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High Molecular Weight Glutenin Subunit Variation among Indian Wheat Varieties

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ABSTRACT

Improving wheat for end use quality is an important goal for wheat breeders. The composition of high molecular weight glutenin subunits (HMW-GS) contributes to a great extent in determining wheat quality for processing. The HMW-GS are known to be encoded by six genes located at the *Glu-1* loci on the long arms of chromosomes 1A, 1B and 1D. The endosperm storage proteins of 62 Indian bread wheat cultivars were fractionated by sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE) to determine their high molecular weight (HMW) glutenin subunit composition. In total, three alleles (*Ax2**, *Ax1* or *Ax* null) at *Glu-A1*, seven allele/allelic pairs (*Bx7*, *Bx7+By8*, *Bx7+By9*, *Bx20*, *Bx13+By16*, *Bx13+By19* and *Bx17+By18*) at *Glu-B1* and two allelic pairs (*Dx2+Dy12* and *Dx5+Dy10*) at *Glu-D1* were identified in the analysed varieties. Allele or allelic pair *Ax2** (59.7%) at *Glu-A1*, *Bx17+By18* (27.4%) at *Glu-B1* and *Dx2+Dy12* (69.4%) at *Glu-D1* were present most frequently in wheat varieties taken for study.

Quality score of varieties were ranged from 4 to 10, with an average of 7.55 indicating vast genetic diversity among the varieties. The presence of subunits combinations in different varieties with low, medium and high gluten strength indicated that breeding wheat for bread, chapatti and biscuits is possible as per end use requirement.

INTRODUCTION

High molecular weight glutenin subunit composition of a genotype heavily determines the end use quality of wheat. These high molecular weight glutenin subunits are encoded by genes at the *Glu-A1*, *Glu-B1* and *Glu-D1* loci on the long arm of homoeologous chromosomes 1A, 1B and 1D, respectively (Payne and Lawrence, 1983). These loci encode an x-type subunit of higher molecular weight and a y-type subunit of lower molecular weight (Harberd et al., 1986). Most of the bread wheat cultivars possess from three to five active high molecular weight glutenin subunits due to silencing of some of these genes. The HMW-GS composition of a genotype is one of most important genetic factor for determining processing quality of wheat. There are differences in quality effects of glutenins coded by same locus. The alleles Ax1 and Ax2* of *Glu-A1* have been found to have a better effect on bread-making quality compared to Ax-null allele (Gupta et al., 1994; He et al., 2005). The High Molecular Weight subunits Dx5+ Dx10 of the *Glu-D1* are correlated with higher dough strength, whereas the Dx2+ Dx12 alleles are correlated with poor bread-making quality (Branlard and Dardevet, 1985; Glanibelli et al., 2001).

Deletions at different HMW-GS loci on A,B or D genomes have shown to produce processed products with varied quality scores (Jondiko et al., 2012; Mondal et al., 2008; Uthayakumaran et al., 2003) and specialty breads with improved quality (Zhang et al., 2014). Rheological studies on deletions of different high molecular weight glutenin subunits loci at one genome and keeping intact HMW loci at other genome helps to investigate the role of each of these subunits on dough functionality (Jondiko et al., 2012; Mondal et al., 2008). Quality scores were assigned to individual high molecular weight glutenin subunits based on sodium dodecyl sulfate (SDS) sedimentation volume and alveographic parameter W (Payne et al., 1987; Pogna et al., 1992). Characterization of wheat genotypes for high molecular weight glutenin subunits is useful for breeders in choosing parental lines and selecting progenies with superior gluten quality.

In this study, the electrophoretic patterns of HMW glutenin subunits were analysed from 62 spring wheat cultivars released between 1965 and 2001. These cultivars were developed for five wheat agroclimatic zones of India, viz, North Western Plains Zone (NWPZ), Northern Hills Zone (NHZ), North Eastern Plains Zone (NEPZ), Central Zone (CZ) and Peninsular Zone (PZ) (Table1).

