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ASSESSMENT OF MINERAL ELEMENTS CONTENT OF DIFFERENT SESAME GENOTYPES

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Abstract

Mineral elements are play important role in plants, animals and the human body. Micronutrient deficiencies are a vital problem and affected over 3 billion people in the World. Biofortification is one of the effective and sustainable interventions to fight micronutrient deficiency. Sesame contains an average of 50% oil and 85% of this oil consists of unsaturated fatty acids. However, despite its high oil content, sesame is mostly utilized as a whole seed in the world. Therefore, it is important to determine the mineral elements contained in sesame seeds. This study was conducted to assess for 9 mineral element content of 55 sesame genotypes from 22 countries. The N, P, K, Ca, Mg, Fe, Zn, Mn and Cu contents were varied between 20.9-38.1, 2-9.9, 3.2-9.9, 8.2-24.8, 5-8.1 g kg^{-1}, 18.9-280.8 mg kg^{-1}, 38.2-88.9 mg kg^{-1},12.5-25.7 mg kg^{-1} and 15.3-45.7 mg kg^{-1}, respectively.

Key words: *sesame, biofortification, iron, zinc, hidden hunger.*

INTRODUCTION

The human body requires around 40 known nutrients in optimum amounts to live a healthy and productive life.

These nutrients play crucial roles in human physical and mental development (White and Broadley, 2005). After the 1960's, agricultural researchers have focused on increasing agricultural productivity not quality of crops (Karaköy et al., 2012; Kurt et al., 2018). However, this has led to unforeseen negative consequences such as an increase in the prevalence of micronutrient malnutrition diseases. Today, micronutrient malnutrition is estimated to affect over half of global population. Deficiencies in Fe and Zn are the most common types of micronutrient malnutrition in the world. More than 2 billion people are affected by Fe deficiency while over 1 billion people are Zn and Se deficient (Pandey et al., 2017; Kurt et al., 2020).

The primary reason for the prevalence of mineral malnutrition worldwide is the consumption of foods with very low micronutrient content.

Also, micronutrient malnutrition affects about 38% of pregnant women and 43% of pre-school children worldwide. Interventions to decrease the issue of mineral malnutrition have been implemented such as food fortification, pharmaceutical supplementation and dietary diversification (Steina et al., 2005). However, none of these approaches have proven sustainable for various reasons such as poor delivery systems and infrastructure in developing countries. Biofortification is the process of increasing the bioavailable concentrations of vitamins and minerals in edible crops through agronomic practices, plant breeding or genetic selection to improve nutritional status (White and Broadley, 2005; Kanatti et al., 2014; Bouis and Saltzman, 2017). Fertilization is one of the remedies used to enhance mineral concentration in staple crops. Though this intervention increases leaf mineral concentrations and improves yield, it does not always enhance mineral concentration in the seed (White and Broadley, 2005). Additionally, use of fertilisers may be problematic, both economically and environmentally. Exploitation of natural biodiversity to improve the micronutrient quality of staple crops is important in breeding programs.

Sesame (*Sesamum indicum* L.) seed, the oldest oilseed crops known, is used mostly in bakery products and also made into tahini (sesame butter) and halva (sweet confections made from tahini) (Kurt et al., 2020).

Sesame seed contains oil (50%), protein (24%) and microelements (Fe, Zn, Ca, Mg, and Cu etc.).

Although sesame is generally grown in developing countries, it is consumed in varying amounts by almost every country. Hence, it is important to determine the nutrient content of sesame genotypes to provide the necessary nutritional information to the grower and consumer. Also, characterization of genetic resources has always remained one of the important methods of the breeders to investigate the novel variations which can be used for the development of improved cultivars expressing higher yield with better quality, biotic and abiotic stress resistance (Martins et al., 2006; Kurt et al., 2020).

The aim of this study was to evaluate the variability of 9 mineral elements (Fe, Zn, Cu, Mn, N, P, K, and Mg) among 55 sesame accessions from Turkey and 22 other countries.

