

A paradigm shift in quality of modern bread wheat varieties cultivated in north-western plains of India

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Wheat (*Triticum aestivum* L.) is a prominent staple food crop spread over different agro-ecological regions of India. The national wheat research system of the country i.e. All India Coordinated Research Project on Wheat and Barley (AICRPW&B) has classified these regions as northern hills zone (NHZ), north-western plains zone (NWPZ), north-eastern plains zone (NEPZ), central zone (CZ) and peninsular zone (PZ). It has generated data on quality traits of irrigated wheat varieties popular in timely-sown and late-sown conditions of these five zones. Depending upon the quality of the materials developed for each production environment, every production environment has some characteristic features of value addition and agronomic properties. Strength and the pitfalls are therefore liable to differ under diverse production environments. Traditionally, wheat harnessed in the Central and Peninsular India is rated high in quality. Emphasis given to wheat quality in the present era has brought tremendous difference in value addition properties of wheat. Reports emerging from India have underlined progression in many parts of the country not only for productivity but for quality of the wheat as well (Mohan *et al.*, 2017). Value addition properties are changing fast in the Indian wheat, especially in the NWPZ. The present study has examined wheat quality characteristics of the irrigated

wheat varieties released from 2010 onwards. An attempt has been made to emulate the strength and weakness in quality of the modern wheat varieties harnessed in the different production environments.

Productivity level of modern Indian wheat varieties in different production environments

A large number of wheat varieties had been examined for quality traits during the ten year period 2011-2022 (Table 1). Varietal cafeteria for new cultivars is quite big in timely-sown wheat (TSW) of the Indo-Gangetic plains i.e. NWPZ and NEPZ. In the late-sown category (LSW) however, the varietal options are limited in NEPZ. Option of new high yielding wheat varieties are just a few in TSW of NHZ and CZ also. After release of HI 1544 in 2008, the next two varieties for timely-sown condition of CZ were indentified in 2021 only. In TSW, productivity in NWPZ is significantly higher than all other zones whereas CZ and NWPZ hold this tag together in LSW. 1000 grain weight (TGW) of wheat varieties is however lowest in NWPZ under both production conditions. Traditionally, CZ is known for big grain size but now PZ has emerged as another territory of bold grains in the country (Mohan *et al.*, 2022). Currently, TGW of timely-sown wheat varieties is at par in CZ and PZ.



Table 1. Average productivity and grain weight in different production environments (period: 2011-22)

Zone	Productivity (q/ha)	TGW (g)	List of varieties
Timely-sown wheat			
NHZ	45.8	41.9	VL 907, HS 507, HS 562 and HPW 349
NWPZ	55.7	39.3	WH 1105, HD 2967, HD 3086, HD 3226, DPW 621-50, DBW 88, DBW 222 and DBW 187
NEPZ	45.9	40.8	RAJ 4229, NW 5054, K 1006, HD 2967, HD 3086, HD 3249, DBW 39 and DBW 187
CZ	53.8	43.8	HI 1636 and GW 513
PZ	45.8	43.8	UAS 304, MACS 6222, MACS 6478 and DBW 168
Late-sown wheat			
NHZ	30.4	41.8	VL 892 and HS 490
NWPZ	46.5	36.7	WH 1124, PBW 752, PBW 771, JKW 261, HD 3059, DBW 90, DBW 71 and DBW 173
NEPZ	39.3	38.3	HI 1621, HI 1563, HD 2985, HD 3118 and DBW 107
CZ	47.2	41.1	RAJ 4238, MP 3336, HI 1634 and CG 1029
PZ	40.5	39.4	HI 1633 and HD 3090

Wheat grain quality in different production environments Perusal of average performance reveals that every production environment has certain characteristic features (Table 2). Highest bread loaf volume in the country is now achieved in NWPZ and PZ under both production conditions. However, PZ has an edge over NWPZ in bread quality score in both categories of wheat. Bread loaf volume achieved in these two zones is significantly higher than CZ in TSW as well as LSW. Best *chapati* quality in the country is expressed in CZ. Wheat grown in the hills is best suited only for biscuit making. Irrespective of sowing time, the physical grain qualities like grain appearance score, test weight and 1000 grain weight are always best achieved in CZ. Varieties of PZ always excel in grain protein content in both wheat categories whereas NHZ varieties are the poorest in this aspect. However, protein yield per hectare is always higher in NWPZ. In the late-sown category, CZ

also matches NWPZ in the harvested protein yield. Zone wise, the timely-sown varieties don't differ much in grain hardness index. Under late-condition however, NWPZ has stronger grains in comparison to all other zones. Because of higher protein content, PZ tops in the gluten content but strength of the gluten i.e. sedimentation value; is highest in NWPZ. Quality of the gluten is adjudged by gluten index and HMWGS composition. Genotypes with 5+10 subunits at Glu-D1 locus express better dough quality than the 2+12 types. Varieties with the Glu 1 score 10 are rated best for quality of the gluten (Payne *et al.*, 1987; Pena, 2011). NWPZ leads in both the aspects of gluten and dough quality. In case of micronutrients, iron content is highest in LSW of NEPZ and PZ (40-41ppm) whereas zinc content is best achieved (41ppm) in the LSW of PZ and TSW of CZ.

