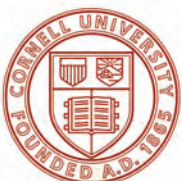


Delivering Genetic Gain in Wheat (DGGW)

Status and Opportunities for Wheat Seeds in India, Bangladesh, Nepal & Bhutan



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We thankfully acknowledge the contribution from Indian Council of Agricultural Research (ICAR); Indian Institute of Wheat and Barley Research (IIWBR); Bangladesh Agricultural Research Institute (BARI); Nepal Agricultural Research Council (NARC); Agriculture Research and Development Center (ARDC), Ministry of Agriculture and Forests, Bhutan; Bangladesh Agricultural Development Corporation (BADC); Seed Quality Control Center (SQCC), Nepal and several private seed companies involved in development of this report.



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Executive Summary

India

- Second largest producer of wheat in the world with about 96 million MT cultivated in an area of approximately 30 million Ha (2017).
- Average productivity has increased from 2.8 MT/Ha in 2000 to 3.1 MT/Ha in 2016 as a result of substantial research in breeding and increase in SRR.

Genetic gains in India

- While until last decade, increasing yield, along with disease and pest resistance were the key contributors towards genetic gains, developing varieties suitable to abiotic stresses, especially climate resilience, has taken priority in the last decade.
- The utility of new breeding technologies like genomic selection and molecular marker technologies are immediate priorities to accelerate breeding process by reducing cycling time.
- In India, no variety in vogue is susceptible to Ug99.

Seed System in India

- Currently, the wheat seed market in India is around 3 million MT, out of which 50 percent is formal seed system, i.e. 1.3-1.5 million tons.
- Over the last decade, the involvement of the private sector has accelerated wheat research with its own breeder lines as well as access gained to public sector research lines. Private sector engagement in wheat seed development, multiplication and delivery have accelerated significantly. Private sector research varieties are currently at 5% market share, growing at 8 to 10 percent year-on-year. Additionally, public varieties are delivered by private sector due to their last mile delivery efficiency and reach.
- Wheat seed multiplication and distribution is primarily dominated (56 percent) by a unique partnership of public and private players along with public channels and private companies of all sizes. Currently, private sector involvement is highly fragmented and consists of numerous small players on the one hand, and half a dozen large companies on the other.
- No blockbuster variety rules the wheat seed market as public and private research institutions are continuously bringing improved varieties in the system.

Value chain - India

- Consumption of packaged wheat flour has increased at an average annual rate of 19 percent. The branded wheat flour consumption is preferred, not just in urban India but rural India as well.
- The integrated supply chain model of large food products companies with wheat flour as a key staple is the reason for consolidation of the milling industry in India. This consolidation has also triggered large brand owners engaging in direct procurement from farmers, offering relatively higher prices than Minimum Support Prices.

- There is a need for shift from the procurement-based model to an integrated model that has active involvement in breeding and processing cycles, as the varieties need to be suitable for meeting demands of the milling industry.

Bangladesh

- In 2016, Bangladesh's domestic wheat grain production stood at 1.35 million MT from an acreage of 0.45 million Ha with an average productivity of 3.03 MT/Ha. Compared to 2000, production and area have gone down from 1.84 MT and 0.83 million Ha respectively. Whereas wheat yield has gone up from 2.21 MT/Ha.
- In 2016-17, imports comprised ~81 percent of the total available wheat in the country where the wheat imports by quantum has risen by ~280 percent from ~1.5 million MT in 2000 to 5.69 million MT in 2016-17.

Genetic Gain in Bangladesh

- Till 2017, Bangladesh has 40 publicly released varieties with an SRR of ~35 percent for wheat. In varietal release, BARI Gom 32 and 33 bring the latest developments in wheat owing to blast tolerance (BARI Gom 33 is yet to be released).
- Genetic gains in wheat in Bangladesh is on account of cohesive efforts of BARI and CIMMYT whereas, seed multiplication and distribution quantum remain dominated by BADC – a public sector entity.
- High yield, bold and larger grain, short duration, tolerance to terminal heat stress and lodging, salinity, Bipolaris Leaf Blight (BpLB) and resistance to leaf rust were the most preferred characteristics by farmers. These characteristics were found to be drivers for varietal research and development currently and in the near future.

Seed System in Bangladesh

- Out of the total certified wheat seed produced by the formal sector (~19000 MT), ~94 percent is multiplied and distributed by BADC (~18000 MT) whereas, the private sector accounts for 4 percent (~ 800 MT) of certified seed quantum altogether.
- In the last ten years, ACI Seeds, BRAC, Supreme Seeds, Lal Teer, Ispahani Agro, Neel Sagar are some of the national companies that have emerged in multiplication and distribution of wheat seeds. The seed sale quantum remains around 100 MT/annum/player.
- Currently, there exists no differentiation in the trait factors of the wheat varieties by public and private players as everyone is selling the same publicly released varieties. The only competitive determinants of their success remain distribution strength and the price factor. Subsidized seed prices of BADC was found to pose a challenge for the private sector's ability to match on the price front.

Value Chain - Bangladesh

- Catering to ~18 percent of its domestic demand for wheat, Bangladesh depends heavily upon Russia, Ukraine (major), Australia, USA and India to fulfil its remaining 80 percent of the demand.

- Organized sector entry in wheat milling and food retailing has triggered a surge in wheat milling and selling of branded wheat flour with around ten reputed, large wheat millers in the wholesale and retail flour segment. Private sector import comprises ~50 percent of the total wheat imports.
- Value-added products of wheat remain dominated by the bread and baking section, consuming 60 percent of the flour and the remaining in whole wheat/brown wheat flour. Estimated wheat milling capacity of the country (organized and unorganized) is ~6 million MT.

Nepal

- In 2016, Nepal recorded wheat acreage of 0.73 million Ha with the quantum production of 1.74 million MT and average productivity of 2.5 MT/Ha. Though area (0.66 million Ha) and production (1.18 million MT) have not increased tremendously from 2000, due to geographic size of the country; there has been ~39 percent significant yield gains (about 39 percent since 2000).
- Despite recording significant varietal development and subsequent genetic gains in wheat, SRR in Nepal for wheat remains comparatively lower at 14 percent than other parts in South Asia. There remains a considerable gap between production and uptake of seeds by farmers.
- Though the formal wheat seed market in Nepal is estimated to be ~8.1 million USD, the immediate potential with improved uptake by the farmers is expected to be ~20 million USD (assuming an improved SRR of 30 percent).

Genetic Gains in Nepal

- NARC acts as a primary institution to source germplasm for continuous varietal development where key source linkages are from CIMMYT Mexico (44 percent); India – mainly CIMMYT India and ICAR (30 percent) and local germplasm (26 percent).
- Private seed sector is almost non-existent in wheat research; however, it plays a crucial role in seed multiplication to later generation seeds.
- With 43 varieties of wheat released until 2017, 30 are currently in vogue nationally.
- Currently, Nepal's research priority is focused on multiple disease resistance towards yellow rust, leaf rust, foliar blight, loose smut, powdery mildew and Karnal bunt, and abiotic factors such as terminal heat tolerance, drought tolerance, amber colour and lodging.
- With a robust varietal development pipeline for each region and given the achievements so far, wheat varieties in Nepal have gained resilience to major outbreaks like Ug99, rust, foliar blight and blast (pipeline). Nepal has nine varieties resistant to Ug99, three varieties resistant to leaf rust, and five yellow rust resistant varieties where national coverage of wheat for rust-resistant varieties stands at ~ 40 percent.

Seed System in Nepal

- Current quantum for breeder seed is ~63 MT and for certified seeds is ~11000 MT.

- Breeder seed production of wheat remains entirely within the public sector whereas, there is significant involvement of both public (DADO, STC and NSC) and private sector players (~22), farmers' cooperatives and other stakeholders in the foundation and certified seed production.
- The emergence of private seed players in wheat under Nepal's seed system happened during 2002 to 2007 with five players engaging in multiplication and distribution. The number has currently grown to around 22 private players
- Informal wheat seed exports account for ~1000 MT annually where, Gautam, NL 297 and Bhrikuti varieties of Nepal are in high demand in the bordering states of Uttar Pradesh and Bihar (in India).

Value Chain - Nepal

- With increased domestic consumption of wheat, private wheat processing industry picked up from 2005 to 2017 leading to ~20 sizable players in branded wheat products.
- With limited home-grown wheat production, ~60 percent of the wheat for private sector processing comes through organized and unorganized channels from India whereas, ~40 percent is procured from domestic markets through aggregators or traders.
- Processed wheat is primarily used for packaged whole and refined flour and extruded products like noodles, pasta and baked goods.

Bhutan

- Bhutan currently produces 2683 MT of wheat from 1465 hectares that meets the partial domestic market needs. Bhutan has focused on wheat over the last eight years with active collaboration with countries such as India, CIMMYT and Nepal.

Genetic Gains - Bhutan

- A holistic approach for adoption of improved varieties and agronomic practices will drive wheat production in Bhutan over the next decade.
- Accelerated evaluation of adaptability of elite germplasm from CIMMYT and SAARC nurseries will be critical to improve the germplasm pool and enhanced varietal release in Bhutan. There is an effort to plant wheat in the Terai region with the identification of suitable germplasm.
- Need for quicker varietal improvement to bring significant acreage under multiple promising varieties is crucial to drive enhanced production and continued resistance.
- Global collaborations, exposure at international arena and research capacity enhancement have triggered the release of rust resistant wheat variety in Bhutan in 2014 after a period of 20 years

Seed Systems - Bhutan

- Availability of quality seeds of improved varieties with high yielding, disease resistant traits complemented with adoption of desired agronomic practices will be the key to the improved wheat production.





Preamble

Wheat (*Triticum* sp.) is the most important cereal crop in South Asia based on acreage planted. It is the key staple in diets primarily in the north and north-western parts of India, Bangladesh, Nepal and Bhutan. Wheat belongs to the family Poaceae (Gramineae) and includes major crop plants such as wheat, barley, oat, rye, maize and rice.

In 2016, wheat was grown globally on an area of 220 million Ha with production of 750 million MT. World production has increased from 673 to 749 million MT over a period of five years at CAGR of 2.16 percent. The average productivity has also grown over the years, from 3.09 tons/Ha in 2012 to 3.4 tons/Ha in 2016¹.

India, Nepal, Bangladesh and Bhutan altogether produced about 96.59 million MT (2016) of wheat covering 31.43 million Hactares thus, emerging as a quantum producer of wheat.

Table 1: Wheat grain scenario in South Asia – Growth in past decade²

Countries	Area (million Ha)				Production (MMT)				Yield (MT/Ha)			
	2000	2005	2010	2016	2000	2005	2010	2016	2000	2005	2010	2016
Bangladesh	0.83	0.56	0.38	0.45	1.84	0.98	0.90	1.35	2.21	1.75	2.40	3.03
India	27.49	26.38	28.46	30.23	76.37	68.64	80.80	93.50*	2.78	2.60	2.84	3.09
Nepal	0.66	0.68	0.73	0.75	1.18	1.44	1.56	1.74	1.79	2.07	2.13	2.50

*Production reached 96 million tons in 2017 (Indiastat)

Source: FAOSTAT and countrywide annual reports from respective Ministries of Agriculture, 2016

India is the second largest wheat-producing country in the world and the first in South Asia, with an annual production of about 96 million MT (2017). China stands first with 252 million MT. This region has apparently taken over the production of wheat from the USA, with US annual production going down to 55 million MT, within an area of 19 million Ha³.

South Asia region enjoys a strategic position as the largest contiguous wheat producing region in the world and has high regional connectivity and interdependency. Wheat has always been an essential crop for this region. It is a key staple and drives region's food security. Wheat provides about 20 to 24 percent of the protein and the calories consumed by the 1.6 billion people living in the South Asia. The increasing population of this region puts pressure on these countries to increase the production of wheat by 2 to 2.5 percent every year to feed the growing population⁴ Since there is little scope to expand the area under production, developing an approach to improve the yield from the given land becomes inevitable. Thus, developing new genotypes targeted for South Asia that are more productive and tolerant of biotic and abiotic stresses is the need of the hour.

¹ INDIASTAT, Accessed on February 22, 2018

² FAOSTAT, Accessed on March 18, 2018

³ INDIASTAT, Accessed on February 22, 2018

⁴ Leonard P.Gianessi, International Pesticide Benefits Case study No. 106, October 2014

India alone saw a tremendous increase in area, production and productivity, accounting for the largest producer of wheat in South Asia. In the last 10 years, it has been observed that the area under wheat production has gone from 28 million Ha in 2006 to 30 million Ha in 2016-17, while output rose from ~76 million MT to ~96 million MT in 2016-17. Neighbouring countries like Bangladesh, Nepal, and Bhutan depend on India for securing quality wheat for processing, seeds for sowing, and improved research materials for variety development.

Production scenario in India

Originally, *Triticum sphaerococcum*, commonly known as Indian Wheat was widely cultivated in the country but was gradually replaced by present-day species, *Triticum aestivum* (bread wheat), *Triticum durum* (macroni wheat) and *Triticum dicoccum* (emmer wheat). Figure 1 captures the wheat grain production in India so far.⁵

India ranks second in terms of cultivable area and wheat production after China, with 30 million Ha and 96 million MT. The average productivity is 3.2 MT/Ha which is lower than Germany (9.3 MT/Ha), France (7.8 MT/Ha), China (5.3 MT/Ha) and Ukraine (4 MT/Ha).

Production scenario in Bangladesh

Wheat planted area and production for 2014-15 have been revised to 437,000 hectares (0.4 million hectares) and 1.34 million tons, respectively. In 2017 to 18 fear of wheat blast dissuaded some farmers from planting wheat. If favourable weather conditions persist, 2017/18 wheat crop is forecast to reach 1.3 million tons from 0.42 million hectares of land. Wheat accounts for about 12 percent of total cereal consumption; it is the second most important food staple in Bangladesh after rice. Figure 2 showcases the dynamics of wheat grain in Bangladesh^{6,7}.

