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ROLE OF SPRAYING BORON AND ANTI-TRANSPIRATION AGENTS IN IMPROVING POLLEN PROPERTIES AND GRAIN YIELD OF SPRING CORN

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Abstract

Two field experiments were conducted on fields of Agricultural Engineering Sciences Faculty, University of Baghdad in Al Jadriya during spring seasons of 2017 and 2018 to investigate the role of spraying boron and Anti-transpiration agents in improving pollen properties and grain yield of corn (*Zea mays* L.) cultivar "Buhoth 5018". Three anti-transpirations agents were used, Glycerol (4%), $MgCO_3$ (4%), Green miracle (0.3%) and control (distilled water spray) whereas three concentrations of boron (40, 80, 120 mg kg^{-1}) in addition to control (distilled water spray). The experiment was set as Random Complete Block Design (RCBD) using split plot layout with three replicates. Plants were sprayed with Anti-transpirations agents and boron twice, at 6-8 leaf stage and at flowering stage. Results indicated that there was a significant effect of adding Anti-transpiration agents in improving the studied traits compared to control in both seasons. First season, green miracle achieved the highest increase in pollen viability with mean of 6.55% while second season, glycerol achieved the highest percentage (12.30%) compared with control. As for grain yield, $MgCO_3$ gave the highest percentage increase with mean of 26.66% in first season while green miracle achieved the highest increase in second season with mean of 26.81%. Significantly, the application of boron improved all the studied traits compared with control as well as a significant difference between boron concentrations was revealed. Using 120 mg kg^{-1} zinc recorded the highest increase of all the traits. The increment in pollen viability was 12.93% and 13.52% compared with control for both seasons respectively, while the increment in grain yield was 62.59% and 46.38% compared with control for both seasons respectively. It was observed that the treatment of glycerol with 120 mg kg^{-1} boron was superior and gave the highest rate of pollen viability with mean of 82.78% and 87.42% for both seasons respectively. The result of grain yield indicated that the treatment of $MgCO_3$ with 120 mg kg^{-1} boron provide with highest average of 10.334 Ton ha^{-1} in first season while applying of green miracle with same concentration of boron gave the highest average of 12.345 Ton ha^{-1} in 2018 season. All anti-transpirations agents were significantly differ compared with water spraying treatment under the same concentration of boron.

Key words: Corn, Anti-transpirations, Boron, Pollen viability.

Introduction

Global warming has become a reality and the changes in the concentration of carbon dioxide and other gases have increased surface air temperatures by 0.8 percent over the last century and global temperatures are expected to increase by about 4.0-1.8 percent at the end of this century (IPCC, 2007). Temperature is a key determinant of plant growth rate. It is increases as a result to climate change will significantly reduce plant productivity (Hatfield and Prueger, 2015). Under conditions of middle and southern part of Iraq, corn cultivated at spring season is characterized by a decrease in grain yield due to the increase in number of empty and incomplete ears as a result to the synchronization of the flowering stage, release of pollen and fertilization with high temperatures and low relative humidity. Flowering is one of the most sensitive stages to high temperatures in all plant species. During this evolutionary stage, extreme temperatures can have a significant impact on production. Stone *et al*., (2001) point out that stage of formation and shading of pollen is one of the most sensitive stages of heat stress in cereals. This is confirmed by Cross *et al*., (2003) who demonstrated that pollen production, silk development, growth and elongation of pollen tube are the most sensitive stages of heat stress. Johnson (2000) found that heat stress affected the viability and germination of pollen, which weakened process of seeds sit, leading to a decrease in grain yield and quality. Under conditions of heat stress, the low number of grains in ears due to the abortion of grain due to low pollen viability and poor pollination, which result in the reduction of productivity of crop (Cicchion *et al*., 2010). For this, low grain yield was associated with low pollen viability and poor fertilization under high temperature conditions (Rowhani *et al*., 2011). Therefore, when temperatures are above 35°C and for several hours, the probability of fertilization success is greatly reduced (Farrell *et al*., 2007). Temperature is one of the factors that cannot be controlled as they are related to natural climate change, but it is possible to reduce its negative effects on crops by using of some applications and transactions.

