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Research Paper

ANALYSIS OF ALLELIC VARIATION FOR HMW GLUTENIN SUBUNITS AND *Glu-1* QUALITY SCORE DATA IN INDIAN WHEAT LINES

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Abstract

Wheat is the most important cereal crop in Indian subcontinent used for making various products like bread, chapati, cakes, biscuit, noodle, semolina, chapatti and pasta. The quality and quantity of seed storage proteins in wheat determine the properties of end products. The major component of seed proteins is gluten which is composed of monomeric gliadins and polymeric glutenins. The glutenins consist of protein subunits present in polymeric forms stabilized by interchain disulphide bonds. Reduction of interchain disulphide bonds results in subunits, which are soluble in aqueous alcohol and are classified as high molecular weight glutenin subunits (HMW-GS) and low molecular weight glutenin subunits (LMW-GS). HMW-GS subunits are largely responsible for dough viscoelasticity and affect quality of various products like bread, noodle, pasta, chapatti etc. The HMW-GSs are coded by genes at the *Glu-A1*, *Glu-B1* and *Glu-D1* loci on chromosomes 1A, 1B and 1D respectively. Allelic variation at each locus has produced extensive variability in wheat cultivars. Screening of Indian wheat lines for allelic variation at the above loci is a useful tool for selecting progenies for further breeding programmes and also selecting varieties for using in various end products. In the present paper, data from published reports have been analysed to determine bread making quality of Indian wheat lines. From the data analysed, it was revealed that for *Glu-D1* loci, subunits 2+12 were more prevalent than subunits 5+10, indicating poor bread-making quality of Indian wheat lines. The most prevalent combination observed in Indian bread wheat lines were 2*, 2+12, 7+8. For durum wheat, combination 1, 14+15 was observed in maximum lines. Here it has been suggested on the basis of data anylysis that stress should be given on cultivation of the specific lines for desired end products.

Key words: Wheat, gluten, HMW glutenin subunits, breadmaking quality, *Glu-1* score

INTRODUCTION

Wheat is one of the most important staple foods used throughout the world in one way or the other. Wheat feeds about half the population of the world and constitutes 20% of total protein and calorie intake in human nutrition (1). Wheat flour has unique properties for making various products like bread, chapatti, cakes, biscuit, noodle, semolina, chapatti and pasta. The unique quality of wheat is largely determined by the storage proteins found in the endosperm of wheat grain. The quality and quantity of these storage proteins in wheat determine the properties of end products. About 85% of total protein content in wheat endosperm is gluten which is responsible for its unique viscoelastic properties. The major components of gluten are monomeric gliadins and polymeric glutenins. Gliadins are soluble in aqueous alcohol (60-70% ethanol, 50% propane-1-ol) and are present as monomeric proteins (2). The glutenins are insoluble in aqueous alcohol and consists of protein subunits present in polymeric forms stabilized by interchain disulphide bonds. Reduction of interchain disulphide bonds with a reducing agents like 2-Mercaptoethanol or Dithiothrietol (DTT), results in subunits, which are soluble in aqueous alcohol and are classified as high molecular weight glutenin subunits (HMW-GS) and low molecular weight glutenin subunits (LMW-GS). HMW-GS are subdivided into 'x' and 'y' type based on differences in electrophoretic mobility, isoelectric focusing, amino acid composition and structure (3, 4). The glutenin polymers are largely responsible for gluten and dough viscoelasticity, (3, 5-8). These properties are exploited in the production of various products like bread, noodle, pasta, chapatti and other wheat based foods. The HMW GS of glutenin polymers are of special importance because, despite constituting only about 10% of the total flour proteins, they make a profound contribution to dough strength (5). The association of HMW GS to SDS sedimentation values, an indicator of bread-making quality has been demonstrated by many researchers (5, 9). The HMW-GSs are coded by genes at the *Glu-A1*, *Glu-B1* and *Glu-D1* loci on chromosomes 1A, 1B and 1D respectively (10). Allelic variation at each locus has produced extensive variability in wheat cultivars (11). Each variety of wheat contains between 3 and 5 major HMW-GSs, two coded by genes at *Glu-D1* locus, one or two by *Glu-B1* and one or none by *Glu-A1* locus. These subunits are distinguished by using SDS-PAGE analysis (12). HMW GS scoring system has been developed by Payne et al (5), as the sum of the contributions of each of the three HMW GS loci in bread making quality. India is one of the main wheat producing countries in the world. Screening of

Indian wheat cultivars is a useful tool for the selecting progenies for further breeding programmes and also selecting varieties for using in various end products.

Analysis of data on allelic variation for HMW glutenin subunits

In the present paper the data on HMW GS available from published reports (13-34) for various Indian wheat cultivars were collected and analyzed. The various published report included in this study are compiled in tables 1-4 and figures 1-3. Information about different variants of these subunits and their relevance in bread quality and end product quality of the Indian wheat's had been investigated by many researchers (5, 18, 22, 24, 26, 27, 35-37). The findings of these researchers have been utilized to evaluate quality of various Indian wheat lines.

HMW GS composition and Glu-1 quality score in Indian wheat lines

Since the 80's the research of HMW GS composition has remained a field of interest for researchers working on the quality of wheat products. In India this area of research gained momentum in the beginning of 21st century. However reports on a few varieties were also available on Indian wheat cultivars prior to 21st century (14, 38). Data obtained from study material (Table 1) revealed two variants of *Glu D1* allele (5+10 and 2+12), three of *Glu A1* allele (2, 1 and null) and thirteen alleles for the locus *Glu B1* (6+8, 7, 7+8, 7+9, 9, 13+16, 13+19, 14+15, 17+18, 17*, 20, 20+8, 23+18) in 593 varieties of bread and durum wheat cultivars from India. Based upon the allelic distribution, 47 combinations were observed in bread wheat cultivars and 15 combinations were observed in durum wheat lines. *Glu-1* quality score calculated for these lines have been presented in table 1 for 478 bread wheat lines.

