Chapter-IV

ELEMENTAL CHARACTERIZATION IN INDIAN AND TURKISH WHEAT GRAINS

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4.1 Introduction

Crop species in general need 17 indispensable elements for best possible growth and progress. These elements are categorized in to macronutrients, that are required in large amount and micronutrients that are crucial in small amounts. Though micronutrients are essential in reasonably lesser amount for plant growth, they are as significant as macronutrients. Undoubtedly, throughout the world several billion people depend on wheat for fulfilling their nutritional requirements. As aleurone layer of wheat grains is basically rich in nutrient elements (Buri *et al.,* 2004), for sustaining good health whole meal products have been recommended to be used (Slavin, 2004). Hence, such breeding strategies should be adopted for the improvement of nutritional standard of wheat products that can deal with the choice of wheat varieties with mineral content. In addition to the nutritional upgrading, efforts for elevated elemental content should not negatively affect the yield. Such means of bio-fortification may be followed that may have significant developmental consequences for mounting the crop production in an environmentally supportive manner.

A number of researches have shown that nutrient rich seeds are related to higher seedling growth intensity that is consecutively related to increased crop production (Faridi *et al.,* 1982; Flynn *et al.,* 1987; Graham, 1991; Rengel and Graham, 1995). Also, minerals are crucial in facilitating the plants to cope up with the environmental strains (Foy, 1992; Lynch, 1995) and defend against the infections (Graham and Rovina, 1984; Sparrow and Graham, 1988; Graham and Webb, 1991; Thongbai *et al.,* 1993) that in turn may lead to lessen use of fungicides, water for irrigation and fertilizers.

Crop upgrading through breeding can be achieved successfully if sufficient genetic disparities exist in the gene pool. To facilitate the further breeding programs and for the assessment of genetic variability for element content, a crucial venture has been initiated (http://www.harvestplus.org)(reviewed by Bouis, 1996; Cakmak *et al.,* 1996; Anglani, 1998; Graham *et al.,* 1999, 2001; Gregorio, 2002; Welch and Graham, 2002, 2004; White and Broadley, 2005).

Numerous studies have focused on the importance of wild relatives, landraces and cultivated durum wheat, bread wheat and triticales as nutritional source and underlined the significance of vitamin A, zinc and iron (Bouis, 1996; Graham *et al.,* 1999; Cakmak *et al.,* 2000, 2004; Chhuneja *et al.,* 2006; Ozkan *et al.,* 2007). Following this information, over 3000 Gen Bank accessions, involving diploid, tetraploid and hexaploid wheats were tried at CIMMYT for zinc and iron quantities (Monasterio and Graham, 2000).

Lack of nutritional efficiency is widespread among human populations and increasing the nutrient content in wheat symbolizes a promising approach to make people healthy and nutritionally efficient. All around the world, nearly 3 billion people are sufferers of micronutrient malnutrition that is influencing a major sector of society including infants, children and women mainly in developing countries.

Among all the nutritional deficiencies, anaemia has placed itself as the most relevant problem in the world. Beside iron deficit, Zn deficiency syndrome has come forward as a major challenge towards the world's population. The quantity of Zinc in human is directed according to their dietary intake and is responsible for the normal reaction and utilization of over 300 enzymes. WHO in their studies have confirmed that due to frequent occurrence of zinc dearth, incident of stunted growth through out the world is common in nearly 30% of the children.

The Macroelements (K, P, Mg, Ca, Na, S) and Microelements (Cu, Zn, Fe and Mn) used in this study are important components of the enzymes and are critical for the physical and biochemical reactions in the cereals. Understanding the functional correlation among these elements is one of most useful informations contributing towards human nutrition. To attain novel information on the genetic variability related to element content in different wheat species, present study was done to accomplish the following objectives:

(1) To find out the correlations among different macroelements and microelements in wheat varieties belonging to India and Turkey

(2) To understand the level of crucial macroelements (K, P, Mg, Ca, Na, S) and microelements (Cu, Zn, Fe and Mn) in Indian and Turkish wheat varieties

4.2 Materials and Methods

The materials used and different methods adopted for the Elemental analysis are presented as follows:

4.2.1 Materials for Elemental Analysis

The Plant material, Chemicals, Labware and Equipments used for Elemental were as follows:

4.2.1.1 Plant material for Elemental analysis: The whole grain flour of wheat genotypes collected from India, Turkey and Kazakhstan except the US wheat variety (the Sample No. 97 - viz., Anza) as listed in Table 3.1 was used in the elemental analysis part of this investigation.

4.2.1.2 Chemicals, Reference material and Labware used for Elemental analysis: The basic Chemicals used in the analysis were Nitric acid and Hydrogen peroxide.

The 8346 durum wheat flour, 1567a wheat flour obtained from National Institute of Standards and Technology (Gaithersburg, MD, USA) was used as the certified reference material for calibrating ICP-AES values for estimation of element content.

The Labware used for Elemental analysis were Centrifuge tubes and Zipper-top poly bags.

4.2.1.3 Equipments used for Elemental analysis: In elemental analysis, Mixer grinder (Philips), Incubator, Closed microwave system (Model: MARS-CEM Xpress) (CEM Corp., USA, 3100 Smith Farm Road, Matthews, NC) (Figure 4.1), Inductively Coupled Plasma- Atomic Emission Spectrophotometer (ICP-AES) (Vista-Pro Axial; Varian Pty Ltd, Australia) and Laboratory Refrigerator (Bosch) were used.

4.2.2 Methodology for Elemental analysis

4.2.2.1 Sample Preparation for elemental analysis: The seed lots of 100 wheat varieties were washed separately using double distilled water and kept for drying in incubator at 60^{o}C for one day. Dried seed samples were ground separately using Philips mixer and collected the fine powder samples for elemental analysis.

4.2.2.2 Wet Digestion of wheat flour samples: Approximately 0.1 to 0.2 g of dried powder samples of whole wheat grains along with 5 ml of 65% nitric acid and 2 ml of 35% hydrogen peroxide were added to Teflon digestion vessel and kept for wet digestion in Closed microwave system (Figure 4.1) for about 30 minutes at 1800 watt and 200°C. The digested samples were filtered using filter paper and their volumes were adjusted to 20 ml using double distilled water.

Figure 4.1: Sample Digestion Vessels and MARS-CEM Xpress Closed Microwave Digestion System

4.2.2.3 Determination of elemental content: The technical replicates of element concentrations of diluted samples were measured by ICP-AES (Figure 4.2). The working conditions of ICP-AES machine with specifications have been mentioned (Skujins 1998) in Table 4.1. The estimated values were checked using the certified reference material (, 8346 durum wheat flour, 1567a wheat flour) obtained from National Institute of Standards and Technology (Gaithersburg, MD, USA). The concentrations were determined in parts per million (mg/kg) of dry matter.

Figure 4.2: Elemental Analysis of digested wheat flour samples in ICP-AES machine at Soil Laboratory, Selcuk University, Konya, Turkey

Table 4.1: Working conditions and Specifications of ICP-AES

RF power	**0.7–1.8 kW (1.2–1.3 kW for axial)**
Auxilary gas flow rate (Ar)	1.5
Plasma gas flow rate (Ar)	10.5–15 L/min (radial), 15 "(axial)"
Copy time	3 s (max. 100 s)
Copy and reading time	1–5 s (max. 60 s)
Viewing height	5–12 mm

4.2.2.4 Statistical Analysis of macro and micro element content determination: For the statistical analysis, Minitab 14 software was used to compare the concentrations of different elements and to determine the correlations among them using Pearson correlation. The significance of these correlations was determined by 'p' value. Based on the elemental concentrations of three replicates, standard deviation for all the elements was also calculated. Also, the average macro- and micro- element content in the flour samples of collected varieties were compared on the basis of ploidy and geographical region.

