DF-529
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RESEARCH ARTICLE Agricultural Science Digest

Study on Selected Metals and Nutritional Status of Maize (*Zea mays* L.) Grown under Different Rates of Fertilizers in Wolaita Zone, Southern Ethiopia

Desalegn Dana Dinato[1], Alemu Lelago[1], Mesfin Bibiso[1], Abraham Bosha[1]

10.18805/ag.DF-529

ABSTRACT

Background: The main aim of this study was to investigate the nutritional value of maize samples grown under the different rates of blended fertilizer in Wolaita Zone, southern Ethiopia.

Methods: Maize samples that were grown under combined application of the two fertilizers (K and NPSB) with ratio rates of (0:0, 25:50, 50:100, 75:150 and 100:200) kg ha^{-1} were used as treatment. The content of nutrients from the maize was determined by flame atomic absorption spectrometry.

Result: The mean concentration of metal in the maize sample ranged as (mg/kg): Ca (512.48-725.86), K (786.62-901.907), Mg (440.23-618.61), Fe (31.52-39.63), Zn (29.45-35.58), Pb (0.005-0.034), Cd (0.014-0.13). The study also revealed that the proximate analysis of the maize sample grown under different rates of blended fertilizer ranged as moisture (5.57-9.56%), ash (0.76-2.29%), fat (2.83-5.95%), fiber (0.93-2.25), 6.83-11.86% and Carbohydrate (68.08-83.07%). For most metals and nutritional values, the highest content was obtained in maize samples grown under the application of 100 K and 200 NPSB kg per hectare.

Key words: Blended fertilizer, Carbohydrate, Fat, Fiber, Proteins, Wet-digestion.

INTRODUCTION

Maize belongs to the family Poaceae, genus Zea and species *Zea mays*-corn **(**Adane *et al*., 2017). South Africa is the largest producer of maize in Africa followed by Nigeria. Ethiopia is the fourth largest maize-producing country in Africa next to South Africa, Nigeria and Egypt (Macauley, 2015). Nutritionally, maize has a high content of carbohydrates, fats, proteins and some important vitamins and minerals and it has acquired a well-deserved people's food consumption (Punita, 2006).

In Ethiopia, the fertilizer use trend has been focused mainly on the use and application of nitrogen and phosphorous fertilizers in the form of Di-ammonium phosphate and Urea for a long time since 2013. However, research findings in Ethiopia showed that sulfur, potassium, boron and other elements are deficient and NPSB and K are recommended, Also, their rates are reported by research outputs (Fanuel, 2015).

The blended fertilizer that contains balanced nutrients with recommended amounts of N, P, S and B produced significantly higher maize yield compared to the blanket fertilizers (Habtamu *et al*, 2013). However, there is no investigation into the impacts of such blended fertilizer on the nutritional quality of maize. Based on these facts using a balanced fertilizer is boosting maize yield. However, the impacts of the application of fertilizers in the study are not studied yet. Therefore, the basic aim of this research was to determine the concentration of essential metals (Mg, Ca, K, Fe Zn) and the nutritional composition of maize grown under the application of different rates of fertilizes.

[1]Wolaita Sodo University, P.O.Box 138 Wolaita Sodo-Ethiopia.

Corresponding Author: Alemu Lelago, Wolaita Sodo University, P.O.Box 138 Wolaita Sodo-Ethiopia.
Email: lelagoalem@gmail.com

How to cite this article: Dinato, D.D., Lelago, A., Bibiso, M. and Bosha, A. (2023). Study on Selected Metals and Nutritional Status of Maize (*Zea mays* L.) Grown under Different Rates of Fertilizers in Wolaita Zone, Southern Ethiopia. Agricultural Science Digest. doi:10.18805/ag.DF-529.

Submitted: 03-01-2023 **Accepted:** 14-06-2023 **Online:** 03-07-2023

MATERIALS AND METHODS

Sample collection and preparation methods

The experiment was conducted in 2021 at Wolaita Sodo University. Maize samples that were grown under combined application of the two fertilizers (K and NPSB) with ratio rates of (0:0, 25:50, 50:100, 75:150 and 100:200) kg ha^{-1} were used as treatment. 15 samples were collected from maize grown under five different fertilizer rates by three replications. Flour from maize seed was prepared based on the method described by Adeleke and Odedeji (2010).

Method for determination of essential and non-essential metals

The metals were analyzed with FAAS equipped with a deuterium arc background corrector by using standard optimum conditions for each element.

