



SOIL SCIENCE

AGRONOMIC BIOFORTIFICATION OF DESI CHICKPEA (*CICER ARIETINUM* L.) WITH ZINC AND IRON

Zia Chishti¹, Sumreen Siddiq^{*2}, Waqar Ahmad³, Khalid Hussain⁴, Sadia Kaukab⁵, Hina Nazir⁶, Kamara Mehmood⁷

ABSTRACT

Pulses and grain legumes like chickpea are important contributor of plant protein in food chain. Biofortification is a tool by which nutritive value of Pulses can be enhanced either through genetic breeding approach, transgenic techniques, and agronomic measures, so it may help in reducing the malnutrition. In humans zinc (Zn) and iron (Fe) deficiencies are commonly reported and these mineral deficiency-related health problems may be solved by improving their concentration in grain crops. The study was conducted at research area of Pulses Research Institute, Ayub Agriculture Research Institute, Faisalabad for consecutive three years 2018-19, 2019-20 and 2020-21 aimed to investigate the effects of soil applied and foliar sprays of zinc and iron on grain yield, grain weight and other agronomic attributes which increased under soil application of zinc and iron as compared to foliar application. Chickpea crop did not respond well to the foliar application of zinc and iron (T_8 , T_9 and T_{10} where Zn and Fe were applied @ 0.1% either alone or in combination) for agronomic parameters, growth and yield. Plant height (86.5 cm), Pods per plant (49.4), 1000 grain weight (245.4 gm) and grain yield (1560.4 kg/ha) increased in T_7 where zinc and iron were applied in combination @ 5.0 kg/ha. Soil application of zinc @ 5.0 kg/ ha at sowing resulted in the highest Zn (32.02 mg Zn/ kg grain) followed by zinc application @ 2.5 kg/ ha where 30.39 mg Zn/ kg grain was obtained. Similar trend was observed for Fe content in grains. Protein content remained unchanged, significant over control with these treatments. However, crude fat and fiber contents were highest in T_{10} , where 0.1% foliar solution of Zn & Fe micronutrients was applied. Thus biofortification of Zn and Fe can help in reducing malnutrition in mushrooming human population.

KEYWORDS: *Cicer arietinum*; biofortification; zinc, iron; nutritional quality; Pakistan

¹Principal Scientist, Soil Fertility,

⁶Scientific Officer, Soil & Water Testing Laboratory, ²Principal Scientist, ³Scientific Officer Biochemistry Section, Post Harvest Research Centre, ⁴Chief Scientist, ⁵Principal Scientist, Pulses Research Institute, ⁷Senior Scientist, Pathology Research Centre, Ayub Agricultural Research Institute, Faisalabad, Pakistan.

*Corresponding author's email: drsumreensiddiq@yahoo.com

Article received on:

27/02/2025

Accepted for publication:

27/06/2025



INTRODUCTION

Grain legumes have potential to generate good income and source of nutrition to billions of farmers with small land holdings and consumers around the globe. Grain legumes are sometimes referred to be the poor man's meat in developing nations because of their valuable nutritional role in the food of all the people. Due to their high calorie, protein, mineral, vitamin, and fiber content as well as the presence of possibly health-promoting phytochemicals, chickpeas have an advantage over other crops in agricultural production (Wood and Grusak, 2007). Chickpeas' complex carbohydrates and high dietary fiber are essential for metabolic and physiological processes because they include a variety of bioactive substances (Begum *et al.*, 2023). Cultivation of chickpea can provide enormous opportunities and new horizons of value addition as it is included in manufacturing products like snacks and gym/sports foods. This crop's health advantages, which include lowering the risk of cancer, diabetes, and cardiovascular

disease, are another plus. In Pakistan, during the year 2022–2023 period, the chickpea cultivated area was 830,000 ha, with production of 238 thousand tons having an average yield of 287 kg/ha (Pakistan Bureau of Statistics, 2023). Leguminous crops have unique feature to form root nodules and can fix atmospheric nitrogen by a symbiotic nitrogen fixing bacteria named *Rhizobium*. Because of multi-functional and diverse roles played by pulse crops in cropping systems and food security.

