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Approach to harness genetic improvement in important quality attributes of Indian Bread Wheats

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ABSTRACT

Important quality parameters like chapati and bread quality, flour recovery, per hectare flour yield, grain protein content, protein yield and important micronutrients like beta carotene, iron and zinc contents were examined for a period of 3-5 years in irrigated bread wheat varieties. Selection criteria in aid to wheat breeder were also defined for the important quality attributes. It was suggested that instead of applying quality in totality, it would be better to focus on the issues that can actually be exploited in a given environment. Bread quality can be best exploited in the peninsular India but dividend will flow better if genetic improvement could be focussed in the northwestern plains due to high yield potential. Critical quality factors contributing to bread quality differed under those two diverse environments. In peninsular India, several late sown varieties existed to harness bread quality but in northeastern India such an advantage lied in couple of timely sown varieties only. Except the hill regions, chapati quality of the Indian bread wheat is generally good and limited success is anticipated to raise it further. Flour recovery and tonnage of flour yield suggested that just a handful of locations could be exploited to raise industrial output. In nutrition quality, protein yield and grain protein content were emphasized and in combination it was best exploited at locations surrounding Ludhiana and Delhi (northern India) and Pune (peninsular India). Genotypic specificity and soil conditions suggested promoting iron rich varieties in peninsular India and northeastern plains and zinc flavoured genotypes under timely sown condition of central India.

Keywords: Product quality, flour yield, protein content, micronutrients, irrigated bread wheat

Genetic improvement of quality traits in bread wheat is becoming a new thrust area in the Indian wheat programme in context to fast expanding global economy. The interface between actual field nutrient status, cultivar productivity and product quality has become an important issue. The concept of wheat quality, however, means different things to different people. A growers may be looking for high yields of attractive looking, well-filled grains to capture best price. Millers think in terms of wheat that gives good tonnage of white flour. Preferences to various other quality attributes go dear to the Cereal Processors, the millers' customers, as different grain quality properties are required for different end products. In a big country like India where wheat acreage is spread over highly diverse agro-climatic zones, it is rather difficult to harness every important quality attribute at each place. In varietal development also, it may not be required to address all quality parameters uniformly at all places. Strategy therefore, has to be devised for prioritizing genetic improvement efforts in quality traits concentrating on i) quality of the end-products, ii) industrial out put and iii) nutritional quality of the grains.

MATERIALS AND METHODS

Data generated at the Directorate of Wheat Research at Karnal for quality analysis of the final year entries of the coordinated programme and the important released varieties was examined for the period 2003-07 as per different zones and production conditions (Table 1). Character association between different quality parameters was examined in 40 irrigated bread wheat varieties and three years zonal mean was computed for correlation studies. Multiple regression analysis was done in that set of varieties to note key quality attributes in product quality.

Table 1 Performance of final year entries and notified varieties (Irrigated AVT's: 2004-07)

Character	NHZ		NWPZ		NEPZ		CZ		PZ		SHZ
	TS (24)	LS (19)	TS (38)	LS (32)	TS (35)	LS (32)	TS (15)	LS (29)	TS (22)	LS (23)	TS (22)
Chapati score	7.19	7.31	7.33	7.41	7.46	7.25	8.01	7.65	7.44	7.45	7.35
Loaf volume (cc)	548	524	542	558	568	544	545	561	545	563	542
Flour recovery (%)	65.6	64.9	68.1	68.1	70.7	70.3	69.3	70.2	69.7	69.5	67.9
Grain protein content (%)	10.9	11.0	12.1	12.4	12.1	12.7	11.9	13.0	12.3	13.2	11.5
Hectolitre weight (kg/hl)	80.7	77.5	78.3	77.2	78.5	76.2	81.3	82.0	81.4	80.7	80.3
Sedimentation value (ml)	41	45	37	39	45	47	38	41	42	46	43
Hardness index	77	74	84	82	87	80	81	85	83	82	82
ß carotene content (ppm)	3.80	3.46	3.77	3.21	3.44	3.01	2.53	2.42	2.77	3.03	3.10
Iron content (ppm)	30	30	36	38	36	54	31	33	41	51	62
Zinc content (ppm)	25	31	35	35	30	35	41	29	33	38	39