Figure 1: Historical performance of wheat in India

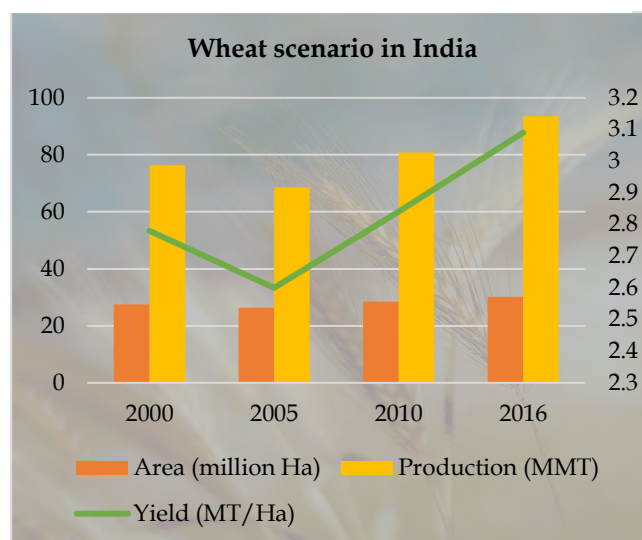
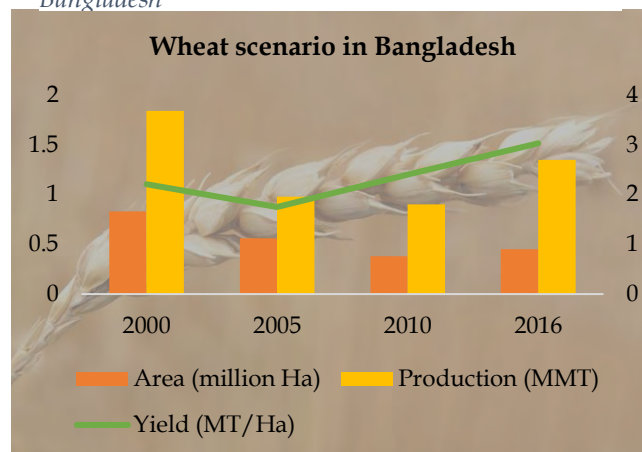


Figure 2: Historical performance of wheat in Bangladesh



⁵ INDIASTAT, As Accessed on March 25, 2018

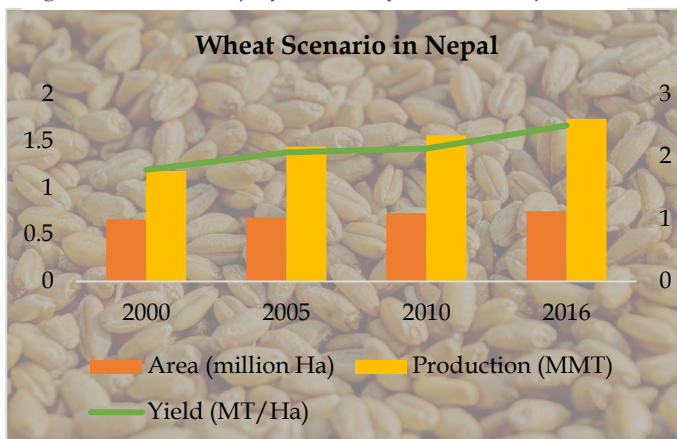
⁶ FAOSTAT, As accessed on March 10, 2018

⁷ Bangladesh Bureau of Statistics, 45 years Agriculture Statistics of Major Crops (Aus, Amon, Boro, Jute, Potato & Wheat), 2018, Pg.193

Production scenario in Nepal

Wheat forms the third most important crop in Nepal after rice and maize, both in area and production. In 2016, wheat acreage was 0.75 million Ha and production stood at 1.74 million MT. The average national yield was recorded at 2.5 MT/Ha in 2016. An overview of wheat grain in Nepal is captured in Figure 3⁸.

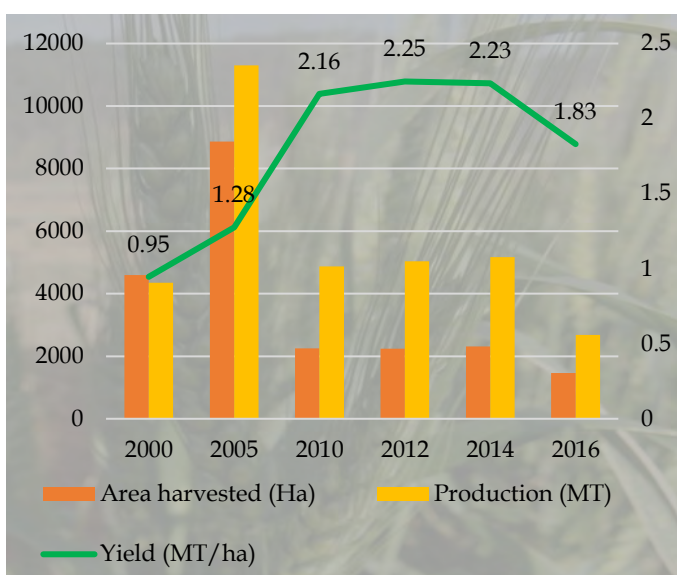
Figure 3: Historical performance of wheat in Nepal



Production scenario in Bhutan

Wheat is the third most important cereal crop in Bhutan (in terms of area and production) after rice and maize, grown in all zones of Bhutan ranging from 300 to 2500 meters AMSL. It is cultivated in an area of 1,465 Ha with a total production of 2683 MT⁹. However, in the recent years, the productivity has been declining and has reduced to 1.83 tons/Ha in 2016 from 2.25 MT in 2012. The primary reasons contributing to the low declining productivity are limited varietal options, weak agronomic practices and losses due to diseases. Further, poor seed quality was also attributed to low average yield in Bhutan¹⁰.

Figure 4: Area, production and productivity of wheat in Bhutan



⁸ Ministry of Agriculture Development, Government of Nepal, Statistical information on Nepalese Agriculture, 2014/15, Area, production and yield of cereal crops in Nepal, pg. 5

⁹ FAOSTAT, Accessed on April 2, 2018

¹⁰ Neuhoff, D., Tashi, S., Rahmann, G. and Denich, M. (2014). Organic agriculture in Bhutan: Potential and challenges; *Organic Agriculture* 4:209–221.





INDIA



Part 1 – India

Element 1: Genetic Gains in India

Introduction of genetic gains

Indian wheat production and productivity increased over the years from 69 million tons in 2000 to around 98 million tons in 2017 and 2.7 MT/Ha to 3.2 MT/Ha, respectively¹¹. This is a result of strong research in breeding that resulted in high yielding and disease resistant varieties, with improved quality of grain. Other factors which contributed towards increasing production and productivity are better production techniques, increased SRR and various crop development programs like National Food Security Mission (NFSM) and Rashtriya Krishi Vikas Yojana (RKVY), along with an increase in minimum support price for the grain.

The table below captures the prominent varieties and common traits that have been developed in wheat since 1991. As observed below, the focus has gradually shifted from quantity to quality improvement, terminal heat tolerance, Adult Plant Resistance (APR) and Durable Rust Resistance (DRR), Karnal Bunt Resistance (KBR), genetic adaptation of wheat to salt tolerance, genetic bio-fortification and hybridization. Improving the yield parameters in varieties and introducing disease and pest resistance were the key contributors to the introduction of genetic gains.

Table 2: Historical landmark and dominating wheat varieties with their traits¹²

Timeline	Landmark varieties	% Coverage	Traits observed
Pre 2008	PBW 343, Raj 3765, PBW 373, Lok 1, C 306	85%	Resistant to rust (brown, yellow) and Karnal bunt
2008-2012	PBW 502, PBW 550, DBW 17	65%	Moderate resistance (PBW 502- susceptible to loose smut, DBW 17- new races of yellow rust susceptible)
2012 Onwards	HD 2967 (40-45% area), HD 3086, PBW 725, PBW 677	75%	Better resistance against all rusts and leaf blight, Karnal bunt and loose smut; some varieties with better protein content, bread making and milling properties

Most of the popular wheat varieties lost genetic resistance to the detrimental diseases, like rust, leaf blight and Karnal bunt, and thus had to be replaced with better and more resistant varieties. Popular varieties like PBW 343, tested positively susceptible to Ug99, were rapidly replaced by new varieties that were resistant to stem rust and mitigated the risk of diseases like karnal bunt and leaf blight with improved yield potential. The replaced variety, if derived from the previous parent variety, had a shorter life cycle as observed in case of PBW 550 which was derived from PBW 343 and only had a short life cycle of two years.

¹¹ INDIASTAT, As accessed on 4th February , 2018

¹² Sathguru compilation

Key research focus for genetic gains

Research focus on developing varieties suitable for abiotic factors has taken priority in the last decade in India: In wheat cultivation, high temperature and low water availability greatly affect yield. Some of the key trends observed in abiotic stress mitigation are:

1. Many heat tolerant varieties like DBW 14, DBW 16, RAJ 3765, Lok 1, GW 322 are emerging as popular varieties in India, and planted on a large scale; and research is further focused on developing more such heat tolerant varieties.
2. Drought tolerance became a vital trait to focus on because of changing climatic conditions and decreasing water table levels.
3. Delayed sowing induced: stress due to changes in crop rotation.
4. Restricted irrigation due to depleted water levels.
5. Increasing nitrogen use efficiency due to rising input costs and pollution effects, and short duration varieties.
6. Reducing seed rate

Research focus on developing varieties suitable for nutritional improvement: With the increasing preference of consumers for a more nutritious diet, the wheat researchers are targeting nutritional improvement for genetic gains. The major targets of quality improvements are increasing protein content, increasing essential amino acids such as lysine, and increasing high molecular weight gluten to improve breadmaking quality and modifying starch composition. Private companies are working towards increasing protein content to 13 to 14 percent due to consumer demand for nutritionally enhanced wheat flour¹³. Still, some farmers are growing old varieties like Lok-1, C-306 because of their good breadmaking quality and limited premium price advantage for these older varieties.

Hybrid wheat: There is continued focus on the part of private companies to develop hybrid wheat with limited success so far. Hybrid wheat occupies a niche segment in commercial wheat seed production compared to other cereals. Although there are many advantages of wheat hybrids such as the potential for higher yield, better grain quality, fewer input requirements and adaptability to less-favourable, semi-subsistence environments, the challenges remain for commercial introduction of hybrid wheat; limited heterosis has been accomplished so far. An indication of a molecular breakthroughs with potential for the introduction of hybrid wheat in South Asia by the private sector remains. The hybrid development for the north-western India area is current focus because there is an ample scope of yield enhancement in this region. Syngenta has announced its launch of hybrid wheat, first in Western Europe and then in India by 2020, and has made a significant commitment of resources for its development.¹⁴ More research is needed to increase the effectiveness of hybrids in different wheat growing regions across the country.

¹³ Based on primary interaction with private players

¹⁴ Business Line, published on April 15,2016

Future trends and drivers:

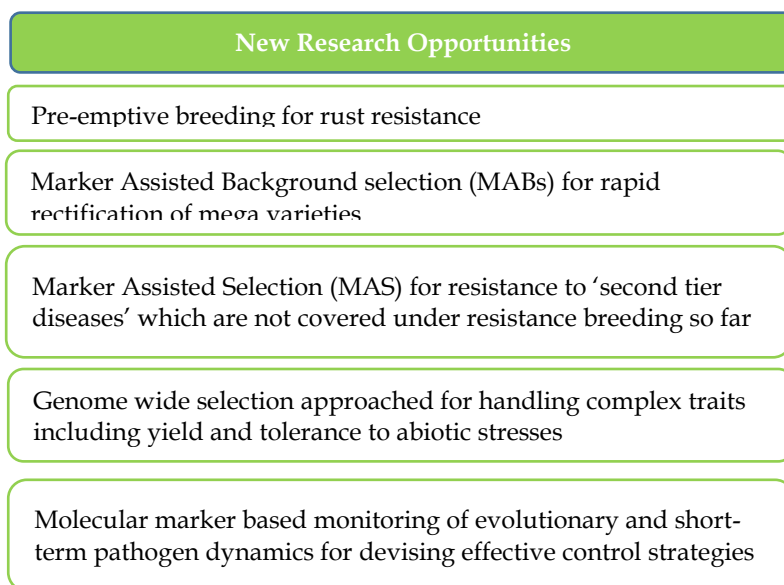
Research focus on developing varieties suitable for climate change:

On an average, around 32 to 39 of the variability in wheat yield is caused by climate variations. This translates to annual production fluctuations of ~9 million MT¹⁵. The Intergovernmental Panel on Climate Change predicted a 20 percent reduction in the annual wheat production by 2030. A UN report (Anon, 2011) stated that the earth would be warmer by 2.4 degree Celsius by the year 2020 and the crop yield in India may fall by up to 30. The breeding programs should be focused on developing heat-tolerant varieties. Higher temperature immediately after an anthesis result in a decrease in productivity. Low temperatures during the initial stages and high temperatures at later maturity stages leads to the completion of a major part of the wheat growth cycle. Enhanced membrane thermos stability can incorporate late heat tolerance, significant canopy temperature depression, increased stay-green habit and better stem-reserve mobilization rates. Earlier the problem was restricted to the north-eastern plain zone but slowly, this is affecting the north-western plain zone also, and that too in an erratic manner because of changing climatic conditions. Current breeding techniques by both the public and private sectors involve shuttle breeding, i.e. evaluating the breeding material alternatively at locations in the north-eastern plain and the north-western plain, focusing on heat adaptive traits, and fitting in the cropping system and the duration of the growing season of Punjab and Haryana.

New technologies

The newer tools and technologies like genomic selection and; molecular marker technologies provide a range of opportunities for breeders to improve their selection process. These tools accelerate the breeding process by reducing the cycling time as it is based on genomic evaluations in which selections can be generated in a very short period, rather than based on phenotypic evaluations in the fields which take a number of years. The time and cost will be significantly reduced due to fewer materials that need to be advanced for replication and multi-location testing.

Figure 5: Futuristic trends and opportunities in wheat research - India



¹⁵ Deepak K. Ray, James S. Gerber, Graham K. MacDonald, Paul C. West, Climate variation explains a third of Global crop yield variability, 22 Jan, 2015

In Vision 2050 document, IIWBR has mentioned that new technologies like RNAi, Targeted mutagenesis, Micro RNA, Cis-trans techniques in wheat will also be utilized.

A high throughput genotypic platform is essential for genomic selection. The limiting factors today in establishing such platforms are the technology barriers and high establishment costs. For such a platform to be established, a public-private partnership model should be harnessed for greater genetic gains in wheat and food security in India.

Element 2: Seed Systems

Currently, the Indian seed industry is valued at USD 3.2 billion and is growing at a CAGR of 8.4 percent.¹⁶ The wheat seed market in India is around 3 million MT as the seed rate is 100 Kg/Ha and area under wheat production is 30 million Ha. Of this, approximately 60 percent is the informal seed system which covers farmers' own saved seeds and local non-branded seeds¹⁷. Only the 40 percent is the formal seed system which accounts for 1.2 million MT, consisting of all public institutions and private enterprises¹⁸.

Wheat seed value chain

The early stages of the Indian wheat seed value chain viz. germplasm sources, research, production of nucleus seed and breeder seed are all dominated by public sector institutions. It is also observed that the downstream activities viz. breeder seed multiplication to the foundation and certified/truthfully labelled seed, and distribution to farmers has higher participation by private sector entities. Various stages in the organized wheat seed value chain with the participation share of the public and private sectors are provided in the illustration below¹⁹.

