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ORIGINAL ARTICLE / ORIGINALBEITRAG

Change in Chemical Composition and Morphological Traits of Chickpea (*Cicer arietinum* L.) Genotypes Grown Under Natural Conditions

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Abstract
Chickpea is an important edible pulse able to be grown under rain-fed conditions. Chickpea kernels are quite rich in protein, carbohydrates, amino acids, vitamins and minerals, thus play a great role in daily diets. Present experiments were conducted for two years in 2018 and 2019 growing seasons with 27 kabuli chickpea genotypes registered between the years 1991–2013 under rain-fed and natural conditions. Chemical and organic fertilizers were not used in both years of the experiments. Experiments were conducted in randomized blocks design with 3 replications. For morphological traits, plant height, the first pod height, number of pods per plant, number of kernels per pod, number of kernels per plant, kernel yield and kernel protein contents were determined. For chemical composition of kernels, heavy metals (Cr, Ni), macro (Ca, K, Mg, Na, P, S) and micro elements (Cu, Zn, Mn, Fe) were determined. Significant increases and decreases were encountered in investigated traits based on registration years. Principal component analysis (PCA) for morphological traits and chemical composition of 27 different genotypes revealed that there were significant positive correlations between phosphorus and zinc contents and Akcin 91 cultivars was prominent for these two elements; there were positive correlations also between copper and iron and Cakır and Ilgaz cultivars were prominent for these elements. In terms of kernel yield, the cultivars (Aziziye 94 and Damla 89) registered in 1994 were found to be prominent. Kernel yields had positive correlations with Na content, but negative correlations with Ca, Fe, Cu and Mn contents.

Keywords Chickpea · Heavy metal · Macro and micro element · Morphological traits · PCA

Introduction

In terms of production quantity, chickpea (*Cicer arietinum* L.) has the third place among the edible legumes after dry bean and peas in the world but has the first place in Turkey (FAO 2021). According to World Health Organization (WHO) records, it is possible to mention about a quality and balanced nutrition when the daily protein intake of an individual was composed of 60% plant and 40% animal-originated proteins (Ciftci et al. 2020). Edible legumes rich in protein, carbohydrate, soluble solids, vitamins and minerals play a great role in human nutrition (Kaya et al. 2018). Chickpea is among the oldest and mostly consumed edible legumes worldwide and it is grown in about 45 different countries including tropical and subtropical regions (Ozer et al. 2010). There are two types of chickpea cultivated worldwide: Desi, so called as microsperma, with pink flowers and Kabuli, so called as macrosperma, with white flowers. Desi types are generally cultivated in Asia and Africa; Kabuli types are commonly cultivated in North America and Europe (Gaur et al. 2016). Chickpea is also used in animal feeding in some developed countries. Chickpea is able to fixate atmospheric nitrogen into the soils and improve soil fertility of dry lands with root residues left in the soil (Krouma 2009). However, chemical composition and morphological characteristics of each chickpea largely rely on genotype, seed characteristics, agronomic practices, climate and soil parameters (Kaur et al. 2005). Fertilizers play a significant role in increasing yields, but extreme use of chemical fertilizers may result in notable environmental problems (Wang et al. 2021).

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A comprehensive literature review revealed that there were not any studies conducted on chickpea cultivation without any fertilizer inputs. Therefore, in this study, 27 different kabuli chickpea cultivars registered in Turkey between the years 1991–2013 were grown under natural conditions (without any organic or chemical fertilizer inputs). Year-based performance and chemical composition of chickpea cultivars were investigated under natural conditions.

Materials and Methods

Experiments were conducted over the experimental fields of Erciyes University for two years (2018 and 2019) in Kayseri province of Turkey. The research site with an altitude of 1094 m is located between 34° 56′–36° 59′ east longitudes and 37° 45′–38° 18′ north latitudes. Experiments were conducted in randomized blocks design with 3 replications. Each plot had 6 rows, rows of 3 m long, row spacing was 30 cm and on-row plant spacing was arranged as 5 cm. Precipitations especially in June, July and August of the second year prolonged the vegetation duration of chickpea (Table 1). Agronomic practices were not conducted on experimental fields during the last 3 years. Chemical and organic fertilizers were not used in both years of the experiments. However, fungicide treatments were practiced twice in both years since cultivar tolerance to pests and diseases were different. In this study was used 27 kabuli chickpeas cultivars (Akcin 91 cultivar registered in 1991, Izmir 92 and Menemen 92 cultivars registered in 1992, Aziziye 94 and Damla 89 cultivars registered in 1994, Gokce cultivar registered in 1997, Cevdetbey 98 and Sarı 98 cultivars registered in 1998, Er 99, Kusmen 99 and Uzunlu 99 cultivars registered in 1999, Cagatay and Gulumser cultivars registered in 2001, Inci cultivar registered in 2003, Isık 05 and Yasa 05 cultivars registered in 2005, Dikbas cultivar registered in 2006, Aksu and Azkan cultivars registered in 2009, Hasanbey and Seckin cultivars registered in 2011, Cakır, Ilgaz, Sezenbey and Zuhal cultivars registered in 2012, Akca cultivars registered in 2013 and Osmanbey is not a standard cultivar, it is a genotype). In present experiments, registered in Turkey between the years 1991–2013 were used as the plant material.

Soil samples were taken from 0–30 cm soil depth at different points as to represent the research site. Air dried samples were passed through 2 mm sieves and subjected to soil analyses (Table 2).

Morphological traits of plant height, the first pod height, number of pods per plant, number of kernels per plant and number of kernels per pod were calculated from randomly selected 10 plants after omitting side effects. Kernel yield was calculated after harvesting the entire plot, except for side effects and fixing kernel moisture at 14%. Kernel total protein content was determined with the use of Kjeldahl method. Heavy metal (Cr, Ni), macro (Ca, K, Mg, Na, P, S) and micro (Cu, Zn, Mn, Fe) element contents were determined with the use of Agilent 5800 VDV model ICP-OES device. Seed mineral composition was also analyzed. Approximately 0.5 g of seed was taken and 10 ml of nitric+ perchloric acid mixture was added to the sample to determine some minerals in the seed. Then the samples were subjected to wet ashing until 1 ml of sample remained. Following the ashing procedure, samples were diluted with distilled water and analyzed in ICP-OES device (Mertens 2005).

Experimental data on technological traits of chickpea cultivars were subjected to analysis of variance with the use of JMP 13.2.0 (SAS Institute Inc., Cary, NC, USA)

Table 1 Climate parameters of the experimental years and long-term averages

Months	Monthly average temperature (°C)			Monthly relative humidity (%)			Monthly total precipitation (mm)		
	2018	2019	1931–2019	2018	2019	1931–2019	2018	2019	1931–2019
May	*16.7*	17.4	*15.0*	*61.2*	50.2	*61.0*	*51.9*	*23.7*	*51.5*
June	*20.4*	21.3	*19.0*	*56.7*	55.8	*55.8*	*78.8*	*55.2*	*40.2*
July	*24.1*	21.6	*22.2*	*45*	49.1	*49.3*	*0.6*	*35.9*	*10.6*
August	*22.9*	22.3	*22.0*	*42.3*	50.3	*49.1*	–	*12.1*	*8.7*
September	*19.2*	17.4	*17.4*	*45.5*	51.2	*53.7*	*2.9*	*10.6*	*14.5*

Source: Kayseri Provincial Directorate of Meteorology

Table 2 Soil physical and chemical properties

Years	pH	Organic matter %	Lime %	Texture	P_2O_5 kg/da	EC mmhos/cm
2018	8	0.66	2.38	Sandy-Loam	6.785	0.112
2019	8	0.67	2.38	Sandy-Loam	6.806	0.117

statistical software. Significant means were compared with the use of Tukey's test ($p \leq 0.05$) (Chen et al. 2020).

Results and Discussion

Heavy Metal

In the first year, chromium contents varied between 0.36 (Uzunlu 99)–0.83 (Isık 05) ppm. In the second year, the highest chromium content (2.44 ppm) was obtained from Inci cultivar followed respectively by Er (1.39 ppm), Sezenbey (1.22 ppm), Izmir 92 (1.05 ppm), Akcin 91 (1.04 ppm), Uzunlu 99 (1.02 ppm) and Gokce (0.94 ppm) cultivars and they all were placed into the same statistical group. The lowest value (0.37 ppm) was obtained from Azkan cultivar. Except for Akcin, Er 99, Gokce, Inci, Izmir 92, Sezenbey and Uzunlu 99 cultivars, chromium content of the other cultivars were placed into the lowest group. When the variation in chromium contents were assessed based on registration year, it was observed that average chromium content was 0.61 ppm, the highest variation was seen among the cultivars registered in 1999 (Er 99, Uzunlu 99, Kusmen 99) and the average chromium content of the cultivars registered in 2013 (Akca, Osmanbey) were below the general average (Fig. 1, Table 3). Complying with the present findings, Kaya et al. (2018) reported chromium contents of chickpeas as between 0.20–2.25 ppm.