Anti-transpirations agents are compounds sprayed on plant to reduce the loss of water from the plant by transpiration process and have been used for this purpose since 1950. A very small proportion of the water absorbed by plant roots is used in the growth and development of agricultural crops. The largest proportion of which is about 95% of the absorbed water is lost from the plant by transpiration process (Parkash and Ramachandran, 2000). Reducing this process can have a beneficial role by preventing excessive loss of water from plants to the outer environment through stomata (Kahalil, 2006). Minimizing transpiration may be a solution to counteract the negative effects of water shortages and improve crop productivity under semi-arid conditions where transpiration is most likely to be obtained from absorbed water (Polijakoff and Gale, 2012). The effectiveness of anti-transpirations agents in influencing grain yields when sprayed in drought-sensitive stages as division and pollen formation is due to its role to reduce the loss of water from plants at these stages, which improves water effort of plants and thus increase number and viability of pollen and improve the efficiency of fertilization resulting in increasing cereal production and increase the yield (Kettlewell, 2014).

Boron is the only non-metallic element as essential micronutrients that plants need continuously throughout their life cycle to obtain natural growth and development (Gupta and Solank, 2013). Weir and Dear (2004) point out that the importance of boron comes from its close association with cell division and development in plant growth areas near the growing tips of root and stem. It is also necessary for the growth of pollen tube during the pollination process, so it is important to set seeds and develop good fruits; It is also notes to increase the production of nectar that is important in attracting pollinated insects. Brown *et al*., (2002) found that exposing of corn plants to boron deficiency a week before the emergence of male flowers and even full grain maturity slowed the growth and production of pollen, as well as a decrease in the growth rate of female flowers. Vaughan, (1977) detected that the pollen germination is completely inhibited when temperature is above 21°C under boron deficiency, which confirms its importance in growth stage of corn especially in spring season. The objective of the study was to investigate the effect of boron and anti-transpiration agents on reducing the negative effect of high temperatures and improving pollen properties and corn yield when cultivated in spring season.

Materials and Methods

A field experiment was carried out during spring seasons of 2017 and 2018 on fields of Agricultural Engineering Sciences Faculty, University of Baghdad in two kinds of soil (Loam and Clay Loam soil) to study the effect of spraying boron and Anti-transpiration agents on pollen properties and grain yield of corn (cultivar 5018). Experiments were designed according to randomized complete block with split plot layout with three replicates and the cultivation was carried in rows (3 meter length row and 0.75m in between) as well as seeds were planted in holes with 0.20 m between them on 27 of March 2017 and 22 of March 2018 respectively. At planting date, 240 and 200 kg ha^{-1} of DAP fertilizer (18% nitrogen and 46% phosphorus) and Potassium fertilizer (potassium sulfate) respectively were added while 360 kg ha^{-1} of urea fertilizer (46% N) was splitted, first addition was after one month of planting and second addition was at beginning of the flowering stage. Anti-transpiration agents were 4% of Glycerol ($C_3H_8O_3$), 4% of $MgCO_3$, 0.3 % of Green miracle (a long-chain of fatty acid that formed a thin glassy layer on the plant leaves) and control (distilled water), while boron was sprayed with three doses of 40, 80 and 120 mg kg^{-1} plus control. Antiperspirants were distributed on main plots and boron levels on secondary plots. Plants were sprayed with Anti-transpiration agents and boron twice, the first was in 6-8 leaves stage and second one was in flowering stage.

The studied attribute

Relative water content (R.W.C.) (%): It was estimated according to the method described by Barrs and Weatherly (1962) using the following equation:

R.W.C. (%) = FW-DW / TW-DW × 100

Where: FW fresh weight of leaf, TW turgid weight and DW dry weight.

Pollen moisture %: Were estimated according to the method described by AOAC (1995) using the following equation:

Pollen moisture percentage=100- [(m'-t/m-t)×100

Whereas:

m = total weight of container and pollen prior to drying

m = Total weight of container and pollen after drying

t = container weight.

Pollen viability (%): *In vitro* fertilization was used to quantify the number of live pollen by the total number of grains examined in the field of vision of Slide the microscope multiplied by 100 (Sass, 1958).

Fertility rate (%): According to the following equation:

$$\text{Fertility percentage (\%)} = \frac{\text{Total number of grains in ear}}{\text{Total number of ovaries in ear}} \times 100$$

(Gardner *et al*., 2017).

