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An analysis to explore divergence of HMW glutenin subunits in high-yield Indian wheat of different production environments

Devinder Mohan* and Raj Kumar Gupta

ICAR-Indian Institute of Wheat and Barley Research, Karnal, Haryana, India

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****Corresponding author***

Email: *devmohan@gmail.com*

Abstract

Fifteen years grain quality data of 231 high yielding bread wheat genotypes evaluated in different production environments of India was examined to understand prevalence of high molecular weight glutenin subunits (HMW-GS) in different production environments. Six agro-climatically diverse zones and two production conditions (timely-sown and late-sown) per zone represented diverse wheat growth environments prevailing in India. Difference in frequency level of different subunits has been explained in this review. Accurance of various subunits varied promptly in diffrenrent zones (Glu B1) and climates (Glu D1). Diffrence as per production condition was also noticed in same variants of Glu B1 locus. Parallelism between quality of bread and the glutenin subunits was observed under varying wheat growth environments. It was further demonstrated that overall product quality of a given production environment can be better explained by ratio between desirable and undesirable HMW glutenin subunits.

Keywords: HMWGS distribution, bread quality, production environments, Indian wheat

1. Introduction

India has diverse production environments and the end-use quality of wheat also varies accordingly (Mohan *et al.*, 2011, Mohan and Gupta 2015 and 2015a). One important constituent of wheat dough quality is the HMW-GSwhich are encoded by three different loci namely Glu-A1, Glu-B1 and Glu-D1. Different variants of these glutenin subunits have been described for each locus and each variant has different effect on gluten strength (Payne *et al.* 1981; Payne *et al.*1987).

Importance of HMW-GS has also been substantiated in the Indian wheat and their use as selection parameter has been emphasised to enhance bread quality (Ram 2003; Chowdhury *et al.,* 2006; Sharma *et al.,* 2012; Mohan and Gupta 2013; Sarkar *et al.,* 2015). Reports of the All India Coordinated Research Project (AICRP) on Wheat and Barley Improvement does mention composition of HMW-GS in various test entries but whether these subunits are equally spread in all production environments, is not well known. Unlike other grain quality parameters, HMW-GS have not been critically examined for any divergence under varying production environments. It is apparent that HMW-GS composition of a given genotype remains unchanged under any environment but what kind of HMW-GS composition is ascertained in a particular environment is not well understood.

It is interesting to establish whether variations in agro-climatic and production conditions also make difference in HMW-GS composition. Divergence of HMW-GS in wheat had been reported from Croatia (Horvat *et al.,* 2002) and impact of environmental influence on their distribution had also been examined in Turkey (Kaya and Akcura, 2014). This aspect requires critical examination in India as reports published so far are scanty even though agro-climatic diversity and production conditions are quite diverse. Except a few reports like frequency distribution of various HMW-GS in the peninsular region (Shitre *et al.,* 2016) and preponderance of 2+12 subunit in comparison to 5+10 (Glu D1)inthe heat stressed environments (Mohan and Gupta 2013a), no detailed investigation had been done under Indian conditions. AICRP on Wheat and Barley Improvement provides a perfect platform to examine such issues as it evaluates wheat entries for yield and quality traits in different production environments. Utilising 15-year data of this national project, this investigation makes comprehensive study on distribution of all glutenin subunits in high yielding wheat genotypes under diverse production environments and also tries to correlate concurrence of the desirable HMW-GS and their combinations with quality of the bread.

2. Study material, production environments and methodology

Bed In total, 231 bread wheat (*Triticum aestivum L.*) genotypes were evaluated during the period 2002-16 as released (checks) and pre-released (final year entries) varieties by the AICRP on Wheat and Barley Improvement in two trial series (timely-sown and late-sown) of the irrigated Advance Varietal Trials (AVT's). This elite group of the high yielding wheat genotypes (HYW's) belonged to six agro-climatic regions named as Northern Hills Zone (NHZ), North Western Plains Zone (NWPZ), North Eastern Plains Zone (NEPZ), Central Zone (CZ), Peninsular Zone (PZ) and Southern Hills Zone (SHZ).

