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ORIGINAL PAPER

ACCUMULATION OF HEAVY METALS IN DRY BEANS SOWN ON DIFFERENT DATES*

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Abstract

Apart from water, living organisms need minerals, i.e. nutritional compounds and vitamins, to survive. Demand for minor minerals in the human body is quite low but most of them are essential as well. Heavy metals are components of mineral substances that are widely used for medical, agricultural, industrial, technological and domestic purposes and have effects on the environment. The present research was conducted by sowing 7 dry bean genotypes on 6 different dates for 2 years (2010 and 2012) in Konya, Turkey, to determine changes in heavy metal concentrations. According to the results, differences statistically significant at a 1% significance level were found for all the factors and their interactions except for the year factor. Mean concentrations of the analysed minerals ranged as follows (in mg kg^{-1}): 0.00-0.06 for Cd, 0.00-0.84 for Co, 0.36-10.47 for Cr, 1.06-14.17 for Cu, 6.81-59.71 for Fe, 1.65-12.31 for Ni, 0.00-0.44 for Pb and 2.31-26.27 for Zn. In summary, the content of Co, Cu, Ni and Zn showed a decrease in beans sown late, while Cr and Fe presented a decreasing tendency in general. Additionally, the content of Cd and Pb in beans sown on 15th May at the latest varied depending on the sowing dates. Consequently, delayed sowing of bean resulted in a significant decrease in the heavy metal content of dry bean seeds. Further studies into the nutritional quality and agronomic characteristics of plants are needed, including such aspects as well-balanced yield and quality traits, in order to ensure sustainable functional food production and sustainable agricultural systems.

Keywords: food quality, human health, *Phaseolus vulgaris*, sustainable agriculture, trace elements.

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INTRODUCTION

Demand for healthy food and balanced nutrition as well as the need to maintain sustainable production systems can be satisfied to some extent by increasing the production of legumes, including dry bean seeds (Peksen 2005). The concept of sustainable agricultural systems may be summarized as a continuous and long-lived production system, viable in terms of both yields and consumer benefits, and achieved through a combination of experience and modern techniques for the main purposes such as environmental protection, economic development, prevention of migration from rural areas and enhancement of the living standard. The increasing human population has led to a reduction in the total coverage of agricultural areas and a development of intensive agricultural models that shift the focus to the achievement of higher yields by using more chemical fertilisers and pesticides.

The content of elements in plant seeds and crops' requirements for elements vary widely (Thompson, Troeh 1973). The functions of essential elements for plant growth and development are not realised by other elements (Bergensen 1971, Gezgin, Hamurcu 2006). Furthermore, a change in the metal content of food depends on cooking conditions such as a cooking medium, temperature and time factors (Perello et al. 2008, Filiz 2011).

Heavy metals have metallic characteristics, which are described by various features based on the number of atoms, atomic weight, density, chemical structure, toxicity, etc., and some of these elements are essential for humans and animals in small amounts, while higher quantities have toxic effects. Quantities of metals above their essential values create "a metal load in an organism" and some of them (such as aluminum, cadmium and lead) increase in concentration with age. Heavy metal pollution originates from natural resources, mining, industrial waste, detergents, burning fossil matter, urban waste and wastewater as well as pesticides and fertilisers used in agriculture. Factors that influence the absorption of heavy metals in soil are soil pH, organic matter, liming and soil structure, mainly. Toxic elements collect in the soil and can be transferred up in the food chain (soil-air-plant--animal-human). Some metals, for instance arsenic, cadmium, chromium, cobalt, iron, lead, nickel, titanium and zinc, are known as have carcinogenic effects. Vital heavy metals are essential for organisms in certain concentrations which affect biological reactions. Therefore, those have to be taken to the bodies regularly. From this perspective, agricultural production systems and cultivation practices are important for humans and for the environment (Sebastian, Prasad 2016, Kahraman 2017).

As with other plants, bean – the most important legume in the world – is sensitive to climate changes, which is why the sowing time affects the yield and nutritional value of this crop, due to the water and temperature factors which influence the growth, development, yield and quality characteristics (Bozoglu, Sozen 2007, Krzebietke, Sienkiewicz 2010, Jankowski et al.

2015). Present and expected climate changes raise the need to develop well-adapted varieties with desired traits relative to the consumers' health. Konya is the largest dry bean producer in Turkey. Dry bean growers often mention the problem of choosing the right sowing time for dry bean, which is important for the yield volume and quality. The present research contains an evaluation of trace elements in dry bean genotypes depending on different dates of sowing, the aim of which was to ensure a better contribution to human health and economic output, and to maintain sustainable agricultural systems.

MATERIAL AND METHODS

In the present study, 7 dry bean genotypes which belonged to 4 certified dry bean varieties (Akman-98, Doruk, Karacaşehir-90 and Noyanbey-98) and 3 local dry bean populations (Sarıkız, Horoz and Sarnıç) were used as the material for analysis. The above choice of dry bean varieties was dictated by their popularity.