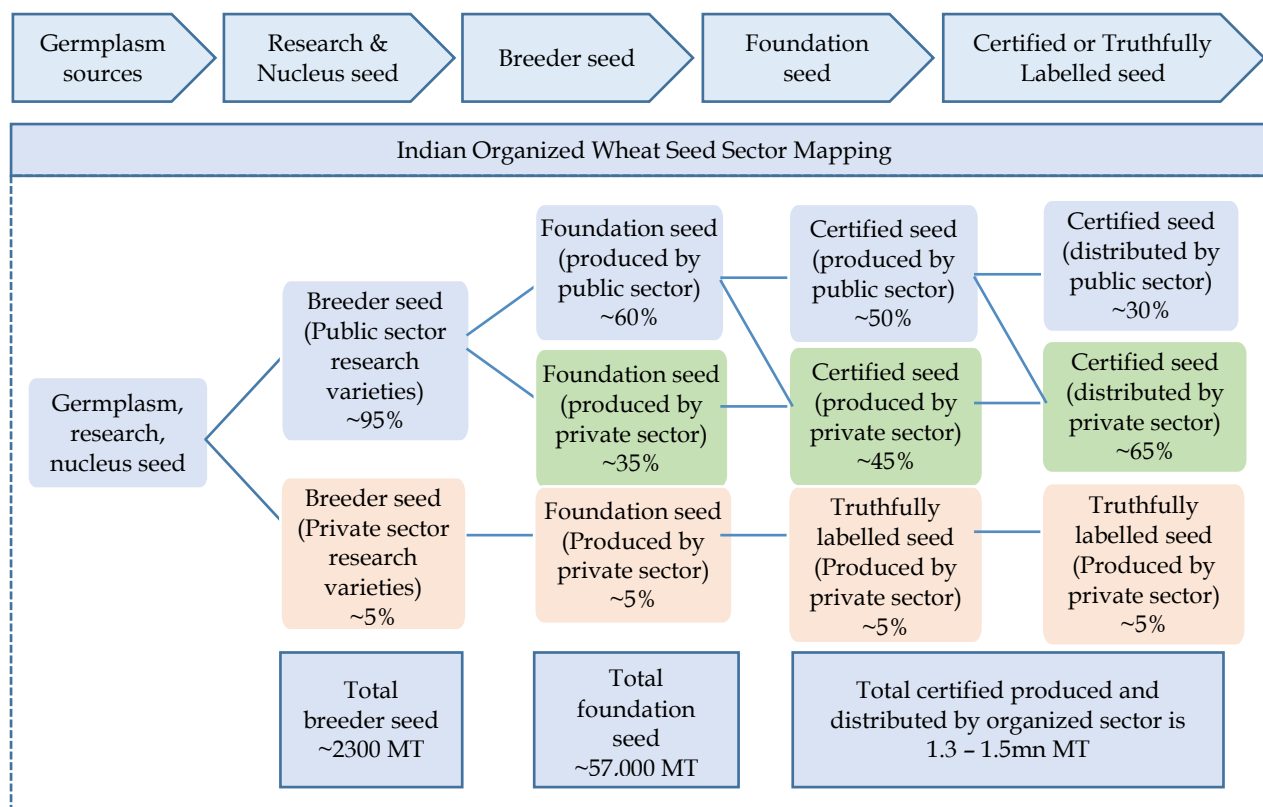
¹⁶ Kulshrestha, Indian hybrid seed makers see a fifth of cotton seed return, 2016, Economic Times

¹⁷ Data with consensus from primary sources & Estimations by authors

¹⁸ Kumar, P. R. (2017). Quality status of wheat seed in eastern India and the early vegetative growth of wheat (*Triticum aestivum* L.) In relation to size of seed.

¹⁹ Sathguru compilation

Figure 6: Private sector involvement at various stages of wheat seed value chain



Presence of Public and Private Sectors across the Seed Value Chain

Before 2005, research activities in wheat breeding and dissemination of seeds to farmers were predominantly carried by ICAR research institutions and state agricultural universities. However, over the last decade, research opportunities created in terms of adoption of public research material with the further generation of own breeder lines, increased the involvement of the private sector in wheat research. Private sector research varieties (current market share of ~5 percent) are growing at a rate of 8 to 10 percent²⁰ year-on-year because of an increase in farmers' awareness and accomplishment of higher SRR due to broader market accessibility by farmers. Some of the challenges that have limited private sector investment in wheat research in the past were a) high research costs b) uncertainty of research outcomes) elapsed time before financial returns d) limited success of wheat hybridization programs and e) subsidized sale of wheat seed by the public sector. Farmers reuse their seed, and there was very little practical intellectual property for introducing new varieties. However, the registration of wheat traits for protection by the Protection of Plant Varieties and Farmer's Right (PPV&FR) Authority of India has triggered private sector focus on protection of wheat varieties. The industry have witnessed a number of plant varietal protection (PVP) filings by the private sector with (PPV&FR) Authority of India in the last five years.

During the initial years, the downstream activities of the Indian seed industry were dominated by two national organizations, the National Seeds Corporation (NSC) established in 1963 and the States Farms Corporation of India Limited (SFCL), formed in 1969 which were

²⁰ Based on primary interactions with private players

involved in producing breeder, foundation, and certified seeds of high yielding varieties. During the 1970's and 1980's, 13 State Seeds Corporations (SSCs) were formed to take over the role of the NSC in individual states.

The private companies slowly emerged in the late 1990s since the NSCs, and the SSCs gradually became defunct due to rising demand and the fixed costs set by the government, which did not always reflect the actual cost of production and distribution. The presence of private players increased after 2003 to 04 after truthfully labelled seeds were allowed. The private sector was able to fine tune seeds distribution as per regional demands and also meet the rising demand for seeds thus, emerging as a key player in the downstream activities of multiplication and distribution due to the following reasons:

- Lack of capacity in public sector institutions to meet the high demand for seed at the level of over 1 million MT annually.
- Wheat is a voluminous seed (seed rate of 100 Kg/Ha). Logistically, it is advantageous to do the seed multiplication/processing closer to sales/consumption areas. Therefore, a lot of small wheat seed multiplication companies have mushroomed all over wheat growing regions that cater only to their catchment area.
- Wheat crop is seen as a very stable and assured commodity. Thus, the wheat seed is a stable business with low to moderate returns but assured sales

The private sector in seed multiplication and distribution stages is currently highly fragmented and consists of numerous small companies. Every year more than 100+ companies approach the National Seed Association of India (NSAI), and place their breeder seed requirement for certified seed production and distribution. While these smaller seed companies do not have the capacity to invest in research, they do find it profitable to secure breeder seed from public sources, multiply certified seed and deliver it to farmers located within their region. We are beginning to see consolidation of these smaller seed companies by larger players. Future trends indicate the emergence of medium-sized entities that will be dominant in seed multiplication and distribution regionally.

Some states have a stronger presence in private sector. There is a higher concentration of private seed sector in Maharashtra. Many of the top 10 companies, including MAHYCO, Ankur, Ajeet and Nirmal, are present in the state, since it is a well-known seed hub in India. Punjab and Haryana too have high private sector participation (more than half the companies in the indent list are from these two states). The stage-wise mapping of major public and private stakeholders in the seed value chain is explained in Table 3 below.

Table 3: Stage-wise major public and private stakeholders and their share

Stage in wheat seed value chain	Public sector entities (Public research institutions, SAUs, Gov. agencies)	Private sector entities (Private companies)
1. Germplasm sources Public sector ~100% Private sector ~0%	The international entity with wheat seed germplasm source is CIMMYT. Most Indian public research entities also have their own germplasm sources	None known in India.

	<ul style="list-style-type: none"> - CIMMYT (150,000+), IIWBR (30,000+), IARI & SAUs (25,000+) - Other international centres like ICARDA, US Land grant universities, Australian University sources etc. 	
<p>2. Research & Nucleus seed</p> <p>Public sector ~95%</p> <p>Private sector ~5%</p>	<p>There are many public-sector research organizations involved in wheat research. Few well known are:</p> <ul style="list-style-type: none"> - IIWBR, Karnal; PAU, Punjab; IARI, (many locations in India); CCS HAU, Haryana; JKVV, Indore; UAS, Dharwad 	<p>The number of private sector investors in wheat research is increasing such as: Mahyco, JK Agri, Eagle Seeds, Shriram, Rasi, Ajeet, Ankur and Nirmal</p>
<p>3. Breeder seed</p> <p>Public sector ~95%</p> <p>Private sector ~5%</p>	<p>Public sector research institutions produce breeder seed on their own farms.</p> <p>They sell the breeder seed through government indent process.</p>	<p>The larger private sector players involved in own research produce breeder seed in their own farms.</p> <p>Most other private sector players participate in government indent process and apply for breeder seed from public institutions.</p>
<p>4. Foundation seed</p> <p>Public sector ~60%</p> <p>Private sector ~40%</p>	<p>Public sector research institutions produce limited foundation seed for their autonomous seed distribution programs in their own farms or through contracted farmers and companies. Other government agencies like National seed corporation, state seed corporations and cooperatives like IFFCO, KRBHCO, and Tarai get breeder seed through indent process and multiply the same to produce foundation seed.</p>	<p>All private sector companies are very involved in the multiplication of breeder seed to foundation seed. Most use public research varieties. Few into research (see above, point 2) have their own varieties</p>
<p>5. Certified seed/ Truthfully labelled seed</p> <p>Public sector ~50%</p> <p>Private sector ~50%</p> <p>* Share of the private sector in final seed distribution is higher, ~70% because government agencies use private dealers to reach seed to farmers.</p>	<p>Public research institutions and other organizations (see above, point 4) that took breeder seed, actively multiply the same to produce and sell certified seed (certified implies notified varieties).</p>	<p>Large private sector companies sell their own researched varieties as truthfully labelled (implies non-notified varieties or non-certified seed production), probably because volumes are still low to justify costs of certification.</p> <p>Many private sector companies multiply foundation seed of public research varieties and sell as certified seeds/ truthfully labelled seeds to farmers.</p>

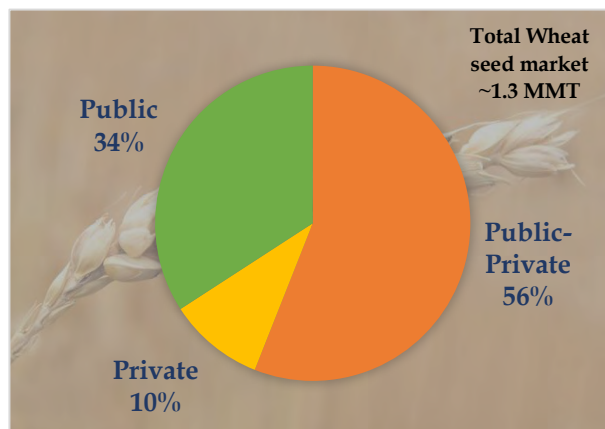
Source: Primary interaction with stakeholders and internal analysis

Seed multiplication and distribution

The seed multiplication and distribution landscape is a mix of large seed corporations, cooperatives, large and small private seed companies. There are lacunae in the published information to map the entire wheat seed distribution landscape (Fig 6)²¹, partly due to the emergence of the

private sector in wheat seed multiplication and distribution over the last decade. Indian wheat seed multiplication and distribution is dominated by a unique partnership of the public and private sector. From total dominance of public sector, the private sector engagement in the multiplication and dissemination has brought focus to public-private partnership with 56 percent of total share of seeds delivered in public-private partnership mode. National Seed Corporation and some State Seed Corporations still play a significant role in the wheat seed market with volumes of 50,000 MT delivered by some of the State Seed Corporations. The public seed corporations cumulatively provide about 50 percent of the total wheat seed. Over the last decade, national fertilizer distribution companies have taken an increasing interest in delivering wheat seed as a complimentary product to fertilizers. In 2008, the ICAR–Cornell–Sathguru under the umbrella of the Durable Rust Resistance in Wheat (DRRW) project convened public and private wheat seed producers, and large fertilizer companies and provided an opportunity for them to explore the potential for their engagement in wheat seed distribution. Many large fertilizer companies capitalize on their ability to invest working capital and across their extensive distribution channels to undertake wheat seed dissemination. Currently, large fertilizer companies such as the Indo Gulf, Tata Group, DCM Shriram, IFFCO and KRIBCO (about 8 percent) are engaged in wheat seed distribution with 5 percent market share in terms of volume. Big private sector seed companies (many with their own research varieties) like MAHYCO, JK Agri, Eagle, Krishidhan, Nuziveedu, Ajeet, Ankur, Green gold, Rasi, Nirmal – make up about 8 percent of the market. The rest of the 34 percent is produced and distributed in public-private partnership mode with several small seed companies engaged in the multiplication of public varieties and distribution Larger seed companies and fertilizer companies may take a more dominant presence in the market over the next ten years. Based on investment envisioned by large agricultural input entities and stand-alone seed entities, this share would move to about 40 percent by larger companies in the next few years, with incremental shares to be captured by State Seed Corporations and micro enterprises engaged in seed delivery not backed by internal research.

Figure 7 Wheat seed market in India



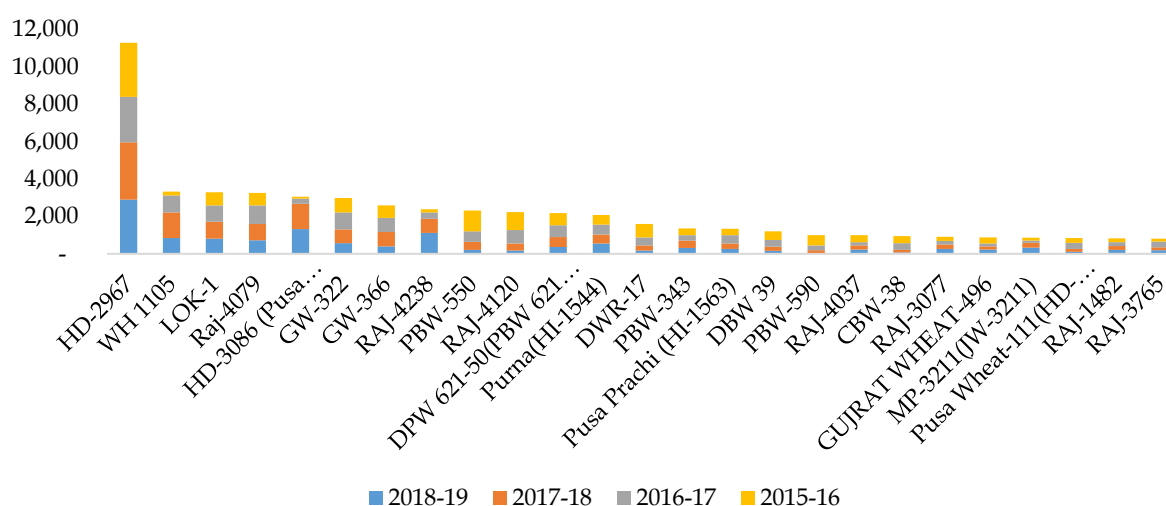
Increasing PVP filings implies increasing breeding activities. The PVP filings as on this writing are 366, out of which 42 percent filings from farmers, 51 percent from public institutions and only

²¹ Primary Interviews and calculations by the authors

7 percent are from private players²². Major players among public institutions for filing PVPs are the Indian Council of Agricultural Research (ICAR), Punjab Agricultural University (PAU) and Indian Agricultural Research Institute (IARI), Dr. Panjabrao Deshmukh Krishi Vidyapeeth, National Agri-Food Biotech Institute and Chaudhary Charan Singh Haryana Agricultural University. There are several thousand extant lines in the public research which are contemplated to be registered with the PPV&FR Authority but the process of registration has been slow. The goal of the public research institutions to file PVP registration is to let the private sector deploy their lines as parental lines with structured benefit sharing agreed upon for the private sector to pay royalties to the public sector. The PPV&FR authority has also developed capacity for accelerated DUS tests for wheat and in the future we see a surge of filings from the public and private sector for the current pipeline products (advanced breeding lines) to be registered with the PVP Authority. Among the private players Ajeet seeds, MAHYCO, JK Agri-Genetics, Nirmal seeds, Green Gold, Ankur seeds, Krishidhan seeds, Eagle seeds and Basant Agrotech have filed registrations with the PVP Authority. Private companies have started filing from 2007 which clearly indicates that breeding programs are going with their own germplasm, with the pace of investment accelerating from 2010. 92 percent of the PVP is filed for bread wheat. Filings for Durum and Diccocum wheat started in 2013. So far, 26 filings are done for Durum wheat and 5 for Diccocum wheat.

