

THE GOLDEN GRAIN: UNVEILING THE MYSTERIES OF WHEAT AND ITS PAKISTANI HISTORY

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ABSTRACT

Wheat is the staple crop in the world, and one of the most grown crops in Pakistan is used for human food and livestock feed. Foods made with wheat are a severe part of the diet for over a third of the world's people. A crop that triggered an agricultural revolution and went through an evolution process to become one of the growing crops in the world has a very significant history in Pakistan. From the Pre-Green revolution till now, wide wheat varieties have been developed to enhance the production and quality of wheat, and the efforts are continuing. New trends like biofortification are emerging in wheat to fulfill the zinc requirements of the nation. Newly developed diseases and urbanization created a hurdle in the production and quality of wheat. Current and future concerns include sustaining wheat production and quality with reduced inputs of agrochemicals and developing lines with improved quality for specific end-uses, notably for biofuels and human nutrition.

Keywords: Wheat varieties, Hexaploid wheat, Bio-fortification, Genetics, Diseases, Green revolution, Pakistan

INTRODUCTION

Almost every meal contains wheat in some shape or form. Flour is created from ground-up wheat kernels and is used to make bread, biscuits, cakes, crackers, macaroni, spaghetti, and other types of pasta. Wheat currently contributes 37% of Pakistan's food energy intake (PBS, 2022). Wheat also contains essential vitamins and gluten (the protein found in cereal crops). Humans began eating wheat as whole grain as it has its nutritional value, as shown in **Table 1** (Wrigley *et al.*, 2004). Wheat grain was domesticated as early as 9000 BC, wheat was initially found in the Near East (Syria, Jordan) and Egypt, and early Egyptians developed bread-making methods (Gustafson *et al.*, 2009). Wheat is the world's largest grain crop due to its ability to be grown in various climates. It is sown on 219 million hectares worldwide with 772 million tons of production, an average of 2500 kg grain per hectare. Pakistan stands in ninth place in terms of area (9.1 million hectares) and 32nd in terms of yield (27.4 million tons) annually in the world (Agricultural statistics of Pakistan 2019-2022). In the trader rank, Pakistan stands at 25th rank in terms of export, and it stands at 24th rank in terms of wheat exporter in the world. The average per acre yield of wheat is estimated between 20 and 25 mounds and above. It needs extra effort and natural supporting factors (Khan *et al.*, 2000).

Table 1. Nutritional Values 100g Wheat.

Nutritional Values 100g	
Energy	1,506 KJ (360 kcal)
Carbohydrates	51.8 g
Dietary fiber	13.2 g
Fat	9.72 g
Protein	23.15 g
Thiamine (vit B1)	1.882 mg (164%)
Vitamin B6	1.3 mg (100%)

Evolution of Hexaploid Wheat

Wheat was the oldest cultivated crop in the world. Hexaploid wheat was the boom of nature. Around twelve thousand years ago agricultural revolution started with wheat cultivation (Consortium *et al.*, 2014). The first wild species of wheat domesticated was *Triticum boeoticum*, also called wild Einkorn (Feldman and Sears, 1981). Natural changes occur in this wild species, and it can be said that natural selection happened. *Triticum*

boeoticum changed according to nature. After the natural mutation, this wild species converted into a cultivated species. This cultivated species is known by the name *Triticum Monococcum* (AA), is also known as wheat einkorn. It was a diploid species with chromosome number ($2n=14$) (Miroshnichenko *et al.*, 2018).

Monococcum crossed with an unknown species, while researchers confirmed that the unknown species was *Aegilops speltoides* (BB), and some researchers said that the species crossed with *T. monococcum* is still unknown (Sharma, 2008). No one crossed these species. All this process happened in nature, but it is clear that this unknown species is diploid and has chromosome number ($2n=14$) and a different Genom (BB). This cross's F1 hybrid (AB) $2n=14$ was sterile because both were different Genome. Natural chromosomal doubling of this cross happened in nature, which introduces new Tetraploid species, *Triticum turgidum* (AABB), with chromosome number $2n=28$, it cultivated for a very long period, and this species converted in *Triticum Durum* (AABB) with the same chromosome numbers ($2n=28$) (Rodriguez *et al.*, 2000).

