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Harness value-addition in bread wheat (*Triticum aestivum* L.) through genotype and location specificity in highly productive north western Indo-Gangetic plains

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ABSTRACT

A study was conducted during 2005–08 to examine the prospect of value addition in wheat under highly productive environments. A number of processing and nutrition quality attributes were studied in 10 popular bread wheat varieties of the Indo-Gangetic plains at five locations. Significant differences were noticed among varieties, locations and the crop seasons. Variety-location interactions were largely insignificant but year × variety registered importance for a number of quality traits. Location effect was not noticed in *chapati* quality, flour recovery, gluten index and iron content. Bread wheat varieties with acceptable grain quality for the industrial usages were investigated. It was demonstrated that targeting well-characterized production environment and selection of quality superior genotypes are important to augment quality in production supportive wheat areas.

Key words: Bread wheat, Location effect, North-western Indo-Gangetic plains, Production condition, Quality parameters, Variety-location interactions

The north western Indo-Gangetic plains occupy a major status in wheat cultivation. It occupies 9.0–9.5 million ha wheat area in the most productive Indian territory covering Punjab, Haryana, Delhi, Rajasthan (except Kota and Udaipur division) and western Uttar Pradesh (except Jhansi division), Uttrakhand (Tarai region), parts of Jammu and Kashmir (Jammu and Kathua district) and Himachal Pradesh (Una district and Paonta valley). Widely known (North-western plains zone (NWPZ) , this continuum is recognized as wheat bowl of the country not only for high productivity and market surplus ratio but also for the highest breeder seed demand (Mohan *et al.* 2001). Since 90–95% wheat to the national pool comes from NWPZ, enhanced quality of the wheat produced in this region is viewed highly rewarding for the nation, not only for the domestic and industrial concerns but also for global trading (Nagarajan 2005, Mishra 2006). Improvement of end-use quality in wheat depends on thorough understanding of the influences of environment, genotype, and their interaction (Pena 2002, Mohan *et al.* 2009). Nevertheless, it becomes more important in NWPZ which has a wide range of environments, the cold Himalayas on one side and the arid warmer Rajasthan on the other, and a large number of wheat cultivars.

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A study was conducted to examine the role of these important factors in augmenting wheat quality under production supportive environments prevailing in north-western Gangetic plains of India. The investigation included four years performance of ten popular wheat varieties at five important test sites and examined the extent of environmental (locations as well as years) influence on quality of the end-products and major nutritional cum processing parameters. Varieties distinct in wheat quality and the sites to harvest richness in quality attributes were investigated to give an insight to production of the quality superior wheat in the region that plays the most crucial role in imparting food security to the country.

MATERIALS AND METHODS

Ten irrigated bread wheat varieties and five locations of NWPZ were analyzed for four years period during 2005–08. Since quality was to be examined in the backdrop of high yield, the varieties used as high yielding checks in the coordinated trials were evaluated. To ensure similarity in production conditions between the locations, testing material was collected from harvest of the advance varietal coordinated trials for NWPZ. The testing material included six timely-sown (‘WH 542’, ‘HD 2687’, PBW 343’, PBW 502’, PBW 550’ and ‘DBW 17’) and four late-sown varieties (‘RAJ 3765’, PBW 373, ‘UP 2425’ and ‘DBW 16’). Importance of the chosen varieties in the region could be viewed from the fact that during 2008, these ten varieties constituted 26.5% of the total breeder seed produced for the whole country. The selected locations represented five states like Punjab (Ludhiana), Haryana (Hisar), Delhi, northern Rajasthan (Durgapura) and foothills (*tarai*) area of Uttrakhand (Pantnagar) and this subset of locations was adequate to represent end-use quality requirements suggested by Pena (2008). In coordinated trials, average productivity of the selected ten varieties remained above 4.0 tonnes/ha at all the test sites. Per hectare tonnage was highest at Ludhiana (4.68), followed by Durgapura (4.50), Delhi (4.33), Hisar (41.8) and Pantnagar (4.06). Processing and industrial quality was examined through test weight, hardness index, sedimentation value, gluten index and flour recovery percentage while the nutritional components included protein, yellow pigment, iron, zinc, copper and manganese contents in the grain. End-use quality was tested for two important products, ie *chapati* and loaf volume of the bread. AACC method was applied to examine processing and milling quality while micronutrient content was recorded through atomic absorption technique (Jackson 1973). For statistical differences between varieties and locations and their interactions, two factor analysis was applied using years as replications. To examine year effect and variety-year interactions, same analysis was done using locations as replications. 20 data points (five locations and four years) of ten varieties were used for single factor analysis as well to estimate the extent of environmental impact on individual quality traits.

