SCREENING FOR SALT TOLERANCE IN MAIZE AND COMPARATIVE EVALUATION ON CHEMICAL COMPOSITION AND MINERAL NUTRIENTS

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ABSTRACT

Soil salinity is one of the significant environmental issues that have adverse effects on growth and productivity in Maize (*Zea mays*). Ultimately, the level of soil salinity hampers grain nutrition in maize. The availability of salt-tolerant maize genotypes, with an adequate grain nutritional quality, is a challenge in agriculture. Despite numerous nutritional studies in maize have been conducted, no report has been made on how nutrition is being affected under saline conditions. Therefore, the objective of this study was to screen the elite genotypes could sustain chemical composition and mineral nutrients under saline conditions. The hydroponic system was used to screen twenty genotypes of maize for salinity tolerance at the seedling stage. The study employed a completely randomized design (CRD) to test the genotypes under four different levels of salinity (control, 0, 4, 8 and 12dS/m). At the maturity stage, the genotypes were further screened in saline and normal field conditions. Randomized complete block design (RCBD) under split-plot arrangement with four different levels of salinity (control, 0, 4, 8 and 12dS/m) was used. Quantitative analysis of mineral contents was performed using inductively coupled plasma mass spectrometry (ICP-MS). Both maize under normal and saline field conditions were analyzed. Greenhouse hydroponic screening revealed that G-12, G-13 and G-15 performed best in morphological and physiological traits under saline condition. G-12, G-13 and G-15 performed best in field screening under normal and saline conditions based on yield and yield-related components (plant height, grain yield per plant, 100-grain weight and number of grains per cob). Grain chemical composition showed that G-12, G-13 and G-15 contained high protein (5.93-11.79%) and carbohydrate contents under saline conditions. G-15 was found to have the highest concentration of nutrients such as Ca, Fe and Zn under salinity. Further, the effect of ion antagonism was found to play a vital role in the decrease or increase of mineral nutrients in 20 genotypes under saline conditions. The study results concluded that G-15 performed the best among the 20 genotypes of maize recommended for cultivation under saline condition.

ABSTRAK

Saliniti tanah adalah salah satu isu alam sekitar penting yang mempunyai kesan buruk terhadap pertumbuhan dan produktiviti dalam Jagung (*Zeamays*). Hasilnya, kandungan garam dalam tanah menganggu nutrisi bijiran jagung. Kebolehdapatan genotip jagung tahan garam serta mengandungi nutrisi bijiran cukup berkualiti adalah satu cabaran dalam bidang agrikultur. Walaupun beberapa kajian nutrisi jagung telah dijalankan, tiada laporan dibuat mengenai bagaimana kandungan nutrisi dipengaruhi oleh keadaan bergaram. Oleh yang demikian, objektif kajian ini adalah untuk menyaring genotip elit yang dapat mengekalkan komposisi kimia dan nutrisi mineral di dalam keadaan bergaram. Sistem hidroponik telah digunakan untuk memeriksa 20 genotip jagung tahan garam di peringkat anak benih. Kajian ini menggunakan reka bentuk rawak lengkap (CRD) untuk menguji genotip di bawah empat tahap garam yang berbeza (kawalan, 0, 4, 8 dan 12dS/m). Pada peringkat matang, genotip diperiksa dengan lebih terperinci dalam keadaan bergaram dan keadaan normal. Rekabentuk blok rawak lengkap (RCBD) di bawah susunan plot berpecah dengan empat tahap garam yang berbeza (kawalan, 0, 4, 8 dan 12dS/m) telah digunakan. Analisis kuantitatif kandungan mineral dijalankan dengan menggunakan Gabungan Induktif Spektrometri Jisim Plasma (ICP-MS). Analisis dilakukan di dalam dua keadaan iaitu, normal dan bergaram. Penggunaan sistem hidroponik di dalam rumah hijau menunjukkan G-12, G-13 dan G-15 memberikan prestasi yang terbaik dari segi morfologi dan fisiologi dalam kondisi bergaram. Pemeriksaan dalam padang keadaan normal dan bergaram menunjukkan G-12, G-13 dan G-15 memberikan prestasi yang terbaik berdasarkan hasil jagung dan hasil jagung yang berkaitan (tinggi pokok, hasil bijiran setiap pokok, berat 100 biji, bilangan bijiran setiap tongkol). Dapatan kajian komposisi kimia bijiran menunjukkan bahawa G-12, G-13 dan G-15 mengandungi protein tinggi (5.93-11.79%) dan kandungan karbohidrat dalam kondisi bergaram. Analisis kuantitatif nutrisi mineral menunjukkan G-15 kekal paling tinggi dengan kandungan nutrien seperti Ca, Fe dan Zn dalam keadaan bergaram. Tambahan pula, hasil pemerhatian menunjukkan bahawa kesan ion antagonis memainkan peranan penting dalam peningkatan atau penurunan nutrisi mineral dalam kesemua 20 genotip di dalam kondisi bergaram. Berdasarkan keputusan eksperimen, G-15 menunjukkan prestasi yang terbaik dalam kalangan 20 genotip jagung yang boleh direkomenkan untuk ditanam dalam kondisi bergaram.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Maize or corn (*Zea mays subsp. Mays.)* belongs to the Poaceae family and is one of the most important cereal crop in the world (Gallavotti and Whipple, 2015; Vincent, 2007). It is used as feedstock, livestock, poultry and food for humans. Around 9000 years ago, it was originated as a wild grass called teosinte in the Mesoamerican region, currently known as Mexico and Central America (Tokatlidis and Koutroubas, 2004; Wang *et al.*, 2005). Currently, it is cultivated in many places of the world including, Africa, Brazil, India, Malaysia, Middle East, Pakistan and southern states of USA etc. The nutritional values in the corn grain is much higher as compared to other crops as it contains 1.7% ash, 8.5% fiber, 4.8% oil, 10% protein, 72% starch and 3.0% sugar (Debnath *et al.*, 2017; Iqbal *et al.*, 2006; Zamir *et al.*, 2011).