In African and Asian nations malnutrition is a crucial, widely spread concern which due to severe health associated issues has gained the world attention. Every year approximately 2.0 million malnourished and low birth weight infants are born. As per the World Health Organization (WHO, 2018) malnutrition reports, under 5 years of age, 150.8 million of children are found to be stunted, 50.5 millions are wasted and 38.3 millions are overweight. One third of adult women population is found anemic, thus more susceptible to malnutrition and higher prevalence of obesity as compare to

human. Micronutrient deficiencies (Zn and Fe) have triggered now a days because of many factors like cultivation of hybrid varieties of high yields, intensive cropping system, lack of or inappropriate application of micronutrients and low organic matter content. In chickpea growing region of the world Iron deficiency has been established and is most widespread among the micronutrients. Iron is considered as important element for plant growth and development as it involved in chlorophyll formation, development of chloroplast (Banjara and Majgahe, 2019). Deficiency of iron restricts oxygen supply to cells, which ultimately may cause fatigue, hinders working ability, reduction in immunity and death (Jones *et al.* 1996). Zinc influences the synthesis of auxin and helpful in increasing water use efficiency, nodule formation and nitrogen fixation in pulses which improves the vigor of crop and eventually the grain yield (Kasthurikrishna and Ahlawat 2009; Roy *et al.*, 2013). Zinc is an essential trace element with structural roles in controlling the proteins, as an enzyme cofactor (Sobczyk and Gaunt 2022). Liu *et al.* (2022) reported improved pollen viability, number of kernel and weight of grains (apical section) in maize by Zn biofortification.

Consumption of bio-fortified crops increased the daily intake of micronutrients among individuals and help to address micronutrient deficiencies (Bouis *et al.*, 2011). Bio-fortified pulse crops are therefore considered as the best remedies to feed malnourished population of developing countries.

Keeping in view the importance of Zn and Fe betterment of yield, quality of the crop and eliminating malnutrition the current study of biofortification was planned and done to evaluate and compare the effect of foliar and soil application of zinc and iron on growth, yield and their concentration in the grains of chickpea at Pulses Research Area, Ayub Agricultural Research Institute Faisalabad from year 2018-19 to 2020-21.

MATERIALS AND METHODS

Field trials were conducted in three consecutive Rabi seasons from 2018-2019, 2019-2020 and 2020-2021 at field area of Pulses Research Institute situated at Ayub Agricultural Research Institute Faisalabad to assess the effect of soil and foliar application of Fe and Zn on growth, yield and nutritional quality attributes of desi chickpea variety named "Bittal-2016". Pulses Research Institute falls in the Semi-Arid Plain Zone where winters are extreme cold and summers are hot. Frost spell appearance is also common phenomenon during winter. The physico-chemical characters of soil of the pulses research field area pre sowing and after harvest are given in Table 1 a and 1b.

One popularly grown desi chickpea variety Bittal -2016 was selected and ten treatments of nutrition were applied given as under;

T₁ : only recommended dose of N and P₂O₅ (control)

T₂ : 2.5kg Zinc /ha

T₃ : 5.0 kg Zinc/ha

T₄ : 2.5kg Iron /ha

Table 1a: Pre Sowing soil analysis for various physicochemical characters

Depth	ECe	Soil pH	O.M.	Available phosphorus	Available potassium	Fe	Zn	Saturation	Texture
cm	ds/m		%	ppm				%	
0-15	2.1	8.3	0.56	7.8	360	2.35	0.5	36	Sandy Loam
15-30	2.18	8.1	0.36	4.6	340	2.20	0.35	34	Loam

ECe Electrical conductivity of soil extracts, OM organic matter

Table 1b: Post harvest soil analysis for various physicochemical characters

Depth	ECe	Soil pH	O.M.	Available phosphorus	Available potassium	Fe	Zn	Saturation	Texture
cm	ds/m		%	ppm				%	
0-15	2.13	8.2	0.98	10.9	290	3.96	1.6	36	Sandy Loam
15-30	1.96	8.1	0.91	9.2	185	3.52	1.4	34	Loam

- T₅ : 5.0 kg Iron /ha
 T₆ : 2.5kg Zinc +2.5 kg Iron /ha
 T₇ : 5.0 kg Zinc +5.0 kg Iron /ha
 T₈ : 0.1% foliar spray of Zinc
 T₉ : 0.1% foliar spray of Iron
 T₁₀: foliar spray of 0.1% Zinc +0.1% Iron)

