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Genetic improvement trend analysis for end-use quality characteristics among wheat cultivars of North-Western India

Soma Gupta, Rajbir Yadav*, Kiran Gaikwad, Ashutosh Kushwah[1], Anju M. Singh and Naresh Kumar Bainsla

Division of Genetics, ICAR-Indian Agricultural Research Institute, New Delhi 110 012; [1]Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana 141 004, Punjab

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Abstract

To test the perception among consumers in India for declining nutritional quality of wheat, the trends in end-use quality characteristics of popular wheat cultivars of North Western Plain Zone were studied. Fourteen mega varieties released since 1900 were grown in randomized block design over two years. ANOVA revealed no significant differences for nitrogen percentage in grain as well as straw, however, significant differences among the genotypes within breeding period for kernel hardness, sedimentation value and thousand kernel weights was observed. Linear regression equation for thousand kernel weight indicated a poor gain of 0.036g per year. However, the cubical polynomial regression equation significantly improved the association between kernel weight and year of release (R^2 = 0.675). Similarly, cubical polynomial equation indicated continuous decline for sedimentation value with indication of some improvement in recent past. The present study therefore, clearly establishes no perceptible loss in nutritional quality. No trend was observed for flour recovery over the years. The study establishes that breeders did not deliberately modify any of the quality traits except grain plumpness and perceived changes are either not true or due to deterioration in production environment over years. GGE biplot analysis grouped HD 2967, HDCSW 16, HD 3086 along with C 591 and identified HDCSW 16 as the most ideal genotype for grain weight.

Key words: Bread wheat, genetic gain, grain quality traits, breeding period, genotypes

Introduction

Wheat is the world's most important cereal crop contributing to the global food supply and economic security. Globally, 728.96 million-tonnes of wheat was harvested from an area of 221.61 million ha and an average yield of 3289 kg per hectare (FAOSTAT, 2014). Wheat provides more nourishment to humans than any other food source as it is staple food for about 40% of the world's population. In 2013-14, India made remarkable gain in wheat productivity and achieved a record production of 95.91 m tones (DAC, GOI, http://agricoop.nic.in/Annualreport2013-14/artp13-14ENG.pdf). North western plain zone (NWPZ) is food bowl of India making maximum contribution toward buffer stock. The major part of wheat produced in India is used for human consumption. Bread wheat in India is used in making mainly chapatti (unleavened bread) followed by bread, rolls, cakes, cookies and pastries. Durum wheat is mainly used for making pasta products. Before the introduction of dwarf varieties of wheat, India was mainly growing tall varieties under rain-fed or limited irrigation conditions. Keeping quality, whiteness along with puffiness of chapattis were important criteria among consumers and bold and lustrous grain were directly correlated with these parameters. Taller wheat varieties like C 306 and K 68 became highly popular among consumers, because of their better grain quality parameters relevant for chapatti making. Among these, C 306 is still under cultivation and commands near about Rs. 1000/q premium in the market. Availability of better irrigation facilities coupled with dwarf input responsive varieties revolutionized the wheat production in India. Gain in yield is well recognized and documented, however, chapatti consumers are raising concern for grain and nutritional qualities of these varieties and a variety with high yield and chapatti making quality equivalent to C 306 is still elusive. However, chapatti quality in India is strictly consumer preference with no

*Corresponding author's e-mail: rajbiryadav@yahoo.com
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correlation with nutritional quality. Evaluation of historic collections of mega varieties provides clue for such changes attributable to breeding. Critical analysis of realized changes in phenotype may help identifying avenues for future improvement. Historical series of genotypes have been deployed and used in several countries to assess the genetic gains achieved during a period of time through selection and breeding (Austin et al. 1989; Donmez et al. 2001; Morgounov et al. 2010). The genetic improvement trend in wheat for end-use quality characteristics are also very important for wheat breeding as breeding strategies may be guided by evaluation of genetic gain or loss of these traits. Fufa et al. (2005) observed that there had been a decrease in flour protein content but an increase in end-use quality in 30 hard red winter wheat cultivars released from 1874 to 2000 in Nebraska (USA). Underdahl *et al*. (2008) reported that protein content, flour-extraction yield, and dough character score of spring wheat cultivars released in 1968 did not vary significantly from cultivars released after 1968.