In the first year, the highest Ni contents were obtained from Aziziye 94 (3.68 ppm), Er 99 (3.63 ppm), Dikbas (3.57 ppm), Sarı 98 (3.54 ppm) and Isık 05 (3.51 ppm) cultivars. Except for Sezenbey and Uzunlu 99 cultivars, Ni contents of the other cultivars were placed into the highest group. The lowest Ni contents were obtained from Uzunlu 99 and Sezenbey cultivars (81.83 ppm). In the second year, the highest value (4.65 ppm) was obtained from Uzunlu 99 cultivar. Except for Aziziye 94 and Osmanbey cultivars, Ni contents of the other cultivars were placed into the highest group. The lowest value (2.72 ppm) was obtained from Aziziye 94 cultivar. When the variation in Ni contents were assessed based on registration year, it was observed that average Ni content was 3.06 ppm, the highest variation was seen among the cultivars registered in 2012 (Cakır, Ilgaz, Sezenbey, Zuhal) and the average chromium contents decreased in cultivars registered especially after the year 2006 (Fig. 1, Table 3). Similar with the present findings, Vandemark et al. (2018) reported Ni contents of chickpea cultivars as between 4.17–5.74 ppm and Kaya et al. (2018) as between 0.45–7.05 ppm.

Micro Elements

In the first year, the highest copper content (4.80 ppm) was obtained from Ilgaz cultivar. Except for Seckin cultivar, the other were all placed into the highest group. The lowest value (3.04 ppm) was obtained from Seckin cultivar. In the second year, Cu contents of chickpea

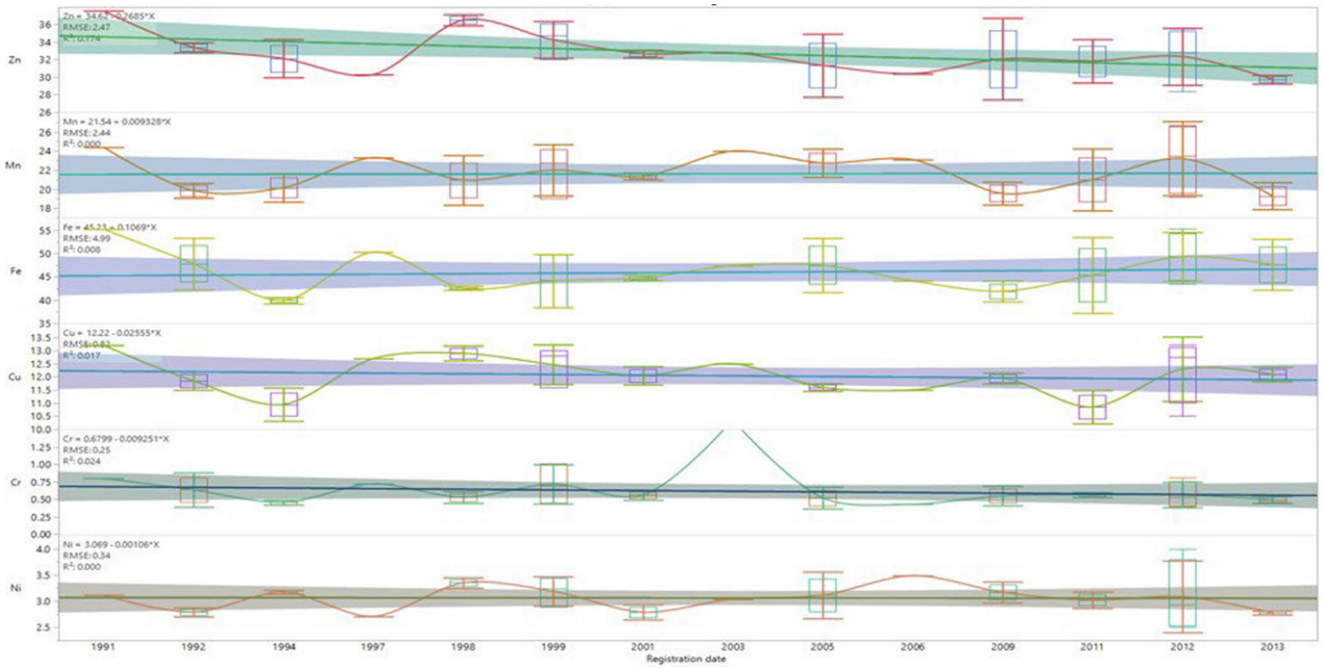


Fig. 1 Changes in Ni, Cr, Cu, Fe, Mn and Zn contents of chickpea cultivars registered between the years 1991–2013. (Error Bars = Standard Deviation, Curve line = Mean)

Table 3 Heavy metal and micro element contents of chickpea cultivars registered between the years 1991–2013

Heavy metals					Micro elements							
Registration year/Cultivar	Cr		Ni		Cu		Fe		Mn		Zn	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
1991_Akçin 91	0.55	1.04 ab	3.05 ab	3.18 abc	4.24 ab	22.16	46.25 a	64.24	28.68 a	20.09 b–e	35.16 abc	39.95
1992_Izmir 92	0.56	1.05 ab	2.39 ab	3.06 abc	3.77 ab	19.38	32.91 abc	54.95	21.53 a–d	17.12 de	30.21 a–f	35.84
1992_Menemen 92	0.42	0.49 b	2.79 ab	2.91 abc	3.77 ab	20.48	29.17 abc	74.28	20.90 a–d	19.96 b–e	29.35 b–g	38.32
1994_Aziziye 94	0.44	0.42 b	3.68 a	2.72 c	4.17 ab	18.66	30.99 abc	47.82	21.63 a–d	16.64 e	27.61 d–h	33.57
1994_Damla 89	0.49	0.47 b	3.06 ab	3.24 abc	3.73 ab	17.28	33.48 abc	47.28	23.61 a–d	18.81 cde	25.71 d–i	41.67
1997_Gökçe	0.51	0.94 ab	2.16 ab	3.25 abc	3.58 ab	21.89	30.46 abc	70.21	23.77 a–d	22.83 a–e	25.38 d–i	35.22
1998_Cevdetbey98	0.47	0.47 b	2.74 ab	3.81 abc	3.60 ab	22.58	30.69 abc	53.94	20.02 a–d	18.15 cde	29.26 b–g	42.97
1998_Sarı98	0.55	0.63 b	3.54 a	3.30 abc	3.68 ab	21.64	24.34 c	61.36	21.37 a–d	24.30 a–d	32.19 a–d	41.76
1999_Er 99	0.63	1.39 ab	3.63 a	3.24 abc	4.20 ab	21.44	37.24 abc	62.12	25.17 abc	23.28 a–e	36.87 a	35.34
1999_Küsmen99	0.50	0.40 b	2.11 ab	3.67 abc	4.10 ab	21.82	31.92 abc	56.78	20.20 a–d	25.35 abc	26.86 d–h	42.84
1999_Uzunlu 99	0.36	1.02 ab	1.83 b	4.65 a	3.14 ab	20.13	26.48 bc	50.04	18.50 bcd	19.42 b–e	24.39 f–i	39.70
2001_Çağatay	0.61	0.60 b	2.13 ab	3.26 abc	4.72 ab	18.92	35.79 abc	52.93	23.67 a–d	18.47 cde	25.10 e–i	40.81
2001_Gülümser	0.58	0.43 b	2.63 ab	3.16 abc	3.67 ab	20.94	34.83 abc	55.62	22.75 a–d	20.43 b–e	29.03 c–g	35.84
2003_Inci	0.77	2.44 a	2.78 ab	3.30 abc	3.75 ab	21.31	31.57 abc	63.19	19.89 a–d	28.10 a	28.47 c–g	37.22
2005_Işık 05	0.83	0.43 b	3.51 a	3.35 abc	3.97 ab	18.98	44.24 ab	59.03	25.28 abc	22.32 a–e	28.26 c–g	39.54
2005_Yaşa 05	0.38	0.45 b	2.64 ab	2.95 abc	3.14 ab	20.19	34.08 abc	52.65	22.17 a–d	21.31 a–e	19.85 i	37.81
2006_Dikbaş	0.48	0.38 b	3.57 a	3.40 abc	3.96 ab	19.00	38.43 abc	49.82	23.46 a–d	22.73 a–e	26.14 d–i	34.59
2009_Aksu	0.49	0.80 b	2.87 ab	3.18 abc	3.59 ab	20.06	28.03 abc	52.55	18.95 a–d	18.42 cde	24.95 e–i	32.67
2009_Azkan	0.54	0.37 b	3.07 ab	3.54 abc	4.19 ab	20.10	37.59 abc	49.48	22.31 a–d	18.55 cde	31.43 a–e	39.34
2011_Hasanbey	0.45	0.63 b	2.99 ab	3.26 abc	3.47 ab	19.08	36.24 abc	42.90	25.25 abc	21.31 a–e	28.88 c–g	31.22
2011_Seçkin	0.46	0.72 b	2.62 ab	3.19 abc	3.04 b	17.82	29.63 abc	72.57	17.02 cd	20.33 b–e	28.49 c–g	38.78
2012_Çakır	0.37	0.57 b	3.40 ab	4.59 ab	3.56 ab	22.25	40.24 abc	63.62	26.98 ab	26.44 ab	29.65 b–f	39.36
2012_Ilgaz	0.68	0.51 b	3.14 ab	3.34 abc	4.80 a	20.38	37.46 abc	72.87	28.67 a	24.22 a–d	36.06 ab	35.02
2012_Sezenbey	0.39	1.22 ab	1.83 b	3.18 abc	4.12 ab	22.22	29.23 abc	64.42	18.66 bcd	19.68 b–e	21.01 hi	35.79
2012_Zuhal	0.37	0.42 b	2.22 ab	3.03 abc	3.64 ab	17.34	32.55 abc	54.28	20.83 a–d	20.41 b–e	24.35 f–i	37.92
2013_Akça	0.40	0.52 b	2.62 ab	2.88 abc	3.30 ab	20.59	29.66 abc	73.30	13.95 d	22.58 a–e	21.05 hi	37.66

