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Full Length Research Paper

Studying the interactive effect of potassium application and individual field crops on root penetration under drought condition

Sayed Alireza Valadabadi[1] and Hossein Aliabadi Farahani[2]*

[1]Islamic Azad University, Shahr-e-Qods Branch, Iran.
[2]Islamic Azad University, Takestan Branch, Iran.

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In this study, interactive effects of different potassium application and water restrict on: root penetration at Iran. The experimental unit had designed by achieved treatment in factorial on the basis completely randomized block design with three replications. Certain factors including potassium and non-potassium applications (0 and 200 kg/ha), certain field crops (maize, sorghum and millet) and water supply were studied. In this study crops water supply was determined by indicated irrigation conditions by keeping leaf relative water content (RWC) > 95% (non-drought stress condition or irrigation conditions) and drought condition by RWC = 60 - 70%. We noticed, however K fertilizer significantly increased the root penetration of plants. Although the non-drought stress treatment significantly increased root penetration and highest root penetration of maize was achieved under irrigation conditions (non-drought), but the highest roots penetration of sorghum and millet were indicated under the drought condition. Whereas K application persist less damaging of drought stress result and it enabled plant to significantly grew its root and penetrating along soil depth under the drought condition. Our finding may give applicable advice to farmers and agricultural researchers for management and concern on fertilizer strategy and carefully estimate soil potassium supply within arid or semi arid regions as most challengeable issues of environmental safety.

Key words: Potassium fertilizer, drought stress, root penetration, maize, sorghum, millet.

INTRODUCTION

A sufficient supply of soil water is essential for crop growth, replacement of transpiration loss, and transportation of crop nutrients to roots. Drought occurs when there is a deficit in soil water supply to the crop. Severe drought limits crop water use and reduces yield. Earl and Davis (2003) summarized three main mechanisms through which corn yield is reduced by soil water deficit: (i) reduced canopy absorption of incident photosynthetically active radiation, (ii) decreased radiation use efficiency, and (iii) reduced harvest index. The ability to tolerate drought and have acceptable yields is limited among cultivars within a species (Serraj and Sinclair, 2002; Purcell et al., 2003). The objectives of a study were to; (i) quantify the relationship between crop water use and dry matter (DM) yield for corn (*Zea mays* L.), foxtail millet (*Setaria italica* L. Beauv.), and winter triticale (*X Triticosecale* Wittmack); and (ii) determine the range and distribution of expected DM yields for these three crops in the central Great Plains based on historical precipitation records. The three crops were grown in a drought stress condition no-till corn–millet–triticale sequence. Dry matter production was linearly correlated with water use for all three crops, with regression slopes ranging from 24.2 (corn) to 33.0 kg ha^{-1} mm^{-1} (millet). Precipitation use efficiency for the millet–triticale–corn forage system was 8.7 kg ha^{-1} mm^{-1}, suggesting this as an efficient forage system for the region (Nielsen et al., 2006). Bandaru et al. (2006) studied the growing grain sorghum plants in clumps would result in fewer tillers and less vegetative growth so that more soil water would be available during the grain-filling period. The results suggest that planting grain sorghum in clumps rather than spaced uniformly conserves soil water use until later in the season and may enhance grain yield in semiarid dryland environments.

*Corresponding author. E-mail: farahani_aliabadi@yahoo.com.

Table 1. The results of soil analysis.

Soil texture	Sand (%)	Silt (%)	Clay (%)	K (mg/kg)	P (mg/kg)	N (mg/kg)	Na (Ds/m)	EC (1: 2.5)	pH (In soil)	Depth of sampling (cm)
Sandy loam	49	29	22	145.2	4.2	36.7	0.04	0.18	8.0	0-15
	56	25	19	121.3	3.7	25.2	0.03	0.15	7.8	15-30

Drought stress reduced dry matters of balm by reduction in the leaf area, plant height and lateral stem number (Aliabadi et al., 2009). Also, drought stress decreased biological yield, grain yield and root length of barley (Khalvati et al., 2005).

Potassium is important in the growth of crops and an important ion in the physiology of plant water relations. Management practices have a direct effect on P, K, S and Ca availa-bility and utilization by crops. Manure, as opposed to inorganic fertilizers, supplies nutrients over time through mineralization. Also, the addition of organic matter with manure or with the use of an efficient crop rotation will affect soil properties such as cation exchange capacity and pH, and therefore root and nutrient interactions (Hickman, 2002). In addition, the presence or absence of certain elements can affect the general soil quality. For example, K is a soil aggregating agent which is known to have a positive effect on soil physical properties and subsequently crop yields (Hamza and Anderson, 2003). Recommendations of Wortmann et al. (2009) for P, K, and S were evaluated using results from 34 irrigated corn (*Z. mays* L.) trials conducted in diverse situations across Nebraska. The results indicate a need to revise the current recommendation for P, to maintain the current K and S recommendations, and to use soil organic matter and pH in addition to soil test nutrient values in estimating applied nutrient requirements for irrigated high yield corn production. In present study, there has been a growing interest in brown midrib (BMR) sorghum (*Sorghum bicolor* (L.) Moench.) x Sudan grass (*Sorghum sudanense* Piper) hybrids (SxS) as a replacement for silage corn (*Z. mays* L.) in the North-eastern USA.

