JSAES
Journal of Sustainable Agricultural and Environmental Sciences

Print ISSN : 2735-4377
Online ISSN : 2785-9878
Homepage: https://jsaes.journals.ekb.eg/

Research Article

Influence of Potassium and Boron Fertilization on Flowering, Growth Characters, and Grain Yield of Maize Hybrids

EL-Seidy E.H. [1], El Ghonemy M.A.M. [2] and Eman S.E.M. Amer [1,*]

[1] Agronomy Department, Faculty of Agriculture, Tanta University, Egypt; drsayed176@gmail.com
[2] Maize Research Department, Field Crop Institute, Agricultural Research Center, Giza, Egypt; elghonemy538@gmail.com
* Correspondence: Eman, S.E.M. Amer, emansaadamer2@gmail.com.

Article info: -

- **Received:** 13 November 2024
- **Revised:** 4 December 2024
- **Accepted:** 10 December 2024
- **Published:** 21 December 2024

Keywords:
Maize hybrids; Potassium; Boron; Economical traits; Grain yield.

Abstract:

Two field experiments were conducted at the Experimental Farm, Gemmeiza Agriculture Research Station, Agricultural Research Center (ARC), Egypt during two growing seasons (2021 and 2022), to study the response of two maize hybrids (single cross 168 and single cross 180) to three potassium fertilizer levels i.e. without , 24 and 48 kg K_2O /fad. and three spraying boron nutrition levels i.e. without, 400 and 800 mg/L B/fad. Concerning the obtained results, SC 180 out yielded SC 168 in grain yield ard./fad. (combined data) due to its superiority in days to 50% tasseling and silking, plant height and ear leaf area. Increase of boron fertilizer spraying (B) levels up to 800 mg/L B/fad., was followed by a significant increase in grain yield ard./fad. Meantime, plant height, ear height, ear leaf area. As well as the addition of boron fertilizer spraying (B) levels up to 800 mg/L B/fad. led to an earlier flowering on days to 50% tasseling and days to 50% silking. The addition of potassium fertilizer and spraying boron nutrition enhanced maize plant growth parameters (plant and ear height and ear leaf area) as was finally grain yield/fad.

1. Introduction

Maize (*Zea mays* L.) is one of the most important grain crops in Egypt; area devoted to maize cultivation is about 2.8 million faddan. Maize productivity increased from 1.5 ton/fad in 1980 to (3.3 ton /fad) in 2023 season where one faddan = 4200 m^2. In addition, it is the third most important staple food crop in both area and production after wheat and rice in Egypt.

Potassium (K) is substantially an important nutrient for plant growth and has the capability to maximize plant growth and it influences soil-plant interactions as well (Xie et al., 2011). Its application effects on turgor potential, opening and closing of stomata, relative water contents, photosynthetic rate, leaf water potential, grain weight, transpiration rate, grain yield and disturbed consumption mechanism of fixed (Mengel and Kirkby, 2001; Aslam et al., 2014).

Boron has an important role in accumulation of carbohydrates, lignification's, photosynthesis, cell wall structure, vegetative growth cell wall synthesis, and retention of flowers and fruits. It is also responsible indole and phenol acetic acid metabolism, membrane transportation and its insufficiency leads to brownish spots in plant tissues (photosynthesis retardation and speculations stunting of the newly emerged plants (Miwa et al., 2008).

This investigation aimed to detect the physiological response of two maize hybrids to different levels each of potassium fertilizer levels and spraying boron nutrition as well as their interactions.

2. Materials and Methods

Two field experiments were carried out at the Experimental Farm of Gemmeiza Agriculture Research Station, Agricultural Research Center (ARC), Egypt during 2021 and 2022 summer growing seasons.

2.1. The study factors

A- Maize hybrids (H) (Main plots):

1- Yellow single cross (SC) 168: A yellow single cross released by Maize Res. Dept. (ARC) (H_1).

2- Yellow single cross (SC) 180: A yellow single cross released by Maize Res. Dept. (ARC) (H_2).

B- Potassium sulfate K_2SO_4 (levels), kg K_2O /fad. (K) (Sub plots):

1- 0 (k_1)

2- 24 kg K/fad. (k_2)

3- 48 kg K/fad. (k_3)

C- Spraying boron nutrition (17.4% H_3BO_3): mg/L B/fad. (B) (Sub- Sub plots):

1- 0 (B_1)

2- 400 mg/L B/fad. (B_2).

3- 800 mg/L B/fad. (B_3).

2.2. Experimental design

A split-split plot design of four replications was used. Main plots were occupied by the two maize hybrids, Potassium fertilization levels in subplots and sparing boron nutrition levels in sub sub–plots) according to Steel and Torrie (1980).