Field trials ran for 2 years (2010 and 2012) and 6 different sowing dates were tested (15th of April, 1st of May, 15th of May, 1st of June, 15th of June and 30th of June). The experiment was set up in a split blocks design with 3 replications, and conducted at the Konya Soil, Water and Deserting Control Research Institute, which is located near the town Konya, Turkey (1016 m of altitude). During the plant growing season (from April to September) in both years (2010 and 2012), the weather conditions were as follows: mean temperature 20.9°C - 20.6°C, total precipitation 18.2-11.2 mm, and relative humidity 43.1% - 41.2%. The long-term values of these properties, measured from 1980 to 2010, were 18.6°C for mean temperature, 19.9 mm for total precipitation and 48.6% for relative humidity. A drip irrigation system was employed as required by the plants: 4 times in the 2010 and 5 times in the 2012 plant growing season.

The soil was characterised as follows: clay-loamy structure, lower level of organic matter (1.49%), higher level of lime (17.14%), alkaline reaction (pH 8.40), low salinity (0.05%), higher content of potassium (516 kg ha^{-1}), lower level of phosphorus (40.1 kg ha^{-1}) and the following content of iron 3.90 mg kg^{-1}, copper 0.98 mg kg^{-1} and zinc 0.42 mg kg^{-1}. The seed bed was prepared by 20-cm-deep tillage after wheat harvest, 100 kg ha^{-1} of DAP (18% nitrogen and 46% phosphorus) fertilization and 5-cm-deep tillage on 1st of April.

This paper presents some of the results of Ali KAHRAMAN's PhD dissertation (Selcuk University, Konya-Turkey, Project No: 10101017) and summarizes changes in the content of heavy metals in dry bean genotypes correlated with different sowing time. For this purpose, Cd, Co, Cr, Cu, Fe, Ni, Pb and Zn elements were determined by ICP-AES (Varian Vista Model) based

on dry weights of crushed seeds. Analytical results were verified and controlled for repeatability based on standard reference materials (Burt 2004). The content of the elements was expressed in mg kg^{-1}.

Variance analysis was made by considering the trial years as a factor and using JUMP 5.0.1 software, while the Duncan grouping tests (according to the significance levels of "F" values) were made in an MSTAT-C program.

RESULTS AND DISCUSSION

The concentrations of the 8 heavy metals in the 7 dry bean genotypes which were sown on 6 different dates for 2 years in Konya (Turkey) are presented in Tables 1 to 8. The results of the study are summarized as means of the years.

Differences in the cadmium content of dry bean seeds showed statistical significance ($p < 0.01$) for all of the factors (except for the years) and their interactions, while means of the values changed from 0.00 mg kg^{-1} to 0.06 mg kg^{-1} (Sarnıç genotype sown on 15th of June). In general, the content of cadmium showed a decreasing tendency due to late sowing. The documented changes in the bean seed content of Cd as correlated with the sowing dates showed that the Sarnıç variety accumulated the most cadmium while Doruk and Sarıkız accumulated the least of this element. The cadmium content has been reported as 0.01 - 0.21 mg kg^{-1} in various plants (Onder, Dursun 2006), 0.00 - 0.01 mg kg^{-1} in legumes (Cabrera et al. 2003), 0.64 - 0.67 mg kg^{-1} in bean pods (Taskin 2012). Cadmium is mobile in soil, which means it penetrates into groundwater, and in plants it causes negative effects on protein synthesis, nitrogen and carbohydrate metabolism, enzyme activation (nitrate reductase), photosynthesis, chlorophyll synthesis etc., which are responsible for lower yields and worse quality of plants.

Statistical analyses were significant at a level of 1% for all of the factors except for the years and their interactions for the cobalt content of the tested genotypes, which ranged from 0.00 mg kg^{-1} to 0.84 mg kg^{-1} (Karacaşehir genotype sown on 15th of April). The highest cobalt content (0.33 mg kg^{-1}) was obtained from sowing beans on 15th of April, while the lowest value (0.07 mg kg^{-1}) was determined in plants sown on 30th of June. The highest cobalt content (0.39 mg kg^{-1}) occurred in the Doruk genotype in 2010, while the Sarıkız genotype had the lowest cobalt value (0.03 mg kg^{-1}) in 2012. Accumulation of Co depended on the sowing time most strongly in Doruk, and least strongly in Akman. Previous studies reported the cobalt content values as 0.01-0.48 mg kg^{-1} (Onder, Dursun 2006) in various plants, 0.00-2.44 mg kg^{-1} (Kahraman, Onder 2013) in dry bean seeds. It was interesting that the content of cobalt in dry bean seeds decreased due to delayed sowing.