The objective was to evaluate the impact of K fertilizer management (0, 112 or 224 kg K_2O ha^{-1} cut^{-1}) under optimum N management (112-168 kg N ha^{-1} cut^{-1}) on yield, quality and K concentrations of BMR SxS over a 2-year period. Potassium application increased forage K concentration up to 13 mg K kg^{-1} dry matter (in the first cut in 2003). Without K addition in the 2-year period, K concentrations in the forage decreased from 23 g kg^{-1} for the first cutting in 2002 to 15 g kg^{-1} for the second cut in 2003. Low K forage was obtained for all second-cut forage unless 224 kg K_2O ha^{-1} cut^{-1} had been added. These results suggest low K BMR SxS forage can be harvested from initially high K soils without loss in dry matter yield as long as no additional K is added (Ketterings et al., 2005). Rosolem et al. (2005) evaluated K leaching from millet straw grown under potassium rates (0, 100, 200, and 300 mg dm^{-3}), and submitted to five levels of simulated rain (5, 10, 20, 40 and 80 mm). Plants were grown in soil filled pots in a greenhouse. Potassium deficiency speeds up millet dehydration after herbicide application and increases lightly rain water retention in the straw. The amount of K leached right after plant desiccation is correlated with the residue nutrient content and can be as high as 64 kg ha^{-1} considering a mulch of 8 t ha^{-1}. Although well-nourished millet plants release considerable amounts of K with the first rains, a large percentage of the nutrient is still retained in the straw. Therefore, this study was undertaken to examine the interactive effects of potassium fertilizer and water in the soil on root penetration of maize, sorghum and millet.

MATERIALS AND METHODS

This study was conducted on experimental field of the Ishmael Abad station in Qazvin at Iran (36°15' N, 49°55' W; 1300 m above sea level) from 10 June to 20 October 2005, with sandy loam soil (Table 1). The mean annual temperature (27°C) and rainfall in the study area is distributed with an annual mean of 309 mm. The experimental design was a factorial experiment in a completely randomized block design with three replications. The treatments included potassium (K_1) and non-application (K_2) (0 and 200 kg/ha), certain field crops: maize (C_1), sorghum (C_2) and millet (C_3)) and irrigation levels with estimate leaf relative water content (RWC) by > 95% (non-drought stress condition (S_1)) and irrigation under RWC = 60-70% (drought stress condition (S_2)). Maize (*Z. mays* L. Cul. Single-cross 704), sorghum (*S. bicolor* L. cul. Speed Feed) and millet (*Panicum italicum* L. cul. Notre Feed) were used in this experiment. Initially, plant nutrient feed of nitrogen supply was added by applying 300 kg/ha urea twice; 150 kg/ha urea at the cultivation time and further 150 kg/ha urea at beginning of stem elongation stage as well as 200 kg/ha phosphorus (ammonium phosphate) and potassium (K_2O) through cultivation time once. At the plants growth period and between both irrigation, we selected 20 young leaves from each plot for determination of RWC by following formula (Aliabadi Farahani et al, 2008).

$$\text{RWC} = \frac{\text{Leaves fresh weight} - \text{Leaves dry weight}}{\text{Leaves turgid weight} - \text{Leaves dry weight}} \times 100$$

Also, depth of root penetration was determined by sampling of deep soil. Thus, 24 h after irrigation (field capacity condition) depth of root penetration was determined by Auger (Height = 100 cm and Radius = 15 cm). Sampling was performed twice to determination of the depth of root penetration > 100 cm (Newman, 1995). Finally, obtained data were subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS institute Cary, USA, 1988) and means considered significant at P < 0.05.

Table 2. Analysis of variance.

S.O.V	df	Mean squares penetration depth of root
Replication	2	311.41
Drought stress	1	* 598.05
Crops	2	* 701.406
K fertilizer	1	** 712.316
Stress × Crops	2	* 632.011
Crops × K fertilizer	2	281.04
Stress × K fertilizer	1	203.008
Stress × Crops × K fertilizer	2	* 531.106
Error	22	37.084
CV (%)		7.11

Note** and *: Significant at 1 and 5% levels, respectively.

