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Influence of Potassium Foliar Application on Cotton Yield (*Gossypium barbadense* L.) under Saline Condition

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ABSTRACT

There is a lack of sufficient information on cotton responses to time and amount of foliar application of potassium (K) under salt stress environment, The objective of this study was to investigate the effects of potassium (as Solupotasse 50% K_2O and 18% S) rate and application time on yield and yield components of cotton under saline field condition. A factorial experiment based on randomized complete block design with three replications was conducted in Sabzevar Agriculture and Natural Resources Research center in 2015. Factors were: K rate (0, 1, 2 and 3%) and K foliar application time (at early flowering, at peak boll formation and at early flowering + peak boll formation). Increasing of K concentration to 3% increased plant height, sympodial branch number, boll number, boll weight, seed cotton yield and lint yield. Lint percent was not affected by potassium concentration. The highest boll number and lint yield was obtained when potassium spraying at early flowering stage whereas foliar application at peak boll formation had the highest plant height and boll weight. The maximum seed cotton yield was obtained at K application twice at early flowering + peak boll formation. The results obtained here suggest that 3% K application (as Solupotasse) at early flowering + peak boll formation stage can improve the seed cotton yield grown under salt stress environment.

Keywords: *Boll weight, Lint percent, Sympodial branch*

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INTRODUCTION

At the global level, 17% decline in crop yields caused by abiotic stresses. It was estimated that 70% of crop yield reduction belong to drought stress, 20% to salinity, 40% to high temperature, 15% to low temperature and 8% to other abiotic stress (Kafi *et al.*, 2010). In many parts of the world, especially in arid and semi-arid, salinity is one of the main obstacles in the production of crops and garden (Bui, 2013). More than 13 percent of the world's cultivated land and 30 to 50 percent of the world's irrigated lands are under salinity stress (Kafi *et al.*, 2010). Cotton is considered as one of the most important cash crops which are widely used for agricultural and industrial purposes (Stewart *et al.*, 2009). Although cotton is classified as one of the most salt tolerant major crops but its growth and development are adversely effected by soil or water salinity. Germination, seedling emergence and early growth stage are more sensitive to salinity than other stages (Ahmad *et al.*, 2002). Accumulation of salts in saline conditions may prevent or reduce germination, seedling emergence and plant growth through osmotic effects, toxic effects and disturbing the ionic balance of nutrient (Kafi *et al.*, 2010). Potassium (K) is an essential nutrient that affects most of the biochemical and physiological processes are involved in plant resistance to biotic and abiotic stresses (Ashfaq *et al.*, 2015). It is a major nutrient for cotton apart from nitrogen and phosphorus (Zorb *et al.*, 2014). Oosterhuis *et al.* (2013) pointed out that the peak demands for K is at boll filling stage, with higher boll load and potential yield and spraying of foliar K at first bloom (45 to 60 DAS) or squaring and flowering or one to four weeks after first flowering in one to four rounds at 7 to 15 days interval was found to increase kapas yield. 3-5 Kg daily requirement to K and ineffectiveness K uptake by the root system cause potassium have a special role in the growth and development of cotton (Stewart *et al.*, 2009). Although the average amount of potassium in saline soils can be seen as satisfactory or adequate but not a lot of potassium absorption by plants. Several factors such as leaching, change in Na/K and Ca/K ration will be resulted in decreasing of K absorption. Therefore, in such soils K fertilizers will be increase crop yield (Kafi *et al.*, 2010). Proper management of K fertilizer is especially important in saline soils where K application might reduce the adverse effects of salinity on plant growth and yield. It was reported that the best seed cotton yield achieved with a combination of high dose of K fertilizer and split application of K at planting, vegetative stage, flowering and early boll development (Equally at each stage). Increased K rate increased seed cotton yield because of improved boll weight and boll number in saline condition. Boll weight had more correlate with seed cotton yield than boll number (Ardakani *et al.*, 2016). Application of potash (70 kg $K.ha^{-1}$) as Potassium nitrate was better than potassium sulphate and potassium chloride for plant height, number of boll, boll weight, seed cotton yield, lint percentage and earliness in cotton (Armin and Hajinezhad, 2016). Soil application of K is the most commonly method in the Cotton cropping system (Gormus, 2002). When soil K levels and fertilizer K rates are deficient for the crop's needs, foliar K fertilization can decrease injury from leaf spot diseases, increase yields, and improve fiber quality (Oosterhuis, 2002). Foliar fertilization can be used to improve the efficiency and rapidity of utilization of a nutrient urgently required by cotton crop for maximum growth and yield (Oosterhuis and Weir, 2010). Four sprays of 2% KNO_3 resulted in higher seed cotton yield at Nanded and Siruguppa whereas four spray of 3% KNO_3 seemed beneficial at Surat (Rajendran *et al.*, 2010). Sharma and Singh (2007) found that foliar application of K_2O (2%) at initial and peak boll formation significantly increased seed cotton yield, number of open bolls.plant^{-1}, boll weight, K content and uptake. Fiber quality parameters viz., ginning percentage, staple length, uniformity ratio, micro naire and fiber strength were also improved with foliar application of K_2O. Weather conditions has role in cotton reaction to potassium fertilizer. In a relatively dry growing season Cotton lint yield increased linearly with band application of K possibly. Combination of band and broadcast application of K fertilizer was more effective in increasing cotton lint yield than either method alone. Maximum lint yield was obtained with the application of 34 kg K.ha^{-1} banded plus 136 kg K.ha^{-1} broadcast. Although cotton qualitative and quantitative response to potassium fertilizer source and amount of potassium in saline conditions as well as normal conditions is considered by scientists (Ardakani *et al.*, 2016; Armin and Hajinezhad, 2016; Gormus, 2002; Oosterhuis, 2002; Oosterhuis *et al.*, 2013). But there is little knowledge about the foliar application of potassium on cotton yield in saline conditions. The objectives of this study was to determine the effects of various K rates as foliar spray and time of application on cotton yield and yield component in saline soil.