RESULTS AND DISCUSSION

Wheat quality status in NWPZ

Increasing yield potential without affecting negatively the quality of the wheat grain is difficult mainly because increases in grain yield are generally accompanied by a decrease in protein content, which is strongly associated with bread-making quality (Pena 2002). The study showed that quality standard of the wheat produced in north-western plains of India can at best be rated moderate (Table 1). Even though *chapati* making quality (score 7.4) of wheat grown in NWPZ can be rated good, the overall bread quality with loaf volume around 550cc is not good enough to fetch industrial preference. The other factors of processing quality like test weight (78kg/hl), sedimentation value (37ml), gluten index (55%), grain protein content (~ 12%) and flour recovery (67.8%) are of mediocre range. Grains register unattractive look but are generally rich in yellow pigments (3.57ppm), a measure of beta-carotene. Over years, application of narrow band of fertilizers and almost total withdrawal of farmyard manure or green manuring practices have created widespread micronutrient deficiency in the intensively cultivated areas of NWPZ (Nagarajan 2005). Iron, zinc and manganese contents in the range of 35–40ppm are manifestation of micronutrient depleted soils in NWPZ.

Table 1 Character means and extent of variability for quality traits in NWPZ

Attributes	Mean	Varietal range	CV* (%)
Chapati quality (score out of 10)	7.44	6.96–7.82	3.01
Loaf volume (cc)	549	535–564	2.50
Grain appearance (score out of 10)	5.66	5.25–5.97	10.15
Test weight (kg/hl)	78.0	75.4–80.3	3.24
Hardness index	82.2	68.4–92.2	7.50
Flour recovery (%)	67.8	66.2–69.6	2.59
Sedimentation value (ml)	37.0	34.3–44.0	8.57
Wet gluten (%)	30.7	29.1–32.1	14.83
Dry gluten (%)	10.1	9.7–10.6	13.81
Gluten index (%)	54.9	49.7–75.9	12.63
Grain protein (%)	12.2	11.8–12.6	9.99
Yellow pigment (ppm)	3.57	2.67–4.25	6.75
Iron (ppm)	39.4	35.3–44.1	15.24
Zinc (ppm)	38.2	35.2–41.5	15.98
Copper (ppm)	4.94	4.19–5.20	7.57
Manganese (ppm)	36.7	27.8–42.9	12.91

*Coefficient of variability derived from single factor ANOVA

Character response to environment

Grain and non-grain (environment, growing conditions and diseases) factors interact to make the issue of wheat quality rather complex (Pena 2002). In this study, the error variance representing locations and year effects was put to use for measuring the extent of environment influence on various quality parameters and the coefficient of variability (CV) was derived from single factor ANOVA. The role of environment in expression of wheat quality traits was observed highly trait specific. Low CV (<5%) in some traits was an indication that they were least affected by the environment. Such a category included both the end-products (bread and *chapati*), test weight and flour recovery. The most vulnerable quality traits in NWPZ were the grain appearance, gluten content, gluten index and the micronutrient constituents in the wheat grain like iron, zinc and manganese contents (CV >10.0%). Differences in magnitude of environmental effects on quality traits had been reported in bread wheat (Souza *et al*. 2004, Mohan *et al.* 2009) and durum wheat (Rharrabti *et al.* 2003).