Besides agro-climatic diversity, production conditions (early-sown and late-sown) provided another source of variation in every zone as the wheat grown under late-sown condition face higher temperature by virtue of that the grain ripening is quicker in comparison to the timely-sown wheat. As the study material was picked from different production environments, stress bearing capacity in the HYW's varied. Genotypes tested in the two production conditions were pooled zone-wise to note variation in distribution of HMW-GS in the irrigated wheat at the regional level.

Since the material tested in different zones varied in number, comparison was made on the percentage basis. Comparison of HMW-GS distribution under the two production conditions was made across the country by pooling all the zones. In this analysis, SHZ was excluded as late-sown trial is not conducted in this region. Comparison was also made within the same zone to test spread of HMW-GS in two production conditions. Frequency distribution of glutenin subunits was collated with mean bread loaf volume recorded in each environment. Ratio of these three desirable cobinations with the remaining undesiable combinations was derived and this ratio between desirable and undesirable combinations (DUC) was compared with avergae bread loaf volume in the region.

3. Prevalence of HMW-GS in different production environments

3.1 Glu A1 locus : At the Glu A1 locus, three types of HMW-GS are found i.e. null (N), 1 and 2*. Except N, both subunits have desirable effect on dough quality. This investigation revealed that majority of the material across the production environments belonged to subunit 2* and just 11% carried the null subunit. Difference in occurrence of 2* and 1 subunits was not conspicuous between zones and production conditions (Fig 1).

Although genotypes carrying N subunit were few, its proportion was relatively high in NHZ (TS: 20%, LS: 27%) and timely-sown material of NEPZ (21%). In rest of the production environments, frequency of subunit N was less than 20%. NWPZ and CZ are the two high yielding zones of the country (Mohan *et al.* 2016) and prevalence of subunit N was lowest in these two zones. Occurrence of subunit N was rare in late-sown material of the Indian plains.

Differences were more apparent when the HYW's were assorted zone-wise. It was observed that frequency of subunit 2* was higher in the plains (69 to 79%) in comparison to the hills (50%). On the contrary, frequency of N subunit was relatively lower in the plains (5 to 13%) in comparison to the hills (SHZ: 17%, NHZ: 20%). It indicated that null subunit in HYW's was more frequent in the hills in comparison to the plains. Some variation could also be noted in distribution of subunit 1 as its frequency in the timely-sown wheat was higher than the late-sown in NHZ and NEPZ whereas it was just reverse in the NWPZ.