Table 1. HMW glutenin subunit at *Glu1* loci, year of release and zone of cultivation of Indian wheat cultivars

S.No.	variety	Year of release	Zone of cultivation	of Sowing conditions	<i>GluA1</i>	<i>GluB1</i>	<i>GluD1</i>
1	PBW175	1989	NWPZ	TS,RF	2*	7+8	2+12
2	HD1949	1971	Western UP	TS,IR	2*	7+8	2+12
3	HD2281	1983	NWPZ	TS,IR	2*	7+8	2+12
4	HD1982	1974	NEPZ	LS/TS	2*	7+8	2+12
5	HD2285	1983	NWPZ	LS/VLS,IR	2*	7+8	2+12
6	PBW226	1989	NWPZ	LS,IR	2*	7+8	2+12
7	HD2009	1975	NWPZ	TS,IR	2*	7+8	2+12
8	HD2270	1984	NWPZ	LS,IR	2*	7+8	2+12
9	HD2327	1982	CZ	LS,IR	2*	7+8	2+12
10	HD2380	1989	NHZ/PZ	TS/LS,IR/RF	2*	7+8	2+12
11	HD2501	1990	PZ	TS,IR	2*	7+8	2+12
12	HDR77	1990	NEPZ	LS,RF	2*	7+8	2+12
13	HUW234	1985	NEPZ	LS,IR	2*	7+8	2+12
14	NW1014	1997	NEPZ	TS,IR	2*	7+8	2+12
15	NP846	1965	NHZ	TS,RF/LIR	2*	7+8	2+12
16	UP2338	1990	NHZ	TS,IR	2*	17+18	2+12
17	HD2189	1979	PZ	TS,IR	2*	17+18	2+12
18	Kalyansona	1967	NWPZ	TS,IR	2*	17+18	2+12
19	HD2329	1982	NWPZ	TS,IR	2*	17+18	2+12
20	HD2385	1987	FEZ	LS/IR	2*	17+18	2+12
21	WL711	1977	NWPZ	TS/IR	2*	17+18	2+12
22	Hindi62	1935	NEPZ	TS/IR	2*	17+18	2+12
23	Sonalika	1965	NW/NEPZ	LS/IR	2*	7+9	2+12
24	Kanchan	1994	CZ	TS,IR	2*	7+9	2+12
25	HD2687	1999	NWPZ	TS/IR	2*	7+9	2+12
26	NP852	1965	NEPZ	TS/LS,IR	2*	7+9	2+12
27	Lermarojo	1965	CZ	TS,IR	2*	13+16	2+12
28	NW1012	1997	NEPZ	TS,IR	2*	13+16	2+12
29	Kundan	1981	NWPZ	TS,IR	2*	17+18	5+10
30	HI385	1975	CZ	TS,RF	2*	17+18	5+10
31	LOK1	1981	CZ	TS/LS,IR	2*	17+18	5+10

32	WH542	1992	NWPZ	TS,IR	2*	7+9	5+10
33	PBW299	1993	NWPZ	TS,RF	2*	7+9	5+10
34	HD2733	2001	NEPZ	TS,IR	2*	7+9	5+10
35	PBW435	2004	NWPZ	LS, IR	2*	7+9	5+10
36	NP824	1960			2*	7+9	5+10
37	Vidisha	1996	CZ	LS,IR	1	17+18	2+12
38	Raj3077	1989	NWPZ	TS/LS,IR	1	17+18	2+12
39	GW190	1994	CZ	TS,IR	1	7+9	5+10
40	HS240	1989	NHZ	TS,RF/LIR	1	7+9	5+10
41	HUW206	1983	NEPZ	TS,IR	1	7+9	5+10
42	MACS2496	1991	PZ	TS,IR	1	7+9	5+10
43	NIAW34	1995	PZ	LS/VLS,IR	1	7+9	5+10
44	PBW373	1993	NWPZ	TS,IR	1	7	5+10
45	PBW343	1996	NWPZ	LS,IR	1	7	5+10
46	RAJ3765	1995	NW/NEPZ	LS/VLS,IR	1	7	5+10
47	NI5439	1973	PZ	TS,IR/RF	N	17+18	2+12
48	NI5643	1978	PZ	TS,IR	N	17+18	2+12
49	NI747-19	1973	PZ	TS,RF/LIR	N	17+18	2+12
50	C306	1965	NWPZ/NEPZ	TS/RF	N	20	2+12
51	HW2004	1995	CZ	TS,RF	N	20	2+12
52	N-8223	1991	PZ	TS,RF	N	20	2+12
53	C-518	-	-	-	N	20	2+12
54	C-591	-	-	-	N	20	2+12
55	WG357	1973	NWPZ	TS,IR	1	20	2+12
56	C273	-	-	-	1	20	5+10
57	PBW138	1987	NWPZ	TS,IR	N	13+19	2+12
58	NIAW301	2001	PZ	TS,IR	N	7+9	2+12
59	Sonora-64	1965	NPZ/CZ	LS/LS,IR	1	17+18	5+10
60	MP3054	-	-	-	1	17+18	5+10
61	Kharachia-65	1970	All zones	TS,IR	2*	20	2+12
62	Chinese Spring				N	7+8	2+12