Top 25 varieties for the period of 2015-18 does not indicate new blockbuster varieties. The HD 2967 variety from IARI is the one with the highest demand - but not high enough to deem as a landmark). Other important varieties are WH1105, Lok-1, Raj 4079. It is estimated that planted area of HD 2967 is below 40 percent. Emerging varieties are HD 3086 and Raj 4238 (Figure 7)²³.

Figure 8: Top 25 Wheat Seed Indent Varieties 2015-18



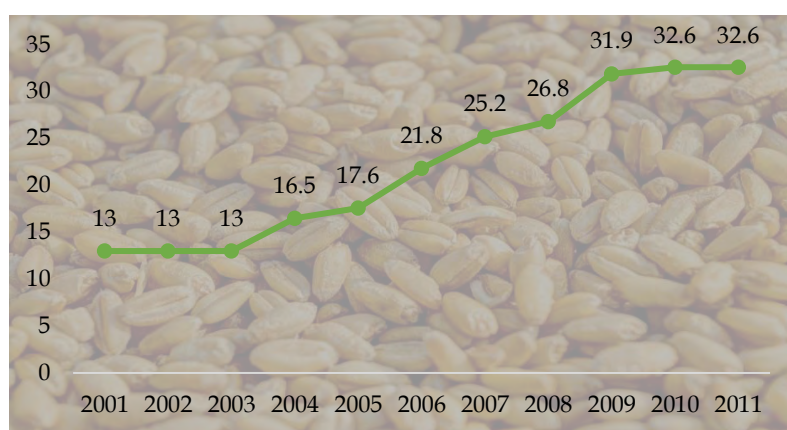
²² Protection of Plant Varieties and Farmer's Right (PPV&FR) Authority of India , as on December 30, 2017

²³ Seednet India Portal, Government of India, as on December 5, 2017

It is interesting to note that, although Lok 1 has never been a landmark variety, it has been one of the favoured long-standing varieties in Central India since its release in 1982. Broadly speaking, all the top varieties have excellent resistance to rust and have good yield potential. This is perceived as a trend going forward – no blockbuster variety may dominate the market with shares of over 50 percent. This is due to the fact that the public research institutions continuously bring out improved varieties in succession. Also, the private sector brings in more research lines with differentiation that they would like to demonstrate on the field for their proprietary lines. Starting in 2008, the potential susceptibility to Ug99 by mega varieties adopted until then has also cautioned the market not to overemphasise one variety that might gain susceptibility over a period. Better to provide a choice of varieties that are benchmarked to perform well. The influence of millers and the wheat value chain has also broadened the demand for greater diversity in wheat varieties grown by the farmers. This has further been described later in the report.

Current SRR could well be above 40 percent compared to the last official SRR figure of 32.6 percent (2011). An extract from an ICAR report of 2015 gives the SRR of ~31.2 percent in 2011 based on seed multiplication ratio (SMR) of 20 and breeder seed indent data. Our extensive interviews suggest that the SMR could be higher at about

Figure 9: SRR (%) growth in India for wheat



~25. Assuming SMR to be 25, the expected SRR in the above would have been calculated to be 48.8 percent²⁴. This clearly shows the high sensitivity of SMR assumption on SRR calculation. Given average assumptions of breeder seed indent of 22,000 quintals, wheat sown area of 30 million Ha, seed rate of 100 Kg, and SMR of 25, it is expected for the current SRR to be 45.8 percent. This higher SRR figure also seems to be more in line with trends heard during primary interviews. Further, many farmers in Punjab are replacing seeds every year, translating into 100 percent seed replacement. The government initially motivated farmers to replace their wheat varieties every third year by supplying subsidized seeds, but farmers have gone far beyond that. The reason for planting new seeds every year is that new seeds are less disease prone and saved seeds need much care to maintain high yields. The deep influence of fertilizer companies and some seed companies and their ability to reach farmers season-after-season with seed packs has also triggered farmers choosing an annual replacement of wheat seeds at an affordable price.

Private sector expansion in wheat seed value chain

The private sector favours their private research varieties due to comfortably high margins on the same relative to public research varieties. The price range for new research variety seed range ~INR

²⁴ Calculation: $((\text{Breeder seed indent} * \text{SMR} * 25) / (\text{Area under certified seed in mha})) * 100$

35/Kg. Prices for the old varieties of seed by the private sector is ~INR 25/Kg. The prices for old varieties of seed includes a subsidy from state agencies of about ~INR 20/Kg. The breeder seed price from IIWBR is INR 56.7/Kg. The price for seed farmer is about INR 19.5/Kg. An organic wheat farmer makes around INR 25/kg. The Minimum Selling Price (MSP) for wheat commodity crop is INR 17.35/kg in 2017 - 18. The cost of wheat production is about INR 12/kg (Commission for Agricultural Costs & Prices- CACP C2 cost). An analysis of the price levels suggests that wheat seed multiplication is a profitable business despite low margins, due to very high volume potential.

The share of private sector research is increasing by year. Currently, private sector research varieties comprises around 75 to 80 thousand tons forming ~5 percent of total wheat seed. The main private players with their research varieties are MAHYCO, JK Agri, DCM Shriram, Eagle, Ajeet, Ankur, Rasi, and Nirmal among others. Private sector research varieties are growing at around 8 to 10 percent²⁵. Reasons are many. Due to increasing awareness, farmers are choosing new seed for better yields and more disease resistances. Germplasm access has become easier over the years with the Indian private sector securing germplasm directly from CG centres, international universities from Australia, US Land Grant universities, and Indian public research institutions. In recent years, some contract research companies have been formed that carry out custom breeding in wheat for larger companies. The private sector inclination to invest in wheat research is driven by the reduction in the reach of public seed companies due to their resource limitations and the growing demand for trait focused wheat seeds by farmers to meet the needs of the processing sector and exports. Opening up opportunities in 2003 to 04 for delivery of truthfully labeled seed also triggered significant interest by Small and Marginal Enterprises (SME), private sector seed players to expand their presence in multiplication and distribution. Direct Benefits Transfer in the subsidy program further contributes to an impact by shifting subsidy dispensation to farmers directly rather than to public or private seed companies. A resourceful private sector has also combined credit to farmers with deferred payment at the end of the crop cycle which further enhances farmer interest in their products.

Element 3: Value Chain

Consumer preferences driving value chain transformation

India has high per capita consumption of wheat flour with average per person consumption of about 200 to 250 grams per day, amounting to overall annual consumption of 63.3 million MT (2016). Though wheat grain production in India and the world has been rising, direct consumption of wheat has been declining. Changes in consumer taste and preferences, cost, availability, convenience and demography have a substantial impact on the growth of packaged wheat flour and the food service industry. Urbanization, and the rise in the population of working women are important factors driving demand for processed food consumption. More than 60 percent of the Indian population is young (25 to 40 years) and this significantly influences changing consumption trend. Use of food products like bread, biscuits

²⁵ Based on primary interactions with private players

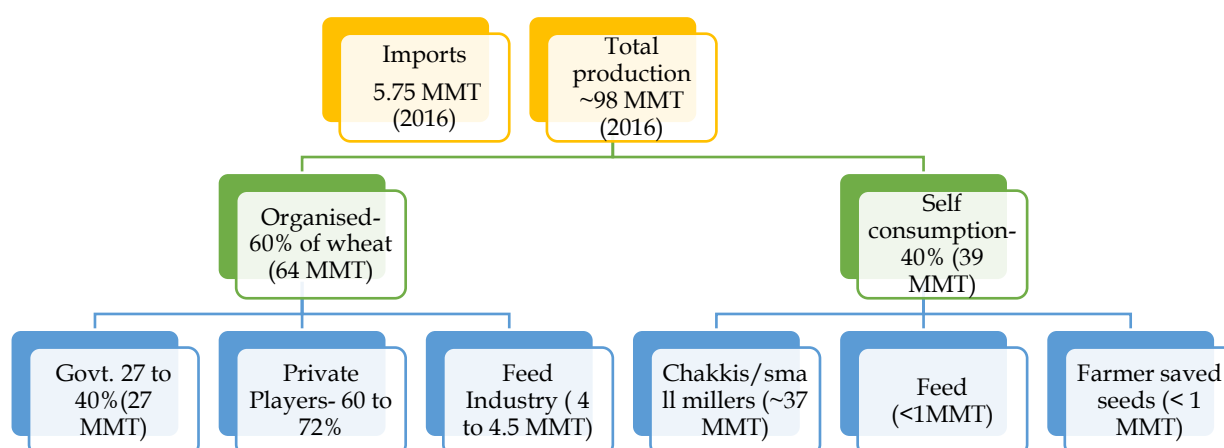
and extruded products like pasta, instant noodles, and breakfast cereals have increased in the past few years, owing to the proliferation of organized retail and foodservice chains.

Driven by the growth of consumption in urban India, the annual growth of packaged wheat flour in India has increased at a rate of around 19 percent²⁶ in the last three years, establishing the highest growth trend in the world. Historically, wheat was milled in traditional local milling units known as Chakkis. However, in the late the 1990s ,big private players such as ITC, General Mills and Cargill entered the market which transformed the Indian milling industry and paved the way for processed wheat products. The branded wheat flour in different forms, including fortified flour, is the most preferred choice of wheat not just in urban India, but in rural India too. During the last 20 years, India has created the second largest incremental wheat milling capacity in the world, transforming the wheat milling industry and wheat flour quality.

Changes in wheat procurement

The entry of multinationals and domestic wheat processing companies (for basic processing and value-added processing) changed the procurement landscape for wheat significantly over the last 15 years. The Food Corporation of India (FCI), the central nodal agency of the government of India and some state agencies procure wheat under a price support scheme. Coarse grains are procured by state government agencies for the central pool as per the direction issued by the Government of India for each of the growing seasons. It is observed that farmers keep about 40 percent of the grains for their household consumption, and sell the remaining 60 percent in the market. Out of the grains entering the organized channel, the government of India roughly procures about 27 percent to 40 percent of the wheat grains traded every year through Food Corporation of India (FCI). The grains procured are distributed through the Public Distribution System (PDS); and the remaining are sold to traders via Open Market Sale Scheme (OMSS). The wheat value chain is further explained in figure 9 below²⁷.

Figure 10: Wheat grain Value Chain- India



MMT: Million Metric tons

²⁶ FnBnews, published on June 30, 2015

²⁷ Sathguru compilation, Exports in the recent past are negligible.

With the entry and growth of private corporations, these large players are now reaching out to farmers directly and offering prices relatively higher than the Minimum Support Price (MSP) offered by the Government, becoming the most prominent buyers of wheat grains in the country. The integrated supply chain model of the large private players for their food products, including atta (ground wheat flour) and packaged food has been instrumental in changing the landscape of the Indian milling industry. Examples include ITC's, the IT-based procurement model of e-Choupal and Tata Kisan Sansars of Tata group. It is said that the FCI that was the largest procurer of wheat grains in the 1990s, is finding it difficult to procure grains/meeting targets.

The import of seeds is regulated whereas the import of wheat for human consumption is permitted through State Trading Enterprises. India imported 5.75 million MT of wheat grains in 2016, which was primarily durum wheat, as India produced only 1 million MT of durum wheat in 2016, with more and more farmers slowly shifting from durum to high yielding non-durum varieties of wheat due to a steady increase in MSP for wheat and lower yield of durum varieties.

Table 4: India's Wheat Trade during 2013-14 to 2016-17²⁸

Year	Export (MMT)	Import (MMT)
2013-14	5.56	0.01
2014-15	2.92	0.03
2015-16	0.61	0.51
2016-17	0.26	5.75

The rising imports of wheat grains explains the increasing private processing capacities and demand for niche quality wheat for specific processing of value-added products. Reasons like low import duty and better quality make it favourable for these large private players to import durum wheat for their processed products, rather than procuring from major wheat producing states and paying a premium. Notably, the southern millers in India find it easy to import wheat since it is more economical due to lower shipment costs than inland transportation cost from the key wheat producing belt of the north.

Element 4: Implications and Synopsis

The development of the food service industry and the rise in food processing industries in terms of baked, processed and extruded goods offers many opportunities for seed companies (public and private) to explore and find new varieties of wheat suitable for secondary and tertiary processing, thus expanding the varietal research opportunity. For instance, the variety HD 3086 became widely famous due to its yield, resistance to diseases and superior quality parameters with protein content (12.5 percent), a sedimentation value (45 ml), best Glu-1 Score (10/10) and good extraction rate (70.5 percent) meeting all the criteria for the superior breadmaking qualities widely preferred in India.

²⁸ Agriexchange, Agricultural and Processed Food Products Export Development Authority (APEDA). Government of India as on April 2, 2018

Private players tend to impact trait and variety adoption based on their milling properties. With value chain influencing the trait adoption, we may observe varietal options gradually decreasing. This also underscores the importance of overall risks of susceptibility at the national level. Thus all the stakeholders need to be educated on changing susceptibility. Although this business-focused, market-driven approach will dominate since millers do not want varieties to change often, we need to slowly shift from a procurement-based model to an integrated model. India currently does not have integrated players across the whole value chain with active involvement from breeding to processing cycle. Even in Western markets, the integrated players are rarely prevalent in France, the US and Australia. Indian private sector majors are involved only in the procurement of desired varieties, which is primarily a market-driven approach. Since the scenario is bound to change, we may see a more collaborative approach among private seed players and private processing players in developing varieties desirable for processing which could shift the research focus to quality improvement (on the model of Cargill and other integrated players).