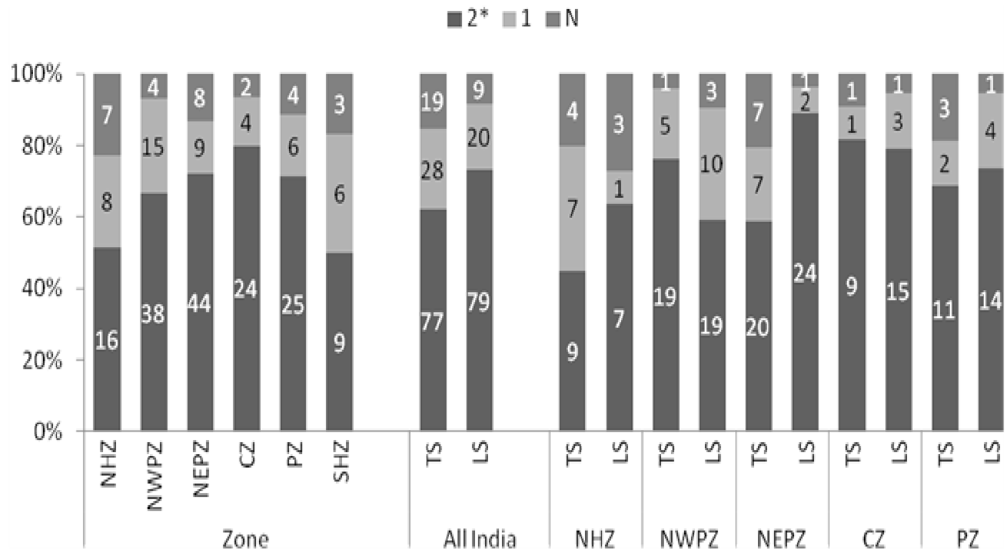

Fig. 1 Distribution of Glu A1 subunits in different production environments

3.2 Glu B1 locus : Four HMW-GS variants (7, 7+8, 7+9 and 17+18) were frequently observed for the Glu B1 locus and frequency distribution was quite different in various production environments. Zone-wise comparison revealed that occurrence of subunit 7 was lowest in every zone. Except NHZ, frequency of subunit 7 was relatively higher in the timely-sown wheat in comparison to late-sown. Subunit 7 is not considered desirable glutenin unit for bread making (Payne *et al.* 1981). Since its frequency was low, no major deviation could be accounted for subunit 7 except that its occurrence was relatively high when climate was cool as noticed in the hills. The timely-sown wheat of the plains had more such subunits in comparison to the late-sown wheat. Subunit 7+9 is also not a preferred subunit for dough quality (Payne *et al.* 1981; Payne *et al.* 1987) but its presence in the HYW's was higher in comparison to subunit 7. Zone-wise comparison revealed that concurrence of 7+9 in HYW's of hills and NWPZ was higher in comparison to rest of the zones. Again except NHZ, its share in the timely-sown wheat was larger than material of the late-sown situation. It showed that when the environment in a given region was cool (hills) or congenial for wheat growth (NWPZ), subunit 7+9 was observed more frequently. Like subunit 7, smoother growth environment in the timely-sown wheat also favoured 7+9 occurrence in the HYW's of the Indian plains.

Results showed that subunit 7+8 was almost equally spread in all the zones and barring NHZ, its relative frequency was generally higher in the late-sown wheat. Difference as per production condition was very acute in the Indo-Gangetic Plains (NWPZ and NEPZ) where only one genotype expressed subunit 7+8 in all timely-sown HYW's of both the zones. It showed that agro-climatic diversity had no major impact on concurrence of subunit 7+8. Unlike 7+9 and 7 subunits, share of 7+8 was higher in HYW's of the late-own condition. Subunit 17+18 is the most preferred subunit for dough quality of the Indian wheat (Sharma *et al.* 2012). Occurrence of subunit 17+18 was lowest in the hills (NHZ: 6%, SHZ: 13%). Relative frequency of subunit 17+18 matched the two production conditions in NHZ, NWPZ and PZ. In NEPZ, 17+18 expressed higher frequency in the timely-sown wheat whereas late-sown wheat outscored in CZ. It showed that occurrence of subunit 17+18 was highly specific to the production environments. When 7+8 and 17+18 subunits were considered together, presence of these most desirable subunits was lowest in the hills (SHZ: 33%, NHZ: 43%) and highest in CZ (71%). Their total frequency in NWPZ, PZ and NEPZ was 52, 61 and 67%, respectively. Occurrence of 17+18 was less in the hills whereas frequency of 7+9 increased in cooler climate of the country *i.e.* NHZ, SHZ and NWPZ.