Number of grains per ear: It was calculated as the average number of grains in ears of five plants per treatment.

Grain yield (Ton ha^{-1}): Ears of five plants were separated and weighed and the average yield of the plant was calculated based on Ton ha^{-1} unit.

The data were statistically analyzed and the averages were compared using the least significant difference of (LSD) at 5% probability level (Steel and Torrie, 1980).

Results and Discussion

Relative water content (%): Application of anti-transpiration agents resulted in a significant increase in leaves relative water content compared with control (Table 1). Anti-transpiration agents did not differ significantly among them. Its obverse that Green miracle gave the highest mean of 84.09% and 99.91% for both seasons respectively and significantly differ from $MgCO_3$ for both seasons. It was also noticed that there was a significant increase in this trait when boron was added. Boron concentrations were significantly different. Using 120 mg kg^{-1} boron recorded the highest average of 84.91% and 89.41% for both seasons respectively. Data showed that spraying green miracle with 120 mg kg^{-1} of boron gave the highest average of 86.76% and 94.63% for both seasons respectively and differed significantly compared with treatment of water spraying under the same concentration of boron. Additionally, it was significantly differ from treatment of $MgCO_3$ in both seasons which indicates the efficiency of green miracle in improving relative water content in plant leaves.

The increment in relative water content when using anti-transpiration agents may be due to their role in reducing the stomatal conductance and reducing transpiration rates and thus increasing the plant's ability to retain water (Contore *et al*., 2009). Khalil, (2015) reported that anti-transpiration agents have reduced the average water loss and improved the aquatic state of plants. The obtained result was confirmed by the results of Farhan (2017), Sanbagavalli *et al*., (2017) and Rania and Elbialy (2018). The increment in relative water content of leaves when boron was added may be due to its role that regulates the amount of water inside cell, thus Plants with boron deficiency showed a decrease in moisture content, low metabolic activity, low water effort and open stomata (Sharma and Ramchandea, 1990). Moreover, Rehem *et al*., (1998) pointed that boron plays a vital role in transferring nutrients and water from root to shoot.

Pollen moisture content (%): The results showed that adding anti-transpiration agents resulted in a significant increase in pollen moisture content compared with control. Anti-transpiration agents did not differ significantly in both seasons (Table 2). In first season (2017), Green miracle gave the highest average of 49.23% while in second season; glycerol recorded the highest mean of 50.23%. Additionally, application of boron increased pollen moisture significantly compared with control as well as a significant difference between the concentrations of boron was noted. Spraying boron with concentration 120 mg kg^{-1} gave the highest mean of 50.09% and 51.18% for both seasons respectively. As for interaction, green miracle and 120 mg^{-1} kg boron gave the highest average of 52.78% and 53.43% for both seasons respectively as well as significantly differ compared with water spray treatment at the same concentration of boron. The increment in pollen moisture may be due to the role of anti-transpiration agents in reducing the stomatal conductance, decreasing transpiration rates and increasing plant susceptibility to water retention (Contore *et al*., 2009). Khalel (2015) reported that anti-transpiration agents have decreased water loss average and improved water status of plants, in addition to its role in increasing the relative water content of plants (Table 1).

Increasing moisture content of pollens may be due to Boron's role in regulating the amount of water inside the cell. Plants with boron deficiency showed a reduction in the percentage of moisture, low metabolic activity, low water effort and open stomata (Sharma and Ramchandea, 1990). Rehem *et al*., (1998) showed that boron plays a vital role in the transfer of nutrients and water from root to shoot, in addition to its role in increasing plant relative water content (Table 1).

Pollen viability (%): Anti-transpiration agents

Table 1: Effect of anti-transpiration agents, boron and their interaction on the relative water content (%) for spring seasons of 2017 and 2018.

Average	Season 2018				Average	Season 2017				anti-transpiration agents
	Boron concentration(mg kg^{-1})					Boron concentration(mg kg^{-1})				
	120	80	40	0		120	80	40	0	
79.86	83.74	81.74	78.25	76.19	79.83	82.16	80.82	79.40	76.95	Control
85.17	88.46	85.87	83.59	82.74	82.93	84.91	84.10	82.76	79.95	$MgCO_3$
88.29	90.80	90.08	86.75	85.55	83.23	85.79	84.01	82.72	80.40	Glycerol
91.99	94.63	93.31	91.56	88.46	84.09	86.76	85.10	83.49	81.01	Green m.
4.39	4.41				1.13	1.42				L.S.D. 0.05
	86.09	87.63	85.04	83.24		89.41	83.51	82.09	79.57	Average
	0.22					0.60				0.05L.S.D

Table 2: Effect of anti-transpiration agents, boron and their interaction on pollen moisture (%) for the spring seasons of 2017 and 2018.