Table 3 (Continued)

Heavy metals					Micro elements							
Registration year/Cultivar	Cr		Ni		Cu		Fe		Mn		Zn	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
2013_Osmanbey	0.63	0.43 b	2.82 ab	2.77 bc	4.34 ab	20.32	37.48 abc	50.21	24.12 abc	16.38 e	22.65 ghi	37.47
Averages												
1st year	0.51		2.81 B		3.82 B		33.74 B		22.20		27.72 B	
2nd year	0.71		3.31 A		20.26 A		58.24 A		21.02		37.71 A	
F values												
Year (Y)	3.737		24.092*		831.093**		702.189**		4.339		162.590*	
Genotype (G)	2.695*		2.268*		0.637		1.425		4.617**		3.067**	
Y × G	1.965*		2.774**		0.578		1.708*		3.497**		2.955**	

Means indicated with the same letters in the same column are not significantly different ($p < 0.05$)
*:$p < 0.05$, **:$p < 0.01$

cultivars varied between 17.34 (Zuhal)–22.58 (Cevdetbey 98) ppm. In terms of registration years, the highest variation in Cu contents was observed among the cultivars registered in 2012 and the least in 2005. Average Cu content of the cultivars was identified as 12.04 ppm (Fig. 1, Table 3). In previous studies, Thavarajah (2012) reported Cu contents of chickpea cultivars as between 7–10.1 ppm, Alajaji and El-Adawy (2006) as 11 ppm, Ramírez-Ojeda et al. (2018) as between 5.9–10 ppm, Sharma et al. (2021) as between 2.6–4.9 ppm, Kaur et al. (2019) as between 2.1–4.3 ppm, Ereifej et al. (2001) as between 13.6–26.6 ppm, Demirbas et al. (2017) as 12.8 ppm, Vandemark et al. (2018) as between 6.56–8.23 ppm, Sali et al. (2016) as between 1.91–3.64 ppm, Kose and Mut (2020) as between 1.61–2.06 ppm and Kaya et al. (2018) as between 0.02–17.97 ppm. Present findings on Cu contents comply with those earlier ones.

In the first year, the highest iron content (46.25 ppm) was obtained from Akcin 91 cultivar followed by Isık 05 (44.24 ppm). Except for Sarı 98 and Uzunlu 99 cultivars, the others were all placed into the highest group. The lowest value (23.34 ppm) was obtained from Sarı 98 cultivar. In the second year, iron contents of chickpea cultivars varied between 50.21 (Osmanbey)–74.28 ppm (Menemen 92) and differences in iron contents of the cultivars were not found to be significant. Average iron content of the cultivars was identified as 45.99 ppm. The highest variation was observed among the cultivars registered in 2011 and the least in 1998 (Fig. 1, Table 3). In previous studies, Thavarajah (2012) reported Fe contents of chickpea cultivars as between 46–67 ppm, Ramírez-Ojeda et al. (2018) as between 34–50 ppm, Olika et al. (2019) as 10.68 ppm, Sharma et al. (2021) as between 33.6–46.7 ppm, Kaur et al. (2019) as between 4.59–9.87 ppm, Gupta et al. (2017) as between 2.5–12.4 ppm, Demirbas et al. (2017) as 260.6 ppm, Vandemark et al. (2018) as between 48.42–56.53 ppm and Kaya et al. (2018) as between 43.74–118.31 ppm. Present findings on Fe contents comply with those earlier ones.

In the first year, the highest manganese contents were obtained from Akcin 91 (28.68 ppm) and Ilgaz (28.67 ppm) cultivars. Except for Akca, Seckin, Sezenbey and Uzunlu 99 cultivars, the others were placed into the highest group. The lowest value (13.95 ppm) was obtained from Akca cultivar. In the second year, the highest value (28.10 ppm) was obtained from Inci cultivar and the manganese contents of Akca, Cakır, Dikbas, Er 99, Gokce, Hasanbey, Ilgaz, Isık 05 Inci, Kusmen, Sarı 98, Yasa 05 and Zuhal cultivars were placed into the highest group. The lowest values were obtained from Aziziye 94 (16.64 ppm) and Osmanbey (16.38 ppm) cultivars. Average manganese content of the cultivars was identified as 21.61 ppm. The highest variation in Mn contents was observed among the cultivars registered in 2012 and the least in 2001 (Fig. 1, Table 3). In terms of average of the years, the highest value (26.71 ppm) was obtained from Cakır cultivar and the lowest value (18.26 ppm) from Akca cultivar. In previous studies, Ramírez-Ojeda et al. (2018) reported Mn content of chickpea cultivars as between 11–47 ppm, Sharma et al. (2021) as between 31.2–49.2 ppm, Kaur et al. (2019) as between 13.1–32.8 ppm, Demirbas et al. (2017) as 91 ppm, Vandemark et al. (2018) as between 54.51–39.26 ppm and Kose and Mut (2020) as between 20.95–12.83 ppm.

In the first year, the highest zinc content (36.87 ppm) was obtained from Er 99 cultivar and the cultivars Akcin 91, Azkan, Ilgaz, Izmir 92 and Sarı 98 were also placed into the highest group. The lowest value (19.85 ppm) was obtained from Yasa 05 cultivar. In the second year, Zn contents of the cultivars varied between 31.22 (Hasanbey)–42.97 (Cevdetbey 98) ppm. In terms of the average of the years, the highest value (37.56 ppm) was obtained from Akcin 91 cultivar. Except for Akca, Aksu, Sezenbey and Yasa 05 cultivars, the others were placed into the highest group. The

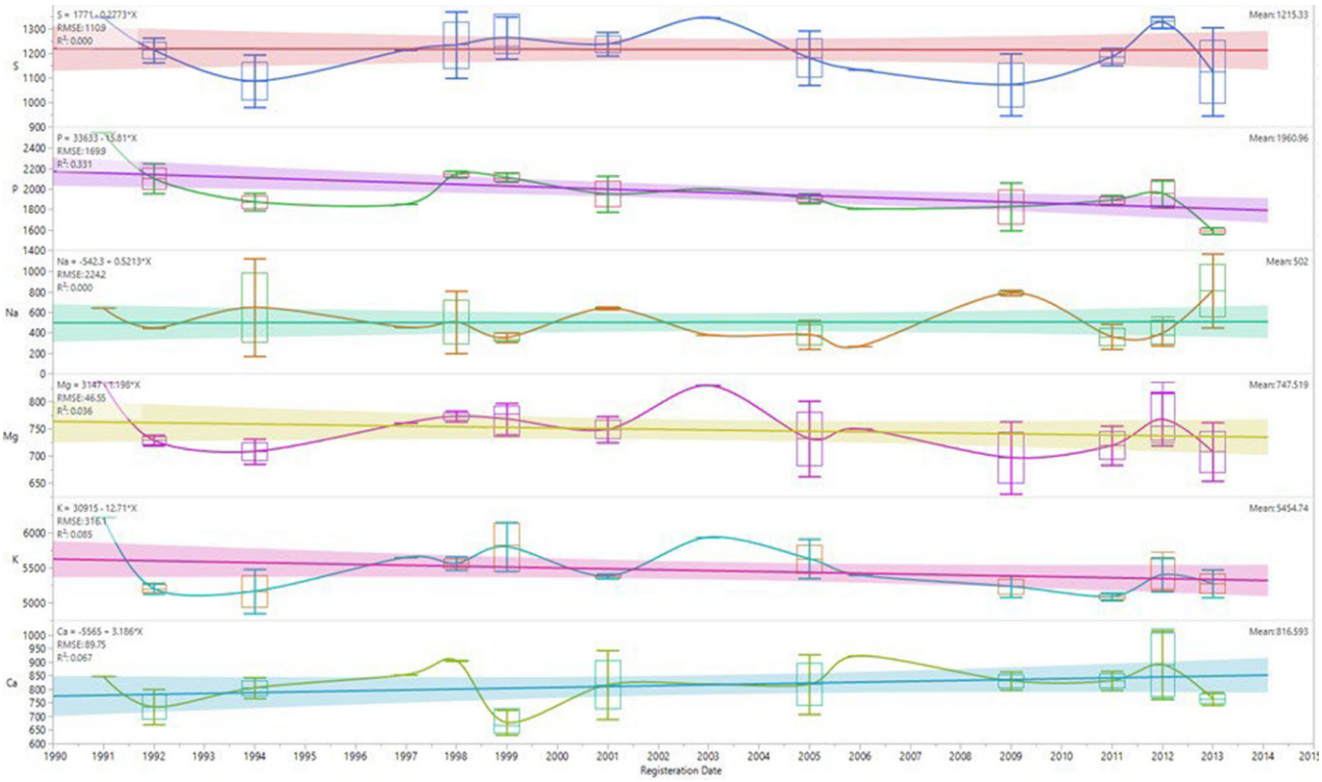


Fig. 2 Changes in the Ca, K, Mg, Na, P and S contents of chickpea cultivars registered between the years 1991–2013

