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Grain Macronutrient Concentrations in Diverse Wheat Landraces under Optimum Fertilizer Management in Pakistan

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Abstract

Macronutrients concentration is an important benchmark to evaluate wheat variety for grain yield and quality parameters. The low nutrients density in grain is bound to affect nutrition quality and causing malnutrition problem and hindrance meeting UN sustainable development goals (UN-SDGs). Grain macronutrients concentration was determined in ninety-seven (97) wheat genotypes. Results showed that all wheat landraces were deficient in major elements. The low nutrients status can be attributed to inadequate supply of these nutrients-based fertilizers in wheat production system and soil characteristics.

Keywords: Crop production, Grain protein, Inceptisols, Macronutrients concentration, Wheat grain

Introduction

Wheat (*Triticum aestivum L*) accounts for 30% of global grain production and 45% of cereal food besides contributing >20% of global calories and proteins consumption (Benincasa et al., 2017; Weichert et al., 2017). In Pakistan as important staple food, wheat is currently cultivated on 9 million ha area showing increase from 23310.8 ('000 tons) to 24349.0 ('000 tons during 2009-2019), with concurrent increase in fertilizer consumption from 1090.1 thousand nutrients tons (TNT) to 1153.465 TNT

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showing an average increase of 4.5% in wheat productivity and 5.8% increase in fertilizer consumption (Pak. Bureau of Stat., 2020). However, keeping into account the growing population and food security, there exists yield gap in wheat productivity mainly contributed by imbalance use of fertilizer such as N: P level of 3.53:1 (NFDC, 2020). Additionally, more emphasized is placed on grain productivity instead of nutrition research (M. Wei et al., 2016).

Earlier work (Ågren, et al., 2012; 2008 and Elser et al., 1996) show that element concentration pattern and stoichiometry can vary depending on species or genotype, ontogeny and environment. Lollato et al. (2019) found that wheat yield was negatively related to grain nitrogen concentration (GNC) comprising 155 site-years for yield (n=8035) and 90 site-years for GNC (n=4580) based on three long-term (1966–2016) experiments in Oklahoma (USA).

To ensure United Nations Sustainable Development Goals (UN-SDGs) "End hunger, achieve food security and improved nutrition and promote sustainable agriculture" crop yield and quality will be required to increase (Akram et al., 2018), currently Pakistan ranks 77th on the global food security index with 22% of its population undernourished (EIU, 2014). Concurrently, Pakistan has been reported to have one of the highest levels malnutrition particularly in child compared to other developing counties (Di Cesare M et al., 2015).

The challenge is not only to increase wheat yield per hectare do improve nutrition of the wheat grain. Therefore, an attempt has been done to probe into (1) macronutrients composition of major wheat landraces growing in Pakistan (2) Whether the current wheat grain could have macronutrients and protein contents fair enough to expect good crop yield with enrich macronutrients concentration and (2) establish correlation among various grain contents in selected wheat landraces.

Materials and methods

Study site description:

The study was carried out during the 2022-23 in Rabi growing seasons at National Agricultural Research Centre (NARC), Park Rd, Islamabad (33.6844° N, 73.0479° E) (Figure 1). The soil at the experimental site is a Hyperthermic Udic Haplustalf deposited probably during the Late Plesitocene period and classified as alkaline with texture class of silt loam (USDA textural classification; 28.4 clay, 46.8% silt, 24.8 sand).

The climate of Islamabad is a humid subtropical climate (Köppen climate classification) with four seasons: a pleasant Spring (March–April), a hot Summer (May–August), a warm dry Autumn (September—October), and a cold Winter (November—February). Wheat is sowing as a winter crop from Oct-Nov. and harvested in May-June.