Average	Season 2018				Average	Season 2017				anti-transpiration agents
	Boron concentration(mg kg^{-1})					Boron concentration(mg kg^{-1})				
	120	80	40	0		120	80	40	0	
45.15	47.89	46.06	44.39	42.25	44.20	47.10	44.74	43.77	41.19	Control
48.99	51.59	48.92	48.76	46.72	48.39	50.07	49.95	47.32	46.21	$MgCO_3$
50.23	51.83	50.61	50.20	48.30	48.06	50.41	48.63	47.03	46.16	Glycerol
49.30	53.43	49.48	47.95	46.36	49.23	52.78	49.60	47.76	46.79	Green m.
1.87	1.88				2.81	2.82				L.S.D. 5%
	51.18	48.77	47.82	45.91		50.09	48.23	46.47	45.09	Average
	0.28					0.37				L.S.D. 5%

Table 3: Effect of anti-transpiration agents, boron and their interaction on pollen viability (%) for spring season of 2017 and 2018.

Average	Season 2018				Average	Season 2017				anti-transpiration agents
	Boron concentration(mg kg^{-1})					Boron concentration(mg kg^{-1})				
	120	80	40	0		120	80	40	0	
73.74	78.22	75.23	72.50	69.01	73.19	76.35	75.25	71.82	69.34	Control
80.33	85.19	80.53	79.64	75.97	77.66	82.61	80.30	75.80	71.92	$MgCO_3$
82.81	87.42	83.26	81.99	78.56	77.76	82.78	79.78	75.94	72.52	Glycerol
79.39	87.07	79.92	76.44	74.12	77.98	82.15	79.49	77.26	73.02	Green m.
3.77	3.85				3.78	3.89				L.S.D. 5%
	84.47	79.74	77.64	74.41		80.97	78.71	75.20	71.70	Average
	0.84					0.94				L.S.D. 5%

application resulted in a significant increase in pollen viability compared to control as well as insignificant difference among anti-transpiration agents for both seasons was revealed (Table 3). In 2017, green miracle recorded the highest average of 77.98%, while in 2018 glycerol treatment recorded the highest average of 82.81%. Moreover, a significant effect of spraying boron was noted, as well as boron concentrations were significantly varied. Boron concentration 120 mg kg^{-1} provides the highest average of 80.97% and 84.47% for both seasons respectively. Represented data showed that spraying glycerol with 120 mg kg^{-1} boron gave the highest means of 82.78% and 96.77% for both season respectively as well as significantly differ from water spray treatment at same concentration of boron. Increasing pollen viability when adding anti-transpiration agents and boron is due to the increased pollen moisture (Table 2). Luna *et al.*, (2001) indicated that pollen viability is highly correlated with its moisture and the relative water content of pollen plays an important role in their viability and dynamic transmission in air streams. Pollen of corn is sensitive to drought and its viability is strongly related to its water content and drought-causing conditions.