Despite their importance, studies on the genetic gain regarding end-use quality characteristics of wheat cultivars have not been done in India using designed experiments. End-use quality genetic gain estimates are important to investigate if improvements in grain yield affected end-use quality (Cox et al. 1989). Wheat breeders in India have mainly selected lines responsive to favorable environments for grain yield and yield components, with consistent or stable performance for end-use quality. The objectives of this study was to address the consumer concerns through systematic evaluation of fourteen wheat cultivars released and dominating production scenario in NWPZ from 1900 till date for different end-use quality traits.

Materials and methods

Plant material

Fourteen bread wheat varieties including the most widely grown mega cultivars in North Western Plain Zone of India and some of the recently developed varieties during last 100 years were collected to examine the end-use quality traits. The experiment was laid out in Randomized Block Design (RBD) with two replications during 2012-13 and 2013-14 crop seasons at the experimental farm, Indian Agricultural Research Institute, New Delhi. The varieties included for experiment are presented along with year of release of each variety (Table 1). Sowing was done with self-propelled Winterstiger seed drill in six rows of 5 m length spaced at 20 cm in mid November and harvested in mid of April during both the crop seasons. A recommended dose of fertilizer i.e. 120:60:40 kg/ha of N, P and K were applied. Fifty percent of nitrogen and full dose of phosphorous and potash were applied as basal dose and remaining 50 % of nitrogen was applied as top dressing. Standard crop productions and crop protections measures were followed to raise a healthy crop.

Table 1. A list of varieties/genotypes included in the experiment

Variety/ genotype	Parentage	Year of release of variety/ genotype
NP 4	Selection local Mundia	1905
C 591	T9/8B	1934
Sonora 64	YAKTANA-54//NORIN-10/ BREVOR/3/2*YAQUI-54	1965
Kalyansona	Selection form S227	1967
HD 2009	LR 64A / NAI 60	1975
WL 711	ALD ‘S’ HUAC//HD 2285 /3/ HFW-17	1977
HD 2329	HD 1962/E 4870/3/K 65/5/ HD1553/4/UP262	1985
WH 542	JUP /BJY’S//URES	1992
PBW 343	ND/VG9144//KAL/BB/3/YCO”S”/ 4/VEES “S”	1996
DBW 17	CMH79A.95/3*CNO 79//RAJ3777	2006
PBW 550	WH 594/RAJ 3858//W 485	2007
HD 2967	ALD/COC//URES/HD2160M/ HD2278	2011
HD 3086	DBW14/HD2733//HUW468	2014
HDCSW 16#	CL 1449/ PBW 343	2012

Registered with PPVFRA

End-use quality analysis

The quality related traits were estimated in grain quality laboratory, IARI, New Delhi. The protein content in the grain samples were determined by Kjeldahl method using the auto Kjeltech system 3100 from Foss, Tecator, USA. Ten ml of concentrated H_2SO_4 and 4.5 g of catalyst mixture of Potassium Sulphate (K_2SO_4) and Copper Sulphate ($CuSO_4$) in the ratio 50:1 was added to 0.5 g of ground sample of grain and straw separately. The samples were digested at 450^{o}C for 30-45 minutes till contents were clear. After cooling, 70 ml distilled water was added to the digestion tubes.

The digested contents were distilled with the distillation system. Multiplication factor of 5.7 and exactly normality of the HCl along with the weight of the sample were fed in the machine. The protein values were obtained by multiplying with a factor of 5.7. SDS-sedimentation test was based on method of Dick and Quick (1983) and Misra et al. (1998). The sedimentation value, a predictive measure of protein quality and gluten strength was determined by manual method using 5 g flour sample. Kernel hardness was measured using Single Kernel characterization system 4100 from Perten Instruments, Australia. All dockage was removed from the sample using seed cleaner and 20 grams of seed was used for analysis. The value of kernel hardness was recorded for 100 seeds of each sample. For thousand kernel weight, 250 grains at random were counted from the threshed material and weighed on electronic balance. The value was extrapolated to 1000 kernel weight.

