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Determination of Some Metals in Popcorn (*Zea mays* L.) Genotypes

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The study was conducted to determine some minerals in popcorn genotypes. Twenty genotypes, hybrid and open-pollinated, were evaluated for potassium, calcium, magnesium, sodium, copper, zinc, manganese and iron contents. The samples were analyzed by flame atomic absorption spectrometry. Contents of K, Ca, Mg and Na of the kernel of genotypes varied from 429–519, 45.8–126, 25.5–42.9 and 20.6–80.8 mg/kg, respectively while the ranges of trace elements were 1.73–11.89 for Cu, 39.0–63.0 for Zn, 13.7–46.5 for Mn and 57.9–112.0 mg/kg for Fe. In general, contents of trace elements tended to be higher in hybrids than open-pollinated populations.

Key Words: Popcorn, Macronutrients, Trace metals, Atomic absorption spectrometry.

INTRODUCTION

Corn (*Zea mays* L.) is the crop with the highest grain production in the world and provides feed, food and resources for many industrial and commercial products. Many plant breeders have devoted their efforts to its improvement. Because of the genetic improvement of maize, grain yield has continued to increase at a fairly constant rate during the last 50 years[1]. In recent years, questions have been raised about possible changes in grain quality associated with this yield increase.

Some reduction in chemical quality of maize may have occurred with breeding for higher grain yield because some macro- and micronutrient concentrations were higher in the earlier dent corn hybrids than those of the modern ones[2]. Quality and chemical composition of grain may be influenced by growing conditions[2–4], cultivars[5, 6] and agricultural practices[2, 7]. It is recognized that the mineral concentrations of crops are influenced by the mineral composition of the

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soil and environment in which plants grow[8, 9]. Therefore, fertilization is one of the important factors that affect the grain quality including mineral composition.

Corn is used as one of the major sources of protein and energy in the preparation of different types of human foods in many parts of the world. Thus, chemical composition of maize for human and animal nutrition is important. Some minerals such as Ca and P are required as structural components of the skeleton and others such as Na and K function in acid-base balance. Cu and Fe are also required for the activity of enzymes[10]. Zinc is an essential element for all living organisms. Zinc deficiency has been shown to be the cause of dwarfism and hypogonadism among adolescents from low social classes[11]. On the other hand, toxic heavy metal contamination in soils and crop plants is of major importance due to their health effects on humans and other animals[12].

Besides the human and animal nutrition, mineral compositions are also important in physiological and biochemical functions in plants. Several plant metabolic processes, *i.e.*, photosynthesis, cellular respiration, nutrient uptake and photolysis of water, may be affected by presence of trace elements such as Cd, Zn, Cu, Fe, Mn and Mo[8, 13].

In contrast to dent and flint corns, popcorn is used primarily for human consumption as a favourite snack food and consumption continues to grow annually. Popcorn is also nutritious since it is low in energy and high in fibre[14]. Extensive data on various popcorn compositions including protein, fat, total carbohydrate, crude fibre, ash content, vitamin, fatty acid and amino acid compositions are available[6, 15]. However, data for the mineral composition of popcorn grain are limited. Thus, in this study, mineral compositions of 20 popcorn genotypes, hybrid and open-pollinated, were investigated.

EXPERIMENTAL

Twenty popcorn genotypes, grown in Tokat province of Turkey, were used in this study. Of these genotypes, 16 were single-cross hybrids while four (Ankara, Amasya, Samsun and Tokat) were open-pollinated populations. The kernel type of all genotypes is classified as yellow pearl except Tokat, which is dark (deep purple) and rice type. Also, they were categorized based on popped colour and shape as white butterfly and yellow mushroom.

A field experiment was carried out at the research fields of the Research Institute of Rural Services, altitude 640 m, in Tokat. Soils of the research area had a texture classification of loam. The soils were slightly alkaline, medium in lime content and very low in salt content. The soils had a low available phosphorus (51 P_2O_5 kg/ha) but a rich potassium (83 K_2O kg/ha) level. Thus, sufficient fertilizer was applied so that yield potential would not be limited by soil fertility. 75 kg N/ha and 60 kg P_2O_5/ha were applied and incorporated into the soil prior to seeding. An additional 75 kg N/ha was applied six weeks later. Plots were irrigated three times in the growing period.