In treatments 2 to 7 Zn and Fe were applied as soil application along with recommended dose of N & P₂O₅ while in last three treatments T₈ to T₁₀ foliar spray was done twice (first spray at flowering stage and second 15 days after first spray) along with recommended dose of N & P₂O₅. The chickpea was sown after 15th October during the three years of cultivation. As per recommendations for this zone 25 kg N + 60 kg P₂O₅ /ha was applied at the time of sowing in all ten treatments. Sources used for Zinc and Iron were ZnSO₄ and FeSO₄ and applied as per treatments. Crop was raised under irrigated condition. Crop protection measures were adopted from time to time and agronomic data was recorded. The crop harvesting was completed before mid of April and data for yield and other attributes (plant height, Number of nodules per plant, Number of pods

per plant, 1000 grain weight (g), grain Yield kg/ha) was recorded. Among nutritional quality parameters protein, fat, fibre, ash%, Zn and Fe contents in seeds was determined.

STATISTICAL ANALYSIS

The experiment was planned according to Randomized Complete Block Design with three replications. Analysis of variance (Steel *et. al.*, 1997) was performed on the recorded data of growth and quality parameters to determine the effect of soil applied and foliar applied Zn and Fe on chickpea. The analysis was performed by using Statistics 8.1.

RESULTS AND DISCUSSION

Growth and yield attributes: Results obtained from this study (Table 2) showed that chickpea performed good for plant height and number of nodules per plant in treatment T₇ (where both zinc and iron were applied @ 5.0 kg /ha along with recommended dose of N and P₂O₅) which was statistically at par with treatment T₆ where half dose of both zinc and iron were applied i.e.

Table 2: Effect of biofortification of Zn & Fe on agronomic parameters

Treatment	Plant height (cm)				No. of nodules/plant				No. of pods /plant			
	2018-19	2019-20	2020-21	Mean	2018-19	2019-20	2020-21	Mean	2018-19	2019-20	2020-21	Mean
T ₁	72.1	77.9	69.4	73.1 e	22.0	26.0	28.3	25.4 e	37.33	36.67	37.33	30.4 g
T ₂	74.5	78.5	75.4	76.1 cde	28.0	32.3	32.0	30.8 cde	42.00	41.33	42.00	35.5 de
T ₃	79.0	80.5	76	78.5 bcd	33.0	35.0	32.7	33.6 cd	43.00	41.67	43.00	37.4 d
T ₄	71.1	78.6	76	75.2 de	37.7	36.7	34.3	36.2 bc	42.33	42.67	42.33	38.9 d
T ₅	76.8	79.9	84.6	80.4 bcd	47.3	39.3	38.0	41.5 b	46.00	44.00	46.00	43.2 c
T ₆	81.6	85.3	84.6	83.8 ab	55.3	45.0	42.3	47.5 a	46.67	46.00	46.67	47.1b
T ₇	78.4	87.7	93.4	86.5 a	50.3	51.0	48.0	49.8 a	49.33	48.33	49.33	49.4 a
T ₈	81.4	79.4	78.6	79.8 bc	30.7	32.0	30.7	31.1 cde	40.67	41.67	40.67	35.4 e
T ₉	79.6	78.2	72	76.6 cde	27.3	31.7	32.3	30.4 cde	40.00	39.33	40.00	34.4 f
T ₁₀	78.0	77.6	74.6	76.7 cde	27.7	30.0	32.0	29.9 de	39.33	40.00	39.33	34.0 f
P 0.0022					0.006				0.004			
LSD (0.05) 4.02					5.87				0.920			

Table 3: Effect of bio fortification of Zn & Fe on growth parameters

Treatment	1000 Grain weight (g)				Grain yield (Kg/ha)			
	2018-19	2019-20	2020-21	Mean	2018-19	2019-20	2020-21	Mean
T ₁	204.3	208.1	210.0	207.4 f	861.1	736.1	1668.8	1088.7d
T ₂	215.9	227.9	229.9	224.5 e	1111.1	791.6	1762.5	1221.8 cd
T ₃	218.7	232.9	232.3	227.9 de	1180.6	895.1	1822.9	1299.6 c
T ₄	220.3	239.1	237.0	232.1 cd	1326.4	888.9	1835.4	1350.2 bc
T ₅	223.2	230.3	235.4	229.6 cde	1187.5	976.4	1835.4	1333.1 bc
T ₆	225.6	245.0	246.4	239.0 b	1409.7	1059.7	1856.3	1441.9 ab
T ₇	229.8	253.5	253.1	245.4 a	1562.5	1236.3	1882.2	1560.4 a
T ₈	223.5	240.2	238.1	233.9 bcd	1180.6	840.8	1698.6	1240.0 c
T ₉	222.3	243.5	240.7	235.5 bc	1295.6	875.6	1691.0	1287.4 c
T ₁₀	224.4	232.4	233.2	230.0 cde	1201.4	913.9	1709.0	1274.8 c
P	0.0004				0.0002			
LSD (0.05)	6.179				13.7			