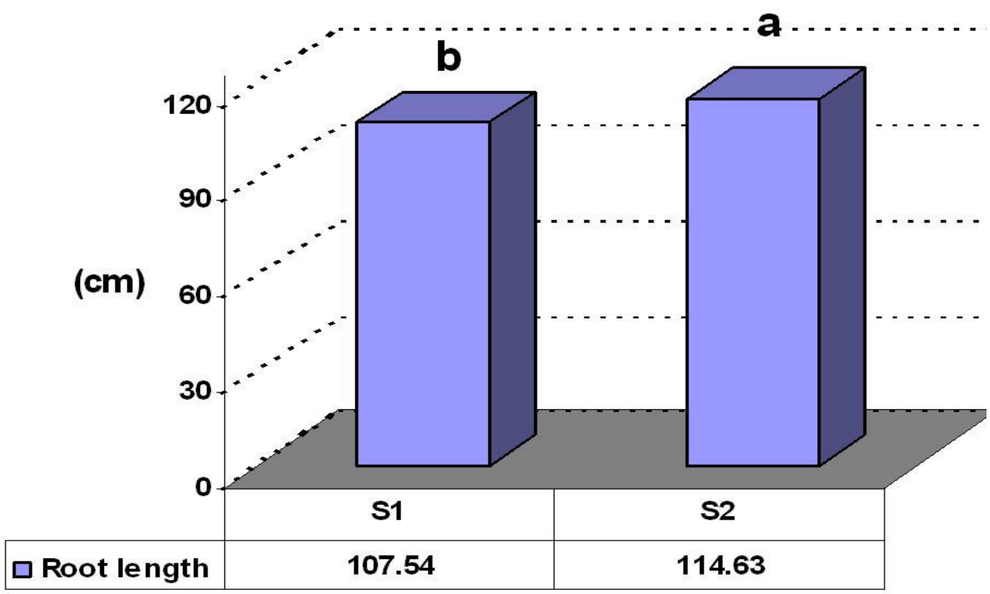

Figure 1. Effect of drought stress on root penetration.

RESULTS AND DISCUSSION

Final results of plants features showed that drought stress had significant effect on root penetration ($P < 0.05$) and we noted a highest depth of root penetration (root length) under the drought stress (Table 2 and Figure 1). Those findings are in agreement with the observations of Katerji et al. (2004) and Ajayi and Olufayo (2004). As it was shown in the results, reducing water supply in soil achieved a situation for plant to pursue root growth though soil depth. This shows that in order to resist drought stress, the plant employed different strategies throughout individual survival straggle by drought conditions. In addition, K application had a significant effect on root penetration ($P > 0.01$), therefore, our findings indicated higher root penetration under K application (Table 2 and Figure 2). Those results were similar with the findings of Wortmann et al. (2009); Yin and Vyn (2002) and Parsons et al. (2007). Potassium is important for a plant's ability to withstand extreme drought stress. Some field crops showed ability of water relations adjustment which refers to water use efficiency. Soil nutrients like as potassium ions affect water transport in whole plant, maintain cell pressure and regulate the opening and closing of stomata (small openings found on the leaf responsible for cooling and taking in carbon dioxide for photosynthesis). Regarding to this fact, our data indicated that crops plant had a significant effect on root penetration ($P < 0.05$) and was preformed higher root penetration in millet (Table 2 and Figure 3).

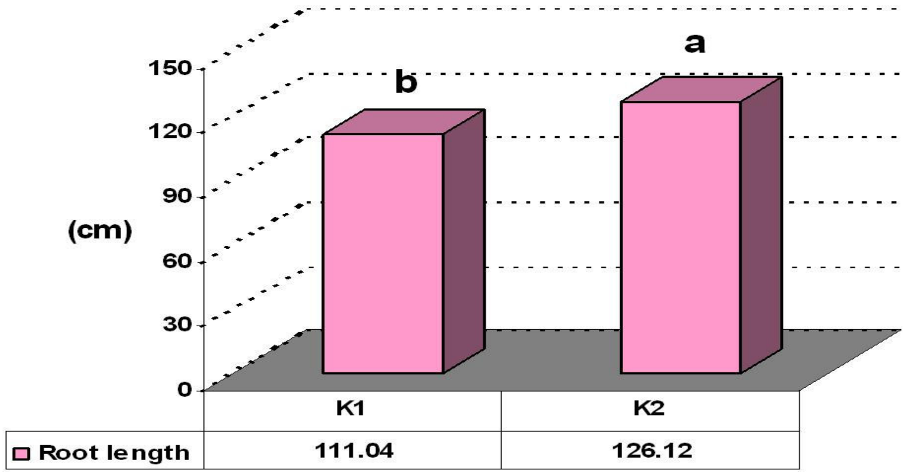

Figure 2. Effect of K application on root penetration.

