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Characterization of popular bread wheat cultivars of India for grain quality and the stable genetic resource

D. Mohan*, R. K. Gupta and Ajay Verma

Directorate of Wheat Research, Karnal 132 001

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Abstract

One hundred high yielding varieties of bread wheat (*Triticum aestivum* L.) were characterised for 20 quality traits which included end-product (*chapati*, bread and biscuit) quality, physico-chemical grain properties (grain appearance score, test weight, sedimentation value, grain hardness index, protein and gluten contents, gluten index and extraction rate) and grain micronutrient density (yellow pigments, iron, zinc, copper and manganese contents) to study divergence and distinctness in the Indian hallmark wheat germplasm. Grain quality analysis revealed that the Indian bread wheat varieties are generally good in test weight, *chapati* quality but need improvement in sedimentation value, flour recovery, gluten index and product quality of bread and biscuit. Even though varietal diversity was of low or medium magnitude, clustering based on end-product quality and grain properties framed them into nine distinct groups. Characteristics grain quality features of each cluster were elaborated. Besides value addition, this assortment clearly brought into light some pattern of regional specificity in the Indian bread wheat varieties. Changes merely in the moisture regime exhibited no distinct alteration in overall grain quality of a variety in the heat or cold stressed environments. Quality parameters were explored and grouped as per consistency levels derived from coefficient of variation. The most consistent grain quality features under Indian conditions were *chapati* score, bread loaf volume, test weight and flour recovery. Parameters like biscuit spread factor, protein and gluten contents, gluten index and all micronutrient except copper were graded highly variable or inconsistent whereas bread quality score, sedimentation value, yellow pigments and copper content were rated moderately consistent. Varieties with dependable and superior grain quality features were noted and suggested for quality improvement.

Key words: Indian bread wheat, genetic divergence, grain and end-product quality, value addition, genetic resource

Introduction

Enrichment of wheat for grain quality is getting prominence in India. Preference goes to the cultivars that not only possess good yield and disease resistance levels but also register superiority in grain quality. The All India Coordinated Wheat and Barley Research Improvement Project (AICW&BIP) examines all pipeline varieties for number of traits related with marketability (grain appearance), industry (hardness index, sedimentation value, grain protein content gluten index, test weight and flour recovery), grain micronutrient density (yellow pigments, iron, zinc, copper and manganese) and end-usages (chapati, bread and biscuit). Majority of these grain quality parameters, including the micronutrients, are associated with quality of the end-products in Indian wheat [1-3]. Even though the Indian bread wheat varieties are recognized globally for good *chapati* making quality, it is imperative to know their superiority for other quality characteristics as well. Varieties in India are adopted primarily for yield and it is always of great concern if some elite ones among them could be exploited on quality grounds. Wheat varieties cultivated in India are not only in large number but they are also specific to different regions and production conditions [4]. Therefore, it shall be interesting to note how diverse this Indian material is in grain quality. There could be some which register commonality in grain quality characteristics across the regions and there might be some with divergence within the same production environment. Besides grain superiority, vulnerability to environmental fluctuations is another attribute that concerns all wheat breeders and it is

*Corresponding author's e-mail: devmohan@gmail.com
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necessary to select donors with least environmental influence. The study focussed to classify some important high yielding wheat varieties under cultivation, examine differences and similarities in their quality characteristics; and search stable and quality rich genetic resource. Varieties identified with reliable quality advantage will not only help to overcome unpredictability in producing quality wheat but also offer various options available for their utilization as genetic resource to endure quality improvement in wheat research.

