Effects of Soil and Foliar Applications of Potassium Sulfate on Yield and Yield Components of Maize SC. 704 under Different Irrigations Levels in Iran

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ABSTRACT

This study was performed to evaluate effect of soil and foliar application of potassium sulfate at stages of plant establishment and tassel emergence under different irrigation conditions in maize sc. 704, during cropping years of 2013-14 at the field located in Khodaafarin county. The experiment was done in form of split plot based on randomized complete block design with three replications. In this research, irrigation intervals was considered as the main factor with three levels of irrigation: once per 7 days, once per 14 days and once per 21 days and usage of potassium sulfate was as subsidiary factor with seven levels: non-use of potassium sulfate, soil application, foliar application at establishment stage, tasselling stage, both stages of establishment and tasselling, soil and foliar applications at establishment, soil and foliar applications at tasselling, soil and foliar applications at establishment and tasselling. The traits of seeds number per row, plant height, total dry weight of plant, number of seeds per plant, seed weight per plant, weight of ear with husk leaf and seed yield were evaluated. The results showed that there were significant different at 1% and 5% probability levels between irrigation levels from the view point of all the studied traits except number of seed rows per ear, weight of ear with husk leaf and seed yield. Delay in irrigation from 7 to 14 and 21 days, caused to significant reduction in number of seed per rows, plant height, total dry weight per plant and seed weight per plant. The highest values of these attributes were obtained in once irrigation per 7 days. Delay in irrigation from 14 to 21 days had no significant effect on these traits. Seed yield in treatment of soil application and treatment of soil + foliar application at both stages of establishment and tasselling had the highest amounts and the lowest value of this trait was related to treatment of foliar application at both stages of establishment and tasselling. It can be expressed that foliar application of potassium can not provide corn needs to this element, but soil application with foliar application leads to better absorption of this element and more proper performance.

INTRODUCTION

Considering that maize have high rank from the view point of importance degree in food program of humans and animals and due to great production of maize and high consumption per capita of this product in different countries; investigation and finding techniques to increase quantity and quality of corn crop are priority in agricultural researches consequently, effort to further production and more economical of this crop is be felt more [11]. Corn is one of the major products; meanwhile it has further expectation and environmental stresses are such factors which restrict usage of maximum potential of soil, water and plant in order to maximum production [28]. This plant due to its antiquity and ability of high adaptability to different climatic conditions has been expanded all over the world. Maize is one of the high noteworthy crops due to its importance in nutrition of livestock and poultry [1]. Drought such as other environmental stresses has deleterious effect on crop yield and in many areas, water deficit is one of the important factors which declines yield. Drought and its stress is a main factor which restricts crop productions and reduces the usage efficiency of arid regions. Drought stress is public tension that has adverse effects on plant growth and crop production [38]. Drought stress causes damage to membrane and photosynthetic system. Photosynthesis can affect by drought stress via two ways, first with stomatal closure which prevents transmission of carbon dioxide to chloroplasts and second by reduction in...
water potential of cell on complex photosynthetic structures. Also, drought stress affects growth of roots and stems and may be causes to reduction in leaf area of plants [20]. Drought stress influences yield of corn and other crops by decrement in absorption of photosynthetic active radiation via canopy, reduction of radiation use efficiency and decline of harvest index [21]. The most critical period of maize growth from the view point of water requirements is stage of male ear emergence up to seed dough stage. Numerous experiments have shown that moisture deficit in this period decreases seed yield significantly [9]. Critical periods of stress in maize are establishment stage of seedling, period of rapid growth, pollination and seed-filling stage; effect of stress on yield can be different because each stage has different physiological processes [29]. Iran is located in arid and semi arid area of earth and average of annual precipitation is 230mm and distribution of rainfall in these areas (arid and semi arid) often do not comply crops requirements and products get involved in continuous or temporary drought stress; hence optimal use of semi-arid areas should be possible with desirable management and cultivation and productivity of these areas should increase [19]. Corn is such a crop that likes potassium. The uptake amount of this element by corn is even greater than nitrogen and during the day absorbs 5 kg of nitrogen, 0.5 kg of phosphorus and 5 kg of potassium approximately per hectare [26]. Potassium is one of the fundamental elements of soil and plant. Some plants absorb potassium from soil about 8% of their dry weight. This amount of potassium is dependent to parent material, soil weathering degree, amount of potassium fertilizer, amount of absorption by plants and losses due to erosion and leaching [4]. Mentioned researchers believe that ability of soil potassium supply for plant nutrition during growth season is related to quantity and intensity of potassium and on the other hand release rate of potassium from non-exchangeable form to exchange and solution form, therefore absorbable potassium is not sufficient and mentioned factors should be considered. Rabbani and Emam reported that plant growth is controlled by some important factors which water has vital role in this regard [31]. Thomas expressed that low available moisture in soil, high evaporation, intensification of respiration due to high temperature, intensive solar radiation, increase of soil mechanical resistance due to dryness are effective factors in drought stress [31]. Cakmak reported that water stress at different growth stages of maize caused to reduction in plant dry matter, harvest index, root dry weight and seed yield [8]. Bukvice et al., reported that adjustment of drought negative effects by maintaining of inflammation pressure, transpiration reduction and increase of water use efficiency has been through consumption of potassium [6]. Jagtap et al., reported increase and improvement of seed yield, dry matter and harvest index with higher amounts usage of potassium under water stress condition [23]. Khavari Khorasani stated that irrigation in this plant should not be delayed because deficit of soil moisture causes leaves to wilt and to roll, also should not be allowed stress symptoms appear because corn damages physiologically before appearance of deficit symptoms and will not has enough growth due to non-growth of root and shoot cells [25]. Sajedi et al., have reported, many studies of researchers indicated that consumption of high-usage fertilizers can increase plants resistance to environmental stresses such as drought and salinity also [33], Khavari Khorasani declared that lack of potassium causes augmentation in sensitivity to water shortages in corn [25]. Tabatabai Ebrahimi et al., concluded that application of appropriate amounts of potassium sulfate in water deficit condition can be partially prevented reduction of yield and yield components of maize [36]. Results of Barzabadi and Farahani demonstrated that in safflower, negative effects of water deficit at stages of vegetative and seed filling can compensate with foliar spray of zinc and potassium; also in pea, application of zinc sulfate at flowering stage can compensate negative effects of water shortage partly [2].