Table 1. HMW GS composition and *Glu-1* quality score of 593 Indian bread and durum wheat lines

Locus and Allele ***Glu-D1***	***Glu-A1***	***Glu-B1***	**Names of Wheat lines**	**Frequency**	***Glu-1* Quality Score**
2+12	1	6+8	NIAW 2273	1	6
		7	C-271, NIAW 1161, NIAW 2348	3	6
		7+8	HD 2428, HPW 42, Long Orion, PBW 222	4	8
		7+9	Barham, CPAN 1922, DI 9, DBW 151, GW 2008-161, HD 2640, HD 2643, HS 365, KRL-19B, MACS 2496, NIAW 1343, PBW 452, Raj 4037, WH 711	14	7

		17+18	C 306M10, CPAN 1796, DI 8, DI 9, DL 784-2, DL 788-2, HI 784, Job-673, K 7410, K 9465, Malaviya-37, Raj 3077, Raj 1482, UP-301, Vidisha, Vaishali, WL 2265	17	8
		20	C-271, DI 105, NIAW 1846, Raj 1482, WG357	5	6
2+12	2*	6+8	GW 173, IWP 72, VW 915, VW 913	4	6
		7+8	DBW14, DBW 17, DWR 16, DWR 39, DWR 1162, GW 173, GW 322, GW 496, GW 503, Halna, HD 29, HD 30, HD 1949, HD 1982, HD 2009, HD 2204, HD 2236, HD 2270, HD 2278, HD 2281, HD 2285, HD 2327, HD 2380, HD 2402, HD 2501, HD 2735, HDR77, HI 1563, HP 1102, HP 1209, HS 490, HS 1138, HUW 234, HUW 468, HW 741, HW 2045, K 0911, K 8962, Lok 1, Lerma Rojo, Oligo, MP 3336, NI 5439, NP 846, NW 1014, Parvati, PBW 154, PBW 175, PBW 226, PBW 644, Raj 3077, Raj 3765, Sonalika, UP 262, UP 1109, VL 404, WH 147, WH 283, WH 291, WH 416, WH 1021	61	8
		7+9	DL 802-3, DL 803-3, GW 120, HB 208, HD 2206, HD 2329, HD 2687, HP-1633, HP 1744, KRL 1-4, Kanchan, NP 852, NP 852, Parbhani 51, PBW 343, Sonalika, Sonak, UP 2338, UP 2382, VL 616, VL 804, VS 1097-17, WH-157	23	7
		20	822-01, C 273, C306, C 591, Kalyansona, Kanak 8872, Kharachia 65, Ridley, WH-291B, WG 357	10	6
		13+16	HW 2004, Lermarojo, NW1012, UP 368	4	8
		13+19	PBW-138	1	?
		17+18	Bihar 124, BW 11, CIM 406, EGA 2248, HD 2189, HD 2206, HD 2285, HD 2307, HD 2329, HD 2385, HD 2781, HD 2932, Hindi 62, HP-1731, HS 295, HYB 65, HUW 468, K 307, K 8027, K 9107, K 9644, Lok 1, Kalyansona, Muzaffarnagar, Muzaffarnagar (2), Narbada 4, NI-5439, NIAW 1049, NIAW 1331, NIAW 1412, NIAW 2304, P 469-4, PBW 65, Pissi Local, PR 45, Raj-3077, Raj 4229, Raj 4238, Unnath- Kalyansona, UP-2338, WL 410, WL 711, WL 1562	43	8
2+12	null	6+8	MP 3075, NIAW 2064	2	4
		7	NIAW 612, NIAW 1045, NIAW 1395, NIAW 2065, NIPHAD 4, Sujata	6	4

		7+8	Ajantha, GW 173, GW 366, GW 496, HD 2428, India-115, Moti, NI5439, PBW 154, PBW 175, PBW 226, WH 283, WH 291	13	6
		7+9	DBW 16, FLW 3, HD 2687, HI 1418, HI 1479, KRL 1-4, NIAW301, NIAW1047, NIAW 1447, NIAW 2346, NIAW 2255, NIAW 2303, NIAW 789, NIAW 2310, NIAW 2345, NIAW 1275, NIAW 34, PBW 57, PBW 154, PBW 175, PBW 226, PBW 3963, Sonak, RAJ 4268	24	5
		9	Lok 1	1	
		20	8A, 9D, C 306, C-518, C-591, DI 16, DI 20, HI 617, HUW 533, HD 2888, HW 2004, N 8223, NIAW 2349, NIAW 2248, NIAW 2030, Ng-14-4-110, Sujata, Sehore, WH 416	19	4
		13+16	DWR 137	1	6
		13+19	IC-212141, IC-212142, IC-212155, IC-212182, IC-212184, Narbada 12, PBW138	7	?
		17+18	CPAN 1676, HD 2998, JOB 666, K 8027, Lok 1, Muzaffarnagar, Muzaffarnagar (1), NI 146, NI 343, NI 747-19, NI 5439, NI 5643, NI 9947, NIAW 2268, NIAW 345, NIAW 560, NIAW 1537, NIAW 2302, NIAW 2400, NIAW 9406, NIAW 2247, NP 846, Raj 4266, UP 2003, UP 2425	25	6
		17*	Pissi Local	1	?
5+10	1	6+8	NIAW 2279, MP 3336	2	8
		7	JS-6-31, JK-ADTY, K 88, NIAW 421, NIAW 1044, NIAW 1088, NIAW 1415, NIAW 1594, NIAW 1689, , NIAW 2059, NIAW 2073, NIAW 2075, NIAW 2275, PBW 343, PBW 373, PBW 502, PBW 533, Raj 3765, WH1080	19	8
		8	WH 423	1	?
		7+8	HS 507, PBW 509, UP-310, VL 421, Yitpi	5	10
		7+9	COW 1, DWR-195, CPAN 3004, GW 190, HD 2610, HD 2745, HD 2793, HS 240, HUW 206, HUW 318, K 0906, K 8804, KRL 19, MACS 2496, Malaviya-206, NIAW-34, NW-1012, NIAW 1342, NIAW 8223, NW 2036, PBW 396, PBW-343, PBW373, PBW 660, Pusa 5-3, Sangam, UP 2338, VL 401, VL 738, WH 331, WH-533	31	9
		9	K 0123	1	?
		13+16	C 591	1	10
		13+19	HD 3043	1	?
		17+18	CPAN 1676, DBW 90, GW 2010-288, GWL	17	10