Materials and methods

Varieties used as checks in the AICW&BIP during 2002-03 to 2010-11 were examined at the Directorate of Wheat Research, Karnal for grain quality as per AACC standards [5]. The material involved 100 bread wheat (*Triticum aestivum* L.) varieties representing different agro-climatic regions or zones of the country i.e. north-western plains zone (NWPZ), north-eastern plains zone (NEPZ), central zone (CZ), peninsular zone (PZ), northern hills zone (NHZ) and southern hills zone (SHZ). Besides regional diversity, the pool had materials specific for sowing time (timely/late/early) and production conditions (irrigated, semi-irrigated, rainfed). Dendrogram was prepared for the diverse gene pool by Wards method using SAS software (version 9.3). Since the material was obtained every year from 3-5 testing sites of each zone, the range over the sites and years was utilized to examine the magnitude of environmental fluctuations by computing coefficient of variability (CV). For this study, preference was given to varieties (70) for which data could be generated for at least 10 production environments of sites x crop years. The parameters where majority of the varieties had CV $\leq$5% were rated consistent whereas the inconsistent ones had CV $\geq$20%.

Results and discussion

Quality status and extent of diversity

Overall performance of the Indian bread varieties in their recommended zone (Table 1) revealed that they are generally good for *chapati* making (7.64 score) as the grains are hard with mean hardness index $\geq$78. Their test weight (79kg/hl) and grain protein content (11.9%) is not far behind the international standards but mediocre sedimentation value (43ml) and gluten index (61%) make them average in bread loaf volume (556cc) and bread quality score (6.9). Since Indian wheat's have hard grain texture, it is difficult to find varieties good for biscuit making and the average spread factor is just 6.82. Micronutrient density in grains of the Indian wheat can be averaged medium to low. Diversity was gauged by coefficient of variation and it was quite low in flour recovery and test weight (2.9-3.2%). The varieties offered limited variability for the *chapati* score and bread loaf volume ($\leq$5%) and the levels were moderate for bread quality score and biscuit spread factor (5-10%) as well. However, varieties did register moderate genetic variability in gluten properties i.e., sedimentation value, sedimentation index, gluten content and gluten index (9-16%). Variability was also good in the micronutrient density of the grain i.e. yellow pigment, iron, zinc, copper and manganese contents (14-18%).

The physico-chemical properties are important quality parameters in wheat [6-7] and selection is exercised for many of them in the quality improvement ventures. Importance of grain micronutrient density has been well recognised in wheat [8] and their relevance has been reported in Indian wheat's as well [3 and 9]. Classification of the 100 bread wheat varieties for these attributes indicated that there are certain quality parameters for which the Indian wheat varieties perform very well (Table 1). In *chapati*, one-half of the lot qualified with good score i.e. 7.5-8.0, many of them scored even better. In case of bread however, only five varieties had good loaf volume ($\leq$600cc) and quality score ($\leq$8.0). Another set of 19 genotypes had loaf volume in the range of 575-600cc. Biscuit making quality as observed through spread factor remained poor ($\leq$7.0) in three-forth study material and only one variety had spread factor ˜10. Flour recovery could be rated good only in 12 varieties (71-72%). Physical appearance of the grains was good in nine varieties (score: 6.5-7.1). Test weight in the Indian varieties met the international standards ($\geq$78kg/hl) in majority of the cases and 12 varieties excelled with range 83-85 kg/hl. Range in grain protein content was quite high (9.7-13.9%) and many of them (45 varieties) had protein levels in the range 12-13%. HMWGS, a character with 100% true expression under all conditions is very important in wheat for end-product quality [10] and its importance has also been realised in Indian wheat's as well [11]. Maximum value of HMWGS i.e., GLU score 10, was noted in nine Indian varieties (Table 5). Sedimentation value is generally low in the Indian materials and only six varieties could be grouped in 55-60ml range. Consequently, sedimentation index and gluten index was also high in just 2-3 cases. Yellow pigment which denotes β carotene content was quite large in the study material

Table 1. Mean performance, diversity and frequency distribution in grain quality of 100 varieties

