Current Trends and Breeding Strategies for the Development of Industry-Quality Durum Wheat: A Comprehensive Review

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Introduction: Durum wheat (*Triticum turgidum* subsp. *durum*) is an important cereal crop known for its superior seed and protein quality. It is widely used in the production of pasta, semolina, couscous, bulgur, noodles, and bakery products.

Objective: This review evaluates the global and Pakistani status of durum wheat, highlighting its lower production compared to common wheat and the importance of quality-related traits.

Methodology: A comprehensive literature review was conducted on durum wheat production, quality traits, and breeding strategies. Both conventional methods (pedigree selection, single-seed descent, bulk selection) and modern approaches (Marker-Assisted Breeding and Marker-Assisted Selection for gene pyramiding) were analyzed.

Results: Protein-related parameters such as glutenins, gliadins, 1000 kernel weight, test weight, yellow pigmentation, SDS sedimentation, and protein content significantly influence industrial quality. Molecular breeding approaches, particularly MAS and gene pyramiding, effectively enhance grain protein and quality traits, enabling the development of improved cultivars.

Conclusion: Integrating conventional and modern breeding techniques is essential for improving durum wheat productivity and quality. Marker-assisted approaches play a key role in developing high-quality cultivars to meet industrial demands, providing direction for future research in Pakistan and globally.

Key words: Durum wheat, Grain quality, Common wheat, Molecular marker, Conventional and Non-conventional strategies.

Introduction:

Durum wheat (*Triticum turgidum* subsp. *durum*) is an important cereal crop for the food industries because of its seed and protein qualities. It is used for the dry pasta, semolina, pizza, couscous, bulgur, puffed cereals, freekeh, noodles, macaroni, spaghetti and filler for pastries [1][2].

Globally, Durum wheat is cultivated at 16 million hectares with the production 34.6 million tons in 2024-25 and increased 10% as compared to 2023-24 [3]. In Pakistan, Durum wheat production is negligible because of lack of clear price advantages, assured markets and less use in value chains.

In the world, conventional and non-conventional breeding methods are used for the improvement of durum wheat. There are some major goals such as Grain yield improvement, Yield stability, Responsiveness to inputs, Improving grain quality, Resistance and tolerance against biotic and abiotic stress. In the conventional breeding method, common classical breeding methods were used according to the objective, such as pedigree, bulk, single-seed, recurrent selection, pure line selection and backcross method to develop cultivars with the desired characters [4][5][6][7].

In the non-conventional breeding method, molecular markers are used to shorten the time as compared to the conventional breeding method. It helps to identify the genotypes or entries that have the desirable genes according to our goals [8]. Molecular markers also help in the characterization, identification of varieties and save the plant breeder right. Marker Assisted Breeding (MAB) with the help of Single Sequence Repeat (SSR) marker was observed to improve quality of durum protein [9][6][7]. The objectives of this review are to compare the production of common and durum wheat; to assess the current status of durum wheat globally and in Pakistan; to evaluate the role of protein-related parameters in determining the quality of industrial products; to examine both conventional and non-conventional breeding strategies for improving industrial quality in durum wheat; and to identify the opportunities and constraints associated with durum wheat production in Pakistan.

Current Status of Wheat in the World:

In 2024–2025, global wheat production was estimated at approximately 800 million tons. According to FAO, production reached about 805.3 million tons in 2025, showing a slight increase (~0.9%) compared to the previous year. Durum wheat, a minor but economically important component, is cultivated on nearly 16 million hectares with an annual production of around 34 million tons, exhibiting slight fluctuations depending on environmental conditions. [3][10].

Globally, Common and durum wheat production in last five years was shown in the figure 1. Common wheat is increasing every year but the durum wheat decreases very rapidly due to the climate change such as high temperature [10][3]. The European Union is the leading producer of durum wheat in the world, followed by Canada, Italy, Turkey, and France as shown in figure 2 [11].