Table 1

Cd content (mg kg^{-1}) in dry bean seeds sown at different times

Years	Sowing times	Genotypes							
		Akman	**Doruk**	**Karacaşehir**	**Noyanbey**	**Sarıkız**	**Horoz**	**Sarnıç**	**mean**
2010	**15 April**	0.01	0.01	0.03	0.02	0.02	0.03	0.02	**0.02*b***
	1 May	0.02	0.03	0.05	0.02	0.02	0.00	0.04	**0.03*a***
	15 May	0.01	0.00	0.00	0.01	0.01	0.01	0.01	**0.01*c***
	1 June	0.04	0.00	0.06	0.01	0.03	0.04	0.02	**0.03*a***
	15 June	0.03	0.01	0.01	0.04	0.00	0.02	0.07	**0.02*b***
	30 June	0.01	0.00	0.00	0.01	0.00	0.00	0.03	**0.01*c***
	mean	**0.02*b***	**0.01*c***	**0.02*b***	**0.02*b***	**0.01*c***	**0.02*b***	**0.03*a***	**0.02**
2012	**15 April**	0.04	0.02	0.03	0.03	0.00	0.00	0.05	**0.02*b***
	1 May	0.02	0.03	0.05	0.00	0.01	0.02	0.02	**0.02*b***
	15 May	0.02	0.02	0.01	0.03	0.00	0.05	0.02	**0.02*b***
	1 June	0.04	0.00	0.01	0.02	0.01	0.02	0.01	**0.01*c***
	15 June	0.01	0.03	0.01	0.02	0.00	0.02	0.06	**0.02*b***
	30 June	0.02	0.00	0.02	0.00	0.01	0.00	0.02	**0.01*c***
	mean	**0.03*a***	**0.01*c***	**0.02*b***	**0.02*b***	**0.01*c***	**0.02*b***	**0.03*a***	**0.02**
Year average	**15 April**	0.03*d*	0.01*f*	0.03*d*	0.02*e*	0.01*f*	0.02*e*	0.04*c*	**0.02*a***
	1 May	0.02*e*	0.03*d*	0.05*b*	0.01*f*	0.01*f*	0.01*f*	0.03*d*	**0.02*a***
	15 May	0.01*f*	0.01*f*	0.00*g*	0.02*e*	0.00*g*	0.03*d*	0.01*f*	**0.01b**
	1 June	0.04*c*	0.00*g*	0.03*d*	0.01*f*	0.02*e*	0.03*d*	0.01*f*	**0.02*a***
	15 June	0.02*e*	0.02*e*	0.01*f*	0.03*d*	0.00*g*	0.02*e*	0.06*a*	**0.02*a***
	30 June	0.02*e*	0.00*g*	0.01*f*	0.00*g*	0.01*f*	0.00*g*	0.02*e*	**0.01*b***
	mean	**0.02*b***	**0.01*c***	**0.02*b***	**0.02*b***	**0.01*c***	**0.02*b***	**0.03*a***	**0.02**

Table 2

Co content (mg kg^{-1}) in dry bean seeds sown at different times

Years	Sowing times	Genotypes							
		Akman	Doruk	Karacaşehir	Noyanbey	Sarıkız	Horoz	Sarnıç	mean
2010	15 April	0.05	0.77	0.48	0.14	0.13	0.32	0.12	**0.29*b***
	1 May	0.30	0.49	0.10	0.16	0.22	0.09	0.32	**0.24*cd***
	15 May	0.28	0.59	0.28	0.14	0.03	0.22	0.43	**0.28*bc***
	1 June	0.18	0.33	0.18	0.00	0.33	0.12	0.29	**0.21*d***
	15 June	0.20	0.00	0.11	0.03	0.01	0.08	0.36	**0.11*e***
	30 June	0.08	0.19	0.02	0.00	0.10	0.04	0.00	**0.06fg**
	mean	**0.18*de***	**0.39*a***	**0.20*cd***	**0.08*fg***	**0.14*def***	**0.15*de***	**0.25*bc***	**0.20**
2012	15 April	0.01	0.33	1.19	0.27	0.02	0.74	0.03	**0.37*a***
	1 May	0.11	0.66	0.36	0.32	0.04	0.02	0.08	**0.23*d***
	15 May	0.05	0.10	0.05	0.02	0.01	0.04	0.07	**0.05*g***
	1 June	0.03	0.05	0.03	0.00	0.06	0.02	0.46	**0.09*efg***
	15 June	0.03	0.00	0.02	0.11	0.04	0.18	0.31	**0.10*ef***
	30 June	0.01	0.39	0.07	0.00	0.02	0.01	0.00	**0.07*efg***
	mean	**0.04*g***	**0.26*bc***	**0.29*b***	**0.12*ef***	**0.03*g***	**0.17*de***	**0.16*de***	**0.15**
Year average	15 April	0.03*lm*	0.55*b*	0.84*a*	0.21*e-h*	0.08*ı-m*	0.53*b*	0.08*ı-m*	**0.33*a***
	1 May	0.20*e-ı*	0.58*b*	0.23*d-h*	0.24*d-g*	0.13*f-l*	0.05*klm*	0.20*e-ı*	**0.23*b***
	15 May	0.16*f-k*	0.34*cd*	0.16*f-k*	0.08*ı-m*	0.02*lm*	0.13*f-l*	0.25*def*	**0.16*c***
	1 June	0.11*h-m*	0.19*e-j*	0.11*h-m*	0.00*m*	0.20*e-ı*	0.07*j-m*	0.38*c*	**0.15*c***
	15 June	0.12*g-m*	0.00*m*	0.07*j-m*	0.07*j-m*	0.03*lm*	0.13*f-l*	0.34*cd*	**0.11*d***
	30 June	0.05*klm*	0.29*cde*	0.05*klm*	0.00*m*	0.06*klm*	0.03*lm*	0.00*m*	**0.07*e***
	mean	**0.11*d***	**0.33*a***	**0.24*b***	**0.10*d***	**0.08*d***	**0.16*c***	**0.21*b***	**0.17**