Fertility rate (%): The obtained results demonstrated that seeds fertility rate was significantly increased when anti-transpiration agents were added compared to control as well as there was no significant difference among them (Table 4). Green Miracle gave the highest mean of this characteristic which were 94.81% and 95.60% for both seasons respectively. Additionally, boron has significantly increased fertility rate compared to control and its concentrations were varied, boron concentration 120 mg kg^{-1} gave the highest average of 96.00% and 96.70% for both seasons respectively. However, $MgCO_3$ with 120 mg kg^{-1} of boron gave the highest mean which was 98.32% in first season while in second season, green miracle with the same concentration recorded the highest percentage with mean of 97.60% and differed significantly from water spraying treatment at the same concentration of boron. The increment in seed fertility rate may attribute to the role of anti-transpiration agents in increasing pollen moisture and pollen viability (Tables 2 and 3) which improved fertilization process. Luna *et al*., (2001) showed that pollens relative water content of Pollen plays an important role in both viability and dynamic transmission in air streams. Kettlewell (2014) pointed that effectiveness of anti-transpiration agents to improve grain yield when sprayed in drought-sensitive stages as a division and pollen formation stage comes as a result of reducing water loss and improving water effort of plants, which leads to an increase in number and pollen viability and consequently improved fertilization efficiency. In addition to its role in increasing the moisture and vitality of the pollen (Tables 2 and 3 respectively), which improved fertilization process. The significant effect of applying boron on fertility rate was due to the fact that it is necessary for the growth of pollen during pollination process and its importance for the success of the fertilization process, set seeds and the development of the fruit (Havlin *et al*., 2005). Weir and Dear (2004) revealed that importance of boron comes from being a necessary element for the growth of pollen tube during the process of pollination of flowers so it is important to sit seeds and the development of fruits and it is also thought to increase the production of nectar that is important in attracting pollinated insects. Vaughan (1977) found in a study on corn that pollen germination was completely inhibited when the temperature is above 21°C in the absence of boron. This confirms its importance in productive stage of corn especially in spring season. Gupta and Solanki (2013) found that lack of boron inhibits the process of fertilization and the formation of grain by inhibiting pollen germination and development of pollen tube. Boron deficiency reduces fertility and slows the development of fruits. In addition to its role in increasing pollen moisture and viability (Tables 2 and 3 respectively), which improved fertilization process.

Number of grains per ear: Significantly, application of anti-transpiration agents increased number of grains in ear compared to control as well as there was insignificant difference among them in both seasons (Table 5). However, green miracle gave the highest average in 2017 with mean of 691.22 grain ear^{-1} while the highest average in 2018 season was in glycerol treatment with mean of 709.91 grain ear^{-1}. There was also a significant increase in this trait when adding boron compared with control, in addition to a significant difference between boron concentrations was found. Boron concentration 120 mg kg^{-1} recorded the highest average of 731.89 and 804.38 grain ear^{-1} for both seasons respectively. Green miracle and 120 mg kg^{-1} boron was significantly superior compared with water spray treatment under the same concentration of boron and gave the highest mean of this trait with means of 844.71 and 831.22 grain ear^{-1} for both seasons respectively, which indicates the efficiency of green miracle with high concentration of boron to increase the number of grains in ear.

The increment in number of grains per ear when adding anti-transpiration agents may be due to their important role in increasing the relative water content of plants, moisture and viability of pollen (Tables 1, 2 and 3 respectively), which improved fertilization and increased fertility rate (Table 4) that resulted in an increase in number of grains in ear. The effect of boron on the increase in number of grains in ear may be attributed to its importance

Table 4: Effect of anti-transpiration agents, boron and their interaction on seed fertility rate (%) for spring season of 2017 and 2018.

Average	Season 2018				Average	Season 2017				anti-transpiration agents
	Boron concentration(mg kg^{-1})					Boron concentration(mg kg^{-1})				
	120	80	40	0		120	80	40	0	
91.0	95.0	93.7	91.6	83.7	81.30	89.59	85.87	78.07	71.66	Control
94.6	97.0	96.8	95.4	89.0	93.59	98.32	93.55	91.74	90.76	$MgCO_3$
94.5	97.3	95.8	94.2	90.9	93.04	98.01	94.43	91.95	87.76	Glycerol
95.6	97.6	96.9	94.6	93.4	94.81	98.07	96.17	93.53	91.48	Green m.
1.2	1.3				1.86	2.10				L.S.D. 0.05
	96.7	95.8	94.0	89.3		96.00	92.50	88.82	85.41	Average
	0.3					0.75				0.05L.S.D

Table 5: Effect of anti-transpiration agents, boron and their interaction on number of grains per ear for the spring seasons of 2017 and 2018.

Average	Season 2018				Average	Season 2017				anti-transpiration agents
	Boron concentration(mg kg^{-1})					Boron concentration(mg kg^{-1})				
	120	80	40	0		120	80	40	0	
613.16	740.29	673.30	569.23	469.80	431.55	557.17	495.80	441.33	231.89	Control
693.22	823.19	742.81	651.53	555.35	653.48	754.93	665.15	634.55	559.29	$MgCO_3$
709.91	822.81	744.56	685.58	586.70	609.18	770.76	659.66	550.85	455.46	Glycerol
704.09	831.22	749.70	658.83	576.59	691.22	844.71	715.12	639.92	565.12	Green m.
47.63	54.08				89.56	92.24				L.S.D. 0.05
	804.38	727.59	641.29	547.11		731.89	633.93	566.66	452.94	Average
	19.55					21.87				0.05L.S.D

Table 6: Effect of anti-transpiration agents, boron and their interaction on grain yield (Ton ha^{-1}) for the spring seasons of 2017 and 2018.

