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Analogy between agronomic and grain quality attributes of wheat for response to crop seasons, locations, site-year and genotype-environment interactions

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Abstract

Locations, crop years and their interactions for yield and quality determinants were compared by evaluating 14 wheat genotypes for four crop seasons across six diverse locations in India. A significant impact of locations, crop seasons and location-year interactions was noted for five important agronomic and grain quality parameters. Sites and crop seasons were equally relevant for grain quality but in agronomic traits, sites contributed more to phenotypic expressions like plant height and days to heading. Genotype-environment interactions were rare as only genotype-location for sedimentation volume and genotype-year for grain hardness index were prominent but many genotypes could thwart such interactions, too. For all agronomic traits except kernel weight, locations expressed more variability than the genotypes. It is suggested that agronomic expression at a test site cannot be rated for any reflection of grain properties but a crop season unfavorable for yield often has less desired quality attributes.

Keywords: Consistency, Grain quality, Indian wheat, Site-year interactions, Stability, Yield components

1. Introduction

A spurt in value addition of wheat has urged Indian breeders to improve grain quality of this highly valuable staple food crop not only to maintain nutrition and food security in the country but also to raise prospects of global trading. In this venture however, breeders are often found skeptical because of concern for high environmental variability of quality parameters which suggests that make genetic improvement of grain quality is more complex in comparison to yield. To resolve this disconnect, it is essential to have critical analyses of the genetic and environmental influences on yield and quality. It is widely known that quality of wheat grain is cultivar and environment specific (Souza *et al.,* 2004, Zhang *et al.,* 2004, Williams *et al.*, 2008). Relevance of environmental fluctuations on yield and quality under Indian conditions is also in reports (Mohan and Gupta,2011, Mohan *et al.,* 2011). However to bridge the disparity between conception of quality and yield improvement, it is essential to have comparative studies of environmental influences on fixed sets of material so as to draw a comparison between major yield and quality determinants. To harness the benefits of value addition in agro-climatically diverse environments of India, it is imperative to visualize the role of factors like sites and crop seasons. Focusing on such issues, the present study addressed the relevance of not only sites, crop seasons and genotypes but also the interactions occurring between location m-year, genotype-year and genotype-locations in major agronomic and basic grain quality attributes. This investigation also compared variation due to sites, crop seasons and their interactions with the genotypes.

2. Materials and methods

Fourteen genotypes were evaluated at six diverse Indian locations during four crop seasons. The study material included eleven *Triticum aestivum* and three *T. durum* genotypes which were part of a national nursery i.e. Quality Component Screening Nursery (QCSN) conducted by the All India Coordinated Wheat and

Barley Research Project. Planting was done in second fortnight of November under irrigated conditions with uniform fertilizer levels and each entry had six row plots of three meter length. Field observations included plant height (HT), days to heading (HD), grain yield/m^2 (YLD), 1000 grain weight (TGW) and grain number/m^2 (GRN) derived from the yield-kernel weight ratio. Grain quality analysis was done at a ISO 90001:2008 certified laboratory located at IARI, New Delhi for the five basic grain quality components i.e. test weight (TW), grain protein content (GPC) derived at 14% grain moisture level, sedimentation value (SV), grain hardness index (GHI) and grain appearance score (GAS). AACC (2000) methods are applied to examine test weight and sedimentation volume. Single kernel characterization system 4100 was used to measure grain hardness index whereas infra-red transmittance-based instrument Infra-tec 1125 was used to record protein content. GAS is a subjective test based on grain size, shape, soundness colour and luster collectively taken into consideration to judge grain appearance out of total score of 10. Two factor statistical analysis was applied for location-year interactions, treating varieties as replications. Variety-location and variety-year interactions were examined separately by two factor analysis, treating years as replication in the first case and locations in the second.

3. Results and discussion

Significance of sites and crop seasons: Two factor statistical analyses of sites and years revealed highly significant ($P < 0.001$) site differences in quality as well as yield parameters (Table 1.). Differences among the four crop seasons were also highly significant ($P \leq 0.001$) for all traits under investigation. This study showed that just like yield, sites and crop seasons are relevant in wheat grain quality. When site variations were compared with that of years, there was hardly any significant difference except for plant height and heading days where sites contributed more in comparison to crop seasons. Big role of locations in plant height and maturity had been described by Yan and Hunt (2001) in winter wheats of Canada.

