Plant Archives Vol. 19 No. 2, 2019 pp. 4155-4161 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

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

Riyadh S. Abbas[1,2] and M. Mubarak A. Abdul-Razak[1]

[1]Department of Field Crop Sciences, Agricultural Engineering Sciences, University of Baghdad, Iraq.
[2]Ministry of Science and Technology, Iraq.

Abstract

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 zinc 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) as well as three concentrations of zinc 100, 150 and 200 mg kg^{-1} plus control (distilled water spray). The experiment was of Random Complete Block Design (RCBD) using split plot layout with three replicates. Plants were sprayed with Anti-transpirations agents and zinc 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 7.68% while second season, glycerol achieved the highest percentage (20.23%). As for grain yield, Green miracle gave the highest percentage increase 33.95% and 27.09% respectively for both seasons. Significantly, the addition of zinc improved all the studied traits compared to control as well as a significant difference between zinc concentrations was revealed. Using 200 mg kg^{-1} zinc provides the highest increase of all the traits. The increment in pollen viability was 26.06% and 16.28% respectively for both seasons while the increment of grain yield was 55.64% and 51.72% respectively for both seasons. As for interaction, it was observed that treatment of green miracle with 200 mg kg^{-1} zinc in first season gave the highest average of pollen viability percentage of 93.53%. In second season, glycerol with 200 mg kg^{-1} zinc recorded the highest average of 96.77%. Regarding to grain yield, green miracle with 200 mg kg^{-1} zinc gave the highest average of 8.865 and 12.760 tons he^{-1} respectively for both seasons.

***Key words*:** Corn, Anti-transpiration, Zinc, Pollen viability.

Introduction

Among the ever-changing environmental factors, continuous rise in the environmental temperature is one of the most damaging environmental stresses (Hasanuzzaman, 2013). Air temperature around the world is expected to rise by 0.2°C every 10 years, resulting in a temperature rise of 1.8°C to 4.0°C higher than the present level by 2100 (IPCC, 2007). Under the conditions of middle and southern part of Iraq, corn cultivated at the spring season is characterized by a decrease in grain yield due to the increase in the number of empty and incomplete ears due to the synchronization of the flowering stage, release of pollen, and pollination and fertilization presses with high temperatures and low relative humidity conditions. Harrison (2011) noted that rising temperatures during flowering periods of corn when silk emergence may inhibit the pollination process and may lead to a complete halt in the development of grains. When compared to vegetative growth, reproductive stage is the most sensitive to heat stress. A slight increase in temperature during the flowering period can cause a significant loss of grain yield (Lobell *et al.*, 2011). In general, high temperatures during the reproductive stage affect the viability of pollen, pollination process and formation of seeds and fruits (Hatfield *et al.*, 2011). Anonymous (2006) noted that increasing temperature to 35°C during the pollination and grain filling process,

***Author for correspondence :** E-mail: ryadsulmani@yahoo.com, drmmubarak@gmail.com

reduced the grain yield of corn by 101 kg he^{-1} day.

Plant spraying with Anti-transpiration agents is one of the most important agricultural trends to increase and improve the productivity of agricultural crops by protecting plants from exposure to drought stresses (Al-Moftah and Hamaid, 2005). Tambussi and Bort (2007) noted that these Anti-transpirations have the potential to increase leaf resistance to loss of water by evaporation, as well as improved water use by plants, increased biological yield and grain yield. Kettlewell (2014) detected that the effectiveness of Anti-transpiration in the effect on grain yields when sprayed in the drought-sensitive stages as pollen division and formation stage is due to its work on reducing the loss of water from plants at this stage, which improves the water effort of plants and thus increase the number and viability of pollen and improve the efficiency of fertilization, which leads to an increase in grain production and yield increase accordingly. Zinc consider as one of the micro nutrients that necessary for the growth and development of the plant despite the need for the plant in small quantities, but it plays an important role in many physiological processes within the plant. The participation of zinc in the process of protein representation made it one of the most important nutrients for plants (Cakmak *et al*., 1998). Cakmak *et al*., (2001) noted that zinc, in addition to its contribution to protein representation, is used by plants in many other vital processes, such as the structure and function of membranes. Brown *et al*., (1993) showed that the formation of male and female reproductive organs and fertilization process is impaired in case of zinc deficiency in these plants.