MATERIALS and METHODS

Plant material: Seeds of 62 bread wheat varieties (Table 1) collected from different research and development institutions in India and maintained at Gamma field, Bhabha Atomic Research Center, Mumbai were used for this study. The grains were ground to fine powder and 10mg was weighted in 1.5mL micro tube. 250 μ L of protein extraction buffer (Tris-HCl 0.05M, pH.8, 0.02% SDS, 30.3% urea, 1% 2-mercaptoetnanol) was added to each micro tube, boiled on flame for 10 minutes, and then after cooling centrifuged at 13000rpm for 10 min. The high molecular weight glutenin subunit profile of wheat varieties was resolved by sodium dodecyl sulfate polyacrylimide gel electrophoresis (SDS-PAGE) procedure according to Laemmli (1970) and latter modified by Bhagwat and Bhatia (1993). The high molecular weight glutenin subunit variation was identified using the numbering system of Payne and Lawrence (1983). The quality scores was assigned to each HMWGS of a subunit pair using scoring described by Payne et al. (1987) and Pogna and Mellini (1986).

RESULTS

Amongst the 62 varieties analysed for high molecular weight glutenin subunits, three alleles and their corresponding subunits *Glu-A1a* (1), *Glu-B1b* (2*) and *Glu-A1c* (Null) with 16.1, 24.2 and 59.7% frequency

were observed. Allelic variation at *Glu-B1* locus showed seven alleles which included *Glu-B1a* (7), *Glu-B1b* (7+8), *Glu-B1c* (7+9), *Glu-B1e* (20), *Glu-B1f* (13+16), *Glu-B1g* (13+19) and *Glu-B1i* (17+18) 4.8, 25.8, 24.2, 12.9, 3.2, 1.6 and 27.4%, respectively. The *Glu-D1* locus showed two alleles with their subunits included *Glu-D1a* (2+12) and *Glu-B1d* (5+10) with frequency of 69.4 and 30.6%. A total of 12 different alleles were identified on all three *Glu1* loci (Table 2).

The maximum frequency of subunit 2* and 1 at *Glu-A1* locus indicated that varieties were improved for higher gluten strength compared to null allele in lowest frequency. The *GluA1c* (null) allele was found to exist only in combination with *Glu-D1a* (2+12) in analysed varieties.

The coexistence of *Glu-1Ac* allele in combination with *Glu-D1a* allele was also observed earlier in Indian wheat genotypes Ram S. (2003). *Glu-B1* locus showed higher frequency of three alleles *Glu-B1b* (7+8), *Glu-B1c* (7+9) and *Glu-B1i* (17+18) and contribute better gluten strength. The subunit 20 at *Glu-B1* locus was found in eight of analysed varieties (Table 3).

The high molecular weight glutenin subunit combinations (allele at *Glu-A1*, *Glu-B1* and *Glu-D1*) and their frequencies in 62 cultivars are given in table 3. Among the 62 wheat varieties analysed, 19 different patterns were observed based on high molecular weight glutenin subunit combination at all three *Glu-1* loci. The most frequent patterns were 2*, 7+8, 2+12 (15 varieties), 2*, 17+18, 2+12 (7 varieties) and 1, 7+9, 5+10 and 2*,

7+9, 5+10 and N, 20, 2+12 (5 varieties each). Three of the analysed varieties namely Kundan, HI385 and LOK1 carried strong subunits at all loci 2* at *Glu-A1*, 17+18 at *Glu-B1* and 5+10 at *Glu-D1*. The major requirement for Indian wheat is for chapatti making and subunit 20 has great role to play for contributing medium gluten strength needed for dough for chapattis. Subunit 20 at *Glu-B1* is present in combination with strong Subunit '1' at *Glu-A1* and weak subunit 2+12 at *Glu-D1* locus in the cultivar Kharchia65. In five varieties C-306, HW2004, C-518, C-591 and N8223, the subunit '20' is present with subunit 'Null' at *Glu-A1* and 2+12 at *Glu-D1* contributing weak

gluten strength. The gel showing the allelic variation and HMW-GS patterns is presented in figure 1a and 1b.