Number in parenthesis indicates number of entries tested

RESULTS AND DISCUSSION

Effect of location or soil fertility status on quality characteristics of the grain and that of the end products has been well realized in wheat (Ereifej *et al.* 1999, Sauza *et al.* 2004, Yong *et al.* 2004, Nagarajan *et al.* 2007). A classified information for the six agro climatic environments, namely Northern Hills Zone (NHZ), North Western Plains Zone (NWPZ), North Eastern Plains Zone (NEPZ), Central Zone (CZ), Peninsular Zone (PZ) and Southern Hills Zone (SHZ) and two production conditions prevailing in irrigated wheat i.e. timely sown (TS) and late sown (LS), was generated to workout the edge that these environments have in wheat quality (Table 1) for each raised issue. Significantly high correlation between chapati and bread quality suggested that in irrigated wheat, a common quality-breeding programme could serve well to develop varieties good genotypes for either of the products (Table 2).

Table 2 Character association in quality traits of irrigated bread wheat varieties

Attribute	Positive Correlation	Negative Correlation
Chapati quality	Loaf volume**, Grain look**, Hectolitre weight*, Grain protein*, Flour recovery** t	Beta-carotene**
Loaf volume	Chapati quality**, Grain look*, Flour recovery***, Protein*** and Gluten** contents, Protein quality**	Nil
Protein content	Chapati score*, Bread quality***, Flour recovery***, Gluten***, Iron** and Copper** contents	Nil
Flour recovery	Chapati score**, Bread quality***, Grain look*, Protein***, Gluten*** and Copper* contents	Beta-carotene***
Beta-carotene	Nil	Chapati**, Grain look***, Hectolitre weight***, Flour recovery ***, Gluten** and copper **
Iron content	Protein*, Gluten**, Zinc* and Manganese* contents	Nil
Zinc content	Iron content*	Nil

*, ** and ***: Significant at P 0.05, 0.01 and 0.001, respectively

(A) QUALITY OF THE PRODUCTS

I) Chapati, the unleavened flat bread made from whole grain, is the major product for wheat consumption in India as nearly 85% of the harvest accounts for it (Misra 1998). Material bred in India is generally good for chapati making as it has hard grains with hardness index well above 75. The only exception is the NHZ where chapati score remains low primarily due to environment hindering the development of hard textured grain (Table 1), especially under timely sown condition. The material good for chapati is rarely noticed in this zone (Table 3) and it would be a tough job to develop varieties very good for chapati. Wheat grown in central India is best suited for chapati making and plenty of very good new materials keep coming in that zone. Chapati quality matching to that of C 306, rainfed variety, is missing in irrigated varieties; however, a couple of very good irrigated varieties are available in CZ (Lok 1, GW 322) and NEPZ (K 9107). In the Indian varieties, lot of traits had shown genetic association with chapati quality but regression analysis revealed that only two of them, namely grain appearance and zinc content were the key contributors. A low adjusted R^2 value (0.283) in that analysis however, warrants limited achievable success in irrigated bread wheat.

Table 3 Frequency of quality rich genotypes (Irrigated AVT's: 2004-07)

Character	Selection criteria	NHZ (43)	NWPZ (60)	NEPZ (67)	CZ (44)	PZ (45)	SHZ (22)
Chapati score (out of 10)	≥ 8.0	3	2	7	17	7	0
Loaf volume (cc)	≥ 575	4	3	15	10	13	0
Flour recovery (%)	≥ 70	0	11	43	28	22	1
Grain protein content (%)	≥ 13	1	7	18	15	19	0
Hectolitre weight (kg/hl)	≥ 80	22	14	13	41	37	17
Sedimentation value (ml)	≥ 50	0	0	23	0	14	18
ß-carotene (ppm)	≥ 3.5	30	30	24	0	7	5
Iron content (ppm)	≥ 50	0	0	23	0	14	18
Zinc content (ppm)	≥ 40	0	10	13	8	18	12

Number in parenthesis indicates number of entries tested

II) Bread quality of the Indian bread varieties is mediocre, in general. A few among them like HI 977, K 9107, PBW 533, K 307, Raj 4083 do have very good loaf volume (≈ 600cc) but otherwise, 2/3 of the released varieties have loaf volume below 550cc. Grain protein content, gluten index and hardness were noted key characters for loaf volume in the irrigated bread wheat varieties. Material excelling in bread quality is rarely seen in the wheat bowl of the country i.e. NWPZ, as the primary requirements like good grains, protein content, test weight, sedimentation value and percentage of flour recovery etc lack in the region (Table 2 & 3). Varieties good in loaf volume are available for timely sowing in NEPZ (K 9107, K 307, HD 2733) and late sown conditions prevailing in the peninsular India (HI 977, PBW 533, NIAW 917). In these zones, material good for bread quality keep flowing in the coordinated programme. Locations like Durgapura (NWPZ), Pusa and Kanpur (NEPZ), Junagarh (CZ) and Pune and Nipahd (PZ) prove conducive for cultivation good bread making wheats (Fig 1).