2.3. Soil sampling and analysis

The soil samples from the experimental locations were taken from the upper 30 cm soil surface during land preparation in both 2021 and 2022 seasons. The soil type in which the experimentation was undertaken was clay loamy in texture (approximately homogenous) with normal percentage of salinity and its drainage was naturally well. The soil samples of the experimental fields in both seasons were laboratory analyzed and their physical and chemical properties are shown in Table (1). Both physical and chemical analysis of the soil used were carried out by following the method described by Jackson (1958). Whereas N, P and K elements as well as some micronutrients were determined by applying the procedure documented by Lindsay and Norvell (1978).

2.4. Studied characters

1- Days to 50 % tasseling: It was recorded on plants per plot basis as the number of days from planting to 50 % tassels emergence of plants.

2- Days to 50 % silking: It was recorded on plants per plot basis as the number of days from planting to 50 % silk emergence 0f plants.

3- Plant height (cm): It was measured as the mean of five guarded plants measured from soil surface to the point of flag leaf insertion.

4- Ear height (cm): It was measured as the mean of five guarded plants from the soil surface to the node bearing of the upper most ear.

5- Stem diameter (cm.): It was measured on the third internode from the ground surface.

6- Ear leaf area: It was measured as described by (McKee 1964)

ELA= Leaf Length x Leaf maximum leaf width x 0.75

7- Grain yield in ardab per faddan (ard /fad.): It was recorded at harvest from the second and third ridges of each plot. Grain yield was adjusted at 15.5 % gram moisture and transformed to ardab per feddan (one ardab = 140 kg and one faddan = 4200 m^2).

2.5. Statistical analysis

The data were statically analyzed according to Gomez and Gomez (1984), using the computer MSTAT-C statistical analysis package (Freed et al., 1989). Treatment means were compared according to the LSD test as described by Waller and Duncan's (1969).

Table 1. The Physical and some chemical properties of the experimental site (0-30 cm depth) averages of both seasons.

Properties	2021	2022
Mechanical analysis		
Sand %	22.70	21.98
Silt %	31.50	31.85
Clay %	45.80	46.17
Soil texture	Clay	Clay
Chemical analysis :		
Ph	8.30	8.05
Ec ds / m	2.30	2.34
O.M %	1.80	1.85
Available N (mg/kg)	31.80	30.79
Available P (mg/kg)	7.01	6.01
Available K (mg/kg)	119.00	121.02
Available Zn (mg/kg)	0.21	0.27
Cation (meq/L)		
Ca^{++}	12.85	13.04
Mg^{++}	10.23	11.85
Na^{+}	42.08	41.22
K^{+}	51.37	53.07
Anion (meq/L)		
CO_3^{-}	0.02	0.05
HCO_3^{-}	2.87	2.93
CI^{-}	62.57	63.45
SO_4^{-}	49.88	51.07

Control Laboratory of Agricultural Research Station Gemmeiza, Tanta, Egypt.

3. Results and Discussion

Flowering, growth characters, and grain yield: Days to 50% tasseling, days to 50% silking, plant height, Ear height, Stem diameter, Ear leaf area, and grain yield.

A-Maize hybrids differences:

The results confirmed significant or highly significant differences between the two maize hybrids concerning grain yield, days to 50 % tasseling and days to 50 % silking in both seasons and their combined data. it is evident from Table (2), the difference between two hybrids were not significant for plant height in both seasons and their combined data and significant for ear height in the first season and combined data. The highest plant and ear height were recorded by SC (180) in both seasons and their combined Table 2 The results indicated clearly that, SC 168 was earliness than SC 180 in each of the aforementioned characters. This was completely true in both seasons and their combined analysis. The differences in these characters between the two maize hybrids might be attributed to the genetically variations. Maize hybrids changes in days to 50 % tasseling, days to 50 % silking. SC. 180 had larger grain yield (ard. /fad.) than SC. 168. SC 180 had larger ear leaf area than SC 168 which reflected in positive in relative photosynthetic potential. These result may be due to the growing seasons had low changing values in the physical and some chemical properties in both seasons for some traits.Table1. And also, it may be due to low changing values between seasons in this study.

B- Potassium sulfate levels effect

Data in Table (2 and 2-cont.) revealed that, the differences between potassium sulfate levels were significant increased maize ear height in the 2021 and their combined analysis. This is due to the importance of the role of potassium in ear height because it is attributed to many vital processes and the activation of many enzymes (Ijaz et al., 2014) But, it was not significant for plant height, 50 % tasseling and days to 50 % silking in both seasons and their combined data. The result showed adding potassium sulfat (k_2 and k_3) increased ear height compared with without control .These trends are similar to those proved by (Amanullah, et al., 2016). Potassium sulfate levels was significant difference for stem diameter in 2021 season only. However, highly significant differences were detected in grain yield and ear leaf area of maize in the both seasons and their combined, This increase is due to the importance of potassium in activating the vital parts of the plant and regulating the work of plant hormones For plant growth and increasing the ear leaf area (Ali et al., 2016) .

