# Borlaug Global Rust Initiative, South Asia, 2008-2020:

## 12 Years of Wheat Improvement in the Durable Rust Resistance in Wheat (DRRW) and Delivering Genetic Gains in Wheat (DGGW) Projects

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Wheat is the world's largest primary commodity, with global production of over 700 million tons on more than 215 million hectares, consumed by over 2.5 billion people in 89 countries. The South Asian Association for Regional Cooperation (SAARC) region of South Asia enjoys a strategic position as the largest contiguous wheat-producing region in the world, where wheat is grown on over 41 million hectares in India, Pakistan, Afghanistan, Bangladesh, Nepal and Bhutan with production of over 131 million tons (FAO, 2018).

The SAARC region has witnessed a 11% increase in wheat production from 118 million tons in 2011 to 131 million tons in 2018 with yield increases from 2.86 tons/ha to 3.20 tons/ha. India surpassed the remarkable milestone of 100 million tons of wheat production in 2018–19 (FAOSTAT). Wheat (*Triticum* sp.) is the most important cereal crop in South Asia based on the amount of acreage planted. Wheat is the key staple, primarily in the north and north-western parts of India, Pakistan, Bangladesh, Afghanistan, Nepal, and Bhutan.

Over the last decade, the SAARC region has witnessed a paradigm shift in wheat research and development under the aegis of two Bill & Melinda Gates Foundation (BMGF) and UK aid (DFID) funded project(s): the Durable Rust Resistance in Wheat (DRRW, 2008-2016) and the Delivering Genetic Gain in Wheat (DGGW, 2016-2020).

Both projects were led by the Borlaug Global Rust Initiative (BGRI) at Cornell University and implemented by Sathguru Management Consultants in the SAARC region. The DRRW was launched to counter the threat of Ug99, a new race of stem rust that came out of East Africa in 1999 to which 80-90% of the world's wheat was susceptible. Building on the success of the DRRW, the DGGW focused on releasing new varieties of wheat with disease resistance for all rusts (stem, stripe and leaf), *Septoria* and spot blotch, improved heat tolerance, and increased wheat yields for smallholder farmers in East Africa and South Asia.

### *Key interventions contributing to the success of the DRRW and DGGW projects (Fig 1)*

**Synergistic efforts to mitigate wheat disease**

- Through cooperation in disease detection, collaborative breeding and seamless exchange of bio resources

**Robust germplasm pool and pipeline development**

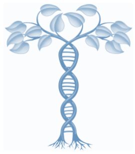
- Through regular screening of lines against rust and successful release of rust resistant varieties

**Building self-sufficiency of national centers in tracking pathogen movement**

- Through surveillance capacity building, training, and promoting maintainence of data centers for national and global visibility of data

**Building an innovative seed system**

- Through establishing seed village model for creating accessibility to quality certified wheat seed for smallholder farmers



**Determination of farm level varietal adoption of wheat in Nepal and Bangladesh**

- Using DNA fingerprinting as a tool to analyse all the wheat varieties in use in Bangladesh and Nepal

*Figure 1: Key interventions contributing to the success of DRRW and DGGW projects, 2008-2020*

## Synergistic efforts to mitigate wheat disease through cooperation in disease detection, collaborative breeding, and seamless exchange of bio resources.

Since 2008, researchers involved in the DRRW and DGGW projects have accomplished an unparalleled and remarkable convergence of inter-disciplinary scientific effort in the SAARC region. There is now a continual and open exchange of information on wheat research efforts worldwide. Partners involved in the projects made progress in assessing regional strengths and weaknesses, devising models to bridge country gaps through pooled and responsive engagement, and high-level capacity building that was accessible to all the players in the region.