Parameters	Mean	CV(%)	Range	Classes and frequency distribution				
				Poor	Average	Good	Very good	Excellent
Chapati quality (score)	7.64	4.07	6.92-8.28	≤7.0 (3)	7.1-7.5 (38)	7.6-8.0 (41)	8.1-8.5 (10)	>8.5 (0)
Bread loaf volume (cc)	556	4.62	494-608	≤525 (11)	526-575 (65)	576-600 (19)	601-625 (5)	>625 (0)
Bread quality (score)	6.86	10.1	5.22-8.23	≤6.0 (11)	6.1-7.0 (50)	7.1-8.0 (35)	8.1-8.5 (4)	>8.5 (0)
Biscuit quality (spread factor)	6.82	7.58	5.97-9.89	≤7.0 (77)	7.1-8.0 (22)	8.1-9.0 (0)	9.1-10.0 (1)	>10.0 (0)
Biscuit diameter (cm)	7.40	2.15	7.12-8.13	≤7.0 (0)	7.1-7.5 (84)	7.6-8.0 (15)	8.1-9.0 (1)	>9.0 (0)
Flour recovery (%)	68.6	3.26	63.3-71.8	≤66.0 (22)	66.1-69.0 (25)	69.1-71.0 (41)	71.1-72.0 (12)	>72.0 (0)
Grain appearance (score)	5.96	6.71	5.22-7.12	≤5.5 (13)	5.6-6.0 (47)	6.1-6.5 (31)	6.6-7.0 (8)	>7.0 (1)
Test weight (kg/hl)	79.4	2.92	74.3-84.7	≤74 (0)	74-76 (11)	77-79 (41)	80-82 (37)	>82 (11)
Grain protein content (%)	11.9	7.70	9.7-13.9	≤11.0 (18)	11.1-12.0 (31)	12.1-13.0 (42)	13.1-14.0 (9)	>14.0 (0)
Wet gluten content (%)	29.9	9.03	22.4-36.1	≤25.0 (4)	25.1-30.0 (43)	30.1-35.0 (50)	35.1-40.0 (3)	>40.0 (0)
Dry gluten content (%)	9.91	9.24	7.75-12.0	≤9.0 (20)	9.1-10.0 (29)	10.1-11.0 (38)	11.1-12.0 (11)	>12.0 (0)
Sedimentation value (ml)	43.5	14.6	34.5-58.7	≤35 (3)	36-45 (49)	46-55 (17)	56-60 (1)	>60 (0)
Sedimentation index	3.68	14.8	2.79-5.34	≤3.0 (14)	3.1-4.0 (63)	4.1-4.5 (18)	4.6-5.0 (4)	>5.0 (1)
Grain hardness index	78.0	10.7	30.0-93.4	≤30 (1)	31-50 (0)	51-75 (29)	76-100 (70)	>100 (0)
Gluten index (%)	60.8	15.9	43.5-86.1	≤50 (9)	51-60 (45)	61-70 (29)	71-80 (12)	>80 (5)
Yellow pigments (ppm)	3.24	17.8	2.02-4.52	≤2.5 (11)	2.6-3.0 (33)	3.1-3.5 (19)	3.6-4.0 (31)	>4.0 (6)
Iron content (ppm)	41.4	17.4	27.0-63.0	≤30 (5)	31-40 (47)	41-50 (40)	51-75 (8)	>75 (0)
Zinc content (ppm)	37.0	13.6	26.6-47.1	≤20 (0)	21-30 (12)	31-40 (63)	41-50 (25)	>50 (0)
Copper content (ppm)	4.91	16.0	2.82-6.25	≤4.0 (7)	4.1-5.0 (24)	5.1-6.0 (46)	6.1-7.0 (23)	>7.0 (0)
Manganese content (ppm)	39.3	15.4	15.9-51.8	≤30 (8)	31-40 (59)	41-50 (29)	51-60 (4)	> 60 (0)

Figure in parenthesis represent number of genotypes

(2.0-4.5ppm) but it interferes strongly with not only *chapati* but test weight, gluten content, flour recovery and vitreous grain appearance as well [3, 9]. In the study material, 11 varieties had yellow pigment content in good range (≥4ppm) whereas it was poor (≤2.5ppm) in another 11 cultivars. Even though iron and zinc levels were generally poor, 15 varieties in iron (50-63ppm) and six for zinc (45-50ppm) registered good density of these micronutrients. High copper content (≥6ppm) was noted in ten varieties whereas manganese superiority (≥50 ppm) was also noticeable in five genotypes.