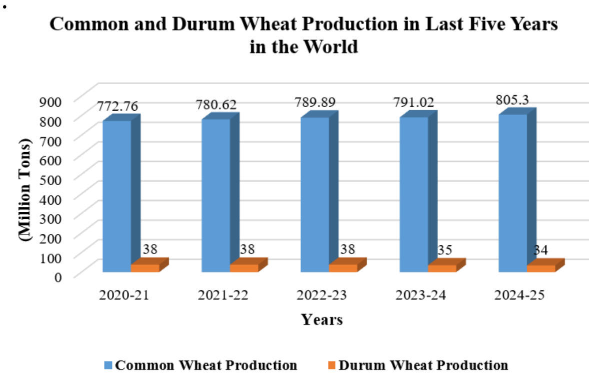

Figure 1. Common and Durum Wheat Production in Last Five Years in the World

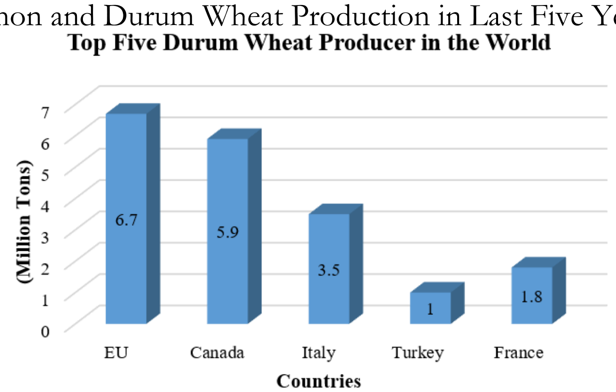

Figure 2. Top Five Durum Wheat Producers in the World

Current Wheat production in the Pakistan:

Common wheat production declined from 31.438 million tons in 2023–24 to 28.98 million tons in 2024–25, representing a decline of 8.9% as compared to previous year shown in figure 3. It is due to the reduction in cultivated area and high temperature during the sowing time (Pakistan Economic Survey, 2024-25).

In Pakistan, Durum wheat production is negligible because of lack of clear price advantages, assured markets and value chains. The local business sector is reluctant to invest in new processing industries and market development without assurance of sufficient durum wheat production by growers. (Table 1)

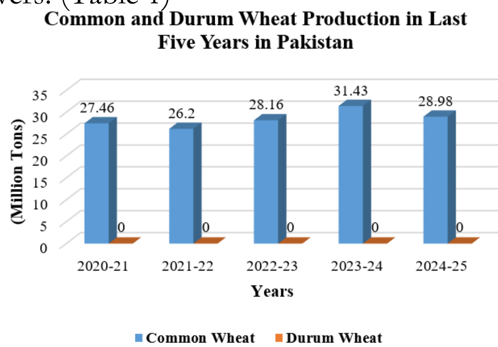

Figure 3 Common and Durum Wheat production in last Five years in the Pakistan

Difference between durum and Common wheat:

Table 1 Difference between Durum Wheat and Common wheat-reasons behind their differential use

Durum wheat	Common wheat
Endosperm is hard	Endosperm is soft to hard
Protein 10-14%	Protein 8-11%
High water absorption	Low water absorption
Endospermic wall contains more Arabinoxylan level.	Endospermic wall contains less Arabinoxylan level.
Thick Endospermic cell wall	Thin endospermic cell wall

Durum Wheat Importance:

Durum wheat flour and semolina are utilized traditionally in many countries such as America, Europe and West Asia in the form of bulgur, pasta, couscous, flat bread and most commonly pasta is used in the Europe [12]. Globally, it is used for the dry pasta, semolina, pizza, couscous, bulgur, puffed cereals, freekeh, noodles, macaroni, spaghetti and filler for pastries [1].

Role of Protein-Related Parameters in Industrial Products:

Durum wheat has specific protein related qualities for the pasta making. Its breeding is most probably restricted due to the protein quality and yield that are quantitative in nature and controlled by many genes [13][14][12].

Glutenins and Gliadins:

Durum protein quality and amount totally depended on the quantities and kind of gliadins and glutenins that are the main portion of gluten which provided the properties such as viscoelastic and dough extensibility [12][15].