			331, HD 3086, HW 3065, MP 3054, NW-1012A, NI 345, Sonora-64, PBW 658, UP 2003, UP 2425, WH 423, WH 423-5, WH 423-6, WH 1100		
		20	824-02, C 273, C 306, C 591, Narbada 4B, Tw-1	6	8
5+10	2*	6+8	NIAW 2300	1	8
		7	DBW 14, DBW 17, HD 2735, HD 3043, HD 3070, HI 1579, HW 5216, NIAW 1121, NIAW 314, NIAW 1161, PBW 534, VW 912, WH 1105	13	8
		7+8	DBW 74, GW 322, HD2987, HY-633, KYZ K2K-13, Raj 1972, Raj 2184, 823-12, WH 542, WH 1097, WH 1098	11	10
		7+9	Bacanora, HB 208, DBW 39, HD 29, HD 30, HD 2028, HD 2206, HD 2733, HGPC, HP 1761, HS 526, HW 1085, NP 824, NP 876, PBW 299, PBW 373, PBW 435, PBW 443, PBW 502, PBW 550, PHS 0622, PR 47, Shera, UP 2425, WH 533, WH 542	26	9
		13+16	DBW 39	1	10
		17+18	DL 153-2, DBW 71, DPW 621-50, GW 2010-285, HD 2967, HD 2985, HD 3040, HD 3059, GW 273, HI 385, HI 977, HI 1077, HPW 349, HS 86, HS 207, HD 2501, HD 2206, NP 4, K 68, K 9106, K 9107, Kundan, HI 385, LOK 1, NIAW 1594, NIAW 1258, NIAW 2073, PBW 299	28	10
		20	HY 65, K 68	2	8
5+10.	null	7	DI 716, PBW 550, PBW 531, PBW 554, PBW 590, WH 800	6	6
		7+8	DBW 16, DI 717, DI 728, HS 277	4	8
		7+9	HD2733, NIAW 1994, PBW 373	3	7
		8	WH 595, WH 712	2	?
		9	WH 1003	1	?
		17+18	K 9006, NIAW 179, NIAW 2325, NI 179, NI 5439	5	8
		20	HD 2932, NIAW 2313	2	6
Durum Wheat Cultivars					
----	2*	6+8	GW1258	1	-
---	2*	13+16	A-739, A-9-30-1	2	-
	2*	14+15	A-0-90, A 206, A 28, Bansi 162, Bansi 207-3, Baxi 288-18, Bijapur 370-4, Dasarkhed 1, Haura, Local Navalgunda, Local Red Dharwad, Local Yellow Dharwad	12	-
---	2*	20	Bansi 103, Baxi 6-1-1, Chandur Biswa 7, Dasarkhed 2, Datala 6, Ekdania 69, HI 7483 (Meghdoot), Kathia 21, Kathia 25, Local	12	-

			Vidharbha, NI 146, Ujjain Progeny 9		
	2*	20+8	GW 1256	1	-
---	1	6+8	Bijapur 487-2	1	-
---	1	7+8	DDK 1009	1	-
---	1	14+15	Arbhavi Local, Azar, Farrum, K 6413, HW 19, HW 24, HW 27, HW 28, HW 65, HW 66, HW 67, HW 68, HW 72, HW 75, HW 63, KDH, Khapli 53, Khapli 2-9-8, Khapli Pink, Khapli-2, Khapli-3, Khapli-4, N 4914, Popatiya, RL 4045, RL 5045, Rufrum II 2701, TTC- a, Ugar khapli, Yellow Khapli	30	-
---	1	23+18	Ex-33, Ex-7, HW 70, HW 71, HW 2, Khapli-1, NP 200, NP 201, NP 202, Sangali 2-2	10	-
---	null	6+8	HD 4502, HD 4530, Jai Raj, Malvi Local, Vishram, WH 896	6	-
---	null	7+8	DDK 1001, DWR 185, GW 1257, MACS 9, PDW 233, Raj 1555	6	-
---	null	13+16	A-1, A-1-8-1, Baxi-112, Bijaga Yellow, JU-12, MACS 2694, MACS 1967, N-5749, N-59, Vijay	10	-
---	null	14+15	MACS 2574	1	-
---	null	20	Bangasia, Bansi168, Bansi-224, Bansi-290, Bhalegaon-3 I, Bhalegaon-4, Bijaga Red, Chandur Biswa 8, Datala 5, HI 7747, HI-8381, Jay, MACS 2846, Narsimgarh-111, PDW 34, PDW 215, PDW 215, Raj 911, Ujjain Progeny 6	19	-
---	null	20+8	GW 1139, GW 1246, GW 1255	3	-

From the data analysed it was observed that in bread wheat at *Glu D1* loci, subunits 2+12 was there in maximum lines (63%), whereas subunits 5+10 were present in 37% bread wheat cultivars. For the loci *Glu A1*, in bread wheat lines subunit 2* was present in maximum number of bread wheat cultivars (228). Subunit null was there in 122 cultivars, whereas subunit 1 was present in 128 cultivars. For the loci *Glu B1*, in bread wheat, subunits 17+18 were present in maximum lines (28.2%) followed by 7+9 (25.3%) and 7+8 (20.5%), whereas 17* (0.2%), 9 (0.6%), 13+16 (1.5%), 13+19 (1.9%) and 6+8 (2.1%) were rarely observed.

In durum wheat for the loci *Glu B1* various HMW GSs present at maximum scale were 14+15 (37.4%), 20 (27%), 13+16 (10.4%). HMW glutenin subunits 9 (2.6%), 20+8 (3.5) and 6+8 (6.1) and 7+8 (6.1) were observed in less number of lines. For the loci *Glu A1*, null subunits was observed in maximum 39.1% lines, followed by subunit 1 in 36.5% then 2* in 24.3% lines.