Analysis of variance (ANOVA)

Mixed model ANOVA were performed for all the studied traits. In the model used for ANOVA, the genotype effect was partitioned into two sub heads: breeding period considered as a fixed effect and genotype within breeding period considered as a random effect. Data observed were subjected to analysis of variance (ANOVA) and analyzed using SAS software package 9.2. Standard analysis of variance (ANOVA) procedures were used to calculate significant differences among genotypes, breeding period and genotypes within breeding period.

Regression analysis

Chronological trends of end-use quality traits were tested using regression analysis of trait deviation *vs.* year of variety release. Regression analysis was done in statistical software SPAR 2.0 (http://iasri.res.in/spar). Regression models, linear or polynomial (cubical) when appropriate, were also fitted to the relationships between traits and the year of release of the genotypes. The coefficient of determination R^2 is the ratio between the sum of squares explained by the linear regression and the total sum of squares i.e., $R^2 = SS_R/SS_Y.$

Results

All source of variation are non-significant for Nitrogen (N) per cent in grain and N per cent in straw, however, significant differences were detected for kernel hardness, thousand seed weight and sedimentation value. Nitrogen percentage in the seed and straw remain unchanged over the years in the genotypes released over different period of time and the regression analysis therefore, shows no trend for these traits (Fig.

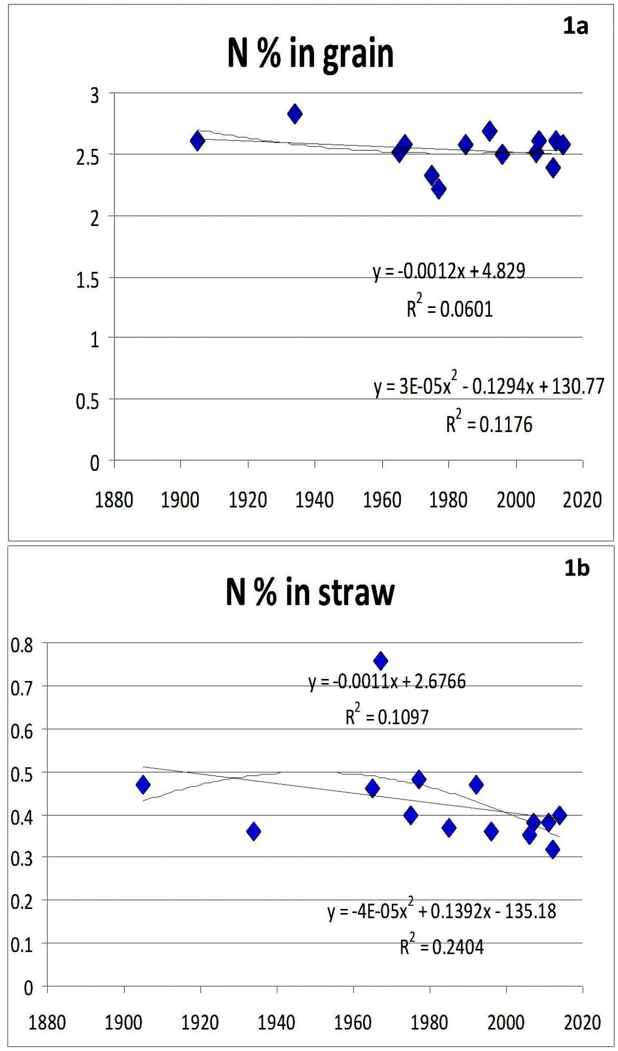

Fig. 1 (a and b). Regression equations for nitrogen percentage in grain and straw weight with year of release

1a and 1b). As genotypic mean sum of squares were significant for thousand seed weight, kernel hardness and sedimentation value, these were further divided into breeding period and genotype x breeding period interaction to pin point the source of variation. Contribution of breeding period toward genotypic sum of squares was quite large for thousand kernel weight and sedimentation value, however for grain hardness it was non- significant (Table 2). The result indicates that sedimentation value and thousand seed weight has changed significantly in different breeding periods