Maize was planted using a 0.7 m by 0.20 m spacing in a completely randomized block design on 30 April 2002. At maturity, ears were hand-harvested at about 25% moisture content and shelled by hand. The grain was air dried at room temperature until a moisture content of 14% was reached. Kernels were then ground in a wood mortar and pestle and samples were sealed in polyethylene bags for analysis. No metal tools were used in any stage of sample preparation.

The samples were dried at 105°C for 24 h. Dried samples were homogenized and stored in polyethylene bottles until analysis. All reagents were of analytical reagent grade unless otherwise stated. Double deionized water was used for all dilutions. HNO_3 and H_2O_2 were of suprapure quality (Merck). A Perkin-Elmer Analyst 700 model atomic absorption spectrometer with deuterium background corrector was used in this study for the elemental analysis. All measurements were carried out in an air/acetylene flame.

Samples (1.0 g) were digested with 6 mL of HNO_3 (65%), 2 mL of H_2O_2 (30%) in microwave digestion system for 31 min and diluted to 10 mL with deionized water. A blank digest was carried out in the same way (digestion conditions for microwave system were applied as 2 min for 250 W, 2 min for 0 W, 6 min for 250 W, 5 min for 400 W, 8 min for 550 W, vent: 8 min, respectively). This procedure was preferred because of its higher accuracy with respect to both time and recovery values. The recovery values were nearly quantitative (95%) for the above mentioned digestion method.

RESULTS AND DISCUSSION

Potassium, calcium, magnesium and sodium contents of kernels of 20 popcorn genotypes are shown in Table-1. Os 30 × 31, hybrid variety, had the highest K content (519 mg/kg) while Ankara population had the lowest K content (429 mg/kg). Calcium content of genotypes varied from 45.8 to 126 mg/kg and the lowest concentration was obtained from Os 252 hybrid. The Tokat population had the highest ratio (126 mg/kg) followed by the Amasya population (105 mg/kg). The other open-pollinated populations, Ankara (52.9 mg/kg) and Samsun (66.9 mg/kg) had considerably lower Ca than many hybrid genotypes.

Variation for Mg content among genotypes was lower than other macronutrients (K, Ca and Na). Os 252, which had the lowest Ca concentration, had the highest magnesium content. Although both hybrid and open-pollinated group had high and low K, Ca, Mg and Na containing varieties, in general, Mg contents of open-pollinated populations were lower than hybrids (Fig. 1). There was not a clear difference between hybrids and open-pollinated populations for others. The biggest variation for macronutrient concentration of genotypes (20.6–80.8 mg/kg) was determined in sodium. There were almost four times differences among varieties for sodium.

Copper contents of the genotypes were between 1.73 (Samsun) and 11.89 (Os 604) mg/kg while zinc contents varied from 39.0 (Tokat) to 63.0 (Os 252) mg/kg. Also, manganese and iron contents in popcorn grain ranged between 13.7–46.5 mg/kg and 57.9112.0 mg/kg, respectively (Table-2). The highest iron content (112 mg/kg) and the lowest zinc content (39 mg/kg) were obtained from Tokat population. Except for Fe content of Tokat, concentrations of trace metals tended to be higher in hybrids than open-pollinated populations (Fig. 2).