Cr content (mg kg^{-1}) in dry bean seeds sown at different times

Years	Sowing times	Genotypes							
		Akman	**Doruk**	**Karacaşehir**	**Noyanbey**	**Sarıkız**	**Horoz**	**Sarnıç**	**mean**
2010	**15 April**	1.07	14.07	1.55	6.07	3.05	4.84	2.52	**4.74*a***
	1 May	7.39	3.72	2.37	1.77	1.66	1.65	0.97	**2.79*c***
	15 May	3.35	7.12	8.45	1.88	1.06	4.93	7.34	**4.87*a***
	1 June	2.21	2.48	1.31	1.65	4.55	3.10	3.45	**2.68*c***
	15 June	1.34	0.48	3.22	0.56	1.62	6.33	3.93	**2.50*d***
	30 June	1.31	9.76	0.20	0.97	0.70	2.05	2.24	**2.46*d***
	mean	**2.78*cd***	**6.27*a***	**2.85*c***	**2.15*de***	**2.11*de***	**3.82*b***	**3.41*bc***	**3.34**
2012	**15 April**	0.28	6.86	2.43	2.17	1.96	7.67	1.48	**3.26*b***
	1 May	2.54	5.46	2.02	2.32	0.28	0.33	1.12	**2.01*e***
	15 May	2.89	3.23	1.51	3.39	1.24	4.91	1.57	**2.68*c***
	1 June	0.72	1.67	0.50	0.78	0.97	1.61	1.77	**1.15*g***
	15 June	0.25	0.25	0.54	1.24	0.89	3.24	3.73	**1.45*f***
	30 June	0.48	2.59	0.69	1.51	0.28	0.58	0.51	**0.95*h***
	mean	**1.20*fg***	**3.34*bc***	**1.28*fg***	**1.90*ef***	**0.93*g***	**3.06*c***	**1.70*ef***	**1.92**
Year average	**15 April**	0.68*op*	10.47*a*	1.99*h-o*	4.12*def*	2.51*h-k*	6.26*b*	2.00*h-o*	**4.00*a***
	1 May	4.97*cde*	4.59*de*	2.19*h-m*	2.05*h-n*	0.97*m-p*	0.99*m-p*	1.05*l-p*	**2.40*c***
	15 May	3.12*fgh*	5.18*bcd*	4.98*de*	2.64*g-j*	1.15*l-p*	4.92*de*	4.46*de*	**3.78*b***
	1 June	1.47*ı-p*	2.08*h-n*	0.91*m-p*	1.21*k-p*	2.76*ghı*	2.36*h-l*	2.61*g-j*	**1.91*d***
	15 June	0.80*nop*	0.36*p*	1.88*h-o*	0.90*m-p*	1.26*k-p*	4.78*de*	3.83*efg*	**1.97*d***
	30 June	0.90*m-p*	6.17*bc*	0.45*p*	1.24*k-p*	0.49*p*	1.32*j-p*	1.38*j-p*	**1.71*e***
	mean	**1.99*d***	**4.81*a***	**2.07*d***	**2.03*d***	**1.52*e***	**3.44*b***	**2.55*c***	**2.63**

Table 4

Cu content (mg kg^{-1}) in dry bean seeds sown at different times

Years	Sowing times	Genotypes							
		Akman	Doruk	Karacaşehir	Noyanbey	Sarıkız	Horoz	Sarnıç	mean
2010	15 April	5.92	11.30	12.23	10.63	6.16	10.92	9.55	**9.53*a***
	1 May	12.42	8.88	6.80	7.77	6.14	7.60	5.33	**7.85*cd***
	15 May	12.21	10.04	10.70	8.30	5.90	9.93	10.66	**9.68*a***
	1 June	12.67	8.43	9.75	2.97	8.09	7.79	7.03	**8.10*bc***
	15 June	9.26	3.07	11.67	2.67	3.08	10.42	10.70	**7.27*de***
	30 June	9.99	11.71	1.08	1.42	4.93	7.67	0.68	**5.35*f***
	mean	**10.41*a***	**8.90*b***	**8.71*b***	**5.63*de***	**5.72*de***	**9.06*b***	**7.33*c***	**7.96**
2012	15 April	1.72	8.52	16.10	11.63	4.11	11.52	7.54	**8.73*b***
	1 May	5.37	13.78	11.78	8.77	1.02	2.49	2.65	**6.55*e***
	15 May	4.76	2.43	3.19	4.34	2.50	4.46	2.65	**3.47*h***
	1 June	4.80	3.71	1.95	2.89	2.07	2.41	7.10	**3.56*gh***
	15 June	1.98	1.56	2.22	3.16	2.98	8.59	9.40	**4.27*g***
	30 June	1.95	7.19	3.01	2.10	1.51	3.82	1.44	**3.00*h***
	mean	**3.43*f***	**6.20*de***	**6.37*cd***	**5.48*de***	**2.37*f***	**5.55*de***	**5.13*e***	**4.93**
Year average	15 April	3.82*j-o*	9.91*bc*	14.17*a*	11.13*b*	5.14*g-l*	11.22*b*	8.55*cde*	**9.13*a***
	1 May	8.90*cd*	11.33*b*	9.29*bc*	8.27*c-f*	3.58*k-o*	5.05*g-l*	3.99*ı-n*	**7.20*b***
	15 May	8.49*cde*	6.24*fgh*	6.95*d-g*	6.32*fgh*	4.20*h-m*	7.19*d-g*	6.66*efg*	**6.58*c***
	1 June	8.73*cde*	6.07*ghı*	5.85*g-j*	2.93*m-p*	5.08*g-l*	5.10*g-l*	7.07*d-g*	**5.83*d***
	15 June	5.62*g-k*	2.31*m-p*	6.95*d-g*	2.92*m-p*	3.03*l-p*	9.51*bc*	10.05*bc*	**5.77*d***
	30 June	5.97*ghı*	9.45*bc*	2.04*nop*	1.76*op*	3.22*l-o*	5.75*g-j*	1.06*p*	**4.18*e***
	mean	**6.92*ab***	**7.55*a***	**7.54*a***	**5.56*c***	**4.04*d***	**7.30*a***	**6.23*bc***	**6.44**