Varietal divergence

The investigation highlighted several cases when a particular genotype was good in some and inferior in other quality attributes. This necessitated classification of varieties taking into account all important quality characters. The dendrogarm revealed that the Indian varieties were quite diverse and could be grouped in nine clusters on quality grounds. Name of the varieties falling in each cluster are provided in Table 2. There were three big clusters (III, VII and IX) with 15-24 varieties each. Five clusters (I, II, V, VI and VIII) had 6-8 varieties each whereas cluster IV had just one genotype HS 490, the only soft grain variety released so far. There are some reports of regional specificity [12-13] and varietal clustering [14] from India earlier but this investigation highlighted some commonality among wheat varieties across the zones. Several varieties of NWPZ, NEPZ and PZ were grouped together in cluster III. Late sown varieties are known to have certain specific features like better protein content and poorer kernel weight, grain appearance and yellow pigment content. Differences in bread loaf volume loaf, sedimentation value and gluten index had also been reported in some parts of India [12-14] but classification on quality parameters placed several late sown varieties of NWPZ (RAJ 3765, DBW 16 and UP 1425) along with timely sown ones in cluster III. Similarly, cases of rainfed cultivars clubbing with irrigated varieties were noticed when rainfed genotypes PBW 175 and PBW 396 were placed together with other irrigated varieties in cluster III. In cluster V also, the rainfed variety K 8027 clubbed with other irrigated varieties of NEPZ. There were a dozen cases when a particular variety was tested in two production conditions like rainfed/ irrigated in NHZ and rainfed/ restricted irrigation in CZ and PZ, and interestingly, they were placed in the same cluster. It suggests that even when differences in protein content and kernel/ test weights are quite obvious under such situations [12], the overall quality rating might not get disturbed under the environments stressed by heat or cold. There were also cases when a particular variety was released in two different zones like PBW 343 in NWPZ/NEPZ and HD 2932 in CZ/PZ. It did not make any change in quality standards of PBW 343 as its performance in two different zones of the Indo-Gangetic plains was clubbed in the same cluster i.e., III. Insignificance of location-cultivar interactions in the presence of large location and cultivar effects had been reported in wheat quality [15-16]; as a consequence genotypes tend to rank similarly across locations. However, it was a different case in HD 2932 when performance of this variety in CZ could be rated different in comparison to PZ as its placing was done in different clusters. It shows that a genotype might change its quality when grown under different regions. Effect of location or soil fertility status on quality characteristics of the grain and that of end-products has been well realised in wheat [12-19] and the varieties of different zones and production conditions register grain quality accordingly. Study on genetic divergence for grain quality was important in this investigation to rank the important and popular varieties of India, which are too many in comparison to other parts of the world. However, a

Table 2. Varieties in different clusters

Cluster	Zone	Varieties
I	NHZ	HS 240[¥], VL 738[¥], VL 804[¥], HS 507[¥]
II	NHZ	VL 616[ë], VL 829[ë], HS 277[ë], HPW 251[ë], VL 892[•], HS 295[•], HS 420[•], Sonalika[•]
III	NHZ	VL 907[¥]
	NWPZ	PBW 343[*], PBW 502[*], PBW 550[*], WH 542[*], HD 2687[*], DBW 17[*], DBW 16[•], UP 2425[•], RAJ 3765[•], PBW 175[®], PBW 396[®]
	NEPZ	HUW 468[*], K 0307[*], HD 2733[*] HD 2824[*]
	CZ	GW 322[*], WH 147[*]
	SHZ	HW 2044[*], HW 5207[*], COW 1[*]
IV	NHZ	HS 490[•]
V	NEPZ	HD 2967[*], CBW 38[*], DBW 39[*], RAJ 4120[*], HI 1563[•], K 8027[®]
VI	NWPZ	C 306[®]
	NEPZ	C 306[®], HD 2888[®], MACS 6145[®]
	CZ	HI 1500[®], HW 2004[®], HI 1531[§]
VII	NWPZ	HD 2967[*], DPW 621-50[*], PBW 373[•], PBW 590[•], WH 1080[®]
	NEPZ	HD 2967[*], HD 2985[•], NW 2036[•], DBW 14[•], HUW 234[•], NW 1014[**•]
	PZ	NIAW 917[*], HI 977[•], RAJ 4083[•] AKAW 4627[•], HD 2932[•], HD 2781[®], NI 5439[§], NIAW 1415[§], HD 2987[§]
VIII	NWPZ	WH 1021[•]
	CZ	MP 1203[•]
	PZ	MACS 6222[*], PBW 533[•], NIAW 34[•], UAS 304[•], MACS 6273[•]
IX	NEPZ	K 9107[*]
	CZ	LOK 1[*], HI 1544[*], GW 366[*], GW 173[•], DL 788-2[•], MP 4010[•], HD 2864[•], HD 2932[•], MP 3288[§]
	PZ	HD 2189[*], RAJ 4037[*], PBW 596[¤]

