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Response of Corn (*Zea mays* L.) Crop Production to Use Different Level of Potassium Sulfate and Boron Foliar Application

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ABSTRACT

BACKGROUND: Management of balanced fertilizer application according to plant growth requirements and soil testing is one of the strategies for improving the quality and quantity of agricultural products.

OBJECTIVES: This study was conducted to assessment effect of different levels of Potassium Sulfate and Boron foliar application on seed yield and morphological traits of Corn under warm and dry climate condition.

METHODS: This research was done via split plot experiment based on randomized complete blocks design (RCBD) with three replications along 2023 year. The main plot included Potassium sulfate (Control, 5 kg.ha^{-1}, 10 kg.ha^{-1}, 15 kg.ha^{-1}) and Boron foliar application (Control, 1 L.ha^{-1}, 2 L.ha^{-1}) belonged to sub plots.

RESULT: Result of analysis of variance revealed effect of different level of Potassium sulfate and Boron foliar application on all studied traits was significant (instead Ear diameter) but interaction effect of treatments was not significant (instead seed yield and biologic yield). Mean comparison result of different level of Potassium sulfate indicated that maximum amount of biologic yield (1630.10 g.m^{-2}), seed yield (6414.01 kg.ha^{-1}), leaf area index (4.19), plant height (202.11 cm), Ear length (19.06 cm) and Ear diameter (4.43 cm) belonged to 15 kg.ha^{-1} Potassium sulfate treatment and lowest amount of mentioned traits was for control. As for Duncan classification made with respect to different level of Boron foliar application the highest and lowest amount of studied traits (instead Ear length loss) belonged to 2 L.ha^{-1} and control treatment.

Assessment mean comparison result indicated in different level of Potassium sulfate the maximum Ear length loss (1.95 cm) was noted for control and minimum of that (1.68 cm) belonged to 15 kg.ha^{-1} Potassium sulfate. Compare different level of Boron foliar application showed that the maximum and the minimum Ear length loss belonged to control (2.13 cm) and 2 L.ha^{-1} (1.61 cm) treatments.

CONCLUSION: Generally result of studied research revealed use of 15 kg.ha^{-1} Potassium sulfate and 2 L.ha^{-1} Boron foliar application had the highest amount of studied characteristics and it can be advice to produces in studied region.

KEYWORDS: *Cereal, Leaf area index, Micro elements, Nutrition, Seed yield.*

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1. BACKGROUND

Management of balanced fertilizer application according to plant growth requirements and soil testing is one of the strategies for improving the quality and quantity of agricultural products (Singh *et al*., 2015). Therefore, consideration of oil testing and application of elements required by plants are important strategies for increasing production of agricultural products (Pervez *et al*., 2004). Macro fertilizer has the pivotal role in increasing crop production. Besides N and P, use of K has been reported to influence productivity of seed yield and seed oil contents (Ghosh *et al*., 1995). Potassium plays a vital role in photosynthesis, translocation of photosynthesis, protein synthesis, control of ionic balance, regulation of plant stomata and water use, activation of plant enzymes and many other processes (Marschner, 1995; Reddya *et al*., 2004). 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). Potassium known to increase pest resistance, as well as resistance to diseases and other biotic and abiotic environmental stresses (Reuveni and Reuveni, 1998; Zafar and Athar, 2013). Potassium mainly exists in three different forms in the soil, which includes usable, stabilized potassium and potassium found in soil minerals. Therefore, in order to supply potassium needed by the plant, soluble and exchangeable potassium should be provided by adding chemical fertilizers or by releasing stabilized potassium and weathering minerals containing Potassium (such as mica and feldspar) (Tabatabaei, 2014). Kuo and Chen (1980) reported that K increased the seed oil content of Tower variety of rapeseed. In a research investigating the effect of potassium sulfate fertilizer on mung bean, it was reported that the yield of pod increased with increasing the amount of potassium sulfate fertilizer from 0 to 50 $kg.ha^{-1}$ under favorable irrigation conditions with a steep slope, which shows that the yield of pod increased to some extent with the increase of fertilizer. Potassium sulfate has increased and since then, with the increase of potassium sulfate fertilizer from 50 to 100 $kg.ha^{-1}$, the yield of pod has decreased rapidly (Ali *et al*., 2010). Mousavi and Sadeghi (2015) by evaluated effects of Soluptas fertilizer on spring corn crop production reported the average of biological yield of corn due to use 15 $kg.ha^{-1}$ Potassium sulfate 11.6% higher than to 5 $kg.ha^{-1}$. Alimuddin *et al*. (2020) reported the highest amount of seed yield, 1000 seed weight, number of leaves, silk dry weight was achieved by 0.5 $kg.ha^{-1}$ boron foliar application. Azizi *et al*. (2011) investigated the effect of different amounts of potassium and boron on the seed yield and its components of corn and reported the effect of boron treatment on 1000 seed weight and grain yield was significant at 5% and 1% probability level, respectively. The effect of potassium treatment on mentioned traits had similar effect. Babaei-Esmaili *et al*. (2013) evaluated the effect of drought stress and foliar application of iron and boron on sweet corn crop production reported the normal irrigation and iron and boron foliar application achieved highest seed and biological yield.