4.3 Results for the Elemental Analyses of Indian and Turkish Wheat

4.3.1 Elemental Content of Different Wheat Genotypes obtained from ICP-AES analysis

Elemental Content of Wheat Genotypes collected from India, Turkey and Kazakhstan except the US wheat variety (the Sample No. 97 - viz., Anza) is listed in Table 3.1 (Page No. 19). All the varieties showed variations in the content of different macro- and microelements viz., Calcium, Potassium, Magnesium, Sodium, Phosphorus, Sulphur, Copper, Manganese, Iron and Zinc (Table 4.2). In Table 4.3, various Indian and Turkish wheat genotypes have been shown those have provided maximum content of different elements. Higher macroelement and microelement contents were found in Indian Wheat varieties [GW03-9, K01006, KLP306 (6X); KBD921, KBD922, KBD9915 (4X)] and [Veeri, HD2236, K616, 30KR8 (6X)] respectively. Similarly, Higher macroelement and microelement contents were estimated in Turkish Wheat Varieties [Eser, Altay, Gerek79, Akbugday, Bayraktar (6X)] and [Konya, Bezostaja (6x); Kaplica (2X)] respectively. Indian hexaploid variety like 30KR8 and tetraploid variety like KBD922 was found to possess maximum content of two elements. Similarly, among Turkish varieties higher content of more than two elements was found in diploid variety, Kaplica and hexaploid varieties, Gerek 79 and Bezostaja.

Table 4.2: Elemental Content of 100 Wheat Genotypes obtained from ICP-AES analysis (given concentrations are in ppm)

S. No.	Genotype with Ploidy	Origin	Macroelements						Microelements			
			Ca	K	Mg	Na	P	S	Cu	Mn	Fe	Zn
1	30KR8_6X	INDIA	464.4	4045.6	2079.1	167.2	4481.4	1354.3	5.3	38.6	22.1	44.0
2	AAI2_6X	INDIA	244.4	3934.1	1541.5	171.9	3168.9	1102.0	8.1	34.7	36.6	30.5
3	AKAW4006_6X	INDIA	370.1	3871.0	1726.1	176.8	3381.4	1142.9	3.8	33.8	20.2	24.3
4	AKDW2997_4X	INDIA	188.4	3834.9	1393.7	122.3	2813.1	1133.4	5.2	23.3	22.1	23.8
5	DBW14_6X	INDIA	369.0	3778.8	1994.2	136.6	4100.5	1178.4	6.1	34.0	37.6	33.4
6	DBW39_6X	INDIA	486.6	3627.4	2021.3	182.1	3693.3	1164.6	6.1	33.4	41.5	33.3
7	DDK1025_6X	INDIA	350.7	3976.8	1729.0	148.8	3226.7	1642.5	6.0	33.4	38.0	27.9
8	DT132_4X	INDIA	216.7	3283.4	1475.0	135.8	2629.7	1277.2	6.3	35.6	23.6	27.0
9	GW03_12_6X	INDIA	211.5	3749.3	1510.3	102.2	2418.4	1297.4	5.1	25.0	22.1	18.5
10	GW03_2_6X	INDIA	239.4	3424.5	1459.0	124.0	2721.5	1208.9	6.1	26.4	27.9	25.7
11	GW03_3_6X	INDIA	308.5	3695.3	1673.0	149.4	2727.2	1400.3	5.5	30.8	27.4	24.2
12	GW03_4_6X	INDIA	200.8	4069.2	1539.9	142.5	2654.9	1200.2	7.2	32.3	24.7	22.9
13	GW03_9_6X	INDIA	637.1	3944.1	1895.1	172.0	3070.5	1365.3	6.3	22.5	36.3	24.5
14	HD_2177_6X	INDIA	390.2	3586.5	1963.8	143.5	4068.3	1083.2	6.1	41.8	29.6	32.8
15	HD2236_6X	INDIA	400.1	3748.2	1727.8	132.9	3493.8	1086.3	4.1	55.0	20.2	25.8
16	HD2270_6X	INDIA	259.9	3404.2	1389.3	128.8	2624.5	871.6	3.3	47.8	18.2	22.0
17	HD2307_6X	INDIA	232.2	3551.1	1650.3	120.3	3477.6	1222.6	5.5	42.7	26.2	28.3
18	HD2329_6X	INDIA	308.2	3663.0	1868.5	131.1	3773.6	1199.8	6.7	43.4	31.6	30.0
19	HD2380_6X	INDIA	343.8	3481.1	1680.9	128.8	3215.0	1027.5	3.3	38.9	28.6	22.0
20	HD2402_6X	INDIA	204.9	3664.1	1787.7	136.2	3595.4	1165.3	5.8	41.1	32.1	30.1
21	HD2501_6X	INDIA	115.7	3667.7	1420.1	100.2	2867.8	953.4	4.2	29.1	17.3	16.7
22	HD2643_6X	INDIA	390.7	3504.1	1639.5	151.1	3242.7	1033.3	5.0	33.0	34.8	24.6
23	HD2881_6X	INDIA	145.5	3789.3	1542.4	174.6	3188.6	1100.9	5.8	39.1	9.2	22.1
24	HUW12_6X	INDIA	169.2	3611.5	1441.2	112.2	2801.2	945.6	3.7	33.3	35.9	21.1
25	HUW251_6X	INDIA	208.9	4473.5	1668.2	128.6	4018.5	1196.2	6.4	35.3	31.8	32.8
26	HUW37_6X	INDIA	105.9	3747.9	1608.9	121.6	3236.3	971.1	5.4	27.0	45.3	22.9
27	HUW468_6X	INDIA	393.4	3379.8	1799.8	141.8	3611.5	1060.4	6.4	37.9	35.0	29.7
28	HUW533_6X	INDIA	231.7	3382.6	1454.9	85.3	3181.4	837.4	4.3	32.9	17.2	24.2
29	HUW55_6X	INDIA	137.8	4131.2	1429.5	136.1	3083.5	1110.0	7.7	44.3	39.7	18.9
30	K01006_6X	INDIA	353.0	4109.9	2133.4	145.5	4257.9	1064.7	6.0	41.0	25.6	35.4
31	K0204_6X	INDIA	560.1	3409.6	1852.1	133.5	3181.2	1450.3	6.0	35.0	41.8	19.9
32	K616_6X	INDIA	160.7	3812.2	1667.4	124.7	3818.6	1260.0	6.4	44.0	49.1	28.3
33	K8020_6X	INDIA	367.7	3595.3	1736.8	151.3	3703.5	1176.9	5.7	42.7	22.3	29.0
34	K86_6X	INDIA	161.3	4113.8	1931.7	138.8	3921.0	1212.5	5.3	41.0	28.1	29.0
35	K88_6X	INDIA	307.1	4113.8	1555.5	138.3	3440.6	1107.9	4.3	35.4	28.7	25.9
36	K911_6X	INDIA	140.0	4252.1	1965.0	156.5	4130.9	1297.0	7.8	39.7	30.3	31.7
37	KALYANSONA_6X	INDIA	250.9	3788.7	1604.6	120.6	3572.7	1067.4	3.3	38.3	18.8	23.9
38	KBD65_4X	INDIA	157.4	4067.3	1480.7	219.9	2906.9	798.4	5.7	20.5	25.4	17.8
39	KBD821_4X	INDIA	215.2	3531.7	1545.1	241.9	3027.2	1019.9	3.8	21.0	22.2	21.3
40	KBD921_4X	INDIA	196.2	4161.4	1661.5	336.7	3732.1	1167.0	9.3	22.1	36.3	32.0
41	KBD922_4X	INDIA	176.0	5192.8	1553.4	260.4	3498.4	1321.0	9.8	19.8	35.8	32.8
42	KBD925_4X	INDIA	357.7	4023.7	1812.3	194.3	3741.5	963.1	6.0	30.2	42.9	28.8
43	KBD9452_4X	INDIA	283.5	3898.0	1514.6	329.9	2951.6	926.2	4.9	19.1	27.7	20.8
44	KBD9915_4X	INDIA	508.4	4289.7	1994.1	271.5	4496.0	1207.4	6.1	30.1	38.6	38.1
45	KBD9851_4X	INDIA	130.7	4006.7	1518.2	149.5	3206.5	934.4	6.0	27.9	21.2	23.1