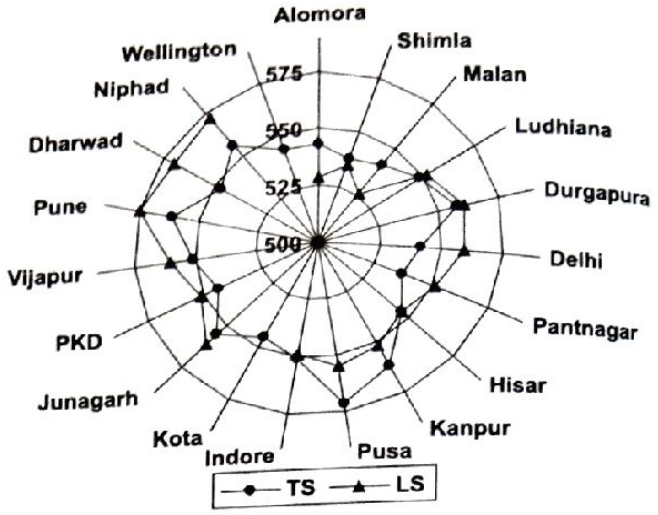

Fig 1 Bread loaf volume at different locations

It is important to realize that the breeding material developed in the Indo-Gangetic plains (NWPZ and NEPZ) and the central peninsular India (CZ and PZ) differs genetically. In the northern belt, winter gene pool and IB/IR based parent lines constitute majority in the crossing blocks where as abiotic stress (heat and moisture) are the major concerns in the central peninsular India. In this scenario, it sounds logical that uniform selection criteria may not be applicable in development of product superior varieties. For investigation, two years performance (2006 & 07) of materials tested in the Indo-Gangetic plains was compared to that of the central peninsular India. Multiple regression analysis revealed that primary contributing factors differed in those two regions. A number of characters like hectolitre weight, protein content, protein quality (Glu 1 score), hardness index, sedimentation value, flour recovery percentage, zincs and copper contents were found to be critical contributors in the northern part (adjusted R^2: 0.322). On the contrary, success was better laid in the central peninsular India (adjusted R^2: 0.373) with just two key contributors namely protein quality and beta-carotene. Difference in primary contributors was obvious for chapati quality as well, and the only commonality between two diverse regions was appearance of the grain. It was noted that that chapati improvement programme under irrigated conditions could be better run in south (adjusted R^2: 0.612) in comparison to north (adjusted R^2: 0.411). Therefore, there is a need to redefine the role of quality contributing traits especially when the environments are so diverse.

Table 4 Performance of final year entries and notified varieties at different locations (2005-07)

Zone	Location	Flour recovery (%)		Flour yield (q/ha)		Protein yield (kg/ha)		Iron content (ppm)		Zinc content (ppm)	
		TS	LS	TS	LS	TS	LS	TS	LS	TS	LS
NHZ	Almora	65.6	65.6	37.7	15.5	626	266	33.6	32.4	32.0	34.4
	Shimla	65.5	65.5	37.2	22.5	598	356	31.3	28.5	27.6	30.2
	Malan	64.3	64.3	23.3	18.9	424	323	34.8	30.5	30.1	32.5
NWPZ	Ludhiana	67.3	67.3	36.2	24.8	645	418	36.0	42.5	40.0	43.5
	Durgapura	68.3	68.3	35.3	24.7	656	511	39.7	38.8	38.2	32.9
	Delhi	67.1	67.1	32.3	26.7	587	477	38.2	37.8	32.4	40.6
	Pantnagar	67.3	67.3	29.0	23.4	492	395	35.5	41.4	34.5	38.1
	Hisar	67.0	67.0	30.0	28.3	510	482	36.6	39.8	36.0	40.2
NEPZ	Kanpur	70.7	70.7	31.9	26.3	536	463	40.1	54.8	34.0	39.8
	Pusa	70.9	70.9	28.3	29.4	507	515	38.2	53.8	30.3	35.5
CZ	Indore	69.5	69.5	38.1	29.3	586	490	34.0	38.0	44.5	34.0
	Kota	70.8	70.8	34.6	-	552	-	31.4	-	43.0	-
	Junagarh	69.0	69.0	31.3	24.2	563	436	30.4	38.2	42.7	28.0
	Powarkheda	69.2	69.2	30.1	27.6	482	492	29.5	37.3	40.0	30.9
	Vijapur	69.5	69.5	29.8	24.6	515	474	34.1	35.1	41.2	28.9
PZ	Pune	69.6	69.6	38.9	32.3	681	605	46.7	52.2	39.8	41.7
	Dharwad	69.3	69.3	31.1	26.4	498	502	44.7	48.3	31.9	34.6
	Niphad	71.0	71.0	35.7	28.5	588	500	45.7	49.4	35.8	38.9