2. OBJECTIVES

This study was conducted to assessment effect of different levels of Potassium Sulfate and Boron Foliar Application on seed yield and morphological traits of Corn under warm and dry climate condition.

3. MATERIALS AND METHODS

3.1. Field and Treatments Information

This research was done via split plot experiment based on randomized complete blocks design with three replications along 2023 year. The main plot included Potassium sulfate (P_1: Control, P_2: 5 $kg.ha^{-1}$, P_3: 10 $kg.ha^{-1}$, P_4: 15 $kg.ha^{-1}$) and Boron foliar application (B_1: Control, B_2: 1 $L.ha^{-1}$, B_3: 2 $L.ha^{-1}$) belonged to sub plots. Place of research was located in Abdolkhan city at longitude 48°14'E and latitude 32°11'N in Khuzestan province (Southwest of Iran). Physical and chemical properties of studied soil mentioned in table 1.

Table 1. Physical and chemical properties of studied soil

Soil Depth (cm)	SP (%)	EC ($ds.m^{-1}$)	pH	OC (%)	P (ppm)	K (ppm)	Soil texture
0-30	48	4.65	7.7	0.82	9.4	265.2	ClayLoam
30-60	46	4.48	7.4	0.75	8.9	271	ClayLoam

3.2. Farm Management

Each sub plot included the 6 planting lines with a length of 5 m. The distance between row and seed on the row were 75 and 18 cm respectively. Irrigation was done every 3 or 4 days and after the plant establishment it was done every 7 to 10 days if necessary. The weeds were controlled via Cruise herbicide by 2 $L.ha^{-1}$ at 4 to 5 leaf stage and Krakrown pesticide by 1 $L.ha^{-1}$ against leaf and stem borer larvae.

3.3. Measured Traits

The final harvest area of each plot was 1.5 m^2. Seed yield, its components and qualitative traits were estimated after the physiological maturity. After separating seed from selected plants and weighing them, seed yield was calculated based on 14% moisture. First, 50 seeds were randomly separated and their weight was calculated. Then the second 50 sample was separated and weighed. If the weight difference of two samples was less than 5%, their total weight was calculated as the 100 seed weight. To measure stem diameter and plant height, five plants from each plot were measured by caliper and cloth meter from the soil surface to the end of the cluster and their average was recorded as plant diameter and height in the desired treatment. To measure the diameter and length of the ear, the average of five ears from each plot was measured with a caliper and ruler and their average was recorded as the diameter and length of the ear in the desired treatment. To measure the baldness of the ear, it was measured randomly using a ruler with an accuracy of 1 mm in five ears and then its mean was recorded as the bald length. To determine the leaf area index (LAI) of the linear relationship S= K. L.W was used in which S, L and W were the leaf area, L and W respectively, the maximum length and width of each leaf and K= 0.75 correction coefficient. The leaf area index was calculated from leaf area ratio to ground level.

