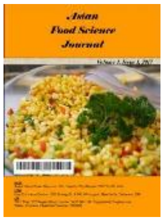

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Nutritive Appraisal of Various Wheat Varieties/Lines for Developing Biofortified Wheat (*Triticum aestivum* L.)

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Authors' contributions

This work was carried out in collaboration between all authors. Authors MA, JA, AJ, MZ, MH and SG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SS and HS managed the analyses of the study. Authors MI and MO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Essential micronutrients such as iron (Fe) and zinc (Zn) deficiency affect more than two billion people globally especially in pregnant women and children under the age of five. Wheat, like many other staple cereals, contains low levels of essential micronutrients such as Fe and Zn. It contributes 13.1% to agricultural value addition and 2.8% to the gross domestic product (GDP) of Pakistan. National Wheat Breeding program at Faisalabad, Pakistan analysed 240 coded samples of wheat varieties/lines both from irrigated and rainfed conditions. The analysis revealed that 1000 grain weight ranged from 23.9-50.2 g in irrigated and 31-42.0 g in rainfed conditions while test weight range was found to be 59.9-75.8 (irrigated) and 64.5-79.9 kghl-1 (rainfed). Protein and gluten content ranged between 12.0-16.1 & 13-16.2 and 21-34 & 21-38% in irrigated and rainfed trial, respectively. Starch content was recorded 51.8-57.1 and 51.9-56.1% under irrigated and

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rainfed condition, respectively. The values of Falling No. (FN) were equally recorded in both sets. Gluten & protein were directly correlated to each other, showing a positive correlation with Fe & Zn whereas a negative correlation was recorded with starch in both sets. However, a direct correlation of FN with starch content was observed only in the rainfed set. In irrigated condition, cluster 3 (5 genotypes) represented relatively high value of Fe and Zn content while in rainfed condition, cluster 2 (31 genotypes) and cluster 3 (15 genotypes) represented relatively high Zn concentration. The genotypes in these clusters might be helpful for developing biofortified wheat varieties to overcome Fe and Zn deficiency among the malnourished population.

Keywords: Nutritive appraisal; biofortified; developing; wheat.

1. INTRODUCTION

Wheat production at 25.750 million tons during 2016-17 [1] was superfluous than country's prerequisite and served as a significant indicator of food security. Annual consumption of wheat per capita is 125 Kg [2] and mostly it is consumed as chapatti (unleavened flat bread).Wheat, like many other staple cereals, contains low levels of essential micronutrients particularly Fe and Zn. Globally up to two billion people are the victim of Fe and Zn deficiency, especially in regions with predominantly cereal-based diets [3]. Nutritional considerations to surmount such deficiencies are imperative. It contributes 13.1% to the agricultural value addition and 2.8% to gross domestic product (GDP) of Pakistan. Wheat crop plays a significant role in satisfying daily calorie requirement of Pakistani people, but wheat grain is inherently very low in Fe, Zn and protein concentration, particularly when grown on Fe and Zn-deficient soils. Wheat serves as an important dietary staple food for the people of Pakistan and accounts for nearly 843 Kcal/capita/day of energy (37% of daily calories) and 22 g/capita/day of protein (37% of daily protein consumption). Therefore, it calls for its quality assessment to determine nutritive value in respect of its intake.

Under the National Wheat Breading program, 240 coded samples of various wheat varieties/lines were included in irrigated and rainfed National Uniform Wheat Yield Trials (NUWYT) during 2016-17 and were physicochemically analysed for different quality characteristics.

2. MATERIALS AND METHODS

In the present study 240 coded wheat varieties/lines were physicochemically evaluated at ISO/IEC-17025:2005 certified Cereal Technology Laboratory, Wheat Research Institute, Faisalabad, Pakistan to find out its qualitative status to develop the biofortified wheat which may be useful in overcoming Fe and Zn deficiency among the vulnerable population.

Protein was determined by Kjeldahl method (Instruction manual VELP Scientifica). Two grams of sample was taken and a tablet of digestion mixture was added along with 10 ml sulphuric acid. Digested sample was diluted. After distillation, the sample was titrated against sodium hydroxide. Protein was determined after multiplying the correction factor with nitrogen percentage.