In the SAARC region, the convergence of regional power through the national wheat research institutes (Indian Institute of Wheat and Barley Research (IIWBR) – India https://www.iiwbr.org/; Pakistan Agricultural Research Council (PARC) – Pakistan; National Agricultural Research Council (NARC) – Nepal http://narc.gov.np/narc/; Bangladesh Wheat and Maize Research Institute (BWMRI) - Bangladesh http://www.bwmri.gov.bd/; National Plant Protection Centre (NPPC) – Bhutan http://www.nppc.gov.bt/) across the SAARC region led to cooperative efforts in disease detection, collaborative breeding, and setting up a new pattern of genetic resource exchange inter-regionally for the common good of the region. The projects have brought over 300 scientists in the region together to move the work collaboratively forward in improving wheat varieties and controlling deadly diseases.

The projects were implemented by working meticulously with the national agricultural research centers and their respective national breeding programs to trigger research to attain genetic protection against major wheat diseases. Scientists and researchers from the region have been trained by global experts using advanced infrastructure through medium- and short-term programs on advanced breeding practices for multiple wheat disease resistance, including marker assisted selection, genomic selection, gene identification, allele mining for identifying new sources of resistance to Ug99 and trait introgression facilitating rust research in the SAARC region. By leveraging their association with global experts, these regional research centers have been oriented to and acquainted with the latest advancements in mitigating the effect of rust and other diseases on wheat. The key scientists and researchers from these regional research centers have participated in the nearly annual collaboration of wheat scientists at the BGRI Technical Workshops to gain exposure to the global advancements on wheat improvement and its management. This global collaboration has helped the South Asian wheat research institutes prioritize research programs, accelerate breeding, and deliver improved varieties.

Further, as a part of this regional collaboration, the BGRI Annual Technical Workshop in 2013 was held in New Delhi, India, jointly hosted by the Indian Council for Agricultural Research (ICAR) and the BGRI South Asian Regional Center. The event also commemorated Dr. Norman Borlaug's first visit to India in 1963. Around 500 delegates from more than 50 countries participated in this first of its kind event organized in India. The program facilitated participation of a large number of scientists and researchers from the SAARC region and helped them connect with global leaders and gain understanding of the recent advancements in wheat research worldwide.

## Robust germplasm pool and pipelines developed through regular screening of wheat lines against rust, and successful release of rust-resistant varieties.

The BGRI collaboration enabled efficacy testing of wheat varieties from the region in international screening nurseries at Kenya and Ethiopia (hotspots) for resistance to Ug99. With over 2500 advanced wheat lines from the SAARC region screened over the last decade, today's researchers have access to a robust germplasm pool of resistant lines. They have released more than 35 rust resistant wheat lines for the farmers of the region including 28 Ug99 resistant varieties (15 from India, 9 from Nepal and 3 from Bangladesh). In addition to Ug99 resistance, these varieties incorporate climate-smart and biofortified traits and resistance to other economically important diseases and abiotic factors.

| S.N. | Country | List of Ug99 resistant varieties |
|---|---|---|
| **1** | India | **Central Zone:** 9 (Lok 1, HI 8498, WH 147, GW 322, HI 1531, HI 8627, HD 4672, DL 788-2 and MPO 1215)<br>**Peninsular Zone:** 7 (Lok 1, NI 5439, NIDW 295, MACS 2846, HI 8663, UAS 321 and UAS 431.) |
| **2** | Bangladesh | BARI Gom 26, BARI Gom 27, BARI Gom 28, BARI Gom 29 |
| **3** | Nepal | Vijay (BL 3063), Gaura (BL 3235), Dhaulagiri (BL 3503), Tilottoma (NL 1073), Danphe (NL 1064), Bandganga (BL 3623), Sorgadwari (BL 3629), Munal, Chyakhura |

National research centers have also collaborated to establish SAARC wheat disease monitoring nurseries planted annually with wheat lines from SAARC nations across more than 27 locations in South Asia. Annually, around 20 lines are planted across the SAARC region, under the direction of the ICAR-IIWBR regional station in Shimla, India. The Shimla station is one of the most renowned and oldest wheat research stations in the world. It monitors variability in wheat incidence across various advanced varietal trial lines from the SAARC region.