Bangladesh



Part 2 – Bangladesh

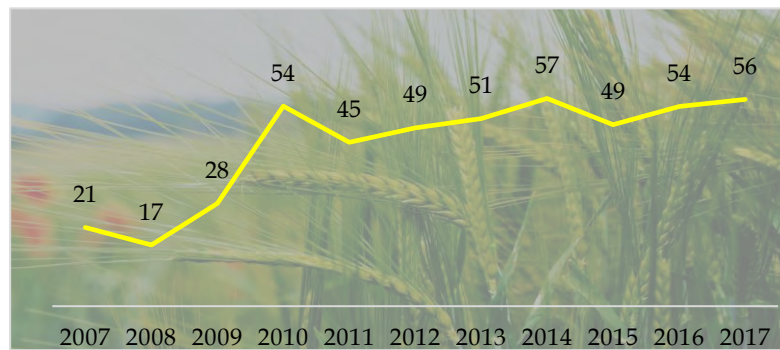
Element 1: Genetic Gains in Wheat - Bangladesh

Over the last 30 years, Bangladesh has moved from complete dependency on imported wheat to developing its public system for research, production and distribution. It is observed that 83 percent of wheat varieties used by the farmers are officially released varieties. SRR for wheat in the country remains comparatively higher (~35 percent) within South Asia. Among the improved or modern varieties of wheat (40), the topmost source linkages were from The National Agricultural Research System (NARS) at 85 percent followed by the Consultative Group for International Agricultural Research (CGIAR), at 47.5 percent and the private sector at 15 percent²⁹.

Mapping wheat seed production dynamics from 2007-2017

Breeder Seed production in Bangladesh, undertaken by the Bangladesh Agricultural Research Institute (BARI), has jumped from 21.4 MT (2007) to 56 MT in 2017³⁰. In the past nine years (2009 to 2017), the Bangladesh Agricultural Development Corporation (BADC) peak production of

Figure 11: Breeder Seed Production – Bangladesh (MT)



wheat seed (Truthfully Labelled Seeds -TLS) reached 26,000 tons with output in the range of 13000 – 26000 tons in this period³¹. However, it has shown a significant decrease in quantity to 9,600 MT in 2015 to 2016 due to fear of blast outbreak in wheat and farmers choosing maize and rice as an alternative to wheat cultivation in the country³². Due to a dip in market demand for wheat seeds from farmers, BADC reported an unsold wheat seed inventory of 47 percent of the Truthfully Labelled Seeds (TLS) produced in 2016 to 17. BADC estimates the demand to improve to 20,000 MT of wheat seeds in 2017 to 18 (certified and TLS seed). The growth in acreage for maize will continue to command the interest of the farmers of Bangladesh, driven by an economic factor of lower price realization for wheat and the continued fear of Blast. Additionally, abiotic stress factors such as terminal heat, shorter winters and erratic rains with high humidity have affected yield levels, resulting in a consequent reduction in farmer income. The booming poultry business offering assured market prices and easy on-farm maintenance of the maize crop are other factors attracting attention from wheat to maize.

²⁹ M. A. Rashid and Tanvir M. B. Hossain, Adoption Of Wheat Varieties In Bangladesh: Expert Elicitation Approach, ISSN 0258-7122 (Print), 2408-8293 (Online), Bangladesh J. Agril. Res. 41(3): 491-505, Sept. 2016

³⁰ Compiled from BARI reports

³¹ Compiled from primary data by BADC

³² Primary interaction with BADC

Wheat varietal development and adoption scenario in Bangladesh – Understanding genetic gains in wheat

Varietal attributes have variations when seen from research focus on pipeline varieties and farmers' preferences while buying seeds.

Among farmers in Bangladesh, few attributes have remained constant since early 2000 which influenced higher adoption of varieties. Yield remained the most important factor for wheat with other preferences moving to resistance to blight and leaf rust. For a decade starting from 2000, **Shatabdi (24.97 percent in 2014)³³, Bijoy (11.06 percent³⁴) and Prodip (28 percent in 2016 to 17³⁵)** remained in strong demand capturing more than 70 percent of the sown area under wheat.

Post 2010, popular varietal attributes that attracted wheat farmers were yield, bold and larger grain, short duration, tolerance to terminal heat stress and lodging, early maturity, tolerance to salinity, tolerance to Bipolaris Leaf Blight (BpLB) and resistance to leaf rust of BARI Gom 25, and BARI Gom 26 released in 2010 met most of these attributes and were well received by farmers with wide adoption. There is also a prevalence of major farmer demand for output traits combined with pest and disease resistance and reduced input traits. Due to a lack of output trait focus, we have witnessed significant import of wheat by all the wheat processors in Bangladesh for meeting their requirement. Combining input and output trait is the challenge going forward for BARI to address in the coming years.

From 2000 to 2017, BARI's research focus for varietal improvement and development of wheat has been captured in Table 6³⁶.

Table 5: Wheat varietal research focus

Research Focus in wheat varietal development ³⁷				
S.no.	2000-2005	2005-2010	2016-2017	Way forward
1	Bipolaris leaf blight (BpLB)	Ug99	Spot Blast	HYV Early maturing
2	Leaf Rust	Bipolaris leaf blight	Leaf Rust	Late planting Tolerant to terminal heat,
3	Heat Stress	Leaf Rust	Drought and Salinity	drought, salinity, and disease resistant to Leaf Rust, BpLB,
4	HYV	Stem Rust	HYV (Equal or higher yielder) Early maturing Late planting	Blast, etc. Bold grains
5		Heat Stress	Terminal Heat stress	

³³ A. Rashid and Tanvir M. B. Hossain, Adoption Of Wheat Varieties In Bangladesh: Expert Elicitation Approach, ISSN 0258-7122 (Print), 2408-8293 (Online), Bangladesh J. Agril. Res. 41(3): 491-505, Sept. 2016

³⁴ A. Rashid and Tanvir M. B. Hossain, Adoption Of Wheat Varieties In Bangladesh: Expert Elicitation Approach, ISSN 0258-7122 (Print), 2408-8293 (Online), Bangladesh J. Agril. Res. 41(3): 491-505, Sept. 2016

³⁵ Primary interaction with BARI

³⁶ Compilation of data from BARI

³⁷ Sathguru Compilation

6		HYV	Tolerant to heat, drought, salinity and disease resistant to Leaf Rust, BPLB, etc.
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Wheat adoption dynamics were in severe turmoil after the outbreak of spot blast in 2016. The blast made some of the most popular varieties in vogue until 2005, i.e. Sufi, Prodip, Bijoy, BARI Gom 25, 26, 27, 28, 29 and 30 highly susceptible to blast. This single event brought change in BARI's research focus to develop blast tolerant/resistant varieties of wheat as an essential trait factor. In 2017, BARI released BARI Gom 31 and BARI Gom 32, with the latter being tolerant to blast. Additionally, these two varieties are high yielding, early maturing and tolerant to terminal heat stress. The latest BARI wheat variety, BARI Gom 33 is proposed for release in 2018 with varietal attributes such as higher zinc expression and resistance to blast. BARI Gom 33, the first blast-resistant variety of wheat in Bangladesh is currently being bulked up for source seed. BARI and BADC will make available certified seeds of this blast-resistant variety to farmers for the 2019 season. Additionally, BARI Gom 33, has white amber and bold grain along with lodging tolerance. The whitish or bleached appearance of flour/bread is one of the most preferred physical characteristics in Bangladesh.

Table 6: Historical wheat varietal release in Bangladesh³⁸

Key highlights - Wheat varieties in Bangladesh ³⁹								
S.no.	Variety name	Year of release	Varietal coverage (%)					Key characteristics
			2012-13	2013-14	2014-15	2015-16	2016-17	
1	BARI Gom 21 (Shatabdi)	2000	35	28	15	13	8	Resistant to Leaf Rust, Spot Blotch
2	BARI Gom 23 (Bijoy)	2005	6	4	10	8	6	Resistant to Leaf Rust, Spot Blotch, Susceptible to WB
3	BARI Gom 24 (Prodip)	2005	39	41	44	35	28	Susceptible to Leaf Rust, Spot Blotch, Wheat Blast
4	BARI Gom 25	2010	6	7	7	12	17	Resistant to Leaf Rust, Spot Blotch, Wheat Blast
5	BARI Gom 26	2010	12	17	19	25	26	Resistant to Leaf Rust, Spot Blotch, Susceptible to Wheat Blast Resistant to Ug99
6	BARI Gom 27	2012	-	-	-	1	3	Resistant to Leaf Rust, Ug99, Spot Blotch, Susceptible to Wheat Blast

³⁸ Primary data collected from BARI

³⁹ Sathguru compilation from BARI Reports

7	BARI Gom 28	2012	-	-	-	1	5	Resistant to Leaf Rust, Ug99, Tolerant to Spot Blotch, Susceptible to Wheat Blast
8	BARI Gom 29	2014	-	-	-	-	0.4	Resistant to Ug99
9	BARI Gom 30	2014	-	-	-	-	0.6	Resistant to Leaf Rust, Tolerant to Spot Blotch & WB
10	BARI Gom 31	2017	-	-	-	-	-	Resistant to Leaf Rust, Tolerant to Spot Blotch
11	BARI Gom 32	2017	-	-	-	-	-	Resistant to Leaf Rust, Tolerant to Spot Blotch & Wheat Blast
12	BARI Gom 33	2017	-	-	-	-	-	Resistant to Wheat Blast
13	Others		2	3	5	5	6	

Till date, considerable genetic gains in wheat have been achieved by Bangladesh in developing mid to high tolerant varieties to BpLB, heat stress and lodging whereas, resistance has been developed towards leaf rust (>10), Ug99 (3 varieties) and blast (1 variety) with rapid response for varietal development to mitigate these outbreaks.

Wheat Research in Bangladesh – A comparative analysis of past trends and status in the Public and Private sector

Varietal improvement and development in wheat in Bangladesh has remained within BARI since the early days of independence. Thus, genetic gains witnessed in wheat by Bangladesh farmers have been the brainchild of BARI along with the continual support of parental lines and germplasm from CIMMYT Bangladesh, India, Nepal and Mexico. Until 2005, early generation wheat seed production, multiplication and distribution was driven by the public sector with BARI carrying out the wheat research, varietal development and breeder seed production and BADC handling seed multiplication, bulking and distribution of certified and truthfully labeled seeds. The year 2006 saw the entry of a homegrown private seed player – Lal Teer which procured breeder seeds from BARI, multiplied certified seeds in in-house farms and distributed over-the-counter seeds through their dealer network.

Over the last 10 years, ten national seed companies have gradually engaged in the production and distribution of certified/TLS. However, the growth has stagnated at the level of ~100MT/year⁴⁰ by the private seed companies. These companies do not foresee a surge in production until a stable blast and rust-resistant high-yielding variety is popularly adopted by farmers. Additionally, seasonal demand fluctuation from farmers for wheat and BADC's subsidized seed rates will also determine private sectors expansion in wheat. Since, late 2014, Lal Teer and ACI Seeds have stepped up their engagement in wheat seed trait development

⁴⁰ Primary discussion with private seed players in Bangladesh

and delivery. ACI Seeds have dedicated plans to be more aggressive in wheat seed production with in-house developed varieties expected to be released by 2020.

Unlike India, MNCs engaged in wheat seed in Bangladesh are not focused on wheat seed, though they do have a presence in other crops such as maize, mustard, rice and vegetable seeds.

Seed System - Bangladesh

In Bangladesh, R&D for seeds falls under the domain of the public sector, especially for wheat. All of Bangladesh's public research institutions come under the umbrella of the National Agricultural Research System (NARS) network. Since 1976, BARI under the NARS network is the key public institution engaged in wheat seed research, varietal development and release, and breeder seed production. These breeder varieties of wheat are sold to state-owned enterprises and private companies for further multiplication and distribution. The Bangladesh Agriculture Development Council (BADC) - public body, handles ~90 percent of wheat seed multiplication (from breeder to foundation, certified and truthfully labelled seeds), processing, distribution and sale of certified seeds to farmers through its network of dealers.

From the 1970s until 2005, the distribution and sales of seeds for improved wheat varieties to farmers was solely under the BADC. Until 2005, the wheat seed sector in the country remained unexplored by private players. In the last 10 years, ACI Seeds, BRAC, Supreme Seeds, Lal Teer, Ispahani Agro, and Neel Sagar are some of the national companies that have emerged in the seed multiplication and distribution business. The seed sale quantum by the private sector has stagnated at about 100 MT/annum. Companies such as ACI, Lal Teer, Supreme Seeds and BRAC have national seed distribution system and the potential to engage more widely and deeply with wheat growing farmers. Their deeper engagement has the potential to enhance SRR for wheat significantly. There is less inducement for the national private seed companies to expand their involvement due to a lack of competitive advantage in focusing on wheat seeds. The commitment of resources for maize and vegetable seeds has been profitable for these seed companies. A well networked public-private partnership with BARI ensured breeder seeds were made available to private companies at an affordable prices (along the lines of the Indian public-private partnerships) and trigger a larger interest from the national private sector seed companies in Bangladesh. Substantially subsidized delivery of wheat seed by BADC also is a deterrent for the private sector to accelerate their distribution.

The retail rate of private players' certified wheat seed was found to be 50 Taka/Kg whereas, BADC usually sold the same at a highly-subsidized rate of 32 Taka/Kg, 36 percent less than the private sector wheat seeds⁴¹. Figure 10 maps seed dynamics in Bangladesh at each stage⁴².

Close to 10 players in private sector offer the same wheat varieties released by BARI. There is no differentiation in the trait factors and the only competitive determinants for their success are market reach and the price factor. To create a more robust seed market for wheat, more

⁴¹ Primary data from private seed players and BADC

⁴² Primary interaction with BARI, BADC and private players

players may need to expand their R&D capabilities. However, the overall market size, area sown, yield and future growth will be key driving factors for investment in wheat research by the private sector in Bangladesh.

The enhancement of SRR for wheat and providing access to high-quality seeds to wheat growing farmers will remain a challenge until the enhanced market presence of the private sector is made sustainable in Bangladesh. Access to international pre-breeding material by the private sector might help them to validate trait relevance in the Bangladesh context and introduce varieties to accelerate the SRR for wheat seed with their growing market reach to wheat growing marginal farmers. Introducing wheat varieties preferred by Bangladesh millers will also enhance the marketability of Bangladesh wheat in the light of the increasing growth of wheat milling industry in the country.