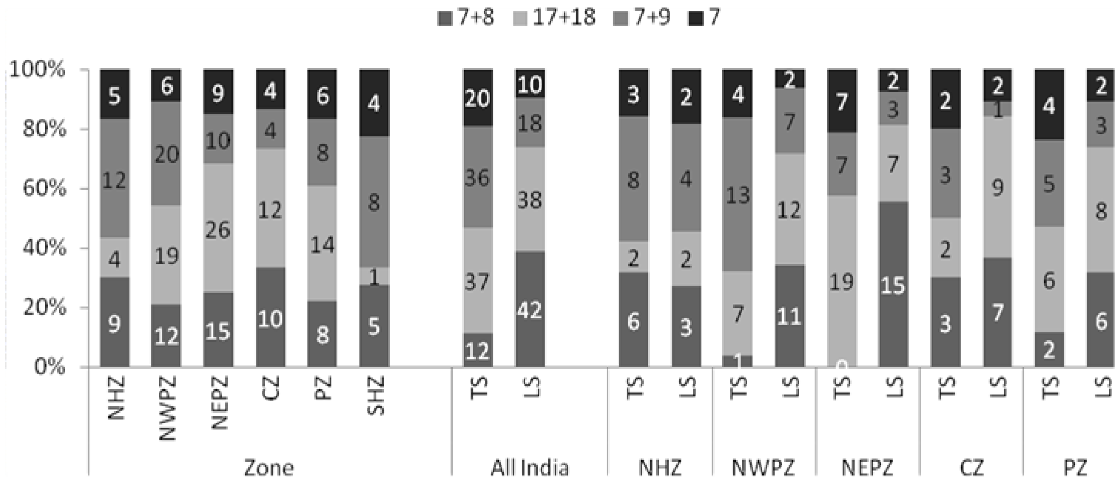

Fig. 2 Distribution of Glu B1 subunits in different production environments

3.3 Glu D1 locus: There are two subunits of Glu D1 locus i.e. 5+10 and 2+12. Results indicated that 5+10 dominated in the most congenial wheat growth region of the country i.e. NWPZ as nearly three-fourth genotypescarried this desirable subunit(Fig 3). It was just the reverse in dry-hot environment of CZ where only one-fifth genotypes had subunit 5+10. In NEPZ and PZ, 2+12 types were slightly in higher proportion (54 and 61%) whereas equalspread was noticed in the hills. Results on production environments further testified that proportion of subunit 2+12 increased in the late-sown HYW's across the country. Even then, frequency of subunit 5+10 was higher in both production conditions of NWPZ (Table 1). Reverse was true in case of CZ where both production conditions expressed higher proportion 2+12 subunit.

It showed that irrespective of production condition, compositions with 5+10 subunit were favoured when climate was conducive for wheat growth and subunit 2+12 dominated when climate was less congenial or even suppressive. Similar observations were recorded earlier by Mohan and Gupta (2013a) in the Indian wheat suggesting that proportion of 2+12 subunit increased at the cost of 5+10 when climate was suppressive for wheat growth. In this investigation, this trend was further testified when two production conditions were compared within and across the zones. Even within the sub territories like the Indo-Gangetic Plains and the central-peninsular India, relatively cooler zone had higher occurrence of 5+10 as observed by comparing NWPZ against NEPZ and PZ against CZ.

4. Influence on differential HMW-GS distribution on quality of bread

To assess quality effect of HMW-GS, different scores proportionate to the gluten strength have been assigned to these subunits(Payne *et al.* 1981& 1987). It is generally stated that 1, 2* (Glu A1); 7+8, 17+18 (Glu B1); and 5+10 (Glu D1) contribute positively to high dough strength (Payne *et al.* 1987; Gianibelli*et al.* 2001; Pena 2008; Guo*et al.* 2010). Though their contribution cannot be overlooked in quality of wheat grains, HMW-GS are not the only factor controlling dough quality as they make up about 6-8% of the total gluten content that in turn constitute about 8-15% of the dry weight of wheat flour. Several other grain and non-grain parameters contribute in product quality of the Indian wheat (Mohan *et al.* 2011; Mohan and Gupta 2015a and 2015b). Some studies had suggested that 1BL/1RS translocation also express adverse affect on end-use quality of the Indian wheat (Dhaliwal *et al.* 1988; Singh and Sreeramulu1994; Singh *et al.* 2009). Still, it was possible to draw parallelism between the end-product quality and the glutenin subunits under varying Indian conditions. When HYW's were put to this test, data on bread quality revealed that loaf volume in PZ (571cc) was significantly better than all other zones whereas hills zones remained at the bottom (NHZ: 542cc, SHZ: 546cc). Average bread volume in the Indo-Gangetic Planis (NWPZ: 560cc, NEPZ: 562cc) was significantly higher