Table 2. Analysis of variance for end-use quality characteristics in 14 Indian bread wheat cultivars

Source of variation	d.f.	N % in straw	N % in grain	Kernel hardness	Sedimentation value	Thousand kernel weight
Replication	1	0.093	0.0018	0.34	1.285	7.08
Genotype	13	0.023	0.021	53.28**	90.36**	62.92**
Breeding period	5	0.034	0.061	12.70	115.00**	104.62**
Genotype x breeding period	8	0.016	0.035	78.64**	74.95**	36.86**
Mean		0.422	2.53	74.19	44.71	35.93
C.V.		36.47	5.83	4.08	5.32	4.82

*,**significant and highly significant at 5 % and 1 % probability level, respectively; d.f. = degrees of freedom; N = Nitrogen

and therefore were probably under selection. However, significance of interaction component for all these three traits indicates toward no unidirectional selection. Interestingly, in this study, thousand kernel weight showed no linear relationship, however, the cubical polynomial equation significantly improved the association between thousand kernel weight and year of release (R^2 = 0.675) (Fig. 2a). Thousand kernel weight improved initially and then dropped dramatically with the release of dwarf wheat varieties. Now-a-days, it has started increasing again with some newly released varieties in 21st century *viz*., HDCSW 16 (46.25 g), HD 3086 (43.05 g) and HD 2967 (41.50 g) (Table 3). Similarly for sedimentation value, the linear regression analysis showed non significant relationship between sedimentation value and year of release, however, polynomial regression dramatically improved the relationship with indication of sharp drop during the green revolution and subsequent period with some revival in recently released varieties (Fig. 2b) Despite significant differences for kernel hardness among the genotypes and presence of strong interaction, even polynomial regression failed to establish any trend (Fig. 2c). As these traits are highly influenced by the environment, biplot was drawn for nitrogen content in grain and thousand kernel weight to identify the pattern as well as most ideal genotypes for these traits. Biplot derived from the two way table of genotype by year is able to explain 100% of G and G x E. Figure 3a Identifies the ideal genotype i.e. genotype with high mean and stability over the years. C591, a high yielding variety of pre green revolution era is the ideal genotype with highest percentage of nitrogen (2.82) whereas; WL711 is farthest from the ideal with lowest nitrogen percentage (2.22) (Table 3). Among the recent varieties, HDCSW 16 and HD 3086 are very close to the ideal genotype. Year 2012-13 and 2013-14 have almost nil correlation as indicated by almost right angle

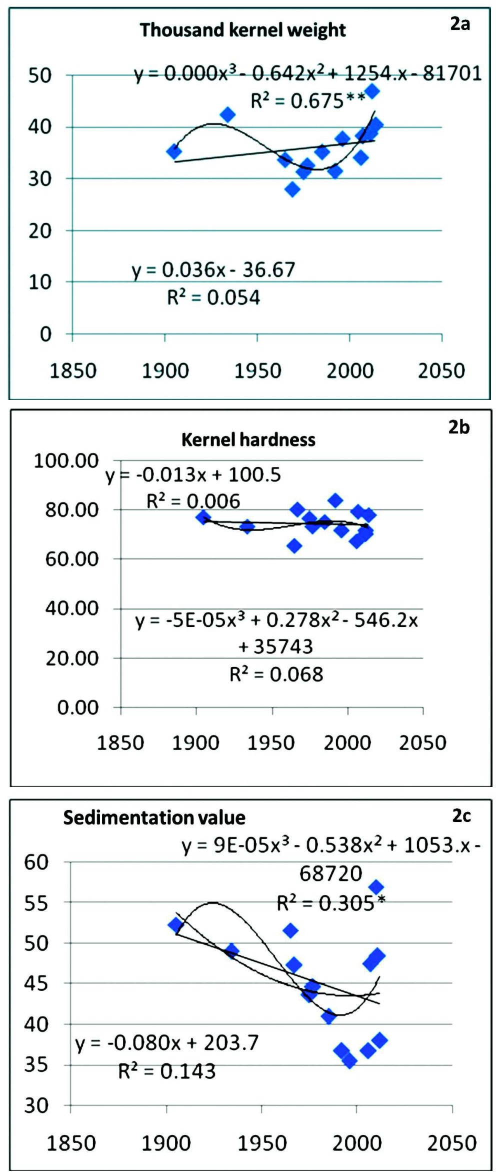

Fig. 2. (a and c). Regression equations for thousand kernel weight, kernel hardness and sedimentation coefficient with year of release