The projects' engagement with National Agricultural Research Systems (NARS) in South Asia has led to the replacement of older susceptible varieties with newer disease-resistance and climate-smart varieties — now a priority in national breeding programs across the region. The successful withdrawal of the popular rust susceptible wheat variety PBW343 from India in a record time of three years (2008–2011), and replacement with durable rust resistant varieties is a prime example. Today, no blockbuster variety rules the wheat seed market as public and private research institutions continuously bring improved varieties into the system. HD 2967 is a popular variety in India today covering about 40-45% of the wheat growing area of the country.

Among South Asian researchers engaged in this global wheat partnership, since 2008, the crop breeding focus of the region has changed from being limited to yield gains to incorporating multiple disease resistance, nutrition improvement, and abiotic factors. Research focused on developing varieties suitable for abiotic factors has taken priority over the last 12 years with varieties like DBW 14, DBW 16, RAJ 3765, Lok 1, GW 322 becoming popular as heat tolerant varieties in India.

For nutritional improvement, the major targets are increasing protein content, increasing essential amino acids such as lysine, and increasing high molecular weight gluten to improve bread making quality, and modifying starch composition. To date, considerable genetic gains in wheat have been achieved by Bangladesh in developing mid- to high-tolerant varieties to *Bipolaris* Leaf Blight, heat stress and lodging. Resistance has also been developed toward leaf rust and Ug99. Wheat varieties in Nepal have gained resilience to major outbreaks like Ug99, rust, and foliar blight. Research programs now focus on varieties with multiple disease resistance towards yellow and leaf rust, foliar blight, loose smut, powdery mildew, karnal bunt, blast and abiotic factors like terminal heat tolerance, drought tolerance, amber color, and lodging. Release of the breakthrough Ug99 resistant variety (Vijay) in Nepal in 2010 is another noteworthy achievement.

Other remarkable achievements include the development and release of a blast resistant wheat variety (BARI GOM 33) by the Bangladesh wheat research team within two years of the initial occurrence of wheat blast in South Asia (2016). The rapid global response for varietal development to mitigate the outbreak was in part due to the international partnership established by the BGRI through the DRRW project.

The exposure of Bhutan wheat scientists to international efforts and research capacity enhancement in the last decade triggered the release of a new varieties (Gumasokha kaa and Bajosokha kaa) in 2014 after a period of 20 years. With the introduction of these new disease-resistant varieties from 2014 onwards, Bhutanese farmers were discouraged from cultivating the popular rust susceptible variety Sonalika, the Indian variety introduced in Bhutan in 1988.

The political awareness, engagement, and the convergence of intra-country policy planners under the BGRI umbrella through the DRRW and DGGW projects have drawn an intense focus on the future of wheat breeding in the region. With wheat research gaining importance in the region, respective wheat research centers in India and Bangladesh were elevated to National Level Crop specific Research Institutes (Directorate of Wheat Research in India to Indian Institute for Wheat and Barley research (IIWBR), and Wheat Research Center (WRC) in Bangladesh to Bangladesh Wheat and Maize Research Institute (BWMRI)). The Nepalese and India wheat teams received the BGRI Gene Stewardship Award in 2012 and 2018, respectively, to honour their efforts in national breeding programmes and for promoting durable wheat varieties and enhancing food security.

The wheat team from NARC, Nepal was awarded the first BGRI Gene Stewardship Award in 2012 (Fig 2) in recognition of their remarkable contributions in bringing about excellence in the development and release of rust resistant wheat varieties, seed multiplication of resistant varieties with diverse genetic backgrounds, disease surveillance, participatory research with farmers, and the improvement of the livelihoods of small-scale farmers to combat the problems of food security. The BGRI Gene Stewardship Award given to the Indian Council of Agricultural Research (ICAR) team from India in 2018 (Fig 3) was in recognition of the outstanding work done by the Indian Wheat Programme in development, release and dissemination of agronomically-superior rust resistant wheat varieties that enabled effective management of rust disease, achieving record wheat production and thereby ensuring greater food security for India.