MATERIALS AND METHODS

Field and Treatment Information

The experiment was conducted at Sabzevar Agriculture and Natural Resources Research center at 2015, in 30 km southwest of Sabzevar (32°32N, 51°23E and 1630 m above sea level). The 30-year averages rainfall during growing season is 37.1 mm and the maximum and minimum temperature is 34 and 10^{o}C, respectively. This experiment was carried out as factorial experiment based on randomized complete block design with 3 replications. Factors were: Growth stage of potassium foliar application (at early flowering, at peak boll formation and at early flowering + peak boll formation) and potassium concentration (0, 1, 2 and 3%).

Crop Management

Field preparation consisted of fall ploughing with mould board plough and spring disking twice and leveling to enable flood irrigation. Prior to planting, the experiment area was treated with Terfelan herbicide at 1.2 kg.ha^{-1} to weed control. Soil samples were collected before planting crop to analyze physicochemical properties of soil (Table 1), also water used properties in experiment mention in table 2. According to soil test recommendation, 50 kg N.ha^{-1} in Urea form and 150 Kg.ha^{-1} P_2O_5 as Super Phosphate triple form before Cotton planting. Plots consisted of six rows spaced 0.5 m in row and 0.2 m in plant (10 plants.m^{-2}) and 6 m in length. Varmain cultivar was sown into dry soil on the 3th of April June 2015 manually at the depth of 5-7 cm approximately. The seeds planted had been acid-delinted and treated with chemicals against seed and seedling diseases. The crop was irrigated after sowing and repeated each 14 days interval based on weather condition. In duration cotton growth, weed and seed control programs were standard for cotton production. Weeds were removed manually two times and insect was controlled by Malathion that was applied post during the growing season as needed.

Table 1. Physicochemical properties of studied soil

Mn	Na	Zinc	Cu	Fe	P	K	N	Sand	Clay	Silt	EC	pH
(mg.kg^{-1})							(%)	%			(ds.m^{-1})	
7	40.5	0.55	0.46	2.42	4	110	14	63	13	24	10.5	8.2

Table 2. Physicochemical properties of used water in research

SO_4	Cl	$CaCo_3$	Na	Mn	Ca	EC	pH
Meq.L^{-1}						(ds.m^{-1})	
21.19	5.36	2.4	51.15	5.02	4.01	9	7.5

Plant height was kept short by hand cutting at first match head square stage followed by second hand cutting after 3 weak later.