3.4. Statistical Analysis

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

4. RESULT AND DISCUSSION

4.1. *Biologic yield*

According result of analysis of variance effect of Potassium sulfate, Boron foliar application and interaction effect of treatments on biologic yield was significant at 1% probability level (Table 2). Yousefi-Fard and Asareh (2018) reported that the application of Soluptas on grain yield and biological yield was significant and led to increase the biological yield of corn in compare to control treatment. Mean comparison result of different level of Potassium sulfate indicated that maximum biologic yield (1630.1 $g.m^{-2}$) was noted for 15 $kg.ha^{-1}$ (Also it doesn't had significant difference with use 10 $kg.ha^{-1}$ Potassium sulfate) and minimum of that (1410.5 $g.m^{-2}$) belonged to control treatment (Table 3). Tabatabaei *et al*. (2014) reported effect of potassium sulphate was significant on number of spike per m^2, number of grain per spike, number of spikelet per spike, protein content, biological yield, seed yield and straw yield also highest of seed yield (6523 $kg.ha^{-1}$) was obtained from 160 $kg.ha^{-1}$ potassium sulphate application. As for Duncan classification made with respect to different level of Boron foliar application maximum and minimum amount of biologic yield belonged to 2 $L.ha^{-1}$ (1662.67 $g.m^{-2}$) and control (1400.60 $g.m^{-2}$) (Table 3). Evaluation mean comparison result of interaction effect of treatments indicated maximum biologic yield (1670.40 $g.m^{-2}$) was noted for 15 $kg.ha^{-1}$ Potassium sulfate and 2 $L.ha^{-1}$ Boron foliar application and lowest one (1402.60 $g.m^{-2}$) belonged to control treatment (Table 4). Application of potassium increased absorption of zinc and boron by plants, led to considerable increases in yield (Munir and McNeilly, 1987). Other researchers evaluated the effect of Boron and Soluptas and reported that the use of Boron and Soluptas increased biological yield (Ali *et al*., 2019; Aghighi Shahverdi Kandi *et al*., 2017).

4.2. Seed yield

Result of analysis of variance revealed effect of Potassium sulfate, Boron foliar application and interaction effect of treatments on seed yield was significant at 1% probability level (Table 2).

Table 2. Result analysis of variance of measured traits

S.O.V	df	Biologic yield	Seed yield	LAI	Plant height	Ear length	Ear diameter	Ear length loss
Replication	2	419.3^{ns}	2102^{ns}	0.33^{ns}	4.52^{ns}	0.61^{ns}	0.002^{ns}	0.01^{ns}
Potassium sulfate (P)	3	732611.2**	641351**	0.641*	937.02*	48.53**	3.66**	1.24**
Error I	6	14033.11	3112.06	0.095	186.41	3.92	0.251	0.09
Boron foliar application (B)	2	561829**	471370.1**	0.766**	1021.50*	36.21**	0.004^{ns}	3.78**
P × B	6	610734.2**	105246**	0.012^{ns}	1.06^{ns}	0.044^{ns}	0.002^{ns}	0.01^{ns}
Error II	16	12155.03	2841.4	0.089	173.8	2.81	0.167	0.06
CV (%)		7.20	9.71	8.24	7.04	9.55	10.72	13.53

$^{ns,\ *\ and\ **}$: no significant, significant at 5% and 1% of probability level, respectively.

According result of mean comparison maximum of seed yield (6414.01 kg.ha^{-1}) was obtained for 15 kg.ha^{-1} Potassium sulfate and minimum of that (4750.30 kg.ha^{-1}) was for control treatment (Table 3). Ahmed *et al*. (2015) investigated response of several canola cultivars to different levels of potassium (K). They reported potassium applied at 60 kg K.ha^{-1} is recommended for higher seed yield of several canola cultivars, however, for higher oil and protein content at 90 kg K.·ha^{-1} was recommended. Evaluation mean comparison result indicated in different level of Boron foliar application the maximum seed yield (6593.80 kg.ha^{-1}) was noted for 2 L.ha^{-1} and minimum of that (4345.90 kg.ha^{-1}) belonged to control treatment (Table 3). Evaluation mean comparison result of interaction effect of treatments indicated maximum biologic yield (6704.10 kg.ha^{-1}) was noted for 15 kg.ha^{-1} Potassium sulfate and 2 L.ha^{-1} Boron foliar application and lowest one (4320.50 kg.ha^{-1}) belonged to control treatment (Table 4). Ul-Allah *et al*. (2020) reported that the application of potassium improved water use efficiency, seed yield, 1000 seed weight and biological yield of Corn crop. The highest seed yield and biological yield were obtained from hybrid DK-6714 and 75 kg.ha^{-1} of potassium. Tahir *et al*. (2012) studied the effect of boron on the growth and Corn crop production. The results showed that foliar spraying with all three amounts of 0.15, 0.3 and 0.45 kg per hectare significantly increased the number of seeds in Ears and Corn grain yield. And the highest seed yield (7145 kg.ha^{-1}) which was obtained from foliar application with 0.3 kg.ha^{-1} of boron. In this experiment, the lowest seed yield was obtained from the control treatment.