*Figure 2: Nepal team awarded with Gene Stewardship Award, BGRI Annual Technical Workshop, Beijing, China, 2012*


*Figure 3: Indian team awarded with Gene Stewardship Award, BGRI Annual Technical Workshop, Marrakech, Morocco 2018*

Of the 55 women scientists who have received the BGRI Jeanie Borlaug Laube Women in Triticum (WIT) Early Career Award since 2010, 13 came from the SAARC region: Arti Singh, India (2013); Naeela Qureshi, Pakistan, and Chhavi Tiwari, India (2014); Philomin Juliana, India (2015); Mitaly Bansal, India, and Irum Aziz, Pakistan (2016); Ritika Chowdhary, India (2017); Sreya Ghosh, India, and Radhika Bartaula, Nepal (2018); Sanu Arora and Jyotoi Saini Sharma from India, and Sabina Asghar, Pakistan (2019); Bharati Pandey, India (2020). Of the 10 Jeanie Borlaug Laube WIT Mentors, two came from the SAARC region: Arun Joshi, Nepal (2014); and Urmil Bansal, India (2018).

## Self-sufficiency of national centers in tracking pathogen movement through surveillance capacity building, training, and promoting maintenance of respective data centers for national and global visibility of data.

Other key achievements of the DRRW and DGGW projects relate to standardization of rust surveillance methodologies across the SAARC region and building mechanisms for exchange of surveillance data and information. In re-defining the boundaries of traditional crop monitoring with sophisticated technologies, the project conceptualized and introduced the ICT-enabled **SAARC Surveillance Toolbox** application through web, mobile and tablet-based platforms. Complementing this over the last decade, efforts have led to developing human and institutional capacities across partner national research institutes by training on rust scoring, wheat surveillance, and monitoring.

Over the last 12 years, more than 350 scientists and researchers have been trained through structured programs on the principles of rust pathology, rust scoring, disease monitoring and surveillance, germplasm screening and evaluation by global and regional experts in trainings conducted in India and Nepal. An annual training on "The Art and Science of Rust Pathology and Applied Plant Breeding" was conceptualized and delivered over the last 12 years by global experts Dr. Gordon Cisar, Senior Project Manager, DRRW; Dr. David Hodson, Senior scientist CIMMYT; Professor Robert Park, a leading pathologist at University of Sydney and Director, Australian Cereal Rust Control Program; and Professor Zak Pretorius, respected pathologist with the University of the Free State in South Africa. Trainings are available as online courses on the BGRI website.

During these trainings, early- and mid-career wheat researchers from the SAARC region gained understanding of the concepts related to wheat diseases and their management, host-pathogen interactions, race typing, chemical interventions, practical exercises in infection type scoring and pathotype identification, field survey protocols, wheat disease monitoring and trap nursery management, practical insights into the science of wheat breeding, how to handle rust collections in lab and greenhouse, and more. Regional SAARC experts joined in to orient the trainers on the regional criticalities, trends of disease incidence, and its management. The strategic locations, hands-on nature of the training programs, and use the regional facilities helped scientists learn efficiently and gain varied regional exposure under the guidance of these experts. Additionally, SAARC scientists were trained at wheat rust hotspots in Kenya and Ethiopia on aspects related to standardization of field notes, germplasm evaluation, rust scoring techniques as a part of annual programs organized by respective national agricultural research institutes (KALRO and EIAR) in cooperation with the International Maize and Wheat Improvement Center (CIMMYT). National SAARC partners are now self-sufficient in tracking, evaluating and predicting the pathogen movement for wheat diseases.

Today, the SAARC Surveillance Toolbox (Fig 4) has brought a renewed sense of vigilance for wheat protection. The tool is being used by 95% of rust surveillance teams in the region and has created a sustainable model for deployment and adoption of this platform for real time data access and sharing through contemporary data exchange platforms. The effort has generated a data repository of more than 6000 data records and ensured the global visibility of surveillance data of South Asia.