The site experienced wet summers and semi dry winters with average annual

precipitation of 1289.69 mm (58% of precipitation as winter and monsoon rainfall respectively, and 42% as winter rainfall) average annual maximum and minimum temperatures are 27.49 °C and 14.4 °C respectively (Figure 2).
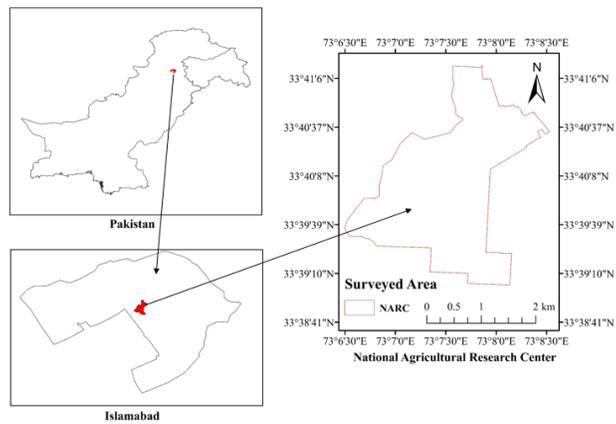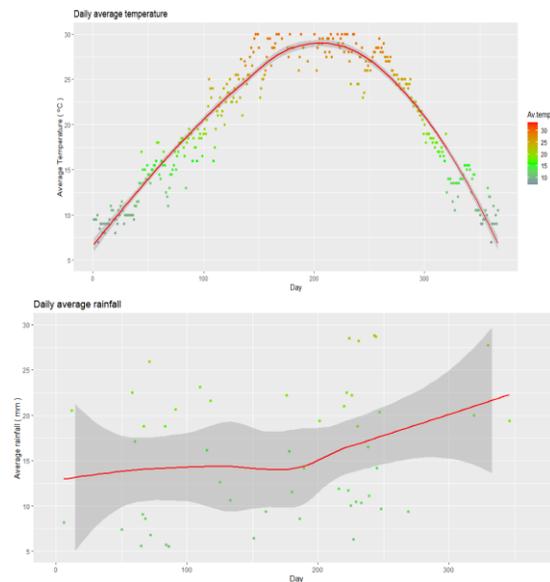

Fig. 1. Location map of site

Fig. 2. Daily temperature and Rainfall of the site

Experimental design and crop management

Conventional tillage system including ploughing and disk harrowing was performed

and Wheat seeds of different lines/varieties were sown in November and harvested in May. Seed rate used @ 50 kg/Acre which equate to 12 g seed m^{-2} or about 300 seeds m^{-2} in two replicates mostly practice in Pakistan. Wheat was fertilized with N as urea (46% N) and P as DAP (46% P$_2$O$_5$) applying half dose of N and full dose of P at the time of sowing (8 and 6 g m^{-2} respectively corresponded to 80 kg N /ha and 60 kg P/ha respectively).

Grain, soil Sampling and Analysis:

Sampling was collected in m^2 (sub-plot). Wheat seed grain was dried; labelled and stored for element analysis. Grain samples were manually threshed, oven-dried at 70 °C for 36 h, weighed and ground in a stainless-steel grinder to pass a 1-mm mesh before nutrient element analysis. Total N concentration was analyzed by Kjeldahl method (AACC, 1995). The calculated % N was multiplied by 5.70 to get grain protein contents (GPrC). Wet digestion was performed for mineral quantification like potassium by flame photometer (Sherwood, England), and grain phosphorus content (GPC) by the reaction of acidified solution of ammonium molybdate containing ascorbic acid and antimony (Chapman and Pratt, 1978). The phosphate in plant sample reacts to form an ammonium molydiphosphate complex, which is reduced to blue color solution by ascorbic acid followed by quantification at 660 nm on UV-visible spectrophotometer (Shimadzu UV-1700, Shimadzu, Japan).

Soil samples were collected from site, ground, extracted by AB-DTPA, and analyzed for soil NO$_3$-N, phosphorus and potassium concentration.

Statistical Analysis:

Summary statistics were calculated by sumtable function st() in vtable package of R cran. Annual weather data was visualized using ggplot2 (V: 3.3.5) in R studio. Plot (Corr) was run using R cran.