The aim of the present study is to investigate the role of spraying zinc and Anti-transpirations materials in reducing the negative effect of high temperatures as well as improving pollen properties and corn yield when cultivated in spring season.

Materials and Methods

A field experiment was carried out on 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 zinc and Anti-transpiration on the 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 0.75 m 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 spplited, first addition was after one month of planting and second addition was at beginning of the flowering stage. The utilized 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 glass layer on the plant leaves) and control (distilled water) while the Zinc was sprayed with three doses of 100, 150, 200 mg kg^{-1} plus control, plants were sprayed with Anti-transpiration agents and zinc twice, the first was in 6-8 leaves stage and second one was in flowering stage.

The studied attributes

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

$$R.W.C.\ (\%) = FW\text{-}DW \ / \ TW\text{-}DW \times 100$$

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:

$$\text{Moisture percentage} = 100\text{-} \ [(m' \text{-} t \ / \ m \text{-} t) \times 100$$

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 the Slide the microscope multiplied by 100 (Sass, 1958).

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

$$\text{Fertility ratio} = \frac{\text{Total number of grains per ear}}{\text{Total number of ovaries per ear}} \times 100$$

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

Table 1: Effect of Anti-transpiration agents, zinc and their interaction on relative water content (%) of corn tissue for spring seasons 2017 and 2018.

Average	Season 2018				Average	Season 2017				Anti-transpiration
	Zinc concentration (mg kg^{-1})					Zinc concentration (mg kg^{-1})				
	200	150	100	0		200	150	100	0	
79.71	83.46	80.43	79.05	75.92	83.43	86.38	85.03	83.80	78.50	Control
82.71	86.65	84.14	80.53	79.53	86.82	89.55	88.24	86.45	83.04	$MgCO_3$
83.14	86.82	84.83	81.45	79.47	86.25	88.88	87.86	87.24	81.0	Glycerol
83.47	87.43	83.59	82.45	80.41	87.20	90.30	88.77	87.00	82.73	Green m.
2.42	2.54				1.1	81.01				L.S.D. 0.05
	86.09	83.25	80.87	78.83		88.77	87.48	86.12	81.32	Average
	0.69					0.56				0.05 L.S.D

Results and Discussion

Relative water content (%): Application of Anti-transpiration agents resulted in a significant increase in the relative water content of leaf compared with control (Table 1) the Anti-transpiration agents did not differ significantly among them. Green miracle gave the highest mean of 87.20% and 83.47% respectively. It was also noticed that there was a significant increase in this effect when zinc was added. Zinc concentrations were significantly different among them. 200 mg kg^{-1} zinc represents highest average of 88.77% and 86.09% respectively. Interaction values showed that the green miracle with 200 mg kg^{-1} zinc gave the highest average of 90.30% and 87.43% for both seasons respectively and differed significantly compared with water spraying treatment under the same zinc level.

The increment in leaves relative water content when using Anti-transpiration agents may be due to their role in reducing the stomata transpiration and reducing transpiration rates and thus increasing the plant's ability to retain water (Contore *et al*., 2009). Khalil, (2015) reported that the Anti-transpiration agents have reduced the average water loss and improved the moister state of plants tissue. The obtained result was confirmed by the results of Farhan (2017), Al-Obaidi (2013), Sanbagavalli *et al*., (2017) and Rania and Elbialy (2018). While the increment in the relative water content of leaves when zinc was added may be due to its role that affect the ability of plants to absorb water and transmit it into plant tissues (Disante *et al*., 2010), which improved plant water status and the relative water content of the leaves. This is confirmed by the results of Vazin, (2012) and Munirah *et al*., (2015).