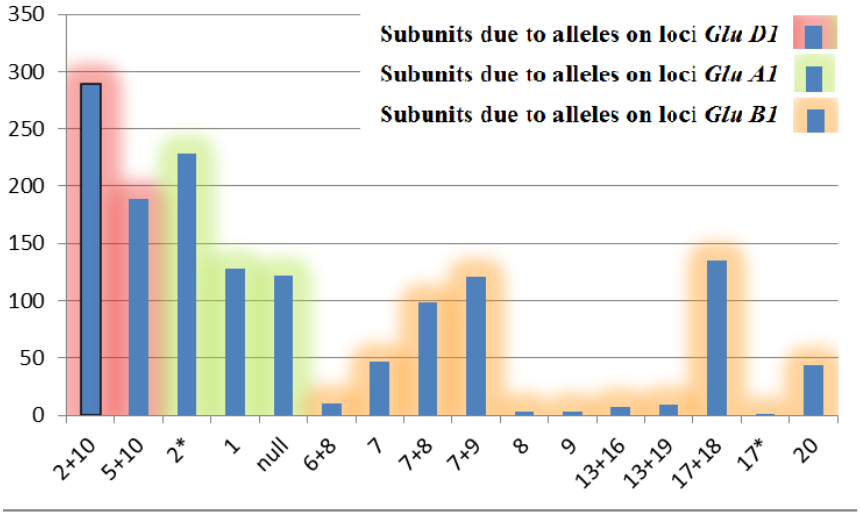

Fig.1. Distribution of various HMW GS in bread wheat lines

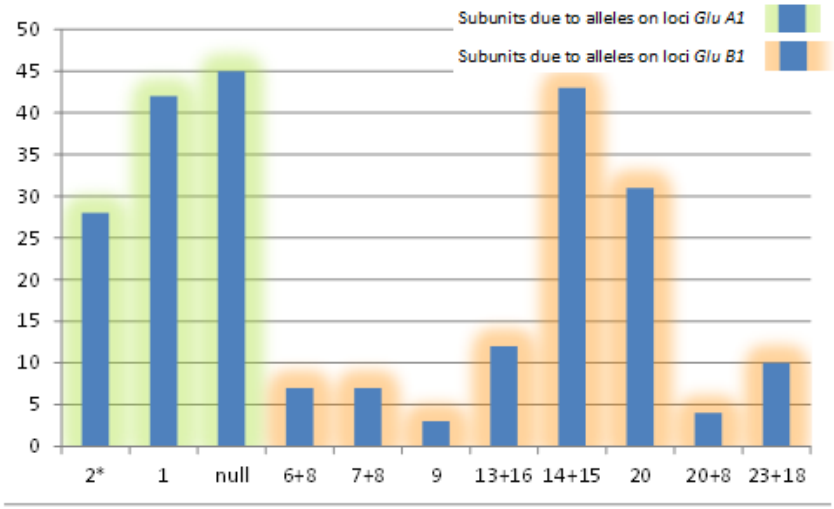

Fig. 2. Distribution various HMW GS in durum wheat lines.

Overall 47 combinations of HMW GS were observed in bread wheat and 15 combinations were there in durum wheat lines. In bread wheat most prevalent combinations occurred were 2+12, 2*, 7+8 which showed their presence in 61 lines (12.8%). Top 10 combinations of HMW GSs have been shown in table 2 for bread wheat lines and in table 3 for durum wheat lines.

Table 2. Top HMW GS subunit combinations in Indian bread wheat lines

Sr. No.	HMW GS Subunit combinations	Frequency	%age	Glu-1 Quality Score
1	2*, 2+12, 7+8	61	12.8	8
2	2*, 2+12, 17+18	43	9.0	8
3	1, 5+10, 7+9	31	6.5	9
4	2*, 5+10, 17+18	28	5.9	10
7	2*, 5+10, 7+9	26	5.4	9
5	Null, 2+12, 17+18	25	5.2	6
6	Null, 2+12, 7+9	24	5.0	5
8	2*, 2+12, 7+9	23	4.8	7
9	Null, 2+12, 20	19	4.0	4
10	1, 5+10, 7	19	4.0	8

Table 3. Top HMW GS Subunit combinations in Indian durum wheat lines

Sr. No.	HMW GS Subunit combinations	Frequency	%age
1	1, 14+15	30	26.1
2	Null, 20	19	16.6
3	2*, 14+15	12	10.4
4	2*, 20	12	10.4
5	1, 23+18	10	8.7
6	Null, 13+16	10	8.7
7	Null, 6+8	6	5.2
8	Null, 7+8	6	5.2
9	Null, 20+8	3	2.6
10	2*,13+16	2	1.7

Glu-1 quality score data (figure 3) revealed that bread quality observed in Indian bread wheat lies in middle range as middle range score (7-8) was there in 221 (46.3%) lines. Only 110 varieties (25.1%) found to exhibit score at higher side (9-10), whereas 121 lines (25.4%) have in lower side (4-6). Subunit combination 5+10, 2*, 7+8 and 5+10, 2*, 17+18 and 5+10, 1, 7+8 and 5+10, 1, 17+18 which gave perfect highest *Glu-1* quality score or at par quality score, was available in 63 varieties.

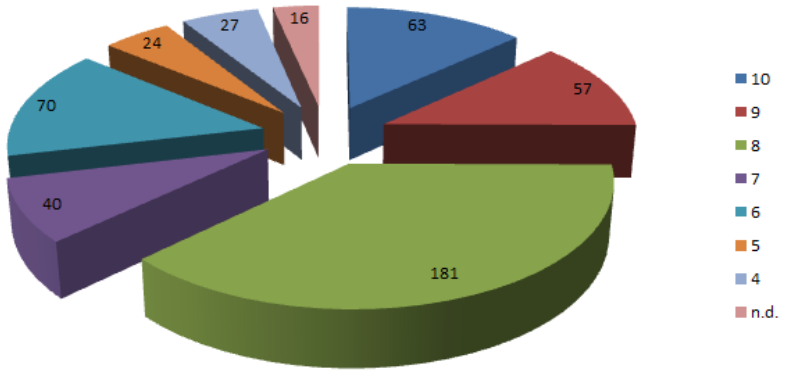

Fig. 3. *Glu 1* quality score of 478 bread wheat lines

One remarkable point seen in Table 1 was that, HMW subunit composition in a wheat line was different in work of different workers means many lines were found heterogeneous for HMW GS composition. Maximum 5 different HMW GS combinations were reported for variety Lok 1, 4 combinations were in two varieties, 3 biotypes were there in twelve varieties and 2 biotypes were reported in thirty eight varieties (Table 4). This type of variation has also been reported in wheat cultivars from other countries (39, 40-43)