Wheat Value Chain – an overview of wheat as a commodity and its trade

From the early 1970s until the mid-2000, the wheat value chain and processing sector was dominated by informal players and involved the production of domestic wheat by farmers and sales to village level middlemen. Thus, wheat processing back in the early 2000 era remained unorganized and unhygienic with small to mid-sized village level processing mills/chakkis. For domestic wheat produced, Farias (small-scale traders) sold to larger traders (beparis) and then wholesalers (aratdars) for aggregation, drying and bagging wheat grain to be sent to local mills. Imports existed back then, which again entered the wholesale markets through government in the form of PDS, food aid or direct sales in wholesale markets followed by sales to village level chakkis.

Over the last 10 years, Bangladesh is experiencing revolutionary trends in the process industry and retail trade. Organized sector entry in wheat milling and food retailing has triggered a surge in wheat milling and the sale of branded wheat flour, a similar transformation that took place in India during the 1990s. Ten reputable, large wheat millers in wholesale and retail flour segment dominate the market today. Modern mills are processing most wheat grain in the country, and the small unorganized milling segment is seen as rapidly losing its market share.

Looking at domestic production statistics, Bangladesh produced 1.27 million MT of wheat grains, whereas, 5.69 million MT⁴³ was imported. The production was comparatively low because the fear of wheat blast dissuaded some farmers from planting wheat. Estimated production of wheat in 2017-18 is 1.3 million MT, and import is forecast at 5.50 million metric tons. Bangladesh produces only 20 to 25 percent of its domestic demand for wheat and imports 75 percent⁴⁴ from Russia, Ukraine, India, Canada and Australia where export bans and international commodity prices influence the quantities from each of these countries. As per the Ministry of Food, Bangladesh imports wheat in the form of wheat grains and not

⁴³ GAIN Report number: BG7004; Grain and Feed Annual; Bangladesh; 2017

⁴⁴ GAIN Report number: BG7004; Grain and Feed Annual; Bangladesh; 2017

flour/atta. Imported grains are then processed within the country for domestic sales and consumption.

Figure 12: Wheat grain volumes in Bangladesh^{45, 46, 47}

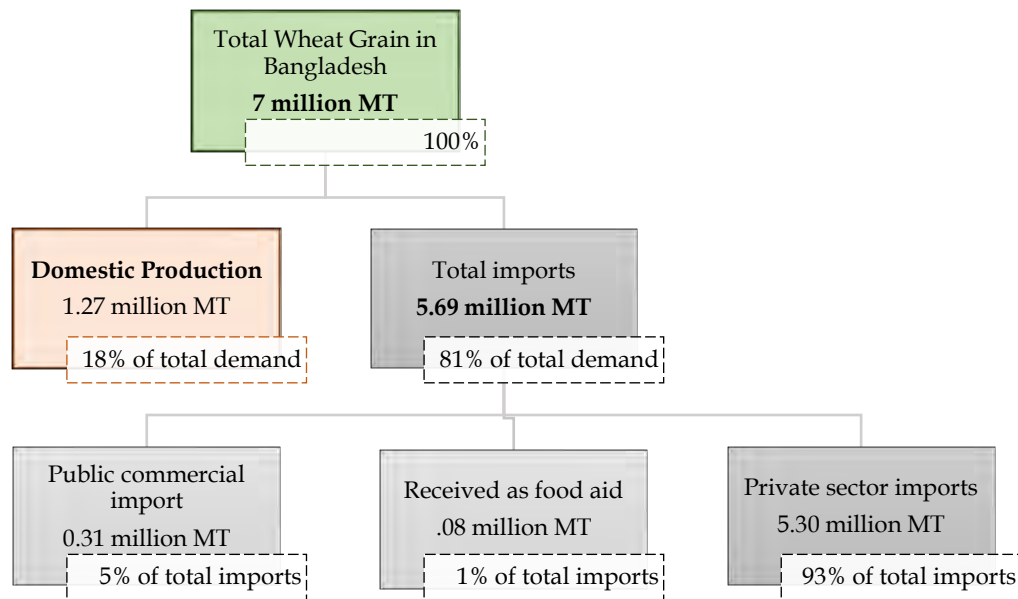
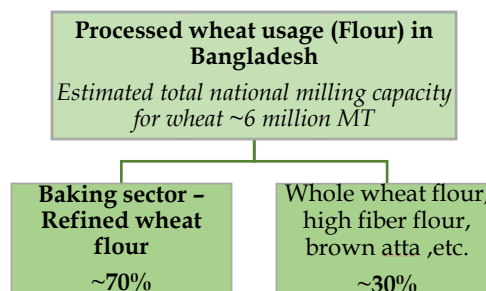


Figure 13: Wheat processing scenario in Bangladesh⁴⁸



Source: Primary interaction with millers and traders

About 10 companies have 50 percent of the imported wheat market share in milling⁴⁹. Among some of the major import businesses, S Alam and Masood Brothers, Nurjahan, Citygroup, TK Group mill, Meghna, Bashundara, and the ACI group are the biggest importers, traders, millers and retail players in the processed wheat segment. This comprises of the formal wheat channels. Distribution follows a similar chain of distributor, wholesaler, retailer and consumer. The following figure is the overall breakdown of the milling sector in Bangladesh for wheat.

⁴⁵ USDA Grain report : BG7004; Grain and Feed Annual; Bangladesh; 2017

⁴⁶ Bangladesh USAID -BEST Analysis; May 2014; page 27,28

⁴⁷ Bangladesh Food Situation Report; Food Planning and Monitoring Unit; Ministry of Food is the Government; October-December 2017

⁴⁸ Primary interaction with millers and traders

⁴⁹ Bangladesh USAID -BEST Analysis; May 2014, page: 28

Table 7: Wheat milling capacity in Bangladesh

Mill Size Approximate	Approximate No. of Mills	Approx. milling capacity (MT wheat grain/day)	Production (MT flour/day)	Average milling capacity (MT grain/day)	Annual capacity (MT)
Large	20	100-500	150	300	1,800,000
Medium	120	40-100	60	60	2,160,000
Small	200	10-40	15	25	1,500,000
Chakki	2000	<1	0.5	1	600,000
Total estimated wheat milling capacity (organized and unorganized)					6,060,000

Source: Primary interaction and internal analysis

Element 4: Implications and Synopsis

The national scenario of wheat in Bangladesh presents contrasting industry dynamics on the commodity side where, maize, also known as corn, has emerged as the most important cereal crop after rice in Bangladesh, relegating wheat to the third position from 2010-2017. The research focus on wheat has shown considerable gains in varietal development of tolerant varieties all through the years. BARI's current and future wheat developments are focused on developing resistance to terminal heat, drought, salinity, and disease resistant to Leaf Rust, Bipolaris Leaf Blight (BpLB), Blast, etc.

Overall, Bangladesh's wheat seed distribution system remains public and is dominated by BADC where about eight private players handle not more than ~1000 MT⁵⁰ (annually) of wheat seeds altogether. This volume which is ~100 MT/private seed company per year was observed to be constant since their inception. The reason are lower margins and, lower market size (compared to other crops). BADC's subsidy on wheat seed in some way makes private players' wheat seed uncompetitive. The private players and BADC source the same breeder seed and hence the private players command no market differentiation for charging higher prices. Currently, both private and public stakeholders, i.e. BADC and seed companies face issue related to unsold stock due to high fluctuations in wheat seed demand from farmers. With BARI Gom 32 (released 2017) and BARI Gom 33 (proposed) having the Wheat Blast tolerant trait with other superior trait characteristics, there is potential for wheat to regain acreage in the next two to three years.

Since the inception of commercial farming of maize in the Bangladesh in mid-1990, maize has become the fastest expanding cereal in the country. Though the maize revolution came hand in hand with the rise of the poultry and fish farming industries, the government focus for current and coming years is to promote maize not just as a feed crop, but also as a food crop.

With the continuous development of abiotic and biotic stress resistant traits in wheat; the implications of improved varieties on value chain and processing were found to be limited. Accountable reasons are that most of domestic production is consumed at the household levels and does not find its way into the processing sector where, 80 percent of milling industry demand is fulfilled by Indian, Canadian and Australian wheat. Amber colour, high gluten and pasta making characteristics were preferred characteristics of imported wheat, which, in turn, is used heavily as refined flour for baking and chapatti consumption. Focus on the output traits will be essential for Bangladesh national varieties to be released for meaningful enlargement of wheat acreage in Bangladesh.

⁵⁰ Primary discussion with private seed companies in Bangladesh

Nepal





Part 3 – Nepal

Element 1: Genetic Gains in Nepal

Cereals in Nepal, majorly rice, maize and wheat, are key components in addressing issues of national food security. Varietal research and development dates to 1960's when wheat research started with the release of Lerma 52, the first released wheat variety of Nepal. Since then wheat research, development and release in Nepal have been under the public system, i.e. Nepal Agricultural Research Council (NARC) with decades of collaboration with International Maize and Wheat Improvement Center (CIMMYT) for wheat research and development. From 1960, until 2018, 43⁵¹ varieties of wheat have been developed by NARC out of which 13 have been de-notified due to redundancy in their genetics, increased susceptibility and frequent replacement by improved varieties.

Table 8: Key Indicators – Genetic gains in wheat

Key Indicators - Genetic Gains in Wheat			
Parameters	2000-01	2016-2017	% gains
SRR (%)	5%	14%	180%
Yield Gains (MT/Ha)	1.8	2.5	39%

Source: MoAD and primary research

Today, improved wheat seed coverage in Nepal stands above 90 percent⁵² (~97 percent under improved wheat with the remaining 3 percent of the area under local wheat varieties)⁵³. SRR for wheat in the country remains at 14 percent, far lower than other countries in South Asia. From 2000 to 2017, Nepal established some significant genetic gains in wheat. The reason for that increase are, varietal improvement (especially HYV introduction during the 1960s) and the encouragement for adoption of wheat in increased acreage. For Nepal, the top source linkage⁵⁴ is from CIMMYT Mexico (44 percent); India, mainly CIMMYT-India and ICAR⁵⁵ (30 percent) and local germplasm (26 percent).

Mapping wheat seed production dynamics from 2000-2017

Nepal has achieved reasonable success in improving its national capacity for wheat seed research, development, improvement and nationwide adoption of improved varieties. Current production of wheat breeder seed is at the level of 63.13 MT⁵⁶ per annum. The current production level accomplished is in sync with the national seed vision drawn for the period 2013-2025. Understanding the current setup of wheat seed multiplication (certified and improved seeds) production of wheat seed in 2017-18 can be forecast at 11,000 MT⁵⁷. The major contribution to the 11,000 MT will come from the private seed sector and farmer cooperatives at 8000 MT, with the rest at 3500 MT coming from the public sector, i.e. National Seed

⁵¹ NARC, 2017

⁵² MoAD, 2013

⁵³ Primary discussion, NWRP Bhairahawa

⁵⁴ NWRP - NARC, Bhairahawa

⁵⁵ ICAR Coordinated Wheat Project

⁵⁶ NARC-NWRP Bhairahawa data 2017

⁵⁷ Sathguru analysis based on primary research

Company (NSC) and Salt Trading Group (STC). The Agriculture and Forestry University has set up a seed processing facility and adopted a seed village model that will contribute to wheat seed production in the coming years.

Table 9: Historical seed production scenario - Nepal

Seed Production in Nepal (in MT)				
Category	2001	2005	2010	2017
Breeder Seeds	23	25	27	63
Foundation Seeds	139	150	220	950
Certified Seeds/Improved seeds	2,878	5,796	8,245	11,000

Source: NWRP and SQCC

The seed production hierarchy in Nepal - In Nepal, the entire quantum of breeder seeds for wheat comes under

the responsibility of NARC. For later generation seed production, there exists a diverse portfolio of stakeholders multiplying breeder seeds to foundation seeds. This includes public sector stakeholders as well as private players. Finally, seed producer groups, cooperatives and private seed companies take up certified seeds to improved seed Production, which are sold to farmers for wheat grain production.

Wheat varietal development and adoption scenario in Nepal - Understanding genetic gains in wheat

Nepal is dependent almost entirely on foreign germplasm sources for varietal development in wheat, most of which come from CIMMYT.

Table 10: Varietal development to address susceptibility

Key releases to address major susceptibility 2000-2017			
Disease	Total no. of resistant varieties	Variety name	Year of release
Ug99	9	Vijay (BL 3063)	2010
		Gaura (BL 3235)	2012
		Dhaulagiri (BL 3503)	2012
		Tilottoma (NL 1073)	2015
		Danphe (NL 1064)	2015
		Bandganga (BL 3623)	2016
		Sorgadwari (BL 3629)	2016
		Munal	2017
		Chyakhura	2017
Leaf Rust	3	Vijay (BL 3063)	2010
		Tilottoma (NL 1073)	2015
		Bandganga (BL 3623)	2016
Yellow Rust	5	Dhaulagiri (BL 3503)	2012
		Danphe (NL 1064)	2015
		Sorgadwari (BL 3629)	2016

Source: NWRP - NARC

Analyzing varietal development, release and adoption of wheat varieties from 2000-2017 in Nepal - Out of the 43 wheat varieties released since 1953, 15 wheat varieties have been developed and released in this period. Nepal is broadly divided into two regions regarding development and release of wheat varieties, viz. Terai (mid-western and far-western terai) and Hills. NARC's top priority remains development of resistant varieties to yellow rust (in hills), leaf rust (in

terai/plains) and foliar blight. Stem rust was also found sporadically in some of the wheat growing regions of Nepal.

Table 11: Wheat variety coverage - Nepal⁵⁸

Varietal adoption - National Coverage for 2016-17				
Wheat variety	Region	Year of release	National coverage (%)	Preferred characters
Vijay (BL 3063)	Terai	2010	21.6	Stays green, Ug99 & leaf rust resistance
Nepal 297	Hills	1985	4.5	High tillering
Gautam	Terai	2004	17.1	Drought resistant
NL 971	Terai	2009	6.7	Low shattering
Bhrikuti	Terai	1994	9.4	High yielding
Aditya (BL 3264)	Terai	2009	11.2	High tillering

Source: NWRP - NARC

NARC research programs for varietal development in wheat are currently focused on, multiple disease resistance towards *yellow rust, leaf rust, foliar blight, loose smut, powdery mildew and Karnal bunt and abiotic factors such as terminal heat tolerance, drought tolerance, amber colour and lodging*. Ug99 in late 2000 had the potential to hit Nepal's wheat production hard. However, as a quick response under the DGGW project, Vijay (BL 3063) was tested and found to be entirely resistant to Ug99, leaf rust and yellow rust. Vijay was aggressively introduced and promoted, making it a widely adopted variety of Nepal. Currently, Vijay has become the variety with maximum wheat coverage (21.6 percent). Vijay in addition to the above-mentioned resistances had multiple disease resistance to loose smut, Karnal bunt, and powdery mildew along with amber coloured grain, high yield and excellent breadmaking characteristics. Since 2009, NARC has been sending close to 100 selected lines every year to Kenya for Ug99 testing, thereby continuously validating the resistance characteristics of their advanced breeding lines to Ug99 and other diseases.