The high molecular weight quality score calculated by adding individual score assigned to each subunit or subunit pair by Payne and Lawrence (1983) and Pogna et al., (1989). The most of varieties (~90%) analysed has higher gluten strength with *Glu-1* score ranging from 8-10 and only 10% of varieties has *Glu-1* score of 5-7 (Table 3). This indicated that the wheat varieties bred in most zones are suitable for bread rather than chapattis and there is need to breed for varieties with medium *Glu-1* score suitable for chapatti making quality.

Table 2. Allele frequencies of HMW Glutenin subunits at *Glu-1* loci in 62 varieties of bread wheat

Locus	Allele	No. of varieties carrying	Frequency
<i>Glu-A1</i>	N	11	17.7
	1	14	22.6
	2*	37	59.7
<i>Glu-B1</i>	7	3	4.8
	7+8	16	25.8
	7+9	15	24.2
	20	8	12.9
	13+16	2	3.2
	13+19	1	1.6
	17+18	17	27.4
<i>Glu-D1</i>	5+10	19	30.6
	2+12	43	69.4

Table 3. Combinations of HMW-GS alleles (*Glu-A1*, *Glu-B1* and *Glu-D1*) and their frequencies in 62 bread wheat varieties from India

<i>Glu-A1</i>	<i>Glu-D1</i>	<i>Glu-B1</i>	Genotype	Frequency	<i>Glu1</i> score	<i>Alveograph' W'</i>
2*	2+12	7+8	PBW175,HD1949,HD2281,HD1982,HD2285,PBW226,HD2009,HD2270,HD2327,HD2380,HD2501,HDR77,HUW234,NW1014,NP846	15	8	8
		17+18	UP2338, HD2189, Kalyansona, HD2329, HD2385,WL711,Hindi62	7	8	13
		7+9	Sonalika, Kanchan,HD2687,NP852	4	7	12
		20	Kharachia-65	1	6	8
		13+16	Lermarojo,NW1012	2	8	12
	5+10	17+18	Kundan, HI385, LOK1	3	10	17
		7+9	WH542,PBW299,HD2733,PBW435, NP824	5	9	16
1	2+12	7+8	HD2428	1	8	6
		17+18	Vidisha, Raj3077	2	8	11
		20	WG357	1	6	6
	5+10	17+18	Sonora-64, MP3054	2	10	15
		7+9	GW190, HS240, HUW206, MACS2496, NIAW34	5	9	14
		7	PBW343, PBW373, Raj3765	3	8	11
		20	C273	1	8	10
N	2+12	17+18	NI5439, NI5643, NI747-19	3	6	10
		7+9	NIAW301	1	5	9
		20	C-306,N8223, HW2004,C-518,C-591	5	4	5
		13+19	PBW138	1	-	4
					7.45	10.45