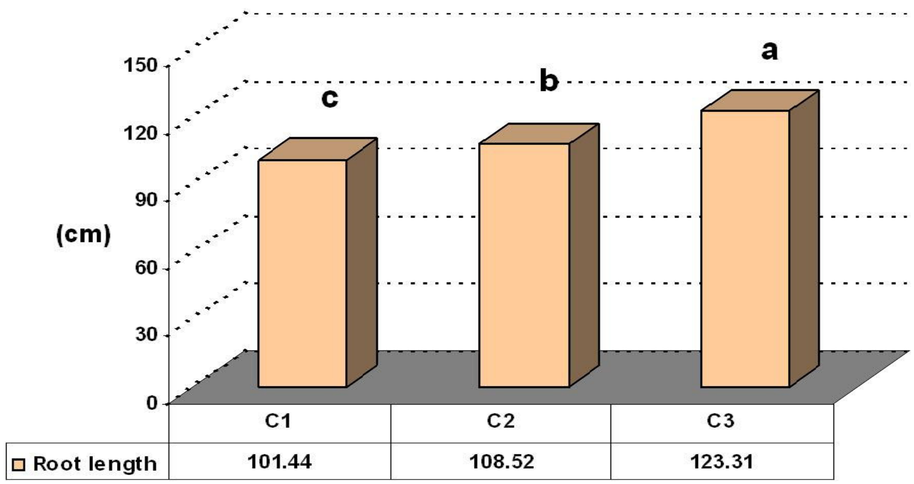

Figure 3. Root penetration in crops plant.

Significant different between crops plants treated with K application under water restriction was highlighted to compare with non-application K under drought condition and treatment had significant effect on depth of root penetration ($P < 0.05$) and however, higher root penetration was indicated millet with K application and none stress condition. Surprisingly, K application contributed plants to approach longer root length as well through the condition of drought stress (Table 2 and Figure 4). Our results of treatments interaction were similar to the results of Rosolem et al. (2005) and Ashraf et al. (2003).

Conclusion

Our study showed that K application reduces the damaging effects of drought stress by increasing depth of root penetration. Control of drought stress has been paying attentions due to the most important environmental factor in arid and semi –arid regions. It may useful to consider on screen certain local crops and fertilizer strategies to gain higher predictability under scope of limited available water recourse in these regions. Practically, findings may suggest farmers and agricultural researchers to consider carefully on limiting or control the huge among of soil potassium application in suffered soils by water restriction as current challenge of scientist in global changes.

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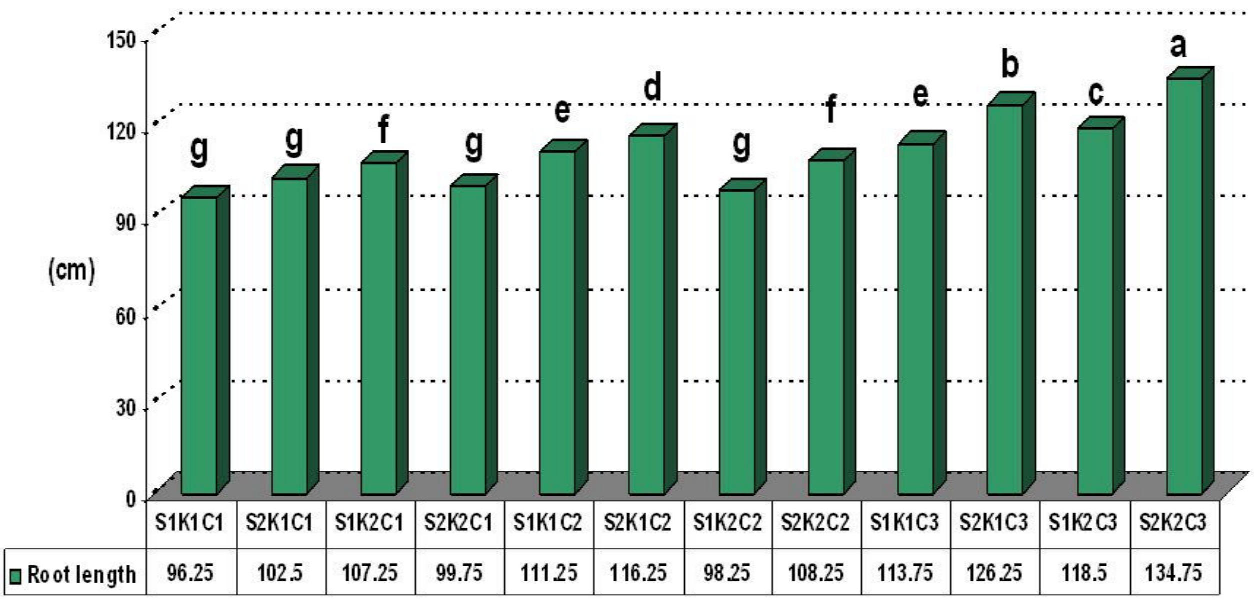

Figure 4. Effect of interaction on root penetration.

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