1000 kernel weight:

1000 kernel weight is positively correlated with the semolina yield of durum and more kernel weight required for the handling, milling, processing and semolina [16]. It also increased the hardness of grain that is required for the pasta making. It also positively correlated with the yield [12].

Test weight:

More test weight and uniformity of durum also increase the grain size that is present mainly in the Canadian durum. It also important parameter in the world market due to positive linked with the flour production, milling yield and baking quality [16].

Yellow color:

Semolina and pasta have two types of colors; one is yellow (desirable for consumers) and second brown (not desirable for consumers). It is due to the accumulation of carotenoid in the entire kernel and indicated good source for nutrients or antioxidants [17][18][19].

Sodium Dodecyl Sulfate (SDS) sedimentation:

SDS sedimentation test is utilized for the categorization of durum flour and meal with the objective of processing and end product [20]. It also helps measure the strength of gluten and protein aggregation [21].

Protein content:

Protein content is largely dependent on the quantity and quality of glutenins and gliadins. Protein content and composition is responsible for the end products. It is negatively correlated with the yield. Past research shows that the increase in yield adversely effected the protein quality as shown in figure 4 [12].

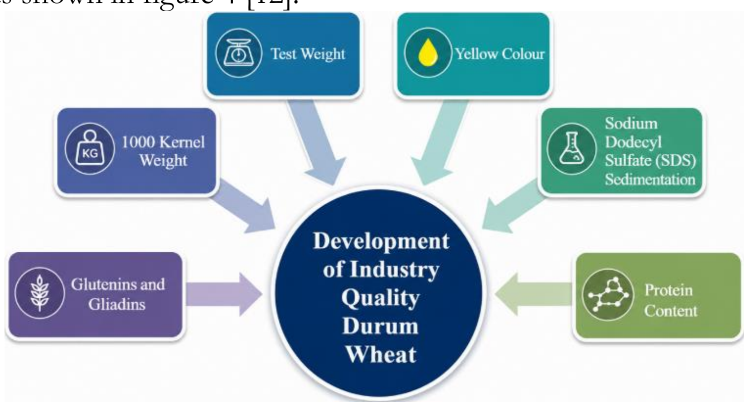

Figure 4. Role of Protein-Related Parameters in Industrial Products

Current Research Approaches use for Improvement of Industrial Quality Durum Protein:

Conventional Approach:

In many countries, breeding program established and used according to the main goals such as better adaptability, enhanced the grain yield, stability in yield, input responsive cultivars, improvement of protein quality and quantity, resistant and tolerant to biotic and abiotic stresses respectively. According to the goals, breeders designed the breeding system for the improvement of cultivars. Mainly convention approaches utilized in Durum shown in figure 5. These approaches can be improved to increase its effectiveness and decrease in time during breeding program such as back cross is used for the transfer of one or few genes against the diseases and improve the protein quality from the donor lines in durum wheat.

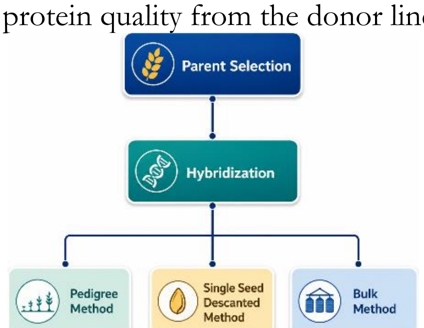

Figure 5. Conventional breeding methods used for development of Durum varieties

In the durum, pedigree method is mainly used for the improvement. Plants are selected from F2, and yield testing is not effective in early generations. Yield test is more effective with the increase in homozygosity in later generations. In single seed descanted, single seed selected from F_2 selected plant and same procedure until F_6. This method is useful for exploiting and utilizing durum wheat genetic resources. In the bulk method, plants are selected from the F_5 generation, further lines are evaluation up to F_{11}. This method is simple and saves breeders' efforts [6].