[¥]Timely sown irrigated and rainfed conditions, [ë]Early sown rainfed condition, [®]Timely sown rainfed condition, *Timely sown irrigated condition, [•]Late sown irrigated condition, [¤]Timely sown limited irrigation, [§]Timely sown rainfed and limited irrigation

good number of them are either direct introductions or have parentage derived from the CIMMYT material. Since IBL/1BR found frequently in CIMMYT derived material, has been linked with protein fractions and dough properties [20], it shall be interesting to derive lineage of this translocation in the Indian varieties. Comparison of pedigrees to isolate the major gene block for wheat grain quality, if any, can throw more light in understanding genetic diversity in the Indian wheat varieties.

Characteristic grain quality features and some geographical pattern were also elaborated in cluster analysis. The study revealed that varieties of NHZ were characteristically different from other parts of the country and nearly all of them could be placed in cluster I & II (Table 3). The cluster I had only timely sown varieties of the region cultivated under rainfed as well as irrigated situations whereas cluster II had the early and late sown genotypes. Varieties falling under those two groups were poor in protein content (10.9%), milling recovery (˜64.5%) and micronutrients especially iron, zinc and copper. The end-product quality of the corresponding varieties was very mediocre in those two clusters. Cluster III had almost one-fourth of the varieties under study and majority of them (14 out of 24) were the timely sown varieties from NWPZ, NEPZ and SHZ. Popular varieties of NWPZ (PBW 343, DBW 17, PBW 550 and WH 542), NEPZ (K 307, HUW 468 and HD 2733) and CZ (GW 322) belonged to one particular group i.e., cluster III. Bread quality in this cluster was again moderate but the *chapati* quality was slightly superior. Grain protein (11.8%) and milling recovery (68.6%) was also better than the NHZ varieties of cluster I & II. Cluster IV had only one entry namely HS 490 which was characteristically different from rest of the genotypes because of low grain hardness index (30) and it is the only Indian variety with good biscuit quality. Cluster V had only six varieties from NEPZ which were good for *chapati* making (score: 7.9) but moderate in bread quality. This cluster also registered superiority in sedimentation value (50ml), sedimentation index (4.5), gluten index (74) and the grains were well dense with micro-nutrients. Rainfed varieties good in *chapati* making occupied cluster VI which grouped C 306 and its derivatives. Varieties in this group had very good physical grain appearance, test weight (82kg/hl), grain hardness index (90), 1000 grain weight (40g), yellow