Pollen moisture (%): Results showed that spraying Anti-transpiration agents resulted in a significant increase in pollen moisture content compared with control. These Anti-transpiration agents did not differ significantly in both seasons (Table 2). First season, Green miracle gave the highest average of 54.72%. In second season, $MgCO_3$ recorded the highest mean of 57.26%. Additionally, application of zinc increased moisture content significantly compared with control as well as a significant difference between zinc concentrations was noted. Zinc concentration 200 mg kg^{-1} gave the highest mean of 59.71% and 59.61% for both seasons respectively. As for the interaction, green miracle and 200 mg^{-1} kg zinc in first season gave the highest average of 62.86% while $MgCO_3$ and the same zinc concentration recorded the highest average of 61.41% in second season and significantly differs compared with water spray treatment under the same zinc concentration. The increment in pollen moisture may be due to the role of Anti-transpiration agents in reducing

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

Average	Season 2018				Average	Season 2017				Anti-transpiration
	Zinc concentration (mg kg^{-1})					Zinc concentration (mg kg^{-1})				
	200	150	100	0		200	150	100	0	
49.96	55.57	51.06	48.08	45.12	50.04	54.99	52.92	47.76	44.48	Control
57.26	61.41	59.69	55.74	52.21	53.37	60.56	54.76	52.35	45.81	$MgCO_3$
56.30	60.56	58.75	55.69	50.17	53.02	60.42	54.76	52.06	44.82	Glycerol
55.82	60.86	56.71	54.62	51.10	54.72	62.86	59.86	51.49	44.66	Green m.
2.42	1.67				2.52	2.65				L.S.D. 0.05
	59.61	56.55	53.53	49.65		59.71	55.58	50.92	44.94	Average
	0.63					0.73				0.05 L.S.D

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

Average	Season 2018				Average	Season 2017				Anti-transpiration
	Zinc concentration (mg kg^{-1})					Zinc concentration (mg kg^{-1})				
	200	150	100	0		200	150	100	0	
76.98	84.68	76.05	74.53	72.67	77.49	83.18	81.24	74.72	70.83	Control
87.76	94.51	92.00	84.33	80.21	81.77	90.44	83.89	80.51	72.26	$MgCO_3$
92.55	96.77	95.59	93.75	84.08	82.27	92.57	84.89	80.15	71.46	Glycerol
86.55	92.89	87.38	85.67	80.25	83.44	93.53	90.00	79.43	70.81	Green m.
6.74	6.93				3.16	3.38				L.S.D. 0.05
	59.61	56.55	53.53	49.65		59.71	55.58	50.92	44.94	Average
	0.63					0.73				0.05 L.S.D

the spread of stomata, decreasing transpiration rates and increasing plant susceptibility to water retention (Contore *et al*., 2009) which improves the water status of plants and causing an increase in the relative water content of plants (Table 1) which resulted in an increase in the moisture content of the pollen as well.

The effect of zinc in increasing pollen moisture content may also due to its role that affects the ability of plants to absorb water and transmit it into plant tissues (Disante *et al*., 2010) and increase the relative water content in the treated plants (Table 1).

Pollen viability (%): The addition of Anti-transpiration agents resulted in a significant increase in pollen viability percentage compared with control as well as not significant difference between the Anti-transpiration agents for both seasons was revealed. First season, green miracle recorded the highest average of 83.44%, while in second season; glycerol recorded the highest average of 92.55%. Furthermore, a significant effect of the addition of zinc was detected as well as zinc concentrations were significantly varied where 200 mg kg^{-1} zinc recorded the highest average of 89.93% and 92.21% for both seasons respectively. As for the interaction green miracle with 200 mg kg^{-1} zinc gave the highest mean which was 93.53% in first season while glycerol with same zinc concentration gave the highest average 96.77% in second season and significantly differ compared with water spraying treatment under the same zinc concentration. Luna *et al*., (2001) indicated that the pollen viability is highly correlated with moisture and that the relative water content in the pollen grain plays an important role in their viability and dynamic transmission in the air. 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 fertility rate was significantly increased in the supplemented treatments compared to control whereas there was no significant difference between the antiperspirant agents (Table 4). Green Miracle gave the highest mean of this characteristic in first season which was 93.21%, while $MgCO_3$ gave the highest mean in second season and recorded rate of 94.69%. In addition, zinc has significantly increased the percentage of fertility compared with control and its concentrations were varied where the concentration of 200 mg kg^{-1} showed the highest average of 94.54% and 96.28% respectively for both seasons. As for the effect of the interaction, green miracle with 200 mg kg^{-1} of zinc gave the highest mean which was 97.97% in first season while in second season, $MgCO_3$ with 200 mg kg^{-1} zinc recorded the highest mean which was 97.70% and differed significantly compared