Triticum turgidum again naturally crossed with *Triticum tauschii* (DD), which has a chromosome number $2n=14$, the F1 (ABD) with a chromosome number $2n=21$ was a triploid and sterile, again natural chromosomal doubling of this F1 happen in nature, due to this natural doubling the species occur the name of that species is *Triticum aestivium* (AABBDD), which is hexaploid species with the chromosome number $2n=42$ (Petersen *et al.*, 2006). This *Triticum aestivium* has a gene of 3 different species, and this hexaploid works as a diploid (Pawar and Singh, 2006). A flowchart representing the evolution of Hexaploid wheat is shown below in **Figure 1**.

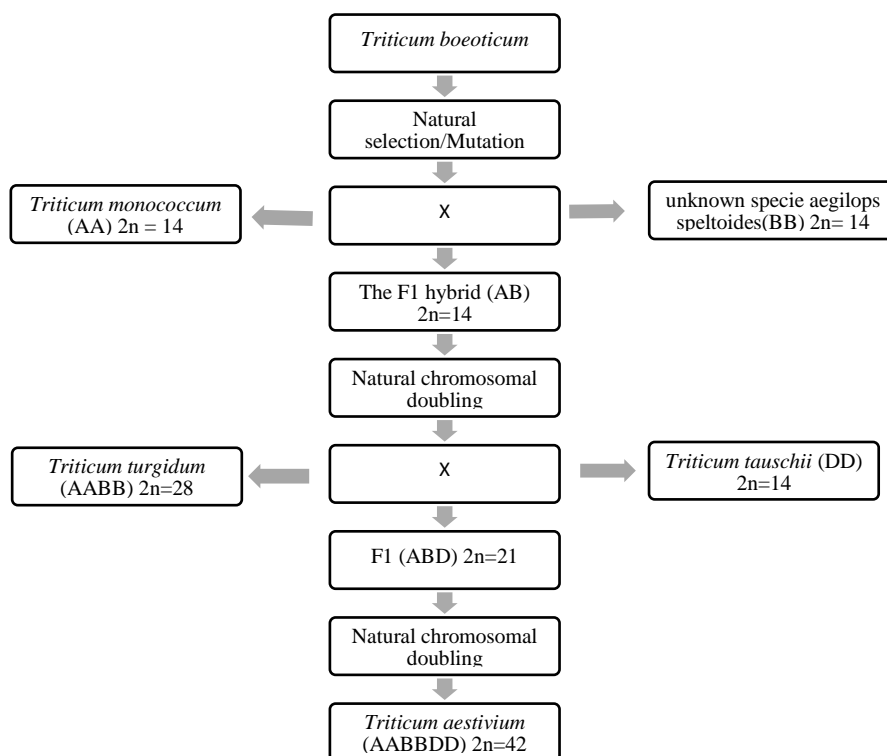


Fig. 1. Evolution of Hexaploid Wheat (Dvorak *et al.*, 1998).

History of Wheat in Pakistan

Wheat production in Pakistan is divided into three distinct periods: 1947-1965, before the release of semi-dwarf wheat; 1966-76, the so-called "Green Revolution" period when High Yielding Varieties (HYVs) were quickly adopted on about two-thirds of the total wheat area; and 1976 to date. It shows that during the pre-green revolution period, more area was brought under wheat cultivation, which caused an increase in production. However, the decaying yield may be due to a lack of modern technology, high-yielding varieties, or limited resources, as the country faced after independence (1947) (Ishaq *et al.*, 2004). The results also show that during the pre-Green Revolution Period (1947 to 1965), wheat crop production was 3716.98 thousand tons. During the green revolution, it increased by 3429.39 thousand tons and was 10374.75 thousand tons during the post-Green Revolution Period.

1947-1965 (The Pre-green Revolution)

The pre-green revolution wheat varieties were considered a broad-based genetic architecture and full of resistance against environmental stresses (Li *et al.*, 2021). The development and release of modern wheat varieties in the early 1960s triggered the green revolution. Pre-green Revolution era–up to 1966 Before the advent of the green revolution era, wheat varieties C591, C518, C217, C250, C271, and C273 were under cultivation all over Punjab (AARI, 2014-2019). These varieties remained widespread among consumers due to exemplary excellent chapatti quality. These varieties were increasingly found unfitting to obtain higher yields under high fertilizer and irrigation input levels (Laghari *et al.*, 2010). Because of their tall stature and lack of fertilizer responsiveness, these varieties tended to severe lodging, and their yield potential remained at only 2.5 to 3 tones/ha. So, from 1962 to 1967, the average yield of Punjab remained stagnant between 800 to 900 kg/ha (Ishaq *et al.*, 2004).