Determination nutritional analysis

All the nutritional status analysis of maize seed flour was done in triplicates by using the methods described by AOAC (2000).

Statistical analysis

Three replicate determinations were carried out for each treatment. When P values (P<5%) were found significant, the means of each parameter were compared using the least significant differences (LSD) procedures.

RESULTS AND DISCUSSION

The metal levels in Maize seed grown under different fertilizer rates

Metals(Ca, K, Mg, Zn and) contents of five maize seeds grown under different fertilizer rates that determined using were FAAS analyzed in comparison and presented in Table 1.

Comparison of individual nutrients in maize sample

Calcium (Ca)

The highest calcium content (725.86 mg/kg) and lowest (512.48 mg/kg) were obtained in the maize sample grown under the application of BR_5 and BR_1, respectively. The calcium content in the maize samples is significantly different (p<5%) among maize samples grown under different blended fertilizer rates. The results showed that the average Ca content in this study is greater than in previous reports. For instance, Mohammed and Ahmad (2014), Ullah (2010), and Gara *et al.* (2013), reported that the Ca amount in maize ranged from 70.00-186.67 mg/kg, 66.5-104 mg/kg), 410-590 and 321.7-789.1mg /kg, respectively.

In all treatments, the combined application of K and NPSB fertilizers significantly (P<0.05) increased the Ca content in maize seed compared to the control (no fertilizer). These indicate that the application of deficient nutrients increases the ability of the maize crop to absorb metals from the soil.

Potassium (K)

Analysis of variance showed that the mean concentration of potassium was significantly (P<0.05) different among maize samples grown under the application of five rates of blended fertilizers (Table 1). The potassium content in the maize sample ranged from 786.62 to 901.907 mg/kg. It was highest in blend ratio five (BR_5) (901.907 mg/kg) and lowest in blend ratio one (BR_1) (786.62 mg/kg).

In potassium metal increased product level from that produced by control treatment. This shows the importance of balanced applications of fertilizers containing all the other nutrients for enhancing not only the productivity of maize in the study area but also seed K contents. As the rate of blended fertilizer increased to a certain level, the nutrient content of maize increased proportionately. This may be because optimum fertilizer application nourishes and supplies nutrients required for good productivity (Onasanya, *et al*, 2009). The maize grown under the application of balanced fertilizer is a good source of potassium and essential food since potassium is a major electrolyte of intracellular solution. It has also a great biological role in the human body and physiological importance, contributing to the transmission of nerve impulses, control of skeletal muscle contractility and the maintenance of normal blood pressure (Minaleshshewa, 2007).

Magnesium (Mg)

As shown in Table 1, there is significantly different (p<5%) magnesium content among the treatments BR_3, BR_4 and BR_5 but the rest were found to be statistically the same. The magnesium content in maize samples ranged from 440.28 to 618.61 mg/kg. The highest (618.6 mg kg^{-1}) value of magnesium was found in blend ratio five (BR_5) and the lowest(440.28 mg/kg) in blend ratio one (BR_1) The Mg concentration of maize in this study was higher than the value reported by (Malomo *et al*., (2013) (248.3-321 mg/kg) but lower than the value by and reported by Ikram Ullah (2010) (392-397 mg/k) and Adane (2015) (985.2-1125.3 mg/kg).

These results line with the finding of Amandikwa and Chinyere (2012) who stated that the application of micronutrient combinations with macronutrients gave the highest nutrient yield in maize. Mg is very important because magnesium mineral functions as a co-factor of many enzymes involved in energy metabolism, protein synthesis, RNA and DNA synthesis and maintenance of the electrical potential of nervous tissues and cell membranes (Habtamu, *et al*, 2013).

Table 1: Mean concentration of metals (mean±SD, n=5) in five maize seeds grown under different fertilizer rates.

Metal (mg/kg)	Blended fertilizer						
	BR_1	BR_2	BR_3	BR_4	BR_5	CV	LSD
Ca	512.48±0.14^e	545.44.25^d	552.76±0.14^c	670.94±0.25^b	725.86±1.07^a	0.472	2.842
K	786.62±0.13^d	795.63±1.12^d	824.23±1.05^c	863.34±1.23^b	901.907±1.32^a	1.052	8.779
Mg	440.23±0.07^d	460.79±0.25^d	520.44±0.34^c	586.42±0.22^b	618.61±0.42^a	2.493	13.09
Fe	31.52±0.15^e	33.27±0.16^d	35.74±0.12^c	38.16±0.17^b	39.63±0.26^a	1.753	0.625
Zn	29.45±0.02^e	30.77±0.05^d	32.18±0.11^c	34.14±0.10^b	35.58±0.16^a	1.350	0.437

Means with the same letter are not significantly different. NPSB=Nitrogen, Phosphorus, Sulfur and Boron blended fertilizer, BR means Blend ratio of K and NPSB (BR_1=0:0, BR_2=25:50, BR_3=50:100, BR_4=75:150 and BR_5=100:200) kg ha^{-1}. ND-Not detected, CV= Coefficient variance, LSD= Least significance difference.