Table 3. Mean comparison effect of different level of Potassium Sulfate and Boron foliar Application on studied traits

Treatment	Biologic yield (gr.m^{-2})	Seed yield (kg.ha^{-1})	LAI	Plant height (cm)	Ear length (cm)	Ear diameter (cm)	Ear length loss (cm)
Potassium Sulfate							
P_1	1410.50c	4750.30c	3.07c	172.03c	15.61c	3.01c	1.95a
P_2	1488.24b	5191.01bc	3.48bc	186.45b	17.42b	3.54b	1.86b
P_3	1597.33a	5602.10b	3.75b	188.30b	18.11ab	4.26a	1.78c
P_4	1630.10a	6414.01a	4.19a	202.11a	19.06a	4.43a	1.68d
Boron foliar application							
B_1	1400.60c	4345.90c	3.01c	170.18c	15.55c	3.73a	2.13a
B_2	1531.51b	5527.60b	3.52b	183.43b	17.1b	3.80a	1.70b
B_3	1662.47a	6593.80a	4.34a	208.05a	20.0a	3.90a	1.61c

*Means with similar letters in each column are not significantly differentt by Duncan's test at 5% probability level.

P1: Control, P2: 5 kg.ha^{-1}, P3: 10 kg.ha^{-1}, P4: 15 kg.ha^{-1}. B1: Control, B2: 1 L.ha^{-1}, B3: 2 L.ha^{-1}.

4.3. Leaf area index (LAI)

Leaf area index (LAI) is the main physiological determinant of crop yield. It describes the surface growth and light use during crop period (Ullah *et al.*, 2013). Dwyer and Tewart (1986) reported that leaf area index is major factor determining photosynthesis and dry matter accumulation. Crop growth rate is related to leaf area index, for this reason that crop growth rate changes is depended to two parameters: namely leaf area index and net assimilation rate. Leaf area index is the component of crop growth analysis that accounts for the ability of the crop to capture light energy and is critical to understanding the function of many crop management practices. Leaf area index can have importance in many areas of agronomy and crop production through its influence on: light interception, crop growth weed control, crop-weed competition, crop water use, and soil erosion. To measure LAI, scientists generally have cut a number of plants at the soil surface, separated leaves from the other plant parts, and measured the area of individual leaves to obtain the average leaf area per plant. The product of leaf area per plant and the plant population gives the LAI. Alternatively, LAI could be measured none destructively with this procedure if area of individual leaves was determined by some combination of leaf length and width measurements (Shirkhani and Nasrolahzadeh, 2016). According result of analysis of variance effect of Potassium sulfate and Boron foliar application on LAI was significant at 5% and 1% probability level, respectively but interaction effect of treatments was not significant (Table 2). Assessment mean comparison result indicated in different level of Potassium sulfate the maximum LAI (4.19) was noted for 15 kg.ha^{-1} and minimum of that (3.07) belonged to control treatment (Table 3).

Table 4. Mean comparison interaction effects of different levels of amino acid and Nitrogen on seed yield and biologic yield

Potassium Sulfate	Boron foliar Application	Biologic yield ($gr.m^{-2}$)	Seed yield ($kg.ha^{-1}$)
P1	**B1**	1402.60d	4320.5f
	B2	1500.1c	4572.8ef
	B3	1509.3c	4924.3de
P2	**B1**	1428.2d	4857.1e
	B2	1511.1c	5189.1de
	B3	1537.4bc	5503.4cd
P3	**B1**	1520.2c	5357.2d
	B2	1538.5bc	5874.6c
	B3	1645.1a	6567.8a
P4	**B1**	1531.2bc	5615.1cd
	B2	1582.37b	6293.7b
	B3	1670.4a	6704.1a

*Means with similar letters in each column are not significantly differentt by Duncan's test at 5% probability level.

P1: Control, P2: 5 $kg.ha^{-1}$, P3: 10 $kg.ha^{-1}$, P4: 15 $kg.ha^{-1}$. B1: Control, B2: 1 $L.ha^{-1}$, B3: 2 $L.ha^{-1}$.

Compare different level of Boron foliar application showed that the maximum and the minimum LAI belonged to 2 $L.ha^{-1}$ (4.34) and control (3.01) treatments (Table 3). Adnan and Muhammad Bilal (2020) assess the role of boron in the growth and corn yield and reported that the application of boron increased the seed yield, leaf area index and plant height.

4.3. Plant height

According result of analysis of variance effect of Potassium sulfate and Boron foliar application on plant height was significant at 5% probability level but interaction effect of treatments was not significant (Table 2). Evaluation mean comparison result revealed in different level of Potassium sulfate the maximum plant height (202.11 cm) was noted for 15 $kg.ha^{-1}$ and minimum of that (172.03 cm) belonged to control treatment (Table 3). Between different levels of Boron foliar application the maximum plant height (208.05 cm) was observed in 2 $L.ha^{-1}$ and the lowest one (170.18 cm) was found in control treatment (Table 3). 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).