MATERIALS AND METHODS

Plant Material. A panel of fifty-five sesame accessions was used as plant material in this study (Table 1). The field experiment was conducted in an augmented design at the Experimental Farm of Cukurova University (37.014564, 35.356717, and 23 m) in Adana, Turkey during the 2019 growing season. Before planting, 200 kg ha^{-1} of diammonium phosphate (36 kg ha^{-1} N, 92 kg ha^{-1} P) fertilizer was applied, while ammonium nitrate (33% N) at the rate of 200 kg ha^{-1} was applied before the first irrigation. Sesame seeds were sown in the second week of June. The accessions were grown in two-row plots of 5 m row length with a row spacing of 70 cm and intra-row spacing of 15 cm. Thinning was carried out after 25 days of sowing to secure one plant per 15 cm. Sprinkler irrigation was established immediately after sowing and thereafter used as needed. Weeding was carried out by hand and no herbicides were applied during the experiment. All the plants were harvested by hand in the last week of September.

Microelement analysis. Samples from 55 genotypes grown in 2019 were subjected to mineral element analysis using an inductively coupled plasma optical emission spectrometer (ICPOES; Vista-Pro Axial; Varian Pty Ltd., Australia). Clean sesame seed samples were taken from every population with 3 replicates and the seeds were bulked. Analysis of the microelements was performed according to the method described by Karaköy et al. in 2012.

Table 1. The list of sesame accessions

Origins	Origins	Origins	Origins
Afghanistan1	Japan 2	Taiwan	Turkey-Kütahya-Gediz
Afghanistan2	Japan 3	Turkey- Diyarbakır -Ergani-Dağarası 2	Turkey-Kütahya-Tavşanlı
China 1	Jordan	Turkey-Diyarbakır-Bismil-Bakacak	Turkey-Orhangazi-99 ©
China 2	Libya 1	Turkey-Diyarbakır-Ergani-Gisgis	Turkey-Osmaniye
Egypt	Libya 2	Turkey-Diyarbakır-Ergani-Gülbaran	Turkey-Şanlıurfa-Suruç
Greece	Mexico	Turkey-Diyarbakır-Lice-Duruköy	Turkey-Tekirdağ-Şarköy
India 1	Mozambique	Turkey-Izmir1	Turkey-Uşak-Sivaslı
India 2	Myanmar	Turkey-Izmir2	USA
Iran	Nepal	Turkey-Izmir3	Venezuala 1
Iraq	Pakistan	Turkey-Izmir4	Venezuela 2
Israel 1	Russia	Turkey-Izmir5	Zaire
Israel 2	South Korea 1	Turkey-Izmir-Tire	
Japan 1	South Korea 2	Turkey-İçel-Anamur	

RESULTS AND DISSCUSSIONS

Although sesame is one of the important oil plants, it is also a rich food source in terms of minerals such as Fe, Zn, and Mg. The nine mineral elements found in 55 sesame accessions from different countries are shown in Table 2 and Table 3. The mean values obtained were 56.32, 66.79, 18.45, 28.08 mg/kg, 3.03, 0.50, 0.65, 1.768, 0.722% for Fe, Zn, Mn, Cu, N, P, K, Ca and Mg, respectively. The sesame accessions contained high amounts of N, P, K, Ca and Mg with mean values of 30.3, 5, 6.5, 17.68 and 7.22 g kg^{-1}, respectively (Table 2).