Starch content was assessed by NIR instrument (instruction Manual Omeg Analyzer G) in which wheat sample was taken in hopper and 18 mm sample spacer was used [4].

Gluten content was analysed by glutomatic apparatus used in ISO-17025 certified CT Lab [5]. A 10-gram sample of flour was weighed and put into the glutomatic washing chamber on top of the polyester screen. The sample was mixed thoroughly and washed with 2% salt solution for 5 minutes. The wet gluten was removed from the washing chamber and centrifuged in the centrifuge holder. The residue, retained and passed through the screen was weighed. The α-amylase activity was examined by the falling number apparatus, in ISO-17025 certified CT Lab [6]. Seven-gram sample of wheat flour was weighed and combined with 25 ml of distilled water in a FN glass tube with a stirrer and shaken to form slurry. As the slurry was heated in a boiling water bath at 100°C and stirred constantly. The starch gelatinized and formed a thick paste. The time taken by the stirrer to drop through the paste was recorded as the FN value.

The 1000-grain weight was determined by counting the grains from the seed counter, Numigral II (Chopin, France). After counting 1000 grains, their weight was taken with the help of a weighing balance (GR 200, Japan) in the ISO-17025 Certified cereal technology laboratory.

For test weight, a bowl of one-liter capacity was filled with wheat grains and their weighing was done with the help of the test weight apparatus. Iron and Zinc concentrations were assayed by Atomic Absorption Spectrophotometer (Model: 969, Unicam Limited, Cambridge, UK); Furnace (Model: GF 90, Unicam Limited, Cambridge, UK) with temperature range 250-600±10°C and Furnace Auto-Sampler (Model: FS 90, Unicam Limited, Cambridge, UK) [7].

3. RESULTS AND DISCUSSION

Analysis of various quality parameters revealed that 1000-grain weight ranged from 23.9-50.2 g in Irrigated and 31.0-42.0 g in rainfed condition while test weight range was found to be 59.9-75.8 (irrigated) and 64.5-79.9 kghl-1 (rainfed). Higher grain weight and test weight of varieties can be related to the higher production of wheat and are helpful to improve food security in the country [8]. Protein content ranged between 12.0-16.1% and 13.0-16.2% in the irrigated and rainfed trial, respectively while gluten was found to be in the range of 21-34% in irrigated set and 21-38% in the rainfed set. Higher values of protein in combination with other foods [9] may be helpful to cover Protein Energy Malnutrition (PEM). Increase in flour protein under water deficit conditions might be due to the lower rate of accumulation of carbohydrates while irrigated condition might decrease flour protein content by dilution of nitrogen with carbohydrates. This suggests that low precipitation restricts yield but is an important factor in producing grains with high protein content as well as high baking quality. Similar findings were also observed in another study [10]. Starch content was estimated to be 51.8-57.1 and 51.9-56.1% in irrigated and rainfed set, respectively and falling number value was recorded in the range of 352-814 sec in both conditions. Falling number value more than 250 seconds represented sound wheat which may again be related to improve country's food security. Most of the varieties/lines were depicted with Zn concentration in the range of 31-32.6 and 31.2-33.9 ppm in the irrigated and rainfed trials, respectively, while Fe content was 35-40 in irrigated and 35-43 ppm in rainfed conditions, respectively [11]. Statistical analysis of both sets showed a positive correlation of gluten with protein and Zn while it was negatively correlated with starch content. In contrast, protein had a positive correlation with Zn and negative correlation with starch (Tables 1 and 2). These results are in good agreement with Ngure et al. [12]. They also revealed a positive correlation between Zn level and protein content in the whole meal flour while Punia et al. [13] found a negative correlation between protein and carbohydrates. Similarly, Fe content showed positive association with protein and Zn. Additionally in the irrigated condition, gluten and Fe showed positive association while Fe and starch association was negatively established [14,15]. The vector view of the Biplot (Figs. 1 and 2) provides a concise summary of the interrelationships among the traits and genotypes. Presentation by Biplots provides impulsive and quantitative categorization of multidimensional data. The distance of each variable with respect to PC1 and PC2 showed the input of difference of diverse traits in the coded varieties/lines.