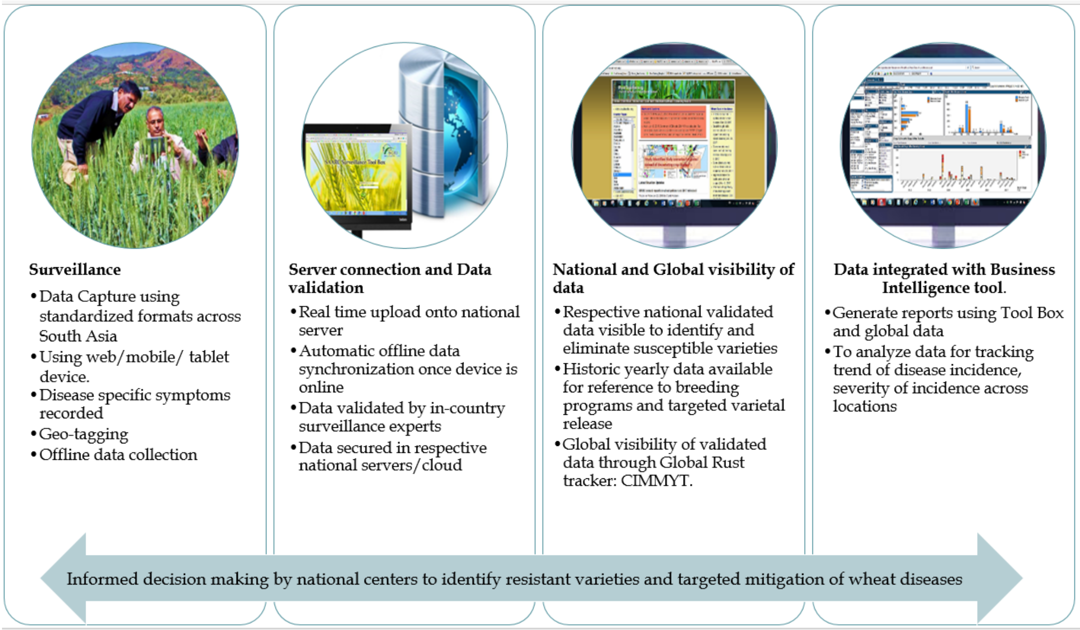



*Figure 4: Framework of SAARC Surveillance Tool Box*

## Building an innovative seed system through establishment of a Seed Village Model for creating accessibility to quality certified wheat seed for smallholder farmers and building capacity for wheat seed systems for the private and public sector entities.

As part of the DGGW project, an innovative seed village model (Fig 5) has been established at the Agricultural and Forest University (AFU) in Nepal for the purpose of creating access to quality certified wheat seed for small holder farmers and building capacity for wheat seed systems for private and public sector entities. The establishment of a seed processing unit has resulted in economic gains for small holder farmers in the Chitwan area of Nepal. The project established the first-of-its-kind end-to-end processing unit in the region. The seed processing unit and testing laboratory that have been established have now been nationally recognised. Efforts have been to build capacities along all value chains and stakeholders, including scientists, researchers, seed unit technicians, extension professionals, seed producers and small holder farmers.