S. No.	Genotype with Ploidy	Origin	Macroelements						Microelements			
			Ca	K	Mg	Na	P	S	Cu	Mn	Fe	Zn
46	KLP306_6X	INDIA	280.6	3414.4	1663.0	141.5	2870.8	1673.1	7.0	38.2	33.1	23.0
47	KLP307_6X	INDIA	562.3	3673.7	2042.6	154.6	3368.0	1451.4	7.0	32.9	30.3	26.2
48	KLPD1106_4X	INDIA	158.7	4313.0	1696.6	216.9	3474.2	1075.3	7.9	32.5	22.8	27.2
49	NAW1448_6X	INDIA	527.5	3410.8	2001.0	154.0	3420.6	1395.8	7.2	38.8	40.8	32.2
50	NIDW295_4X	INDIA	174.8	4233.0	1595.4	155.2	3317.8	1088.5	5.2	35.2	25.2	22.4
51	NW1076_6X	INDIA	491.9	3960.3	1751.8	173.4	3795.7	1094.2	4.0	42.4	30.4	33.5
52	NW2036_6X	INDIA	197.0	3359.5	1520.3	127.1	3225.5	1061.4	3.9	39.0	25.1	23.4
53	PBW550_6X	INDIA	341.7	3780.9	1562.6	157.7	2734.8	1293.8	7.4	30.9	33.5	43.3
54	RAJ1482_6X	INDIA	531.1	3854.3	1876.9	186.6	3979.6	1115.6	4.3	51.7	29.3	31.1
55	RAJ1555_4X	INDIA	172.5	4265.0	1577.6	165.4	3755.5	998.2	6.5	19.3	18.0	28.0
56	RAJ3072_6X	INDIA	455.9	4005.0	1857.8	169.2	3762.8	1025.9	5.4	41.8	24.7	30.6
57	RAJ3077_6X	INDIA	149.0	3678.3	1523.3	109.0	3247.4	976.3	4.3	35.5	20.2	21.2
58	RAJ3777_6X	INDIA	352.1	3597.3	1635.8	162.6	3256.5	1075.3	5.3	40.4	29.3	23.3
59	RAJ4027_6X	INDIA	208.3	4909.4	1762.4	167.3	4015.6	1382.0	9.7	30.3	33.4	32.7
60	RAJ4037_6X	INDIA	256.9	3635.6	1706.3	150.3	3301.4	1115.1	6.1	39.5	28.7	29.3
61	RAJ4120_6X	INDIA	150.5	4306.1	1716.0	174.4	3651.8	1134.9	4.0	38.4	30.8	26.6
62	RAJ6560_4X	INDIA	283.8	4038.0	1432.8	145.2	3254.4	939.0	5.0	27.8	17.0	26.0
63	RD1008_4X	INDIA	228.5	3995.6	1656.8	143.2	3810.7	1520.9	8.0	41.3	26.9	32.5
64	RD1063_4X	INDIA	405.8	3943.6	1758.5	148.3	4006.7	1474.7	7.2	30.6	39.7	38.7
65	RD1093_4X	INDIA	187.8	4229.7	1462.8	148.5	3087.3	1054.1	6.4	26.9	21.8	27.5
66	RD1097_4X	INDIA	115.8	4114.8	1413.0	131.5	3289.0	1114.4	6.0	25.3	21.7	28.5
67	SAW327_6X	INDIA	448.4	3993.4	1739.4	129.8	3826.6	1091.8	5.1	38.4	32.0	31.8
68	SAW337_6X	INDIA	350.7	3717.6	1899.5	157.3	3898.6	1229.7	5.4	34.4	20.9	32.9
69	SAW94_6X	INDIA	514.0	4416.2	1939.4	138.4	4348.7	1180.5	5.4	39.9	26.4	36.4
70	SONALIKA_6X	INDIA	316.1	3913.1	1556.7	141.7	3132.4	888.3	4.4	31.8	18.2	23.3
71	TL2908_TCL	INDIA	630.6	4749.8	2003.5	219.1	3633.6	1261.9	7.6	23.9	38.9	35.3
72	TL2935_TCL	INDIA	181.3	4140.6	1658.0	107.1	2948.0	1293.1	6.3	27.7	23.4	25.5
73	TL2951_TCL	INDIA	167.3	3877.0	1476.5	131.8	2914.8	1180.5	5.9	31.3	29.8	24.8
74	UP2338_6X	INDIA	212.0	3962.9	1767.2	129.2	3931.0	1218.7	4.8	47.7	29.0	32.0
75	UP2511_6X	INDIA	489.1	4926.1	2060.5	179.1	3989.8	1437.6	8.7	30.5	37.6	42.9
76	UP2525_6X	INDIA	170.1	3999.8	1743.4	126.7	4039.3	1189.3	4.6	33.9	21.9	26.7
77	UP2696_6X	INDIA	510.9	3300.7	1816.3	150.2	3243.0	1441.7	7.3	25.5	46.9	40.9
78	VEERI_6X	INDIA	319.4	4531.2	1710.3	235.4	4010.9	1108.2	10.7	35.9	34.2	35.6
79	VL832_6X	INDIA	182.0	4112.6	1534.4	156.0	3692.2	1240.7	4.9	28.4	26.1	22.1
80	WR1381_6X	INDIA	427.3	2986.2	1836.3	137.6	2912.7	1482.3	4.9	31.4	33.8	19.1
81	WR1408_6X	INDIA	517.6	4017.3	1790.2	117.4	2982.0	1413.0	6.7	34.0	38.2	22.6
82	WR1421_6X	INDIA	228.4	3336.7	1712.8	135.3	2696.7	1572.2	6.6	26.6	28.1	23.7
83	BAYRAKTAR_6X	TURKEY	201.2	3117.3	1560.8	483.1	2892.7	1052.2	6.2	29.8	30.5	17.2
84	SEVAL_6X	TURKEY	313.7	3235.3	1466.6	109.5	2034.8	1259.7	7.2	35.0	32.5	20.2
85	KENANBEY_6X	TURKEY	366.6	3176.9	1661.2	142.2	2194.9	1041.4	6.2	27.2	21.0	18.3
86	BEZOSTAJA_6X	TURKEY	274.5	3196.2	1427.7	104.8	2297.7	1338.0	7.2	58.3	40.3	32.1
87	GUN91_6X	TURKEY	298.6	3092.8	1451.3	113.0	2289.5	1050.7	6.8	48.0	37.1	27.5
88	KONYA_6X	TURKEY	321.6	3030.6	1534.5	97.6	2193.2	1164.3	5.2	23.0	43.5	16.0
89	AKBUGDAY_6X	TURKEY	229.0	3412.0	1422.9	103.5	2390.7	1450.1	6.9	33.3	28.4	21.5
90	GEREK79_6X	TURKEY	356.5	4597.5	1733.5	136.4	3263.8	1343.4	7.4	38.4	23.9	26.4
91	KIRAC66_6X	TURKEY	253.3	3396.5	1542.8	97.6	2895.6	1098.6	6.0	36.0	15.7	14.0
92	ESER_6X	TURKEY	424.4	2841.4	1700.7	101.8	2147.9	1157.4	5.8	29.7	30.2	16.1
93	SONMEZ_6X	TURKEY	107.0	3013.6	1266.8	109.2	1926.7	1103.8	7.3	34.0	22.5	27.4
94	HARMANKAYA_6X	TURKEY	226.5	3038.9	1570.4	121.0	1912.4	1318.8	7.7	21.8	28.0	14.1
95	KAPLICA_2X	TURKEY	182.3	3554.1	1462.6	109.9	2872.6	1443.2	8.8	40.3	34.7	30.7
96	ALMALY_6X	KAZAKHSTAN	418.1	4065.9	1612.9	124.5	3497.0	1524.0	7.4	31.0	35.6	42.5
98	KINACI_6X	TURKEY	199.3	3610.5	1337.9	114.6	2595.3	929.1	4.6	40.9	37.7	30.6
99	YUREGIR_6X	TURKEY	141.1	3761.8	1537.0	309.9	3235.3	1047.4	4.8	23.6	32.5	18.3
100	ALTAY_6X	TURKEY	222.9	3995.6	1768.9	139.5	3145.2	1390.5	6.2	29.7	29.6	26.2
101	LUTFIBEY_6X	TURKEY	104.3	2852.4	1431.4	81.3	1775.0	975.6	4.5	23.6	21.9	12.6