Table 2. Quality features of the wheat grown in different production environments (period: 2011-22)

Charcateristics	Timely-sown wheat					Late-sown wheat				
	NHZ	NWPZ	NEPZ	CZ	PZ	NHZ	NWPZ	NEPZ	CZ	PZ
Bread loaf volume (cc)	544	572	541	460	577	506	563	555	522	563
Bread qulaity score (out of 10)	6.30	6.81	6.58	4.54	7.18	5.22	6.74	6.63	5.96	7.12
<i>Chapati</i> score (out of 10)	7.43	7.61	7.68	8.25	7.83	7.05	7.65	7.76	7.93	7.61
Biscuit spread factor	8.12	7.51	7.86	7.23	6.66	9.58	7.52	7.94	6.93	7.68
Grain apperance score	5.9	6.0	5.8	7.0	6.4	5.7	6.0	5.7	6.7	6.0



Test weight (kg/hl)	80.2	78.2	77.4	82.2	80.4	77.6	78.0	77.4	81.9	79.6
Grain protein content (%)	10.0	11.9	11.7	11.3	12.6	10.6	12.1	11.9	12.1	12.6
Protein yield (kg/ha)	452	664	535	594	577	321	561	456	570	509
Grain hardness index	74.7	74.2	75.0	75.2	73.2	47.9	82.4	75.2	73.9	76.2
Sedimentation value (ml)	47.7	54.1	50.8	41.4	42.9	41.5	53.3	46.4	42.2	45.9
Wet gluten (%)	23.7	28.6	27.4	32.9	33.9	24.1	29.4	28.2	31.6	31.9
Gluten index (%)	63.6	76.3	66.1	54.0	47.3	53.9	75.3	65.9	53.0	62.7
5+10 HMWGS (frequency)	4/4	8/8	6/8	0/2	1/4	0/2	8/8	2/5	0/4	2/2
Glu 1 score 10 (frequency)	2/4	7/8	4/8	0/2	0/4	0/2	6/8	0/5	0/4	0/2
Iron content (ppm)	34.9	38.0	38.5	37.2	39.5	37.9	38.6	40.5	38.6	39.9
Zinc content (ppm)	31.3	35.8	33.1	41.2	37.2	34.5	37.0	35.9	38.2	40.9

Bold figures depicts the non-significant group examined by t-test at $P < 0.05$

Data source: Annual Quality reports of AICRPW&B

Zone-wise comparison of wheat quality

Although wheat productivity is high in NWPZ and CZ but big difference prevails in the value addition properties (Table 2). Zone-wise differences detected by the t-test reveal that across the country; TSW of NWPZ has maximum number of the superior quality features like bread loaf volume, protein yield per hectare, gluten strength (sedimentation value), gluten quality (gluten index). LSW of this zone also excels in sedimentation value, gluten quality and grain hardness index. Majority of the NWPZ wheat varieties carry the HMWGS compositions essential for good quality of the dough. In comparison, main feature of the CZ wheat is the physical characteristics of the grains (grain appearance, 1000 grain weight and test weight) and *chapati* quality score. Wheat grown in this region lacks in strength and quality of the gluten. HMWGS composition in wheat varieties of CZ is also poor. It is generally perceived that wheat grown in CZ has hard grain texture but this analysis reveals that grain hardness index in CZ is similar to all other zones under timely-sown condition and inferior to NWPZ under late-sown condition. Both these zones match in iron grain density as well. In comparison to NWPZ; PZ does excel in bread quality and grain protein content but it is significantly inferior in sedimentation value, gluten index and protein yield. Zinc and iron content has always been good (≥ 40 ppm) in LSW of the peninsular region (Mohan *et al.*, 2009). There is no specialty of NEPZ wheat except that it tops in the grain iron density under both conditions.