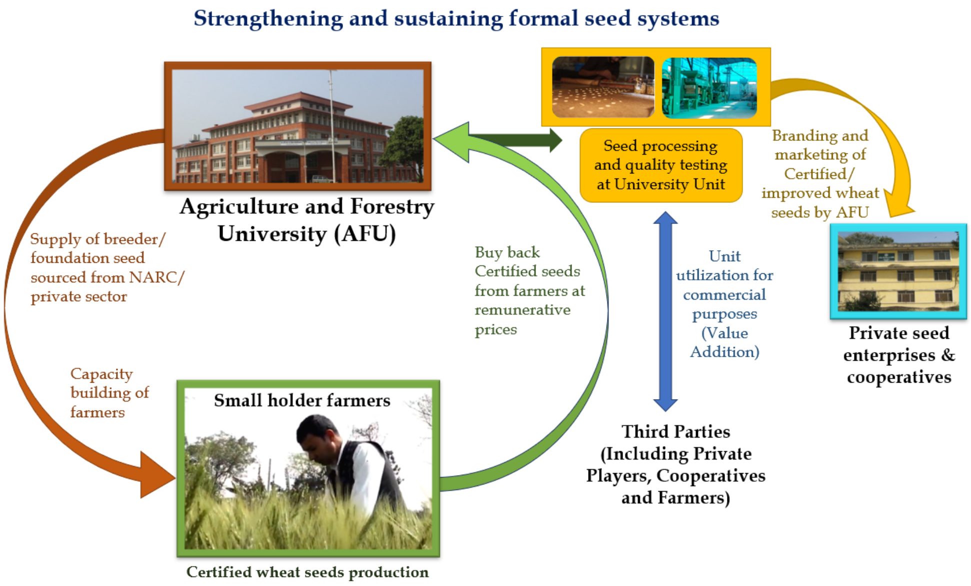
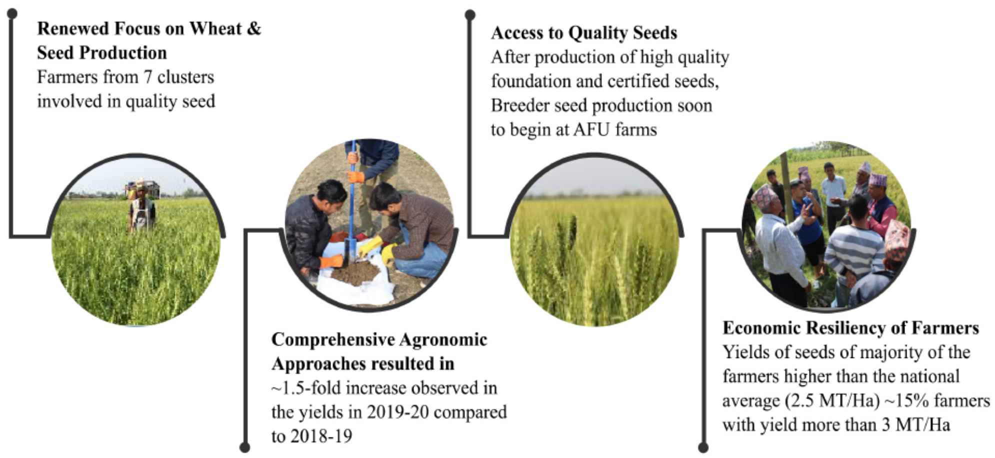



*Figure 5: Seed Village Model, AFU, Chitwan, Nepal*

The project encouraged adoption of a multi-pronged approach by AFU using organized field demonstrations, farmer field schools, farmer knowledge exchange programs, and frequent interactive sessions with farmers by the DGGW team to ensure wide adoption of improved agronomic practices (including timely sowing, improved seed rate, spacing between rows, soil profiling and nutrient management, and pest and disease management) among seed producers. These efforts not only resulted in farmers achieving higher productivity but guaranteed income through the project's seed buy-back strategy. The initiative has been instrumental in building economic resiliency among the beneficiary farmers and making the university a knowledge and business hub for small holder farmers, companies, and distributors. By the third year of its operation, along with AFU the initiative has enrolled more than 220 farmers for production of quality seeds (Fig 6). With the trainings, support and extension work carried out by AFU, many grain growing farmers are now gradually shifting to wheat seed production as their primary source of income. To recognize the efforts of the most progressive farmers involved in the project, the DGGW and AFU celebrated the success of seven farmers at the first nationally recognized farmers' fair, with former Prime Minister of Nepal honouring them. Witnessing the success of the project, additional investment has been made by the AFU towards construction of a storage facility, commencement of a Post Graduate Program in Seed Science and Technology to provide practical exposure to students on seed processing systems as well as model replication for rice seed systems in the region.