Table 3. Clusters and their average performance

Parameter	I (8)	II (8)	III (24)	IV (1)	V (6)	VI (8)	VII (23)	VIII (7)	IX (15)
Bread loaf volume (cc)	545	531	552	537	557	504	**579**	**592**	564
Bread quality score	6.5	6.2	6.8	6.2	6.8	5.5	7.5	**7.9**	7.1
Chapati quality score	7.3	7.3	7.5	7.1	7.9	**8.1**	7.7	7.6	7.8
Biscuit spread factor	6.8	7.1	6.9	**9.9**	7.1	6.5	6.8	6.5	6.6
Flour recovery (%)	64.5	64.8	68.6	63.3	69.4	68.1	**70.1**	69.4	**70.5**
Grain appearance score	5.9	5.8	5.7	5.6	6.0	**6.5**	5.7	6.0	**6.5**
Test weight (kg/hl)	79.9	78.4	78.3	75.5	78.3	**82.4**	78.4	**80.6**	**81.9**
1000 grain weight (g)	38.5	**40.3**	39.4	45.2	**40.3**	**40.8**	37.8	39.3	**41.8**
Grain protein content (%)	10.9	10.9	11.8	11.2	11.6	10.6	12.6	13.0	12.4
Wet gluten (%)	27.1	27.7	29.9	26.4	26.0	26.6	31.5	**34.0**	32.1
Dry gluten (%)	9.0	8.9	9.9	9.0	8.7	9.0	10.5	11.3	10.6
Sedimentation value (ml)	40	41	39	39	**50**	44	**50**	39	43
Sedimentation index	3.66	3.73	3.33	3.44	**4.50**	4.10	3.97	3.03	3.44
Grain hardness index	81	74	79	**30**	74	**90**	78	77	77
Gluten index (%)	63	55	55	52	**74**	61	**70**	51	58
Yellow pigments (ppm)	**3.8**	3.4	3.3	3.9	3.1	**3.6**	3.2	3.3	2.6
Iron (ppm)	35	34	41	41	46	43	46	49	38
Zinc (ppm)	30	38	37	44	43	40	38	41	34
Copper (ppm)	3.3	4.4	4.6	5.9	**5.4**	4.7	**5.5**	**5.4**	5.2
Manganese (ppm)	32	**46**	36	52	43	35	42	**44**	38

Bold figures indicates the topper and the closely resembled ones as worked by t-test

pigment (3.62ppm) and iron contents. Cluster VII was a big group of 23 varieties and it exhibited good bread loaf volume (579cc) and *chapati* quality score (7.7). This group had good flour recovery (70.1%), grain protein content (12.6%), sedimentation value (50ml) and gluten index (70). Even though cluster VII showed predominance of PZ varieties but it involved good quality cultivars of other zones as well. Popular varieties of cluster VII were HUW 234, HI 977, NI 5439, PBW 373, HD 2967 and DPW 621-50. Cluster VIII registered varieties superior in bread loaf volume (592cc), bread quality score (7.9), grain protein content (13%) and gluten contents. The varieties were mainly from the peninsular region and had a clear edge in micronutrient contents. Varieties of cluster IX exhibited superiority in 1000 grain weight (41.8g), test weight (82kh/hl) and physical grain appearance score (6.5). Varieties of this cluster had very good flour recovery (70.5%) and good *chapati* quality. Nutritionally, the varieties had good protein content in this group (12.4%) but they lacked in grain micronutrient density and yellow pigment contents. Mainly, CZ varieties occupied this group (12 out of 15) and the important varieties were LOK 1, HD 2189, HD 2932 and HI 1544. Varietal and geographical differences in grain quality had been reported in India [3, 12 and 19] and many other countries [16-18].

Consistency of quality parameters

Influence of environment in wheat quality is paramount. Vulnerability to environment brings fluctuations in grain quality hampering consistency and stability. Classification of the varieties as per coefficient of variability within the recommended territory of cultivation revealed that wheat varieties respond differently for a given grain quality parameter and no variety can register consistency for all the parameters (Table 4). Majority of the varieties were either consistent or highly consistent in *chapati* score and bread loaf volume. Bread quality score, a parameter that involves six another attributes along with bread volume like stickiness, appearance, crust colour, crumb colour, texture, taste and aroma; was moderately consistent in majority of the varieties. In contrast, consistency level was poor at large for biscuit quality expressed by spread factor. Flour recovery and test weight were another two traits where high levels of consistency and define their high heritability [21]. For rest of the traits, there was just a stray case when a variety showed high levels of consistency. Half of the lot was inconsistent in grain appearance and protein content. Majority of the varieties registered moderate levels of stable performance in case of sedimentation value and yellow pigments. Characters like dry and