Table 2. Macro element content of sesame accessions

Origins	Seed color	N g kg^{-1}	P g kg^{-1}	K g kg^{-1}	Ca g kg^{-1}	Mg g kg^{-1}
Afghanistan 1	BLK	30.2	4.3	6.1	22.3	7.5
Afghanistan 2	DB	26.2	6.5	6.5	23.4	7.4
China 1	LB	31.0	3.9	7.1	18.1	7.6
China 2	G	31.8	3.5	4.9	20.7	6.4
Egypt	W	34.0	3.8	6.6	12.8	7.2
Greece	BLK	33.2	5.3	6.9	27	7.6
India 1	BLK	31.9	5.3	6.1	20	7
India 2	W	30.5	**2**	6.6	**24.8**	7.7
Iran	Y	30.4	3	5.9	18.5	**5**
Iraq	BLK	29.5	3.6	5.6	22.6	7.5
Israel 1	DB	32.4	4.6	5.7	20.8	7.7
Israel 2	BLK	**38.1**	6.7	6.4	23.6	7
Japan 1	BLK	35.3	4.6	5.8	18.6	7.4
Japan 2	DB	31.2	3.2	6	24.4	7.5
Japan 3	DW	31.8	3.4	6.5	16.4	7.8
Jordan	W	29.8	**9.9**	4.5	**8.2**	5.3
Libya 1	B	29.8	3.9	7.1	21.4	7.6
Libya 2	BLK	32.7	9.8	6.4	10.3	6.4
Mexico	B	32.1	3.7	6.6	24.4	7.4
Mozambique	W	30.2	4.6	7.2	18	7.6
Myanmar	DG	30.2	3.5	5.2	27	6.8
Nepal	DB	26.9	4.5	**3.2**	15.6	5.5
Pakistan	W	31.0	4.5	7.2	21.3	7.2
Russia	DB	29.9	6.2	7.7	21.2	7.5
South Korea 1	DW	31.8	3.8	7.5	14.9	8
South Korea 2	BLK	32.8	2.8	6.1	18.9	7.5
Taiwan	BLK	34.4	3.1	5.6	21.7	7.3
Turkey- Diyarbakir -Ergani-Dagarasi 2	B	27.6	3.9	7	23.9	7.8
Turkey- Sanlıurfa -Siverek-Yuvakoy	LB	27.2	8.7	6.1	20.1	6.9
Turkey-Balikesir-Bandirma	W	27.1	9.1	4.3	9.1	8.1
Turkey-Bursa-Orhangazi	LB	32.7	4.9	7.8	10.3	7.7
Turkey-Denizli-Acipayam	LB	31.1	5.7	6.1	16.2	7.7
Turkey-Diyarbakir -Ergani-Dagarasi 1	LB	32.8	2.9	5.7	18.9	7.8
Turkey-Diyarbakir-Bismil-Bakacak	BLK	25.5	3.3	6.3	17.5	6.7
Turkey-Diyarbakir-Ergani-Gisgis	B	29.3	4.6	5.7	16.1	6.3
Turkey-Diyarbakir-Ergani-Gülbaran	DB	27.9	1.5	5.7	18.1	6.8
Turkey-Diyarbakir-Lice-Durukoy	DB	28.6	4.1	6.1	16.6	7
Turkey-Izmir 1	B	28.3	4.5	9	16	7.5
Turkey-Izmir 2	DB	26.7	4.9	5.7	21	7.3
Turkey-Izmir 3	DB	25.7	8.5	**9.9**	13.3	7.4
Turkey-Izmir 4	W	28.5	3.8	4.4	10.4	5.6
Turkey-Izmir 5	Y	34.6	5.3	6.7	21.6	8
Turkey-Izmir-Tire	LB	25.8	3.4	7.1	16.2	7.6
Turkey-İcel-Anamur	LB	26.2	8.5	5.7	16.8	7.6
Turkey-Kutahya-Gediz	BLK	29.8	5.2	6.4	12.1	7
Turkey-Kutahya-Tavsanli	W	24.5	3.7	6.8	10.3	6.6
Turkey-Orhangazi-99 ©	B	35.0	7.1	9.2	16.3	7.9
Turkey-Osmaniye	B	31.3	5.4	5.5	14.1	7.3
Turkey-Sanlıurfa-Suruc	LB	29.6	3.6	7.7	9.8	6.9
Turkey-Tekirdağ-Sarkoy	B	**20.9**	5.4	6.1	11.8	7.3
Turkey-Usak-Sivasli	Y	27.8	9.1	6.2	13.2	7
USA	B	31.1	7.7	7.3	17.2	**8.1**
Venezualla 1	DW	34.1	8.9	8.9	19.2	8
Venezuella 2	W	33.8	4.3	7.5	20.9	8
Zaire	W	33.8	5.7	7	8.7	7
Average		**30.3**	**5.0**	**6.5**	**17.68**	**7.22**
Min.		**20.9**	**2.0**	**3.2**	**8.2**	**5.0**
Max.		**38.1**	**9.9**	**9.9**	**24.8**	**8.1**