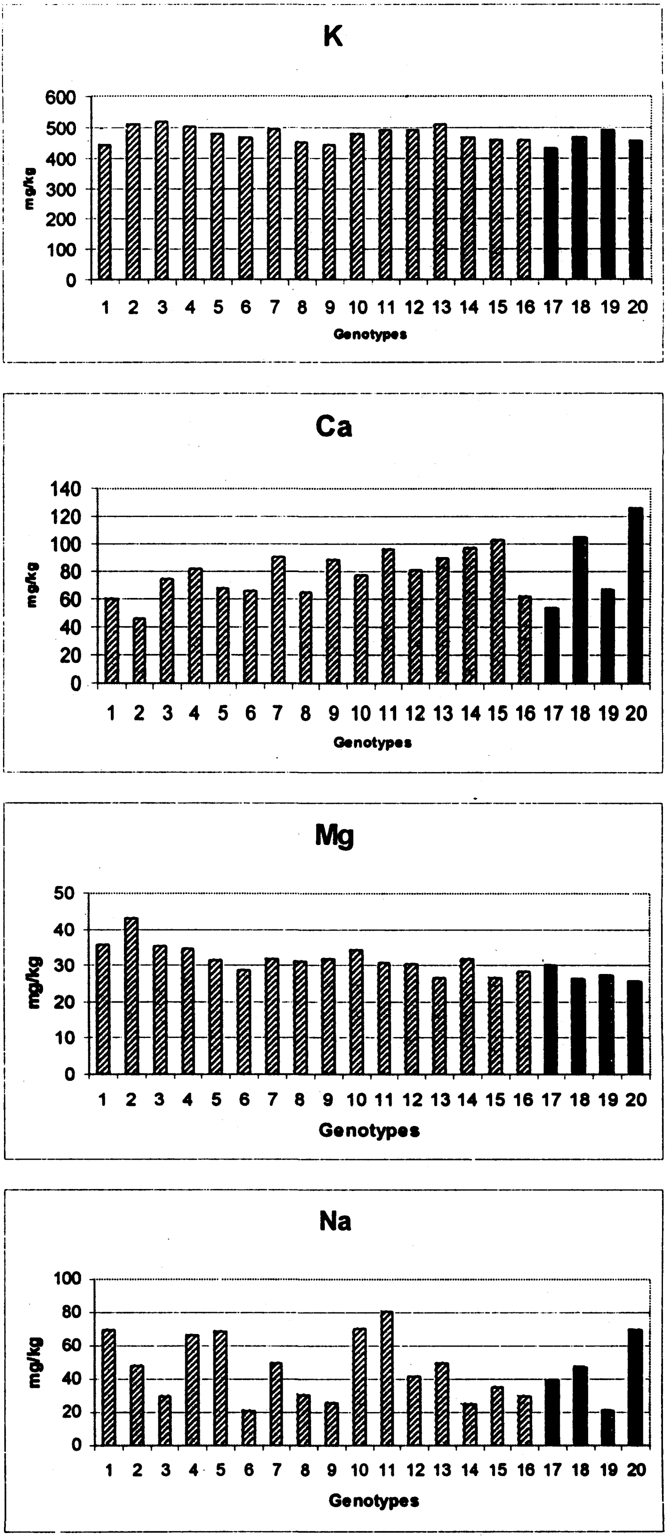

Fig. 1. Contents of K, Ca, Mg and Na of kernel in popcorn genotypes

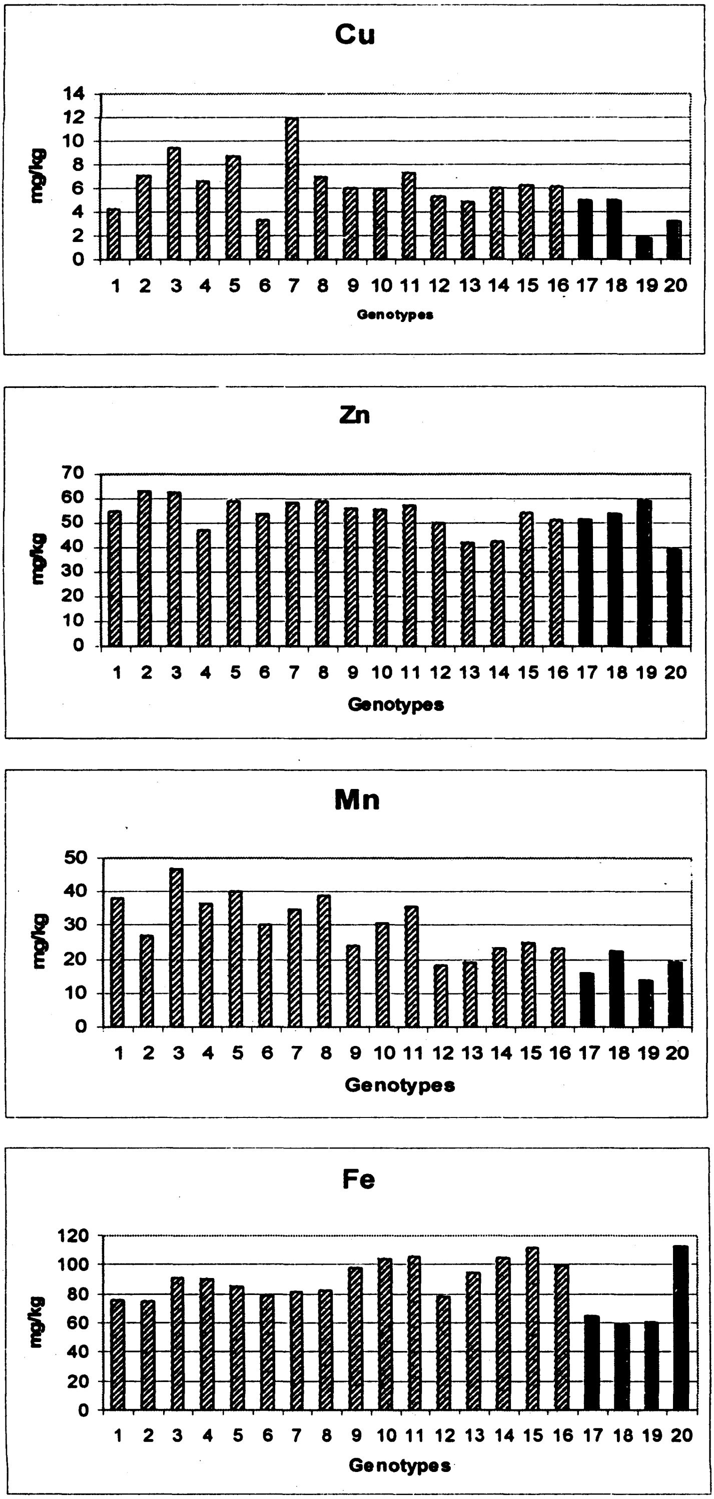

Fig. 2. Contents of Cu, Zn, Mn and Fe of kernel in popcorn genotypes

TABLE-1
CONTENTS OF K, Ca, Mg AND Na OF GRAIN IN POPCORN GENOTYPES (mg/kg)

	No.	Genotypes	K	Ca	Mg	Na
Hybrids	1.	Os 6868 × 6867	444 ± 27	59.7 ± 5.6	35.7 ± 2.8	69.7 ± 6.2
	2.	Os 252	513 ± 43	45.8 ± 3.9	42.9 ± 3.6	48.1 ± 3.7
	3.	Os 30 × 31	519 ± 37	74.6 ± 6.4	35.3 ± 2.8	29.4 ± 2.6
	4.	Os 135 × 134	503 ± 26	82.0 ± 7.3	34.7 ± 2.1	66.2 ± 4.9
	5.	Os 2996E × 31	478 ± 21	67.8 ± 5.5	31.6 ± 2.6	68.5 ± 3.3
	6.	Os 504	467 ± 24	65.9 ± 5.4	28.7 ± 2.7	20.6 ± 1.9
	7.	Os 604	496 ± 33	90.4 ± 8.2	31.8 ± 1.9	49.7 ± 3.8
	8.	Os MED	452 ± 45	64.4 ± 5.2	31.1 ± 2.0	30.5 ± 2.3
	9.	Os GP 3	444 ± 37	88.3 ± 8.7	31.7 ± 2.2	25.8 ± 2.4
	10.	Os 605	480 ± 43	77.5 ± 6.8	34.3 ± 3.1	70.3 ± 5.6