Importance of locations and crop seasons

Splitting the non-grain factors as locations and years (crop seasons) in NWPZ, the analysis showed that along with sites, differences in the crop seasons also matter in quality of the wheat grain (Table 2). It was important that two important traits i.e. *chapati* quality and flour recovery remained unaffected by location and crop year differences. Gluten index and iron content also remained uninfluenced by location effect. It was interesting to find that except gluten contents, none of the traits showed significant location-variety interactions. On the contrary, year-variety interaction played significant role for a number of wheat quality traits.

Interaction in NWPZ, both location-variety as well as year-variety, were found missing for some of the traits like hardness index, flour recovery, grain appearance protein percentage and iron content. Although genotype-environment interactions on quality traits are generally significant, they are less significant that those effecting grain yield (Pena 2008). Insignificance of location-cultivar interactions in the presence of large location and cultivar effects had been reported in wheat quality (Souza *et al.* 2004, Nagarajan *et al*. 2007, Pena 2008, Williams *et al.* 2008); as a consequence genotypes tend to rank similarly across locations.

Area to grow quality superior wheat

Effect of locations on wheat quality becomes highly important in a divergent region like NWPZ (Table 3). There was no statistical difference among sites for some of the traits like *chapati* quality, flour recovery, gluten index and iron contents and the difference between the best and the poorest sites was marginal (<5%) for these specific traits. This difference became too wide (>10%) for certain traits like protein (11.8–13.6%), iron (36–44ppm) and manganese (34–41ppm) contents. Large location effect in traits highly dependent on the soil micronutrient status had been reported in bread wheat (Mohan and Gupta 2008, Mohan *et al.* 2009). Even though good quality *chapati* (score ≥7.5) could be produced in all parts of the zone, Durgapura was found a superior site for bread making (loaf volume 560cc). This area located in northern Rajasthan produced the most attractive (lustrous) grains in the region and also excelled in grain protein content (13.6%). Even protein yield at Durgapura

Table 2 Level of significance (probability) in ANOVA of two-factor analysis

Parameter	Varieties	Locations	Years	Variety × location	Variety × year
Chapati score	0.000	0.299	0.166	0.941	0.001
Loaf volume	0.000	0.000	0.000	0.877	0.021
Grain appearance	0.000	0.000	0.000	0.668	0.983
Hectolitre weight	0.000	0.000	0.000	0.451	0.014
Hardness index	0.000	0.000	0.008	0.148	0.395
Flour recovery	0.000	0.699	0.744	0.976	0.054
Sedimentation value	0.000	0.000	0.000	0.634	0.001
Wet gluten	0.003	0.000	0.000	0.004	0.094
Dry gluten	0.007	0.000	0.000	0.004	0.153
Gluten index	0.000	0.478	0.000	0.225	0.013
Grain protein	0.011	0.000	0.000	0.307	0.079
Yellow pigment	0.000	0.008	0.000	0.616	0.023
Iron content	0.000	0.435	0.000	0.522	0.757
Zinc content	0.001	0.000	0.000	0.064	0.048
Copper content	0.000	0.002	0.000	0.326	0.000
Manganese	0.000	0.000	0.000	0.057	0.009

Table 3 Location advantage in wheat quality in NWPZ

Attribute	Ludhiana	Delhi	Pantnagar	Hisar	Durgapura	CD (5%)
Chapati quality (score)	7.38	7.47	7.45	7.41	7.48	NS
Loaf volume (cc)	548	550	542	543	560	5
Grain look (score)	5.38	5.54	5.65	5.60	6.13	0.31
Test weight (kg/hl)	76.6	78.3	76.8	79.7	78.5	1.3
Hardness index	78.7	85.1	86.3	79.6	81.2	2.3
Flour recovery (%)	67.4	67.9	67.7	67.9	67.9	NS
Sedimentation value (ml)	37.7	37.3	37.0	35.5	38.0	1.5
Gluten index (%)	55.2	54.8	56.2	54.9	53.6	NS
Grain protein (%)	11.8	12.5	11.6	11.4	13.6	0.5
Yellow pigment (ppm)	3.62	3.50	3.66	3.56	3.52	0.10
Iron (ppm)	40.9	39.0	39.4	39.1	38.9	NS
Zinc (ppm)	43.6	36.3	37.0	38.0	36.3	2.1
Copper (ppm)	5.10	4.97	4.91	4.89	4.84	0.13
Manganese (ppm)	40.6	36.4	35.8	36.4	34.2	1.7