Average	Season 2018				Average	Season 2017				anti-transpiration agents
	Boron concentration(mg kg^{-1})					Boron concentration(mg kg^{-1})				
	120	80	40	0		120	80	40	0	
8.149	10.154	8.758	7.426	6.257	7.344	8.874	8.095	6.705	5.702	Control
10.023	11.716	10.306	9.611	8.457	9.302	11.740	10.137	8.317	7.015	$MgCO_3$
9.706	11.426	10.454	9.062	7.880	9.191	11.340	9.929	8.372	7.123	Glycerol
10.334	12.345	10.632	9.772	8.586	9.297	11.553	9.809	8.907	6.921	Green m.
1.502	1.537				1.085	1.272				L.S.D. 0.05
	11.410	10.038	8.968	7.795		10.877	9.492	8.075	6.690	Average
	0.340					0.489				0.05L.S.D

in increasing percentage of pollen germination and growth of the pollen tube, as well as the increase in the transfer of processed carbohydrates to areas of effective growth during the reproductive stage of plants (Khrbeet *et al.*, 2014). As well as its role in improving the relative water content of the plants and pollen moisture and viability (Tables 1, 2 and 3 respectively), which improved fertilization, increased fertility rate (Table 4) and increase number of grains in ear.

Grains yield (Ton ha^{-1}): Grain yield was significantly higher when anti-transpiration agents were sprayed compared to control in both seasons. $MgCO_3$ gave the highest mean of 9.302 ton ha^{-1} in first season while in second season; green miracle showed the highest value with mean of 10.334 Ton ha^{-1}, the differences were not significant between anti-transpiration agents in both seasons (Table 6). Boron application caused as increased in grain yield significantly compared to control and its concentrations varied where the concentration of 120 mg kg^{-1} boron recorded the highest average of 10.877 and 11.410 ton ha^{-1} for both seasons respectively. Treatment of $MgCO_3$ and 120 mg kg^{-1} of boron recorded the highest value with means of 10.877 in first season while in second season, green miracle and 120 mg kg^{-1} boron showed the highest yield with mean of and 12.345 ton ha^{-1}. However, it differed significantly from the treatment of water spraying at the same concentration of boron.

The increment in grain yield when adding anti-transpiration agents may be due to their ability to increase leaves resistance to loss of water by transpiration and also improve the process of water use by plants and thus increase the grain yield (Tambussi and Bort, 2007). Kettlewell (2014) points out that it works to reduce the loss of water from plants, which improve water effort of plants, increasing number and pollen viability as well as improve fertilization efficiency, which leads to increased grain production. Abo-Muriefah (2013) showed that increase in grain yield when adding anti-transpiration agents may be due to their effect in regulating physiological processes, improving vegetative growth and activating the transfer of photosynthate from source to sink. As well as the effect of these anti-transpiration agents to improve the content of relative water, pollen moisture and its viability, fertility rate and number of grains in ear (Tables 1, 2, 3, 4 and 5 respectively), which resulted in an increase in the grain yield. This is confirmed by Farhan (2017).

The increment in grain yield when adding boron was due to improved relative water content of plants, pollen moisture content and viability (Tables 1, 2 and 3 respectively), which increased fertility rate (Table 4) and number of grains in ear (Table 5) that resulted in an increase in grain yield. Obtained results were confirmed by findings of Tahir *et al*., (2012), Mohammad and Abu-dahi (2013), AL-Dulami and AL-Hadethi (2015) who detected that adding boron with different concentrations have led to a significant increase in grain yield of plants treated.

In sum, it looks that using spraying Anti-transpiration agents, green miracle in most cases and glycerol in some, with 120 mg kg^{-1} of boron leads to improve most of spring corn pollen properties and grain yield. These agents can be used to avoid the elevated temperature stress at spring season of Iraq.

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