	11.	85Ant 2503 × 2509	491 ± 46	96.2 ± 9.3	30.9 ± 2.7	80.8 ± 6.3
	12.	P.206 × 85Ant2503	492 ± 39	80.5 ± 7.2	30.5 ± 2.6	41.9 ± 3.2
	13.	OKUR 370	510 ± 27	89.7 ± 7.8	26.6 ± 1.5	49.3 ± 3.7
	14.	OKUR 232	467 ± 22	96.8 ± 5.6	31.7 ± 1.6	24.9 ± 2.1
	15.	P 608	460 ± 35	103.0 ± 6.0	26.6 ± 1.4	35.1 ± 4.9
	16.	P 4050	460 ± 42	62.1 ± 5.5	28.4 ± 2.1	29.3 ± 2.9
Open-pollinated	17.	Ankara	429 ± 28	52.9 ± 2.7	29.9 ± 2.6	39.4 ± 3.7
	18.	Amasya	466 ± 45	105.0 ± 7.8	26.3 ± 1.3	47.1 ± 4.2
	19.	Samsun	492 ± 26	66.9 ± 5.9	27.1 ± 1.8	20.6 ± 1.8
	20.	Tokat	456 ± 46	126.0 ± 10.7	25.5 ± 1.7	69.6 ± 5.4

Differences in grain mineral element contents among varieties could be associated with differences in adaptation ability of genotypes and reacted differently to soil and climate conditions. Oikeh *et al.*[16] also reported that genetic component accounted for 34% of the total variation in kernel-Zn and for 11% of the variation in the kernel-Fe levels.