Table 4: Effect of Anti-transpiration agents, zinc and their interaction on Fertility rate (%) for the spring seasons of 2017 and 2018.

Average	Season 2018				Average	Season 2017				Anti-transpiration
	Zinc concentration (mg kg^{-1})					Zinc concentration (mg kg^{-1})				
	200	150	100	0		200	150	100	0	
89.68	93.67	92.53	88.23	84.30	84.94	89.14	86.85	83.34	80.44	Control
94.69	97.70	95.70	94.23	91.13	91.60	96.28	93.35	89.31	87.48	$MgCO_3$
93.64	96.90	95.13	94.40	88.13	91.18	94.77	92.48	91.08	86.40	Glycerol
94.02	96.87	94.60	92.97	91.67	93.21	97.97	94.52	92.79	87.56	Green m.
2.43	3.13				2.24	2.26				L.S.D. 0.05
	96.28	94.49	92.46	88.81		94.54	91.80	89.13	85.47	Average
	1.36					0.37				0.05 L.S.D

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

Average	Season 2018				Average	Season 2017				Anti-transpiration
	Zinc concentration (mg kg^{-1})					Zinc concentration (mg kg^{-1})				
	200	150	100	0		200	150	100	0	
578.63	677.14	623.56	532.70	481.10	535.77	637.13	571.40	510.17	424.40	Control
655.98	766.18	672.51	608.04	577.18	601.81	721.53	626.95	564.59	494.19	$MgCO_3$
666.07	769.78	705.97	622.95	565.57	605.59	723.39	654.02	558.47	486.47	Glycerol
666.06	797.70	697.16	600.19	569.17	628.45	770.73	687.36	569.12	486.60	Green m.
46.13	48.14				27.41	33.21				L.S.D. 0.05
	752.70	674.80	590.97	548.25		713.20	634.93	550.59	472.92	Average
	12.71					13.42				0.05 L.S.D

with water spraying treatment under the same zinc concentration. The increment in fertility rate may attribute to the role of the Anti-transpiration agents in increasing the pollen moister and viability (Tables 2 and 3) which improved fertilization process. Luna *et al.*, (2001) showed that the relative water content of Pollen plays an important role in its viability and dynamic transmission in air. Kettlewell (2014) pointed that the effectiveness of Anti-transpiration agents in influencing the grain yield when sprayed in the drought-sensitive stages as pollen division and formation stage comes as a result of reducing water loss and improving water effort of plants, which leads to an increase in number and viability of pollen and improved fertilization efficiency.

The increase in fertility rate at the addition of zinc may also be attributed to its work on increasing the moisture and viability of pollen (Tables 2 and 3 respectively), which improved the pollination and fertilization process as well as the contribution of zinc to the development and role of reproductive tissues such as anthers, gynoecium in many species of plants (Hafeez *et al.*, 2013). Marschener (1995) noted that one of the symptoms of zinc deficiency is the sterility of spiklets. On the other hand, it activates many enzymes responsible for the formation of pollen. Brown *et al.*, (1993) showed that female and male reproductive organs and fertilization processes are impaired in the case of zinc deficiency.