Dynamism of wheat quality progression in NWPZ

Tremendous improvement has been witnessed in value addition properties of the wheat harnessed in NWPZ and progression in wheat quality traits has been exemplary (Mohan *et al.*, 2017). In the past, best bread loaf volume was recovered in PZ but now the present wheat varieties of NWPZ also offer similar loaf volume. This zone now offers the country best sedimentation value and gluten index. *Chapati* quality may look better in CZ but except NHZ, every other zone offer varieties that make good *chapati* (range: 7.5 to 8.0). If progress in wheat quality is gauged by comparing the five year mean of the earlier era i.e. 2006-10 (Table 3) with present status provided in the Table 2; it becomes clear that the wheat improvement programme of NWPZ has been highly dynamic in comparison to CZ and PZ (Table 3). In comparison to timely-sown varieties of the past era (PBW 343, PBW 502, PBW 550, DBW 17, WH 542), the new breed of NWPZ varieties has shown tremendous progress in bread loaf volume (from 553 to 572 cc), gluten index (59 to 77 %) and sedimentation value (39 to 54 ml). Chances of high class biscuit quality are obviously bleak in NWPZ because of the non-availability of soft grains; little improvement is still evident for this product as biscuit spread factor has increased from 6.78 to 7.51. There is some improvement in the physical grain quality parameters as well. In NWPZ, there are certain restrictions imposed by the climate due to which big jump is not possible in physical grain quality (Mohan *et al.*, 2017a). The post-anthesis period available in this part of the country is not sufficient to fill a larger number of



grains (Mohan *et al.*, 2020). Still, the region has witnessed some improvement in TGW (38.9 to 39.3 g) under timely-sown condition. Heavy grain bearing restricts the grain protein concentration and the gluten content in NWPZ. With productivity levels amounting to 5.5 t/ha, this much protein (11.9%) and hectoliter weight (78.2 kg/hl) is not bad in timely-sown wheat of this region especially when big improvement is witnessed in lot of other quality attributes. Grain appearance scores, a closely associated trait with *chapati* quality (Mohan *et al.*, 2013); has also improved in both categories of wheat (from 5.7

to 6.0). In the late-sown category; similar improvement has been observed in comparison to the old cultivars like PBW 373, PBW 590, DBW 16, Raj 3765 and WH 1021. In addition, there is some improvement in the *chapati* quality also as score has increased from 7.51 to 7.65 in late-sown wheat of this region. Besides, there has been tremendous change in the HMWGS composition. Varieties of Glu1 score 10 were very rare earlier but now majority of the varieties are marked with this desirable attribute which has played major role in improving the dough quality NWPZ.

Table 3. Performance of old wheat varieties during the five year period 2006-10

Characteristics	North Western Plains Zone		Central Zone		Peninsular Zone	
	Timely-sown	Late-sown	Timely-sown	Late-sown	Timely-sown	Late-sown
Bread loaf volume (cc)	553	561	554	569	567	587
Bread quality score (out of 10)	6.87	7.10	6.91	7.25	7.27	7.77
<i>Chapati</i> score (out of 10)	7.51	7.51	7.96	7.79	7.64	7.55
Biscuit spread factor	6.78	6.95	6.57	6.48	6.69	6.51
Grain appearance score	5.7	5.8	6.4	6.4	6.1	5.9
Test weight (kg/hl)	78.5	77.8	81.8	81.9	81.8	79.2
Grain protein (%)	12.1	12.2	11.1	12.4	11.7	12.6
Sedimentation value (ml)	39.4	39.6	39.4	41.4	42.7	48.2
Grain hardness index	80.1	80.7	74.9	77.6	80.7	73.6
Iron content (ppm)	38.4	46.2	35.9	39.1	48.8	52.1
Zinc content (ppm)	39.8	40.4	40.0	31.2	40.3	40.8
Wet gluten (%)	30.7	32.0	29.7	33.6	30.6	33.5
Gluten index (%)	58.9	56.6	52.7	53.7	61.3	67.9
5+10 HMWGS (frequency)	5/5	3/5	1/4	0/5	1/2	1/4
Glu 1 score 10 (frequency)	0/5	1/5	1/4	0/5	0/2	1/4
Grain yield (q/ha)	47.9	39.5	49.3	40.6	44.6	39.0
1000 grain weight	38.9	35.5	46.2	40.4	41.1	39.4

In comparison to NWPZ, achievements in wheat quality are limited in CZ. No doubt, the region has been successful in maintaining the *chapati* standards (score > 8.0) set by LOK 1 in the newly developed varieties HI 1636 and GW 513 but otherwise, there is hardly anything worth mentioning in CZ wheat. Instead, this region has witnessed big decline in bread loaf volume. During the five year period 2006-10, average bread loaf volume recorded in the prevailing checks i.e. LOK 1, GW 322, HI 1544 and

GW 366 was 554 cc which has now been reduced to 460 cc. There is big drop in size of the grains as TGW of TSW has reduced from 46.2 to 43.4 g. In LSW, there is definite yield advantage over the varieties of the period 2006-10 like GW 173, MP 4010, HD 2932, HD 2864 and DL 788-23, but there is hardly any gain in quality of the harnessed grains.