lowest value (28.40 ppm) was obtained from Sezenbey cultivar. Average Zn content of the cultivars was identified as 32.71 ppm. In terms of registration years, decreasing Zn contents were observed in newly registered cultivars (Fig. 1, Table 3). In previous studies, Thavarajah (2012) reported Zn contents of chickpea cultivars as between 37–74 ppm, Alajaji and El-Adawy (2006) as 43.2 ppm, Ramírez-Ojeda et al. (2018) as between 26–76 ppm, Olika et al. (2019) as 7.06 ppm, Sharma et al. (2021) as between 21.8–34.6 ppm, Gupta et al. (2017) as between 18–2.9 ppm, Ereifej et al. (2001) as between 29.8–60.3 ppm, Vandemark et al. (2018) as between 42.78–34.82 ppm, Kose and Mut (2020) as between 25.93–18.79 ppm and Kaya et al. (2018) as between 18.71–77.24 ppm.

Macro Elements

In the first year, the highest Ca content (1000.4 ppm) was obtained from Cakır cultivar followed respectively by Ilgaz (998.2 ppm), Gulumser (894.6 ppm), Damla 89 (774.1 ppm) and Gokce (773.7 ppm) cultivars, which were all placed into the highest group. The lowest value (473.9 ppm) was obtained from Uzunlu 99 cultivar. In the second year, the highest Ca content (1134.7 ppm) was obtained from Dikbas cultivar followed respectively by Cevdetbey 98 (1127.9 ppm) and Sarı 98 (1097.6 ppm) cultivars. Except for Cagatay, Er 99, Kusmen, Menemen 92, Osmanbey, Uzunlu 99 and Yasa 05 cultivars, the others were placed into the highest group. The lowest value (764.2 ppm) was obtained from Menemen 92 cultivar. In terms of registration years, general average of cultivars was identified as 816.59 ppm (Fig. 2, Table 4). In previous studies conducted on chickpeas, Ca contents were reported as between 575–1080 ppm (Ramírez-Ojeda et al. 2018), as 1267.33 ppm (Olika et al. 2019), as between 1620–3160 ppm (Sharma et al. 2021), as between 564.4–1228 ppm (Kaur et al. 2019), as between 1400–3400 ppm (Ereifej et al. 2001), as between 280.56–441.5 ppm (Sali et al. 2016), as between 936.2–1370.2 ppm (Kose and Mut 2020) and as between 886–3008 ppm (Kaya et al. 2018). Present findings on Ca contents comply with those earlier ones.

In the first year, the highest K content (6609 ppm) was obtained from Er 99 cultivar followed by Akcin 91 (6584 ppm), Osmanbey (6242 ppm), Isık 05 (6158 ppm) and Inci (6110 ppm) cultivar which were all placed into the same statistical group. The lowest value (4678 ppm) was obtained from Akca cultivar followed by Sezenbey (4708 ppm) cultivar which was placed into the same group. In the second year, the highest K content (6008 ppm) was obtained from Kusmen cultivar respectively followed by Cevdetbey 98 (5913 ppm), Akcin 91 (5860 ppm), Inci (5761 ppm), Aksu (5748 ppm), Sarı 98 (5692 ppm), Uzunlu 99 (5675 ppm), Er 99 (5680 ppm), Sezenbey (5642 ppm), Gulumser (5601 ppm), Akca (5591 ppm),

Table 4 Macro element contents of the chickpea cultivars registered between the years 1991–2013

Macro elements												
Registration year/Cultivar	Ca		K		Mg		Na		P		S	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
1991_Akçin 91	636 cd	1059 a–d	6584 ab	5860 ab	885 ab	785 a–e	446 e–k	839 abc	2707 a	2399 a	1352 ab	1344 a–f
1992_Izmir 92	667 bcd	893 a–f	5430 f–m	4869 ij	741 a–e	701 c–f	514 d–j	385 e–h	1992 e–h	2006 c–f	1072 e–k	1280 b–g
1992_Menemen 92	614 cd	764 f	5244 h–n	5271 c–i	718 b–e	753 a–f	539 d–h	349 fgh	2242 bcd	2170 bc	1112 c–j	1383 a–f
1994_Aziziye 94	621 cd	934 a–f	5901 c–g	4875 ij	737 a–e	646 f	977 b	994 a	2203 b–e	1664 jkl	1042 e–k	978 h
1994_Damla 89	774 abc	889 a–f	4885 mn	4997 g–j	778 a–e	671 def	289 i–m	330 gh	2031 d–h	1596 kl	1102 d–k	1224 b–h
1997_Gökçe	773 abc	932 a–f	5826 c–h	5467 a–h	765 a–e	756 a–f	502 d–j	404 e–h	1954 f–i	1747 h–k	1118 c–j	1308 b–g
1998_Cevdetbey98	681 bcd	1127 a	5078 k–n	5913 ab	711 b–e	821 abc	638 c–f	802 a–d	1939 ghi	2396 a	1048 e–k	1227 b–h
1998_Sarı98	715.3 bc	1097 ab	5567 e–k	5692 a–d	740 a–e	819 abc	238 klm	337 gh	2011 e–h	2232 ab	1040 e–k	1619 a
1999_Er 99	646.6 cd	806 c–f	6609 a	5670 a–d	846 a–d	736 a–f	304 h–m	332 gh	2287 bc	1861 f–j	1374 a	1348 a–f
1999_Küsmen99	547 cd	788 ef	5629 d–k	6008 a	716 b–e	837 ab	455 e–k	354 fgh	2113 c–g	2101 b–e	1046 e–k	1409 a–e
1999_Uzunlu 99	473 d	800 def	5213 i–n	5675 a–d	661 cde	811 abc	151 m	521 e–h	1888 h–k	2430 a	947 ijk	1454 a–d
2001_Çağatay	625 cd	827 c–f	5782 c–i	4929 hij	858 abc	674 def	644 c–f	657 b–e	2374 b	1776 g–k	1187 a–g	1219 c–h
2001_Gülümser	894 ab	918 a–f	5207 i–n	5601 a–f	717 b–e	746 a–f	855 bc	406 e–h	1668 lm	1984 c–g	1036 f–k	1507 ab
2003_Inci	572 cd	1064 abc	6110 a–e	5761 abc	805 a–e	854 a	382 g–m	375 fgh	1740 i–m	2259 ab	1194 a–g	1496 abc
2005_Işık 05	763 bc	1026 a–e	6158 a–d	5499 a–g	799 a–e	761 a–f	406 g–l	556 d–g	2018 e–h	1724 ijk	1192 a–g	1326 b–f
2005_Yaşa 05	617 cd	861 b–f	5498 f–l	5361 b–i	634 e	730 a–f	147 m	415 e–h	1896 hij	1982 c–g	960 h–k	1244 b–h
2006_Dikbaş	711 bc	1134 a	5363 g–m	5426 b–i	768 a–e	731 a–f	279 j–m	254 h	1882 h–l	1731 h–k	1131 c–j	1135 e–h
2009_Aksu	661 cd	952 a–f	4932 lmn	5748 abc	644 de	654 ef	743 bcd	874 ab	1607 mn	1719 ijk	931 jk	1033 gh
2009_Azkan	714 bc	992 a–f	5146 j–n	5103 e–j	768 a–e	720 b–f	660 cde	885 ab	2146 c–g	1839 f–j	1158 b–h	1165 e–h
2011_Hasanbey	752 bc	959 a–f	5382 g–m	4870 ij	811 a–e	677 def	529 d–i	368 fgh	2175 b–e	1674 jkl	1150 b–i	1171 d–h
2011_Seçkin	626 cd	986 a–f	4938 lmn	5160 d–i	664 cde	723 a–f	191 lm	358 fgh	1724 j–m	1985 c–g	1023 g–k	1398 a–e
2012_Çakır	1003 a	933 a–f	6002 b–f	5453 a–h	731 a–e	799 a–d	486 e–j	622 b–f	2085 c–h	1942 d–h	1292 a–d	1395 a–e
2012_Ilgaz	998 a	1043 a–e	5751 c–i	5065 f–j	931 a	738 a–f	522 d–j	316 gh	2272 bc	1917 e–i	1319 abc	1377 a–f
2012_Sezenbey	664 cd	960 a–f	4708 n	5642 a–e	688 b–e	759 a–f	167 lm	378 fgh	1675 klm	2140 bcd	1022 g–k	1611 a
2012_Zuhal	631 cd	888 a–f	5703 c–j	4869 ij	798 a–e	691 c–f	179 lm	486 e–h	2167 b–f	14601	1248 a–e	1349 a–f
2013_Akça	569 cd	995 a–f	4678 n	5591 a–f	620 e	719 b–f	604 d–g	505 e–h	1436 n	1698 jk	895 k	1101 fgh