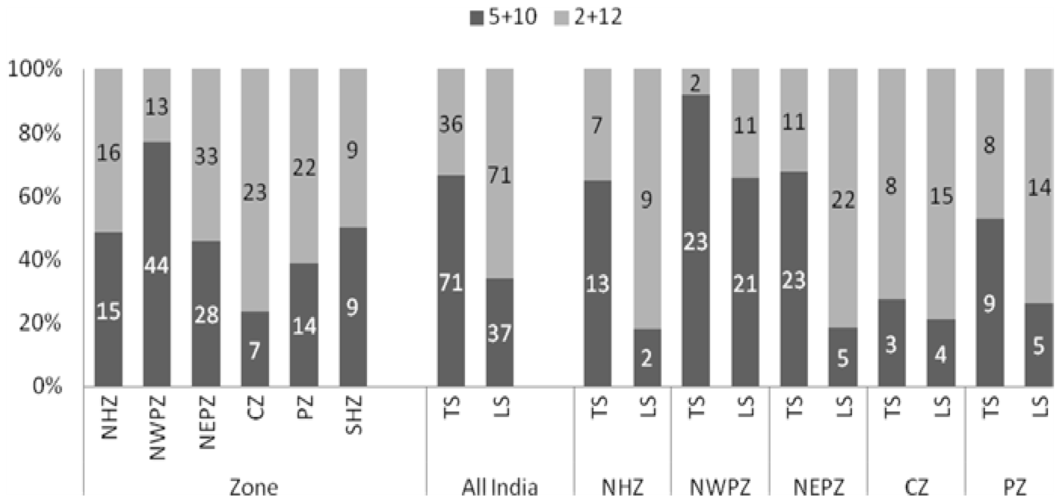

Fig. 3 Distribution of Glu D1 subunits in different production environments

than central India (CZ (554cc). HMW-GS frequency suggested that lower bread quality in the hills could be related with lower percentage of subunit 17+18 (NHZ: 13.3%, SHZ: 5.6%) and larger proportion of subunit 7+9 (NHZ: 36.6%, SHZ: 44.4%). Relatively higher frequency of N subunit was another deterimenmtal factor in these two regions.

When two zones of central-peninsular India (CZ and PZ) were compared, lower bread loaf volume in CZ in compariosn to PZ could be attributed to relatively lower frequency of subunit 5+10, otherwise occurance of the other desirable subunits like 17+18, 7+8 and 2* was comparable in the two zones. Better dough quality of 5+10 in comparison to 2+12 had been found in several studies (Payne *et al.* 1987; Gianibelli*et al.* 2001; Ram 2003; Oury*et al.* 2010; Mohan and Gupta 2015a). In the Indo-Gangetic Plains, NEPZ had an edge over NWPZ inspite of lesser proportion of subunit 5+10 simply because HYW's of NWPZ had lesser proprtion of 7+8/ 17+18 subunits in comparion to NEPZ and subunit 7+9 also figured more frequently in wheat bowl of the country.

5. Relevance in quality improvement

On the basis of this investigation, it was easier to equate quality of the bread with the HMW-GS compositions in a given agroclimatic region. Although combinations of the subunits 2*/1 (Glu A1), 7+8/17+18 (Glu B1) and 5+10 (Glu D1) are best suited for` good quality gluten; some reports from India also suggest that 2+12 can give similar results when 17+18 exists at Glu B1.

The test material in two production conditions of each zone was therefore assorted to note number of the three most desirable combinations i.e. i) 5+10 with 2*/1 and 7+8, ii) 5+10 with 2*/1 and 17+18, and iii) 2+12 with 2*/1 and 17+18. Ratio of these three desirable cobinations with the remaining undesiable combinations was derived and this ratio between desirable and undesirable combinations (DUC) was compared with avergae bread loaf volume in the region.