C-Spraying boron nutrition levels effect:

It is evident from Table (2and 2-cont.) that, each spraying boron nutrition increment up to 800 mg /L., produced a highly significant increase in each on days to 50 % tasseling and days to 50 % silking, plant height, ear leaf area, grain yield and ear height in both seasons and their combined and significant in the second season for ear height. Highly significant differences between rates of spraying boron nutrition for stem diameter in the first season The increases on days to 50 % tasseling and days to 50 % silking, plant height, ear leaf area, grain yield is due to the role of boron in increasing carbohydrate accumulation, hardening, photosynthesis, and cell wall synthesis for vegetative growth and elongation of plant cells (Miwa et al., 2008).

Interactions effects: The interaction between maize hybrids and potassium fertilizer levels Table (3) exhibited highly significant effect for ear height, ear leaf area and grain yield in both seasons and combined, days to tasseling and silking in the first year 2021 and combined and not significant effect in the second season for plant height and stem diameter in both seasons and combined. Generally is evident from Table (3) showed that, growing two maize under k_1, k_2 and k_3, ear height of SC 180 was higher than that of SC 168 hybrid. Also, ear leaf area exhibited more response to potassium fertilizer when plants were fertilized by 60 and 120 kg K/fad., ear leaf area increased up to 120 kg K/fad. registered, the largest ear leaf area (622.91 and 632.21 cm^2) were recorded of two maize hybrids SC 168 and SC 180 , respectively. In general, each potassium fertilizer levels increment was effective to increase both grain yield/fad., for the two maize hybrids i.e. SC 168 and SC 180. It seemed that SC 180 hybrid always had higher grain yield/fad, than SC. 168 under the different potassium levels.

The interaction between maize hybrids and spraying boron nutrition Table (4) exhibited highly significant for all the studied traits, except ear height which had not significant effect on stem diameter for two hybrids 168 and 180 in two seasons and combined data. These results support the findings of Sayed (1998) who reported that, the application of boron increased the chlorophyll content and relative water contents which increased the ear leaf area of maize plants, which the increase of spraying boron nutrition increment up to 800 mg /L. led to increase for Ear leaf area due to effect of spraying boron nutrition on vegetative growth which in turn favored metabolic processes and increased growth and yield attributes of maize due to boron nutrition (Bayard et al., 2024).

Table (5) showed the interactions between (K x B) were highly significant for all the studied traits in both years and combined data. It was not significant effect on stem diameter, days to tasseling and silking in both seasons and combined data and ear height in the first season. This result due to the potassium fertilizes (k) was affected by spraying boron nutrition (B) Potassium has an important role in ear height because it is attributed to many vital processes and the activation of many enzymes (Ijaz et al., 2014). The increase in plant height and ear height is due to the role of boron in increasing carbohydrate accumulation, hardening, photosynthesis, cell wall synthesis, and cell wall synthesis for vegetative growth and elongation of plant cells (Miwa et al., 2008).

Table (6) shows that the interaction between (H x K x B) was significant long for all traits in both seasons and combined Plant and ear height of two hybrids SC 168 and SC 180 responded to boron fertilization up to 800 mg/L/fad, potassium fertilization 48 kg/fad, which led to highly significant differences in these traits. This is attributed to the role of potassium. (Ali et al., 2016) explained that potassium regulates the work of plant hormones and plant growth regulators that help in the formation, production and growth of flowers, as boron is one of the microelements necessary for plant growth and is needed by the plant in small quantities. Boron has an important effect in stimulating vital processes in the flowering stage (Shorrocks, 1988). The significant interaction between these treatments indicated that, these factors depend on each other's in their effect on these traits.

Table 2. Days to 50 % tasseling , Days to 50 % silking, Plant height cm , Ear height cm Stem diameter cm , Ear leaf area and Grain yield ard./fad of the two maize hybrids under affected by Potassium fertilizer levels, Spraying boron nutrition and their interactions of both seasons and their combined data.