Global production of maize is around 961.10 million metric tons on an area of 177.76 million hectares during the year 2015-2016; among which 60% is produced by the United States of America and China, and the rest is produced in tropical and subtropical areas of Africa and southern Asia. Corn is considered as third most important crop after wheat and rice in Pakistan and is widely grown in the spring and autumn seasons (Tariq and Iqbal, 2010). The overall production and yield of maize grown in different parts of Pakistan is approximately 4.9 million tons and 3264kg/ha respectively (Rashid and Rasul, 2011). On the other hand, in Malaysia, maize is harvested over 10,030 ha area in 2017 with the total production of 58 million tons.

Salinity problem (abiotic stresses) is the highest limitation to global agricultural production, which reduce yields by more than 50% (Sinha *et al.*, 2014). Salinity stress includes both stronger ionic and osmotic stresses in dry and semiarid areas that exacerbate the effects of salinity due to limited precipitation, high evapotranspiration, high temperatures, poor water quality, and poor soil management practices (Niu *et al.*, 2012b). Salinity not only decreases the rate of leaf expansion, but also affects adversely on plant morphology and physiology. Excess of salts in the soil can decrease the rate of seed germination, slows down the growth of seedlings, and causes significant reduction in dry matter accumulation (Haq *et al.*, 2012; Singh *et al.*, 1989). The extent of salt tolerance varies both at inter-specific and intra-specific levels. (Murillo-Amador *et al.*, 2001; Yildirim and Güvenç, 2006). Interestingly, the sensitivity of plants to salinity differ at its various growth stages. It has been demonstrated that most of the plants can tolerate salinity at germination stage, but shows salt sensitivity during emergence and vegetative development stage (Tsegay and Gebreslassie, 2014; Xianzhao *et al.*, 2013). The reduction in shoot growth due to salinity is usually higher than root growth and can reduce the number of florets per ear, increase sterility and affect the time of flowering and maturity in crops (Lauchli and Grattan, 2007).

Nutrients or trace elements are generally classified into three types:1) Essential trace elements (iron, zinc, copper, cobalt, chromium, fluorine, iodine, manganese, molybdenum and selenium) (Bhattacharya *et al.*, 2016; Kabata-Pendias, 2010; Prashanth *et al.*, 2015): 2) Probably essential trace elements (nickel, tin, vanadium, silicon, boron) (Underwood, 1973) and 3) Non-essential trace elements (aluminium, arsenic, barium, bismuth, bromine, cadmium, germanium, gold, lead, lithium, mercury, rubidium, silver, strontium, titanium and zirconium) (Ludajić *et al.*, 2015). Information on nutritional value of maize and its products is scarce or has been inconsistent among various reports. Additionally, nutritional data for grains and/or the milled products of genetically distant accessions of maize grown under various salinity levels are not available in the literature.

Nutrients or Trace elements are usually estimated using colorimetric ally or spectroscopically which have many limitations including accuracy and reliability. In current studies, we used Inductively Coupled Plasma Mass Spectrometry (ICP-MS) for the quantitative analysis of grain mineral nutrients contents in maize. ICP-MS technique offers some distinctive advantages over other detection techniques.