With consideration to the importance of maize in nutrition of humans and livestock and weather conditions of arid and semi arid, supplementary irrigation is necessity for cultivation of this plant in Iran; with regard to role of potassium in reducing sensitivity of plants to water deficit, this study was performed with the purpose of evaluation in effects of this element in form of soil application and foliar spray in corn at two stages of establishment and tassel emergence under different irrigation conditions in Khodaafarin region.

**MATERIALS AND METHODS**

In this study, cultivation of maize sc. 704 was conducted during cropping years of 2013-14 at the field with area of 600 square meters located in Khodaafarin County, center of Chenagchi village. The experiment was done in form of split plot based on randomized complete block design with three replications. In this research, studied treatments were included: Irrigation intervals was considered as the main factor with three levels of irrigation: a1: once per 7 days, a2: once per 14 days and a3: once per 21 days. Usage of potassium sulfate was as subsidiary factor with seven levels: b1: non-use of potassium sulfate, b2: soil application, b3: foliar application at establishment stage (with plant height of 40cm), b4: foliar application at tasselling stage, b5: foliar application at both stages of establishment and tasselling, b6: soil and foliar applications at tasselling stage, b7: soil and foliar applications at both stages of establishment and tasselling. On May 2013, cultivation supplementary operations consist of plow, disk and ridges preparation were carried out. Planting was done in form of row by row and based on planting map and seeds were at depth of 5cm. Each replication with dimensions of 45 meters by 4 meters at 1.5m distance from each other was involved three main plots and two non-planting rows between main
plots and 21 sub-plots with three planting rows for each treatment and spacing between each row was 60cm also plants distance on row was considered 20cm. Potassium in form of potassium sulfate with rate of 250kg ha\(^{-1}\) based on soil analysis was used for soil application treatment which was concurrent with planting and foliar application was done with concentration of 5\% at two stages of plant establishment and tasselling based studied treatments. Urea with amount of 150 kg ha\(^{-1}\) and triple superphosphate with amount of 100 kg ha\(^{-1}\) were used before planting. Irrigation treatments in form furrow irrigation continued until the end of growth season. Plants harvest was carried out on end of Sep. 2013. In this study, the traits of seeds number per row, plant height, total dry weight of plant, number of seeds per plant, seed weight per plant, weight of ear with husk leaf and seed yield were evaluated. Analysis of variance for measured traits was done in form of split plot based on randomized complete block design with three replications. Before analysis of variance, assumptions of normality in deviations distribution and variances homogeneity were examined. Mean comparisons of traits were carried out using Duncan's multiple range test at 5\% probability level. Computer software of MSTATC, SPSS-15, and Excel were used for statistical calculations, draw figures and tables.