Table 4. Biotypes observed in various bread and durum wheat lines

Sr. No.	Names of wheat lines	Nos. of wheat cultivar	No. of biotypes
1	Lok 1	1	5
2	HD 2206, PBW 373	2	4
3	C-306, GW 173, KRL 1-4, NI 5439, PBW 226, PBW 154, PBW 175, PBW 343, Raj 3077, UP 2338, UP 2425, WH 291	12	3
4.	C 273, C 591, CPAN 1676, DBW 14, DBW 17, DBW 39 GW 322, HD 2285, HD 2687, HD 2735, HD 3043, HW 2004, Kalyansona, KRL 19, K 8027, K 9107, Lerma Rojo, MACS 2496, MP 3336, Muzaffarnagar, Narbada 4, NIAW 1161, NIAW 2073, PBW 57, PBW 138, PBW 299, PBW 550, Pissi local, Raj 1482, Raj 3765, Sonalika, Sonak, UP 2003, WH 283, WH 533, WH 416, WH 542	38	2

Role of HMW GSs in various end products of wheat

The assessment of quality of wheat products on the basis of HMW GS composition is a tool used all over the world. Payne et al (5, 44) have assigned a score to these subunits on the basis of experimental data. This score has been found valid by

many workers and is used to assess quality of wheat cultivars at prelimnary level. Ivanov et al (45) reported that the cultivars having high *Glu-1* score referred as good quality cultivars and they also have large SDS sedimentation value. Payne et al (5, 12), Wieser & Zimmermann (46) and Burnouf & Bouriquet (47) reported that wheat cultivars having *Glu-1* score above 8 are good bread making cultivars and below 7 are poor bread making quality cultivars. Commonly, there is a tendency towards using only the subunits coded by genome D (2+12 and 5+10) as molecular markers for the potential bread-making quality in wheat. The subunit 2+12 was correlated with poor bread-making quality potential and subunit 5+10 was correlated with high bread-making quality potential. Better quality of dough had been found associated with 5+10 subunits in several studies (5, 13, 26 ,48-49). Alleles at loci *Glu A1* and *Glu B1* also found to have positive effect on quality. HMW glutenin subunits 1, 2* (*Glu A1*); 7+8, 17+18 (*Glu B1*) are known to have positive effect on quality of wheat products (5, 35-36).

Mohan and Gupta (50) observed that for bread, the superior compositions were 5+10 with 2*, 17+18; 2+12 with 2*, 17+18/ 7+9, whereas for chapatti score the superior compositions were 5+10 / 2+12 with 2* and 17+18. Chapatti, which is a routine food in Indian subcontinent and parts of the Middle East, forms a cheap, primary source of protein and calories and staple diet common to Pakistan, India, and some parts of Africa (51-52). Around 90% of the wheat produced in India is consumed as chapatties. Srivastava et al (53) reported that cultivars having 5 + 10 subunits were having better chapatti quality. In contrast to the above studies, Sreeramulu et al (54) reported association of the subunit 20 with *null* alleles for better chapatti quality. Many other studies also reported the association of subunit 20 with good chapatti making quality (13, 33). In a study by Mohan et al (55), it was observed that four varieties having best chapatti making score were having different subunit composition. These varieties were C 306 (2+12/5+10, 1/null, 20), HW 2004 (2+12, 2*, 13+16), PBW 175 (2+12, null/2*, 7+8/7+9), K 9107 (2+12/5+10, 2*, 17+18). The high chapatti scores were assigned to varieties C 306, GW 190, GW 322, HD 2687, HW 2004, K 8027, K 9107, LOK 1, PBW 175, UP 1109, UP 2382, UP 262, UP 2425, (56), these varieties are known to have diverse HMW GS composition. However prevalence of 2+12 subunits (8 varieties) over 5+10 subunits (2 lines) are there in this study also. Here three varieties were having biotypes heterogenus for *Glu-1 D* alleles. For good biscuit making quality, the

composition 2+12, 2*, 7+8 was found best suited by Mohan and Gupta (50). Yadav and Singh (21) also reported that subunit 2+12 can be used as an indicator of good biscuit making quality, whereas 5+10 as a negative indicator. For other end products of wheat also, the HMW subunits are a fair indicator (57, 58). Durum wheat is the main material used to manufacture pasta products, couscous, bulghur and in some countries bread also. In case of durum wheat subunit 20 is widely distributed in tetraploid pasta wheat is associated with poor quality for pasta making when compared with other chromosome 1B encoded subunits (59). Studies have shown that lines possessing subunit 20 generally associated with weak gluten strength and subunits 6+8, 7+8, 13+16 and 7+16 are associated with medium to strong gluten character (60-62).

From the table 1, is clear that HMW GS variation is quite good in Indian wheat lines. So wheat lines for breeding purposes are available with us for developing new high yielding varieties. Wheat in India is grown under different production environments and these subunits are not giving the same results in terms of quality in different environmental conditions. Some reports like that of Mohan and Gupta (26) have noticed that recent bread wheat varieties in Indian genotypes with superior bread quality have matched in two alleles at *Glu D1* loci i.e. 2+12 and 5+10. Despite the fact that in Indian wheat lines HMW GS are not the only factors governing quality but several other grain characters and non grain parameters contribute in product quality (26). Still a parallelism between the end product quality and the glutenin subunits occur under varying conditions in India showing importance of HMW GS composition in wheat lines (63).

DISCUSSION AND CONCLUSION

The most important source of food proteins are cereals, including wheat. Wheat is a staple diet all over the world and is used in various ways in different end products. The major factor influencing the technological quality of wheat flour is the quantity and quality of seed storage proteins (11). High molecular weight glutenin subunits (HMW-GS) influence the quality of seed both in a positive and a negative way. HMW GS localized on *Glu-D1* namely, 5+10 has a positive effect and 2+12 subunit has a negative effect on the rheological quality of wheat grain as evidenced from many studies cited above.