**One stop solution for quality seed processing and storage**
- End to end processing unit with state of art equipment, large storage unit

**Adoption of new wheat varieties**
- Encouraging adoption of new wheat seed released by NARC suitable for the region, increasing yield and disease resistance

**Enhanced university (AFU) credence among farming community**
- Continued Information and knowledge transmission between AFU and farmers bridging skill gaps for quality seed production

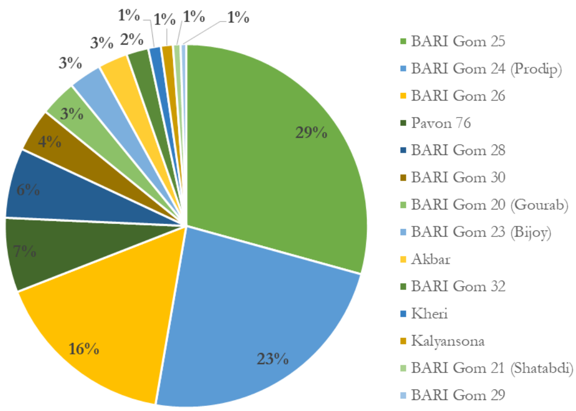
**Growing knowledge and business hub**
- AFU is gradually emerging as the go to solution for value chain stakeholders for quality seed production and support

*Figure 6: Milestones Achieved and Impact of Innovative Seed System Model*

The DRRW and DGGW projects have been instrumental in creating a paradigm shift across the region (particularly in India and Nepal) by engaging the cooperation of the private seed sector with public research institutes to increase seed multiplication and distribution to resource-constrained farmers across the region. In regards to this, a wheat values chain report 'Status and Opportunities for Wheat Seeds in India, Bangladesh, Nepal & Bhutan' was collated to highlight the paradigm shift that has taken place in wheat over the years in varietal research, production, distribution of seeds as well as consumption as a commodity. The report was released during the BGRI Annual Technical Workshop in 2018 at Marrakech, Morocco. The report received accolades from all the country representatives from across the South Asian region for its in-depth country wise coverage on wheat value chain.

## Determination of farm level varietal adoption of wheat in Nepal and Bangladesh.

Development, dissemination, and adoption of improved wheat varieties are absolute imperatives for national food and nutritional security. Awareness of varietal distribution across these countries has a huge impact in determining replacement strategies for new varieties, and in developing and implementing newer agricultural policies. With the growing number of varieties and the increase in wheat seed production, it is essential to keep track of variety purity. To determine varietal adoption in wheat across Bangladesh and Nepal, the project carried out a study using DNA fingerprinting as a tool to analyse all the wheat varieties in vogue in the region. The findings of the study in Bangladesh revealed that BARI Gom 25 (29%) is the most common variety preferred amongst farmers and was found in all six divisions under study. This variety is leaf rust and blight resistant and can tolerate high salinity and heat. The next most common varieties were BARI Gom 24 (23%) and BARI Gom 26 (16%) followed by the less common varieties, Pavon 76, BARI Gom 28, BARI Gom 30, and others (Fig 7). The findings in Nepal revealed that Gautam (20%) and Vijay (19%) were the most popularly grown wheat varieties across Nepal (Fig 8). Gautam exhibits resistance to leaf rust and yellow rust and is tolerant to spot blotch whereas Vijay is Ug99 and leaf rust resistant.



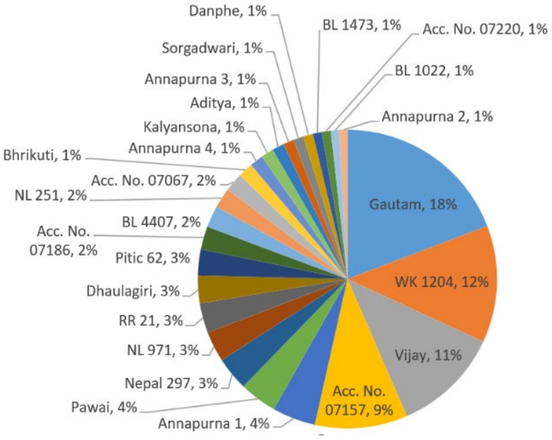



*Figure 7: Prominent Wheat varieties cultivated in the six divisions of Bangladesh*

*Figure 8: Prominent Wheat varieties cultivated in the seven provinces of Nepal*

## Way Forward: Accelerating breeding programs and public-private partnerships to drive greater genetic gains and increased adoption of wheat in the SAARC region.