Number of grains per ear: Significantly, spraying Anti-transpirations agents increased number of grains per ear compared with control as well as there was insignificant difference among Anti-transpirations agents in both seasons. However, green miracle gave the highest average in first season with mean of 628.45 grain ear^{-1} while the highest average in second season was in the glycerol treatment with mean of 666.07 grain ear^{-1}. There was also a significant increase in this value when adding zinc compared with control in addition to a significant difference among zinc concentrations was found, where 200 mg kg^{-1} zinc recorded the highest average of 713.41 and 752.70 grain ear^{-1} for both seasons respectively. The interaction between green miracle and the zinc with concentration of 200 mg kg^{-1} was significantly superior compared with water spraying treatment under the same concentration of zinc and gave the highest mean of this trait with means of 770.73 and 797.70 grain ear^{-1} for both seasons respectively.

The improvement 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, the moisture and viability of pollen (Tables 1, 2 and 3), which improved fertilization and increased fertility rate (Table 4) resulting in an increase in grains of ear. The

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

Average	Season 2018				Average	Season 2017				Anti-transpiration
	Zinc concentration (mg kg^{-1})					Zinc concentration (mg kg^{-1})				
	200	150	100	0		200	150	100	0	
8.269	9.598	8.928	7.671	6.879	5.550	6.570	5.714	5.376	4.538	Control
10.480	12.451	11.202	10.195	8.072	7.041	8.704	7.538	6.886	5.037	$MgCO_3$
10.489	12.575	11.131	9.885	8.365	7.056	8.743	7.328	6.472	5.681	Glycerol
10.509	12.760	10.838	10.522	7.918	7.434	8.865	7.840	7.160	5.872	Green m.
1.355	1.485				0.263	0.514				L.S.D. 0.05
	11.846	10.525	9.568	7.808		8.221	7.105	6.474	5.282	Average
	0.489					0.271				0.05 L.S.D

effect of zinc supplementation on this increase was due to the fact that its addition reduces the competition of floral structures, which increases the percentage of fertilized flowers and thus increases the number of grains in ear, this agreed with Kadhim and Jabbar (2014) as well as its role in improving the relative water content of plants, moisture and viability of Pollen (Tables 1, 2 and 3) which improved fertilization and increased fertility rate (Table 4), which in turn increased the number of grains per ear. This was confirmed by the results of Ehsanallah *et al.*, (2015), Iqbal *et al.* (2016) and Amanullah *et al.,* (2016).

Grains yield (Ton ha^{-1}): The average of grain yield was significantly higher when the Anti-transpirations agents were sprayed compared to control. In the two seasons, green miracle gave the highest mean of 7.434 and 10.509 ton ha^{-1} for the both seasons respectively and also significantly higher than the other Anti-transpiration agents in first season while the differences were not significant in second season (Table 6). Zinc application increased grain yield significantly compared with control and its concentrations varied, where zinc concentration 200 mg kg^{-1} recorded the highest average of 8.221 and 11.846 ton ha^{-1} for both seasons respectively. As for interaction between treatments, green miracle with 200 mg kg^{-1} zinc recorded the highest value with means of 8.865 and 12.760 tons ha^{-1} for both seasons respectively. However, it differed significantly compared with treatment of water spraying under the same concentration of zinc.

The improvement in grain yield by adding Anti-transpiration agents may be due to their increased resistance to water loss by transpiration, as well as improved water use by plants and thus increased grain yield of plants (Tambussi and Bort, 2007). Kettlewell (2014) noted that it works to reduce water loss from plants, improving the water effort of plants, increasing the number and viability of pollen and improving the efficiency of fertilization, leading to increase grain production. Abo-Muriefah (2013) showed that the increase of grains yield when adding Anti-transpiration agents may be due to their effect in regulating physiological processes, improving vegetative growth and activating the transfer of photosynthetic from source to sink. In addition to the effect of Anti-transpiration agents on pollen moisture content, viability of the pollen, fertility rate and the number of grains per ear (Tables 1, 2, 3, 4 and 5), which resulted in an increase in grain yield. This is agreed with Farhan (2017). The effect of adding zinc on the increase of grain yield may also be attributed to its effect in increasing the efficiency of photosynthesis and the rapid transmission of its products within the plant, which leads to an increase in yield components its effect on the grain yield (Kazem and Jabbar, 2014). Also, it can be attributed to its role in increasing the relative water content, the moisture in pollen, pollen viability, fertility rate and the number of grains per ear (Tables 1, 2, 3, 4 and 5), resulting in an increase in grain yield. This is confirmed by the results of Mosavifeyzabadi *et al.*, (2013) and Amanullah *et al.*, (2016).