Table 4.3: Various Indian and Turkish wheat genotypes showing the maximum content of different elements (given concentrations are in ppm)

[a] Macroelement content

Wheat	Calcium	Magnesium	Potassium	Phosphorus	Sulphur	Sodium
INDIAN	GW03_9 _6X (637)	K01006 _6X (2133)	KBD922 _4X (5193)	KBD9915 _4X (4496)	KLP306 _6X (1673)	KBD921 _4X (337)
	TL2908 _TCL (631)	30KR8 _6X (2079)	UP2511 _6X (4926)	30KR8 _6X (4481)	DDK1025 _6X (1642)	KBD9452 _4X (330)
TURKISH	ESER _6X (424)	ALTAY _6X (1769)	GEREK79 _6X (4598)	GEREK79 _6X (3264)	AKBUGDAY _6X (1450)	BAYRAKTAR _6X (483)
	KENANBE Y_6X (367)	GEREK79 _6X (1734)	ALTAY _6X (3996)	YUREGIR _6X (3235)	KAPLICA _2X (1443)	YUREGIR _6X (310)

[b] Microelement content

Wheat	Copper	Manganese	Iron	Zinc
INDIAN	VEERI_6X (11)	HD2236_6X (55)	K616_6X (49)	30KR8_6X (44)
	KBD922_4X (10)	RAJ1482_6X (52)	UP2696_6X (47)	PBW550_6X (43)
TURKISH	KAPLICA_2X (9)	BEZOSTAJA_6X (58)	KONYA_6X (43)	BEZOSTAJA_6X (32)
	HARMANKAYA_6X (8)	GUN91_6X (48)	BEZOSTAJA_6X (40)	KAPLICA_2X (31)

4.3.2 Correlation analysis of different macro and micro elements

According to the matrixplots drawn (Figure 4.3), clear relationships have been found between the concentrations of the several investigated elements in wheat grain. The extent of association and its significance can be understood with the Pearson's correlation coefficient and paradox 'p' value respectively (Figure 4.4). As higher the value of Pearson's correlation coefficient (r), the stronger is the association among the two elements. But the importance of that association is defined by observing the 'p' value. Lower is the 'p' value between the two nutrients, more is the importance of that correlation. The association can also be experienced by observing the concentration of different dots along the diagonal axis in the scatter plot. If the dots are concentrated along the axis, the correlation is positive, if dots are concentrated against the axis, the correlation is negative between the two nutrients. Magnesium was found in strong positive significant correlation with Calcium (r= 0.671), Phosphorus (r=0.685) and Zinc (0.519) while Phosphorus was established to be strongly associated with Potassium (r=0.644) and Zinc (0.656). Sodium and Manganese were observed to be negatively linked with negative value of 'r' (-0.297). Actually, Zinc was found moderately synergetic with all the elements except sodium. Calcium was related to phosphorus, sulphur, iron and zinc while copper was found in good coordination with potassium, sulphur, iron and zinc.

Association of potassium with sodium, magnesium and zinc was obtained. Similarly, mutually correlated profile of Magnesium with sulphur and iron, manganese with phosphorus and zinc, sodium and phosphorus and sulphur with iron and zinc was obtained.