Traits Measure

To evaluate yield components of cotton including Plant height, sympodial branch number, boll number and boll weight, 10 plants were selected randomly from final harvest area. At harvesting time one meter from the beginning and a half meter around each plot was removed as a marginal effect. The remaining area was harvested by hand for determine of seed cotton yield and biological yield. Seed-cotton samples were ginned to separate the fiber (lint) from the seed. Lint percentage (%) was calculated as the weight of lint to weight of the seed-cotton.

Statistical Analysis

Analysis of variance and mean comparisons were done via SAS software (Ver.8) and Duncan multiple range test at 5% probability level.

RESULTS AND DISCUSSION

Plant height

Time of foliar application had significant effect on plant height (Table 3). As shown in table 4 Solopotash application at early flowering stage had the maximum plant height and the minimum plant height was observed at peak boll formation. There was no significant difference between twice and once Solo Potassium fertilizer application. Foliar application of potassium at the time of boll stage resulted to increased 2.83 and 4.66% compare than flowering+ bolling and flowering stage, respectively. It seem that hand cutting at first match head square and low availability of potassium before this stage resulted to reduced final plant height. Increasing of Solo Potassium concentration was increased plant height by 12.67%. The positive effect of potassium in height is due to role of potassium in maintaining osmotic potential in salty conditions. In this study it seems that more consumption of potassium is effective in maintaining leaf water potential in saline condition and thus the potential of cell swelling, which leads to better absorption of food and water from soil, subsequently leads to an increase in the plant height. It was reported that in saline conditions, reduction in plant height is due to negative effects of high osmotic potential of soil solution that decreases absorption of water and nutrients in soil (Munns, 2002). In saline condition application of potassium increased stability of enzyme and protein reduce effects of toxicity Na^+ (Zheng *et al.*, 2008).

Sympodial branch number

Means comparison of treatment showed foliar use of K at early flowering had maximum branches number (6.4) and 2 foliar application at early flowering+peak boll formation had lowest number of branches (5.6).

Table 3. ANOVA result of measured traits

S.O.V	df	Plant height	Sympodial branch	Boll No.	Boll weight	Seed cotton yield	Lint yield	Lint percent
Replication	2	4.45^{ns}	0.45^{ns}	3.28^{*}	0.14^{ns}	16157^{ns}	11813^{ns}	17.11^{ns}
Growth stage potassium application (A)	2	32.70^{*}	1.57^{*}	4.28^{**}	0.42^{*}	876076^{**}	77493^{**}	427.36^{ns}
Potassium concentration (B)	3	7159^{**}	11.20^{**}	34.03^{**}	1.01^{**}	296241^{*}	103339^{**}	167.37^{ns}
A*B	6	40.37^{ns}	2.98^{ns}	7.86^{ns}	0.32^{ns}	20982^{ns}	944054^{ns}	213.82^{ns}
Error	22	6.59	0.40	0.55	0.11	51768	81119	215.32
CV (%)		8.04	10.70	8.92	8.90	10.70	6.21	22.34

$^{ns,\ *\ and\ **}$: non-significant, significant at the 5 and 1% probability, respectively.

The maximum of reproductive branches number in foliar application of potassium at early flowering can be attributed to providing more potassium in vegetative stage. Although cotton is considered indeterminate and after flowering plant also has the ability to produce reproductive branches but because most reproductive branches are produced in the early stages of plant growth Therefore, although later potassium consumption increases the number of branches, but this increase is much less in comparison with the early stages of growth. Reducing the number of reproductive branches at foliar stage may be due to boll are the major reservoir for potassium uptake. At this stage, most of potassium spent to boll development which reduces the amount of potassium in the leaves and reduce production of carbohydrates so loss of photosynthetic plant resulted in less produce reproductive branches. The results correspond with the results (Read *et al.*, 2006).