Table 1: The results of physicochemical analysis for soil sample of tested field.

<table>
<thead>
<tr>
<th>Depth cm</th>
<th>Electrically conductive</th>
<th>PH</th>
<th>Total nitrogen %</th>
<th>Absorbable phosphorus p.p.m</th>
<th>Absorbable potassium p.p.m</th>
<th>Absorbable zinc p.p.m</th>
<th>Absorbable iron p.p.m</th>
<th>Absorbable manganese p.p.m</th>
<th>Sand %</th>
<th>silt %</th>
<th>clay %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30</td>
<td>1.58</td>
<td>7.84</td>
<td>0.075</td>
<td>3.4</td>
<td>153</td>
<td>0.26</td>
<td>0.54</td>
<td>1.8</td>
<td>1.86</td>
<td>58</td>
<td>26</td>
</tr>
</tbody>
</table>

**RESULTS AND DISCUSSION**

Results of variance analysis for the studied traits are presented in Table 2.

**Plant height:**

Alterations of plant height are most noticeable variations caused by growth condition in majority of crop and plant height is affected by moisture in environment. Delay in irrigation led to significant reduction in plant height. Treatment of soil application + foliar application in both stages of establishment and tasselling at irrigation condition of once per 7 days had the highest average of plant height (211.7cm) which was in superior statistical group. Treatment of irrigation once per 21 days with foliar application of potassium sulfate at establishment stage and treatment of irrigation once per 21 days with soil +foliar applications at tasselling stage with averages of 172.3cm and 172.8cm, respectively had the lowest plant height (Figure 1). Graham *et al.*, (2004) reported that water stress at different growth stages was significant at 1\% probability level on traits of plant height and ear height above ground level [18]. Plant height decreased with increasing severity of water stress which its reason is reduction of vegetative growth due to decrease of cell division and cells growth. The results of this study are in conformity with findings of Imanzade *et al.*, Ouda *et al.*, also reported that drought stress during growth season caused to reduction in plant height of corn [22, 30].

**Total dry weight of plant:**

The highest total dry weight of plant with rate of 148.45g. was obtained in irrigation condition of once per 7 days and the lowest total dry weight of plant with significant difference was in treatment of irrigation once per 21 days with amount of 115.11 g per plant. Delay in irrigation from 7 days to 14 days and 21 days decreased total dry weight of plant up to 8.76\% and 22.46\%, respectively (Table 3). Edalatifar and Imanzade *et al.*, (2014) reported that dry weight of shoots reduced significantly due to drought stress intensity [13, 22]. Stress causes to reduction in cell development via depletion in cell inflammation and photosynthesis reduction which eventually, growth declines and then stops [34]. Khavar Khurasani stated that irrigation in this plant should not be delayed because deficit of soil moisture causes leaves to wilt and to roll, also should not be allowed stress symptoms appear because corn damages physiologically before appearance of deficit symptoms and will not has enough growth due to non-growth of root and shoot cells [25].

**Number of seeds per row:**

Emam and Seghateleslami reported that whereas final number of seed rows is determined on ear before other yield components, probably; there was low competition for receiving food between physiological sink at determination stage of rows number per ear and therefore studied treatments had no significant effects on this trait [15]. Delay in irrigation led to significant reduction in number of seeds per row. Maximum number of seeds per row with amount of 21.67 was obtained in irrigation condition of once per 7 days which had no significant difference with irrigation condition of once per 14 days. The lowest number of seeds per row (16.85) with significant difference was obtained in irrigation treatment of once per 21 days. With delay in irrigation from 7 days to 14 and 21 days, number of seeds per row reduced up to 6.75\% and 24.60\%, respectively (Table 3).
Setter et al., stated that process of seed formation in maize determines by leaves photosynthesis, amount of sugars, starch, Abscissic acid and cytokinin; hence, water deficit at pollination stage via impact on these phenomena caused to reduction in seed formation at bottom of the ear [35]. They demonstrated that drought stress at flowering stage had the most effect on number of seeds per ear. So that, number of seeds per ear was 17.8% lower than control treatment. In their experiment, effects of drought and hybrids on number of seeds per ear were significant at 1% probability level. Brien reported that water stress during vegetative stage caused inflorescence becomes smaller and lower rows of seed create in ear [3].