Table 4 (Continued)

Macro elements												
Registration year/Cultivar	Ca		K		Mg		Na		P		S	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
2013_Osmanbey	637 cd	858 b–f	6242 abc	4588 j	858 abc	633 f	1560 a	575 c–g	1568 mn	1658 jkl	1237 a–f	1268 b–g
Averages												
1st year	688 B		5539 A		755		496		1993		1120 B	
2nd year	944 A		5369 B		739		507		1929		1310 A	
F values												
Year (Y)	541.493**		9.459*		3.241		0.352		6.302		79.085*	
Genotype (G)	8.350**		19.418**		4.389**		43.955**		54.675**		11.668**	
Y × G	4.616**		20.545**		5.545**		17.468**		43.736**		8.807**	

Means indicated with the same letters in the same column are not significantly different ($p < 0.05$)
*:$p < 0.05$, **:$p < 0.01$

Isık 05 (5499 ppm), Gokce (5467 ppm) and Cakır (5453 ppm) cultivars which were placed into the same statistical group. The lowest value (4588 ppm) was obtained from Osmanbey cultivar (Table 4). In previous studies con chickpeas, Thavarajah (2012) reported K contents as between 7320–11,260 ppm, Ereifej et al. (2001) as between 9600–17,600 ppm, Demirbas et al. (2017) as 21,100 ppm, Sali et al. (2016) as between 5930.47–5232.43 ppm and Kose and Mut (2020) as between 6051.8–8467.0 ppm. Present findings on K contents comply with those earlier ones.

In the first year, the highest Mg content (931.7 ppm) was obtained from Ilgaz cultivar. Except for Akca, Aksu, Cevdetbey 98, Kusmen, Menemen 92, Seckin, Sezenbey, Uzunlu 99 and Yasa 05 cultivars, the others were placed into the highest group. The lowest value (620.8 ppm) was obtained from Akca cultivar followed by Yasa 05 (634.5 ppm) cultivar, which was placed into the same group. In the second year, the highest value (854.63 ppm) was obtained from Inci cultivar and the lowest values were obtained from Aziziye 94 (646.1 ppm) and Osmanbey (633.6 ppm) cultivars. Except for Akca, Aksu, Aziziye, Azkan, Cagatay, Damla 89, Hasanbey, Izmir 92, Osmanbey and Zuhal cultivars, the others were placed into the highest group (Table 4). In previous studies conducted on chickpeas, Thavarajah (2012) reported Mg contents as between 1250–1590 ppm, Ramírez-Ojeda et al. (2018) as between 1082–1305 ppm, Sharma et al. (2021) as between 1210–1590 ppm, Kaur et al. (2019) as between 737.1–1322.7 ppm, Vandemark et al. (2018) as between 1489–1303 ppm, Sali et al. (2016) as between 696.26–556.5 ppm and Kaya et al. (2018) as between 886–3008 ppm. Present findings on Mg contents comply with those earlier ones.

In the first year, the highest Na content (1560.1 ppm) was obtained from Osmanbey cultivar and the lowest values were obtained from Uzunlu 99 (151.7 ppm) and Yasa 05 (147.2 ppm) cultivars. In the second year, the highest value (994.1 ppm) was obtained from Aziziye 94 followed by Aksu (874.0 ppm) and Akcin 91 (839.7 ppm) cultivars, which were placed into the same group. The lowest value (254.7 ppm) was obtained from Dikbas cultivar (Table 4). In previous studies, Alajaji and El-Adawy (2006) reported Na content of chickpea as 1210 ppm, Ereifej et al. (2001) as between 188–285 ppm, Sali et al. (2016) as between 21.68–48.6 ppm, Kose and Mut (2020) as between 430.2–786.5 ppm and Kaya et al. (2018) as between 10–507 ppm.

When the variations in potassium, magnesium and sodium contents of chickpea cultivars were assessed based on registration years, it was observed that there was not much variation among the cultivars registered in 1992 by the same institute. In terms of potassium contents, variations were especially seen among the cultivars registered in 1999. Average potassium, magnesium and sodium content of the cultivars were respectively identified as 5454.74, 747.52 and 502 ppm. Magnesium contents of the cultivars registered in 1998 were greater than the average and there was not much variation among the cultivars. In terms of sodium contents, the highest variation was observed among the cultivars registered in 1994 and the least among the cultivars registered in 2001 (Fig. 2, Table 4).

In the first year, the highest phosphorus content (2707 ppm) was obtained from Akcin 91 cultivar and the lowest (1436 ppm) from Akca cultivar. In the second year, the highest values were obtained from Uzunlu 99 (2430 ppm), Akcin 91 (2399 ppm) and Cevdetbey 98 (2396 ppm) cultivars. The lowest value (1460 ppm) was obtained from Zuhal cultivar. Average phosphorus content of the cultivars was identified as 1960.96 ppm. The highest value (2553 ppm) was obtained from the cultiavars registered in 1991 and the lowest value was obtained from the cultivars registered in 2013 (Fig. 2, Table 4). In previous studies on chick-

Table 5 Morphological traits of the chickpea cultivars registered between the years 1991–2013

Registration year/Cultivar	Plant height (cm)		The first pod height (cm)		Number of pods per plant*		Number of kernels per plant *		Number of kernels per pod*		Kernel yield (kg/da)*		Protein content (%)*	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
1991_Akçin 91	43.2 ab	35.4 a–f	27.7 bcd	25.8 ab	14.5 hij	5.4 bc	14.2 g–k	5.1 bc	0.98 b–g	0.95 ab	82.8 a–d	73.7 ab	25.3	22.4
1992_Izmir 92	42.0 a–e	37.1 a–f	29.8 ab	26.0 ab	13.7 hij	7.8 ab	15.6 f–j	7.2 ab	1.14 abc	0.92 ab	68.4 bcd	79.9 ab	21.7	21.9
1992_Menemen 92	43.6 ab	36.3 a–f	29.6 ab	25.0 ab	17.2 f–i	7.7 abc	22.2 a–e	6.1 abc	1.29 a	0.77 b	86.9 abc	71.6 ab	25.6	20.9
1994_Aziziye 94	41.7 a–e	32.8 b–f	24.0 efg	23.5 ab	24.5 a–d	7.8 ab	24.6 ab	6.7 abc	1.01 b–f	0.86 ab	85.8 abc	108.4 a	28.0	23.3
1994_Damla 89	39.1 b–h	38.3 a–e	21.0 h–k	31.7 a	27.0 ab	8.9 a	23.4 a–d	8.7 a	0.87 d–i	0.97 ab	74.3 bcd	100.0 ab	24.1	20.7
1997_Gökçe	37.2 d–h	29.2 f	20.6 ijk	20.6 ab	23.4 b–e	5.4 bc	24.8 ab	5.0 bc	1.06 b–e	0.90 ab	86.0 abc	66.9 ab	24.6	21.8
1998_Cevdetbey98	43.1 abc	31.7 c–f	27.2 bcd	22.8 ab	18.1 e–i	5.2 bc	15.7 f–j	4.0 bc	0.86 e–i	0.79 b	64.0 cd	72.8 ab	27.9	22.9
1998_Sarı98	35.9 fgh	29.3 f	25.4 def	21.9 ab	10.4 j	5.4 bc	9.2 k	5.4 abc	0.90 d–i	1.01 ab	72.6 bcd	78.0 ab	26.6	22.1
1999_Er 99	39.0 b–h	28.9 f	23.6 e–h	20.9 ab	21.1 b–g	6.3 abc	22.8 a–e	6.4 abc	1.08 bcd	1.00 ab	68.0 cd	103.9 a	27.6	21.7
1999_Uzunlu 99	45.3 a	40.9 ab	28.9 abc	28.3 ab	13.5 ij	5.9 abc	12.5 ijk	5.4 abc	0.92 d–h	0.91 ab	68.4 bcd	106.7 a	24.5	24.7
2001_Çağatay	34.7 gh	39.5 a–d	18.2 k	25.4 ab	29.8 a	7.0 abc	25.4 a	6.6 abc	0.85 e–i	0.94 ab	112.0 a	93.2 ab	27.0	22.2
2001_Gülümser	36.1 fgh	39.8 abc	21.0 h–k	27.4 ab	26.3 ab	6.1 abc	21.9 a–e	5.7 abc	0.84 f–i	0.95 ab	100.4 ab	96.8 ab	24.3	20.7
2003_Inci	40.2 a–g	32.1 c–f	25.6 def	22.4 ab	15.0 hij	6.1 abc	15.8 f–j	5.4 abc	1.05 b–e	0.89 ab	75.3 bcd	64.8 ab	24.2	23.0
2005_Işık 05	37.5 c–h	42.6 a	22.9 f–h	27.9 ab	18.6 d–i	6.2 abc	18.2 d–h	6.2 abc	0.98 b–g	1.01 ab	77.7 bcd	74.6 ab	24.6	20.4
2005_Yaşa 05	37.4 d–h	31.1 def	21.5 g–j	22.7 ab	15.5 g–j	5.5 abc	15.2 g–j	5.1 bc	0.97 b–g	0.94 ab	87.1 abc	66.7 ab	23.8	18.3
2006_Dikbaş	38.6 b–h	30.6 ef	21.7 g–j	22. 5ab	22.0 b–f	6.3 abc	19.3 b–g	6.0 abc	0.88 d–i	0.96 ab	69.7 bcd	97.5 ab	24.3	20.8
2009_Aksu	39.8 a–g	31.2 c–f	25.0 def	21.9 ab	19.6 c–h	6.1 abc	18.9 c–h	5.7 abc	0.98 b–g	0.93 ab	88.2 abc	71.8 ab	23.8	22.3
2009_Azkan	42.5 a–d	28.7 f	30.6 a	20.7 ab	14.1 hij	5.5 abc	13.5 h–k	5.3 abc	0.96 c–g	0.96 ab	74.8 bcd	72.8 ab	27.3	21.5
2011_Hasanbey	41.8 a–e	32.9 b–f	26.2 cde	22.5 ab	17.2 f-i	6.5 abc	15.7 f–j	5.6 abc	0.91 d–h	0.85 ab	85.2 abc	76.5 ab	25.0	22.0