Table 4. Frequency distribution based on coefficient of variability (%)

Parameters	Total	Up to 2	2-5	5-10	10-20	20-30
Chapati quality	1.2–6.7	10	57	3	0	0
Bread loaf volume	1.6–5.9	9	60	1	0	0
Bread quality	3.0–14.2	0	16	49	5	0
Biscuit quality	5.1–16.0	0	0	26	44	0
Flour recovery	1.3–4.6	15	55	0	0	0
Grain appearance	4.9–14.7	0	1	37	32	0
Test weight	1.1–5.4	17	52	1	0	0
Protein content	6.6–18.4	0	0	30	40	0
Wet gluten	8.3–23.7	0	0	6	41	13
Dry gluten	4.9–23.6	0	1	5	52	12
Sedimentation value	4.8–22.1	0	1	48	20	1
Hardness index	3.8–21.2	0	1	24	43	2
Gluten index	6.7–18.3	0	0	7	63	0
Yellow pigments	4.4–22.3	0	3	55	11	1
Iron	9.4–26.0	0	0	1	60	9
Zinc	6.3–24.3	0	0	1	63	6
Copper	3.8–22.0	0	6	51	12	1
Manganese	8.3–26.8	0	0	10	58	2

wet gluten contents, gluten index, grain hardness index and micronutrients (except copper) had poor or very poor levels of consistency. Similar pattern in quality traits had been reported earlier in NWPZ [19]. These variations made it amply clear that grain quality characters in wheat can broadly be placed in three categories. Group I has parameters that behave truly and carry very little influence of the environment; and *chapati* score, bread loaf volume, test weight and flour recovery belong to this highly heritable group. The 2nd group is highly inconsistent and includes biscuit spread factor, protein and gluten contents, gluten index and all micronutrient except copper. The3rd group is moderately consistent and covers parameters like bread quality score, sedimentation value, yellow pigments and copper content.

Stable genetic resource

Cultivar selection is crucial for achieving a desired end-use with location effects being of secondary importance [7, 14] but choosing genotype with reliable quality is equally important in breeding ventures for quality traits [1, 14, 18]. Matching the quality attributes of a variety with coefficient of variability, genetic resources with least environmental influence could be noted (Table 5). The study revealed that genetic resource with high consistency levels was available for *chapati* and bread. Varieties like C 306, HW 2004, PBW 175 and K 9107 don't only excel in *chapati* score (8.2-8.3) but also register high relability. HI 977 and MACS 6222 occupied this distinction in bread quality and loaf volume. High flour recovery (˜71.5%) with good consistency levels was noted in NIAW 5439, HUW 468 and K 9107. For gluten index also, one variety

Table 5. Varieties with high or moderate consistency for quality improvement

Parameters	Value	Genetic resource
Chapati quality score	8.2-8.3	C 306©, HW 2004©, PBW 175©, K 9107©
Bread loaf volume	600-608 cc	HI 977©, MACS 6222©, AKAW 4627@, PBW 533@
Bread quality score	8.0-8.3	HI 977©, MACS 6222©, AKAW 4627@, PBW 533@
Biscuit diameter	8.1cm	HS 490©
Biscuit spread factor	9.9	HS 490§
Flour recovery	71.5-71.8%	NI 5439©, HUW 468©, K 9107©
Protein content	13.7-13.9%	NIAW 34®
Gluten index	82-86%	HD 2987©, K 8027©,CBW 38@
Wet gluten	36%	NIAW 34§
Dry gluten	12%	NIAW 34§
Test weight	83-85 kg/hl	HW 2004©, HI 1531©, HI 1500©
GLU 1 score	10	HS 507, DBW 16, DPW 621-50, HD 2967, CBW 38, LOK 1, HD 2987, HI 977, RAJ 4083
Grain look score	6.8-7.2	HI 1500®, HW 2004®, MP 3288®
Sedimentation value	55-59 ml	HI 977®, HD 2987®, HD 2967®, K 8027§, CBW 38§, DPW 621-50@
Grain hardness index	90-94	HI 1531®, HI 1500®, WH 542®, MACS 6145®, HW2004§
Yellow pigments	4.5ppm	NW 2036®
Iron	55-63ppm	NIAW 34§, NW 1014@, MACS 6145®, RAJ 4120@
Zinc	47ppm	K 8027§, GW 366§
Copper	6.2-6.3ppm	HD 2987©, NIAW 1415©, GW 173®
Manganese	50-52ppm	HUW 234®, PBW 590®, HS 490®, DBW38@