Results and Discussion

Soil chemical properties:

Chemical properties of soil (pH, EC, NO$_3$-N, and P) and organic matter listed in Table 1 show that soil is primarily classified as alkaline calcareous, the dominant soil classification found in Pakistan, mean pH value with SE 7.82±0.02, electrical conductivity (EC) of 0.292±0.02 dSm^{-1} and NO$_3$-N deficient (1.63±0.08 mg/kg against > 20 mg/kg as adequate), and P 5.06±0.19 against >7 mg/kg as adequate, and K as 105.9±3.64 mg/kg against 120 mg/kg as adequate (ICARDA, 2013).

Table 1. Physico-chemical properties of soil

pH	EC	NO₃-N	P	K	SOM	Texture
(1:1)	ds/m		(mg/kg)		%	class
7.8±0.02	0.29±0.02	1.63±0.08	5.06±0.19	105.9±3.64	0.94±0.03	Silt loam

Mean followed by ±se, EC=Electrical conductivity, NO3-N= Nitrate nitrogen, P=Phosphorus, K=Potassium, SOM=Soil organic matter

Descriptive Statistics

Table 2 provides a summary of nutrient densities for three (03) nutrients and GPrC. Mean with standard error, standard deviation, median, maximum and minimum values are presented in Table 1. Distribution of grain nitrogen concentration (GNC) show mean with standard error (1.79±0.03), maximum (2.34), and minimum (0.69) %N concentration. Grain phosphorus concentration (GPC) show means with standard error (0.28±0.01), 0.05, 0.11 and 0.48 for standard deviation, minimum and maximum respectively. The grain potassium concentration (GPtC) show means with standard error (0.66±0.02), minimum (0.24) and maximum (1.0) across all lines. Grain protein content (GPtC) show mean with standard error as 10.22±1.91, and 1.83, 3.93, 13.34 as standard deviation, minimum and maximum respectively.

Table 2. Descriptive statistics of macronutrients concentration in grain

Nutrient	N	Mean	Median	SD	Min.	Max.
GNC (%)	95	1.79±0.03	1.83	0.32	0.69	2.34
GPC (%)	95	0.28±0.01	0.27	0.05	0.11	0.48
GPtC (%)	95	0.66±0.02	0.62	0.15	0.24	1.00
GPrC (%)	95	10.22±1.91	10.46	1.83	3.93	13.34

Mean±se. GNC=grain nitrogen concentration, GPC=grain phosphorus concentration, GPtC=grain potassium concentration, GPrC=grain protein concentration

Macronutrients and Protein Concentration of Wheat grain:

Grain Macronutrients concentration (%):

The GNC ranging from as low as 0.68% to 2.74% in this study (Figure 3, A-E). Highest GNC (2.74%) was found in NR499 followed by 2.34% and 2.33% in NR571 and NR548 respectively. Whereas the lowest GNC of 0.68% was found in 2nd NESWYT B6. Similarly, GPC (%) ranging from as low as 0.10% to 0.48% (Figure 3, A-E) with an average of 0.28%. The maximum and minimum GPC was observed in