4.4. Ear length

Result of analysis of variance revealed effect of Potassium sulfate and Boron foliar application on Ear length was significant at 1% probability level but interaction effect of treatments was not significant (Table 2). Mean comparison result of different level of Potassium sulfate indicated that maximum Ear length (19.06 cm) was noted for 15 $kg.ha^{-1}$ and minimum of that (15.61 cm) belonged to control treatment (Table 3). Yar (2021) evaluated the application of boron on the growth yield of corn and reported that the highest plant height, Ear length, leaf area index, thousand seed weight, number of seeds in the Ear row, harvest index and grain yield were obtained from the application of boron treatment, and the lowest amount of these traits was obtained from not using boron. As for Duncan classification made with respect to different level of Boron foliar application maximum and minimum amount of Ear length belonged to 2 $L.ha^{-1}$ (20.0 cm) and control (15.55 cm) (Table 3). Kaur and Nelson (2014) stated that the application of foliar boron on early stages of corn growth (4 to 6 leaves) was more beneficial for produce high yield. Researchers reported that the use of potassium sulfate in mung bean is directly related to growth, biomass and yield. The results showed that the yield response to different levels of potassium (0, 100, 120 $kg.ha^{-1}$) is different. The lowest yield (700 $kg.ha^{-1}$) was obtained with no potassium application (control treatment) and the highest yield (1096 $kg.ha^{-1}$) was obtained with the application of 120 $kg.ha^{-1}$ potassium (Kumar *et al*., 2014). According to the research of Gomaa *et al*. (2017), the maximum ear length was obtained with the application of potassium fertilizer. They stated that the increase of potassium fertilizer provided a suitable environment for the growing cobs and the transfer of photosynthetic materials to them. The observations of Dheyab Abed (2017) in increasing the length of pods with the application of potassium fertilizer confirmed the results of this research.

4.5. Ear diameter

According result of analysis of variance effect of Potassium sulfate on Ear diameter was significant at 1% probability level but effect of Boron foliar application and interaction effect of treatments was not significant (Table 2). According result of mean comparison maximum of Ear diameter (4.43 cm) was obtained for 15 $kg.ha^{-1}$ Potassium sulfate (although it doesn't had significant difference with 10 $kg.ha^{-1}$) and minimum of that (3.01 cm) was for control treatment (Table 3). Ghanbari *et al*. (2021) investigated the effect of urea and Suloptas on the morphophysiological and biochemical characteristics of sweet corn reported that the effect mentioned treatment on plant height, leaf length and width, Ear diameter, number of seeds per row, number of seeds per Ear, 1000 seed weight, seed yield, harvest index and protein percentage were significant. The highest grain yield was obtained from the treatment of 150 $kg.ha^{-1}$ of urea fertilizer and 200 $kg.ha^{-1}$ of Soluptas fertilizer. By investigating and studying different levels of potassium sulfate in mung bean plant, it was reported that the number of pods plant, seed and biological yield were significantly affected by potassium. The lowest number of pods and the number of seeds per pod were obtained from the treatment without potassium (control) (Abbas *et al*., 2011).

4.6. Ear length loss

Result of analysis of variance revealed effect of Potassium sulfate and Boron foliar application on Ear length loss was significant at 1% probability level but interaction effect of treatments was not significant (Table 2). Assessment mean comparison result indicated in different level of Potassium sulfate the maximum Ear length loss (1.95 cm) was noted for control and minimum of that (1.68 cm) belonged to 15 $kg.ha^{-1}$ Potassium sulfate (Table 3). Compare different level of Boron foliar application showed that the maximum and the minimum Ear length loss belonged to control (2.13 cm) and 2 $L.ha^{-1}$ (1.61 cm) treatments (Table 3). Zorb *et al*. (2014) reported that increasing the amount of potassium has a positive effect on the inoculation and filling of corn seeds and reducing the ear length loss, which was consistent with the results of this research.

5. CONCLUSION

Generally result of studied research revealed 15 $kg.ha^{-1}$ Potassium sulfate and 2 $L.ha^{-1}$ Boron foliar application had the highest amount of studied characteristics and it can be advice to produces in studied region.

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FOOTNOTES

AUTHORS' CONTRIBUTION: All authors are equally involved.

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