Table 4. Mean comparison of potassium application time on measured traits

Treatments	Plant height (cm)	No. Sympodial branch	Boll No.	Boll weight (g)	Seed cotton yield ($kg.ha^{-1}$)	Lint Yield ($kg.ha^{-1}$)	Lint percent (%)
Growth stage potassium application							
Early flowering	81.11 ^{b}	6.40 ^{a}	9.04 ^{a}	5.16 ^{b}	1774 ^{b}	1546 ^{a}	53.21 ^{a}
Peak boll formation	84.89 ^{a}	5.71 ^{b}	7.66 ^{b}	6.24 ^{a}	2226 ^{a}	1362 ^{b}	42.61 ^{a}
Early flowering + peak boll formation	82.55 ^{ab}	5.64 ^{b}	8.42 ^{a}	5.93 ^{ab}	2373 ^{a}	1436 ^{b}	40.28 ^{a}

*Similar letters in each column show non-significant difference at 5% level in Duncan's multiple rang test.

The number of bolls per plant

Analysis of variance showed a significant effect of foliar application of potassium on the number of bolls per plant at the statistical level of one percent. Spraying at early flowering had the largest number of bolls per plant. There was no significant difference between spraying two-stage (early flowering + peak boll formation). It is observed that the delay in potassium application reduced positive effects of this element on the number of bolls per plant. Although the maximum requirement to potassium in cotton begins at flowering stage, But because potassium is moving element, Potassium storage in vegetative organs before peak demand can be very effective in a number of bolls per plant (Armin and Hajinezhad, 2016). It is reported that the efficiency of nutrient uptake in cotton is reduced after flowering so this the lack of uptake of potassium in the flowering stage, especially application of K at boll stage has less effect on number of boll per plant (Oosterhuis, 2002). The results presented in Table 3 indicated that potassium concentration had a significant influence on number of bolls per plant. The highest number of open bolls was obtained by 3% foliar application of potassium. There was no significant difference between 1% concentration and control treatment indicated spraying with 1% is not sufficient for boll production. Role of K in decrease boll shedding and more bolls to be set before cutout are main reason for increase bolls per plant with increasing of K concentration. Sawan *et al.* (2008) reported apply 47.4 kg $K.ha^{-1}$ was increased 9.52 and 7.61% as compared to untreated plants in first and second years of study.

Boll weight

The comparison of means showed that foliar application of potassium at early flowering had the lowest boll weight and spraying at peak boll formation had the highest boll weight. There was no significant difference between once spraying and twice at early flowering + peak boll formation for boll weight (Table 4). More boll number at early flowering caused less carbohydrate partition to ever boll so that boll weight decreased. The physiological role of potassium in the fruit formation and ripening can relate to the metabolism and transport of metabolites from the leaves to other growing organs for boll development. As shown in table 5 increasing of K concentration significantly increased boll weight (Table 5). The amount of photosynthetic available for reproductive sinks reduced when K is lower than normal because Potassium has pronounced effects on carbohydrate partitioning by affecting either phloem export of photosynthesis (sucrose) or growth rate of sink and/or source organs (Cakmak *et al.*, 1994), These results for boll weight agree with those obtained by (Sawan *et al.*, 2006) who reported that application of 319 g $K.ha^{-1}$ relative to the control significantly increased boll weight. Boll weight didn't response to more increase potassium rate. Having medium K fertility and received a fertilizer K application are reason for low responses of boll weight to more K application as spraying. The same finding was reported by (Ardakani *et al.*, 2016; Gormus, 2002).

Table 5. Mean comparison of potassium concentration on measured traits

Treatments	Plant height (cm)	No. sympodial branch	Boll No.	Boll weight (g)	Seed cotton yield ($kg.ha^{-1}$)	Lint yield ($kg.ha^{-1}$)	Lint percent (%)
Potassium concentration (%)							
0	76.32 ^{c}	4.02 ^{c}	5.35 ^{c}	4.89 ^{c}	1725 ^{c}	730 ^{c}	42.35 ^{a}
1	80.55 ^{b}	4.86 ^{c}	6.22 ^{c}	5.23 ^{b}	1963 ^{b}	894 ^{b}	45.89 ^{a}
2	82.05 ^{b}	5.80 ^{b}	8.91 ^{b}	5.74 ^{b}	2086 ^{b}	899 ^{b}	43.30 ^{a}
3	85.99 ^{a}	7.08 ^{a}	10.02 ^{a}	6.41 ^{a}	2321 ^{a}	1032 ^{a}	44.91 ^{a}

*Similar letters in each column show non-significant difference at 5% level in Duncan's multiple rang test.