genotype NR499 (0.48%), and genotype 2nd NESWYT B6 (0.10%) these values for P are less than reported earlier (Hafiz et al., 2019) reported range of grain P concentration in 57 wheat genotypes as 0.2-0.89% with an average of 0.66%.
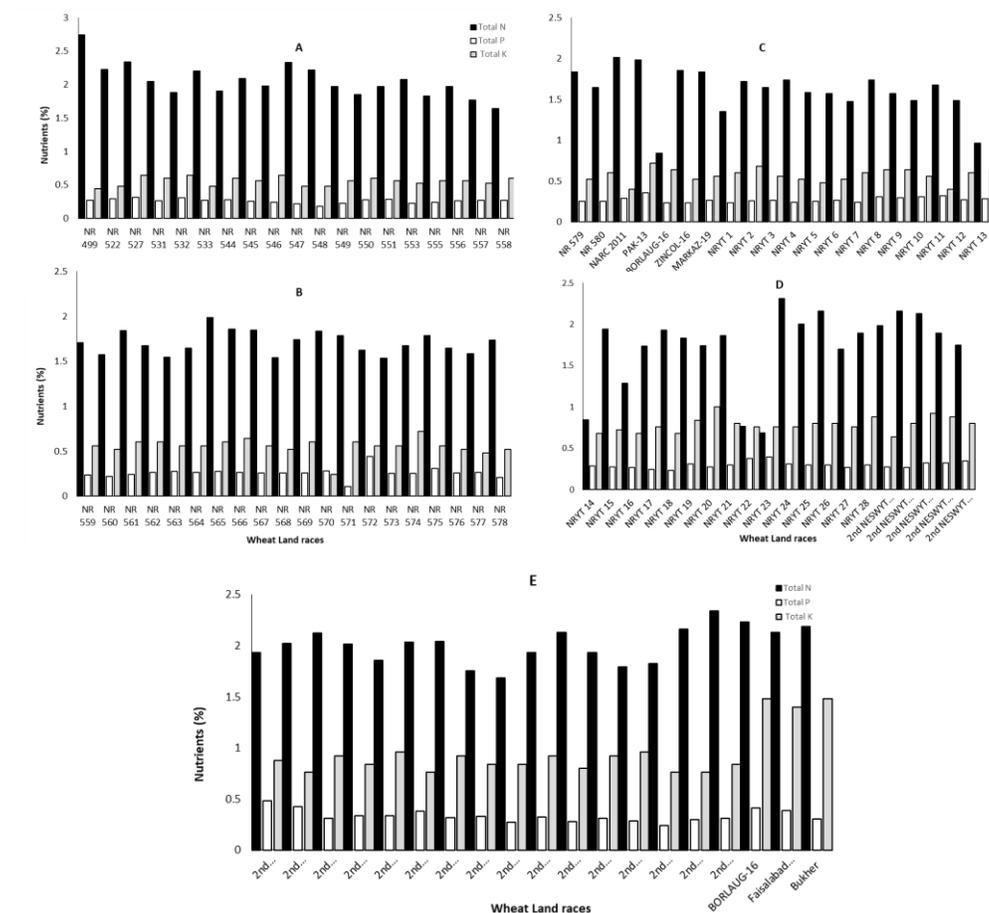

Fig. 3.   Nitrogen, Phosphorus and Potassium Concentration in grain of different Wheat landraces

Grain Protein contents (%)

Grain protein contents (GPrC) have been observed ranging from 3.9% to 15.6% in all landraces. The highest GPrC of 15.6% was observed in NR 499 followed by over 13.3% each in NR 548, NR 578 and NR 547 respectively. Whereas lowest GPrC of 3.9% was found in 2nd NESWYT B6.

Depending on genetic make-up and external factors GPC of wheat varies between 8% and 17% showing that values fall within range in this study. Ikhtiar et al. (2007)

