study of mitochondrial gene sequences revealed significant diversity among wheat aphids when compared with existing sequences in gene banks. We constructed a phylogenetic tree that grouped the aphid samples into five distinct clades, highlighting genetic variation. These findings enhance our understanding of aphid genetic diversity in wheat, thereby enriching the scientific knowledge base and facilitating future research.

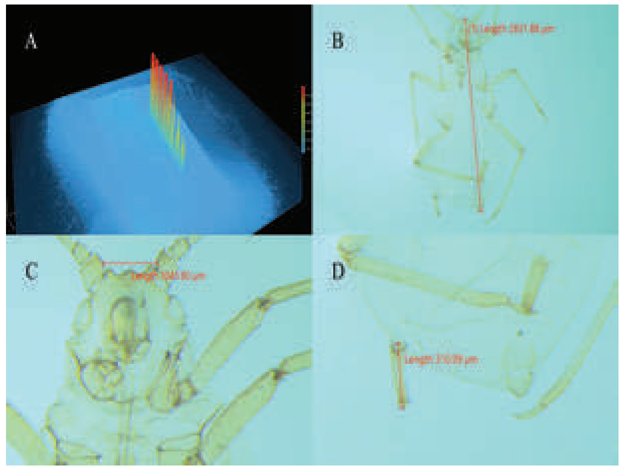


Figure 4.15. Some morphological identifying characteristics of aphids (A) Gel electrophoresis 3D view (B) Body length (C) Width between two antennae (D) Cornicle length

4.2.6. Assessment of stemborer incidence and genetic diversity in maize in Bangladesh during the Rabi season 2024–25

A field surveillance was conducted during the Rabi season of 2024–25 to assess the incidence of maize stemborer across major maize–growing regions of Bangladesh. The survey covered 26 upazilas in nine districts, where two to three villages per upazila and multiple fields per village were surveyed. Stemborer infestation was recorded at different maize growth stages, ranging from VE to V6. Results showed that infestation varied significantly across districts ($P < 0.0001$), with the highest incidence in Thakurgaon (9.59%) and Dinajpur (7.69%), while the lowest was recorded in Jashore (1.88%) and Chuadanga (1.84%). Growth stage analysis indicated that maize was most vulnerable at the early vegetative stages (VE–V3), with mean infestation levels exceeding the economic threshold (≥3%). Infestation declined sharply after V4, and no damage was observed at V5–V6. Through molecular identification, *Sesamia inferens* and *Chilo auricilius* were identified from 9 districts of major maize–growing regions. Both species were identified from six districts, where a single species was observed in Chuadanga, Jashore, and Jhenaidah. The phylogenetic analysis confirms the accurate identification of two major maize stem borer pests in Bangladesh: *Sesamia inferens* and *Chilo auricilius.* Both species show close genetic relatedness to populations from neighbouring countries (Thailand, Indonesia), suggesting regional connectivity or shared ancestry. Within–species variation exists, but no strong geographic structuring is evident, indicating gene flow across populations. This molecular confirmation supports morphological identification and provides a reliable basis for developing species–specific pest management strategies.

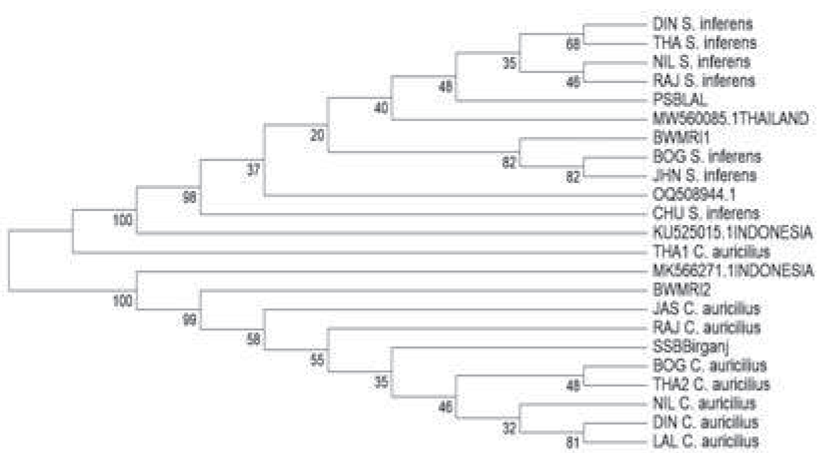


Figure 4.16. Maximum Likelihood (ML) tree based on partial COI sequences of Stemborers from selected maize growing districts in Bangladesh.