Table 5 (Continued)

Registration year/Cultivar	Plant height (cm)		The first pod height (cm)		Number of pods per plant*		Number of kernels per plant *		Number of kernels per pod*		Kernel yield (kg/da)*		Protein content (%)*	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
2011_Seçkin	38.6 b–h	35.1 a–f	27.4 bcd	23.7 ab	13.2 ij	6.6 abc	15.3 f–j	6.5 abc	1.17 ab	0.97 ab	62.0 cd	80.9 ab	24.9	24.8
2012_Çakır	38.7 b–h	29.8 ef	22.2 g–j	19.1 b	14.1 hij	6.1 abc	13.9 g–k	5.2 bc	0.98 b–g	0.85 ab	52.4 d	80.3 ab	26.1	22.8
2012_Ilgaz	33.9 h	28.8 f	21.3 g–j	23.5 ab	14.3 hij	3.7 c	10.6 jk	3.5 c	0.74 hi	0.94 ab	63.6 cd	51.6 b	26.0	20.4
2012_Sezenbey	36.6 e–h	31.8 c–f	19.4 jk	22.4 ab	29.9 a	5.2 bc	23.9 abc	4.8 bc	0.80 ghi	0.93 ab	58.4 cd	63.7 ab	27.7	22.9
2012_Zuhal	41.9 a–e	33.8 b–f	24.1 efg	29.6 ab	25.5 ab	5.7 abc	17.6 e–i	5.3 abc	0.69 i	0.94 ab	76.4 bcd	83.0 ab	26.5	20.9
2013_Akça	39.4 b–h	29.8 ef	24.0 efg	21.6 ab	24.9 abc	5.7 abc	20.8 a–f	5.2 bc	0.84 f–i	0.91 ab	64.9 cd	79.3 ab	26.2	21.7
2013_Osmanbey	40.6 a–f	32.1 c–f	21.5 g–j	22.1 ab	25.4 abc	5.6 abc	23.3 a–d	5.8 abc	0.92 d–h	1.03 a	88.7 abc	93.1 ab	22.3	23.6
Averages														
1st year	39.55 A		24.3		19.6 A		18.2 A		0.95		76.68 B		25.3 A	
2nd year	33.4 B		23.9		6.2 B		5.7 B		0.93		81.6 A		21.9 B	
F values														
Year (Y)	26.383*		0.299		972.962**		1030.803**		1.084		2.191*		39.594*	
Genotype (G)	8.275**		4.056**		23.587**		19.181**		5.334**		4.219**		1.192	
Y × G	6.340**		3.896**		20.222**		13.431**		7.665**		2.848**		0.922	

Means indicated with the same letters in the same column are not significantly different ($p < 0.05$)
*:$p < 0.05$, **:$p < 0.01$

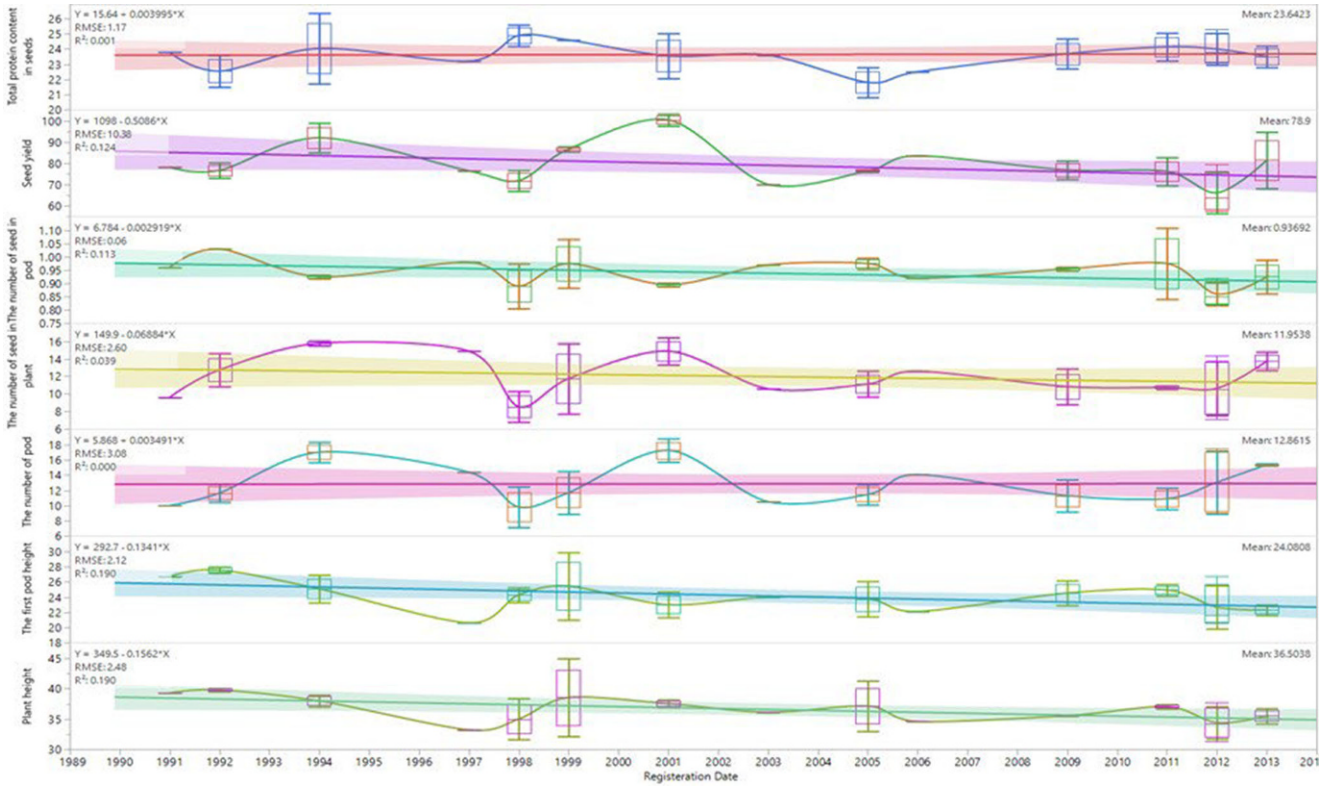


Fig. 3 Changes in morphological traits of chickpea cultivars registered between the years 1991–2013