Location differences in wheat have been realized for many traits in different parts of the world, like Pakistan (Sial *et al.,* 2000) Spain (Rharrabti *et al.,* 2003), China (Zhang *et al.,* 2004), USA (Souza *et al.,* 2004), Australia (Williams *et al.,* 2008), Serbia (*Veselinka et al.,* 2009), Southeast Europe (Nikola *et al.,* 2010) and India (Mohan and Gupta, 2011). Crop season variations, especially temperatures, have been significance in wheat grain quality(Blumenthal *et al.,* 1991 and 1993; Stone and Nicolas, 1994; Borghi *et al.,* 2002; Mohan and Gupta, 2011). The present investigation assertedthat crop seasons and sites play were equally important for defining grain quality of wheat under irrigated conditions in India.

Table 1. Mean sum of squares in site x year ANOVA

Parameter	df	Quality trait					Agronomic trait				
		TW	SV	GPC	GHI	GAS	YLD	TGW	GRN	HT	HD
Replication	13										
Site	5	167	71.1	63.0	610	15.0	421228	219	224	8030	13870
Year	3	65.7	132	35.2	160	1.85	109582	175	45.5	732	714
Site x year	15	115	42.8	12.6	206	5.38	77597	186	44.6	201	224
Error	299	3.78	15.4	0.69	29.6	0.26	2999	11.2	1.81	21.2	10.7

Location-crop season interactions: Interactions between genotypes and environments have been well addressed in wheat for yield as well quality parameters. Examples of site-crop season interactions are however rare (Veselinka *et al.,* 2009; Abbate *et al.,* 2010) and need more detail to define their relevance in wheat. In this investigation, a highly significant effect of site-crop season interactions ($P < 0.001$) was recorded for all parameters (Table 1). This study thus made it clear that besides years and locations, interactions between these two variables is also crucial in articulating yield and quality characteristics of wheat. It clearly illustrates that a crop season favorable for a particular location may not necessarily have a similar impact at other locations, and this holds true both for yield and quality parameters. With such interactions, it often becomes difficult to rank yield levels and grain quality of a test site under varying crop seasons. Even though site-year interaction assumed significance in all traits, ANOVA indicated that the proportionate contribution made by this interaction was higher for most quality attributes than for yield. When the magnitude of site-year interactions were compared with crop years, no statistical difference was observed for any trait. It shows that the magnitude of the variation due to site-year interactions matched that of crop seasons. The picture was different when comparisons were made against locations. For GPC sites dominated but for all other quality traits, differences between variance of sites and site-year interaction were not significant. In contrast, all yield components except TGW, expressed significantly lower levels of site-year interactions in comparison to sites. This investigation made it clear that even although site-crop season interactions have relevance in wheat yield and quality, magnitude of such variations can be as large as that of locations or crop seasons in some important grain quality traits like test weight, grain appearance, grain hardness and sedimentation volume. It's only GPC where the magnitude of such site-year interactions can remain low in comparison to sites. The scenario changes for agronomic traits where except TGW; the contribution of site-year interactions is small in comparison to locations. This indicates that site-year interactions are relevant in grain yield determinants but variations imposed by sites are the major source of variation.

Genotypic interactions with year and sites: Genotype-environment interactions (GE) in wheat quality traits are generally significant but they assume less significance than those affecting the grain yield (Pena, 2008). In this study however, genotype interactions with sites or crop seasons were not significant for all agronomic traits. And among grain quality also, they were generally inconsequential with two exceptions i.e. sedimentation value for genotype-year and grain hardness for genotype-location interactions. Sedimentation value (range: 29-57ml) and grain hardness index (range: 27-86) were the two quality parameters which expressed maximum genotypic variability in the study material. Genotype interactions with year or site make these quality traits (hardness and sedimentation volume) more complex in comparison to grain protein, test weight and grain appearance. Though genotypic interactions with environment were significant in sedimentation volume and hardness; there were certain genotypes which did not express such interactions. Genotype-location interaction was not expressed by three genotypes and genotype-year interaction was missing in six genotypes, too. It shows that certain genotypes are more stable for both yield and grain quality. Finding GE interactions inconsequential in this study was astonishing. It could happen because non-adaptive genotypes were discarded during the evaluation process in QCSN. The study material chosen from the nursery therefore involved genotypes which retained their superiority across the diverse environmental conditions and were able to dispel the GE effects.