Table 3. Mean performances for end-use quality characteristics in 14 Indian bread wheat cultivars

Genotypes	Mean of traits recorded				
	SDS sedimen-tation value (ml)	Kernel hard-ness	Thou-sand kernel wt. (mg)	Nitro-gen % in grain	Nitro-gen % in straw
NP 4	53.00	78.10	33.60	2.60	0.47
C 591	48.00	72.60	41.09	2.82	0.36
Sonora 64	52.00	65.40	33.40	2.51	0.46
Kalyansona	47.00	81.05	25.45	2.58	0.76
HD 2009	42.00	74.40	32.40	2.32	0.40
WL711	44.00	71.30	31.20	2.22	0.48
HD 2329	42.00	77.10	37.72	2.58	0.37
WH 542	37.00	81.10	30.11	2.68	0.47
PBW 343	36.00	70.80	35.83	2.50	0.36
DBW 17	37.00	66.85	36.33	2.51	0.35
PBW550	48.00	81.05	35.18	2.60	0.38
HD 3086	58.00	76.85	43.05	2.57	0.40
HD 2967	49.00	71.65	41.50	2.38	0.38
HDCSW 16	38.00	70.50	46.25	2.60	0.32
CD (0.05)	2.84	3.62	2.06	0.17	0.30
CD (0.01)	3.86	4.88	2.78	0.24	0.40

between them, however, none of the year has better discriminating ability. To visualize the which-won-where situation, a polygon is drawn in Fig. 3b by joining the genotypes which are furthest from the biplot origin (Yan and Tinker 2006). It is clear that irrespective of years, C591 was the winner and it was followed by HDCSW 16, HD 3086 and WH 542. Flour recovery has also not changed over the years and it was observed to be 68.04 per cent in C 591 and 67.09 and 67.20 per cent, respectively in the latest release namely HD 2967 and HD 3086.

Biplot analysis for thousand kennel weight was done to identify any pattern in the data. It explained 100% of the variation. In the biplot, two test environments forms two environment vectors and the cosine of the angle between these vectors depicts the correlation between two environments (Yan and Tinker 2006). An acute angle between them shows a positive correlation, it suggested that, same information for thousand kernel weight has been obtained in both years (Fig. 4a). Ideal test genotype in two years of evaluation could be seen in figure 4b. A recently developed wheat genotype for conservation agriculture condition by IARI New Delhi, HDCSW 16 showed highest seed weight (43.25 g) in both years of evaluation, therefore it has occupied the center of concentric circle of the biplot. A mega variety Kalyansona having thousand grain weight of 25.45 g (Table 3), occupies position at the last concentric circle whereas recently developed HD 2967 and HD 3086