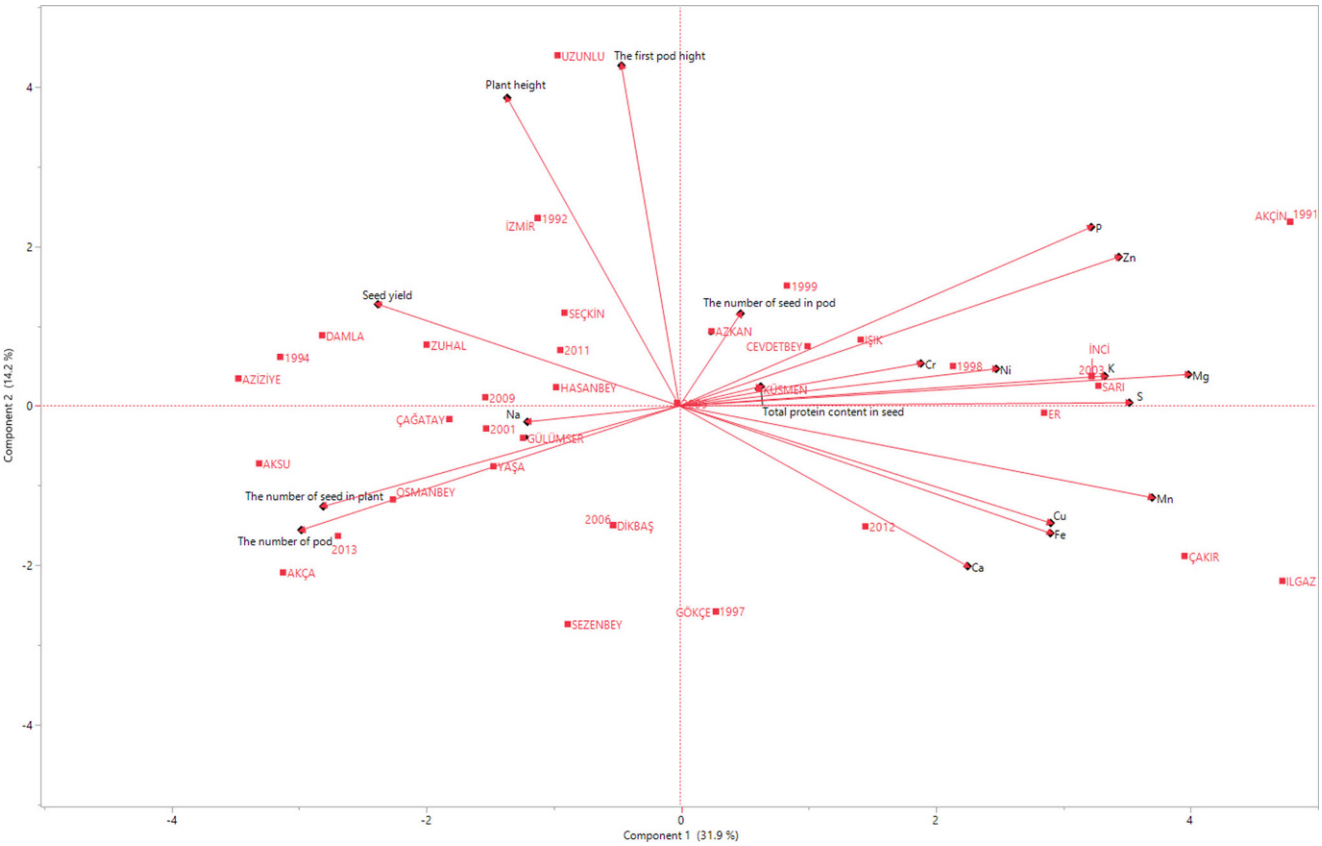


Fig. 4 PCA for minerals and morphological traits based on registrations year

Table 6 Eigenvalues, variance, total variance, probabilities for investigated traits and principal component analysis results

	PC1	PC2	PC3	PC4	PC5	PC6
Eigenvalue	6.0588	2.6963	2.2203	1.7372	1.3526	1.2434
Variance (%)	31.888	14.191	11.686	9.143	7.119	6.544
Total variance (%)	31.888	46.079	57.765	66.908	74.027	80.571
Principle component analysis results						
Traits	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**
Cr	0.16382	0.06902	0.30839	–0.32456	–0.27686	0.10451
Ni	0.21489	0.06021	–0.17472	0.26167	0.38543	0.27139
Ca	0.19559	–0.26032	–0.32317	0.12341	0.25885	–0.06024
K	0.28854	0.04854	0.34081	0.00999	0.08197	0.16602
Mg	0.34535	0.05106	0.18228	0.02331	0.10222	–0.26791
Na	–0.10311	–0.02584	0.14603	0.48264	0.09811	0.32450
P	0.27940	0.29053	0.08760	0.18092	–0.13049	–0.12780
S	0.30524	0.00529	0.17939	–0.14687	0.01178	–0.31407
Cu	0.25188	–0.19015	0.20632	0.24178	–0.28847	0.07435
Fe	0.25170	–0.20675	0.05450	–0.18704	–0.01523	0.05289
Mn	0.32068	–0.14887	0.04963	–0.08558	0.39093	–0.10048
Zn	0.29806	0.24197	0.00584	0.18463	0.10548	0.00298
Plant height	–0.11677	0.50041	0.09783	0.01521	0.10757	–0.14138
The first pod hight	–0.03929	0.55296	–0.14881	–0.06396	–0.00194	–0.13996
The number of pods	–0.25642	–0.20148	0.34445	0.07318	0.11670	–0.32946
The number of kernels per plant	–0.24156	–0.16316	0.43870	–0.02054	0.16107	–0.03342
The number of kernels per pod	0.04155	0.15006	0.16668	–0.36464	0.09021	0.64814
Kernel yield	–0.20449	0.16513	0.35426	0.16188	0.40329	–0.00063
Protein content	0.05520	0.03164	0.12345	0.46792	–0.44105	0.06652

pea cultivars, Thavarajah (2012) reported P contents as between 2630–3700 ppm, Alajaji and El-Adawy (2006) as 2260 ppm, Ereifej et al. (2001) as between 1100–4600 ppm, Demirbas et al. (2017) as 2500 ppm, Kose and Mut (2020) as between 2514.1–3094.0 ppm and Kaya et al. (2018) as between 3109–5503 ppm. Present findings on P contents comply with those earlier ones.

In the first year, the highest sulphur content (1374.4 ppm) was obtained from Er 99 cultivar and the cultivars Akcin 91, Cagatay, Cakır, Ilgaz, Isık 05, Inci, Osmanbey and Zuhal were also placed into the highest group. The lowest value (895.7 ppm) was obtained from Akca cultivar. In the second year, the highest values were obtained from Sarı 98 (1619.8 ppm) and Sezenbey (1611.5 ppm) cultivars and Akcin, Cakır, Er 99, Gulumser, Ilgaz, Kusmen, Menemen 92, Seckin, Uzunlu 99 and Zuhal cultivars were also placed into the highest group. The lowest value (978.8 ppm) was obtained from Aziziye 94 cultivar. Average sulphur content of the cultivars was identified as 1215.33 ppm. Although 4 cultivars were registered in 2012, the least variation in sulphur contents was observed in that year. The highest variations were seen among the cultivars registered in 2013 (Fig. 2, Table 4). In previous studies, Vandemark et al. (2018) reported S contents of chickpea cultivars as between 2115–1790 ppm and Kose and Mut (2020) as 1614.3–2063.7 ppm.

Morphological Traits

In the first year, the highest plant height (45.3 cm) was obtained from Uzunlu 99 cultivar and the cultivars Menemen 92, Akcin 91, Cevdetbey 98, Azkan, Izmir 92, Zuhal, Hasanbey, Osmanbey, Inci and Aksu were placed into the same group. The lowest plant height (33.9 cm) was obtained from Ilgaz cultivar. In the second year, the highest plant height (42.63 cm) was obtained from Isık 05 cultivar and the cultivars Akcin 91, Cagatay, Damla 89, Gulumser, Izmir 92, Menemen 92, Seckin and Uzunlu 99 were placed into the same group. The lowest value (28.73 cm) was obtained from Azkan cultivar and the cultivars Er 99, Gokce, Ilgaz and Sarı 98 were placed into the same statistical group. The average plant height was identified as 36.50 cm and the highest variation was observed among the cultivars registered in 1999. There was quite less variation among the cultivars registered especially in 1992 and 2011 (Fig. 3, Table 5). Present findings on plant heights comply with the results of Babagil (2011), Gungor and Dumlupınar (2018) and Yalcın et al. (2018).