In sum, it looks that using spraying Anti-transpiration agents, green miracle in most cases and glycerol in some, with 200 mg kg^{-1} of zinc 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.

References

A.O.A.C. (1995). Official Methods of Analysis 16th Ed, A.O.A.C Benjamin franklin Station, Washington, D.C, U.S.A.

Abu-Muriefah, S.S. (2013). Effect of chitosan on common bean (*phaseolus vulgaris* L.) plants grown under water stress conditions. *Int .Res .J. Agric. Sci. Soil. Sci.,* **3(6):** 192-199.

Al-Moftah, A.E. and A.R. Al-Hamaid (2005). Response of vegetative and reproductive parameters of water stressed tuberose plants to vapor Gard and Kaolin anti-transpirants. *Arab. Gulf. J. Sci. Res.*, **23(1):** 7-14.

Al-Obaidi, Z.H.H. (2013). Effect of Salicylic Acid and PGPR on Enzymatic and Non Enzymatic Antioxidants in Growth and Yield of (*Zea mays* L.)Under NaCl Stress. Ph.D. dissertation, College of Agricultural engineering sciences, University of Baghdad, Iraq.

Amanullah, Saleem A., A. Iqbal and S. Fahad (2016). Foliar Phosphorus and Zinc Application Improve Growth and Productivity of Maize (*Zea mays* L.) Under Moisture Stress conditions in Semi-Arid Climates. *J. Microbe. Biochem. Techno.,* **8:** 433-439.

Anonymous (2006). Agricultural Statistics of Pakistan., 18, 19, 106.

Barrs, H.D. and P.E. Weatherly (1962): Are-examination of relative turgidity technique for estimating water deficits in leaves. *Aust. J. Bio. Sci.,* **15:** 413-428.

Brown, P.H., I. Cakmak and Q. Zhang (1993). Form and function of zinc in plants. PP.93-1.6. in: A. D. Robson (Ed), F.P., Pearce, R.B. and Mitchell, R.L. 2017. *Physiology of crop plants.,* **Ed.2:** 327.

Cakmak, I., B. Torun, B. Erenoglu, L. Ozturk, H. Marschner, M. Kalayci, H. Ekiz and A. Yilmaz (1998). Morphological and Physiological Differences in the Response of Cereals to Zinc Deficiency. *Euphytica.,* **100:** 349-357.

Cakmak, I., L. Ozturk and S. Karanlik (2001). Tolerance of 65 Durum Wheat Genotypes to zinc Deficiency in a Calcareous Soil. *Journal of Plant Nutrition.*, **24:** 1831-1847.

Contore, V., B. Pacea and R. Albriziob (2009). Kaolin based particle film technology affects tomato physiology yield and quality. *Environ. and Experiment. Bot.*, **66:** 279-288.

Disante, K.B., D. Fuentes and J. Cortina (2010). Response to drought of Zn-stressed (*Quercus suber* L.) Seedlings. *Env. Exp. Bot.,* **70:** 96-103.

Ehsanullah, A.T., M.A. Randhawa, S.A. Anjum, M. Nadeem and M. Naeem (2015). Exploring the role of zinc in maize (*Zea mays* L.) through soil and foliar application. *Uni. J.of Agri. Research.,* **3(3):** 69-75.

Farhan, L.D. (2017). Effect of irrigation dates, potassium levels and anti-Transpirant on growth and yield of corn (*Zea mays* L.). Ph.D. dissertation, College of Agricultural engineering sciences, University of Baghdad, Iraq.

Gardner, F.P., R.B. Pearce and R.L. Mitchell (2017). Physiology of crop plants Ed.2 pp327.

Hafeez, B., Y.M. Khanif and M. Saleem (2013). Role of Zinc in Plant Nutrition. *American Journal of Experimental Agriculture.*, **3(2):** 374-391.