Non-conventional approaches:

Molecular Markers:

Molecular markers are used in plant breeding to marker-assisted selection by increased the efficiency of crop in short duration. It allows the breeder to select desirable genes by using different markers that is difficult to select on the basis of phenotype. It is vital to understand the genetics of important agronomic traits for improving selection [22]. Environmental factors have no effect on molecular markers but it can interact with the environment. They can be detectable at any stage of plants life cycle. For better performance and genetic improvement in durum wheat based on the recognition of Quantitative trait loci and closely linked different molecular markers. For the identification of genotype, genetic diversity and mapping different molecular markers SSRs, RAPD and ISSRs are used in durum wheat as shown in figure 6 [23][24].

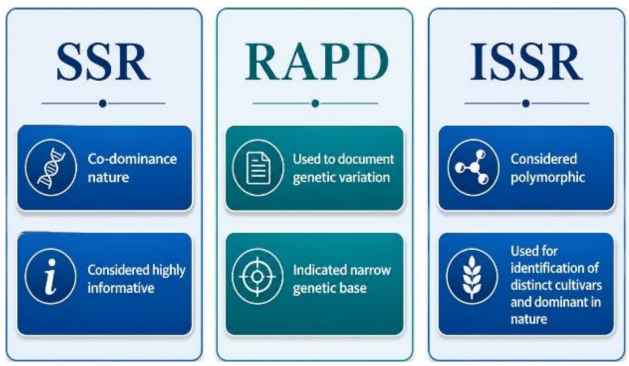

Figure 6. Markers used for identification of genotype, genetic diversity and mapping.

Genetic improvement for grain protein concentration (GPC) in durum breeding programs is one of main objective worldwide. Increase grain protein potential is difficult to attain because of its negative correlation with yield. Grain protein concentration is important factor that affect the pasta-making property [25].

By crossing DT695× strongfield F1 double haloid were obtained. From these lines 94 double haploid lines were randomly selected for QTL analysis. Genetic map was constructed by using SSR and DArT markers. A simple sequence repeat (SSR) marker evaluated on the Double haploid population includes gwm, cfa-d, barc and wmc. Quantitative trait loci for GPC were observed in durum wheat on 1, 2, 7A chromosome and on 5B and 6B. But it expressed only QGpc. usw-A3 on 2B and QGpc.usW-A3 on 7A. The strong field which is high GPC parent contributed for GPC alleles. Strong field allele at barc108 increased in the grain protein concentration about 0.4 to 1.0 with a little effect on the yield in different environments. By observing the constant expression of barc108 in multiple populations resulted that it would be useful for high GPC in marker assisted selection. [26].

PSY-1SSR a DNA marker for the concentration of yellow pigment QTL, Qyp.macs7A, was develop to use in durum wheat for marker assistant selection breeding scheme [25] there are various quality link traits such as test weight, yellow pigment, gluten strength, thousand-kernel weight and protein content grain. Furthermore, 18 SSR markers earlier described to be linked with quality traits as shown in table 1 [27].

TKW:1000-kernel weight, TW: Test weight, YPC: yellow pigment content, YIB: yellow index brightness, SDS-volume sedimentation, GPC: Grain protein content, C': Carotenoids G': Glutamine synthetase

Ch=Chromosome, T(ºC)=annealing temperatur

Table 1. List of SSR markers alleles associated with quality traits (TKW, TW, YP, B, L, SDS, and GPC), effects, sequences and their annealing temperature.