Table 5

Fe content (mg kg^{-1}) in dry bean seeds sown at different times

Years	Sowing times	Genotypes							
		Akman	**Doruk**	**Karacaşehir**	**Noyanbey**	**Sarıkız**	**Horoz**	**Sarnıç**	**mean**
2010	**15 April**	22.52	51.35	50.20	45.07	27.40	43.19	53.58	**41.90*a***
	1 May	43.15	43.11	27.77	46.22	50.47	29.51	28.16	**38.34*b***
	15 May	40.88	56.53	35.38	41.39	21.98	34.56	83.20	**44.85*a***
	1 June	58.27	32.65	33.21	15.74	43.82	29.64	38.09	**35.92*bc***
	15 June	31.39	22.85	39.46	12.21	12.69	68.54	43.06	**32.88*c***
	30 June	37.27	49.68	6.04	7.87	23.21	35.40	5.10	**23.51*e***
	mean	**38.91*a***	**42.70*a***	**32.01*bc***	**28.08*cde***	**29.93*bcd***	**40.14*a***	**41.87*a***	**36.23**
2012	**15 April**	11.01	32.51	69.22	42.28	15.66	32.58	37.56	**34.40*c***
	1 May	16.86	73.60	52.18	32.26	8.41	9.12	10.94	**29.05*d***
	15 May	17.46	14.48	10.67	19.47	13.73	17.17	20.52	**16.21*f***
	1 June	19.14	17.27	6.80	13.95	12.23	8.49	29.37	**15.32*f***
	15 June	6.08	34.23	7.86	13.46	11.37	46.40	32.89	**21.76e**
	30 June	8.03	30.00	11.99	11.36	7.73	15.50	8.51	**13.30*f***
	mean	**13.10*g***	**33.68*b***	**26.45*def***	**22.13*f***	**11.52*g***	**21.54*f***	**23.30*ef***	**21.67**
Year average	**15 April**	16.77*o-u*	41.93*cd*	59.71*a*	43.67*bcd*	21.53*j-r*	37.88*c-g*	45.57*bc*	**38.15*a***
	1 May	30.01*e-k*	58.36*a*	39.97*cde*	39.24*c-f*	29.44*f-l*	19.32*l-s*	19.55*l-s*	**33.70*b***
	15 May	29.17*f-m*	35.50*c-h*	23.03*j-q*	30.43*e-j*	17.86*n-t*	25.87*h-o*	51.86*ab*	**30.53*c***
	1 June	38.70*c-f*	24.96*ı-p*	20.00*k-r*	14.85*p-u*	28.03*g-n*	19.07*l-t*	33.73*d-ı*	**25.62*d***
	15 June	18.73*m-t*	28.54*g-m*	23.66*ı-p*	12.84*q-u*	12.03*r-u*	57.47*a*	37.97*c-g*	**27.32*d***
	30 June	22.65*j-q*	39.84*cde*	9.01*tu*	9.62*stu*	15.47*o-u*	25.45*h-o*	6.81*u*	**18.41e**
	mean	**26.00*cd***	**38.19*a***	**29.23*bc***	**25.11*d***	**20.73*e***	**30.84*b***	**32.58*b***	**28.95**