The DRRW and DGGW projects have helped bring about substantial and sustainable changes within the national wheat research systems across the SAARC nations. Today, with additional efforts from national centers in using systems established and capacities built across the wheat research value chain over the last 12 years, the SAARC region is well prepared to address regional concerns regarding food security and nutrition.

Going forward, the SAARC countries will need to further leverage the enhanced research capacity and make comprehensive efforts to continue to work together through the systems and processes to improve the productivity and production of wheat. This could be achieved through the collective adoption of multiple approaches:

- Engagement by these research centers in ***rapid validation and adoption*** of comprehensive rust resistant and regionally important disease-resistant high-yielding varieties which are paramount to accomplishing the potential genetic gains in the SAARC region necessary for food security.
- ***Augmenting breeding efforts through advanced breeding techniques*** like marker assisted selection and genomic selection to accelerate the breeding process and develop climate-resilient varieties keeping in mind the adverse effects of climate change.
  - In the Vision 2050 document, IIWBR has mentioned that new technologies like RNAi, Targeted mutagenesis, Micro RNA, Cis-trans techniques in wheat will also be utilized. The limiting factors today in establishing such platforms are the technology barriers and high establishment costs.
  - For such platforms to be established, public-private partnership models should be harnessed for greater genetic gains in wheat.
- ***Utilizing comprehensive quantity of surveillance data intra-regionally generated*** by a ***robust system of data management and analytics*** is necessary for providing data to breeders on susceptible varieties and resistance durability.
  - This surveillance data should be leveraged to generate analytical data on rust incidence and sub-regional susceptibility which will be helpful in region-wide distribution of high yielding resistant wheat seeds.
  - Combined engagement of public and private sector seed players in wheat disease surveillance activities will help in scaling up the intervention and accelerated and targeted dissemination of resistant varieties of wheat.
  - Continued surveillance and historical data can be utilized for developing forecasting tools to predict the spread of diseases in the future.

- The determination of farm level varietal adoption of wheat can be further extended to India and Bhutan to track varietal adoption.
- National research efforts in wheat has evolved significantly over the years but there lies an immense opportunity to bridge the variety adoption gap by increasing availability and uptake of quality certified seeds by farmers across the SAARC nations.

**ADDITIONAL BACKGROUND:** *The Bill & Melinda Gates Foundation (BMGF) and UK aid from the British people (UK Department for International Development [now the UK Foreign, Commonwealth and Development Office (FCDO]) funded the Durable Rust Resistance in Wheat (DRRW) (2008–2016) and the Delivering Genetic Gain in Wheat (DGGW) (2016-2020) projects.*

*The objectives of the DRRW were to mitigate rust threats through coordinated activities to replace susceptible varieties with durably resistant varieties, create accelerated multilateral plant breeding, and deliver varieties through optimized developing country seed sectors. The objectives of the DRRW's successor project — the DGGW — was to strengthen the pipeline for delivering new varieties of wheat with disease resistance for all rusts (stem, stripe and leaf), Septoria and spot blotch, as well as improved heat tolerance, and increase wheat yields for smallholder farmers in Ethiopia and South Asia.*

*A collaborative effort of researchers from 22 institutions around the world, the DRRW and DGGW were led by the Borlaug Global Rust Initiative (BGRI) at Cornell University and implemented in partnership with Sathguru Management Consultants, the BGRI's South Asian regional partner.*

*In March 2020, Accelerating Genetic Gains in Maize and Wheat (AGG) was launched. Led by CIMMYT, AGG brings partners in the global maize and wheat communities together with national agricultural research and extension systems to accelerate the development of higher-yielding varieties of maize and wheat that are highly nutritious, climate-resilient, and pest- and disease-resistant. Funded by the BMGF, FCDO, US AID and the Foundation for Food and Agricultural Research, AGG is expected to leverage and build on the impacts of the DRRW and DGGW over the last 12 years.*