5. Biotechnology

Molecular characterization of parents and hybrids of BWMRI released maize varieties

The objective of this study was to identify informative SSR markers for distinguishing released maize varieties and their parental lines, assess genetic diversity for intellectual property characterization, and estimate genetic relatedness among the genotypes.

DNA fingerprinting was generated using 13 SSR markers on 29 maize genotypes including BWMRI release varieties and hybrids. A total of 57 alleles were identified with an average of 9.25 alleles per locus. Locus Phi015 was the most informative among the 13, which distinguished seven loci. The SSR marker analysis (Umc1353, Umc1177, Umc1292, Umc1160, Phi015, Phi041, Phi002, Phi042, Spf01, Phi021, Spf03, Spf06 and Phi036) reveals highly informative polymorphic patterns that effectively distinguish between the tested varieties and provide unique molecular signatures for each genotype. The PIC values for 13 primers obtained in the present experiment varied from 0.080 for Phi042 to 0.789 for Phi015 with an average value of 0.567. The cumulative fingerprinting profile demonstrates that despite many genotypes sharing the common BIL-28 background, sufficient molecular diversity exists to unambiguously identify each variety, with certain genotypes like Titan-26 x BIL-114 and Pina-3 X BIL-28 showing distinct banding patterns that clearly differentiate them from their BIL-28 counterparts, providing robust molecular tools for variety identification, genetic purity assessment, and breeding program management. From the Principal Component Analysis (PCA) of these genotypes, by PC5, the cumulative variance reaches 52.1%, indicating that just over half of the genetic variability is captured by these five components. The comprehensive analysis revealed substantial genetic diversity among the tested genotypes, with unique polymorphic patterns generated across all primer combinations providing distinctive molecular fingerprints for each variety, thereby enabling accurate genotype identification and genetic purity assessment. The genetic diversity parameters and clustering relationships revealed through this study provide a robust foundation for optimizing crossing strategies, maximizing heterosis potential through inter-cluster hybridization, and maintaining genetic diversity within breeding populations.

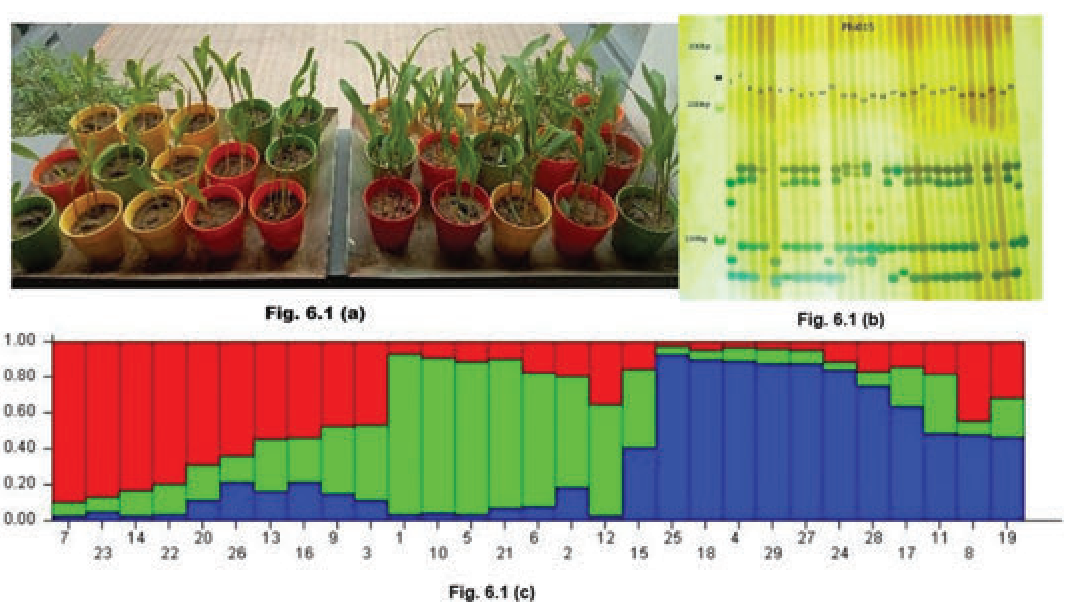


Figure 5.1: (a). Growing of Maize seedling for DNA extraction; (b) Gel picture of genotypes from Maize hybrids for the primer Phi015; (c) Population structure based on genotypic data.