Number of seeds per ear:
Delay in irrigation led to significant reduction in number of seeds per ear. The highest number of seeds per ear with amount of 265.28 was obtained in irrigation condition of once per 7 days and the lowest amount (210.09) with significant difference was achieved in irrigation treatment of once per 21 days. This rate had no significant difference with irrigation per 14 days. With delay in irrigation from 7 days to 14 and 21 days, number of seeds per ear reduced up to 7.19% and 20.8%, respectively (Table 3).

Seed weight per plant:
The highest average of seed weight per plant with amount of 81 g. was belonged to treatment of irrigation once per 7 days and non-used of potassium. Treatments of irrigation once per 21 days with foliar application at tasselling stage and irrigation once per 21 days with foliar application at both stages of establishment and tasselling had the lowest seed weight per plant with averages of 39 and 38.07 g., respectively (Figure 2). With consideration to potassium role in maintenance of plant water and prevention of water wasting, therefore in stress condition which plant is facing with water deficit, existence of enough potassium caused to maintenance of photosynthesis activity and production of photosynthetic materials and with augmentation of stress intensity, potassium role is justifiable in prevention of reduction in seeds number per row. By taking consideration to potassium role in transmission of assimilate and nutrients, increase of seeds number per row by using potassium is justifiable [12]. Cakir has reported significant reduction in seed weight due to water deficit [7]. Barzabadi and Farahani showed that water deficit at different growth stages of maize had various effects on seed yield and its components [2]. Brown et al. demonstrated that effect of drought is quite obvious at seed filling stage [4]. Whatever drought stress during seed filling stage become severe, seed weight and 100-seeds weight reduce and if field confronts with water deficit at seed filling stage, transmission of nutrients from leaves to seed reduces and 100-seeds weight decreases which is corresponded with the results of this research. Imanzade et al., reported that the highest seed weight per plant was related to treatments of soil application and foliar application at both stages of establishment and tasselling and soil application and foliar application at tasselling stage and the lowest seed weight was belonged to treatments of non-used and foliar application at tasselling stage [23].

Weight of ear with husk:
The highest weight of ear with average of 92.5 g. was related to treatment of irrigation once per 7 days and non-used of potassium sulfate and was in superior statistical group. Treatments of irrigation once per 21 days with foliar application at both stages of establishment and tasselling and irrigation once per 21 days with foliar application at tasselling stage had the lowest weight of ear with averages of 50.13 and 50.67 g., respectively (Figure 3).

Seed yield:
Seed yield in soil application of potassium sulfate and also soil application with foliar application at both stages of establishment and tasselling had the highest amounts and treatment of foliar application at both stages of establishment and tasselling had the lowest seed yield (Table 4). Jamin and Ridwan with conduction of experiment on maize in Indonesia stated that corn yield increased with usage of potassium [24]. Bukvice et al. have reported that consumption of zinc sulfate and potassium sulfate increases seed yield under drought stress [6]. Emam and Farley and Coot stated that under drought stress treatment, higher seed yield during seed filling stage as compared with flowering stage was related to assimilate remobilization [14, 16]. So that, if plant at seed filling stage encounters with environmental stress (especially drought stress), share of assimilate increases in remobilization for seed filling. Fusheng in an experiment on corn observed that potassium duties are as follows: activation of enzymes, accelerators of photosynthesis process, carbohydrate synthesis and transport of synthesized carbohydrates in photosynthesis process, protein synthesis, improving and augmenting in plants resistance to stress and appropriate amount of potassium can improve crop quality [17]. Increase of crop yield has been reported with consumption of potassium [10, 27, 32].