Situation is slightly better in the adjoining peninsular region where *chapati* quality has improved in TSW



as *chapati* score has improved from 7.64 to 7.83. In comparison to the old timely-sown varieties like NIAW 917 and RAJ 4037, there is some gain in bread loaf volume as well but there is no improvement in the bread quality score. Although there is no gain in wheat yield but the TGW has improved (41.4 to 43.8g) in new timely-sown high yielding wheat varieties of this region. The old late-sown varieties like HI 977, RAJ 4083, NIAW 34 and HD 2932 had an edge over the present lot in the bread loaf volume as it has now been reduced from 587 to 563 cc. Iron content and gluten index was lot better in the old cultivars in both categories of wheat. Iron content has been reduced from 49 to 40 ppm in TSW and 52 to 41 ppm in LSW of the region. Similarly, gluten index has dropped from 61 to 53% in TSW and from 68 to 63 % in LSW of PZ. Quality pockets to harness good wheat quality in NWPZ Locations have big impact on grain quality and the same has been demonstrated in NWPZ, too (Mohan *et al.*, 2011). To harness better value addition, it is important to identify the suitable pockets in the zone. Study done by Mohan *et al.* (2022a) on the basis of wheat quality index has clearly indicated that amongst the five test sites of NWPZ; quality of wheat harnessed in Durgapura and Delhi is far better than Ludhiana, Hisar and Pantnagar. In a large and most important wheat zone, information related to just five sites is not enough. It is desired to have grain quality information on more number of sites to identify the pockets where not only productivity is high but the quality of the harnessed produce is also impressive.

Breeding prospect for improvement in end-product quality In the breeding ventures, relationship of the component traits is exploited for each product. If the association of the components traits is strong with the given product, the prospects of further improvement go higher. Besides the end-products, AICRPW&B also generates data for the grain quality traits like test weight, grain protein content, sedimentation value, grain hardness index, wet gluten content, gluten index and GLU 1 score. If all these seven grain quality components are regressed with quality of a given product, the multiple coefficient of determination (R^2) presents the significance level of their combined relationship which can be related to the breeding prospects of quality improvement for a given end-product. Regression analysis done for different production environments (period 2006-22) exposed association of these seven components with different end-products. This exercise depicted that NWPZ is the only region where R^2 value is either significant or highly significant for each product (Table 4). It is envisaged that prospects of developing product superior varieties are quite good in NWPZ, especially TSW. In comparison, CZ holds promise for only bread and *chapati* in TSW and bread and biscuit in LSW. In PZ, selection through component traits can be rewarding for *chapati* quality of TSW and biscuit quality of LSW. It underlines that the prospects of quality improvement through targeted breeding are quite good in NWPZ, especially for the timely-sown wheat.

Table 4. Association of eight quality traits with the end-products (Period: 2006-22)

Zone	R ² value: Timely-sown wheat			R ² value: Late-sown wheat		
	Bread quality	Chapati quality	Biscuit quality	Bread quality	Chapati quality	Biscuit quality
NWPZ	0.216**	0.264***	0.360***	0.260***	0.158*	0.175*
CZ	0.382**	0.443***	0.126	0.331**	0.074	0.381***
PZ	0.339*	0.547***	0.344*	0.194	0.237	0.343**

*, ** and *** denote significance of R² at P ≤ 0.05, 0.01 and 0.001, respectively.

With the advent of good quality wheat, prospects of commercialization have increased for the wheat harnessed under timely-sown condition of NWPZ. This region has the most congenial wheat growth environment in the country and is recognized as wheat basket of the country because of the high productivity potential. Number of

well equipped laboratory to support quality evaluation is highest in this region. Facilities for quality testing of wheat are now available in New Delhi, Karnal, Ludhiana, Hisar, Durgapura and Pantnagar. Thrust on value addition has been realized in this region and several quality enriched varieties have been developed. Consumer satisfaction



is high for the newly developed wheat varieties of this production environment and improvement has been witnessed in physical grain quality, dough quality and quality of the end-products. High yield potential of new wheat varieties ensures consistent supply for the global trading and industrial usages. There is possibility of further enhancement in value addition properties by selection of suitable quality pockets and varieties.

This exercise clearly demonstrates that quality of wheat harnessed in NWPZ has improved a lot. Now, it not only matches the quality standards set by central-peninsular India but also excels in many aspects of value addition like sedimentation value, gluten index and desirable HMWGS combinations. Breeding prospects for further improvement in value addition properties are also good in this zone. It has been suggested to promote NWPZ as hub of quality wheat in India and exploit commercial aspect of these assets gathered through successful wheat breeding.

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Author contributions

Conceptualization of experimentation (DM, OPG & CNM); Designing of the experiments (DM, VP, SR & GPS); Experimental materials (DM, OPG & SK); Execution of field experiments and data collection (DM and OPG); Analysis of data and interpretation (KDB, DM SR & GPS); Preparation of the manuscript (all authors).

Conflict of interest

The authors declare no conflict of interest.

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