6. Postharvest Technology and Nutrition

Analysis of gluten content in BWMRI wheat varieties: This study established the first baseline dataset on dry gluten content in 14 wheat varieties released by BWMRI, a critical determinant of processing quality and end–use suitability. The gluten content ranged widely from 2.01% in Triticale to 12.28% in BARI Gom 32. Six varieties were categorized as high–gluten types (>10%), making them suitable for bread–making. These findings provide essential information for breeders, farmers, and millers to match wheat varieties with appropriate end–use applications, such as bread, cakes, or biscuits.

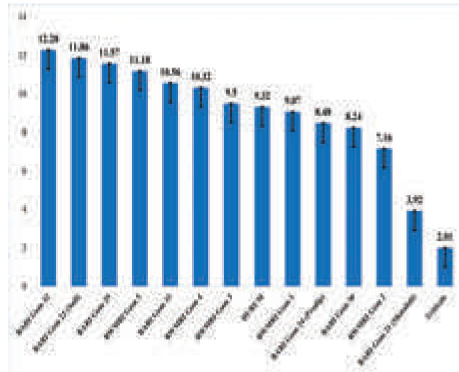


Figure 6.1. Dry gluten content (%) in BWMRI released wheat varieties

Optimization of maize–fortified pusti cake: The study evaluated wheat–maize composite flour cakes to enhance both nutritional and sensory qualities. Five flour substitution ratios were tested, ranging from 100% wheat to 100% maize. The formulation containing 60% wheat and 40% maize (Sample S2) was significantly preferred ($p<0.05$), receiving the highest sensory scores for texture (8.56), flavor (8.22), and overall acceptability (8.67).

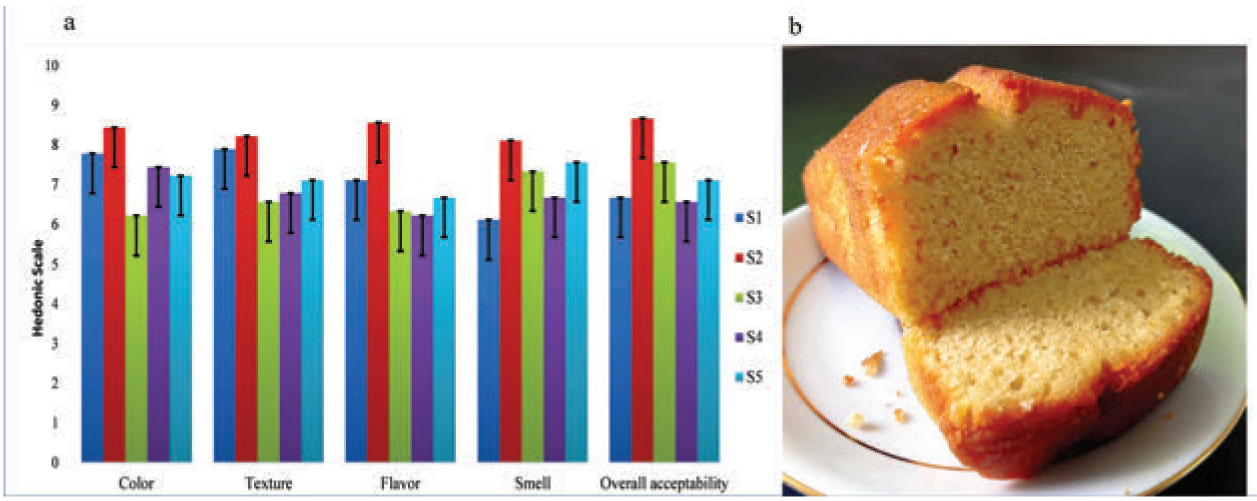


Figure 6.2. Consumer preference of pusti cake samples based on sensory parameters using the hedonic scale: (a) graphical representation of all five samples; (b) sample S2 (40% maize + 60% wheat flour) as the best-performing combination.

Incorporation of 40% maize optimizes consumer acceptability while improving the nutritional profile of bakery products, thereby encouraging the utilization of locally produced maize.

Valorization of agricultural waste: development of corncob jelly: This research explored the conversion of corncobs, an abundant agricultural by–product, into a value–added food product in the form of jelly. Five formulations with varying proportions of sugar, pectin, and corncob extract were tested. Sample S3 (800 g sugar + 13 corncobs + 20 g pectin + 8 g citric acid + 0.2 g KMS + 1100 ml corncob extract) was identified as optimal, achieving the highest scores across sensory attributes with an overall acceptability rating of 8.11. The results demonstrate that corncobs can be effectively valorized into palatable jelly, offering both waste reduction and economic opportunities.