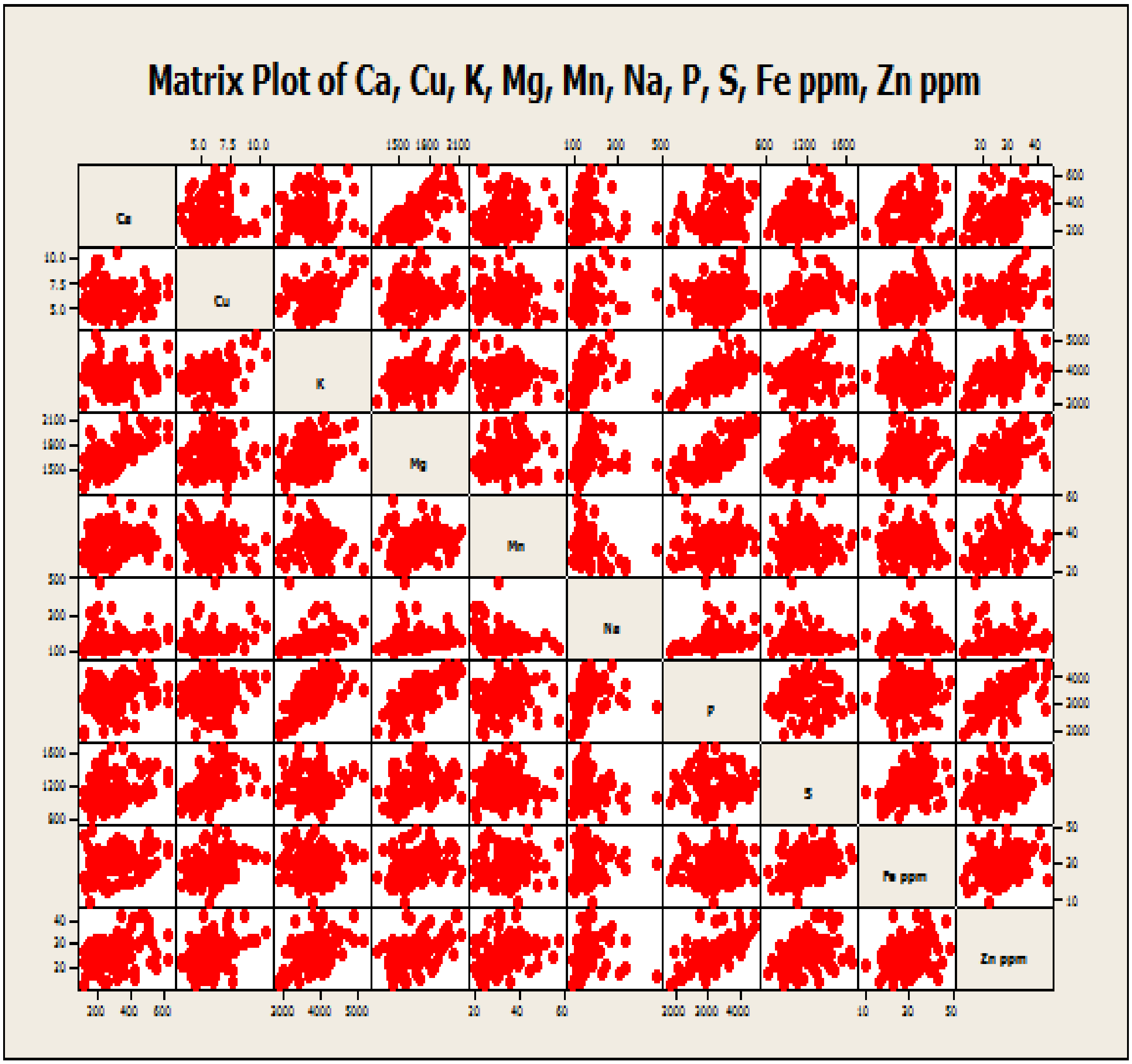

Figure 4.3: Matrix plot showing correlation among different macro and microelements (given concentrations are in ppm)

Correlations: Ca, Cu, K, Mg, Mn, Na, P, S, Fe, Zn

	Calcium	Copper	Potassium	Magnesium	Manganese	Sodium	Phosphorus	Sulphur	Iron
Copper	0.039								
	0.697								
Potassium	0.017	0.322							
	0.866	0.001							
Magnesium	**0.671**	0.139	0.293						
	0.000	0.169	0.003						
Manganese	0.132	-0.139	-0.113	0.173					
	0.189	0.169	0.263	0.086					
Sodium	0.057	0.192	0.274	0.152	-0.297				
	0.576	0.056	0.006	0.130	0.003				
Phosphorus	0.277	0.056	**0.644**	**0.685**	0.240	0.257			
	0.005	0.580	**0.000**	**0.000**	0.016	0.010			
Sulphur	0.315	0.485	0.065	0.355	0.022	-0.119	0.053		
	0.001	0.000	0.520	0.000	0.832	0.240	0.604		
Iron	0.344	0.388	0.023	0.292	0.027	0.119	0.103	0.373	
	0.000	0.000	0.822	0.003	0.789	0.239	0.309	0.000	
Zinc	0.389	0.384	0.480	**0.519**	0.243	0.097	**0.656**	0.310	0.323
	0.000	0.000	0.000	**0.000**	0.015	0.337	**0.000**	0.002	0.001

Cell Contents: Pearson correlation
P-Value

Figure 4.4: The Pearson's correlation coefficient (*r*) for different elements correlations in wheat grains

4.3.3 Comparative analysis of different macro and micro elements among all the Indian and Turkish genotypes

In the comparison of average macro- and micro- element content of all the Indian and Turkish wheat varieties (including diploid, triticale, tetraploid and hexaploid) (Figure 4.5 and Figure 4.6 respectively), Indian varieties were found to be highly rich in Calcium, Magnesium, Potassium, Phosphorus, Manganese and Zinc concentrations. However, Turkish varieties had shown elevated average iron content; the difference was not too much significant for Copper and Sodium.

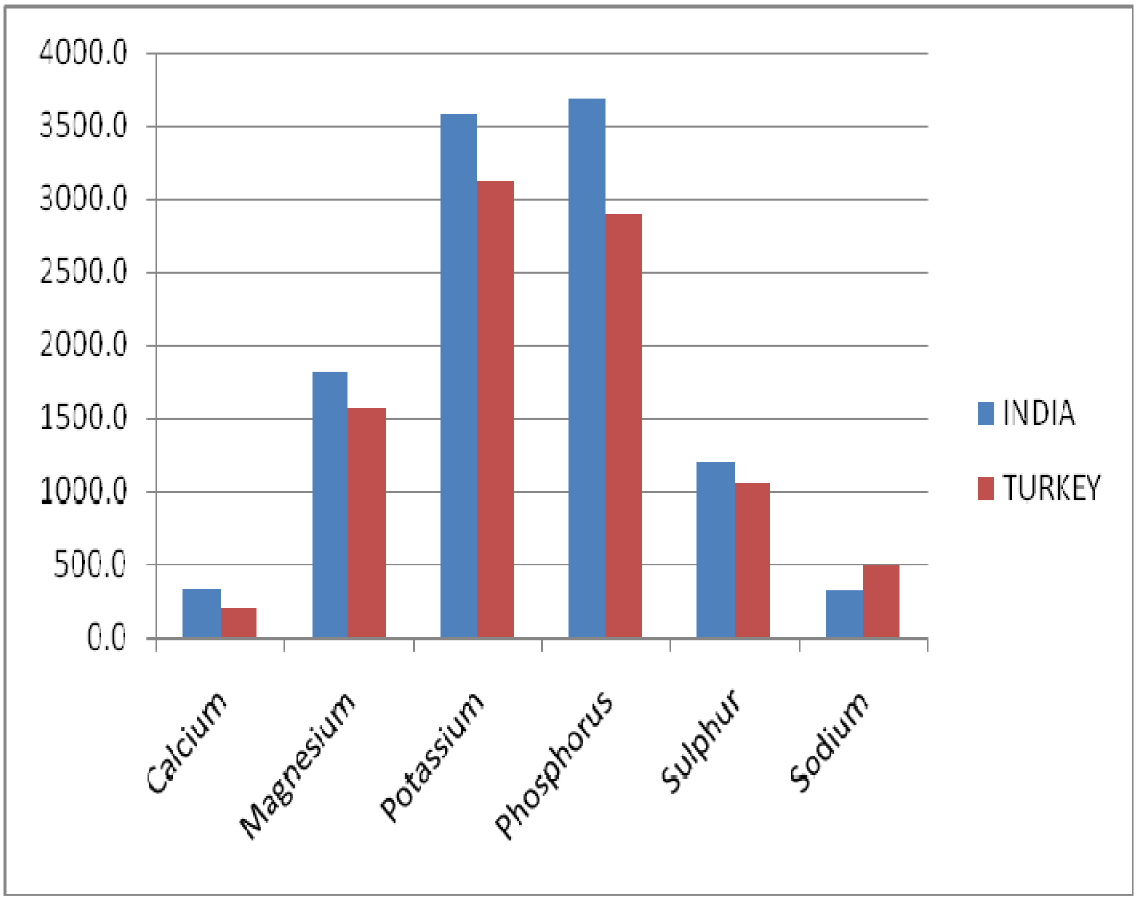

Figure 4.5: Comparison of average macroelement content of all the Indian and Turkish wheat genotypes (given concentrations are in ppm)