©: Turkish cultivar; B: Brown; DB: Dark Brown; LB: Light Brown; BLK: Black; Y: Yellow; W: White; DW: Dirty White; G: Grey

Table 3. Micro elements content of sesame accessions

Origins	Seed color	Fe (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Cu (mg/kg)
Afghanistan 1	BLK	73.2	67.3	19.7	40.2
Afghanistan 2	DB	51	66.7	17.5	18.9
China 1	LB	51	61.1	16.1	24.8
China 2	G	91.2	50.3	15.4	32.8
Egypt	W	66	60.6	12.8	40.4
Greece	BLK	59.4	68.4	19.7	30.1
India 1	BLK	53.1	48.7	17.1	37.2
India 2	W	46.8	67.5	13.7	28.6
Iran	Y	60	66	13.6	33.2
Iraq	BLK	43.2	71.9	22	24.6
Israel 1	DB	61.5	65.1	14.9	16.6
Israel 2	BLK	71.4	80.4	23.2	23.3
Japan 1	BLK	77.4	64	16.4	37.3
Japan 2	DB	43.2	69.5	17.1	18
Japan 3	DW	63.3	73	17	37.2
Jordan	W	40.6	45.3	14	15.5
Libya 1	B	55.5	78.7	17.9	23.1
Libya 2	BLK	27.6	58.7	17.1	20.7
Mexico	B	41.1	64.6	17.8	30.8
Mozambique	W	34.2	69.6	**12.5**	15.7
Myanmar	DG	61.8	71.9	20.2	26.1
Nepal	DB	48	47.4	11.7	23.1
Pakistan	W	27.3	52.5	22.1	25.4
Russia	DB	75	50.4	20.6	40.6
South Korea 1	DW	31.8	79.1	19.9	27.5
South Korea 2	BLK	**280.8**	80.2	23.0	32.1
Taiwan	BLK	75.3	79.7	16.1	39
Turkey- Diyarbakir -Ergani-Dagarasi 2	B	48	79.7	20.4	26.7
Turkey- Sanlıurfa -Siverek-Yuvakoy	LB	36.6	72.8	23.1	31.6
Turkey-Balikesir-Bandirma	W	25.7	**38.2**	14.6	15.3
Turkey-Bursa-Orhangazi	LB	26.1	74	19.4	24.6
Turkey-Denizli-Acipayam	LB	33.6	68.6	15.4	22.3
Turkey-Diyarbakir -Ergani-Dagarasi 1	LB	43.8	71.9	16	31.1
Turkey-Diyarbakir-Bismil-Bakacak	BLK	31.2	64.6	22.2	27.7
Turkey-Diyarbakir-Ergani-Gisgis	B	**178.5**	65.4	**25.7**	32.7
Turkey-Diyarbakir-Ergani-Gülbaran	DB	24.6	58.4	22	19.7
Turkey-Diyarbakir-Lice-Durukoy	DB	48.3	75.7	20.9	23.3
Turkey-Izmir 1	B	61.8	76.6	25.2	39.3
Turkey-Izmir 2	DB	77.7	68.3	22	37.4
Turkey-Izmir 3	DB	78	74.7	22.1	36.9
Turkey-Izmir 4	W	68.7	70.1	20.9	**45.7**
Turkey-Izmir 5	Y	55.8	74.3	12.8	12.9
Turkey-Izmir-Tire	LB	34.8	60.1	22.6	29
Turkey-İcel-Anamur	LB	33.3	55.5	14.5	27.1
Turkey-Kütahya-Gediz	BLK	30.6	65.5	19.4	28.5
Turkey-Kütahya-Tavsanli	W	**18.9**	73.5	21.7	25.4
Turkey-Orhangazi-99 ©	B	34.8	**88.9**	23.7	25.7
Turkey-Osmaniye	B	56.4	64.8	16.4	35.3
Turkey-Sanlıurfa-Suruc	LB	31.8	59.3	23.7	32.7
Turkey-Tekirdağ-Sarkoy	B	49.8	66.5	16.6	29.3
Turkey-Usak-Sivasli	Y	36	59.6	15	19.2
USA	B	72	76.6	20.2	30.5
Venezuala 1	DW	60	62.4	17.4	28.2
Venezuela 2	W	42	83.8	13.5	**12.9**
Zaire	W	48	65	18.5	30.6
Average		**56.32**	**66.79**	**18.45**	**28.08**
Min.		**18.90**	**38.20**	**12.50**	**12.9**
Max.		**280.8**	**88.9**	**25.7**	**45.7**