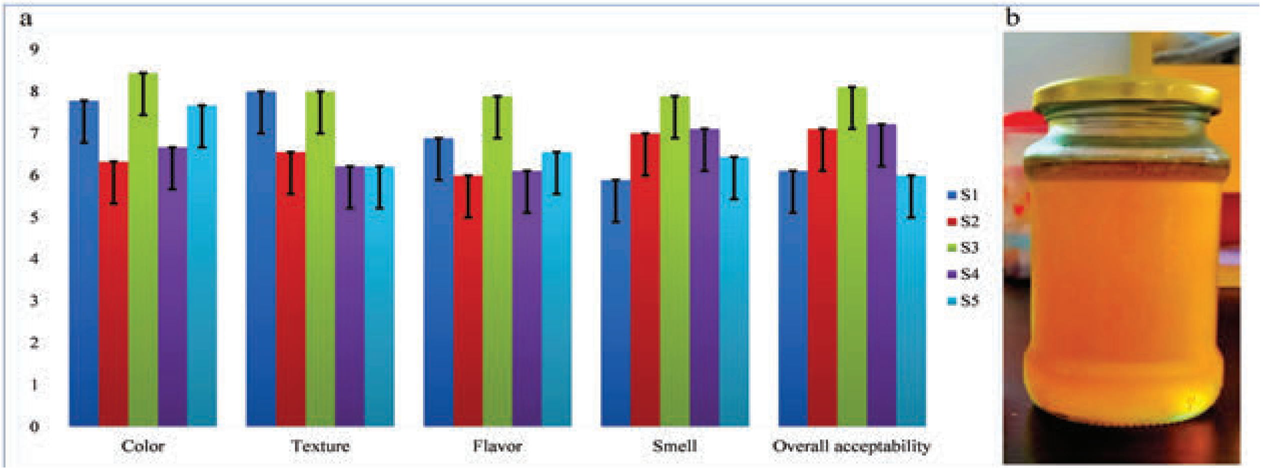


Figure 6.3. Consumer preference of corncob jelly samples based on sensory parameters using the hedonic scale: (a) graphical representation of all five samples; (b) sample S3 identified as the best-performing jelly.

Development of optimized deep–fried crispy corn: A novel deep–fried snack was developed from raw corn kernels using five maize cultivars. Sensory evaluation was conducted by a trained panel using a 9–point hedonic scale. Sample S4, derived from BWMRI Hybrid Maize 2, was significantly superior ($p<0.05$), with the highest ratings for color (8.11), flavor (8.33), and overall acceptability (7.89). These results indicate that BWMRI Hybrid Maize 2 is the most promising cultivar for commercial production of highly acceptable crispy corn snacks.

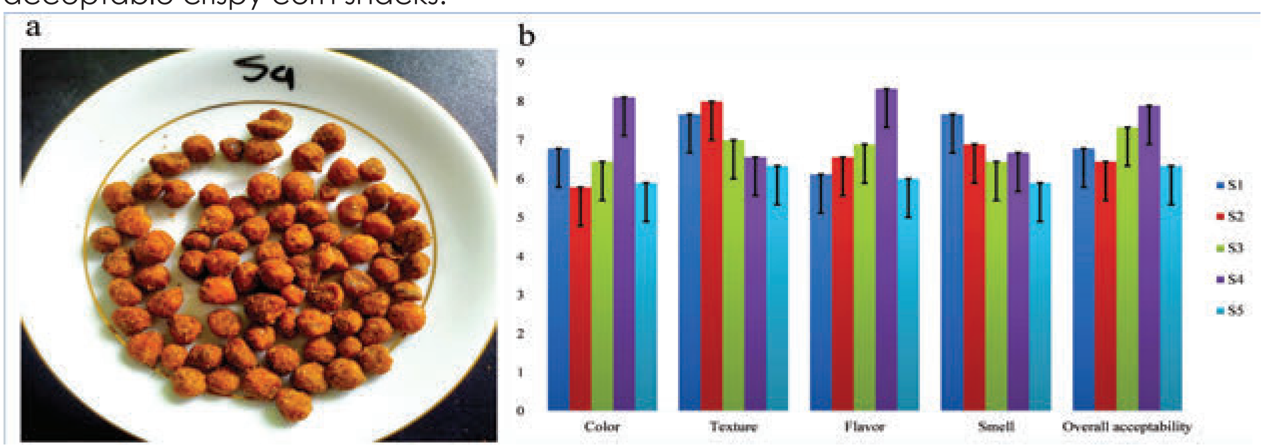


Figure 6.4. Consumer preference of crispy corn samples based on sensory parameters using the hedonic scale: (a) sample S4 identified as the best-performing crispy corn; (b) graphical representation of all five samples