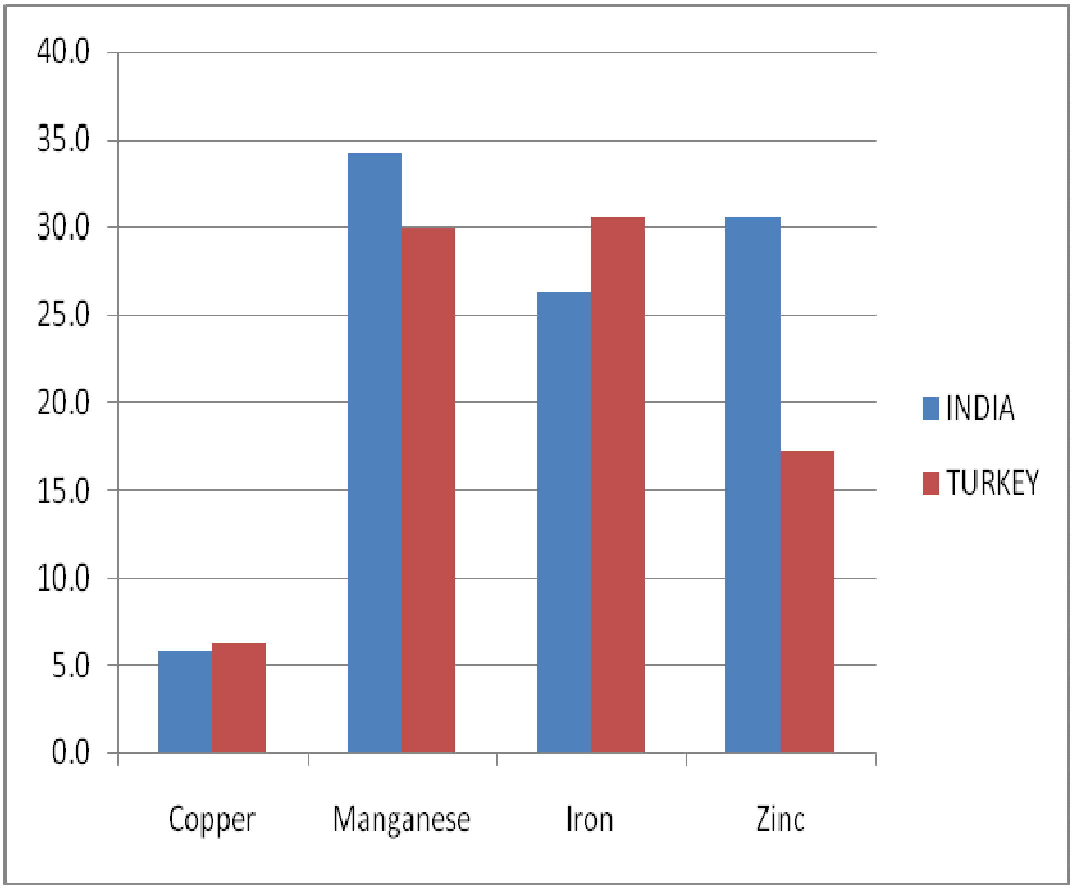

Figure 4.6: Comparison of average microelement content of all the Indian and Turkish wheat genotypes (given concentrations are in ppm)

4.3.4 Comparative element analysis among wheat genotypes on the basis of ploidy

As different genotypes including diploid, tetraploid, triticale and hexaploid wheat varieties have been used in the study, it was necessary to estimate the element content among different genotypes at ploidy level (Figure 4.7 and Figure 4.8). In case of macroelements, triticale varieties were found maximum rich in average Calcium, Potassium, Magnesium and Sulphur content while durum wheat was found to be loaded with Phosphorus. The Diploid variety was found to have highest average content of Copper, Manganese, Iron and Zinc.

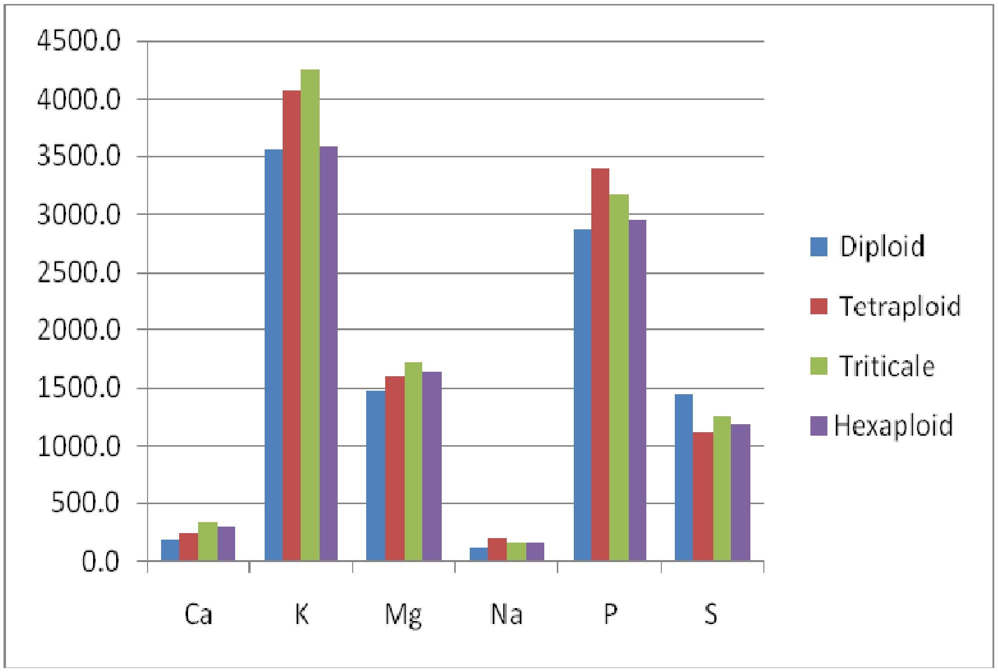

Figure 4.7: Comparison of average macroelement content of wheat genotypes on the basis of ploidy (given concentrations are in ppm)