1966-1976 (Green Revolution)

The development of semi-dwarf varieties was made possible by the hybridization program's utilization of a dwarfing gene taken from the wheat variety Norin-10 (Gohar *et al.*, 2022). A medium to firm, white grain line from the cross 8156's segregating generation was chosen in 1961, and the variety known as MexiPak-65 was created. In Pakistan, this cultivar sparked the green movement (CIMMYT, 1995). Pakistan became the first developing nation in Asia to achieve self-sufficiency in wheat production when national wheat production climbed from 4 million tonnes in 1965–1966 to over 7 million tonnes in 1968–1969 (CIMMYT, 2021). After the publication of MexiPak-65, this Institute's wheat breeders began to cross Mexican semi-dwarfs with their native tall types (Lumpkin, 2015). As a result, they produced several excellent varieties, including Chenab-70, SA-42, Blue Silver, and Barani-70. Compared to taller, Semi-dwarf cultivars were more resistant to lodging under higher levels of irrigation and fertilization because they had a larger tillering capacity, more grain-filled spikes, and a shorter stature (AARI, 2014-2019). Below is **Table 2** showing the wheat varieties introduced during the green revolution period.

Table 2. Wheat Varieties Introduced During the Green Revolution Period (AARI, 2014-2019)

Varieties	Year of release	Yield potential (kg/ha)
Mexipak-65	1965	6252
Chenab -70	1970	6000
Barani-70	1970	5073
Blue sliver	1971	5757
SA 42	1971	5513
Sandal 73	1973	5220
PARI -73	1973	6135
LYP-73	1973	5000
Potohar	1973	5693
SA 75	1975	5838
Yecora	1975	6125

1976 to Date (The Post-green Revolution)

In 1996 a wheat variety Kiran-95 was released, which was made through the inqilab-91 variety by mutation, inqilab-91 variety was mainly affected by stem rust disease. A newly developed variety Kiran-95 is a high-yielding mega variety with wide adaptability, and tolerance to environmental stresses, golden glumes of spikes with a potential yield of 6200 kg/ha, and an average yield of 4000-4500 kg/ha (NIA, 2021).

Several abiotic factors affect wheat yield negatively (drought, terminal heat, frost, and salinity) and biotic (rusts and smut, spot blotch, bunt diseases, weeds) factors. However, drought and rusts are of prime importance in rainfed areas of Pakistan Development of wheat cultivars with enhanced rust resistance is of prime significance because chemical control of rusts is very costly and ineffective. The incessant release of rust-resistant/tolerant varieties in Pakistan has significantly reduced wheat crop loss due to rust (Qamar *et al.*, 2023).

On the other hand, with time breakdown of resistance of wheat varieties occurs due to the emergence of new rust races through mutations. For this reason, it is essential to synthesize new varieties with a broad genetic foundation having high yield potential, improved disease resistance, and the development of an elite, high-yielding, drought tolerant, and rust-resistant wheat variety developed from a local cross made during 2003-04

(Mapuranga *et al.*, 2022). The variety was approved by Punjab Seed Council under the name “Fatehjang-2016” during the year 2016 for general cultivation in the Barani areas of Punjab (Arshad *et al.*, 2018).

New wheat variety Fatehjang-2016 was developed by crossing two parents, “ERA F 2000” and “FONG CHAN #3 / TRT’S’//VEE#9/3/COOK/ VEE’S’// DOVE’S ’/ SERI” during rabi season of the year 2003-04 at Barani Agricultural Research Station, Fatehjang, Punjab, During 2014-15, Fatehjang-2016 has tested again along with 40 other genotypes at 14 locations in Pakistan. The grain yield data indicated that Fatehjang-2016 got sixth in Punjab, producing 4510 kg ha⁻¹ compared to the local check (4212 kg) (Arshad *et al.*, 2018). Similarly, Fatehjang-2016 produced more average grain yield (3982 kg ha⁻¹) than local check (3728 kg) and attained a fifth position in Pakistan during 2014- 15. Fatehjang-2016 produced a 7.07% higher grain yield than the local check-in Punjab and a 6.81% higher grain yield than the local check at the Pakistan level. Fatehjang-2016 was also assessed for its reaction against rust diseases (yellow, leaf, and stem rust) at CDRI, Islamabad. The variety proved resistant to all three rusts during 2013-14 and 2014- 15 (Arshad *et al.*, 2018). **Figure 2** depicts the graphical representation of wheat production in Pakistan (1950-2022) and **Table 3** shows the production of wheat in Pakistan decade wise (1950-2022) (Agricultural statistics of Pakistan 2019-2022.).