Table 6.1. Key outcomes of the research initiatives from postharvest technology and nutritional division

Research Product	Optimal Sample	Key Sensory Score (Out of 9)	Recommended Raw Material
Wheat Gluten Content	–	Max: 12.28% (BARI Gom 32)	BARI Gom 32 (Best for Bread)
Maize–Fortified Cake	S2	Overall: 8.67	60% Wheat + 40% Maize Flour
Corncob Jelly	S3	Overall: 8.11	BARI Sweetcorn 1 Cobs (13 nos)
Deep–Fried Crispy Corn	S4	Overall: 7.89	BWMRI Hybrid Maize 2

7. On–Farm Research

On–Farm validation of de–topping on the grain and forage yield of maize: This study was carried out in the Thakurgaon and Dinajpur districts during the Rabi season of 2024-25 to validate the effect of de-topping of maize on the grain and forage yield. The BWMRI Hybrid Maize-2 was seeded on 4th and 15th December 2024, respectively, with a spacing of 60 cm × 25 cm. De-topping was performed 140 days after sowing. In Dinajpur, the de-topped maize yielded 12.26 t ha^{-1}, while the non-de-topped yielded 12.31 t ha^{-1}, indicating no significant reduction in yield due to de-topping. Moreover, the forage yield under de-topping was recorded at 5.82 t ha^{-1}, suggesting that de-topping positively influences forage production. The MBCR was 1.43 for de-topping and 1.39 for non-de-topping practices. These findings demonstrate that, while de-topping does not significantly reduce maize grain yield, it contributes to an increase in forage yield, offering a potential trade-off for farmers aiming to enhance forage production for livestock. Unfortunately, the maize plants in Thakurgaon were destroyed by a storm, resulting in a total loss of yield. Further validation across diverse regions is essential to assess the consistency of these results and determine the broader applicability of de-topping as an effective agricultural practice.

Figure 7.1. De–topping and without de–topping of maize at Dinajpur

Intercropping maize with different vegetables in the farmer's fields: The on-farm data on maize yield from red amaranth and cilantro intercropping systems and sole maize cultivation were recorded from the Thakurgaon and Dinajpur districts during the 2024-25 Rabi season. The objective of this study was to assess the profitability of intercropped maize cultivation with red amaranth and cilantro compared to the sole maize in the farmer's field. Seeding of all crops occurred on 4th December in Thakurgaon and 22nd December in Dinajpur. Red amaranth and cilantro were broadcasted, while maize (cv. BWMRI Hybrid Maize 2) was sown in rows with spacing of 60 cm × 25 cm. In Thakurgaon, intercropped red amaranth yielded 11.98 t ha^{-1} maize and 4.69 t ha^{-1}, and cilantro produced 3.95 t ha^{-1}. Unfortunately, no yield data was recorded for both intercropped and sole maize in this district due to destruction by a storm, resulting in a complete loss of yield. In Dinajpur, maize intercropped with red amaranth produced 11.98 and 6.20 t ha^{-1}

maize and red amaranth, respectively. While maize intercropped with cilantro yielded 12.06 and 3.70 t ha^{-1} maize and cilantro, respectively. The maize equivalent yield (MEY) of maize + red amaranth system is 16.23 t ha^{-1} and the maize + cilantro is 14.20 t ha^{-1}. In contrast, sole maize cultivation resulted in 12.12 t ha^{-1}. Result suggested a 34% higher yield of maize + red amaranth system and 18% higher yield of maize + cilantro system compared to the sole maize system. The marginal benefit-cost ratio (MBCR) of maize + red amaranth, maize + cilantro and sole maize was calculated as 1.61, 1.49 and 1.38, respectively. These findings suggest that intercropping maize with red amaranth and cilantro offers advantages in terms of crop diversification without compromising maize yield compared to sole maize cultivation, underscoring a potential trade-off between maximizing yield and benefiting from crop diversification.