The traits values are joined to the origin by sidelines. Values with short spokes do not exert strong interactive forces. Those with extended spokes put forth well-built interaction. The values representing the traits are connected to the origin. In irrigated condition (Fig. 3), cluster 1, cluster 2 and cluster 3 consisted of 33, 22 and 5 genotypes, which represented 55%, 37% and 8% of total genotypes, respectively. Cluster 1 exhibited a relatively high value of protein and gluten while a low value of starch.

Table 1. Correlation coefficients for qualitative traits in bread wheat under irrigated condition

Variables	GW	TW	Protein	Starch	Gluten	FN	FE
TW	0.02						
Protein	0.11	0.16					
Starch	-0.16	0.20	-0.47**				
Gluten	0.09	-0.02	0.68**	-0.62**			
FN	-0.23	0.03	0.21	-0.13	-0.03		
Fe	-0.09	0.25	0.69**	-0.23	0.40**	0.23	
Ze	0.12	0.09	0.70**	-0.40**	0.53**	0.07	0.70**

*1000 Grain weight (GW), Test weight (TW), Falling number (FN), Iron (Fe), Zinc (Zn) *Significant at 5% level and ** highly significant at 1% level*

Table 2. Correlation coefficients for qualitative traits in bread wheat under rainfed condition

Variables	GW	TW	Protein	Starch	Gluten	FN	FE
TW	0.013						
Protein	-0.20	-0.23					
Starch	-0.15	0.16	-0.48**				
Gluten	-0.16	-0.23	0.63**	-0.51**			
FN	-0.07	0.10	-0.29*	0.32*	-0.23		
Fe	0.01	-0.07	0.60**	-0.15	0.36**	-0.13	
Ze	0.03	0.04	0.56**	-0.21	0.27*	-0.15	0.59**

*1000 Grain weight (GW), Test weight (TW), Falling number (FN), Iron (Fe), Zinc (Zn) *Significant at 5% level and ** highly significant at 1% level*