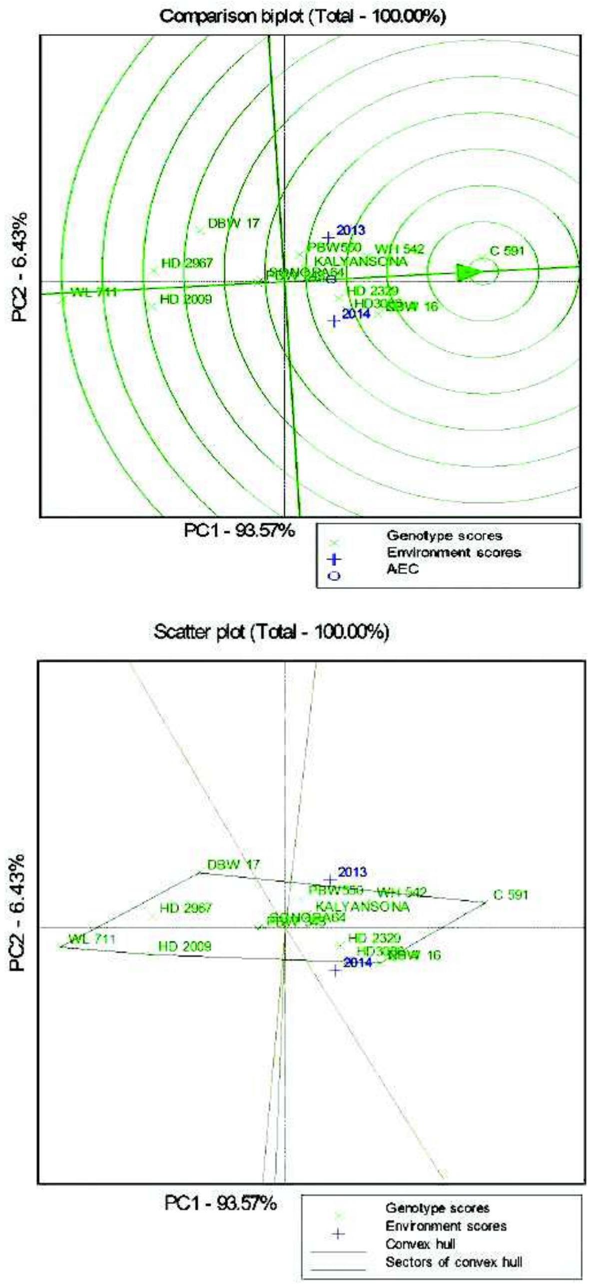

Fig. 3 (a and b). Biplot showing ideal test genotype and ranking of other test genotypes and the which-won-where view of the GGE biplot for nitrogen per centage in grain

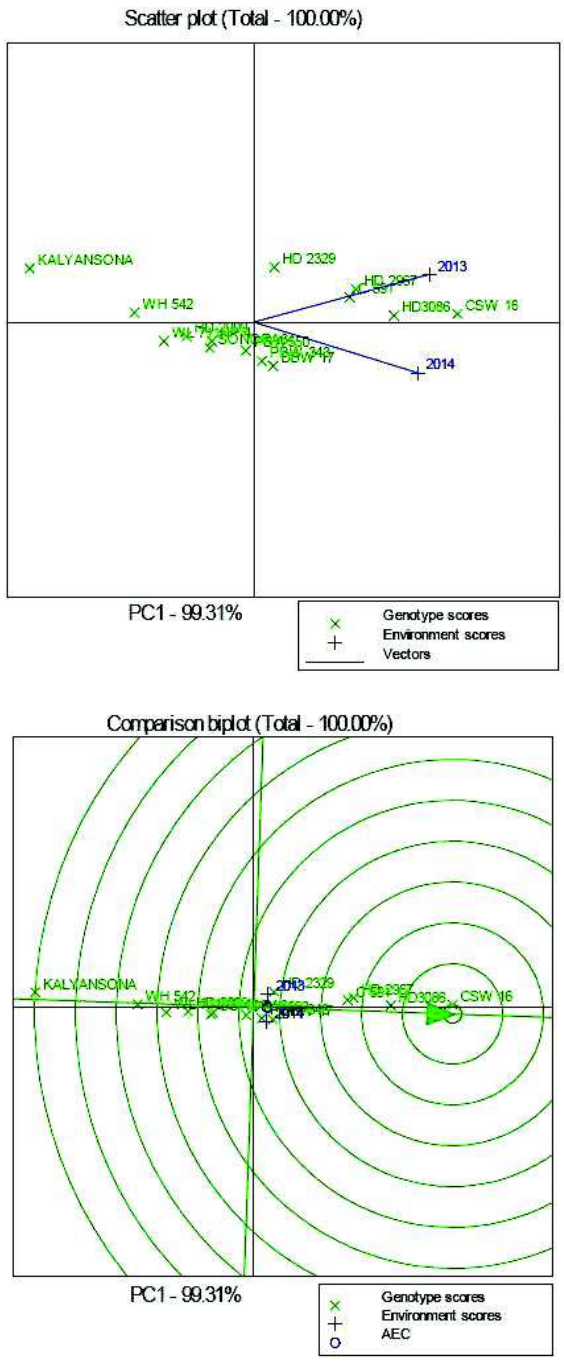

Fig. 4. (a and b). The environment vector view of the GGE biplot and biplot showing ideal test genotype and ranking of other test genotypes for thousand kernel weight