Figure 7.2. Field view of maize + red amaranth, maize + cilantro and sole maize

Cultivation of wheat under minimum tillage using Power Tiller–Operated Seeder (PTOS) in the farmers' field: The on-farm wheat yield (cv. BARI Gom 33) was recorded from the Dinajpur district under two different sowing methods, namely PTOS and broadcasting, during the 2024-25 Rabi season. The objective of this study was to compare the yield and economic benefits of the PTOS method over the conventional broadcasting method of wheat cultivation. Both sowing methods were conducted on 10th December 2024. The yield of wheat from PTOS sowing was recorded at 4.07 t ha^{-1}, while the broadcast sowing method yielded 3.56 t ha^{-1}. These results demonstrate that PTOS sowing provides a significantly higher wheat yield, with a 14% increase compared to the broadcast sowing method. This underscores the effectiveness of PTOS sowing in maximizing wheat yield in Dinajpur. On the other hand, the total variable cost for the PTOS method was estimated at 95,057 Tk. ha^{-1}, whereas the conventional broadcasting method incurred a cost of 1,26,921 Tk ha-1. Hence, the PTOS incurred a 25% less variable cost than the broadcasting method. The marginal benefit-cost ratio (MBCR) for PTOS was calculated at 1.49, which was approximately 34% higher than the broadcasting method, which had an MBCR of 1.12. These findings highlight PTOS as a more economically beneficial and productive approach for farmers seeking both higher yields and greater economic returns. Further studies and validation across different regions are essential to assess the broader applicability of these findings for promoting sustainable farming practices.

Wheat variety demonstration in farmer's field through DAE: During the Rabi 2024-25 season, a total of 905 demonstrations (size: 20 decimal per demo.) with eight wheat varieties viz. BARI Gom 30 (released in 2014), BARI Gom 32 (released in 2017), BARI Gom 33 (released in 2017), BWMRI Gom 1 (released in 2019), BWMRI Gom 2 (released in 2019), BWMRI Gom 3 (released in 2020), BWMRI Gom 4 (released in 2022) and BWMRI Gom 5 (released in 2024) were conducted in 905 farmers' fields of 35 districts in 12 agriculture regions. Besides 06 Block demonstrations each of 20 bigha were conducted at 06 different districts viz. Dinajpur, Thakurgaon, Panchagarh, Jamalpur, Magura and Kushtia. The mean yield of all the eight varieties over locations was 4.11 t ha^{-1}. Based on variety, the highest mean yield was recorded in BWMRI Gom 4 (4.23 t ha^{-1}) followed by BWMRI Gom 3 (4.19 t ha^{-1}) and the lowest identical mean yield was found in BARI Gom 30 and BARI Gom 32 (3.70 t ha^{-1}). Considering districts, the highest mean yield was obtained from Chapainawabganj (5.17 t ha-1) followed by Meherpur (4.95 t ha^{-1}) and Thakurgaon (4.57 t ha^{-1}). Sherpur showed the lowest yield with an average of 3.0 t ha^{-1} followed by Bhola (3.14 t ha^{-1}) and Jamalpur (3.31 t ha^{-1}). According to DAE, the national average yield of wheat under Bangladesh was 3.87 t ha^{-1} while the overall mean yield of the demonstrated new eight varieties was 4.11 t ha^{-1} that was 6.30 % higher than the national average. So, the yield gap can remarkably be eliminated using good seeds of new varieties, seeding in optimum time and using recommended fertilizers, irrigations and other management practices.

Figure 7.3. Demonstration of wheat in Kurigram & maize in Rangpur

Maize variety demonstration in farmer's field through DAE: The demonstration of the newly released maize variety aims to introduce and evaluate its performance in farmers' fields' condition across different locations. Consequently, 550 demonstrations were conducted of newly released BWMRI Hybrid Maize-2 (Released in 2022) in 550 farmers' fields across 27 districts during the Rabi 2024-24 season. Seeds were sown with a spacing of 60 cm × 25 cm. The mean yield of all districts was 10.86 t ha^{-1} where the highest yields observed in Thakurgaon (12.71 t ha^{-1}), followed by Jashore (12.51 t ha^{-1}), and Dinajpur (12.12 t ha^{-1}). In contrast, the lowest yields were reported in Mymensingh (8.86 t ha^{-1}), and Jhenaidah (8.89 t ha^{-1}), respectively. Farmers of most of the districts expressed satisfaction with the yield, though many indicated a preference for varieties with orange-colored kernels.

Yield performance of BARI Hybrid Maize 17 in Kharif–1 2024–25 season: The yield performance of BARI Hybrid Maize 17 was evaluated at two locations, reflecting both yield outcomes and farmer observations. In Chirirbandar, Dinajpur, five demonstrations recorded an average yield of 7.45 t ha^{-1}, with farmers noting that the grain size was relatively small. Meanwhile, in Baliadangi, Thakurgaon, three demonstrations achieved a higher average yield of 8.02 t ha^{-1}, with farmers reporting that the yield was satisfactory and suggesting that earlier sowing could further enhance productivity. These findings indicate that while BARI Hybrid Maize 17 performs reasonably well in both regions, agronomic practices such as optimal sowing time can significantly influence the overall yield and grain quality.

