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RESEARCH ARTICLE

Sugar beet yield and industrial sugar contents improved by potassium fertilization under scarce and adequate moisture conditions

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Abstract

Sugar beet (*Beta vulgaris* L.) is an industrial crop, grown worldwide for sugar production. In Pakistan, sugar is mostly extracted from sugarcane, soil and environmental conditions are equally favorable for sugar beet cultivation. Beet sugar contents are higher than sugarcane sugar contents, which can be further increased by potassium (K) fertilization. Total K concentration is higher in Pakistani soils developed from mica minerals, but it does not represent plant available K for sustainable plant growth. A pot experiment was conducted in the wire-house of Institute of Soil and Environmental Sciences at University of Agriculture Faisalabad, Pakistan. K treatments were the following: no K (K_0), K application at 148 kg ha^{-1} (K_1) and 296 kg ha^{-1} (K_2). Irrigation levels were used as water sufficient at 60% water holding capacity and water deficient at 40% water holding capacity. The growth, yield and beet quality data were analyzed statistically using LSD. The results revealed that increase in the level of K fertilization at water sufficient level significantly increased plant growth, beet yield and industrial beet sugar content. The response of K fertilization under water deficient condition was also similar, however overall sugar production was less than that in water sufficient conditions. It is concluded from this study that K application could be used not only to enhance plant growth and beet yield but also enhance beet sugar content both under water-deficient as well as water-sufficient conditions.

Keywords: potassium, irrigation levels, beet yields, sugar contents

1. Introduction

Sugar beet (*Beta vulgaris* L.) belongs to Chenopodiaceae family and is mainly used for sugar production in different parts of the world (Rashid 1999). Sugar beet has 20% share in total sugar production of world (FAO 2009). Furthermore, it is also used for the production of ethanol (BSRI 2005). It is better than sugarcane in many aspects such as its short duration (5–6 mon) and high sucrose content (14–20%) (Anonymous 2004). Sugar beet is generally considered as a temperate region crop, but it has become a potential cash crop for tropics and subtropics due to the development of new bolting-resistant varieties (Cosyn *et al.* 2011). Requirement of sugar beet crop for water and fertilizers is 30–40% less than sugarcane and it can be grown in a wide range of climatic conditions (Chakauya *et al.* 2009). In Pakistan, initially it was confined to Peshawar valley of Khyber Pa-

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khtoon Khwa (KPK) but now is grown in Dera Ismail Khan Distrct of KPK, Mianwali, Bhakkar and Layyah districts of Punjab Province. It has been found wide adaptable in different agro-climatic regions of Pakistan (Ahmad and Rasool 2011; Kaloi *et al.* 2014). However, genotypic variations and agro-climatic conditions play a very important role in beet sugar contents (Asadi 2007).

Potassium (K) is the third most important nutrient for plant growth and development, and its significance in agriculture is comprehensively documented. It is an essential nutrient required in higher amounts for plant metabolism especially for photosynthesis and assimilates transport (Wang *et al.* 2015). Foliar application of potassium nitrate has also shown ameliorative effect under salt stress by enhancing photosynthetic rate, reducing Na^+ uptake, increasing K^+ uptake and improving wheat crop biomass, grain weight and yield (Ahmad 2014). The concentration of K in earth's crust is 2.3% (Sparks and Haung 1985), however K deficient soils are extensively found worldwide, i.e., 66% in southern Australia, 25–75% in China (Rengel and Damon 2008), and 30–35% in Pakistan (Akhtar *et al.* 2003). Pakistani soils are developed in the result of weathering of clay minerals containing high K content (Ranjha *et al.* 1992), but K availability to plant is tricky due to fixation and release of K from clay minerals (Mengel 2006). Use of K fertilizer is very low in Pakistan and is considered as "the neglected nutrient". The significance of K as a plant nutrient must be highlighted in an aggressive way by mentioning its role in crop yield and produce quality (Rengel and Damon 2008). It is a versatile element due to wide array of biochemical and physiological activities in plants (Krauss 1997). It has an important osmotic and charge balance role in plants (Tisdale *et al.* 1985), however, it is not an integral part of chemical structure of plants. Furthermore, it plays many important regulatory roles in plant development, that's why K is considered as vital to many plant metabolic processes. It has considerable significance in protein synthesis, stomatal conductance, enzyme activation, water-relation and photosynthesis in plants (Marschner 1995). When K becomes deficient in maize and sugar beet, the rate of photosynthesis in leaves declined (Terry and Ulrich 1973). When plants suffered under water deficient condition, it may require higher amount of internal K to maintain stomatal opening and closing and minimize reduction of CO_2 because photosynthesis and fixation of CO_2 maintain plant metabolic processes (Cakmak 2005). Furthermore, K enhanced the tolerance under water scarcity condition by enhancing the translocation and maintaining osmotic charge.

A number of investigations have anticipated the efficiency of K application and its critical role in transfer of sucrose to storage root (Winzer *et al.* 1996). When sugar beet plants suffer deficiencies of K, translocation of photosynthates from leaves to roots reduced resulting in less industrial sugar production (Hermans *et al.* 2006). Many researchers indicated that use of both K and N improved the quality and yield of sugar beet (Etemadi 2000). Keeping in view the possible role of K in plant growth and photosynthates translocation, the study was conducted to investigate the effect of K application under water deficient and sufficient levels on sugar beet yield and beet sugar contents.

2. Materials and methods

The pot experiment was conducted in the rain protected wire house at Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad from October, 2013 to May, 2014. The plastic pots containing 45 kg soil were placed in completely randomized manner during the whole growth season. Texture of the soil was sandy clay loam, pH was 7.7, electrical conductivity of soil saturation paste extract (EC_e) was 2.57 dS m^{-1}, sodium adsorption ratio (SAR) was 7.86 (mmol $L^{-1})^{1/2}$, saturation percentage was 30% and exchangeable K was 112 mg kg^{-1}. Two water levels were maintained, i.e., the water sufficient at 60% water holding capacity and water deficient at 40% water holding capacity of soil.

Seeds of the sugar beet (*cv*. Bond, Strube Company, Germany) were sown in sand to raise nursery and 20-d-old plants were transplanted in plastic pots at the rate of one plant per pot. Nitrogen (N), phosphorus (P) and boron (B) equivalent to 124, 124 and 6 kg ha^{-1} were applied as urea, diammonium phosphate and H_3BO_3, respectively. Treatments were control (K=0), K application at 148 kg K_2O ha^{-1} (K_1) and K_2 (296 kg K_2O ha^{-1}) as potassium sulphate under water sufficient and water deficient conditions. All the fertilizers were applied at the time of sowing. The crop was irrigated with distilled water and plants were harvested 180 days after transplanting. Beet size including length and diameter was measured with the help of measuring scale and vernier caliper. Fresh weight of shoot and beet was recorded respectively, and then shoot and beet were oven-dried at 80°C in oven after isolating the fresh beet sample for sugar analyses. Shoot and beet samples were digested by dry-ashing method (Chapman and Pratt 1961) and B in filtrate was measured by colorimeter using azomethine-H (Bingham 1982) as an indicator. Sodium and K in shoot and beet were determined in plant samples by wet digestion procedure using mixture of nitric and perchloric acids with ratio of 2:1 (Rashid 1999) using flame photometer according to the method described by Chapman and Pratt (1961). Chlorophyll contents were measured with chlorophyll meter (SPAD 502 P, Konica Minolta Inc., Japan).

Recoverable sugar content was determined by chopping and extracting the juice in a blender. Few drops of juice