©: Turkish cultivar; B: Brown; DB: Dark Brown; LB: Light Brown; BLK: Black; Y: Yellow; W: White; DW: Dirty White; G: Grey

These values were higher than reported in previous studies (Deme et al., 2017; Wacal et al., 2019; Özcan, 2006). The Recommended Daily Intakes (RDIs) of Mg for adult men is 350 mg, while for women this value is 300 mg. For children aged 3 to < 10 years, an RDI for magnesium is set at 230 mg/day for both sexes (EFSA, 2015). The results show that sesame seeds are an alternative food source that will contribute to meet the daily Mg need for children.

The Mn values of the 55 sesame accessions varied between 12.5-25.7 mg kg^{-1} and the average being 18.45 mg kg^{-1}. Turkey-Diyarbakır-Ergani-Gisgis accession had the highest Mn (25.7 mg kg^{-1}) and the lowest was for Mozambique (12.5 mg kg^{-1}). The Cu values ranged from 12.9 (Venezuela 2) to 45.7 (Turkey-Izmir 4) mg kg^{-1} is the average value 28.08 mg kg^{-1}. The Cu content in this study was higher than that reported by Hu and Zhou (2019), Wacal et al. (2019), Kurt et al. (2018) and Pandey et al. (2017). Zinc is one of the most important micronutrients in biological systems and plays a vital role in protein synthesis and metabolism. Several Zn-binding proteins are transcription factors necessary for gene regulation and necessary for more than half of enzymes and proteins involved in ion transport (Andreini et al., 2006). Any decrease in Zn concentration in the human body may result in a number of cellular dysfunctions, including a high susceptibility to infectious diseases, retardation of mental development, and stunted growth of children (Black, 2003). The highest Zn value was obtained from the Turkey-Orhangazi-99 cultivar (88.9 mg kg^{-1}), while the lowest value was obtained from Turkey-Balikesir-Bandirma accession (38.2 mg kg^{-1}). The most of Turkish accessions had Zn content higher than the mean value.

The RDIs of Zn for adult men is 11 mg, while for women this value is 8 mg. This value is 5 mg/day for children <8 years old. Due to its high zinc content, sesame has the potential to be an important food source in fighting zinc deficiency, especially in children. In fact, if approximately 30 grams of sesame seeds are eaten daily from Orhangazi-99 variety, half of the daily need will be met. Although iron is very important for human health, it is the most common micro element deficiency. The most important reason for this is feeding with cereals with low iron content. Fe content in sesame accessions of different origins ranges from 18.9 (Turkey-Kütahya-Tavsanli) to 280.8 (South Korea 2).

Among the Turkish accessions, the highest Fe content belonged to the Turkey-Diyarbakir-Ergani-Gisgis accession (178.5 mg kg^{-1}), while the Turkey-Kütahya-Tavsanli (18.9 mg kg^{-1}) accession had the lowest value. In the present study, the average Fe content value was lower than reported in earlier studies (Hu and Zhou, 2019; Wacal et al., 2019; Kurt et al., 2018; Obiajunwa et al., 2005), while higher than Deme et al. (2017). It has been determined that there is a significant variation between sesame accessions in terms of the traits examined.

CONCLUSIONS

In this study, significant variation was found in all studied mineral elements among sesame accessions from different origins.

The results show that sesame seeds contain rich essential mineral elements important for the human body and can play an important role in fighting malnutrition.

Sesame breeders can use the results of the present study to further the breeding programs for the development of new biofortified varieties.

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