Table 3. Production of Wheat in Pakistan Decade Wise (Agricultural statistics of Pakistan, 2019-2022.)

Year	Production (tons)
1950-1959	3930-3581
1960-1969	4266
1970-1979	9143.7
1980-1989	12015.9
1990-1999	16650.5
2000-2009	23294.7
2010-2022	25249.5

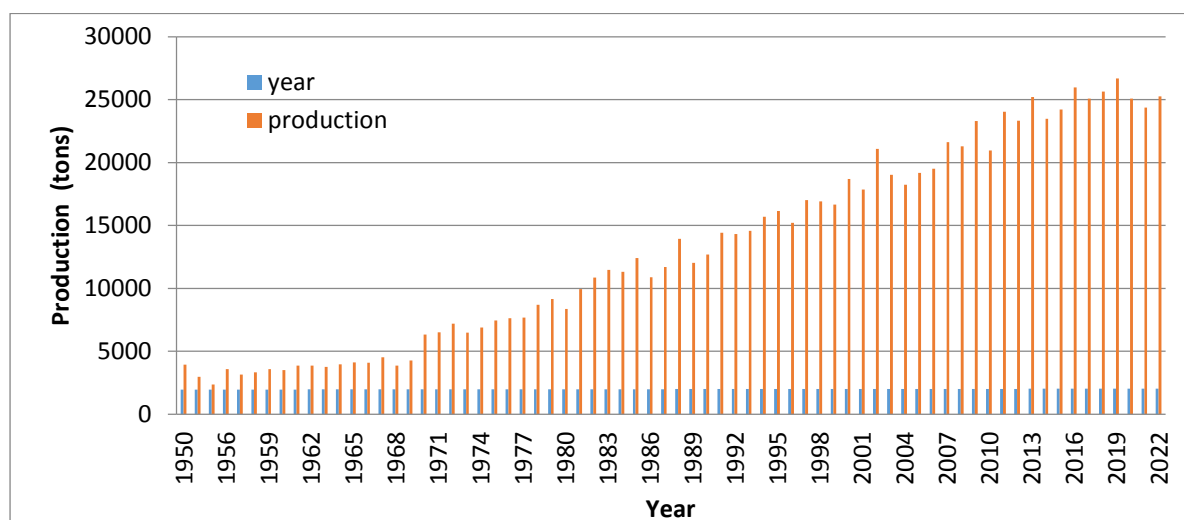


Fig. 2. Graphical Representation of Wheat Production in Pakistan (1950-2022) (AMIS, 2022).

Current trends in Wheat

Bio-fortification

Breeding crops to increase their nutritional values is known as bio-fortification. In Pakistan, 39% of children and 48% of pregnant women suffer from zinc deficiency, according to a 2011 National Nutrition Survey. These deficiencies lead to child stunting rates of over 40 percent and high infant mortality. Zinc deficiency causes stunting, lowers immunity, and increases the risk of diarrheal disease and respiratory infections. 45% of children under the age of 5 in Pakistan are estimated to be zinc deficient (WHO). Mineral and vitamin deficiencies cost Pakistan nearly 3 billion USD in GDP losses annually (Bank, 2021).

Years of biofortification research and breeding have resulted in Zincol, a high-yielding, zinc-enhanced variety released in 2016, gaining popularity in Pakistan. Zincol resulted from CIMMYT’s biofortification

breeding research, focused on enhancing nutrient levels in the grain of essential food crops. The creators of Zincol drew upon diverse genetic resources, including wheat landraces and wild relatives with the genetic potential to accumulate zinc in the grain. Genes for enhanced grain zinc content from those sources were crossed into adapted, high-yielding varieties over repeated cycles of selection involving many thousands of plants. “Zincol also carries the genetic background of NARC 2011, a popular, high-yielding Pakistan wheat variety that resists wheat stem rust, a deadly disease that threatens wheat worldwide,” added Velu Govindan, a CIMMYT wheat breeder who specializes in biofortification and helped develop Zincol. It took nearly a decade to reach farmers after the initial breeding cross in 2007, several years faster than is the norm in Pakistan. Today enough Zincol seed has been distributed to cover over 20,000 hectares (CIMMYT, 2017).