Improvement in wheat grain quality has become an important component of wheat research in India and abroad and HMW GS can play an important role in this endeavor. Although they are not the only governing factor in grain quality yet they act as good markers as HMW GS composition of a genotype remains unaffected by the environmental variations. This analysis has indicated that relevance of HMW GS in the Indian wheat lines is not exactly similar to other parts of the world and all combinations of HMW GS are not equally spread in the country. Also *Glu-1* Quality score or HMW GS composition has not proved a good indicator of chapatti or biscuit making quality, but association of Null allele along with subunit 20 in known for better chapatti quality.

Present analysis showed a low frequency of good quality alleles producing subunits 5+10 (39.5%), hence generally low bread making quality of Indian wheat lines is there. Some recent reports also suggested generally low bread making quality of the evaluated wheat germplasm (56, 64). Due to prevalence of 2+12 HMW GS, Indian wheat lines are considered as low in bread making quality but Panghal et al (56) showed that varieties with 2+12 subunits have performed better in terms of chapatti making quality. Indian wheat lines showed presence of 47 different allelic combinations in 593 lines with a total of 33 *Glu-1* alleles (Table 1), depicting the presence of high allelic variation of HMW-GS responsible for differences in bread-making properties as well as providing tools for breeding future novel varieties. Storage protein being the direct expression of its genotype and is expected to be a cultivar constant element, thus it can provide a useful aid to cultivar identification. New wheat cultivar production is costly, time consuming and demands a lot of effort. The high molecular weight glutenin subunits of wheat are of immense importance in determining the quality and the end use properties of the dough and can be improved by integration and expression of specific HMW-GS genes also (65). HMW-GS can serve as good biochemical markers to breeders for screening wheat germplasm with high bread making quality, developing uniformity and improving heterogenus cultivars selecting best genotypes. On the basis of this analysis and other such studies, suitable genotypes for particular end products having best result in particular agro climatic zone may also be suggested to farmers for better performance. Despite of mixing all varieties in Mandis, varieties for specific end products can be collected and stored separately, so that at the time of making products best quality grains can be used for specific purposes.

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REFERENCES

1. Gupta, R.B., MacRitchie, F., 1991. A rapid one-step one-dimensional SDS-PAGE procedure for analysis of subunit composition of glutenin in wheat. *J Cereal Sci* 14:105–109.

2. Shewry, P.R.; Tatham A.S. and Lazzeri P. 1997. Biotechnology of wheat quality. J. Sci Food Agric. 73 : 397-406.

3. Payne, P.I., 1987. Genetics of wheat storage protein and the effect of allelic variation on bread making quality. *Ann. Rev. Plant Physiol*. 38:141–153.

4. Shewry, P. R., Halford, N. G. and Tatham, A. S., 1989. The high molecular weight subunits of wheat, barley and rye: genetics, molecular biology, chemistry and role in wheat gluten structure and functionality. In: Miflin, B.J. (Ed.), *Oxford Surveys of Plant Molecular and Cell Biology*. Oxford University Press, Oxford, pp. 163–219.

5. Payne, P.I., Nightingale, M.A., Krattiger, A.F., and Holt, L.M., 1987. The relationship between HMW glutenin subunit composition and the bread-making quality of British-grown wheat varieties. *J. Sci. Food Agric*. 40. 51-65.

6. Shewry, P. R., Tatham, A. S., Barro, F., Barcelo, P. and Lazzeri, P. A. 1995. Biotechnology of breadmaking: unraveling and manipulating the multi-protein gluten complex. *Nature Biotechnology.* 13:1185-1190.

7. Liu, L., He, Z.H., Yan, J., Zhang, Y., Xia, X. and Peña, R.J. 2005. Allelic variation at the *Glu-1* and *Glu-3* loci, presence of the 1B.1R translocation, and their mixographic properties in Chinese bread wheats. *Euphytica* 142:197–204.

8. Li Vigni, M,, Baschieri, C. and Marchetti Cocchi, M., 2013. RP-HPLC and chemometrics for wheat flour protein characterisation in an industrial bread-making process monitoring context. *Food. Chem.* 139:553–562.

9. Payne, P. I., Corfield, K. G., and Blackman, J. A. 1979. Identification of a high-molecular-weight subunit of glutenin whose presence correlates with bread-making quality in wheats of related pedigree. *Theor. Appl. Genet*. 55:153

10. Payne, P.I.; Holt, L.M.; Lawrence, G. J., and Law, C.N. 1982. The genetics of gliadin and glutenin, the major storage proteins of thre wheat endosperm. *Qual. Plantarum: Plants Foods Hum. Nutr.* 31 : 229-241.

11. Payne, P. I. and Lawrence G. J. 1983. Catalogue of alleles for the complex gene loci, *Glu-A1, Glu-B1* and *Glu-D1* which code for high molecular weight subunits of glutenin in hexaploid wheat. *Cereal Res. Commun.* 11:29-35.

12. Payne, P. I., Holt, L. M., Jackson, E. A., Law, C.N.,1984. Wheat storage proteins: their genetics and their potential for manipulation by plant breeding. *Philos. Trans. R. Soc. Lond. B.* 304:359–379.

13. Bakshi, S. and Bhagwat, S. G., 2016. High molecular weight glutenin subunit variation among Indian wheat varieties. *Greener J. Agric. Sci.* 6(11), 349-355.

14. Bhagwat, S.G. and Bhatia, C.R. 1988: Variation in high molecular weight glutenin subunits of Indian wheat varieties and their *Glu-1* quality scores. In: T.E. Miller & K.M. Koener (Eds.), Proc. Seventh Int. Wheat Genetics Symp., Bath Press, Bath, pp. 933–936.

15. Bhagwat, S. G. and Bhatia, C. R. 1993. Selection for quality in early generation based on the HMW subunits of glutenin in bread wheat. *Indian J. Genet.* 53: 208-214.

16. Das, B.K., Bhagwat, S.G., Marathe, S.A., Sharma, A., and Rao, V.S., 2001. Screening of Indian wheat cultivars for the *Glu-D1d* allele (HMW-glutenin subunits 5+10) by PCR. *Ann. Wheat Newslet.* 47. 62-63.

17. Rao, S., Singh, G. and Chatterjee, M. 2001. Indian wheat pool. In: *The world wheat breeding*. Eds.: Bonjean, A.P. and Angus, W.J. Londres, Paris, NewYork . p. 773-816.