TS: timely sown, LS: late sown

(B) INDUSTRIAL OUTPUT

I) Flour recovery is an important parameter for baking industry as it is not only related to quality of the product but is also embedded with strong commerce. Besides quality of the product, it also ensures better nutrition, be it protein content or minerals (Table 3). Regression analysis (adjusted R^2: 0.55) reveals that for selecting varieties of high flour recovery, two parameters are most critical i.e. protein content (positive effect) and ß carotene (negative effect). Flour recovery is generally low in the hills because of low protein content, grain hardness and high beta-carotene content, therefore the produce remains unsuitable for the industry. Wheat from CZ, PZ and also that of NEPZ has good flour recovery (≈70%) and prospects of getting suitable materials are also high in these areas (Table 1 & 2). Majority of the locations falling in these zones are suitable to nurture industrial requirement of white flour. The main wheat bowl of the country i.e. NWPZ, generally has varieties with moderate extraction rate i.e. ≈68%. However, genetic improvement for raising flour recovery does seem to be a possibility as a newly released variety i.e. DBW 17 has registered 70% flour recovery in the region.

II) Flour yield per unit area is an important aspect that occupies enormous significance especially in a situation when contract farming is adopted by the industry to raise a variety of choice. In this scenario, the late sown varieties will loose the quality advantage as being lower yielder; they will succumb in tonnage of flour yield (Table 4). In plains, locations like Ludhiana and Durgapura in NWPZ, Indore and Kota in CZ, Pune and Niphad in PZ where per hectare tonnage exceeds 3.5 in timely sowings, will be the favourable spots for the baking industry viewpoint.

(C) GRAIN NUTRITION

I) Grain protein content is a highly valued quality characteristic as besides raising nutrition status, it also improves bread quality; flour recovery and iron content (Table 3). Grain protein contents can be increased without sacrificing grain yields in wheat (Asseng and Milroy 2006). Varieties of high grain protein content (≥13%) are a scarce commodity and options are mostly found under late sown conditions of CZ and PZ (Tables 1 & 2). Protein under late sown conditions is always at the expense of yield (Table 4). Therefore, protein yield per hectare should be taken as criteria to select sites for commercial exploitation of protein rich varieties. Selection on protein yield per unit area was suggested long back (Bhatia, 1975, Mc Neal et. al. 1982) where such selections also registered favourable correlated response for grain yield and yield components, too. The sites to exploit commercial cultivation of such a premium commodity will be Durgapura and Pune as first choice, and Ludhiana and Delhi as second choice as they offer grain protein and protein yield in combination (Fig 2). Raising protein levels is a remote possibility in hills due to poor soil status but in plains, concerted efforts will have to be made especially in timely sown varieties.