Main factors		Days to 50 % tasseling			Days to 50 % silking			Plant height cm			Ear height cm		
		2021	2022	Comb.	2021	2022	Comb.	2021	2022	Comb.	2021	2022	Comb.
Maize hybrids (H)													
SC.168 (H_1)		57.85	58.03	57.94	59.18	60.03	59.61	270.11	273.85	271.98	160.70	160.66	160.68
SC.180 (H_2)		60.22	60.74	60.48	62.29	62.74	62.51	271.96	275.03	273.50	166.11	165.48	165.79
F. test		**	*	**	**	*	**	NS	NS	NS	*	NS	**
LSD	**0.05**	--	**1.63**	--	--	**1.68**	--	--	--		**4.18**	--	--
	0.01	**1.94**	--	**1.01**	**2.77**	--	**1.11**	--	--	--	--	--	**4.74**
Potassium sulfate K_2so_4 (levels),kg k/fad.													
0 (K_1)		59.05	59.05	59.05	60.67	61.05	60.86	270.88	273.88	272.38	162.50	161.50	162.00
24 (K_2)		59.00	59.16	59.08	60.83	61.16	61.00	269.66	273.44	271.55	163.00	162.83	162.97
48 (K_3)		59.06	59.94	59.50	60.72	61.94	61.33	272.55	276.00	274.27	164.72	164.88	164.81
F. test		NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	*
LSD	**0.05**	--	--	--	---	--	--	--	--	--	**1.88**	--	**2.09**
	0.01	--	--	--	--	--	--	--	--	--	--	--	--
Spraying boron nutrition (17.4% H_3BO_3) : mg/L B/fad.													
Control B_1		60.16	60.38	60.27	62.16	62.38	62.27	269.44	272.16	270.81	163.00	161.50	162.25
400 mg/ L B_2.		58.94	59.50	59.22	60.38	61.50	60.94	269.44	273.77	271.61	161.77	162.50	162.13
800 mg/L B_3.		58.00	58.27	58.13	59.66	60.27	59.97	274.22	277.38	275.81	165.44	165.22	165.33
F. test		**	**	**	**	**	**	**	**	**	*	**	**
LSD	**0.05**	--	--	--	--	--	--	--	--	--	**3.38**	--	--
	0.01	**1.20**	**1.21**	**0.82**	**1.32**	**1.21**	**0.86**	**4.47**	**4.36**	**3.01**	--	**2.36**	**2.47**
Interactions													
H x K		**	NS	**	**	NS	**	*	NS	NS	NS	**	**
H x B		**	**	**	**	**	**	*	**	**	**	**	**
K x B		NS	NS	NS	NS	NS	NS	*	**	**	**	NS	**
H x K x B		**	**	**	**	**	**	**	**	**	**	**	**

Table 2-cont.

Main factor		Stem diameter cm			Ear leaf area cm^2			Grain yield ard/fad.		
		2021	2022	Comb.	2021	2022	Comb	2021	2022	Comb
Maize hybrids (H)										
SC.168(H1)		3.07	4.06	3.57	589.73	597.77	593.75	33.99	35.68	34.83
SC.180(H2)		3.53	3.56	3.54	599.10	606.66	602.88	38.17	39.80	38.99
F. test		NS	NS	NS	*	*	**	**	**	**
LSD	**0.05**	--	--	--	**6.42**	**6.43**	--	--	--	--
	0.01	--	--	--	--	--	**6.03**	**3.55**	**3.72**	**1.19**
Potassium sulfate K_2SO_4(levels),kg k/fad.										
0(K1)		2.94	3.04	2.99	559.18	564.93	562.05	34.63	36.03	35.33
24(K2)		3.31	4.77	4.04	600.78	609.89	605.34	36.65	38.45	37.55
48(K3)		3.66	3.61	4.64	623.29	631.83	627.56	36.95	38.75	37.85
F. test		*	NS	NS	**	**	**	**	**	**
LSD	**0.05**	**0.13**	--	--	--	--	--	--	--	--
	0.01	--	--	--	**45.96**	**46.67**	**28.51**	**1.45**	**1.55**	**0.89**
Spraying boron nutrition (17.4% H_3BO_3) : mg/L B/fad.										
ControlB1		3.06	4.56	3.81	568.18	572.66	570.43	34.21	36.09	35.15
400 mg/ L B2.		3.28	3.28	3.28	605.59	617.82	611.71	34.92	36.77	35.84
800 mg/L B3.		3.57	3.59	3.58	609.48	616.17	612.83	39.12	40.36	39.74
F. test		**	NS	NS	**	**	**	**	**	**
LSD	**0.05**	--	--	--	--	--	--	--	--	--
	0.01	**0.19**	--	--	**25.14**	**25.28**	**17.21**	**1.37**	**1.34**	**1.26**
Interactions										
H x K		NS	NS	NS	**	**	**	**	**	**
H x B		NS	NS	NS	**	**	**	**	**	**
K x B		NS	NS	NS	**	**	**	**	**	**
H x Kx B		**	**	**	**	**	**	**	**	**

Table 3. Effect of interaction between Maize hybrids and Potassium fertilizer levels on Days to 50% tasseling and Days to 50% silking, Plant height cm, Ear height Stem diameter cm and Ear leaf area and Grain yield ard / fad cm of both seasons and their combined data.