When two production conditions were compared in a given zone, it was observed that bread loaf volume increased with fall in DUC ratio. Bread loaf volume in late-sown wheats of NHZ and NEPZ was lower than the timely-sown wheat as undesirable comninations were relatively more under late-sown situation. On the contraray, late-sown wheat in NWPZ and CZ produced better quality bread and DUC ratio indicated lesser number of underaible combinations in HYW's of late-sown condition. DUC ratio was smaller in both production conditions PZ, consequently bread loaf volume was also higher.

Table 1. Average bread loaf volume and DUC ratio in high-yield genotypes

Characteristic	NHZ	NWPZ	NEPZ	CZ	PZ
(A) Timely-sown wheat					
Total genotypes	20	25	35	11	17
Genotypes of composition 5+10, 2*/1 &7+8	4	0	0	0	1
Genotypes of composition 5+10, 2*/1 & 17+18	2	7	9	2	0
Genotypes of composition 2+12, 2*/1 & 17+18	0	0	9	1	6
DUC ratio	1.0:2.3	1.0:2.6	1.0:0.9	1.0:2.7	1.0:1.4
Bread loaf volume (cc)	552	556	564	541	566
(B) Late-sown wheat					
Total genotypes	11	32	27	19	19
Genotypes of composition 5+10, 2*/1 &7+8	1	2	2	1	1
Genotypes of composition 5+10, 2*/1 & 17+18	0	8	0	2	2
Genotypes of composition 2+12, 2*/1 & 17+18	2	4	7	6	5
DUC ratio	1.0:2.7	1.0:1.3	1.0:2.0	1.0:1.1	1.0:1.4
Bread loaf volume (cc)	528	565	558	562	575

6. Epilogue

This study has made it clear that concurrence of HMW-GS is not uniform in high yield wheat genotypes recommended for cultivation in different parts of India. Variants of Glu D1 are highly sensitive to the production environments whereas Glu A1 subunits are least affected by these factors. Glutenin subunits of Glu B1 are either specific to certain production environments or register predominance in cool or wheat congenial environment. Due to this divergence, certain environments are benefitted and some are not. Strategic planning becomes easy if breeders are mindful of this fact. They need to select the areas where efforts to enhance bread quality will reward suitably. In the quality improvement ventures, HMW-GS certainly enforce some impediments which are hard to overcome as noticed in high-yield genotypes of the hills. It's relatively easy to have good quality bread in the peninsular region as besides other grain quality parameters; desirable HMW-GS combinations occur more frequently than other parts of the country. A good balance of desirable and undesirable HMW-GS combinations is required for good bread making which is eluding in most productive wheat land of the country i.e. NWPZ, thereby restricting the efforts focused on enhancement of bread quality in the region. Though glutenin subunits are not the only regulatory factor in quality improvement, this investigation has demonstrated that composition of HMW-GS is crucial for making good quality bread under diverse Indian conditions.

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References

1. Chowdhury S, RK Sharma and BK Mishra. 2006. The distribution of high molecular weight glutenin subunits among some old wheat varieties of India. *Crop Improvement* **33**(2): 114-18.
2. Gianibelli MC, RB Gupta, D Lafiandra, B Margiotta and F MacRitchie. 2001. Polymorphism of high mrglutenin subunits in *Triticum tauschii*: Characterization by chromatography and electrophoretic methods. *Journal of Cereal Science* **33:** 39-52.
3. Dhaliwal AS, DJ Mares, DR Marshall and JH Skeritt. 1986. Protein composition and pentosan content in relation to dough stickiness of 1B/1R translocation wheats. *Cereal Chemistry* **62:** 143-149.
4. 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. *Genetic Resources and Crop Evolution* **57**(8): 1217-1225.

5. Horvat CA, Z Jurkovic, R Sudar, D Pavlinic and G Simic. 2002. The relative amount of HMW glutenin subunits of OS wheat cultivars in relation to bread-making quality. *Cereal Research Communication* **30:** 415-422.

6. Kaya Y and M Akcura. 2014. Effects of genotype and environment on grain yield and quality traits in bread wheat (T. *aestivum L.*). *Food Science and Technology, Campinas* **34**(2): 386-393.