Table 2. Mean sum of squares in genotype x environment ANOVA's

Parameter	df	Quality trait					Agronomic trait				
		TW	SV	GPC	GHI	GAS	YLD	TGW	GRN	HT	HD
Genotype x Year											
Replication	5										
Year	3	66.1	132	35.2	160	1.85	109582	175	45.5	732	714
Genotype	13	65.7	1873	11.0	4891	2.79	20295	364	31.4	679	554
Genotype x year	39	3.05	37.3	0.37	23.8	0.42	3396	11.4	2.21	28.6	9.19
Error	275	10.1	13.8	1.39	40.1	0.52	7002	20.6	4.09	29.9	22.6
Genotype x Site											
Replication	3										
Location	5	167	71.1	63.0	610	15.0	421228	219	244	8030	13870
Genotype	13	65.7	1873	11.0	4891	2.79	20295	364	31.4	679	554
Genotype x site	65	5.57	13.1	0.89	59.0	0.35	3776	20.0	2.36	32.9	23.7
Error	249	10.2	17.7	1.36	32.6	0.55	7280	19.3	4.25	29.0	20.2

Significant GE effects had been reported in wheat for several quality traits (Ereifej *et al.,* 1999; Basset *et al.,* 1989; Mut *et al.,* 2010; Taghouti *et al.,* 2010) and yield components (Tapley *et al.,* 2013; Roozeboom*et al.,* 2008; Murphy *et al.,* 2011). In separately run analysis for genotype-year and genotype-location interactions, highly significant genotypic differences were observed for all traits under study (Table 2). The results showed that for quality parameters, variation accrued at genetic level was significantly higher than locations or sites in sedimentation volume and grain hardness index. In contrast, variations expressed by genotypes for grain protein content were significantly higher among locations. It reveals that environmental and genetic factors contribute equally in expressing variation in physical grain quality traits like test weight and grain appearance score. In contrast, location assumes relevance greater than genetic factors in protein content and lesser in sedimentation volume and grain hardness. It asserts that gluten strength and grain hardness are more heritable than grain protein content. High heritability of gluten sedimentation volume, grain hardness had been reported by Branlard *et al.*

(2001). Dominating role of environmental factors is not uncommon in wheat quality and had been reported in several grain characteristics by Peterson *et al.* (1992).

Environment specificity: Since location specificity has been observed in all parts of the world, there can always be locations where some components of grain quality are better expressed. Investigation in this study revealed that it's hard to find locations excelling in all grain quality attribute but location specificity for component traits does exist and can be exploited through strategic planning (Table 3). In this study, test weight and grain appearance was best at Pune whereas GPC was highest at Dharwar. Delhi had clear edge in sedimentation volume and grain hardness. Just like locations, expression of quality components also varied with crop seasons. Test weight, grain hardness and grain score was best observed during 2011-12 crop season, whereas 2012-13 was most favorable for grain protein and sedimentation volume.

Table 3. Location and crop season differences

Parameter	Quality traits					Agronomic traits				
	TW (kg/hl)	SV (ml)	GPC (%)	GHI (index)	GAS (score)	YLD (g/m^2)	TGW (g)	GRN ('000/m^2)	HT (cm)	HD (days)
Location										
Delhi	76.5	43	13.9	76	5.3	313	38.3	8.27	91	95
Pantnagar	76.7	41	12.1	67	5.3	385	40.0	9.68	96	93
Indore	78.3	41	13.1	75	5.9	393	39.5	10.0	98	76
Vijapur	77.9	40	13.9	71	6.1	191	41.4	4.75	77	66
Pune	81.0	41	13.0	71	6.3	376	43.2	8.79	83	63
Dharwad	76.5	41	15.2	70	5.1	227	38.1	6.09	67	58
CD (5%)	0.7	1	0.3	2	0.2	20	1.2	0.5	2	1
Crop season										
2009-10	77.1	40	13.8	70	5.7	294	38.3	7.77	86	71
2010-11	77.5	40	13.5	72	5.6	277	39.8	6.97	86	77
2011-12	79.0	42	12.7	73	5.9	385	41.8	8.65	89	77
2012-13	77.5	43	14.2	73	5.7	329	40.4	8.34	82	75
CD (5%)	0.6	1	0.3	2	0.1	17	1.0	0.4	1	1