Interaction		Days to 50 % tasseling			Days to 50 % silking			Plant height cm			Ear height cm		
		2021	2022	Comb.	2021	2022	Comb.	2021	2022	Comb.	2021	2022	Comb.
H1	K1	58.22	58.33	58.27	59.44	60.33	59.88	269.33	272.33	270.83	159.55	157.88	158.72
	K2	57.55	57.44	57.50	59.00	59.44	59.22	268.66	273.00	270.83	161.55	162.11	161.83
	K3	57.77	58.33	58.05	59.11	60.33	59.72	272.33	276.22	274.27	161.00	162.00	161.50
H2	K1	59.88	59.77	59.83	61.88	61.77	61.83	272.44	275.44	273.94	165.44	165.11	165.27
	K2	60.44	60.88	60.66	62.66	62.88	62.77	270.66	273.88	272.27	164.44	163.55	163.9
	K3	60.33	61.55	60.94	62.33	63.55	62.94	272.77	275.77	274.27	168.44	167.77	168.11
F. test		**	NS	**	**	NS	**	NS	NS	NS	**	**	**
LSD	0.05	--	--	--	--	--	--	--	--	--	--	--	--
	0.01	**1.76**	--	**1.07**	**1.73**	--	**1.06**	--	--	--	**3.88**	**8.52**	**4.07**

Interaction		Stem diameter cm			Ear leaf area cm^2			Grain yield ard/fad.		
		2021	2022	Comb.	2021	2022	Comb.	2021	2022	Comb.
H1	k1	2.72	2.83	2.77	554.26	561.26	557.76	33.70	35.05	34.38
	K2	3.07	5.95	4.51	596.25	604.92	600.58	34.03	35.87	34.95
	K3	3.43	3.40	3.41	618.68	627.13	622.91	34.24	35.1	35.17
H2	K1	3.16	3.24	3.20	564.10	568.60	566.35	35.55	37.06	36.28
	K2	3.54	3.59	3.56	605.31	614.87	610.09	39.28	41.03	40.15
	K3	3.89	3.83	3.86	627.89	636.52	632.21	39.67	41.39	40.53
F. test		NS	NS	NS	**	**	**	**	**	**
LSD	0.05	--	--	--	--	--	--	--	--	--
	0.01	--	--	--	**65.01**	**66.01**	**40.33**	**2.05**	**2.05**	**1.26**

Table 4. Effect of interaction between Maize hybrids and Spraying boron nutrition on Days to 50% tasseling , Days to 50% silking , Plant height cm Ear height cm Stem diameter cm and Ear leaf area and Grain yield ard./fad of both seasons and their combined data.

Interaction		Days to 50 % tasseling			Days to 50 % silking			Plant height cm			Ear height cm		
		2021	**2022**	**Comb.**	**2021**	**2022**	**Comb.**	**2021**	**2022**	**Comb.**	**2021**	**2022**	**Comb.**
H1	**B1**	59.55	59.88	59.72	61.33	61.88	61.61	268.88	271.88	270.72	159.11	158.55	159.16
	B2	57.88	57.77	57.83	58.77	59.77	59.27	269.55	274.11	271.50	159.77	160.22	159.66
	B3	56.11	56.44	56.27	57.44	58.44	57.94	271.88	275.55	273.72	163.22	163.22	163.22
H2	**B1**	60.77	60.88	60.83	63.00	62.88	62.94	269.33	272.44	270.88	166.22	164.44	165.33
	B2	60.00	61.22	60.61	62.00	63.22	62.61	270.00	273.44	271.72	164.44	164.77	164.61
	B3	59.88	60.11	60.00	61.88	62.11	62.00	276.55	279.22	277.88	167.66	167.22	167.44
F. test		**	**	**	**	**	**	**	**	**	**	**	**
LSD	**0.05**	--	--	--	--	--	--	--	--	--	--	--	--
	0.01	**1.71**	**1.71**	**1.16**	**1.87**	**1.71**	**1.27**	**6.33**	**6.17**	**4.26**	**6.44**	**3.34**	**3.50**