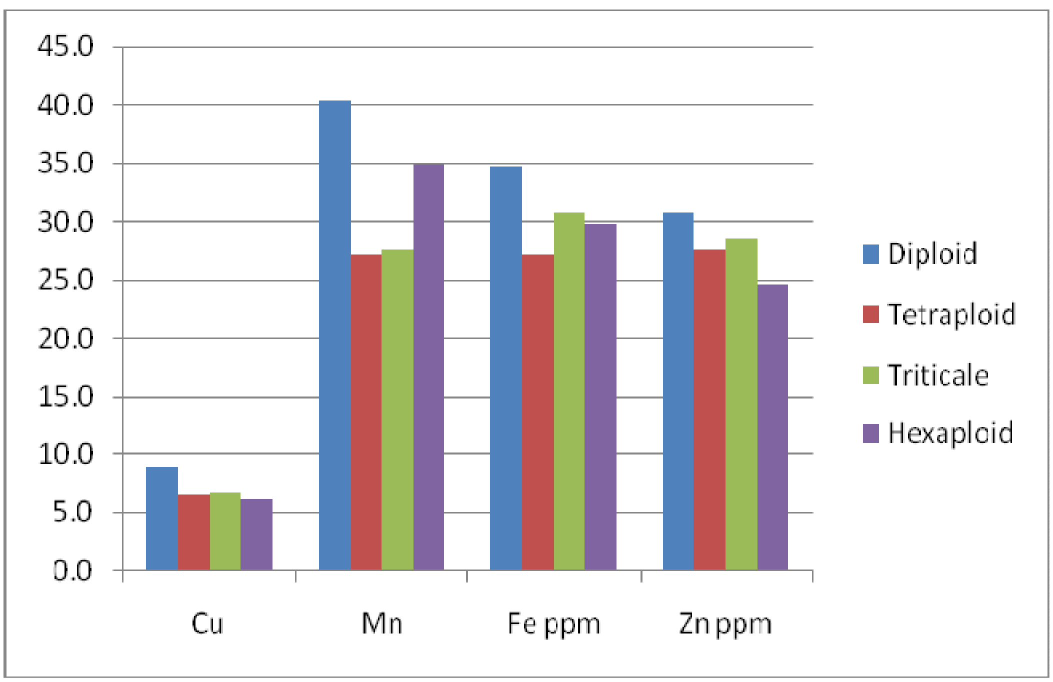

Figure 4.8: Comparison of average microelement content of wheat genotypes on the basis of ploidy (given concentrations are in ppm)

4.3.5 Comparison of Indian and Turkish Bread wheat genotypes for the element content

In this section, a comparative outcome of elemental analysis among Indian and Turkish Hexaploid Wheat varieties has been obtained (Figure 4.9 and Figure 4.10). Indian bread wheat varieties were found to be richer than Turkish ones in average Potassium, Magnesium, Phosphorus, Manganese and Zinc content. While Turkish hexaploid genotypes were found slightly more in Copper content than Indian varieties.

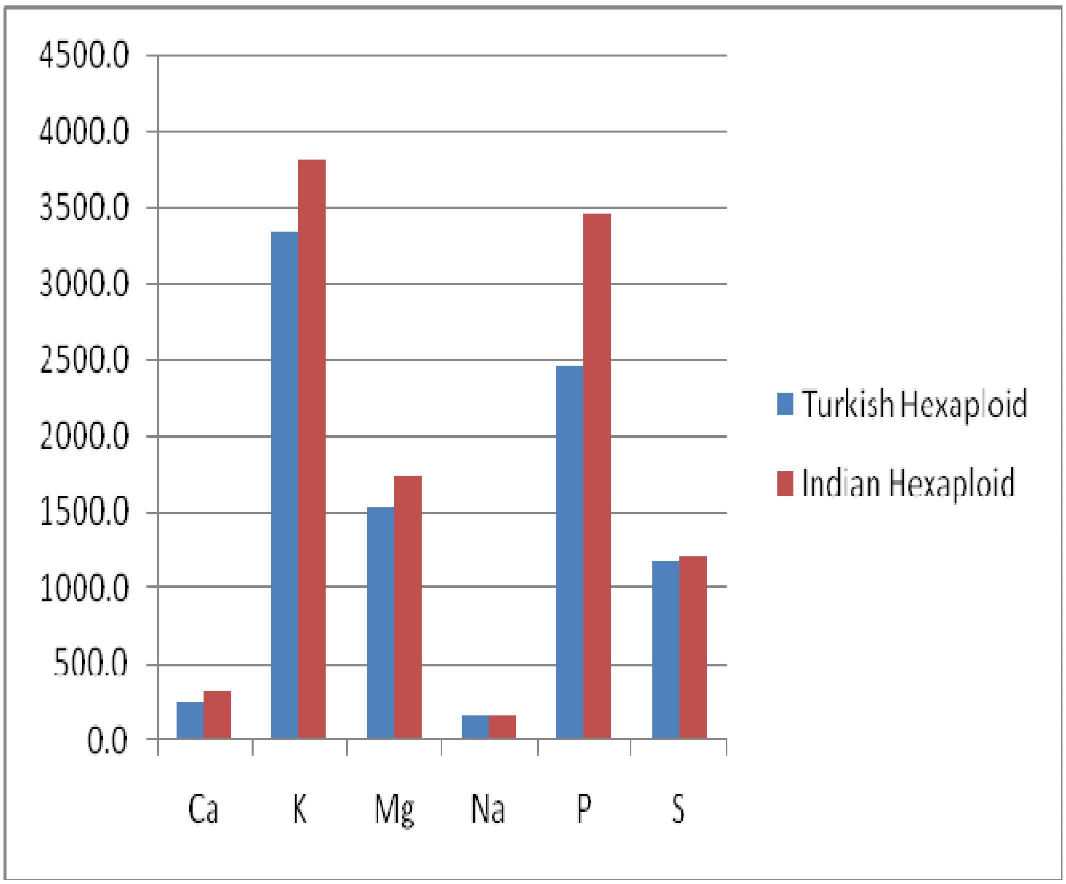

Figure 4.9: Comparison of average macroelement content of Indian and Turkish hexaploid wheat genotypes (given concentrations are in ppm)