Table 6

Ni content (mg kg^{-1}) in dry bean seeds sown at different times

Years	Sowing times	Genotypes							
		Akman	Doruk	Karacaşehir	Noyanbey	Sarıkız	Horoz	Sarnıç	mean
2010	15 April	5.13	12.35	9.67	10.29	5.22	11.10	7.45	**8.75*a***
	1 May	11.9	9.72	6.90	8.86	6.06	8.58	4.98	**8.15*ab***
	15 May	10.60	10.18	7.63	8.30	4.50	9.89	8.58	**8.53*ab***
	1 June	10.30	8.83	7.32	2.98	6.93	8.73	5.92	**7.29*c***
	15 June	9.19	3.31	9.50	2.83	2.81	8.83	8.11	**6.37*d***
	30 June	8.92	10.54	1.55	1.70	5.02	7.75	1.20	**5.24*e***
	mean	**9.35*a***	**9.16*a***	**7.10*b***	**5.83*cde***	**5.09*ef***	**9.15*a***	**6.04*cde***	**7.39**
2012	15 April	1.95	8.08	13.89	10.24	3.41	11.61	7.01	**8.03*b***
	1 May	5.73	14.89	13.57	8.53	1.01	2.77	2.55	**7.01*c***
	15 May	4.38	2.69	2.80	3.73	2.46	4.89	2.56	**3.36*f***
	1 June	4.50	3.93	1.71	2.73	1.92	3.00	6.15	**3.42*f***
	15 June	2.07	1.48	2.03	3.72	2.86	8.23	7.83	**4.03*f***
	30 June	2.22	8.45	3.79	2.55	1.77	4.08	2.10	**3.56*f***
	mean	**3.48*g***	**6.59*bc***	**6.30*bcd***	**5.25*def***	**2.24*h***	**5.76*cde***	**4.70*f***	**4.90**
Year average	15 April	3.54*l-p*	10.22*bc*	11.78*ab*	10.27*bc*	4.32*j-n*	11.36*ab*	7.23*e-h*	**8.39*a***
	1 May	8.85*cde*	12.31*a*	10.24*bc*	8.70*cde*	3.54*l-p*	5.68*g-k*	3.77*k-o*	**7.58*b***
	15 May	7.49*efg*	6.43*f-ı*	5.22*h-l*	6.02*f-j*	3.48*l-p*	7.39*efg*	5.57*g-k*	**5.94*c***
	1 June	7.40*efg*	6.38*f-ı*	4.51*ı-m*	2.86*m-p*	4.43*ı-m*	5.86*g-j*	6.04*f-j*	**5.35*d***
	15 June	5.63*g-k*	2.40*nop*	5.76*g-j*	3.28*l-p*	2.84*m-p*	8.53*cde*	7.97*def*	**5.20*d***
	30 June	5.57*g-k*	9.49*cd*	2.67*m-p*	2.13*op*	3.39*l-p*	5.91*g-j*	1.65*p*	**4.40*e***
	mean	**6.41*b***	**7.87a**	**6.70*b***	**5.54c**	**3.66*d***	**7.45*a***	**5.37*c***	**6.14**

Table 7

Pb content (mg kg^{-1}) in dry bean seeds sown at different times

Years	Sowing times	Genotypes							
		Akman	Doruk	Karacaşehir	Noyanbey	Sarıkız	Horoz	Sarnıç	mean
2010	15 April	0.30	0.06	0.17	0.13	0.12	0.04	0.19	**0.14*bc***
	1 May	0.00	0.19	0.00	0.18	0.19	0.18	0.00	**0.10*ef***
	15 May	0.18	0.12	0.40	0.10	0.20	0.05	0.10	**0.16*b***
	1 June	0.00	0.07	0.12	0.00	0.22	0.14	0.33	**0.13*cd***
	15 June	0.01	0.07	0.00	0.14	0.03	0.30	0.22	**0.11*de***
	30 June	0.08	0.00	0.02	0.00	0.09	0.20	0.30	**0.10*ef***
	mean	**0.10*def***	**0.08*f***	**0.12*cde***	**0.09*ef***	**0.14*bc***	**0.15*bc***	**0.19*a***	**0.12**
2012	15 April	0.17	0.01	0.03	0.19	0.18	0.01	0.03	**0.09*ef***
	1 May	0.00	0.17	0.00	0.21	0.03	0.16	0.00	**0.08*f***
	15 May	0.25	0.20	0.47	0.36	0.22	0.17	0.34	**0.29*a***
	1 June	0.00	0.11	0.31	0.00	0.15	0.02	0.19	**0.11*de***
	15 June	0.03	0.25	0.00	0.05	0.12	0.50	0.04	**0.14*bc***
	30 June	0.01	0.00	0.06	0.01	0.33	0.03	0.20	**0.09*ef***
	mean	**0.08*f***	**0.12*cde***	**0.15*bc***	**0.14*bc***	**0.17*ab***	**0.15*bc***	**0.13*cd***	**0.13**
Year average	15 April	0.24*bcd*	0.03*pqr*	0.10*k-o*	0.16*f-k*	0.15*g-l*	0.02*qr*	0.11*j-n*	**0.12*b***
	1 May	0.00*r*	0.18*d-ı*	0.00*r*	0.19*c-h*	0.11*j-n*	0.17*e-j*	0.00*r*	**0.09*c***
	15 May	0.22*b-f*	0.16*f-k*	0.44*a*	0.23*b-e*	0.21*b-g*	0.11*j-n*	0.22*b-f*	**0.23*a***
	1 June	0.00*r*	0.09*l-p*	0.21*b-g*	0.00*r*	0.19*c-h*	0.08*m-q*	0.26*b*	**0.12*b***
	15 June	0.02*qr*	0.16*f-k*	0.00*r*	0.09*l-p*	0.08*m-q*	0.40*a*	0.13*h-m*	**0.13*b***
	30 June	0.05*n-r*	0.00*r*	0.04*o-r*	0.01*r*	0.21*b-g*	0.12*ı-m*	0.25*bc*	**0.10*c***
	mean	**0.09*d***	**0.10*d***	**0.13*bc***	**0.11*cd***	**0.16*a***	**0.15*ab***	**0.16*a***	**0.12**