Interaction		Stem diameter cm			Ear leaf area cm^2			Grain yield ard/fad.		
		2021	2022	Comb.	2021	2022	Comb.	2021	2022	Comb.
H1	**B1**	2.81	5.75	4.28	563.63	568.07	565.85	39.83	32.40	31.11
	B2	3.04	3.04	3.04	603.34	617.90	610.62	34.07	35.56	34.82
	B3	3.37	3.39	3.38	602.23	607.34	604.78	38.07	39.07	38.57
H2	**B1**	3.31	3.36	3.33	572.74	577.25	575.00	40.01	41.14	40.57
	B2	3.52	3.52	3.52	607.83	617.73	612.78	34.34	36.62	35.48
	B3	3.77	3.79	3.78	616.73	625.01	620.86	40.15	41.65	40.90
F. test		**NS**	**NS**	**NS**	**	**	**	**	**	**
LSD	**0.05**	--	--	--	--	--	--	--	--	--
	0.01	--	--	--	**35.56**	**35.76**	**24.33**	**1.92**	**1.90**	**1.31**

Table 5. Effect of interaction between Potassium fertilizer levels and Spraying boron nutrition on days to 50% tasseling , days to 50% silking Plant height cm, Ear height cm ,Stem diameter cm, and Ear leaf area in two seasons and their combined data.

Main effect		Days to 50 % tasseling			Days to 50 % silking			Plant height cm			Ear height cm		
		2021	2022	Comb.	2021	2022	Comb.	2021	2022	Comb.	2021	2022	Comb.
K1	B1	59.67	60.17	59.92	61.67	62.17	61.92	271.16	272.16	271.66	162.00	157.66	159.83
	B2	59.33	59.17	59.25	60.67	61.17	60.92	267.16	270.83	269.00	160.66	161.50	161.08
	B3	58.17	57.83	58.00	59.67	59.83	59.75	274.33	278.66	276.50	164.83	165.33	165.08
K2	B1	59.83	60.00	59.92	62.00	62.00	62.00	266.00	269.16	267.58	160.66	162.00	161.33
	B2	58.83	59.33	59.08	60.33	61.33	60.83	270.50	275.00	272.75	163.16	163.33	163.25
	B3	58.33	58.17	58.25	60.17	60.17	60.17	272.50	276.16	274.33	165.16	163.16	164.16
K3	B1	61.00	61.00	61.00	62.83	63.00	62.92	271.16	275.16	273.16	166.33	167.83	165.58
	B2	58.67	60.00	59.33	60.17	62.00	61.08	270.66	275.50	273.08	161.50	162.66	162.08
	B3	57.50	58.83	58.17	59.17	60.83	60.00	275.83	277.33	276.58	166.33	167.16	166.75
F. test		NS	NS	NS	NS	NS	NS	**	**	**	NS	**	**
LSD	0.05	--	--	--	--	--	--	--	--	--	--	--	--
	0.01	--	--	--	--	--	--	7.75	7.56	5.22	--	4.09	4.29

Interaction		Stem diameter cm			Ear leaf area cm^2			Grain yield ard /fad.		
		2021	2022	Comb.	2021	2022	Comb.	2021	2022	Comb.
K1	B1	2.71	2.84	2.78	538.85	543.52	541.18	33.54	35.17	34.35
	B2	2.91	3.03	2.97	562.99	572.49	567.74	32.55	33.85	33.20
	B3	3.20	3.25	3.23	575.70	578.79	577.24	37.81	39.05	38.43
K2	B1	3.15	7.54	5.35	577.66	582.16	579.91	36.24	38.06	37.14
	B2	3.21	3.22	3.22	626.26	641.42	633.84	34.94	37.26	36.10
	B3	3.56	3.56	3.56	598.43	606.10	402.26	38.79	40.04	39.41
K3	B1	3.31	3.28	3.29	588.05	592.31	590.18	34.98	37.08	36.03
	B2	3.71	3.61	3.66	627.52	639.54	633.53	35.15	37.17	36.15
	B3	3.96	3.96	3.96	654.30	663.63	658.96	40.74	41.99	41.37
F. test		NS	NS	NS	**	**	**	**	**	**
LSD	0.05	--	--	--	--	--	--	--	--	--
	0.01	--	--	--	43.56	43.81	29.81	2.38	2.33	1.61

Table 6. Effect of interaction between Maize hybrids, Potassium fertilizer levels and Spraying boron nutrition on Days to 50 % tasseling , Days to 50 % silking, Plant height cm, Ear height cm Stem diameter cm , Ear leaf area Grain yield ard/fad cm of both seasons and their combined data.