Yield performance of BWMRI Hybrid Maize 2 at MLT sites during Rabi 2024–25 season: The yield performance of BWMRI Hybrid Maize-2 at MLT (Multi-location Trial) sites during the Rabi season of 2024-25 shows promising results across the two evaluated locations. In Khagrachori, Chittagong, 20 demonstration trials recorded an average yield of 12.3 t ha^{-1}, indicating strong performance in this region. Similarly, in Habiganj, Sylhet, 10 trials achieved a slightly lower average yield of 11.79 t ha^{-1} but still demonstrated robust productivity. These results highlight the potential of BWMRI Hybrid Maize-2 to perform well in diverse agro-climatic conditions, particularly in the southeastern and northeastern regions of Bangladesh, and suggest its suitability for wider cultivation with further optimization of local agricultural practices.

Yield performance of different wheat varietiesat MLT sites during Rabi 2024–25 season: The yield performance of wheat at MLT (Multi-location Trial) sites during the Rabi season of 2024-25 reveals varied results across the different wheat varieties tested in two locations. In Habiganj, Sylhet, the BWMRI Gom 1 variety showed an average yield of 3.86 t ha^{-1} across 8 demonstration trials, while the BWMRI Gom 2 variety achieved a slightly higher average yield of 4.02 t ha^{-1} from 10 trials, indicating its better performance in this region. On the other hand, in Khagrachori, Chittagong, the BARI Gom 32 variety recorded a relatively lower average yield of 2.22 t ha^{-1} across 20 trials. These results suggest that BWMRI Gom varieties are more suited to the conditions in Sylhet, whereas BARI Gom 32 may face challenges in the Chittagong region, possibly due to variations in soil type, weather, or cultivation practices. These insights are valuable for determining the best-suited wheat varieties for specific regions in Bangladesh.

Yield performance of wheat varieties/lines at saline prone Amtali, Barguna MLT site during Rabi 2024-25 season:

The yield performance of various wheat varieties at the MLT site in Amtali, Barguna, during the Rabi 2024-25 season. The salinity level was 10.09 dS m^{-1} Among the tested materals, BAW 1390 exhibited the highest yield at 1.919 t ha^{-1}, establishing itself as the top performer in this trial. BWMRI Gom 1 followed closely with an impressive yield of 1.719 t ha^{-1}, demonstrating its suitability for the agro-climatic conditions in Barguna. Other notable high-yielding varieties include BAW 1243, which recorded 1.422 t ha^{-1}, and BARI Gom 32, with a yield of 1.419 t ha^{-1}, further indicating their potential for high performance in this region. On the other hand, the BWMRI Gom series, specifically BWMRI Gom 3 (0.650 t ha^{-1}), BWMRI Gom 4 (0.811 t ha^{-1}), and BWMRI Gom 5 (0.719 t ha^{-1}), demonstrated significantly lower yields, highlighting that these varieties are less adapted to the local conditions at this site. The results suggest that while varieties like BAW 1390 and BWMRI Gom 1 show strong potential for high yields in the Amtali area, the BWMRI Gom varieties may require further refinement or adjustment in agronomic practices to achieve higher productivity. These insights are crucial for selecting the most suitable wheat varieties for cultivation in this region and guiding future research for improved wheat production in Barguna.

8. Technology Validation and Transfer

Technology validation and transfer are essential components in advancing agricultural practices and improving crop productivity among farmers. This involves conducting on–farm trials of various wheat varieties, which serve to assess their adaptability and yield potential under local conditions. Additionally, on–farm trials examining the application of dolomite in wheat and maize cultivation have been conducted to determine its effectiveness in enhancing soil health and crop performance. Demonstration trials of released wheat varieties from the BWMRI have taken place across multiple locations, showcasing their benefits to farmers and encouraging adoption. Complementing these practical demonstrations, a series of trainings, workshops, field days, and visits have been organized to disseminate knowledge and foster engagement among farmers and stakeholders. Publications documenting these efforts serve as valuable resources, further facilitating the transfer of innovative technologies and practices to enhance agricultural productivity and sustainability in the region.