Additionally, Nepal's national wheat seed program under NWRP is working actively on blast by actively testing their lines at USDA labs in Bolivia and Maryland for susceptibility to blast. The eastern part of Nepal being in proximity to Bangladesh poses a potential wheat blast threat for Nepal. Additionally, parental crossing to develop blast tolerance/resistant varieties is one of the key pipeline activities under NWRP-NARC.

Table 12: Wheat varietal releases and adoption percentage in Nepal⁵⁹

Regional varietal adoption - Most popular varieties 2016-17		
Region	Most popular varieties	Year of release
Terai	Gautam (> 40% coverage in Terai)	2004
	Vijay	2010
	NL 971	2009
	Bandganga (BL 3623)	2016

⁵⁸ NARC- NWRP Bhairahawa data 2017

⁵⁹ NARC - NWRP Bhairahawa data

	Tilottoma (NL 1073)	2015
	Nepal 297	1985
	BL 1473	1999
	Achyut	1997
Hills	WK 1204 (~ 70% coverage in hills)	2007
	Annapurna 4	1994
	Pasang Lhamu	1997
	Dhaulagiri (BL 3503)	2012
	Gaura (BL 3235)	2012
	Danphe (NL 1064)	2015
	Sorgadwari (BL 3629)	2016

Source: NARC-NWRP

Table 13: Wheat varietal development in Nepal

Wheat varietal development in Nepal			
Region in Nepal	Before 2008	2008-2012	2012-17
Terai	Nepal 297, BL 1473, Achyut, Gautam	Nepal 297, BL 1473, Achyut, Gautam, Vijay, NL 971	Nepal 297, BL 1473, Achyut, Gautam, Vijay, NL 971, Bandganga (BL 3623), Tilottoma (NL 1073)
Hills	Pasang Lhamu, Annapurna 4	Pasang Lhamu, Annapurna 4, WK 1204, Dhaulagiri (BL 3503), Gaura (BL 3235)	Pasang Lhamu, Annapurna 4, WK 1204, Dhaulagiri (BL 3503), Gaura (BL 3235), Danphe (NL 1064), Sorgadwari (BL 3629)

Source: NARC-NWRP

Key traits influencing adoption at the farmer level in Nepal are high yield, resistance to diseases (mainly foliar blight, yellow rust, stem rust and leaf rust), good taste and lodging. Another key trend in wheat varietal adoption in Nepal is that the farmers' responsiveness to adoption of newly released, improved and more resistant varieties is very high. A new variety gains traction quickly due to this factor, to replace redundant ones. However, five popular varieties dating back to 1985 and the late 1990s (Achyut, BL 1473, Nepal 297, Annapurna 4 and Pasang Lhamu) have remained constant in their coverage and popularity among farmers, despite the introduction of improved varieties.

To date, genetic gains in wheat has resulted in over 90 percent coverage of improved varieties where varietal development from 2008 onwards has been more intensively focused on developing an improved levels of susceptibility to yellow rust, stem rust, foliar blight and leaf rust along with terminal heat stress, drought tolerance and lodging. With nine varieties resistant to Ug99, three varieties resistant to leaf rust and five yellow rust resistant varieties, Nepal's national coverage of wheat for rust-resistant varieties stands at about 40 percent. This a significant improvement from the 2005 situation when widely adopted varieties in Nepal were found to be highly susceptible to Ug99.

Wheat Research in Nepal – A comparative analysis of past trends and status in the public and private sectors

Wheat breeding in Nepal started back in 1951 under the public system with the introduction of wheat genotypes that led to the first wheat varietal release (Lerma- 52) through a simple mass selection of genotypes. Since then, entire research, sourcing of germplasm from national or international sources (mainly CIMMYT), development and provision of nucleus and breeder seeds for wheat to cater to national seed demand falls under the ambit of NARC, the national body of the government of Nepal.

NARC acts as a primary institution to source germplasm for continuous varietal development where key source linkages are from CIMMYT Mexico (44 percent); India – mainly CIMMYT India and ICAR (30 percent) and local germplasm (26 percent). Private seed sector is almost non-existent in wheat research; however, it plays a crucial role in seed multiplication of later generation seeds from breeder to foundation seeds-certified seeds-improved seeds, processing, distribution and sales. The scenario remains the same for all the crops in Nepal.

Observing current dynamics and transition in private sector, there is sufficient interest among leading private seed players to develop their research infrastructure and focus on developing research capabilities in the next 5 to 10 years.

Among the **breeding techniques** being currently used by NARC and other research stations for wheat, conventional or classical plant breeding methods are dominant. Common breeding techniques used for wheat were maintenance breeding, backcrossing, mass selection, pure line selection, bulk method, heterosis breeding, cultivars mixture (varietal blend), modified pedigree-bulk method, recurrent selection, and population improvement. Among all these, the modified pedigree-bulk method is the most common and widely used breeding technique in Nepal for wheat⁶⁰.

Public-private sector view on wheat hybrids: Currently, all the wheat varieties in Nepal are self-pollinated public varieties and have 100 percent coverage. The major focus remains on developing multiple disease resistance and enhanced level of biotic and abiotic tolerance in current lines. Hence, in Nepal, hybrid varieties in wheat is not a focus in the near and midterm future. The Government is open to testing hybrids if any of the private sector and bring them to the country with trait factors relevant to the region.

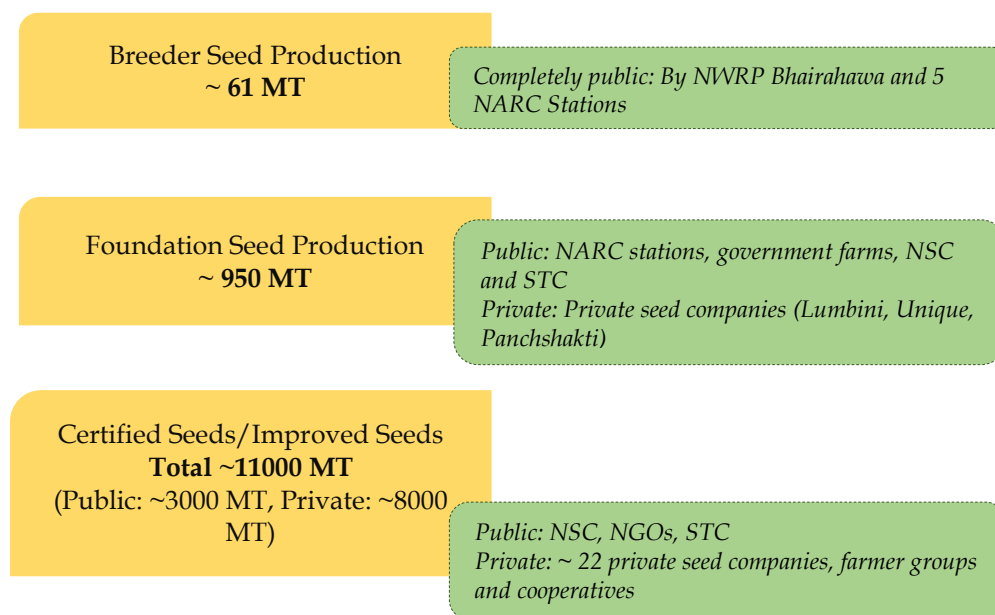
Element 2: Seed System in Nepal

The seed system in Nepal is classified into two sections- public and private, where nucleus and breeder seed release and production is entirely governed by the public sector, and the latter controls multiplication to later generations, marketing and distribution. Under the public sector, NARC along with its national wheat seed program, NWRP, and regional

⁶⁰ Based on primary discussion with NWRP, Bhairahawa

research stations form the centres of breeder seed production for the country. Since the early 1960s, when wheat varietal development and production took place, the initial generation source seed production (mainly breeder seeds, to some extent foundation seeds) continued to remain under the public system. Before 2000, multiplication of all generations of wheat seeds was done by public research stations in minuscule quantities, and there was very little adoption of improved varieties (SRR below 5 percent).

Figure 14: Wheat Seed Production in Nepal⁶¹



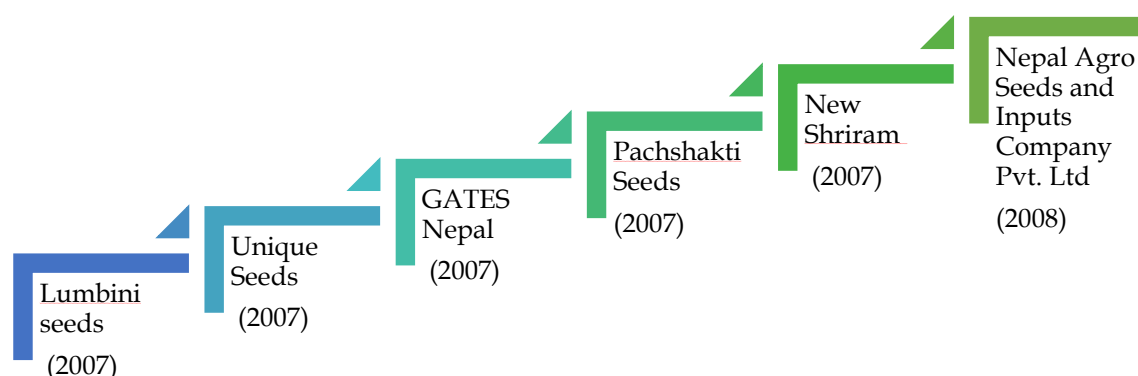
Since 2000, wheat seed multiplication and distribution from Breeder Seeds (BS) to later generations goes through a mix of public and private stakeholders who multiply, market and distribute seeds through their networks to farmers. Stakeholders multiplying BS to FS include public sector organizations such as District Agriculture Development offices (DADO), Government Farms, Salt Trading Company (STC), National Seed Company (NSC) and private seed companies. The stakeholders remain the same for multiplying Foundation Seeds (FS) to Certified Seeds (CS) and CS to Improved Seeds, i.e. DADO, STC, NSC, seed producers, private sector (around 22), NGOs, and a large number of seed producer groups.

Improved seeds are sold to farmers through various marketing channels which involve agro vet shops, government seed stores and individual seed distributors and retailers by each of the companies, cooperatives, etc. Seed Quality Control Centre (SQCC) is the key authority for quality testing and seed certification in Nepal.

The emergence of private seed players in wheat under Nepal's seed system happened during 2002 to 2007 when five private seed companies were registered and started their operations from CS to IS seed production and sales. Today, these five companies (Lumbini, Unique, GATES Nepal, Panchshakti, Nepal Agro Seeds and Input Company and New Sriram) are progressive and the leading seed companies of Nepal in terms of infrastructure, operations, volumes and market coverage.

⁶¹ Primary interaction with public and private stakeholders

Figure 15: Emergence of private seed players in wheat - Nepal⁶²



Wheat Seed Imports

Informal wheat seed trading in the border areas of Nepal and India is a common phenomenon. This accounts for ~1000 MT⁶³ of wheat seed trade every year from Nepal to India. The key reasons for this trading is open border access for traders and agro vets; easy accessibility of seeds and proximate markets across border; cultural social and ethnic relations which promote the casual exchange of seeds/gifting, etc. Most of the wheat seed is traded from the western part of Nepal to India and not vice versa since Nepalese farmers prefer their own varieties for wheat.

Among the wheat traded varieties through the informal channel, three varieties from Nepal – Gautam, NL 297 and Bhrikuti are in high demand and popular in the states of Uttar Pradesh and Bihar (in India). The other key factors that promotes cross-border trading of wheat seeds from Nepal to India includes higher price (INR 1-2/Kg higher) realization in the Indian market for Nepal’s varieties such as Gautam, NL 297 and Bhrikuti⁶⁴.

Element 3: Wheat Value Chain- An overview of wheat as a commodity and its trade

With available land and natural resources, there have been a noteworthy gains in acreage production and yield of wheat in Nepal. In the past 15 years, wheat acreage has gone up by 19 percent from 0.64 million ha to 0.76 million Ha; production (cereal) has grown by 59 percent from 0.91 million MT in 2000 to 1.44 million MT in 2015, and yield gains have been 43 percent from 1.8 MT/Ha in 2000 to 2.5 MT/Ha in 2015⁶⁵.

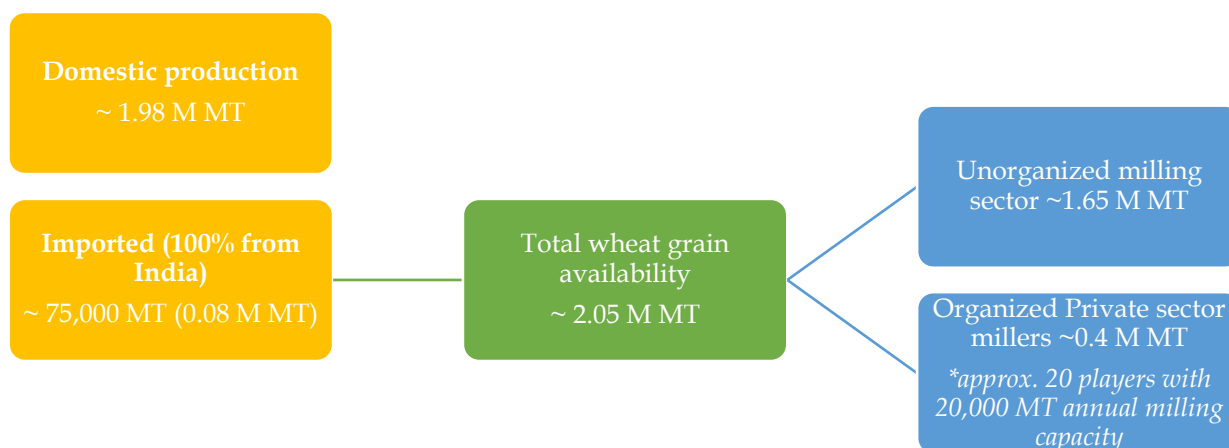
⁶² Primary interaction with private seed companies

⁶³ Primary interaction with seed companies and traders

⁶⁴ Primary discussion with wheat seed stakeholders in Nepal

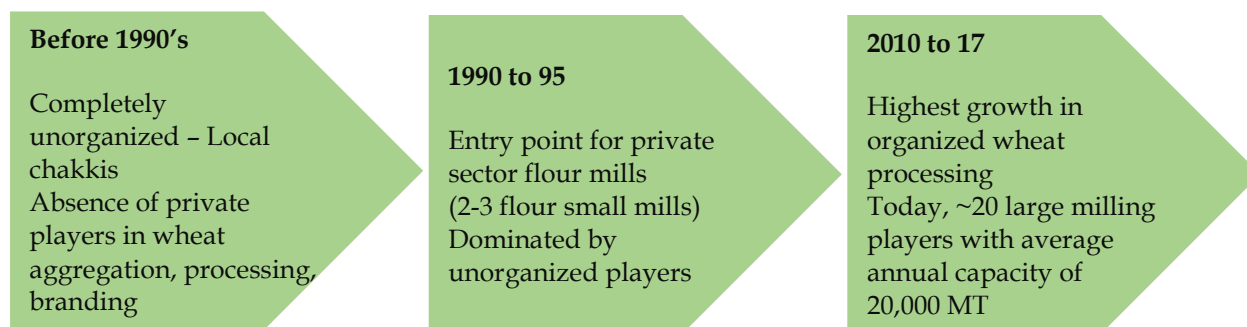
⁶⁵ MoAD 2015, Nepal

Figure 16: Wheat grain value chain – Nepal^{66, 67}



Until early 2000, the wheat value chain and processing sectors were dominated by informal players involving production of wheat by farmers, mainly for household consumption purpose. Thus, wheat processing back in the early 1990s remained unorganized, and branded flour was still a distant thought in the country.