Quality vis-a-vis yield: It was also observed that yielding ability or the yield governing traits of a location were no indicators of grain quality parameters. To some extent, yield appeared to have been adversely affected by grain protein. But it cannot serve as any yardstick as three locations namely Pantnagar, Indore and Pune had non-significant yield differences but grain protein content in the harvested produce varied vividly (12.1 to 13.9%). It is perhaps the environment, soil type and climate which regulate wheat grain properties at a given location. It was interesting to note that the crop season best for yield and other agronomic traits i.e. 2011-12, also expressed superiority in all quality parameters except GPC. However, it did not really mean that season good for GPC was negatively linked with grain yield as maximum grain protein was observed in the second best yielding season i.e. 2012-13. This study demonstrated that for superior grain quality harvest, the higher priority is to have good field crop. A season not benefitting yield can restrict grain quality as observed in the first two crop seasons of the study.

In grain quality of Indian wheats; test weight, grain protein percentage, sedimentation volume, grain hardness and physical appearance of grains are prime factors for end-product quality (Mohan and Gupta, 2013). It is imperative to have clear understanding of available genetic variability and the influence of surrounding environment to bring qualitative changes in grain properties. This study clearly illustrated that just like yield enhancement, differences in genetic architecture, locations and crop seasons merit importance for basic grain characteristics of wheat. Interaction between location and crop seasons make wheat quality unpredictable and more complex and this hinders the ranking of sites on the basis of grain quality characteristics. Breeders, however, should not restrain from quality aimed ventures from such interaction as similar pattern is noted in yield governing traits as well. Even though analogy exists between yield and quality traits for responsiveness to environmental factors, this study suggests that field expressions at a location cannot be taken as any indicator of wheat grain quality. The foremost thing to ensure good grain quality is to raise good wheat crop as good crop seasons had been found conducive in several grain quality characteristics. For certain quality parameters, locations assume more importance than genetic factors as noted in grain protein but it happens in several yield governing traits as well. This investigation emphasized that genetic factors count more for gluten strength and grain hardness and genetic improvement in these parameters becomes slightly tedious because of significant genotype-environment interactions. Taking cognizance of such findings, wheat breeders can make strategic planning to combine high yield with superior grain quality.

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References

1. AACC. 2000. Approved methods of american association of cereal chemists. *American Association of Cereal Chemists.* 15th Edition. Arlington, USA.
2. Abbate PE, F Gutheim, O Polidoro, H Milisichy and M Cuniberti. 2010. Bases for the segregation of Argentine bread wheat by quality: effects of cultivar, location, year and their interactions.*Agriscientia* **27**:1-9.
3. Bassett LM, RE Allan and GL Rubenthaler. 1989. Genotype x environment interactions on soft wheat winter wheat quality. *Agronomy Journal* **81**(6):*955-960.*
4. Blumenthal CS, IL Batey, F Bekes, CW Wrigley and EWR Barlow. 1991. Seasonal changes in wheat-grain quality associated with high temperatures during grain filling. *Australian Journal of Agricultural Research* **42**:21-30.
5. Blumenthal CS, EWR Barlow and CW Wrigley. 1993. Growth environment and wheat quality: the effect of heat stress on dough properties and gluten proteins. *Journal of Cereal Science* **18**(1):3-21.
6. Borghi B, M Corbellini, C Minoia, M Palumbo, N Di Fonzo and M Perenzin. 1997. Effects of Mediterranean climate on wheat bread-making quality. *European Journal of Agronomy* **6**(3-4):145-154.
7. Branlard G, M Dardevet, R Saccomano, F Lagoutte and J Gourdon. 2001. Genetic diversity of wheat storage proteins and bread wheat quality. *Euphytica* **119**(1-2):59-67.
8. Ereifej KI, MM Ajlouni and RA Shibli. 1999. Cultivar and location effects on wheat quality in northern Jordan. *Dirasat Agricultural Sciences* **26**(2):216-225.
9. Mohan D and RK Gupta. 2011. Harness value-addition in bread wheat through genotype and location specificity in highly productive north western Indo-Gangetic plains. *Indian Journal of Agricultural Sciences* **81**(5):433-437.
10. Mohan D, SS Singh and RK Gupta. 2011. Vibrancy of the Indian wheat in upholding yield and quality under global environmental change. In: Wheat: Productivity Enhancement under Changing Climate. Singh SS, Hanchinal RR, Singh G, Sharma RK, Tyagi BS, Saharan MS and Sharma Indu (eds.), Narosa Publishing House, New Delhi, 87-94.
11. Mohan D and RK Gupta. 2013. Analysing grain properties of Indian bread-wheat cultivars for defining route to end-product quality and key attributes for selection. *Indian Journal of Genetics and Plant Breeding* **73**(4):1-8.
12. Murphy KM, A Lori, LA Hoagland, L Yan, M Colley and SS Jones. 2011. Genotype x Environment interactions for mineral concentration in grain of organically grown spring wheat. *Agronomy journal* **103**(6):1734-1741.
13. Mut Z, N Aydin, H Orhan Bayramoglu and H Ozcan. 2010. Stability of some quality traits in bread wheat (*Triticum aestivum*) genotypes. *Journal of Environmental Biology* 489-495.
14. Nikola N, N Mladenov, V Djuric, A Kondic-Spika, A Marjanovic-Jeromela and D Simic. 2010. Genotype by environment interactions in wheat quality breeding programs in southeast Europe. *Euphytica* **174**(3):315-324.
15. Pena RJ. 2008. Improving or preserving bread making quality while enhancing grain yield in wheat. In: International Symposium on Wheat Yield Potential: Challenges to International Wheat Breeding. Reynolds MP, Pietragalla J and Braun HJ (eds.): CIMMYT, Mexico, D.F., 171-74.
16. Peterson CJ, RA Graybosch, PS Baenziger and AW Grombacher. 1992. Genotype and environment effects on quality characteristics of hard red winter wheat. *Crop Science* **32**(1):98-103.
17. Rharrabti Y, C Royo, D Villegas, N Aparicio and LF García del MoralLF. 2003. Durum wheat quality in Mediterranean environments: I. Quality expression under different zones, latitudes and water regimes across Spain. *Field Crops Research* **80**(2):123-131.