8.1. Training

Farmers and field staffs of DAE, NGOs, BWMRI and officers and stuffs of other institute and organizations were trained to make them familiar with the new wheat and maize varieties, modern crop management practices, seed preservation techniques, insect pest management, disease management and mechanization in wheat and maize cultivation. Training program for farmers, scientists, BWMRI field staffs and others were conducted through audio–visual aids, demonstrations, lectures, group discussions, training classes, field days, motivational tours etc. by wheat and maize scientists.

In total 4814 personnel attended the training programs in different aspects during 2024–25. Out of those, 3597 farmers, 647 SAAO/SSA/SA and 570 Officers of BWMRI and other institute and organization were trained on wheat and maize. Officers and staffs were trained on different aspects of modern office management. Trainings of farmers were imparted on new wheat and maize variety demonstration, participatory variety selection and yield maximization, quality wheat seed production of new wheat varieties, seed production and preservation of new wheat and maize varieties, wheat blast management and introduction of new wheat and maize varieties & modern production techniques etc.

Figure 8.1 Training programs organized by BWMRI: (a) induction training for newly recruited scientists; (b&c) farmer field training; (d) collaborative training with stakeholders; (e) emergency response and rescue training for BWMRI staff.

Total 126 Scientists have attended different training, seminar, workshop, scientific meeting in different institute and organizations like NATA, BARC, BARI, SCA, DAE and Ministry of Agriculture throughout the reporting year which helps in human resource development and management. They also get new ideas on different aspect of profession.

Scientists have gone abroad for training, Higher Studies and other scientific meetings for different periods of time. This plays an important role in improving their skills in research activities. Total 18 scientists visited different countries like Kenya, Nepal, Mexico, China, and Malaysia during 2024–25.

8.2. Workshops

BWMRI organized nine seminar/workshops during 2024–25, where total participants were 341. Scientists from different research organizations, officials (UAO, ADD, DTO, DD and AD) from Department of Agricultural Extension (DAE), Bangladesh Agricultural Development Corporation (BADC), Seed Certification Agency (SCA), non–government organizations, seed dealers and teachers from public universities participated in those workshops.

Figure 8.2. BWMRI organized workshops during 2024–25,

8.3. Field Days, Visits and Publications

A group of scientists, ministry people, DAE personnel, foreign delegates and farmers visited the demonstrations and seed production plots several times and were impressed to see the plots. A good number of visitors both from home and abroad also visited the on–station and on–farm activities of BWMRI. Twenty field days were organized by BWMRI about new variety demonstration, modern production technologies, quality wheat and maize seed production, wheat blast management, environment friendly control measures of Fall Armyworm insect in maize, increase soil & crop productivity through climate smart conservation technology in drought–prone areas, salt tolerant wheat varieties in coastal saline area etc. where about 1500 participants were present. The farmers participating in the field days were very much interested in cultivating new varieties of wheat. Huge number of colored pictorial factsheet and leaflets of modern wheat and maize cultivation were published and distributed among the farmers and related personnel.

Figure 8.3. Field day organized by BWMRI to promote technology dissemination: (a) wheat; (b) maize.

Figure 8.4. Visits of national and international officials to BWMRI research activities of ongoing wheat and maize improvement programs

Figure 8.5. BWMRI Publications

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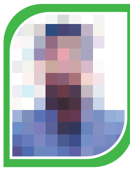

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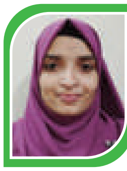

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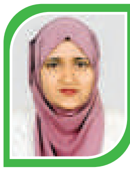

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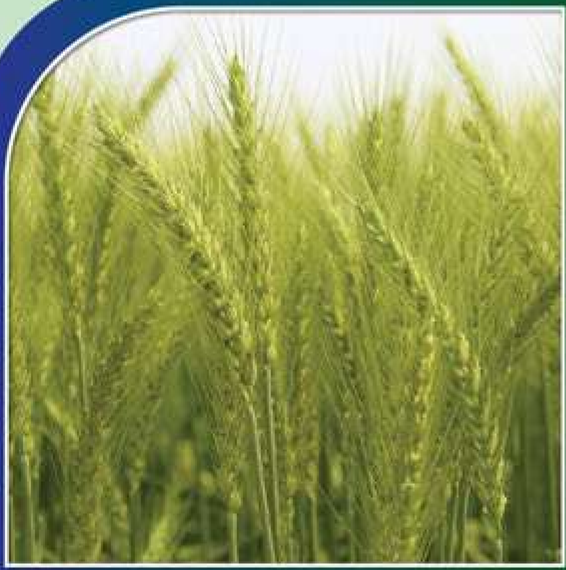

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