A possible solution to some wheat-related problems

Increasing yield potential

Because of the complex nature of wheat, yield potential has a low, narrow sense of heritability (Barnard *et al.*, 2002); therefore, it is difficult to achieve considerable improvement in this character by using simple selection procedures. Some breeders feel that efforts should be made to improve yield potential by improving its component characters rather than using selection procedures directly to improve yield (Kholová *et al.*, 2021). However, a negative correlation between some component characters creates difficulty in such an approach. However, this problem can be overcome, at least to some extent, by improving one component character while keeping the value of the other character almost constant. This approach has been followed in many other countries, and considerable progress has been achieved in some cases (Gustafson *et al.*, 2009). Not only the above-ground parts of the wheat plant are important in determining yield potential, but the underground parts also contribute towards yielding ability (Fischer, 2020). The root system plays a decisive role in determining yield potential in wheat. The parameters of both the seminal and adventitious roots should be compared and used as a selection method for increasing yield (Ekboir, 2002). However, the direct relation of the root system with 1000-grain weight and grains per ear could not be proved so far. Unfortunately, the genes determining the properties of the root system have not been studied in detail, and the effect of the loss of any chromosome(s) on root characteristics could not be ascertained so far.

Drought tolerance

The primitive forms of the genus *Triticum* possessed enough tolerance to drought, probably because this genus evolved under arid conditions (Renzi *et al.*, 2022). However, after the domestication of common wheat and the development of high-yielding varieties of this cereal, we cannot expect a similar water requirement by the new wheat varieties. Two preconditions for harvesting high wheat yields are (1) The required amount of moisture; and (2) a balanced nutrient supply (Wójcik-Gront & Studnicki, 2021). Of course, durum kinds of wheat possess a high degree of resistance to drought, which is why this wheat is principally grown in dry areas of the Middle East and North Africa. Drought resistance, like grain yield, is a polygenically controlled complex character; thus, improving this character is not easy. Of course, identifying transgressive segregants and their use in breeding programs may help wheat breeders to some extent.

Cold hardiness

A certain temperature range during different stages of plant development is indispensable to realize a wheat cultivar's hereditary genetic yield potential. Exceptionally low temperatures can cause serious injury to wheat plants either through the freezing of plant tissues or may cause the death of the plant, that is, unrecoverable injury. Such temperatures exert a hereditarily determined adverse influence on the development yield components. Resistance to extremely low temperatures is called cold hardiness, winter hardiness or resistance to winter injury. Varietal differences for cold hardiness have been observed in several cases. It has been concluded that cold hardiness is a polygenically controlled complex character and can be improved through transgression (Pawar and Singh, 2006).

Karnal bunt disease

This disease is causing considerable damage to wheat quality in India and has considerably threatened wheat consumption. Another problem faced by wheat breeders about this disease is the presence of low variability for the disease. Mutation breeding is perhaps an appropriate approach to increase variability to control Karnal bunt and overcome this problem (Yadvinder Singh *et al.*, 2021).

Future strategies

Looking at the multidimensional challenges ahead, especially the rapidly increasing human population, declining resources (water, arable land, etc.) and degrading environment, it is imperative to take the following

steps regarding wheat breeding in Pakistan. All possible efforts must be made to develop hybrid wheat varieties and make hybrid wheat a viable commercial proposition. Production of hybrid varieties would allow the exploitation of intra-genomic heterosis in the three wheat genomes (Feldman and Levy, 2005).

The possibilities of growing winter wheat in some parts of the country should be explored. Winter wheat show natural flowering in some hilly places in the country. These places can be used for making winter x spring wheat crosses and combining desirable characteristics of the two types of wheat. More emphasis should be given to wheat quality by bringing together desirable combinations of different components of wheat proteins (high molecular weight glutenin, low molecular weight glutenin and gliadin) and by increasing the amount of specific essential amino acids (especially lysine content) through systematic efforts (Feuillet *et al.*, 2008).

Transgenic technology methods have emerged as a powerful tool for crop improvement in terms of yield, quality, and quantity in many countries. However, Pakistan is far behind in the use of these modern technologies, we should increase the use of modern technology in crop improvement. The use of biotechnological tools has a vast scope in the improvement of wheat. These tools/ techniques should be more extensively used for screening genotypes resistant to diseases (rusts, powdery mildew, Karnal bunt) and tolerant to abiotic stresses like salinity, heat stress and drought, for improving any characteristic (heat tolerance, salinity tolerance) (Pawar and Singh, 2006).

Statement and declarations

Authors Contribution: All the authors have contributed to the designing, executing, analyzing, and writing this article.

Funding Source: No funding was received.

Conflict of Interest: The authors have no conflicts of interest to declare.

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(Accepted for publication August 2023)