Markers	Parameters	Forward (F:) and Reverse (R:) SSR Primer	Ch	T(°C)	References
Xgwm46	TKW, YIB, GPC	F:GCACGTGAATGGATTGGAC R:TGACCCAATAGTGGTGGTCA	7BS	55.3	[28][29]
Xgwm146	TKW, TW, YPC, YP, GPC	F:CCAAAAAAACTGCCTGCATG R:CTCTGGCATTGCTCCTTGG	7BL	55.35	[30][31]
Xgwm299	TKW, TW, YPC, YP, GPC	F:ACTACTTAGGCCTCCCGCC R:TGACCCACTTGCAATTCATC	2BS	56.45	
Xgwm344	TKW, TW, YPC, YIB, YP, GPC	F:CAAGGAAATAGGCGGTAACT R:ATTTGAGTCTGAAGTTTGCA	7BL	51.35	[31]
Xgwm371	TKW, TW	F:GACCAAGATATTCAAACTGGC R:CTGCTCAGCTTGCTTGGTACC	5BL	56.65	[32]
Xgwm408	YPC, YIB, YP	F:TCGATTTATTTGGGCCACTG R:GTATAATTCGTTCACAGCACGC	5BL	54.5	[28]
Xgwm471	TW	F:CGGCCCTATCATGGCTG R:GCTTGCAAGTTCCATTTTGC	7AS	55.2	[33]
Xgwm499	TKW, TW, YP, SDS, GPC	F:ACTTGTATGCTCCATTGATTGG R:GGGGAGTGGAAACTGCATAA	5BL	54.65	[34][35]
Xgwm508	YPC	F:GTTATAGTAGCATATAATGGCC R:GTGCTGCCATGATATTT	6BS	49.75	[36]
Xgwm550	TKW, TW, YP, SDS, GPC	F:CCCACAAGAACCTTTGAAGA CATTGTGTGTGCAAGGCAC	1B	54.3	[29]
Xwmc283	YPC, YP	F:CGTTGGCTGGGTTATATCATCT R: GACCCGCGTGTAAGTGATAGGA	7A	57.65	[34]
Xwmc522	TKW, TW, YP, GPC	F: AAAAATCTCACGAGTCGGGC R: CCCGAGCAGGAGCTACAAAT	2AS	56.4	[34][37][38]
Xwmc809	YPC	F: CAGGTCGTAGTTGGTACCCTGAA R: TGAACACGGCTGGATGTGA	7AL	57.4	[39]
Xcfa2099	GPC	F: TGCGAAGTATTCAGTGCGTC R:TCAAGACCATCAGCACTCAGA	2A	55.5	[29]
Xcfa2174	TK, WYP, SDS, GPC	F:ACGGCATCACAGGTTAAAGG R:GGTCTTTGCACTGCTAGCCT	7A	56.45	[29][30]

Xdupw38	YIB, YPC, TW	F:ATTAGACACGACCAAACGGG R:TCAAACAAACAACAGCCAGC	1A	54.4	[28][29]
Xgpw2333	GPC	F:ACAAGCCCAAAAGACACACA R:ACATCACTTCCTCCGGTTTG	7A, 2B	54.4	[29]
Xuhw89	GPC	F:TCTCCAAGAGGGGAGAGACA R:TTCCTCTACCCATGAATCTAGCA	6B	56.75	[40]
Lpx-B1s	C’	F: CCAAGATGATACTGGGCGGGC R: CGCCGCCTTGCCGTGGTTGG	-	72	[41]
Lpx B1.1a/Lpx B1.1b/	C’	F: CTGATCGACGTCAACAAC R: CAGGTACTCGCTCACGTA	-	72	
Lpx-B1.1c	C’	F: CCAAGATGATACTGGGCGGGC R: CGCCGCCTTGCCGTGGTTGG	-	62	
Lpx B1.2	C’	F: TACACGCCGGTGCCGAGCGGCAG R: CGTGTCACGCTGCCCGAGGTAGAG	-	72	
scar3362	YPC	F: TTGGCTTATTCCAATGCACA R: TGTAAGGGCAACTCCCACAT.	7AL	50 or 60	[28]
scar807	YPC	F: GAGAGAGTCTTATCTGATGTACCG R: GAGAGAGTGGAATCACTTTGTGAG.	7AL	50 or 60	
GS	G’	F:CCCTGGCCCCCAGGGTCCATACTACT G R: GTCATGCCTGGTCAGTGGGAGT		60	[42]

Gene pyramid on the base of Marker Assist Selection (MAS):

A gene pyramid, in the context of Marker-Assisted Selection (MAS), refers to the strategic stacking or combining of multiple genes or alleles associated with desirable traits in a plant or crop to create a new cultivar with enhanced characteristics. MAS is a breeding technique that uses molecular markers to identify and select plants or individuals with specific genes of interest. Gene pyramiding in MAS aims to accelerate the development of improved crop varieties by incorporating multiple genes for various traits into a single plant (Figure 7).