Harrison, J. Michaelsen, C. Funk and G. Husak (2011). Effects of temperature changes on maize production in Mozambique Clim Res **46:** 211–222, 2011 climate research.

Hasanuzzaman, M., K. Nahar, M.M. Alam, R. Roychowdhury and M. Fujita (2013). Physiological, biochemical and molecular mechanisms of heat stress tolerance in plants. *International Journal of Molecular Sciences.*, **14:** 9643-9684.

Hatfield, J.L., K.J. Boote, B.A. Kimball, L.H. Ziska, R.C. Izaurralde, D. Ort, A.M. Thomson and D.W. Wolfe (2011). Climate impacts on agriculture :implications for crop production. *Agron. J.,* **103:** 351-370.

IPCC (Intergovernmental Panel Climate Change) (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, U.K. and New York, NY.

Iqbal, J., R. Khan, A. Wahid, K. Sardar, N. Khan, M. Ali and R. Ahmad (2016). Effect of nitrogen and zinc on maize (*Zea mays* L.) yield components and plant concentration. *Advances in Environmental Biology.*, **10(10):** 203-209.

Kadhim, S.H. and Z.H. Jabar (2014). Effect of Benzyl Adenine and Zinc in yield and quality of (*Zea mays* L.). *Al-Furat Journal of Agriculture Science.,* **6 (1):**144-153.

Kettlewell, P.S. (2014). Waterproofing wheat-are-evaluation of film antitranspirants in the context of reproductive drought physiology. *Outlook on Agri.* **43(1):** 25-29.

Khalel, A.S. (2015). Effect of drip irrigation intervals and some antitranspirants on the water status, Growth and yield of potato (*Solanum tuberosum* L.). *J .Agric. Sci. Techno.,* **5:** 15-23.

Lobell, D.B., M. Banziger, C. Magorokosho and B. Vivek (2011). Nonlinear Heat effects on African maize as evidenced by historical yield trials. Nature Climate Change. **1:** 42-45.

Luna, V.S., M.J. Figueroa, M.B. Baltazar, L.R. Gomez, R. Townsend and J.B. Schoper (2001). Maize pollen longevity and distance isolation requirements for effective pollen control. *Crop Science.,* **41:** 1551-1557.

Marschner, H. (1995). Mineral Nutrition of Higher Plants, 2nd edn. London, UK: Academic Press.

Mosavifeyzabadi, S.H., F.Vazin and M. Hassanzadehelouei (2013). Effects of nitrogen and zinc spray on yield of corn (*Zea mays* L.) In drought stress. *Ceretari Agronomic in Moldova*., **3(155):** 29-38.

Munirah, N., M. Khairi, M. Nozulaidi and M. Jahan (2015). The effects of zinc application on physiology and production of corn plants. *Australian Journal of Basic and Applied Sciences.*, **9(2):** 362-367.

Rania, F. and M. El Bialy (2018). Effect of antitranspirants application on growth and productivity of sunflower under soil moisture stress. *Nat. Sci.,* **16(2):** 92-106.

Sanbagavalli, S., K. Vaiyapuri and S. Marimuthu (2017). Impact of mulching and antitranspirants on growth and yield of soybean (*Glycine max* L. Merril). *Advances in Environmental Biology.*, **11(1):** 84-89.

Sass, J.E. (1958). Botanical micro technique. 3rd. pp.228. The Iowa State collage press; constable and co.

Steel, R.G.D and J.H. Torrie (1980). Principles and Procedures of Statistics. McGraw Hill, New York.

Tambussi, E.A. and J. Bort (2007). Water use efficiency in C3 cereals under Mediterranean conditions: a review of physiological aspects. *Annals of Applied Biology.*, **150:** 307-321.

Vazin, F. (2012). Effect of Zinc sulfate on quantitative and qualitative characteristics of corn (*Zea mays*) in drought stress. *Cercetãri Agronomic în Moldova,* **Vol. XLV, No. 3:** (151)/2012.