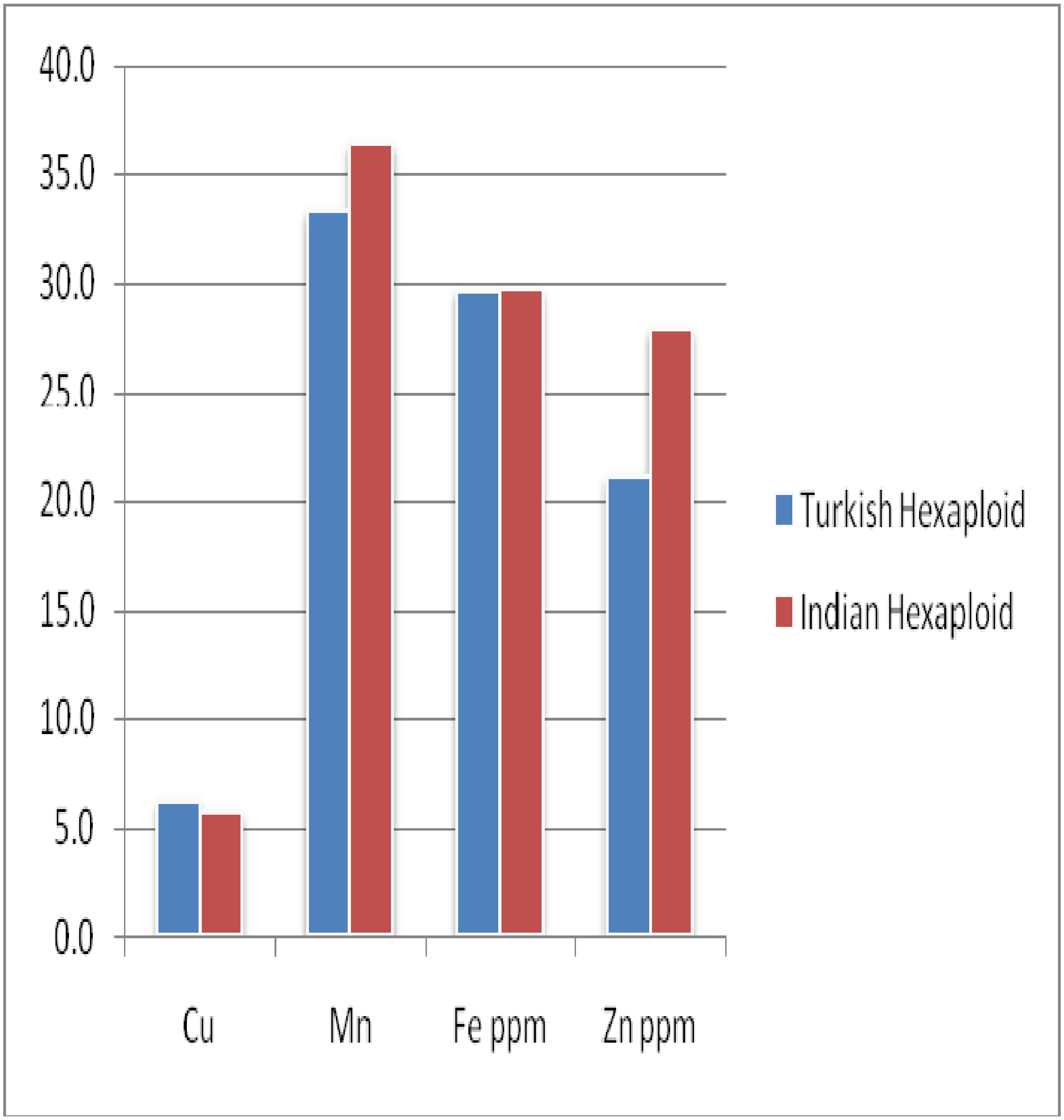

Figure 4.10: Comparison of average microelement content of Indian and Turkish hexaploid wheat genotypes (given concentrations are in ppm)

4.4 Discussion

Variability in the grain element content of wild relatives of wheat (Graham *et al.,* 1999; Cakmak *et al.,* 2000; Balint *et al.,* 2001), durum wheat (Clarke *et al.,* 2002), triticale (Feil and Fossati, 1995) and bread wheat (Zook *et al.,* 1970; Toepfer *et al.,* 1972; Nahapetian and Bassiri, 1976; Dikeman *et al.,* 1982; Davis *et al.,* 1984; McGrath, 1985; Peterson *et al.,* 1983, 1986; Monasterio and Graham, 2000) has previously been portrayed by several workers.

Concentration of minerals in wheat seeds depends upon the variety, type of the soil, cultivation strategy and climatic conditions that elucidate the major differences in the results observed by several authors (Anglani, 1998). Despite of these influencing factors, in order to look for the innovative genetic sources of crucial elements in wheat, constant research efforts are indispensable. Such innovative sources can be utilized either in a straightforward way as cultivated forms or obliquely as breeding samples for availing the nutritionally enriched wheat varieties.

The results of present study illustrated that the element concentrations in wheat samples from different regions of India and Turkey had their specific distinctiveness. These distinct features could be associated with the soil structure. Despite of the influences of the harvest duration, varietal features and followed agricultural methods on the element content of wheat, it is beneficial to sort wheat varieties as per their geographical origin using multielement studies with statistical analyses. The simplicity and competence of multielement analysis make it a finest alternative for origin based classification of wheat varieties. The quantity of the entire elements in seed grain demonstrated a huge disparity amongst genotypes, with the maximum content for all elements nearly twofold in comparison to the lowest. Such disparities in the elemental content for wheat samples were probably owed to their genetic origin. A strong discrimination between samples of wheat grain of different origin have been identified by several authors using a principal component analysis (PCA) (Škrbić and Onjia, 2007).

In the present study, at ploidy level, Calcium, Potassium and Magnesium content of triticale were found at high levels in comparison to diploid, tetraploid and hexaploid wheat varieties. In case of, phosphorus and and sodium, tetraploids were found to be richer in sodium and phosphorus content (Figure 4.7).

The seeds of diploid variety Kaplica, had demonstrated the higher content of Sulphur and all the microelements including Copper, Manganese, Iron and Zinc (Table 4.2). These results were in accordance with the results showed by Hussain *et al.* (2010). They determined the element content of organically developed wheat genotypes and depicted the higher concentration of copper, zinc and sulphur in prehistoric wheat in comparison with the other genotypes. They studied on the mineral composition of organically grown wheat genotypes and reported that primitive wheat showed significantly the highest concentrations of Copper, Zinc and Sulphur compared to all other genotype groups. However, Manganese content in their study was found to be lower in the primitive wheat.

In our experiment, calcium content of wheat grains changed between 104.3 to 637.1 mg/kg, potassium between 2841.4 and 5192.8 mg/kg, magnesium between 1266.8 and 2133.4 mg/kg, sodium concentrations between 81.3 and 483.1 mg/kg, Phosphorus between 1775 and 4496 mg/kg and Sulphur between 798.4 and 1673.1 mg/kg. Among micronutrients, Copper was found between 3.3 and 10.7 mg/kg. While Mn contents ranged between 19.1 and 58.3 mg/kg, Iron between 9.2 and 49.1 mg/kg, Zinc content varied among 12.6 and 44.4 mg/kg. Similar elemental range was found by Harmankaya *et al.* (2012) with K, Ca, Mg, S, P and Na contents of wheat genotypes between 3,029 and 5,566 mg/kg, 266 and 531 mg/kg, 972 and 1,525 mg/kg, 1,241 and 2,052, 2,422 and 4,610 mg/kg and 277 and 368 mg/kg mg/kg, respectively. The variation in concentration was also similar with manganese, iron and zinc ranging from 27.6 to 64.8, 24.2 to 43.1 and 10.4 to 38.2 mg/kg, respectively (Table 4.2).

In our study, average potassium concentration of tetraploid varieties (4079 mg/kg) was found to be higher than hexaploid varieties (3576.8 mg/kg). These results were in accordance of Piergiovanni *et al.* (1997) and Grela (1996) work who noted significantly higher potassium concentrations in the grain of emmer compared to common wheat. The average phosphorus concentration of hexaploid varieties in our study were found to be lower than tetraploid content, similar to the study done by Suchowilska *et al.* (2012) while the average magnesium content was contradictory to their results. The seeds of some of the Turkish wheat varieties used in our study viz., Bayraktar, Seval, Bezostaja, Gun 91, Konya, Kirac, Eser, Harmankaya, Kinaci, Yuregir, Altay for elemental determination were used by Harmankaya *et al.* (2012) and had given the similar results.

In the Principal Component Analysis, in majority of cases, a clear relationships among the concentrations of pairs of the explored elements in wheat grain, has been obtained (Figure 4.3 and Figure 4.4). Associations among different elements have been explained in section 4.3.2. By using this correlation data, several genotypes can be selected that are abundant in one of these elements and allow obtaining forms where the remaining elements are also present in high quantities. As Zinc and iron were positively correlated in the study, similar correlation was found by several authors in their elemental studies (Peterson *et al.,* 1986; Morgounov *et al.,* 2007). The obtained results imply the subsistence of an alliance of a common environment and suggested that the genes scheming the concentration of zinc and iron content in the wheat grains are probably co-segregating. Suchowilska *et al.* (2012), in their study suggested that the presence of positive correlations between the concentrations of zinc and iron in different species could have important implications for the breeding of new varieties containing high levels of both elements. In the present work, the seeds of Indian wheat variety UP2696 and the Turkish variety Bezostaja were found to be rich in both Iron and Zinc content.