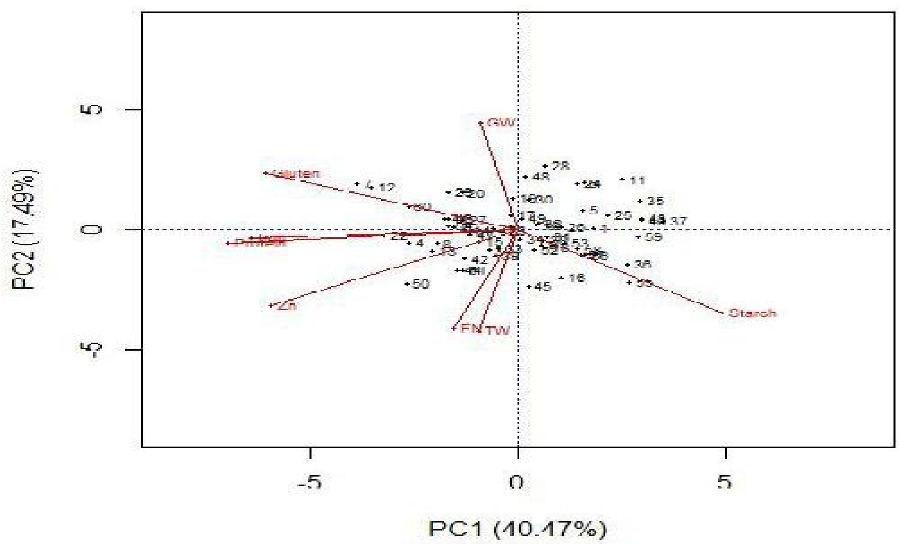

Fig. 1. Biplot of wheat varieties/lines under irrigated condition

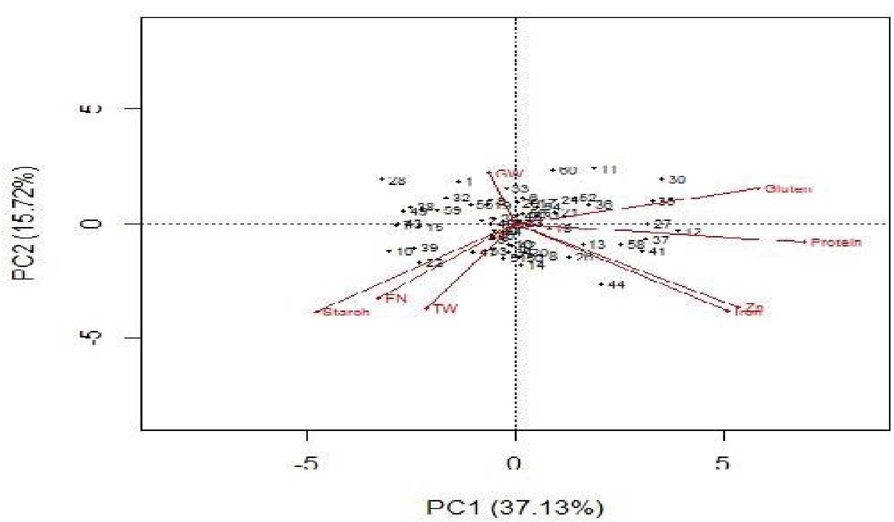

Fig. 2. Biplot of wheat varieties/lines under rainfed condition

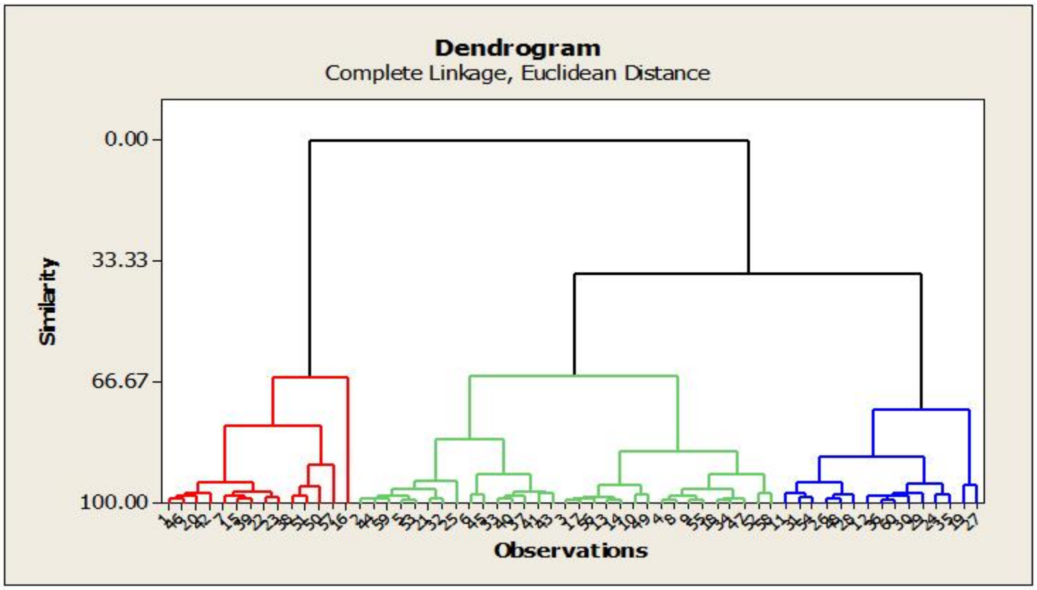

Fig. 3. Dendrogram of wheat varieties/lines under irrigated condition

Cluster 2 showed a relatively high value of grain weight while notably the lowest value of falling number. Cluster 3 represented a relatively high value of Fe and Zn contents. In rainfed condition (Fig. 4), cluster 1, cluster 2 and cluster 3 consisted of 14, 31 and 15 genotypes, which represented 23%, 52% and 25% of total genotypes, respectively. Cluster 1 exhibited relatively high value of test weight. Cluster 2 showed high value of Fe, and cluster 3 represented relatively high value of grain weight, protein, gluten and Zn while the lowest value of falling number (Table 3). The dendrogram showed results comprising of main groups each of which is further subdivided into subgroups. The wider distances between the clusters could be utilized in the breeding program to develop zinc and iron-rich wheat cultivars.