Iron (Fe)

Iron ranged from 31.52 to 39.63 mg/kg and its content was highest in blend ratio five (BR_5) (39.63 mg/kg) and lowest in blend ratio one (BR_1) (31.52 mg/kg). The iron content in maize samples was significantly different (p<5%) among all blended treatments.

Some research studies indicate the effect of iron fertilizers on quantitative and qualitative traits and the positive role of these elements in increasing maize nutrients. The current study showed that the application of balanced fertilizer improved the iron content of maize. Higher iron content in food is very important since iron is an important trace element for hemoglobin formation, normal functioning of the central nervous system and the oxidation of carbohydrates, protein and fats (Million and Tesfaye, 2017).

Zinc (Zn)

The mean concentration of Zn ranged from 29.45 to 35.58 mg/kg. The estimated values of zinc were highest (35.58 mg/kg) in blend ratio five (BR_5) and lowest (29.45 mg/kg) in blend ratio one (BR_1). The zinc content in maize samples was significantly different (p<5%) among all blended treatments. The zinc content in the maize sample was found to be 29.45-35.58 mg/kg. The content of Zn was higher than the previous reports by Adane (2015) (61.7-77.6 mg/kg) by Ikram Ullah (2010), (37.05- 52.40 mg/kg). The study showed that the application of blended fertilizer rates resulted in increases in the content of micronutrients such as Zn.

Zinc is found in all body tissues and fluids. It plays a central role in the immune system, affecting several aspects of cellular and humeral immunity. In animals mainly, this element is used for the regulation of gene activity and the balance of carbohydrate metabolism and blood sugar. The utilization of this maize seed should be pursued to help in the alleviation of zinc deficiency which is associated with to stunt of children (Mekbib and Deressa, 2016).

Proximate analyses of maize flour

The percentage composition of proximate analyses such as moisture, fiber, fat, protein, carbohydrate and energy contents of maize flour which is grown under different rates of balanced fertilizer were presented in Table 2.

The moisture content of maize flour samples in this study result was shown in Table 2. The mean values for moisture content in maize samples under study ranged from 5.57-9.56%. The highest moisture content was observed in the BR_5 maize sample and the lowest value was observed in the BR_1 maize sample. There is a significant difference at the 5% level observed in the moisture content among the maize sample grown under the different rates of fertilizer application. The moisture content of food is related to the amount of dry matter contains in food. Maize that contains high moisture is subject to rapid deterioration from mold growth and insect damage to mention a few (Luther *et al.*, 2005). The lower moisture content is important as it enables long storage by minimizing fungal contamination and spoilage of the maize or maize products. The high moisture content among blended fertilizer rates reveals that they need great care for appropriate preservation as they will be prone to deterioration.

The mean values of ash content in the maize samples ranged from 0.77-2.29%. The highest ash content was observed in blend ratio five BR_5 and the least ash content was observed in blend ratio one BR_1 maize sample. In the present study, the ash content in maize samples was not significantly different (p>5%) between blend ratio one (BR_1) and BR_2 samples but there was a significant difference among the rest samples.

The percentage of ash gives ideas about the content of the inorganic or mineral of food that indicates the total mineral residue left after the incineration of organic matter (Puwastien *et al.*, 2011). Total ash content is directly proportional to inorganic element content. Hence the samples with high percentages of ash contents were expected to have high concentrations of various mineral elements (Habtamu *et al.*, 2013). In this study, the ash content increased with the application of blended fertilizer confirming that the application.

As presented in Table 2, the crude fat content of flour derived from the maize grown under the application of different rates of blended fertilizer sample was 2.83 to 5.95%. The fat content values among the maize samples were found to be significantly (p<0.05) different. The fat contents reported in this study were lower than the findings of

Table 2: Proximate composition (mean±SD, n=5) of maize samples.