Interaction			Days to 50 % tasseling			Days to 50 % silking			Plant height cm			Ear height cm		
			2021	2022	Comb	2021	2022	Comb	2021	2022	Comb	2021	2022	Comb
H1	K1	B1	59.33	59.67	59.50	61.33	61.67	61.50	268.3	268.0	268.2	159.6	154.3	157.0
		B2	58.67	58.67	58.67	59.33	60.67	60.00	269.0	273.3	271.1	158.6	158.6	158.6
		B3	56.67	56.67	56.67	57.67	58.67	58.17	270.6	275.6	273.1	160.3	160.6	160.5
	K2	B1	59.67	59.67	59.67	61.33	61.67	61.50	267.0	270.0	268.5	161.0	161.6	161.3
		B2	57.33	57.33	57.33	58.33	59.33	58.83	268.6	275.0	271.8	160.0	160.6	160.3
		B3	55.67	55.33	55.50	57.33	57.33	57.33	270.3	274.0	272.1	163.6	164.0	163.8
	K3	B1	59.67	60.33	60.00	61.33	62.33	61.83	273.3	277.6	275.5	158.6	159.6	159.2
		B2	57.67	57.33	57.50	58.67	59.33	59.00	269.0	274.0	271.5	158.6	161.3	160.0
		B3	56.00	57.33	56.67	57.33	59.33	58.33	274.6	277.0	275.8	165.6	165.0	165.3
H2	K1	B1	60.00	60.67	60.33	62.00	62.67	62.33	274.0	276.3	275.2	164.3	161.0	162.7
		B2	60.00	59.67	59.83	62.00	61.67	61.83	265.3	268.3	266.8	162.7	164.3	163.5
		B3	59.67	59.00	59.33	61.67	61.00	61.33	278.0	281.7	279.8	169.3	170.0	169.7
	K2	B1	60.00	60.33	60.17	62.67	62.33	62.50	265.0	268.3	266.7	160.3	162.3	161.3
		B2	60.33	61.33	60.83	62.33	63.33	62.83	272.3	275.0	273.7	166.3	166.0	166.1
		B3	61.00	61.00	61.00	63.00	63.00	63.00	274.7	278.3	276.5	166. 7	162.3	164.5
	K3	B1	62.33	61.67	62.00	64.33	63.67	64.00	269.0	272.7	270.8	174.0	170.0	172.0
		B2	59.67	62.67	61.17	61.67	64.67	63.17	272.3	277.0	274.7	164.3	164.0	164.2
		B3	59.00	60.33	59.67	61.00	62.33	61.67	277.0	277.7	277.3	167.0	169.3	168.2
F. test			**	**	**	**	**	**	**	**	**	**	**	**
LSD		**0.05**	--	--	--	--	--	--	--	--	--	--	--	--
		0.01	**2.98**	**2.97**	**2.01**	**3.27**	**2.99**	**2.11**	**11.04**	**10.77**	**7.33**	**11.24**	**8.53**	**6.52**

Interaction			Stem diameter cm			Ear leaf area cm^2			Grain yield ard /fad.		
			2021	2022	Comb.	2021	2022	Comb.	2021	2022	Comb.
H1	K1	B1	2.47	3.17	2.82	535.53	539.20	537.37	29.01	30.99	30.00
		B2	2.70	3.30	30.0	561.10	574.10	567.60	33.76	34.83	34.29
		B3	3.00	3.53	3.27	566.16	570.49	568.32	38.35	39.35	38.85
	K2	B1	2.90	2.93	3.49	573.13	575.13	574.13	30.34	32.89	31.62
		B2	2.97	3.45	3.21	623.30	640.63	631.97	34.85	36.83	35.84
		B3	3.36	3.82	3.59	592.33	599.00	595.67	36.92	37.92	37.42
	K3	B1	3.06	3.50	3.23	582.23	589.90	586.07	30.14	33.33	31.73
		B2	3.47	3.87	3.67	625.63	638.97	632.30	33.63	35.04	34.34
		B3	3.77	4.33	4.05	648.20	652.53	650.37	38.96	39.96	39.46
H2	K1	B1	2.97	3.52	3.24	542.17	547.83	545.00	38.07	39.37	38.72
		B2	3.13	3.75	3.44	564.88	570.88	567.88	31.33	32.88	32.11
		B3	3.40	3.97	3.49	585.26	587.09	586.17	37.27	38.77	38.02
	K2	B1	3.40	4.00	3.70	582.20	589.20	585.70	42.13	43.23	42.68
		B2	3.47	3.98	3.73	629.22	642.22	635.72	35.05	37.70	36.37
		B3	3.76	4.30	4.03	604.53	613.20	608.87	40.66	42.16	41.41
	K3	B1	3.56	4.06	3.81	593.87	594.73	594.30	39.83	40.83	40.33
		B2	3.97	4.40	4.15	629.41	640.11	634.76	36.66	39.31	37.98
		B3	4.17	4.70	4.18	660.40	674.73	667.57	42.53	44.03	43.28
F. test			**	**	**	**	**	**	**	**	**
LSD		**0.05**	--	--	--	--	--	--	--	--	--
		0.01	**0.47**	**0.61**	**0.39**	**61.99**	**62.34**	**41.80**	**3.39**	**3.32**	**2.26**