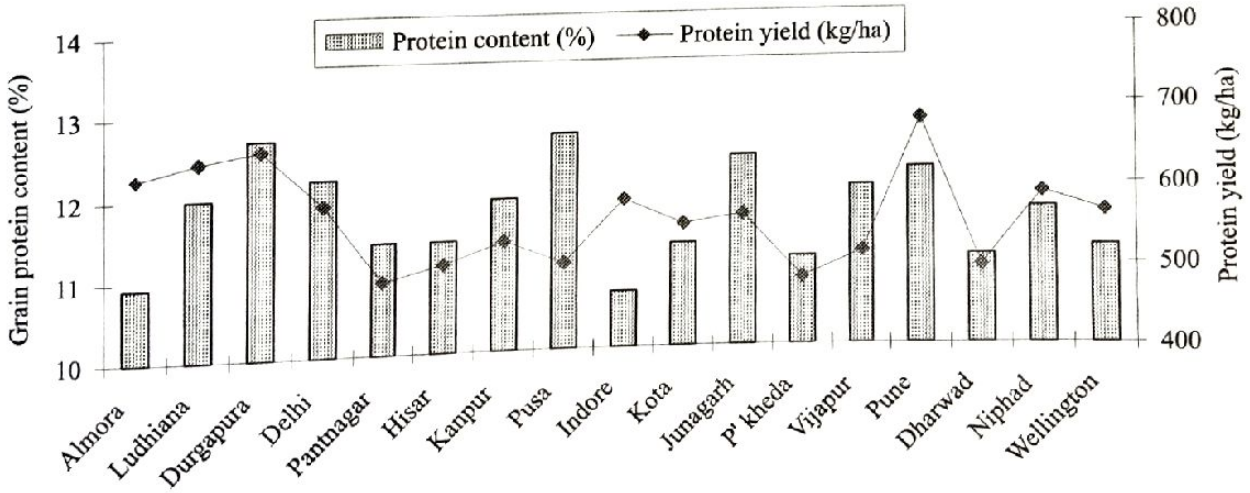

Fig 2 Protein yield and grain protein content at different locations

II) Micronutrients enrichment through bio-fortification is fast becoming forte in cereal research. Wheat, a traditional staple food crop of India, is seen as major route to better nutrition in the country as it has an edge over other major cereals in protein, beta-carotene and mineral contents; and also provides tremendous scope of further improvement in nutritive properties of the grain (Misra *et al.* 2004). Since no other grain nutritional components except protein content has reported any negative impact on grain yield (Welch and Graham 2002), bio-fortification in wheat therefore seems to be a certainty in varietal development.

Iron content in wheat grain is vital among micronutrients as besides health benefits; it has shown strong relationship with protein content and gluten content (Table 2) in the Indian varieties. It also influences flour recovery and other micronutrients like zinc, copper and manganese. Barring a few, most of our varieties are found wanting in iron content. Iron rich material is noted in the NEPZ, PZ and SHZ only. Wheat in the northern hills and central India has low iron content in the grains and soil fertility status plays an important role in this regard. Iron content is generally high in PZ and SHZ, irrespective of

the sites or production condition (Table 4) and therefore peninsular India is most suited to raise iron rich varieties. In NEPZ, only late sown material registers advantage in grain iron content, therefore, genetic superiority of late sown varieties may prove handy while promoting iron rich genotypes in that region.

Zinc content in the wheat grain has no bearing on product quality (Table 2) and is also influenced by the soil structure, characteristics that are so similar to that of iron. Since it is strongly associated with iron, prospects of improving both these traits simultaneously are quite high. A significantly high and positive correlation between seed concentrations of Fe and Zn had been reported in *Triticum* and CIMMYT reports have suggested 20% advantage in iron and/ or zinc concentration in varietal development (Graham et al 1999, Monasterio and Graham 2000, Cakmak *t* 2004). Best-suited sites for this micronutrient are Pune and Ludhiana. Good zinc content was also noted in different locations of CZ but it was restricted only to timely sown material, another example of genotypic superiority for micronutrient in wheat.

Beta-carotene in wheat grain is quite sufficient in northern India (3-4 ppm), be it plains or the hills. And in the carotene deficit regions i.e. CZ and PZ, limited success can be anticipated due to adversity posed by high temperature. However, ß carotene is such a trait where lot of negativity is associated, especially with chapati quality, grain appearance, hectolitre weight, wet gluten, flour recovery etc (Table 2). In comparison to other major cereals, wheat is comfortably placed for this micronutrient, therefore, raising it further may not prove rewarding.

Quality improvement has been a great challenge in wheat research. It requires concerted efforts to combine quality with yield along with biotic and abiotic stresses so as the developed material could be released as a variety. Besides, a breeding programme on wheat quality has another four basic concerns, i) it should be demand driven, ii) it must suit the baking industry, iii) there should be ways and means to enforce genetic improvement and iv) there has to be a conducive environment to exploit the targeted quality characteristic. However, the issues can not be applied uniformly at every centre due to varying quality needs and diverse production environments. Setting quality targets for each place is crucial so as a premium quality product developed through targeted breeding can prove niche and deliver proper benefits to the farmers, consumers and the industry.

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