2.5 kg /ha along with recommended dose of N and P₂O₅. Both these treatments were slightly superior to rest of the treatments (Table 2). Treatment 7 also performed better for number of pods per plant (49.4) followed by T₆ (47.1). Chickpea crop did not respond significantly to the foliar application of Zinc and Iron (T₈ to T₁₀) for all these three agronomic attributes. That might be due to the low concentration of nutrients in the foliar sprays. The maximum weight of 1000 grains and yield (245.4g and 1562.5kg ha⁻¹) was recorded under T₇ where Zn and Fe were applied @ 5.0 kg Zn +5.0 kg Fe /ha in soil (Table 3). Statistically non-significant difference was observed for grain yield with application of half dose of Zn and Fe was applied in soil (T₆). While rest of the treatments were statistically at par for grain yield. Under soil application of Zn and Fe, the increase in growth and other agronomic characteristics might be credited by higher rate of photosynthesis, translocation and accumulation of metabolites which eventually contributed in increasing number of pods plant⁻¹ and seed weight. Similar results were also reported by (Singh *et al.*, 2015; Banjara & Majgahe 2019).

Quality attributes: Proximate analysis (protein, fat, fibre and ash content) helps ensure the consistency and quality of food. Proximate analysis allows us to make legitimate comparisons of food stuff on the basis of specific nutrients. Proximate analysis was done by using methods mentioned in AOAC 2023 and results are given in Table 4. Protein content was found statistically non-significant in all treatments whether soil applied or foliar application of Zn and Fe. Chickpea crop did not respond to application of zinc and iron with respect to protein content that remained statistically at par in all treatments. Crude fat content increased in seeds where Zn and Fe were applied either alone or in combination as foliar sprays (T₈ to T₁₀). Maximum fat (2.90) contents was achieved in T₁₀ (0.1% foliar solution of Zn & Fe micronutrients) followed by T₈ (2.7%) and T₉ (2.85%) where 0.1% Zn and Fe solution was sprayed respectively. Similarly, crude fiber content was highest (2.65%) in T₁₀ (0.1% foliar solution of Zn & Fe micronutrients) followed by T₉ (2.56%) and T₈ (2.53%) where foliar application of Fe and Zn was applied. Ash content was determined according to the procedure

Table 4: Effect of biofortification of Zn & Fe on quality parameters

Treatment	Crude protein (%)				Crude fat (%)				Crude fiber (%)				Ash %			
	2018-19	2019-20	2020-21	Mean	2018-19	2019-20	2020-21	Mean	2018-19	2019-20	2020-21	Mean	2018-19	2019-20	2020-21	Mean
T ₁	19.08	19.13	19.25	19.15	2.11	2.13	2.08	2.11 f	1.75	1.8	1.84	1.80 h	3.12	2.98	3.12	3.07 c
T ₂	19.43	19.20	19.33	19.32	2.18	2.05	2.12	2.12 f	1.91	1.93	1.86	1.90 g	3.27	3.09	3.27	3.21 bc
T ₃	19.6	19.44	19.58	19.54	2.26	2.2	2.29	2.25 e	2.04	2.1	2.08	2.07 f	3.05	3.12	3.05	3.07 c
T ₄	19.78	19.7	19.25	19.58	2.39	2.32	2.4	2.37 d	2.17	2.24	2.19	2.20 e	3.22	3.20	3.22	3.21 bc
T ₅	20.48	20.35	20.1	20.31	2.45	2.41	2.35	2.40 d	2.28	2.32	2.27	2.29 d	3.28	3.31	3.28	3.29 b
T ₆	20.56	20.6	20.66	20.61	2.56	2.5	2.44	2.50 c	2.35	2.39	2.45	2.40 c	3.34	3.40	3.34	3.36 ab
T ₇	20.74	20.6	20.54	20.63	2.78	2.8	2.65	2.74 b	2.41	2.44	2.49	2.45 c	3.53	3.48	3.53	3.52 a
T ₈	20.56	20.6	20.47	20.54	2.7	2.65	2.76	2.70 b	2.52	2.6	2.46	2.53 b	3.35	3.54	3.35	3.41 ab
T ₉	21.35	21.1	21.19	21.21	2.84	2.9	2.81	2.85 a	2.57	2.5	2.62	2.56 b	3.28	3.58	3.28	3.38 ab
T ₁₀	21.88	21.8	21.65	21.78	2.9	2.86	2.94	2.90 a	2.64	2.7	2.6	2.65 a	3.22	3.72	3.22	3.38 ab
P	0.132				0.0001				0.0038				0.003			
LSD (0.05)	NS				0.0895				0.0765				0.2042			