Conclusions:
With reduction of irrigation intervals from 7 days to 21 days; traits of plant height, seed weight per plant, number of seeds per row and total dry weight of plant decreased up to 20.8%, 24.60%, 22.24% and 22.46%,
respectively. Reduction of irrigation intervals from 7 to 14 days did not cause significant alteration in mentioned traits which indicates reduction in irrigation intervals from 7 to 14 days in corn 704 not only amounts of traits have no significant reduction but level of used water in Khodaafarin county saves up to 100%. Seed yield in treatment of soil application of potassium sulfate with foliar application at both stages of establishment and tasselling with average of 5349.94 kg. ha⁻¹ had the highest amount and seed yield with average of 4066.59 kg. ha⁻¹ in treatment of foliar application at both stages of establishment and tasselling had the lowest amount. Hence, it can be expressed that foliar application of potassium can not provide corn needs to this element, but soil application with foliar application leads to better absorption of this element and more proper performance.

Table 2: Variance analysis of studied traits in form of split plot based on randomized complete block design.

<table>
<thead>
<tr>
<th>S.O.V</th>
<th>DF</th>
<th>Mean of Squares</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rep</td>
<td>2</td>
<td>554.94</td>
</tr>
<tr>
<td>Factor a</td>
<td>2</td>
<td>131.25**</td>
</tr>
<tr>
<td>Error a</td>
<td>4</td>
<td>30.15</td>
</tr>
<tr>
<td>Factor b</td>
<td>7</td>
<td>16.18</td>
</tr>
<tr>
<td>b x a</td>
<td>14</td>
<td>15.34</td>
</tr>
<tr>
<td>Error b</td>
<td>42</td>
<td>18.95</td>
</tr>
<tr>
<td>C.V%</td>
<td>22.16</td>
<td>5.48</td>
</tr>
</tbody>
</table>

Differences between averages of each column which have common characters are not significant at probability level of 5%.

Table 3: Mean comparisons of studied traits in irrigation levels.

<table>
<thead>
<tr>
<th>Irrigation Levels</th>
<th>Traits</th>
<th>Number of seeds per row</th>
<th>Total weight of plant</th>
<th>Number of seeds per ear</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 days</td>
<td>a</td>
<td>21.67</td>
<td>148.44</td>
<td>265.281</td>
</tr>
<tr>
<td>14 days</td>
<td>a</td>
<td>21.43</td>
<td>135.433</td>
<td>246.205</td>
</tr>
<tr>
<td>21 days</td>
<td>b</td>
<td>16.85</td>
<td>115.105</td>
<td>210.091</td>
</tr>
</tbody>
</table>

Differences between averages of each column which have common characters are not significant at probability level of 5%.

Table 4: Mean comparisons of seed yield under levels of potassium sulfate.

<table>
<thead>
<tr>
<th>Sulfate Potassium levels</th>
<th>Seed yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>non-use of potassium sulfate</td>
<td>5267.91 a</td>
</tr>
<tr>
<td>soil application</td>
<td>5314.77 a</td>
</tr>
<tr>
<td>foliar application at establishment stage</td>
<td>5013.82 ab</td>
</tr>
<tr>
<td>foliar application at tasselling stage</td>
<td>4460.11 ab</td>
</tr>
<tr>
<td>foliar application at both stages of establishment and tasselling</td>
<td>4066.59 b</td>
</tr>
<tr>
<td>soil application and foliar application at tasselling stage</td>
<td>4350.84 ab</td>
</tr>
<tr>
<td>soil application and foliar application at both stages of establishment and tasselling</td>
<td>5349.94 a</td>
</tr>
</tbody>
</table>

Differences between averages of each column which have common characters are not significant at probability level of 5%.

Fig. 1: Effect of potassium application and irrigation levels on maize plant height.

Fig. 2: Effect of potassium application on maize seed weight.
**Fig. 3:** Effect of potassium application and irrigation levels on maize weight of ear with husk.

b₁: non-use of potassium sulfate, b₂: soil application, b₃: foliar application at establishment stage, b₄: foliar application at tasselling stage, b₅: foliar application at both stages of establishment and tasselling, b₆: soil and foliar applications at tasselling stage, b₇: soil and foliar applications at both stages of establishment and tasselling

### REFERENCES