4. Conclusions

We recommend increasing the level of boron spraying to 800 mg boron/fad because it leads to an earlier number of days until up to 50% of the tasseling and days to 50% silking in both seasons and their combined. It was observed that there was a highly significant interaction between maize hybrids, the levels of potassium fertilization and the levels of spraying with boron for plant height, ear height, ear leaf area, stem diameter and grain yield (ard/fad).

Data Availability Statement: The data that supports the findings of this study are contained within the article and available from the corresponding author upon reasonable request.

Acknowledgments: The authors would like to appreciate to both of the Faculty of Agriculture, Tanta University and Sakha Agricultural Research Station, Agriculture Research Center (ARC) for their assistance for this work

Conflicts of Interest: The authors declare no conflict of interest.

Reference

Ali, A.; Hussian, M.; Habib, H.S.; Kiani, T.T.; Anees, M.A.; and Rahman, M.A. (2016). Foliar spray surpasses soil application of potassium for maize production under rainfed conditions Turkish Journal of Field crop, 21(1): 36-43.

Aslam, Zamir, M.S.I.; Afzal, I.; and Amin, M. (2014). Role of potassium in physiological functions of spring maize (*Zea mays* L.) grown under drought stress. Journal of Animal and Plant Sciences, 24(5): 1452-1465.

Amanullah, I.A.; Irfanullah, I.; and Hidayat, Z. (2016). Potassium management for improving growth and grain yield of maize (*Zea mays* L.) under moisture stress conditionScientificReports,6:34627,DOI:10.1038/srep34627.

Bayard, J.; Shah, S.; Khan, W.; Okla, M.K.; Yasmeen, A. Alwasel.; Saleh,I.A.; AbdElgawad,H.; Rahim, W.; Iqbal, A.; and Jalal, A. (2024). Boron foliar application improves growth, yield and grain quality of maize. Polish Journal of Environmental Studies, 33(5):1-11.

Freed, R.S.P; Eisensmith, S.P; Goetez, S.; Reicosky, D.; Smail V.W.; and Wolberg, P. (1989) User's Guide to MSTAT-C A software program for the design, management and analysis of agronomic research experiments. Michigan State University, U.S.A.

Gomez, K.H.; and Gomez, A.A. (1984). Statistical Procedures for Agriculture Research. John Willy and Sons, Inc., New York.

Jackson, M.L. (1958). Soil Chemical Analysis. Prentice – Hall, Inc., England Cliffs, V.S. Library of Congress, USA.

Lindsay, W.L.; and Norvel, W.A. (1978). Development of DTPA soil test for micronutrients. Soil Sciences Society of America journal, 42: 421 – 428.

Ljaz, M.; Mahmood, A.; and Ullah, H. (2014). Response of Maize Hybrid (*Zea mays* L.) to Different Levels of Potassium. Agricultural Research Communication (1):30-38.

McKee, G.W. (1964). A coefficient for computing leaf area in hybrid corn. Agronomy Journal, 56: 240-241.

Mengel, K.; and Kirkby, E.A. with the support of Kosegarten H. and Appel T. (5 Ed.) (2001). Principles of plant nutrition. Springer Science and Business Media.

Miwa, K; Takano, J.; and Fujiwara T. (2008). Molecular mechanism of boron transport in plants and its modification for plant growth improvement. Protein, Nucleic acid, Enzyme 53:1173-1179.

Sayed, S.A. (1998). Impacts of boron application on maize plants growing under flooded and unflooded conditions. Biologia Plantarum, 41: 101-109.

Shorrocks, V.M. (1988). Boron deficiency its Prevention, and cure chessington Borax Holdings Limited.

Steel, R.G.D.; and Torrie, J.H. (1980). Principles and Procedures of Statistics: A biometrical approach. 2nd ed. Mc Graw-Hill Book Co New York USA.

Waller, R.A.; and Duncan D.B. (1969). A Bayes rule for symmetric multiple comparisons problems. Journal of America Statistical Association, 64:1484-1503.

Xie, W.J; Wang, H.Y; Xia, J.B; and Yao, Z.G. (2011). Influence of N, P, and Kapplication on Zea mays L. growth and Cu and Pb accumulation. Plant Soil Environment, 57(3): 128-134.