reported GPrC of 11.2% protein in variety Bakhtawar-92 followed by 11% each in Tatara, Watan, Bhakkar-01, Wafaq-01, Gandam-2002 and Chaudry-97. The lowest was found to be 9.0% in Saleem-2000 wheat variety (Figure 4 A-E).
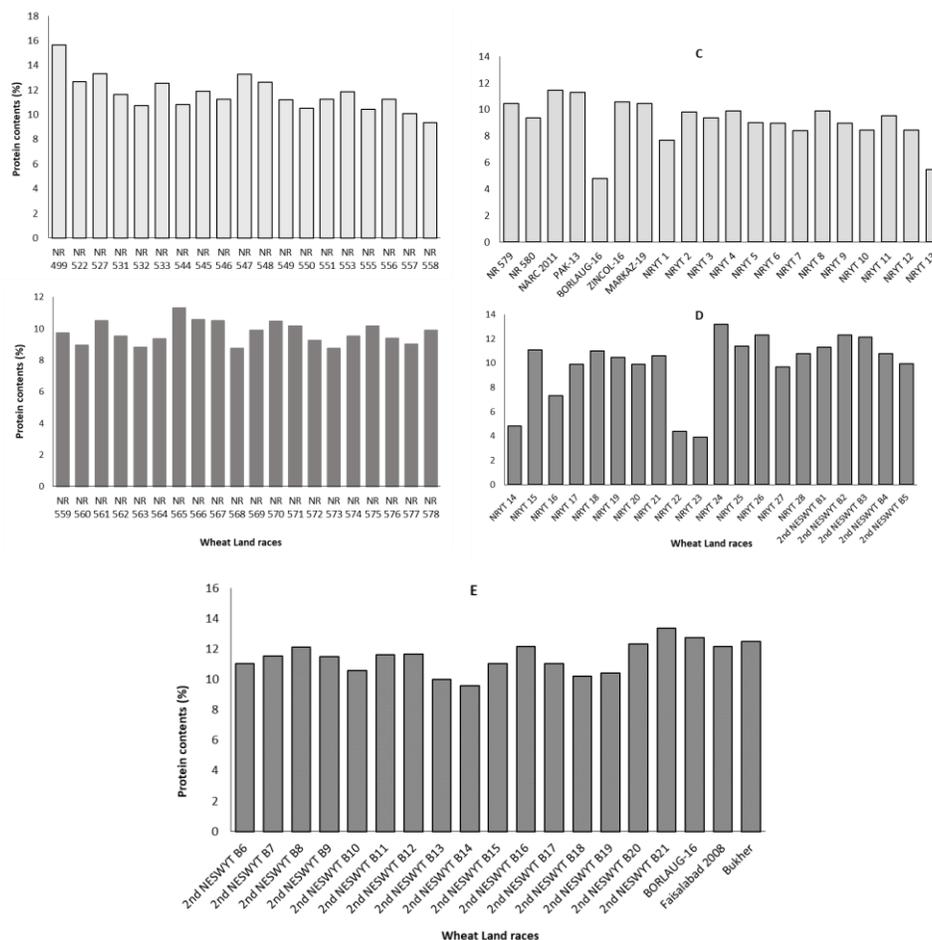

Fig. 4: Protein contents in grain of different Wheat landraces

The GPtC was found in the range of 0.24-1.0%, showing maximum GPtC in NR 499 followed by 0.96% each in NR 571 and NR 548 whereas lowest (0.24%) was found in 2nd NESWYT B6 (Table 4). These results showed that the mean value of total N in this study was 1.79%, slightly above deficient level (<1.6), and below the adequate P level (>2.0), grain mean P was found to be 0.28% though slightly above deficient level (<0.25), but far below the adequate level (0.37-0.53) (Table 4). These results show that all grain samples analyzed were marginal in terms of grain N and P concentration. Interaction effect shows a stronger relationship between total N and

protein contents and mild relation between grain N and Phosphorus and its weaker relation with grain K (Figure 5).

Table 4. Range of concentrations (% dry weight) of N, P, K grain of wheat

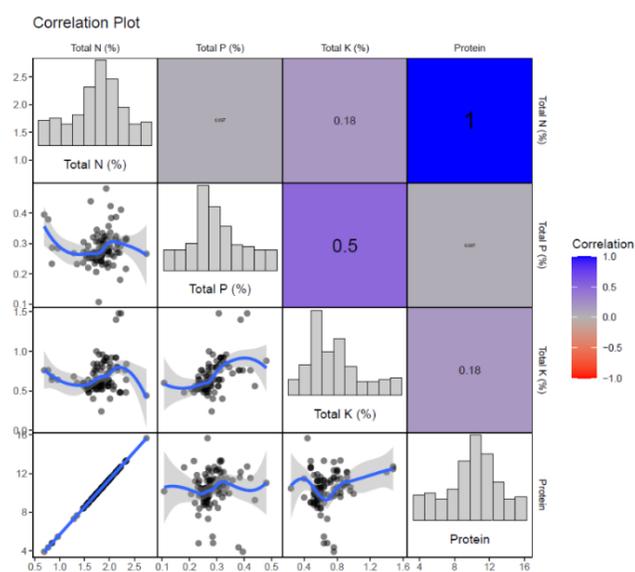| Nutrient	Grain (%)	
	Deficient	Adequate
N	< 1.6	>2.0
P	<0.25	0.37-0.53
K	nd	0.3-0.6