7. Mohan D, SS Singh and RK Gupta. 2011. Vibrancy of the Indian wheats in upholding yield and quality under global environmental change. In: SS Singh, RR Hanchinal, Gyanender Singh, RK Sharma, BS Tyagi, MS Saharan and Indu Sharma (eds), *Wheat: Productivity Enhancement under Changing Climate,* 87-94, Narosa Publishing House, New Delhi.

8. Mohan D and RK Gupta. 2013. Analyzing grain properties of Indian bread-wheat cultivars for defining route to end-product quality and key attributes for selection. *Indian Journal of Genetics and Plant Breeding* **73**(4): 1-8.

9. Mohan D and RK Gupta. 2013a. An analysis to visualize influence of global warming on wheat grain quality with high molecular weight glutenin subunits at Glu D1 Locus. *Molecular Plant Breeding* **5**(7): 36-42.

10. Mohan D and RK Gupta. 2015. Understanding dynamics of gluten harvest in augmenting bread quality of high-yield Indian wheats. *Indian Journal of Genetics and Plant Breeding* **75**(3): 318-323.

11. Mohan D and RK Gupta. 2015a.Relevance of physiological efficiency in wheat grain quality and the prospects of improvement. *Physiology and Molecular Biology of Plants*, doi: 10.1007/s12298-015-0329-8.

12. Mohan D and RK Gupta. 2015b. Gluten characteristics imparting bread quality in wheats differing for HMWGS at Glu D1locus. P*hysiology and Molecular Biology of Plants,* doi: 10.1007/s12298-015-298-y.

13. Mohan D, V Tiwari and RK Gupta. 2017. Progression in yield and quality of wheat. *Indian Journal of Genetics and Plant Breeding* **77**(1): 16-24.

14. Oury FX, H Chiron, A Faye, O Gardet, A Giraud, E Heumez, B Rolland, M Rousset, M Trottet, G Charmet and G Branlard. 2010. The prediction of bread wheat quality: joint use of the phenotypic information brought by technological tests and the genetic information brought by HMW and LMW glutenin subunits. *Euphytica* **171**: 87-109.

15. Payne PI, KG Corfield, LM Holt and JA Blackman. 1981. Correlations between the inheritance of certain high-molecular weight subunits of glutenin and bread-making qualities in progenies of six crosses of bread wheat. *Journal of the Science of Food and Agriculture* **32**: 51-60.

16. Payne PI, JA Seekings, JA Worland, MG Jarvis and LM Holt. 1987. Allelic variation of glutenin subunits and gliadins and its effect on bread-making quality in wheat: analysis of F5 progeny from Chinese Spring x Chinese Spring (Hope 1A). *Journal of Cereal Science* **6:**103-118.

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

18. Ram S. 2003. High molecular weight glutenin subunit composition of Indian wheats and their relationships with dough strength. *Journal of Plant Biochemistry and Biotechnology* **12**: 151-155.

19. Sarkar S,AM Singh, AK Ahlawat, M Chakraborti and SK Singh.2015. Genetic diversity of bread wheat genotypes based on HMWGS profiling and its relation to bread making quality. *Journal of Plant Biochemistry and Biotechnology* **24**(2): 218-224.

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

21. Shitre AS, S Bakshi, DA Gadekar, AP Padhye and BK Das. 2016. Characterization of high molecular weight glutenin subunits of wheat genotypes. *Electronic Journal of Plant Breeding*, ISSN 0975-928X,doi: 10.5958/0975-928X.2016.00036.3.

22. Singh NK and G Sreeramulu.1994. High molecular weight glutenin subunits of Indian wheat cultivars: Association of subunits 5+10 with the 1BL/1RS wheat-rye translocation. *Journal of Cereal Science* **20**(3): 217-225.

23. Singh R, R Tiwari, RK Gupta, Priyamvada, J Shoran andB Mishra. 2009. 1RS.1BL translocation and grain yield as well as bread loaf volume in Indian wheats. *Cereal Research Communication* **37**(3): 441-448.