are very close to ideal genotypes. This shows that, the varieties developed in last decade have gradual improvement in seed weight.

Discussion

Grain boldness along with colour has always caught the imagination of Indian breeders largely because of consumer preference and economic incentive attached with these traits in the market. All other traits like kernel hardness, sedimentation value and protein content, though routinely analyzed in coordinated wheat yield trial, have never been selected for or against by the breeders largely because of no economic incentive attached with them. There are instances where, a variety with very small grains like WH 542 could not attract farmers' attention because of small grain size whereas others like C 306 (a genotype for rainfed condition) attract very strong premium in the market because of plump and lustrous grain along with its suitability of Chapati making. The contribution of kernel weight for wheat yield enhancement have been debated, present study clearly indicate Indian breeders maintain their fascination for bold and plump grain because of consumer preference. Significant differences between breeding period for yield and grain weight were also observed by Sanches-Garcia et al. (2013). Morgounov et al. 2010 found linear and significant ($P < 0.05$) association of 1000 kernel weight with grain yield ($R^2 = 0.59$) and genetic gain over time suggested their importance for breeding progress.The present study clearly dispel the consumer concerns regarding loss of nutritional value indicated by hardly any change in protein content in the grain in the high yielding wheat varieties released over the years. The sedimentation value, however poorly, indicates some declining trend. Sedimentation which indirectly measures gluten strength and loaf volume, have been slightly improved in recently released varieties viz., HD 2967 (49 ml) and HD 3086 (58 ml) (Table 3). Both of these varieties are non IB/IR carrier, the segment which affects negatively the protein quality.

Nitrogen content was never selected for and against by the breeders, however, its content increased in wheat grain over years largely because of continuously increasing application of highly subsidized urea. Souza et al. (1993) evaluated 45 Pacific Northwest (PNW) hard red spring wheat varieties released from 1911 to 1990 and reported flour protein content to be negatively correlated to date of release (–0.41) which declined significantly on an average of 0.018 g/kg/year and found no significant change in flour yield_Cox et al. (1989) in a study of hard red winter wheat observed a slight decline in flour protein over time. Underdahl et al. (2008) found that grain protein content did not decrease but remained the same since 1968 and has been maintained with a slight increase of 0.08 g/kg/yr. They did not observe a significant negative correlation between grain yield and grain protein content, even though grain yield was substantially higher among the newer cultivars /lines. Indian breeders were well aware of the fact that kernel hardness is an important trait particularly for leavened bread making. However, bread making industries in India did not evolve in such a way that it asks for a separate grain lot of particular standard and in turn pay premium for such products. Our results clearly indicate hardly any change in kernel hardness over years (Fig. 2c). Similarly sedimentation value have never been selected for or against as there were no dedicated breeding programmes for end use quality traits in India except for some isolated efforts for end use traits, though evaluated in coordinated programme were never given weightage for varietal identification. Fufa et al. (2005) reported modern cultivars to be more responsive for sedimentation value and mixing tolerances and less stable for these traits relative to lines released before the 1960s in Nebraska.

Lack of any trend for nitrogen content in grain, straw and kernel hardness from present study clearly establishes that breeders did not deliberately modify any of these traits except grain boldness and luster and perceived changes are either not true or due to deterioration in production environment over years. Among the various traits for quality, present study clearly establish that thousand grain weight has been breeders' selection and GGE biplot analysis not only pools the recently released varieties (HD 2967 and HD 3086) into single group but also identify the HDCSW 16 a non-release genotype for conservation agriculture as most ideal genotype for this trait.

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