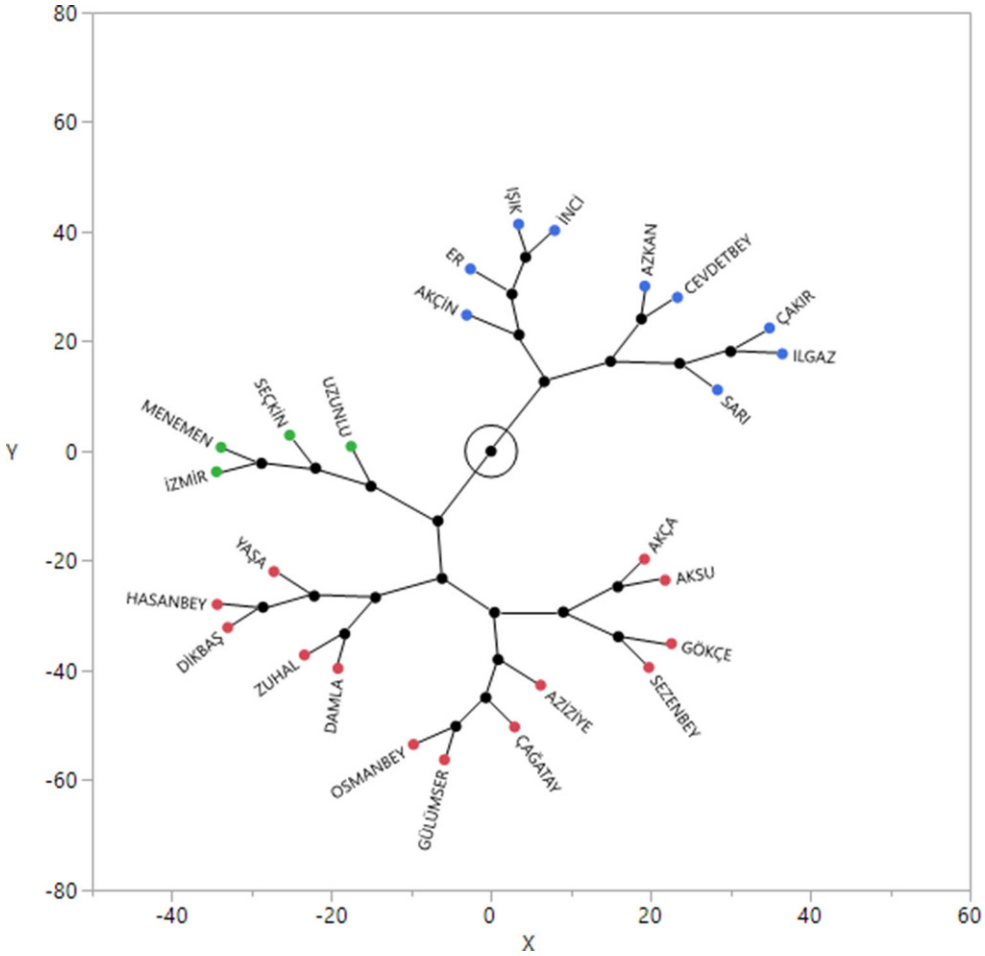


Fig. 5 Constellation plot for agro-morphological traits and mineral composition in chickpea genotypes

In the first year, the highest first pod height (30.6 cm) was obtained from Azkan cultivar and the cultivars Izmir 92, Menemen 92 and Uzunlu 99 were placed into the same statistical group. The lowest value (18.2 cm) was obtained from Cagatay cultivar. In the second year, the highest value (31.67 cm) was obtained from Damla 89 cultivar and the lowest value (19.10 cm) was obtained from Cakır cultivar. Except for Cakır cultivar, the others were all placed into the same group with Damla 89 cultivar. Average first pod height of the cultivars was identified as 24.08 cm with the highest variation among the cultivars registered in 1999 (Fig. 3, Table 5). Present findings on the first pod height comply with the results of Babagil (2011), Gungor and Dumlupınar (2018), Yalcın et al. (2018) and Kaya et al. (2018).

In the first year, the highest number of pods per plant (29.99 pods/plant) was obtained from Sezenbey cultivar and the cultivars Akca, Aziziye 94, Cagatay, Damla 89, Gulumser, Osmanbey and Zuhal were also placed into the same statistical group. The lowest value (10.36 pods/plant) was obtained from Sarı 98 cultivar. In the second year, the highest value (8.93 pods/plant) was obtained from Damla 89 cultivar and the lowest (3.70 pods/plant) from Ilgaz cultivar. Except for Akcin 91, Cevdetbey 98, Ilgaz, Sarı 98 and Sezenbey cultivars, the others were placed into the highest group. Average number of pods per plant was identified as 12.86 pods/plant. The highest variation was observed among the cultivars registered in 2012 and number of pods per plant of the cultivars registered in 1993 and 2001 were greater than the averages (Fig. 3, Table 5). Present findings on number of pods per plant comply with the findings of Gungor and Dumlupınar (2018), Bicer et al. (2017) and Yalcın et al. (2018).

In the first year, the highest number of kernels per plant (25.43 kernels/plant) was obtained from Cagatay cultivar and the cultivars Akca, Aziziye 94, Damla 89, Er 99, Gokce, Gulumser, Menemen 92, Osmanbey and Sezenbey were also placed into the same statistical group. The lowest value (9.21 kernels/plant) was obtained from Sarı 98 cultivar. In the second year, the highest value (8.67 kernels/plant) was obtained from Damla 89 cultivar and the lowest (3.50 kernels/plant) from Ilgaz cultivar. Average number of kernels per plant was identified as 11.95 kernels/plant and the cultivars registered in 1994, 1997, 2001 and 2013 had values greater than the averages (Fig. 3, Table 5). Present findings on number of kernels per plant comply with the results of

Gungor and Dumlupınar (2018), Bicer et al. (2017) and Yalcın et al. (2018).

In the first year, the highest number of kernel per pod (1.29 kernels/pod) was obtained from Menemen 92 cultivar and the cultivars Seckin (1.17) and Izmir 92 (1.14) were also placed into the same group. The lowest value (0.69 kernels/pod) was obtained from Zuhal cultivar. In the second year, the highest value (1.03 kernels/pod) was obtained from Osmanbey cultivar and the lowest value (0.77 kernels/pod) from Menemen 92 cultivar; the cultivar Cevdetbey 98 (0.79 kernels/pod) was also placed into the same group. Except for Cevdetbey 98 and Menemen 92 cultivars, the others were all placed into the highest group. Average number of kernels per pod was identified as 0.94 kernels/pod. The highest values were observed in cultivars registered in 2011 and the highest variation was also seen among the cultivars registered in that year (Fig. 3, Table 5). Present findings on number of kernels per pod comply with the results of Erdemci (2012) reporting number of kernels per pod of chickpea cultivars as between 0.99–1.19 kernels/pod.

In the first year, the highest kernel yield (112.0 kg/da) was obtained from Cagatay cultivar and the cultivars Akcin 91 (82.8 kg/da), Aksu (88.2 kg/da), Aziziye 94 (85.8 kg/da), Gokce (86.0 kg/da), Gulumser (100.4 kg/da), Hasanbey (85.2 kg/da), Menemen 92 (86.9 kg/da), Osmanbey (88.7 kg/da) and Yasa 05 (87.1 kg/da) were also placed into the same statistical group. Also, Ozaktan (2021) reported that the Cagatay variety had a low cooking time. The lowest value (52.4 kg/da) was obtained from Cakır cultivar. In the second year, the highest kernel yield (108.37 kg/da) was obtained from Aziziye 94 cultivar and the lowest (51.63 kg/da) from Ilgaz cultivar. Except for Ilgaz cultivar, the others were all placed into the same statistical group. In terms of registration years, the highest kernel yields were obtained from the cultivars registered in 2001. Average kernel yield was identified as 78.9 kg/da (Fig. 3, Table 5). Present findings on kernel yields comply with the results of Babagil (2011), Gungor and Dumlupınar (2018) and Bicer et al. (2017).

Protein contents of chickpea cultivars varied between 21.69 (Izmir 92)–28.00% (Aziziye 94) in the first year and between 18.32 (Yasa 05)–24.78% (Seckin) in the second year. Average protein content of chickpea cultivars was identified as 23.64% and the highest variation was observed among the cultivars registered in 1994 (Fig. 3, Table 5). Present findings on protein contents comply with the results of Ma et al. (2011), Yalcın et al. (2018) and Kaya et al. (2018).

Pca and Constellation Plot

Principle component analysis (PCA) was conducted on experimental data. Investigated traits and principal component axes are presented in Fig. 4, eigenvalues variance, total variation ratios, PC axes for investigated traits and corresponding factor coefficients are provided in Table 6. In terms of investigated traits, independent 19 PC axes, 6 of them with eigenvalue of greater than 1, were obtained. Eigenvalues of these axes varied between 1.24–6.06 and they were able to explain 80.571% of total variation. For efficient use of PCA and reliable assessment of corresponding outcomes, the first two or three components should explain at least 25% of the total variation (Mohammadi and Prasanna 2003). In present analysis, the first three component explained 57.77% of total variation. Considering the explanation of 2/3 of total variation (66.66%), 4 principal components already met such a criterion. In principle component analysis, component weights are considered to be significant when they have a value of ≥ 0.3 (Gozen 2008). When the weight values of investigated traits were taken into consideration (Table 6), it was observed that the traits on PC1 (Mg, S and Mn) explained 31.89% of total variation, the traits on PC2 (plant height and the first pod height) explained 14.19% of total variation, the traits on PC3 (Cr, K, number of pods, number of kernels per plant and kernel yield) explained 11.69% of total variation, the traits on PC4 (Na and protein content) explained 9.14% of total variation, the traits on PC5 (Ni, Mn and kernel yield) explained 7.12% of total variation and the traits on PC6 (Na and number of kernels per pod) explained 6.54% of total variation (Table 6). Ozaktan et al. (2022), Ozaktan and Doymaz (2022) reported similar results. The constellation plot for agro-morphological characteristics and mineral composition in chickpea genotypes is given in Fig. 5 and supports the results obtained from PCA.

Conclusion

In terms of mineral contents, there were positive correlations between phosphorus and zinc and between potassium and magnesium. Positive correlations were encountered between plant height and the first pod height and between number of kernels per plant and number of pods per plant. Number of kernels and pods per plant had negative correlations with phosphorus and zinc contents. Kernel yield had positive correlations with Na contents, but negative correlations with Ca, Fe, Cu and Mn contents. Since the highest grain yield is obtained from Cagatay and Gülümser varieties in Kayseri natural conditions, these varieties can be recommended for local growers.

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Conflict of interest H. Ozaktan, S. Uzun, O. Uzun and C. Yasar Ciftci declare that they have no competing interests.

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