(612 kg/ha) was much higher when compared to that of Ludhiana (552 kg/ha). Durgapura also occupied the first non-significant group in hectolitre weight (79 kg/hl) and sedimentation value (38 ml). This part of the NWPZ is relatively hotter and the effect of high temperatures on improved quality had been reported in bread wheat (Tahir *et al.* 2006). Irrigated tracts of northern Rajasthan are therefore the most suitable areas to produce superior wheat not only for the products (*chapati* and bread) but also for processing and industrial quality. Ludhiana had an edge in several nutritional components like yellow pigments, zinc, copper and manganese. Rivers running through this state add certain advantage to the soil micronutrients which results in enhanced concentration of these elements in the wheat grains. Wheat with flour recovery 67.8%, gluten index 55% and iron content 39ppm could be grown in any part of the region. Areas similar to that of Hisar were found relatively poor in industrial quality standards pertaining to loaf volume, protein content, sedimentation value and grain hardness index. Wheat produced in Tarai region of Utrakhand and western Uttar Pradesh had relative advantage in hardness index and beta carotene content (3.66pm). When location effects are large, it becomes essential to harness quality by targeting well-characterized production conditions (Pena 2008, Williams *et al.* 2008, Mohan *et al.* 2009). It is imperative that gains from high yield potential are complimented with acceptable grain quality. The study proved that value-added bread wheat can be produced in NWPZ by careful selection of locations congenial for quality wheat.

Varieties to boost wheat quality

To keep up with the demands of both domestic and international markets, farmers must produce high yields of wheat grain with acceptable quality. Cultivar selection is critical for achieving a desired end-use, with location effects being of secondary importance (Souza *et al.* 2004, Pena 2008). In this study, significant differences among varieties were noticed for majority of the quality traits (Table 4). Though quality of the wheat grown in the NWPZ is generally slated to be of moderate standard, varieties with certain distinction were available for several quality attributes. In a region where *chapati* score hardly exceeds 7.5, 'DBW 17' was found a very good variety with 7.8 score. Loaf volume of this timely sown variety was also statistically better (564cc) than majority of the varieties recommended for the zone. Only one variety, ie 'UP 2425' of the late-sown group could match this genotype in loaf volume. Wheat produced in NWPZ normally lacks in grain appearance but 'UP 2425' was unique in appearance (score 6.0) as well as consistency (CV: 7.8%). Varieties excelling in hectolitre weight are uncommon in the NWPZ but 79–80 kg/hl test weight in 'PBW 550', 'DBW 17' and 'RAJ 3765' can be rated good for industrial usages. Grain hardness is an important aspect of milling quality and majority of the test entries, except 'UP 2425', could be classified hard-grained varieties. In this category, 'WH 542' was distinct as its hardness index (92) could match the best produced anywhere in the whole country. Flour yield is a highly appreciated quality component by the wheat industrial and the NWPZ had one good variety 'DBW 17' (flour recovery □70%) to meet such demands. Statistically, two other varieties, ie 'RAJ 3765' and 'DBW 16' also matched 'DBW 17' in flour recovery. Sedimentation value, another highly rated quality attribute for bread quality, is generally found low (35–40 ml) in NWPZ. Maximum