18. Roozeboom KL, WT Schapaugh, MR Tuinstra, RL Vanderlip and GA Milliken. 2008. Testing wheat in variable environments: Genotype, environment, interaction effects, and grouping test locations. *Crop Science* **48**(1):317-330.

19. Sial MA, MA Arain and M Ahmad. 2000. Genotype x environment interactions on bread wheat grown over multiple sites and years in Pakistan. *Pakistan Journal of Botany* **32**(1):85-91.

20. Souza EJ, JM Martin, MJ Guttieri, KM O'Brien, DK Habernicht, SP Lanning, R McLean, GR Carlson and LE Talbert. 2004. Influence of genotype, environment and nitrogen management on spring wheat quality. *Crop Science* **44**:425-432.

21. Stone PJ and ME Nicolas. 1994. Wheat cultivars vary widely in their responses of grain yield and quality to short periods of post-anthesis heat stress. *Australian Journal of Plant Physiology* **21**(6):887-900.

22. Taghouti M, F Gaboun, N Nsarellah, R Rhrib, M El-Haila, M Kamar, F Abbad-Andaloussi and SM Udupa. 2010. Genotype x Environment interaction for quality traits in durum wheat cultivars adapted to different environments. *African Journal of Biotechnology* **9**(21):3054-3062.

23. Tapley M, BV Ortiz, E van Santen, KS Balkcom, P Musk and DB Weaver. 2013. Location, seeding date, and variety interactions on winter wheat yield in Southeastern United States. *Agronomy Journal* **105**:509-518.

24. Williams RM, L O'Brien, HA Eagles, VASolah and C Jayasena. 2008. The influences of genotype, environment and genotype x environment interaction on wheat quality.*Australian Journal of Agricultural Research* **59**(2):95-111.

25. Veselinka Z, K Desimir, B Jelena and M Milomirka. 2009. Effect of genotype and environment on wheat quality. *Genetika* **41**(3):247-253.

26. Yan W and LA Hunt. 2001. Interpretation of genotype x environment interaction for winter wheat yield in Ontario. *Crop Science* **41**:19-25.

27. Zhang Y, Z He, G Ye, Z Aimin and M Ginkel. 2004. Effect of environment and genotype on bread making quality of spring sown wheat cultivars in China. *Euphytica* **139**:75-83.