Table 8

Zn content (mg kg^{-1}) in dry bean seeds sown at different times

Years	Sowing times	Genotypes							
		Akman	Doruk	Karacaşehir	Noyanbey	Sarıkız	Horoz	Sarnıç	mean
2010	15 April	13.22	22.77	25.58	18.63	12.24	29.74	24.48	**20.95*a***
	1 May	25.85	16.09	14.26	15.01	13.53	19.37	10.94	**16.44*c***
	15 May	23.69	19.73	23.34	17.03	12.13	19.30	22.44	**19.67*b***
	1 June	24.08	15.65	17.14	6.16	16.07	15.68	13.06	**15.41*c***
	15 June	18.32	5.73	20.96	6.29	6.34	21.08	20.49	**14.17*d***
	30 June	19.01	23.48	2.23	3.08	10.63	19.53	1.72	**11.38*f***
	mean	**20.70*a***	**17.24*b***	**17.25*b***	**11.03*c***	**11.82*e***	**20.78*a***	**15.52*b***	**16.34**
2012	15 April	3.23	15.41	26.96	21.28	7.72	21.61	15.38	**15.94*c***
	1 May	9.76	25.33	25.63	15.39	2.25	5.41	5.47	**12.75*e***
	15 May	9.13	5.08	6.32	9.24	5.51	9.41	5.77	**7.21*h***
	1 June	9.35	6.38	3.39	5.90	4.09	4.66	12.58	**6.62*h***
	15 June	3.79	2.78	4.07	8.62	5.79	19.57	17.60	**8.89*g***
	30 June	3.65	14.41	5.63	4.21	3.28	9.03	2.90	**6.16*h***
	mean	**6.49*d***	**11.57*c***	**12.00*c***	**10.77*c***	**4.77*d***	**11.62*c***	**9.95*c***	**9.59**
Year average	15 April	8.22*m-p*	19.09*bcd*	26.27*a*	19.96*bc*	9.98*k-o*	25.68*a*	19.93*bc*	**18.45*a***
	1 May	17.81*b-e*	20.71*b*	19.95*bc*	15.20*d-h*	7.89*m-q*	12.39*g-l*	8.20*m-p*	**14.59*b***
	15 May	16.41*c-g*	12.41*g-l*	14.83*e-h*	13.14*f-k*	8.82*l-o*	14.36*e-ı*	14.10*e-k*	**13.44*c***
	1 June	16.72*b-f*	11.02*h-n*	10.27*ı-n*	6.03*o-s*	10.08*j-o*	10.17*ı-o*	12.82*f-l*	**11.01*d***
	15 June	11.06*h-n*	4.25*p-s*	12.52*g-l*	7.46*m-r*	6.07*o-s*	20.33*bc*	19.05*bcd*	**11.53*d***
	30 June	11.33*h-m*	18.94*bcd*	3.93*qrs*	3.64*rs*	6.96*n-r*	14.28*e-j*	2.31*s*	**8.77*e***
	mean	**13.59*bc***	**14.40*b***	**14.63*b***	**10.90*d***	**8.30*e***	**16.20*a***	**12.74*c***	**12.96**

The content of chromium in dry bean seeds showed statistical significance ($p < 0.01$) for sowing dates, year x sowing time, genotype, year x genotype, sowing time x genotype and year x sowing time x genotype factors and ranged from 0.36 mg kg^{-1} (Doruk sown on 15th of June) to 10.47 mg kg^{-1} (Doruk sown on 15th of April). According as sowing dates, the highest accumulation was found in Doruk and the lowest in Sarıkız. Similar findings were revealed for the chromium content (0.21-19.98 mg kg^{-1}) in another study (Kahraman, Onder, 2013) which was also conducted in Konya and included 41 bean genotypes. Other studies reported the chromium content as 0.08-0.31 mg kg^{-1} (Cabrera et al. 2003) in legumes and 2.06 - 87.15 mg kg^{-1} in various plants (Onder, Dursun 2006). In the present research, the content of chromium was reduced by late sowing.

Analyses of variance for the copper content in the study showed significance at a level of 1% for sowing date, year x sowing time, genotype, year x genotype, sowing time x genotype and year x sowing time x genotype factors, which ranged between 1.06 mg kg^{-1} (Sarnıç genotype sown on 30th of June) and 14.17 mg kg^{-1} (Karacaşehir-90 genotype sown on 15th of April). Seeds of the dry bean genotypes showed the highest Cu accumulation in Doruk and the lowest one in Sarıkız by sowing dates. The copper content was reported as 0.94 - 10.00 mg kg^{-1} in bean seeds (Kahraman, Onder 2013), and 7.65 - 8.19 mg kg^{-1} in pods (Taskin 2012). The present study indicated that late sowing of dry bean led to a decrease in the copper content of dry bean seeds.