Table 4 Genotypic difference in wheat quality of NWPZ varieties

Attribute	'WH 542'	'HD 2687'	'PBW 343'	'PBW 502'	'PBW 550'	'DBW 17'	'RAJ 3765'	'PBW 373'	'UP 2425'	'DBW 16'	CD (5%)
Chapati quality (score)	7.10	6.96	7.53	7.41	7.57	**7.82**	7.63	7.62	7.40	7.32	0.15
Loaf volume (cc)	540	535	551	547	548	**564**	542	556	**559**	544	7
Grain look (score)	5.3	5.3	5.6	**5.7**	**5.9**	5.7	**5.8**	5.5	**6.0**	**6.0**	0.3
Test weight (kg/hl)	77.9	75.8	77.1	78.4	**80.3**	**80.0**	**79.3**	75.4	76.7	78.8	1.3
Hardness Index	**92.2**	88.3	79.2	77.8	85.1	79.6	85.8	82.1	68.4	83.4	3.2
Flour recovery (%)	66.2	66.9	67.1	67.1	67.9	**69.6**	**69.1**	67.3	68.1	**68.4**	1.2
Sedimentation (ml)	39.0	34.6	36.2	34.3	**44.0**	36.1	39.1	36.4	35.6	35.7	1.5
Gluten index (%)	57.4	51.3	53.8	50.1	**75.9**	52.2	53.4	53.2	49.7	52.6	4.0
GLU 1 score	9	8	9	8	9	8	8	9	6	10	-
Grain protein (%)	11.8	11.9	**12.3**	12.1	**12.5**	**12.6**	11.9	**12.4**	**12.2**	12.0	0.5
Yellow pigment (ppm)	3.83	**4.12**	4.08	4.00	2.83	**4.25**	2.90	4.10	2.94	2.67	0.14
Iron (ppm)	**43.1**	**40.9**	37.7	35.3	36.8	36.2	**43.5**	**44.1**	38.8	38.1	3.3
Zinc (ppm)	38.1	37.8	35.2	36.3	**39.1**	**39.0**	36.9	**41.5**	37.7	**40.9**	2.9
Copper (ppm)	**5.15**	**5.10**	4.47	5.07	**5.04**	**5.20**	**5.16**	**5.08**	4.19	4.94	0.18
Manganese (ppm)	**41.2**	29.7	38.5	40.2	39.4	**42.9**	33.8	32.6	27.8	**40.9**	2.4

Figures in bold refer to varieties in the first non-significant group

x

sedimentation value was registered in ‘PBW 550’ (44ml) and that variety also remained class apart in gluten index (76%). For protein content, ‘DBW 17’, ‘PBW 550’ and ‘PBW 343’ belonging to the timely-sown group and ‘PBW 373’ and ‘UP 2425’ of the late-sown group could be clubbed in the elite group with range 12.2 to 12.6%. Varieties with fairly good levels of grain protein content (□12.5%) and consistency (CV: □8%) as noted in ‘DBW 17 and ‘PBW 550’, can be extremely useful to meet protein requirements through this winter cereal. Varieties rich in high molecular weight glutenin subunits with perfect Glu 1 score of 10 were also available (‘DBW 16’) in the region. Statistically superior varieties could also be noted for micronutrients. Yellow pigment is generally good in NWPZ varieties but it was as high as 4.25ppm in case of ‘DBW 17’. Iron content between 41 and 44 ppm was noted in four varieties, ie ‘PBW 373’, ‘RAJ 3765’, ‘WH 542’ and ‘HD 2687’ and among this lot minimum CV was noted in ‘PBW 373’ (12.5%). Varieties over 40ppm zinc content were also available, ie ‘PBW 373’ and ‘DBW 16’ but again, the consistency level was poor (CV 12.5%). Majority of the varieties had copper content between 5.0 to 5.2ppm. Differences in manganese content were quite large in the prevailing varieties (28–43ppm) and the top ranking genotypes, ie ‘DBW 17’, ‘WH 542’ and ‘DBW 16’ could fetch 41–43ppm of this element with no difference in the consistency levels (CV □10%). The study demonstrated that varieties suited for good wheat quality were available in the NWPZ and the best in the lot were ‘DBW 17’, followed by ‘PBW 550’.

Value-addition assumes great significance in north-western plains of India, especially when productivity is stuck and profits are dwindling (Nagarajan 2005). Even though a wide range of environment prevails in NWPZ, it is possible to augment wheat quality through genetic improvement for targeted well-characterized production environments. The present study demonstrated that under production supportive environments also, tremendous opportunities exist for value addition in bread wheat by articulating superior genotypes and quality supportive environments. Suitable varieties (‘DBW 17’ and ‘PBW 550’) and favourable environments existing in the north-western Indo-Gangetic plains (northern Rajasthan and the adjoining areas) can play a decisive role in combining high yield potential with acceptable wheat quality.

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