18. Ram, S., 2003. High molecular weight glutenin subunit composition of Indian wheats and their relationships with dough strength. *J. Plant Biochem. Biotech*. 12:151–155.

19. Oak, M.D., Tamhankar, S.A., Rao, V.S., and Bhosale, S.B., 2004. Relationship of HMW, LMW glutenin subunits and gliadins with gluten strength in Indian durum wheats. *J. Plant Biochem. Biotechnol.* 13. 51-55

20. Singh, B., 2004. Effect of nutrient supply and salinity on seed storage proteins of wheat. Ph.D. Thesis, Kurukshetra University, Kurukshetra, India.

21. Yadava, R. and Singh, T. B., 2004. High molecular weight biscuit making quality) High molecular weight glutenin subunits variation in relation to in wheat (*Triticum aestivum* L. em. Thell.) *Indian J. Genet.*, 64(2): 108-111.

22. Chowdhury, S., Sharma, R.K. and Mishra, B.K., 2006. The distribution of high molecular weight glutenin subunits among some old wheat varieties of India. *Crop Improvement*, 33(2): 114-18.

23. Bekes, F., Cavanagh, C. R., Martinov, S., Bushuk, W. and Wrigley, C.W., 2008. Part II. Composition table for the HMW subunits of glutenin. In: Wrigley, C.W., Bekes, F., Cavanagh, C.R. and Bushak, W. The gluten composition of wheat varieties and genotypes. https://www.cerealsgrains.org/initiatives/definitions/Documents/GlutenFree/II_HMW_Subunits.pd

24. Sharma S, S Ram and R Gupta. 2012. Relationship of high and low molecular weight glutenins with chemical and rheological properties of wheat flour. *J. Wheat Res.* 4(1): 74-78.

25. Mohan, D. and Gupta, R. K., 2013. Analyzing grain properties of Indian bread-wheat cultivars for defining route to end-product quality and key attributes for selection. *Indian J. Genet. Plant Breed.* 73(4): 1-8.

26. Mohan, D, and Gupta, R.K., 2015. Gluten characteristics imparting bread quality in wheats differing for HMW GS at *Glu D1* locus. *Physiol. Mol. Biol. Plants*, 21(3): 447–451.

27. Sarkar, S., Singh, A. M., Ahlawat, A.K., Chakraborti, M. and Singh, S.K., 2014. Genetic diversity of bread wheat genotypes based on HMW GS profiling and its relation to bread making quality. *J. Plant Biochem. Biot.* 24(2): 218-224.

28. Goutam, U., Tiwari, R., Gupta, R. K., Kukreja, S. and Chaudhury, A., 2015. Allelic variations of functional markers for high molecular weight glutenin genes in Indian wheat (*Triticum aestivum* L.) cultivars and their correlation with bread loaf volume. *Indian J. Plant Physiol.* 20:97–102.

29. Patil1, V. R. , Talati , J. G., Singh, C. , Parekh, V. B., and Jadeja. G. C., 2015. Genetic variation in glutenin protein composition of aestivum and durum wheat cultivars and its relationship with dough quality. *Int. J. Food Prop*., 18:2393–2408, 2015

30. Sheoran, S., Sharma, P., Singh, V., Pawar, S., Sharma, D., Jain, N., Kumar, R., Thakur, V., Pandey G.C., Malik, R. and Tiwari, R., 2015. Assessment of genetic diversity in elite wheat genotypes using simple sequence repeat and quality protein markers. *J. Wheat Res*. 7:18–26

31. Shitre, A.S., Bakshi, S., Gadekar, D.A., Padhye, A.P. and Das, B.K., 2016. Characterization of high molecular weight glutenin subunits of wheat genotypes. *Electron J. Plant Breed*. 7:282–290.

32. Nimbal S., Behl, R. K. and Chhabra, A.K., 2017. Study on genotypic differences for high molecular weight subunits of Indian bread wheat (*Triticum aestivum* L.). *J. Genet. Genom. Plant Breed* 1(1) 28-31.

33. Kumar, S., Sohu, V.S., Singh, R.P., Gupta, S.K., Srivastava, P. and Bains, N.S., 2018. Investigating the role of high molecular weight glutenin subunits (HMW-GS) protein in end use quality of Indian flat breads. *Ind. J Biotech*. 17: 65-73

34. Rai, A., Singh, A. M., Ganjewala, D., Kumar, R.R., Ahlawat, A.K., Singh, S.K., Sharma, P. and Jain, N., 2019. Rheological evaluations and molecular marker analysis of cultivated bread wheat varieties of India. *J. Food Sci. Technol.* 56, 1696–1707

35. Pena, R. J., 2008. Improving or preserving bread making quality while enhancing grain yield in wheat. In: MP Reynolds, J. Pietragalla, H.J. Braun (eds), International Symposium on Wheat Yield Potential: Challenges to International Wheat Breeding, CIMMYT, Mexico, D.F. p. 151-155,

36. Guo, X., G. Junxian, L. Xiuquan, Y. Xinming and L. Lihui. 2010. Molecular characterization of two novel *Glu-D1*-encoded sub units from Chinese wheat

(*Triticum aestivum* L.) land race and functional properties of flours possessing the two novel subunits. *Genet. Resour. Crop Evol.* 57(8): 1217-1225.

37. Mohan, D., Tiwari, V. and Gupta, R.K., 2017. Progression in yield and quality of wheat. *Indian J. Genet. Plant Breed.* 77(1): 16-24.

38. Singh, N. K. and Sreeramulu, G., 1994. High molecular weight glutenin subunits of Indian wheat cultivars: association of subunits 5+10 with the 1BL/1RS wheat-rye translocation. *J. Cereal Sci*. 20(3): 217-225.

39. Lawrence, G. J., Moss, H. J., Shepherd, K. W., and Wrigley, C. W., 1987. Dough quality of biotypes of eleven Australian wheat cultivars that differ in high-molecular-weight glutenin subunit composition. *J. Cereal Sci.,* 6, 99–101.

40. Sontag-Strohm, T., 1996. Rapid communication electrophoretic fractionation of wheat glutenin subunits after removal of gliadins by reversed SDS-PAGE. *J. Cereal Sci.* 24: 87-91.