Table 5: Effect of biofortification on Zn & Fe contents of grains

Treatment	Zn (ppm)				Fe (ppm)			
	2018-19	2019-20	2020-21	Mean	2018-19	2019-20	2020-21	Mean
T ₁	27.57	28.60	27.56	27.91 cd	47.37	47.4	47.12	47.30e
T ₂	30.53	30.53	30.11	30.39 b	48.50	48.15	48.12	48.26 d
T ₃	32.27	32.27	31.53	32.02 a	51.03	51.0	50.36	50.80 c
T ₄	29.03	29.03	28.3	28.79 c	53.17	53.3	51.65	52.71 b
T ₅	28.10	28.10	29.12	28.44 cd	54.73	54.64	53.66	54.34 a
T ₆	29.53	29.53	31.2	30.09 b	50.73	50.61	51.12	50.82 c
T ₇	31.17	31.17	30.65	31.00 b	51.03	51.0	51.13	51.05 c
T ₈	28.50	28.50	28.14	28.38 cd	47.60	47.5	46.45	47.18 de
T ₉	27.90	27.90	26.84	27.55 d	48.70	48.22	46.87	47.93 e
T ₁₀	28.53	28.53	27.54	28.20 cd	50.93	50.63	50.23	50.59 c
P					0.001			
LSD (0.05)					0.793			

of AOAC 2023. Ashing is one of the important step in proximate and refers to the inorganic (mineral) residue remained after the combustion or complete oxidation of organic contents in food. Maximum ash content was observed in T₇ where combination of Zn & Fe were applied @ 5 kg/ha in soil. However, soil applied treatments were statistically at par with foliar applied Zn & Fe treatments.

Zinc and iron content in chickpea seed: In agronomic biofortification where the different treatments of Zn & Fe applied as in chickpea, the mean maximum Fe and Zn contents were obtained, where soil application of micronutrients was done. Data given in Table 5 showed that Chickpea variety Bittal-2016 resulted in higher Fe concentration (54.34 ppm) in grains with application of the treatment T₅ (recommended dose of N&P + 5kg/ha Fe) followed by treatment 4 where half dose of Fe was applied to the soil. While other treatments iron content ranged from 47 to 50 ppm. Higher Zn concentration (32.02 ppm) in chickpea grains was observed in T₃ where Zinc was applied @ 5 kg/ha along with recommended dose of N & P.

Significant improvement in Zn & Fe content in chickpea seeds was also reported by Pal *et al.* (2019) and Gupta *et al.*, 2021. In other treatments Zn concentration ranged from 27.91 to 30.39 ppm. Treatments where Fe and Zn was applied in foliar sprays nutrient content in grains remained statistically at par and lower than soil applied treatments (Table 5). Rizwan *et al.* (2018) and Dimkpa *et al.* (2020) found significantly increased Zn and Fe concentration in root, shoot and grains with nano zinc and iron treatments.

CONCLUSION

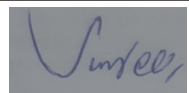
The results obtained from three years of chickpea field study revealed that the soil application of Zn and Fe resulted in better yield, improved nutritional quality attributes and Zn and Fe concentration in seeds rather than their foliar applications and thus can played an important role in bio fortification. The recommended dose of N and P fertilizers along with soil application of 5 kg/ha ZnSO₄ + 5kg/ha FeSO₄ resulted in higher Zn and Fe fortification in desi chickpea and can help in reducing deficiencies of Zn and Fe in food chain of

human population.