1.2 Problem Statement

Human body requires certain minerals in trace quantities, generally less than 20 milligrams per day to perform a variety of physiological functions. These trace minerals mediate vital biochemical reactions within the body either by acting as cofactors for many enzymes, or by playing their integral role in stabilizing the structures of enzymes and proteins. However, deficiency or excess of these minerals may cause severe malfunctioning or even death in extreme cases as they directly influence their metabolic and physiological phenomena. Excessive amount of toxic minerals in the rhizosphere poses a serious threat to maize productivity in the arid and semi-arid regions around the globe. The correlations between salinity and mineral nutrition of maize are extremely complex (Grattan and Grieve, 1998a). A complete understanding of this interaction would require inputs from a multidisciplinary program of research. Previous studies generally focused on investigating effects of salinity on germination, vegetative and reproductive growth of maize crop (Farooq *et al.*, 2015; Janmohammadi *et al.*, 2008; Konuşkan *et al.*, 2017). A few studies explained mechanisms involved in ionic toxicity, osmotic and oxidative stress in maize plants (Farooq *et al.*, 2015). Nutritional studies have been conducted but how nutrition is being affected under saline conditions is not reported yet. We believe that the effect of salinity on maize quality depends upon various factors such as salinity level, maize species and their interaction.

1.3 Objectives

Present studies highlight three main objectives:

(a) To conduct hydroponic screening of maize germplasm for salinity tolerance at seedling stage under laboratory conditions.

(b) To evaluate the maize germplasm under normal and saline field conditions.

(c) To investigate the grain chemical composition and mineral nutrients under normal and saline field conditions.

1.4 Aim and Scope of the Study

Selection of salt-tolerant genotypes is very crucial to grow maize on salt-affected areas to meet the growing demand for food. This study first screened the most tolerant maize genotypes for salinity tolerance in the laboratory using a convenient and reliable hydroponic technique for determining differences with respect to salt tolerance of maize genotypes using morphological and physiological traits. In the next step, the salt tolerance of maize genotypes was screened under field conditions by evaluating the changes in Physiological, growth and yield related traits. An investigation was undertaken with the objective to analyze the chemical composition of grains from genetically distant maize accessions that were found most tolerant to salinity both under normal and saline conditions. At final stage of present studies, Inductively Coupled Plasma Mass Spectrometry (ICP-MS) carried out the quantitative analysis of grain mineral nutrients both under normal and saline field conditions. ICP-MS technique offers some distinctive advantages over other detection techniques. It has the capability of measuring simultaneous multi-elements with very low detection limits. It also offers a wider linear dynamic range that allows determination of major and trace elements contained in the same sample. To the best of our knowledge, this is the first report in which grain mineral nutrients in maize were evaluated by ICP-MS technique. Detection of grain metal ions contents or trace minerals and analysis of their composition by ICP-MS technique may also help to assess and monitor various pollutants in soil, water and air to which maize, or other agricultural commodities are in direct contact.

1.5 Significance of the Study

The interaction between salinity and maize genotypes is a complex phenomenon, which depends on maize varieties, plant development stage and level of salinity applied. Present studies would provide useful information on the changes in morphological, physiological and yield traits, grains chemical composition and nutritional composition under salinity stress. To the best of our knowledge, this is the first report in which grain metal ions contents or trace elements in maize were evaluated by ICP-MS technique. Detection of grain metal ions contents or trace minerals and analysis of their composition by ICP-MS technique may also help to assess and monitor various pollutants in soil, water and air to which maize, or other agricultural commodities are in direct contact. The results obtained through the systematic approaches opted during this study would enable us to select desirable maize genotypes which will be suitable to grow under saline conditions.

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LIST OF PUBLICATIONS

1. Rapid Detection of Nutrients in "Zea mays L" using Inductively Coupled Plasma Mass Spectrometry. Shaista Qamar, Muhammad Aslam, Fahrulzaman Huyop And Muhammad Arshad Javed. Romanian Biotechnological Letters, Vol. 23, No. 2, 2018.
2. Comparative study for the determination of nutritional composition in commercial and noncommercial maize flours. Shaista Qamar, Muhammad Aslam, Fahrulzaman Huyop And Muhammad Arshad Javed, Pak. J. Bot., 49(2): 519-523, 2017.
3. A comparative study of the inorganic nutrients in different types of zea mays l. Using inductively coupled plasma mass spectrometry. S. Qamar, M. Aslam, F. Z. Huyop and M. A. Javed. The Journal of Animal & Plant Sciences, 27(4): 2017, Page: 1315-1320.
4. Determination of Proximate Chemical Composition and Detection of Inorganic Nutrients in Maize (Zea mays L.) Shaista Qamar, Muhammad Aslam, Muhammad Arshad Javed. Materials Today: Proceedings 3 (2016) 715 – 718.