Identify Target Traits: Breeders begin by identifying the specific traits they want to enhance in a crop. These traits could include disease resistance, pest resistance, drought tolerance, or any other desirable characteristic.

Identify Molecular Markers: Molecular markers are DNA sequences associated with the target genes. These markers serve as indicators that a plant carries the desired genes. Scientists use techniques like DNA sequencing to identify these markers.

Select Parental Lines: Breeders choose parental lines (plants) that carry different desired genes. Each parental line may contribute one or more target genes.

Cross Parental Lines: The selected parental lines are crossed to create a population of plants with diverse genetic backgrounds.

Marker Screening: Using molecular markers, the offspring (progeny) from the cross are screened to identify individuals carrying the target genes. This is done through DNA testing.

Repeated Crossing: The progeny that carry one or more target genes are selected and used as parents for the next round of crosses. This process is repeated over several generations.

Stacking Genes: At each generation, breeders select plants with the desired genes and stack them together. This stacking continues over multiple generations to create a pyramid of genes, each contributing a specific trait.

Field Testing: The final plant with the desired combination of genes is extensively field-tested for its performance, stability, and adaptability.

Variety Release: Once a stable and high-performing plant with the desired gene combination is obtained, it can be released as a new crop variety for cultivation.

Gene pyramiding helps to create crop varieties that are not only resistant to one specific disease or pest but have multiple layers of protection. This makes them more robust and less susceptible to evolving threats. It's an important strategy in modern agriculture to improve crop yields, reduce losses, and enhance food security.

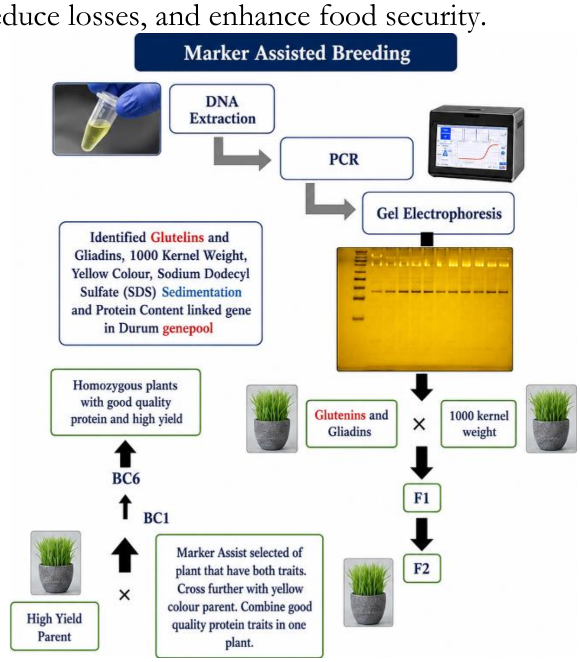

Figure 7. Marker-Assisted breeding and gene pyramiding in durum wheat

Constrains and opportunities of durum in Pakistan:

Durum constrains in Pakistan:

Poor market and procurement system for durum.

Durum seed is not available with good protein quality, high yield and resistant to biotic and abiotic stress.

Farmers are not interested in the durum production.

Durum wheat competes directly with common wheat for cultivation area.

Government does not give support price for durum.

There is a big gap of coordination among the stakeholders.

Durum opportunities in Pakistan:

Durum wheat is increasingly utilized in value-added food products by international food industries.

Government needs to provide the MSP to durum for the popularization of durum.

Government give subsidized on inputs may be beneficial for the durum to introduce in the farmer field.

MSP will be helpful to provide the market availability for the durum.

Disease resistant and high yield cultivars should be desired for the farmers.

Development and popularization of durum will be helpful to reduce the import bill.

Pakistan climate is suitable for the durum wheat.

Conclusion:

In conclusion, the review provides insights into the challenges and opportunities associated with durum wheat production and its quality improvement, shedding light on the crucial role of modern breeding techniques in meeting the demands of both local and global industries. The review's findings are expected to guide future research and initiatives aimed at bolstering durum wheat production and quality in Pakistan and beyond.

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