REFERENCES

- Banjara, G. P. and S. K. Majgahe. 2019. Effect of biofortification of zinc and iron on yield attributes and yields of chickpea (*Cicer arietinum* L.) through agronomic intervention. *The Pharma Innovation Journal*.8(10): 45–47.
- Begum, N., Q.Khan., L.G.Liu , W. Li , D. Liu, I. Haq. 2023. Nutritional composition, health benefits and bio-active compounds of chickpea (*Cicer arietinum* L.). *Front Nutr*. 10:1218468.
- Bouis, H. E., C. Hotz, B. McClafferty, J.V. Meenakshi and W. H. Pfeiffer. 2011. Biofortification: A new tool to reduce micronutrient malnutrition. *Food and Nutrition Bulletin*. 32(1): 315–405.
- Dimkpa, C. O., J. Andrews, J. Sanabria, P.S. Bindraban, U. Singha, W.H. Elmer 2020. Interactive effects of drought, organic fertilizer, and zinc oxide nanoscale and bulk particles on wheat performance and grain nutrient accumulation. *Sci. Total Environ*. 722: 137808.
- Gupta, K. C. , R. Saxena, S. K. Jain, V. Kumar and M. R. Yadav. 2021. Yield and nutrient fortification of chickpea by foliar Fe and Zn application. *Journal of Crop and Weed*. 17(3): 29-34.
- Jones, D. L., P. R. Darrah and L. V. Kochian. 1996. Critical evaluation of organic acid-mediated iron dissolution in the rhizosphere and its potential role in root iron uptake. *Plant and Soil*. 180:57–66.
- Kasthurikrishna, S. and I. P. S. Ahlawat. 2000. Effect of moisture stress and phosphorus, sulphur, and zinc fertilizer on growth and development of pea (*Pisum sativum*). *Indian Journal of Agronomy*. 45(2): 353–356.
- Liu, D.Y., W. Zhang, Y. M. Liu, X. P. Chen and C.Q. Zou 2020. Soil application of zinc fertilizer increases maize yield by enhancing the kernel number and kernel weight of inferior grains. *Frontiers in Plant Science*. 11:188
- Pakistan Bureau of Statistics (PBS). 2023. Pakistan statistical yearbook 2023. Ministry of Food Security & Research, Government of Pakistan.
- Pal, V., G. Singh and S.S. Dhaliwal. 2019. Agronomic biofortification of chickpea with zinc and iron through application of zinc and urea. *Communications in Soil Science and Plant Analysis*. 50(15) :1864-1877.
- Rizwan, M., S. Ali, B. Ali, M. Adrees, M. Arshad, A. Hussain 2018. Zinc and iron oxide nanoparticles improved the plant growth and reduced the oxidative stress and cadmium concentration in wheat. *Chemosphere* 214: 269–277.
- Roy, P. D., R.P. Narwal, R. S. Malik, B.N. Saha and S. Kumar. 2013. Impact of zinc application methods on green gram productivity and grain zinc fortification. *Journal of Environmental Biology*. 35(5): 851–854.
- Singh, U., N. Kumar, C. S. Praharaj, S.S. Singh and L. Kumar. 2015. Ferti-fortification: An easy approach for nutritional enrichment of chickpea. *The Ecoscan*. 9(3): 731–736.
- Sobczyk, M. K. and T.R. Gaunt. 2022. The effect of circulating zinc, selenium, copper, and vitamin K1 on COVID-19 outcomes: A Mendelian randomization study. *Nutrients*. 14 (2): pp.233.
- Steel, R.G.D., J.H. Torrie and D.A. Dickey. 1997. *Principles and Procedures of Statistics; Biometrical Approach* (2nd Ed). McGraw Hill Book Co. Inc, Singapore.
- Wood, J. A. and M.A. Grusak. 2007. Nutritional value of chickpea. In *Chickpea Breeding and Management*. Wallingford UK: CABI. pp. 101-142.
- WHO. 2018. Global nutrition report 2018: Executive summary. Retrieved February 9, 2020. Available online with update at: <https://globalnutritionreport.org/reports/global-nutrition-report-2018/executive-summary/>.

CONTRIBUTION OF AUTHORS

Sr. No.	Author's name	Contribution	Signature
1.	Zia Chishti	Conducted research trials, analysed the data and wrote-up the manuscript	
2.	Sumreen Siddiq	Analysed the nutritional quality attributes and collected the data.	
3.	Waqar Ahmad	Analysed the quality attributes	
4.	Khalid Hussain	Provided resources for research trials	
5.	Sadia Kaukab	Collected the data and wrote up the manuscript	
6.	Hina Nazir	Analysed the micronutrients Zn and Fe	
7.	Kamara Mehmood	Collected the data and wrote up the manuscript	