Blend ratio	Moisture (%)	Ash (%)	Fat (%)	Fiber (%)	Crude protein (%)	CHO (%)
BR_1	5.57±0.125[e]	0.76±0.060[d]	2.82±0.171[e]	0.93±0.050[e]	6.83±0.113[e]	83.07±0.213[a]
BR_2	6.48±0.181[d]	0.95±0.113[d]	3.65±0.109[d]	1.22±0.071[d]	7.69±0.102[d]	80.16±0.421[b]
BR_3	7.28±0.112[c]	1.42±0.128[c]	4.306±0.121[c]	1.56±0.092[c]	9.07±0.10[c]	76.18±0.413[c]
BR_4	8.12±0.141[d]	1.76±0.055[b]	5.13±0.101[b]	1.84±0.091[b]	10.46±0.114[b]	72.64±0.321[d]
BR_5	9.56±0.192[a]	2.29±0.121[a]	5.95±0.111[a]	2.25±0.110[a]	11.86±0.123[a]	68.08±0.412[e]
CV	0.803	10.975	6.743	7.775	4.251	1.700
LSD	0.356	0.157	0.294	0.121	0.390	1.292

Means with the same letter are not significantly different. NPSB= Nitrogen, phosphorus, sulfur and boron blended fertilizer, BR means Blend ratio of K and NPSB (BR_1=0:0, BR_2=25:50, BR_3=50:100, BR_4=75:150 and BR_5=100:200) kg ha^{-1}. ND- Not detected, CV= Coefficient variance, LSD= Least significance difference.

Olufunso *et al.* (2019) and Rupa *et al.* (2018). The low-fat content can enhance the storage life of the flour due to lowered chance of rancid flavor development (Ogunlakin *et al*., 2012). The low-fat content can enhance the flour's storage life due to the lowered chance of rancid flavor development (Ogunlakin *et al*., 2012).

Fat is important in diets as it promotes the absorption of fat soluble vitamins and plays a significant role in the shelf life of food products (Obadine *et al*., 2016). The consumption of an excessive amount of fat has the most dietary factor to increase the level of cholesterol since cholesterol is the result of high fat intake but causes obesity (Bhattacharjee *et al*., 2013).

The maize flour derived from the treatments BR_5 and BR_1 samples exhibited the highest and the lowest fiber content, respectively. The ANOVA result in Table 2 showed that crude fiber content was significantly different (p<5%) among maize samples grown at different rates of fertilizer applications.

Diets with a high content of fiber have a positive effect on health that decreased the prevalence of several types of cancer. It also decreases the absorption of cholesterol from the gut, delaying the digestion and conversion of starch to simple sugars, an important factor in the management of diabetes (Puwastien *et al*, 2011). The presence of crude fiber in the diet is necessary for digestion, the elimination of waste and the contraction of the muscular walls of the digestive tract is stimulated by fiber. So the flour derived from contained higher fiber content that is very important for body health than the flour derived from the BR_5 maize sample because of its higher fiber content.

The value of protein ranged from 6.83 to 11.86%. The highest crude protein content was obtained from BR_5 and the lowest protein content was obtained from BR_1 as presented in Table 2. The protein content of the maize sample significantly differed (p<5%) in the rate of fertilizer applications. The protein content in the maize sample showed an increasing trend with an increased rate of application of blended fertilizers. The possible reason could be that the application of inorganic fertilizers might have increased the efficiency of maize to partition the nutrient. In addition, the increase in protein content with increasing rates of NPSB might be due to the presence of higher amounts of N and S which are the major components of maize protein. The Carbohydrate content of the maize sample varied from 68.08 to 83.07%. The highest and the lowest Carbohydrate content were found in BR1 and BR_5, respectively. In the study, a significant difference was observed in carbohydrate content (p<5%) among all samples.

Among maize grew different rates of blended fertilizer of carbohydrate content were agreed with the reported value of carbohydrate content of cereals was 82 % (Million and Tesfaye, 2017). The high content of carbohydrates observed in the maize sample was attributed to the high amount of energy content for the body since carbohydrates assist in the metabolism of fat and supply quick and metabolizable energy in the body (Obadine *et al*., 2016).

CONCLUSION

The results of this study suggest that maize grown under different rates of blended fertilizer contain different amount of essential metals and nutrients. Comparably maize grown by application of 100 kg K and 200 Kg NPSB per hectare (BR_5) was found to be a potentially good source of most metals and nutritional value than others. Also, increased fertilizer rate resulted in increased metals and nutritional values in maize simple till the optimum rate. From this one can be concluded that the application of balanced fertilizers for maize is important not only to boost maize yield but also to balance the nutritional composition of the maize.

Conflict of interest: None.

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