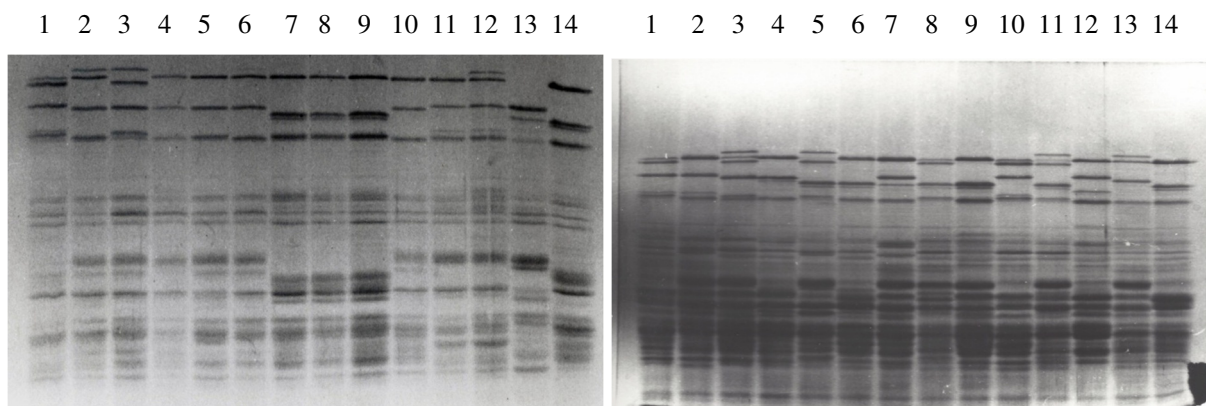


Figure1a:HMW-GS profile of varieties:1-NP824 (2*, 7+9, 5+10), 2- WG357 (1, 20, 2+12), 3-C273 (1, 20, 5+10), 4-C306(N, 20, 2+12), 5-C518 (N, 20, 2+12), 6-C591(N, 20, 2+12), 7-NI5439 (N, 17+18, 2+12), 8-NI5643 (N,17+18, 2+12), 9-NI747-19 (N, 17+18, 2+12),10-N8223 (N, 20, 2+12),11-NIAW301(N, 7+9, 2+12), 12-NIAW34 (1, 7+9, 5+10), 13-NI5749(N, 13+16, 2+12), 14-HD2329 (2*,17+18,2+12)

Figure1b:HMW-GS profile of varieties1-WH42(2*, 7+9, 5+10),2-Sonalika (2*, 7+9,2+12), 3- C273 (1, 20, 5+10), 4-Kharchia-65 (2*, 20, 2+12), 5-Sonora 64 (1, 17+18, 5+10),6-NP846 (2*,17+18,2+12), 7- Lermarojo 64 (2*,13+16,5+10), 8-HI-385 (2*,17+18, 5+10), 9- Hindi62 (2*, 17+18, 2+12), 10-PBW435 (2*, 7+9, 5+10), 11-MP3054 (1,17+18,5+10), 12-Chinese spring (N, 7+8, 5+10), 13-WG357 (1, 20, 2+12), 14-Kalyansona (N,

DISCUSSION

The analysis of glutenin subunits has proved useful for diversity studies and to optimize the variation in wheat germplasm for quality improvement of new wheat selections. The results of present study revealed a broad range of variation for allelic variants at *Glu-1* loci and combination of these alleles at three loci led to 19 different high molecular weight glutenin subunits patterns. Since the plant material for study was varieties released for different cultivation zones, however, there was no association of presence of varieties with specific subunit or subunit combination in the zones of cultivation.

Each zone has varieties differing for gluten strength based on HMW-GS constitution at all three *Glu* loci. It has been established in number of studies that glutenin protein of wheat grain plays an important role in processing quality of wheat particularly for bread and pastas (Branlard and Dardevet, 1985; Ng and Bushuk, 1988). Wheat varieties originated in East Asia countries possess predominantly allele *Glu-D1a* coding for subunits 2 + 12 (Fang et al., 2009; Liu et al., 2007) and contribute weak gluten strength. The results of present study also confirm the same and *Glu-D1a* coded subunit 2+12 is present in 69% of varieties compared to *Glu-D1d*, which is in 30% of varieties. This correspond that the HMW-GS compositions of wheat varieties originated in different countries of the world reveal the purpose for which they were commonly used. It has been observed in studies that alleles known for superior bread-making quality of hexaploid wheat are found in considerably lower frequency in countries such as China or Japan (Li et al., 2009; Tanaka et al., 2003). The presence of subunits 1/2* at *Glu-A1*, 7+8, 17+18 at *Glu-B1* and 5+10 at *Glu-D1* resulted in better rheological properties for bread making. Whereas for chapatti making qualities which is indigenous requirement of India and other Asian countries require medium gluten strength and can be achieved by addition of subunit 20 with strong subunit at other *Glu* loci. Sreeramulu et al., (2004) mentioned the importance glutenin subunits for chapatti making quality. The subunit 20 was more prevalent in old varieties, which are no more in cultivation. However, there is need to bring subunit 20 in combination with other subunits at *Glu-A1* and *Glu-D1* locus in breeding lines for selection of varieties with medium gluten strength for chapatti making quality.

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