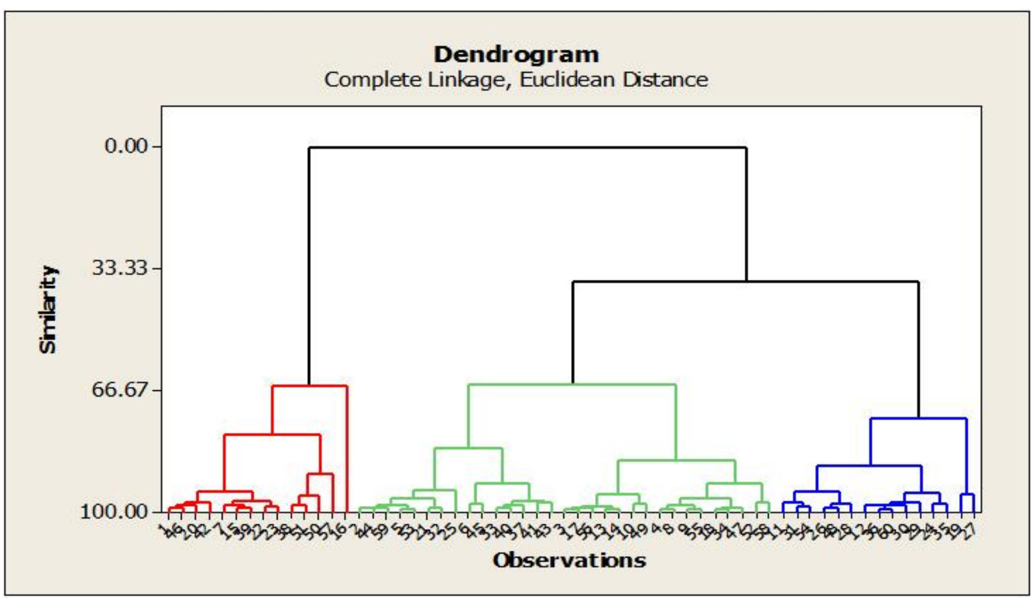

Fig. 4. Dendrogram of wheat varieties/lines under rainfed condition

Table 3. Cluster analysis of wheat varieties/lines under irrigated and rainfed conditions

Variables	Cluster-1		Cluster-2		Cluster-3		G. Centroid	
	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
Grain Wt (grams)	35.855	37.400	37.998	36.971	37.12	37.690	36.746	37.251
Test Wt (kg/hl)	69.455	75.611	69.786	75.479	70.91	74.437	69.697	75.249
Protein (%)	14.808	14.711	14.489	14.977	14.59	15.190	14.673	14.968
Starch (%)	54.523	54.425	54.784	54.190	54.64	53.737	54.628	54.132
Gluten (%)	28.121	27.321	27.909	28.097	26.70	28.867	27.925	28.108
Falling No.(Sec)	597.788	660.964	478.114	565.210	696.80	463.633	562.158	562.158
Fe (ppm)	37.742	38.768	37.205	39.645	38.30	39.500	37.592	39.408
Zn (ppm)	31.842	32.400	31.825	32.447	31.86	32.620	31.837	32.479

4. CONCLUSIONS

The present study revealed that protein content, gluten and test weight were found to be higher in rainfed condition whereas the situation was reversed for 1000-grain weight and starch content. Both sets showed gluten and protein being directly correlated with each other, showing a positive correlation with Fe and Zn but negatively correlated with starch. A direct correlation of FN with starch was recorded only under rainfed sets. In irrigated conditions, cluster 3 (5 genotypes) represented relatively high values of Fe and Zn while in rainfed condition, cluster 2 (31 genotypes) and cluster 3 (15 genotypes) represented a relatively high value of Zn concentration. These clusters suggest that these genotypes may be effectively used for developing biofortified wheat varieties to overcome Fe and Zn deficiency among the malnourished population. There could be several approaches regarding micronutrient fortification but most preferable and sustainable option is the development of biofortified wheat varieties and makes these varieties available to the vulnerable masses.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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