© Stable, ® Moderately stable, § Unstable, @ Stability unconfirmed

namely HD 2987 registered high standards. In a couple of cases, varieties (HD 2987 and NIAW 1415) reliable in copper content could also be noted. Highly stable genetic resource was also available in test weight (˜84kg/hl) and the elite varieties were HW 2004, HI 1531 and HI 1500. Genetic resource was available for other parameters also but the reliability was moderate. In this category, NIAW 34 was outstanding for protein and gluten contents and NW 2026 was good in yellow pigments. In micronutrients also, some good genotypes were available in iron (MACS 6145), copper (GW 173) and manganese (HUW 234, PBW 590 and HS 490) contents. Few varieties with high iron (NIAW 34) and zinc content (K 8027 and GW 366) were also available but their performance was highly variable, too. The only suitable genotype for biscuit making i.e. HS 490 was also highly variable in spread factor.

Wheat in India occupies large acreage (28-29 million hectares) and nearly 150 varieties remain in the seed chain of breeder seed production. At a time when production needs are being well catered, it's the time when quality concern is also addressed adequately. Besides reliable elite genotypes and dependable grain parameters, the programme planning requires information on diversity, distinctness and quality status of the varieties under cultivation. It's not always the product but the overall grain quality which needs to be addressed genetically. The study revealed that diversity in the Indian bread wheat varieties is moderate in certain parameters (sedimentation value, grain harness index, gluten index and the protein, gluten and micronutrient contents) and highly limited in some important ones (*chapati,* bread loaf volume, test weight and flour recovery). The wheat programme needs genotypes that not only have high values but their quality should also be reliable. Such a genetic resource is available in the high yield background for bread loaf volume, flour recovery and gluten index also. Even if their value are not very high, they are distinct, their quality is reliable, hence suit breeders in quality improvement. Isolated cases of varietal superiority are also noticeable in protein, gluten, iron and manganese contents also but their performance is not static. Divergence study indicated that the hill varieties are distinctly inferior in grain quality. Varieties of PZ are distinctly superior in bread and other important quality attributes whereas CZ varieties have an edge in *chapati*, physical appearance of the grain and flour recovery. In wheat bowl of the country, wheat varieties are generally mediocre in grain quality. Since majority of the wheat in the national pool comes from NWPZ, enhanced quality of the wheat produced in this region is viewed highly rewarding not only for the domestic and industrial concerns but also for global trading. Several new cultivars of that area like HD 2967, PBW 590, WH 1021, WH 1080 and DPW 621-50 now match high standards of wheat grown in the peninsular region. The investigation demonstrated that NEPZ varieties generally have an edge over NWPZ varieties and are placed in different clusters. In NEPZ also, several new varieties like DBW 39, HI 1563, HD 2967, CBW 38 and RAJ 4120 are distinct in grain quality. The older ones of the region like K 9107 and HUW 234 also maintain high quality standards and are placed differently from other varieties of NEPZ. The study also revealed that changes in the moisture regime do not alter overall quality of a variety under heat or cold stressed environments and it was true in 12 varieties observed in different parts of the country like NHZ, CZ and PZ. The investigation clearly demonstrated that the Indian bread varieties have different grain quality backgrounds and many of them are distinct, elite and reliable in grain quality.

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