Seed cotton yield

Analysis of variance showed statistically significant differences between times of spraying in relation to the seed cotton yield at 1% probability level (Table 3). The highest cotton yield was observed at early flowering + peak boll formation (2373 $kg.ha^{-1}$) that hadn't significant difference with foliar application at peak boll formation. The lowest cotton yield (1774 $kg.ha^{-1}$) was recorded in K spraying at early flowering stage (Table 4). The increase in seed cotton yield might be due to the increase in number of sympodial branches per plant and bolls number as a result of foliar application of K at early flowering + peak boll formation. Seilspour (2012) reported that soil broadcasting of K hadn't effect on seed cotton yield but top dressing of K at flowering stage increased seed cotton yield. K concentrations significantly ($p<0.05$) affected seed cotton yield (Table 3). Spraying with concentrations of 3% significantly increased yield over the control, although there were no significant differences between concentrations of 1 and 2%. At the same time, differences between control and spraying with concentration of 1% were significant (Table 5). Increased concentration of K increased the seed cotton yield through increasing of number of sympodial branches per plant and bolls number. Yield increases could be attributed to the effect of K on new growth and nutrient uptake which caused favorable effects on the number of opened bolls per plant and boll weight, leading to higher cotton yield. This result is in agreement with those obtained by (Sawan *et al.*, 2008) who reported number of opened bolls per plant significantly increased with application of 47.4 kg $K.ha^{-1}$. It was reported that in saline conditions and potassium deficiency CO_2 and nitrogen assimilation is preventing and the light reaction of photosynthesis photosystem I and II also damaged which ultimately decreases plant growth and yield component. Reduced boll shedding, increased photosynthesis and the number of bolls per plant in cotton plant with K application was reported (Sawan *et al.*, 2008). Similar results were obtained by (Ardakani *et al.*, 2016; Coker *et al.*, 2000; Gormus, 2002; Oosterhuis, 2002; Pervez *et al.*, 2005; Sharma and Singh, 2007). While our result in contrast with finding (Coker *et al.*, 2009) who finds that lint yield had less response to K foliar application, lint yield increased only 4% by foliar K application. They believed that when soil test K levels are adequate, or when recommended rates of K are soil applied foliar K applications do not increase yields in cotton.

Lint percentage

K application time and concentration did not significantly affected lint percentage (Table 3). Similar results were obtained (Sawan *et al.*, 2008) whereas (Gormus, 2002) showed that applications of 160 and 240 kg $K.ha^{-1}$ increased lint turnouts. Lint yield Results from the analysis of variance for lint yield is presented in table 4. As shown on table 4 foliar application of K at early flowering had the greatest lint yield. Similar results were obtained (Ardakani *et al.*, 2016) who found that all soil applied K at early boll development had the highest lint yield whereas half at first square + halt at first white flower had the lowest lint yield. Increases in the uptake of K during early boll set was the reason for high lint yield when K applied at early boll development. It is believed that after first bloom more than 70% of potassium absorb by cotton. K levels showed significant effect on lint yield. Maximum lint yield was found at foliar application of

K with 3%, while minimum lint yield was recorded in control treatment. There was a significant difference among K concentration for lint yield (Table 5). Lint yield increases could be attributed to high seed cotton yield. Sawan *et al.* (2008) reported that potassium application increases dry matter production, total chlorophyll concentration, the number of open bolls per plant, boll weight, seed index, cotton seed per plant and lint yield and cotton seed per plant. 13.8% increasing of lint yield with application of 160 kg $K.ha^{-1}$ potassium compared on unfertilized was reported by (Gormus, 2002). Increasing in lint yield induced by K application in our study confirm by finding of (Ardakani *et al.*, 2016; Armin and Hajinezhad, 2016; Gormus, 2002; Pervez *et al.*, 2005).

CONCLUSION

Our result indicated that foliar application of Potassium in saline condition had positive effect on yield and yield components of Cotton. Yield components to time of spraying were difference. The highest seed cotton yield was achieved at early flowering + peak boll formation whereas maximum lint yield was obtained at early flowering spraying. Increasing of K concentration increased yield and yield component significantly as compared with the untreated control.

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