There were differences for macro and micronutrients between our results and the previous reports in kernel of dent corn of Vyn and Tollenaar[2], who reported that 340–390 for K, 16–21 for Ca, 79–93 for Mg, 13.1–17.1 for Zn, 1.18–2.17 for Cu and 2.88–4.56 mg/kg for Mn, respectively, and Oikeh *et al.*[16] determined that the ranges were 15.5–19.1 for Fe and 16.5–20.5 mg/kg for Zn. The reason for these differences may depend on the contents of mineral nutrients and their combinations in soils and also species. Nan *et al.*[4] and Jarausch-Wehrheim *et al.*[17] reported that mineral element uptake by plants was influenced by both soil and plant factors such as the quantity and mobility of elements in the soil solution around the plant roots, source and chemical form of elements in soil, pH, organic material, plant species and tissues, plant age, etc.

TABLE-2

CONTENTS OF Cu, Zn, Mn AND Fe OF GRAIN IN POPCORN GENOTYPES (mg/kg)

	No.	Genotypes	Cu	Zn	Mn	Fe
Hybrids	1.	Os 6868 × 6867	4.22 ± 0.23	54.7 ± 3.2	38.0 ± 2.7	75.3 ± 6.2
	2.	Os 252	7.10 ± 0.34	63.0 ± 5.4	26.7 ± 1.9	74.9 ± 5.3
	3.	Os 30 × 31	9.38 ± 0.43	62.4 ± 0.37	46.5 ± 3.2	90.8 ± 6.2
	4.	Os 135 × 134	6.56 ± 0.28	46.8 ± 0.29	36.2 ± 3.5	90.0 ± 7.5
	5.	Os 2996E × 31	8.73 ± 0.42	58.9 ± 0.27	40.1 ± 2.6	84.5 ± 5.2
	6.	Os 504	3.24 ± 0.13	53.3 ± 0.24	30.1 ± 1.8	78.8 ± 3.9
	7.	Os 604	11.89 ± 0.78	58.0 ± 4.73	4.7 ± 1.9	81.7 ± 4.6
	8.	Os MED	6.94 ± 0.42	58.8 ± 0.23	8.7 ± 3.0	82.3 ± 7.3
	9.	Os GP 3	5.95 ± 0.37	56.0 ± 4.02	24.1 ± 1.29	97.3 ± 7.5
	10.	Os 605	5.94 ± 0.33	55.3 ± 4.7	30.4 ± 2.8	104.0 ± 6.3
	11.	85Ant 2503 × 2509	7.32 ± 0.28	57.2 ± 5.8	35.7 ± 3.1	105.6 ± 9.2
	12.	P.206 × 85Ant2503	5.24 ± 0.17	49.9 ± 3.6	18.3 ± 1.3	77.7 ± 3.9
	13.	OKUR 370	4.84 ± 0.11	41.7 ± 3.8	19.1 ± 0.7	94.4 ± 6.3
	14.	OKUR 232	6.00 ± 0.22	42.3 ± 2.1	23.3 ± 1.8	104.7 ± 5.6
	15.	P 608	6.25 ± 0.47	54.4 ± 4.9	24.6 ± 1.2	111.1 ± 8.7
	16.	P 4050	6.13 ± 0.53	51.3 ± 2.9	23.3 ± 1.9	99.8 ± 7.2
Open-pollinated	17.	Ankara	4.93 ± 0.24	51.1 ± 5.1	15.9 ± 1.4	64.5 ± 5.2
	18.	Amasya	4.98 ± 0.27	53.7 ± 4.2	22.2 ± 1.7	57.9 ± 3.2
	19.	Samsun	1.73 ± 0.10	58.6 ± 4.0	13.7 ± 0.8	60.3 ± 2.8
	20.	Tokat	3.15 ± 0.17	39.0 ± 2.1	19.2 ± 1.6	112.0 ± 11.3

On the other hand, physical characters of popcorn kernel are very different from those of other corn types. Popcorn kernels are smaller and harder than dent corn and contain a much greater hard endosperm to soft endosperm ratio[18]. The most important difference between popcorn and others (dent, flint and sweet corns) is that popcorn has the thickest pericarp[19]. Since corn pericarp is very rich in mineral nutrients[20] differences between our findings and the results reported here may arise from pericarp character of popcorn.

The data obtained from our study indicate that mineral concentrations of the popcorn vary markedly depending on varieties and seed types (hybrid or open pollinated).

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