The iron content evaluated in the present research showed statistically significant differences ($p < 0.01$) for sowing date, year x sowing time, genotype, year x genotype, sowing time x genotype and year x sowing time x genotype factors, ranging from 6.81 mg kg^{-1} (Sarnıç genotype sown on 30th of June) to 59.71 mg kg^{-1} (Karacaşehir-90 genotype sown on 15th of April) values. The content of Fe in the seeds accumulated the most in Doruk and the least accumulated in Sarıkız in accordance with the sowing dates. Similarly, these values were between 114.86 - 223.52 mg kg^{-1} (Kahraman 2012) in plants. In general, the iron content of the dry bean seeds of the genotypes decreased due to late sowing as a mean of the trial years in the present study. Iron is essential for the human body and has many effects on the body's growth and development, being involved in oxygen transport to tissues.

The present research showed statistical significance (1%) all of the subjected factors (except for the year) and their interactions with respect to the nickel content, which changed from 1.65 mg kg^{-1} (Sarnıç genotype sown on 30th of June) to 12.31 mg kg^{-1} (Doruk genotype sown on 1st of May). The tested sowing dates resulted in the highest Ni accumulation in Doruk and the lowest in Sarıkız. The nickel content has been reported as 0.7 - 12.7 mg kg^{-1} (Kahraman, Onder 2013) in dry bean seeds and 22.50 - 89.63 mg kg^{-1} (Kahraman 2012) in dry bean plants. According to the present results, the nickel content of dry bean seeds showed a decreasing trend due to late sowing as a mean value of the years.

Variance analysis for lead in the present research was statistically significant at a 1% level for all the subjected factors (except for the year) and their interactions, and the mean values were between 0.00 mg kg^{-1} and 0.44 mg kg^{-1} (Karacaşehir genotype sown on 15th of May). Accumulation of Pb depending on the sowing time was highest in Sarıkız and Sarnıç while being the lowest in Doruk. Other relevant studies reported the lead values as 0.37 mg kg^{-1} - 0.69 mg kg^{-1} in legumes (Cabrera et al. 2003) and 0.00 - 0.60 mg kg^{-1} (Kahraman, Onder 2013) in bean seeds. The content of DNA and RNA decreased in bean seedlings due to elevated lead concentrations (Hamid et al. 2010). Results of the present study showed variation in the lead content over the changing sowing time.

Results of the statistical analysis for the zinc content in the present research showed significant differences ($p < 0.01$) for all of the factors (except for the year) and interactions, while mean of the values ranged from 2.31 mg kg^{-1} (Sarnıç genotype sown on 30th of June) to 26.27 mg kg^{-1} (Karacaşehir genotype sown on 15th of April). The highest value for Zn accumulation was found in Horoz and the lowest one in Sarıkız. Similar values of the lead content in beans were reported as 43.04 - 63.72 mg kg^{-1} (Yilmaz, Alagoz 2009), 13.76 - 38.29 mg kg^{-1} (Kahraman 2012). Zinc deficiency in plant production causes significant decreases in yield across the world, for example in wheat production in India (Takkar et al. 1997) and Australia (Graham et al. 1992), while its deficiency in soil is leads to a worse quality of plants (Masroor et al. 2016). As a mean value for the years, the content of lead in dry bean seeds showed a decreasing trend by delayed sowing in the present study.

Overall, the data gathered in the tables prove that the date of sowing caused the highest accumulation of Co, Cr, Cu, Fe and Ni in the Doruk variety, while the same elements were at their lowest in the Sarıkız genotype. Furthermore, the genotypes Sarıkız and Sarnıç accumulated the most of Pb while the Horoz genotype accumulated the most of Zn.

CONCLUSIONS

Evaluation of heavy metal content in dry bean (*Phaseolus vulgaris* L.) seeds that were sown on different dates showed the following status as means of the years:

1. Delayed sowing caused a certain decrease in the cobalt, copper, nickel and zinc amounts in seeds,

2. In general, content of chromium and iron in dry bean seeds decreased due to delayed sowing,

3. The cadmium and lead content of dry bean seeds was variable depending on different sowing dates, while the highest amount of lead was determined in seeds of plants sown on 15th of May, a popular sowing time in the region of Konya, which has the highest dry bean production in Turkey,

4. Variations among the investigated elements were statistically significant ($p < 0.01$) with respect to the sowing time and genotype factors and interactions of the factors (sowing date, year x sowing time, genotype, year x genotype, sowing time x genotype, year x sowing time x genotype) in the trial.

Overall, seed accumulation of the heavy metals depending on sowing dates in the tested dry bean genotypes was the highest in the Doruk variety (for: Co, Cr, Cu, Fe, Ni), Sarnıç genotype (for: Cd, Pb) and Horoz genotype (for: Zn), being the lowest in the Sarıkız genotype (Cd, Cr, Cu, Fe, Ni, Zn), Akman variety (for: Co). Additionally, it was interesting that the accumulation of Pb was highest in the Sarıkız genotype and lowest in the Doruk variety. Finally, our observations of changes in the heavy metal accumulation in the seeds of dry bean genotypes depending on sowing dates may be useful for quality-focused studies.

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