41. Gianibelli, M., Echaide, M., Larroque, O. *et al,* 2002. Biochemical and molecular characterisation of *Glu-1* loci in Argentinean wheat cultivars. *Euphytica* 128, 61–73.

42. Sedighe Bahraei, Saidi A. & Alizadeh D., 2004. High molecular weight glutenin subunits of current bread wheats grown in Iran. *Euphytica* 137: 173–179

43. Yan, Z.H., Dai, S.F., Liu, D.C., Wei, Y.M. and Zheng, Y.L., 2007. Allelic variation of high molecular weight glutenin sub units in hexaploid wheat landraces of Tibet, China. *Int. J. Agric. Res.* 2:838

44. Payne, P.I.; Holt, L.M. and Law, C.N. 1981. Structural and genetical studies on the high molecular weight subunits of wheat glutenin. Part. I. Allelic variation in subunits amongst varieties of wheats (*Triticum aestivum*). *Theor. Appl. Genet*. 60 : 229-236.

45. Ivanov, P., Todorov, I., Stoeva, I., Ivanova, I.,1998. Storage proteins characterisation of group of new Bulgarian high breadmaking quality wheat lines. *Cereal Res. Comm.* 26, 447-454.

46. Wieser, H. and Zimmermann, G. 2000. Importance of amounts and proportions of high molecular weight subunits of glutenin for wheat quality. *Eur. Food Res.Technol.* 210, 324-330.

47. Burnouf, T. and Bouriquet, R., 1980. Glutenin subunits of genetically related European hexaploid wheat cultivars: Their relation to bread-making quality. *Theor. Appl. Genet.* 58, 107–111.

48. Gianibelli, M., Gupta, R. B., Lafiandra, D., Margiotta, B. and MacRitchie, F., 2001. Polymorphism of high Mr glutenin subunits in *Triticum tauschii*: characterization by chromatography and electrophoretic methods. *J. Cereal Sci.* 33:39-52.

49. Zhao, J., Zheng, X., Qiao, L., Ge, C., Wu, B., Zhang, S., et al, 2020. Effects of HMW-GSs on quality related traits in wheat (*Triticum aestivum* L.) under different water regimes. *PLoS ONE* 15(8): e0237711.

50. Mohan, D. and Gupta, R.K., 2018. An analysis to explore divergence of HMW glutenin subunits in high-yield Indian wheat of different production environments. *J. Wheat Res*. 9(2): 87-93

51. Nandini, C.D. and Salimath, P.V., 2001. Carbohydrate composition of wheat, wheat bran, sorghum and bajra with good chapatti/roti (Indian flat bread) making quality. *Food Chem*. 73, 197–203.

52. Rehman, S., Paterson, A. and Piggott, J.R., 2006. Optimization of chapatti textural quality using British wheat cultivar flours. *Int. J. Food Sci. Tech.* 41, 30–36.

53. Srivastava, A. K., Ummiti, J. S., Prasada, R. and Rao, H. P., 2003. Studies on protein and its high-molecular- weight subunit composition in relation to chapatti-making quality of Indian wheat cultivars. *J. Sci. Food Agric.* 83, 225–231.

54. Sreeramulu G., Banerjee R., Bharadwaj A. and Vaishnav P. P., 2004. Understanding the functionality of wheat high molecular weight glutenin subunits (HMW-GS) in chapati making quality. In: *The Gluten Proteins*; The Royal Society of Chemistry, p 162-165.

55. Mohan, D., Gupta, R.K. and Verma, A., 2013. Characterization of popular bread wheat of India for grain quality and the stable genetic resource. *Indian J. Genet. Plant Breed.* 73 (1), 14–22.

56. Panghal, A., Chhikara, N. and Khatkar, B.S., 2019. Characterisation of Indian wheat varieties for chapatti (flat bread) quality. *J. Saudi Soc. Agric. Sci.*, 18 (1): 107-111.

57. Bietz, J. A., and Lookhart, G. L. 1996. Properties and non-food potential of gluten. *Cereal Foods World*, 41(5): 641

58. Chapla, P. I., Vieira, E.S.N., Franco, F. A., Linde G.A., Silva, G.J., Colauto, N.B., Marchioro, V.S. and Schuster, I., 2017. High molecular weight glutenin subunits and the classification used in Brazilian wheat industry. *Genet. Mol. Res.* 16(3): gmr16039744

59. Liu, C. Y., Shepherd, K.W. and Rathjen, A.J., 1996. Improvement of durum wheat pastamaking and breadmaking qualities. *Cereal Chem*. 73:155–166

60. Carrillo, J. M., Vazquez, J. F. and Orkellana, J., 1990. Relationship between gluten strength and glutenin proteins in durum wheat cultivars. *Plant Breeding* 104 (1990): 325-333.

61. Pena, R.J., 2000. Durum wheat for pasta and bread-making: comparison of methods used in breeding to determine gluten quality-related parameters. In : Royo C. (ed.), Nachit M. (ed.), Di Fonzo N. (ed.), Araus J.L. (ed.). Durum wheat improvement in the Mediterranean region: New challenges. Zaragoza: CIHEAM, 2000. p. 423-430

62. Edwards, N.M., Gianibelli, M.C., McCaig, T.N., Clarke, J.M., Ames, N.P., Larroque, O.R. and Dexter, J.E., 2007. Relationships between dough strength, polymeric protein quantity and composition for diverse durum wheat genotypes. *J. Cereal Sci.* 45:140-149

63. Mohan D., Tiwari V. and Gupta, R. K., 2017. Progression in yield and quality of wheat. *Indian J. Genet. Plant Breed.,* 77(1): 16-24

64. Goel, S., Yadav, M., Singh, K., Jaat, R. S. and Singh, N. K., 2018. Exploring diverse wheat germplasm for novel alleles in HMW-GS for bread quality improvement. *J. Food Sci. Technol.* 55(8):3257–3262

65. Anjum, F.M., Khan, M.R., Din, A., 2007. Wheat gluten: high molecular weight glutenin subunits--structure, genetics, and relation to dough elasticity. *J. Food Sci.* 72(3):R56-63.