Fig. 5. Interaction between grain macronutrients and protein

Conclusion

Macronutrients densities vary among cultivars. For reliable nutrients removal, it is important to carry out grain P and K analysis of the above landrace at different locations so that some value can be developed of nutrients contents grown with these landraces on that location.

References

Ågren, G. I., Weih, M. (2012). Plant stoichiometry at different scales: element concentration patterns reflect environment more than genotype. New Phytol. 194, 944–952.

Ågren, G. I. (2008). Stoichiometry and nutrition of plant growth in natural communities. Ann. Rev. Ecol. Evol. Syst. 39, 153–170.

Akram, U., Metson, G. S., Quttineh, N. H., Wennergren, U. (2018). Closing Pakistan's Yield Gaps Through Nutrient Recycling. Frontiers in Sust. Food Syst. 2:24. 1-14. https://doi.org/10.3389/fsufs.2018.00024.

Elser, J. J., Dobberfuhl, D. R., MacKay, N. A. & Schampel, J. H. (1996). Organism size, life history, and N: P stoichiometry. BioSci. 46,674–684.

GOP. (2020). Pakistan Economic Survey., 2019-20. Finance and Economic Affairs Division, Ministry of Finance, Govt. of Pakistan, Islamabad, Pakistan.Rehman, A., Jingdong, L., Shahzad, B.,

Chandio, A. A., Hussain, I., Nabi, G., Iqbal, M. S. (2015). Economic perspectives of major field crops of Pakistan: An empirical study. Pacific Sci. Review B: Humanities and Social Sci. 1(3), 145–158. https://doi.org/10.1016/J.PSRB.2016.09.002.

Di Cesare, M., Bhatti Z., Soofi S.B., Fortunato L., Ezzati M., Bhutta Z.A. (2015). Geographical and socioeconomic inequalities in women and children's nutritional status in Pakistan in 2011: An analysis of data from a nationally representative survey. Lancet Glob. Health ;3: e229–e239. doi: 10.1016/S2214-109X(15)70001-X.

Elser, J. J., Dobberfuhl, D. R., MacKay, N. A., Schampel, J. H. (1996). Organism size, life history, and N: P stoichiometry. BioSci. 46,674–684.

Shahzad, A.N., Qureshi, M.K., Wakeel, A. (2019). Crop production in Pakistan and low nitrogen use efficiencies. Nat. Sust. 2, 1106–1114. https://doi.org/10.1038/s41893-019-0429-5.

Meyer, G., Bell, M. J., Lombi, E., Doolette, C. L., Brunetti, G., Novotny, E. H., Klysubun, W., Zhang, Y., & Kopittke, P. M. (2021). Phosphorus speciation in the fertosphere of highly concentrated fertilizer bands. Geoderma, 403, 115208. https://doi.org/10.1016/j.geoderma.2021.115208

Ikthiar, K., Alam, Zeb. (2007). Nutritional composition of Pakistani wheat varieties. J. Zhejiang Uni. Sci. B, ISSN 1673-1581 (Print); ISSN 1862-1783 (Online).

Reuter, DJ., Robinson, J.B. (1986). Plant analysis: an interpretation manual. Collingwood, CSIRO Publishing, Australia.

Weih, M., Pourazari, F., Vico, G. (2016). Nutrient stoichiometry in winter wheat: Element concentration pattern reflects developmental stage and weather. Sci. Rep. 6, 35958; doi: 10.1038/srep35958.