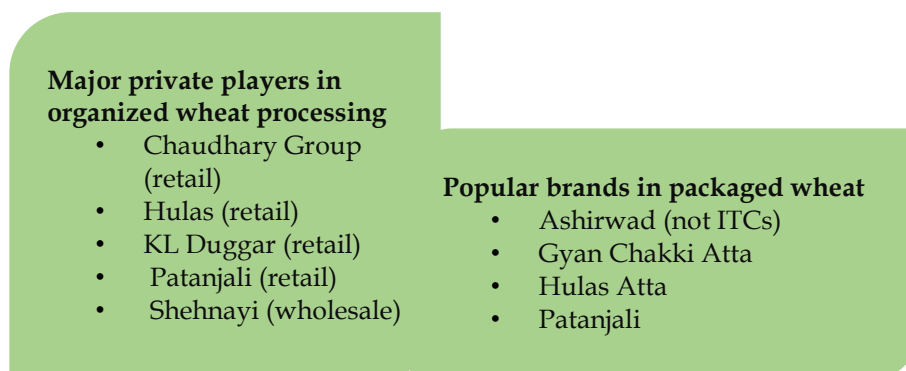
Figure 17: Evolution of private sector wheat milling industry in Nepal⁶⁸



The private wheat processing industry picked up in 2005 to 2017 leading to ~20 sizable players in branded wheat products today.

Only 40 percent of the total wheat processing demand of wheat from organized millers is met by domestic production whereas, 60 percent of the wheat (for processing) comes from the India mainly Uttar Pradesh (the state in India close to the Nepal border)⁶⁹. Key

Figure 18: Popular players and brand in braded flour



⁶⁶ Sathguru analysis based on primary interaction

⁶⁷ Statistical information on Nepalese agriculture;2014/15;Summary;Pg:2

⁶⁸ Sathguru analysis

⁶⁹ Sathguru analysis post discussion with wheat millers

factors behind imports of wheat grains from India is mainly high volumes (and not price, variety or quality) which Nepal's domestic production cannot fulfil.

Element 4: Implications and synopsis

Nepal, overcoming its geographical challenge of comparatively less land than other South Asian countries (after Bhutan) and extremes in topography has shown an optimistic growth in acreage, production and yield gains of wheat. The overall quantum in wheat grain production has increased by 44 percent from mid-2000s to 2015. The key contributors are the introduction of HYV resistant to biotic and abiotic stress (mainly foliar blight, yellow rust and leaf rust, Ug99, short duration and terminal heat tolerance). Nepal took a progressive approach to the early introduction of trait seeds with the distribution of pipeline wheat varieties (prior to release) directly to selected farmers and seed companies thereby paving the way for real-time testing of a variety before the official release. The pipeline varieties with best results on the farmers' fields are filed to SQCC for the official release. Quick varietal adoption of such pre-release tested varieties by farmers was a result of advocacy during the rapid replacement phase by Ug99 resistant seeds.

With a robust varietal development pipeline for each region and achievements so far, wheat varieties in Nepal have gained resilience to major outbreaks like Ug99, rust, foliar blight and blast (pipeline). With a special focus in the hills region on durum varieties, Nepal is balancing the climatic suitability with the changing demands from the processing sector to develop and popularize durum wheat as well. With the high demand from the noodle and pasta industry (the Wai Wai noodles of Chaudhary Group from Nepal is one of the largest noodle brands in Asia), the varietal introduction of durum wheat can expand its coverage due to yield gains, since acreage expansion remains a challenge due to the geographical size of the country.

Insights from wheat seed system in Nepal illustrated an advanced stage of development (when compared to Bangladesh and Bhutan) where the private seed sector holds the majority of the seed operations related to multiplication, marketing and the last mile reach than the public sector. The number of private seed companies (~22), annual quantum handled by them (400-1000 MT each⁷⁰) and overall size of their operations, particularly in wheat, indicates the significant growth established by the private sector in the last ten years. The DGGW project encouraged the private sector in Nepal to recognize and promote delivery of Ug99 resistant seeds. The contribution of NARC, CIMMYT and the private seed sector will need to be focused on improving the SRR with deeper distribution networks to reach farmers in difficult terrains and improve focus on the supply chain. The interest of the private sector in engaging in varietal validation and subsequent release provides an opportunity for national and international varietal developers to partner with the private sector for accelerated introduction of improved varieties.

Linkages between value chain players/wheat processors and breeders are yet to evolve from both sides. Currently, millers in Nepal procure ~40 percent of their total annual wheat demand from the domestic market with no preference for any wheat variety suitable for processing, primarily picking the wheat grain from wholesale markets. With approximately

⁷⁰ Primary discussion with SEAN, Lumbini seeds and others

60 percent⁷¹ of the processed wheat demand met by Indian suppliers, the millers do not seem to be focused on Nepal's internal wheat production providing process-relevant wheat varieties. However, we perceive that with increased wheat production and higher yields, Nepalese millers may focus their demand for output traits for wheat grown in Nepal. This factor should be brought to the fore while targeting traits for the future.

⁷¹ Primary discussion with wheat flour millers

Bhutan





Part 4 – Bhutan

Element 1: Genetic Gains in Bhutan

In Bhutan, two types of wheat (spring and winter) are the most commonly cultivated types, with the former being preferred in terms of cultivated area. Wheat has primarily been grown as an indigenous crop by the farmers of Bhutan, for which rich varietal diversity existed. Majority of these varieties were introduced through seed exchange with neighboring countries. Of these approximately 24 wheat varieties were documented, of which 19 are still being grown⁷². These traditional varieties were characterized as being tall, small spikes, low tillering capacity, weak stems, cold tolerance and better eating quality.

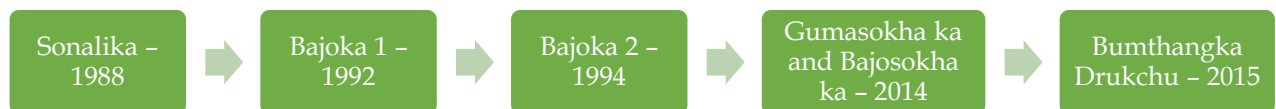
To increase the production and diversify the genetic base, the research system has introduced several improved varieties including “Sonalika” from India in the 1980s. However, farmers in higher elevations had limited access to new improved varieties, as the research system had limited focus to address winter wheat improvement in the past. Consequently, farmers continued cultivating these traditional varieties which did not fetch them high yields⁷³.

Varietal developments in Bhutan

Sonalika, the Indian variety introduced in 1988, remained the most popular variety released in Bhutan so far. It bears the same name as in India. This variety performed well in Bhutanese conditions too, until its breakdown to rust disease. The rusts (leaf, yellow and black), loose smut, Alternaria leaf blight & powdery mildew are the major diseases occurring in the fields. The rusts (with exception to stem rust) have been a recurrent threat to wheat production. Although three improved varieties were officially released from 1988 to 2013, farmers’ continued to grow “Sonalika” despite being resistant to rust, using their own saved seed or via new purchases in certain years. This was primarily due to varietal preference and ease of access across border from the north-eastern states of India.

With growing susceptibility of Sonalika, it was imperative for the research programs to introduce a number of varieties that are not only resistant to rust but also high yielding and early maturing as shown in Figure 23. Consequently, with the introduction of new disease-resistant varieties such as Gumasokha kaa and Bajosokha kaa from 2014 onwards, farmers were discouraged from cultivating Sonalika.

Figure 19: Historical varietal release in Bhutan⁷⁴



⁷² Katwal, T. B., Dorji, S., Dorji, R., Tshering, L., Ghimiray, M., Chhetri, G. B., Dorji, T. Y. and Tamang, A. M. (2015). Community perspectives on the on-farm diversity of major cereals and climate change in Bhutan. *Agriculture* 5:2- 16

⁷³ Sangay Tshewang et al; Challenges and Prospects of Wheat Production in Bhutan: A Review; April 2017

⁷⁴ Primary interactions with Agriculture Research and Development Sub Center (ARDSC), Department of Agriculture (DoA), Ministry of Agriculture and Forests (MoAF), Tsirang, Bhutan

The national wheat program in Bhutan, 2011 onwards, broadened research scope with equal focus on development of winter wheat. This resulted in the release of a new improved winter variety from CIMMYT named Bumthangkaa Drukchu in 2015. Bumthangkaa Drukchu marks a historic milestone as this is the first ever improved variety released for winter wheat ecosystem in Bhutan, but is also making a significant impact to overall production because of high yield potential and wider adoption⁷⁵. Global collaborations, exposure of Bhutan scientists to international arena and research capacity enhancement have triggered the release of wheat variety in Bhutan in 2014 after a period of 20 years. The new varieties promised a yield of 50 percent higher⁷⁶ than “Sonalika”.

The source of germplasm is the CIMMYT, India, Nepal and Bangladesh with seed transfer facilitated under regional seed rules and regulations. More recently, Nepal varieties like Munal and Chyakhura have been evaluated under similar field conditions in Nepal and have been found to be suitable for cultivation in Bhutan⁷⁷.

Table 14: Varietal characteristics of wheat - Bhutan

Variety	Characteristics
Sonalika	Early maturing variety
	Susceptible to yellow (stripe) or brown (leaf) rust
Bajoka-1	Recommended for medium & low altitude
	Matures 155-160 days
	Grows to a height of 80-85cm tall
	Yields 2.5 – 3.0 tons per hectare
	Moderately resistant to yellow and brown rusts.
Bajoka-2	Recommended for low altitudes
	Matures 150-160 days
	Grows to a height of 100cm tall
	Yields 2.5 – 3.0 tons per ha
	Highly resistant to yellow and brown rusts
Bajosokhaka	Resistant to yellow rust
Gumasokhaka	Resistant to yellow rust
NL 1064	Resistant to all rust

Source: ARDSC, DoA, MoAF, Bhutan

Element 2: Seed Systems in Bhutan

Seed multiplication and distribution

The Bhutanese Research Centers develop and identify potential varieties through vigorous on-station and on-farm evaluations. After the variety performance is ascertained, it is formally released/notified. The research centres then provide the breeder seed to the National Seed Center (NSC), a nodal agency for seed production.

⁷⁵ Sangay Tshewang et al; Challenges and Prospects of Wheat Production in Bhutan: A Review; April 2017

⁷⁶ Tshewang, S. (2014). Wheat variety release proposal. In Proceedings of the 16th Technology Release Committee Meeting. Thimphu, August 14, 2014

⁷⁷ Primary interactions with ARDSC, DoA, MoAF, Tsirang, Bhutan

The NSC produces certified seeds on their farms or through registered seed growers. The seeds are then distributed to the farmers through the District Agriculture Extension Office. During 2012–2015, NSC undertook a parallel seed production plan of promising varieties to replace the obsolete “Sonalika” which had dominated wheat seed industry of Bhutan over last 25 years. This production plan was successful in producing a substantial quantity of seed of newly released varieties which was planted in 32 percent of area under spring wheat within the first year of its release⁷⁸.

Element 3: Implications and opportunities

While there is potential to increase wheat production in Bhutan, production is challenged by lack of any private sector presence and socio-economic factors such as labour shortage and low economic returns. However, the availability and accessibility to higher yielding disease-resistant varieties, increased use of fertilizers, appropriate seed rate, optimum planting time, mechanization, rotation with legumes and expansion of wheat area are some factors that can play a crucial role in managing sustainable wheat production in Bhutan. The national plan proposes to continue the emphasis on wheat and intends to cooperate with CIMMYT and neighbouring countries in accessing high yielding resistant varieties for wider adoption in Bhutan.

⁷⁸ National Seed Center. (2014). Annual Report. Department of Agriculture, Paro, Bhutan.



ACRONYMS

AMSL – Above Mean Sea Level

APR -Adult Plant Resistance

BADC - Bangladesh Agricultural Development Corporation

BARI - Bangladesh Agricultural Research Institute

BpLB - Bipolaris Leaf Blight

CAGR- Compound Annual Growth Rate

CACP - Commission for Agricultural Costs and Prices

CS – Certified Seeds

CCS HAU- Chaudhary Charan Singh Haryana Agricultural University

CIMMYT- International Maize and Wheat Improvement Centre

DADO - District Agriculture Development office

DGGW - Delivering Genetic Gains in Wheat

DRRW - Durable Rust Resistance in Wheat

DRR -Durable Rust Resistance

FCI -Food Corporation of India

PPV&FR: Protection of Plant Varieties and Farmer’s Right Authority of India

HYV – High Yielding Variety

IARI- Indian Institute of Agricultural Research

ICARDA- International Centre for Agricultural Research in Dry Areas

ICAR- Indian Council of Agricultural Research

ICRISAT- The International Crops Research Institute for the Semi-Arid Tropics

IIFCO - Indian Farmer Fertilizer Cooperative Limited

IS – Improved Seeds

IWBR- Indian Institute of Wheat & Barley Research

JNKVV- Jawaharlal Nehru Krishi Vishwa Vidyalaya

KBR -Karnal Bunt Resistant

KRIBCO - Krishak Bharati Cooperative Limited

MAHYCO - Maharashtra Hybrid Seeds Company

MSP- Minimum Selling Price

NFSM- National Food Security Mission
NARC - Nepal Agricultural Research Council
NARS - National Agricultural Research System
NSC - National Seed Corporation
NSAI- National Seed Association of India
OMSS-Open Market Sale Scheme
PAU- Punjab Agricultural University, Ludhiana
PDS- Public Distribution System
RKVY- Rashtriya Krishi Vikas Yojana
SEAN - Seed Entrepreneurs Association of Nepal
SFCL - States Farms Corporation of India Limited
SSC - State Seeds Corporation
SQCC - Seed Quality Control Centre
SRR- Seed Replacement Ratio
SMR - Seed Multiplication Ratio
STC - Salt Trading Company
UAS- University of Agricultural Sciences, Dharwad
USDA - United States Development Agency





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