Physiological and anatomical responses of corn crop growing under water stress conditions with the effect of antitranspirants

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Abstract

The experiment was conducted in a field in Babylon province, specifically in Abi Gharaq district, located 10 km from Hilla city, on a corn (*Zea mays* L.), During the autumn season 2025. The aim was to optimize the seasonal water consumption of corn under different water stress levels. The experiment also investigated the role of antitranspirants in mitigating the effects of water stress and its impact on yield. The experimental units were obtained by using a split-plot randomized complete block design (RCBD) with 3 replications or 36 experimental units. Water stress levels were defined as 50% (control), 65% (S2) and 80% (S3). These were most relevant in the major narratives. It was decided to use subplots in the second variable with four different groups of anti-transpirants.Four different groups of antitranspirants were decided upon for the second variable. The treatments consisted of control (distilled water), 6% kaolin, 1% paraffin wax and 15 ml L⁻3 silicone. Both stress treatments S1 and S2 were effective, with slight discrepancies in most of the assessments. In comparison to treatment S1, this leads to a 15% decrease in water use. This reserve can help drought-stricken regions to create viable farmland. Other than the soluble sugar content in the leaves which averaged 51.94%, the S3 treatment produced sub-optimal results when compared with the other treatments in most parameters. The kaolin treatment performed best than the silicon treatment in all other parameters in relation to number of applications of spraying antitranspirants. The averages of all the parameters assessed were reduced except for leaf soluble sugars, stomatal diameters and counts in this treatment as compared to the control using distilled water. These had the highest averages, at 52.22%, 30.38 µm, 14.97 µm, and 43.26 stomas.cm^{-2}, respectively.

Keywords: Corn, water tension, antitranspirants, physiology, anatomical.

Introduction

Corn (*Zea mays L.*) is an economically important cereal crop due to its many applications such as oil production, animal feed, and human consumption. Used in several industries such as starch, dyes, asbestos, ceramics, paper and cork production [1]. Corn is the third most widely cultivated crop in the world in terms of both cultivation area and world production (after rice and wheat). In spite of its importance, the amount of grain production per unit area is still low in Iraq compared to average. The importance of the great losses in productivity during the autumn planting season, which affect function, vital processes and ultimately production, is attributed to the water and heat stresses. Finding ways to maximize water utilization and improve the plant's water efficiency is thus crucial [2].Future expansion of the available cropland would make this an interest for scientists seeking techniques to manage and optimize water use, reduce water waste, and create new technologies that make plants more resistant to water stress. Plants also take several adaptation measures to cope with water stress such as reducing transpiration, maintaining water content and increasing water stress resistance. They are able to maximize the utilization of available water as a result. This necessitates the use of some of the methods available in farming for reducing transpiration while keeping the output of carbon. One of these methods is the use of chemicals, usually as a spray, applied to the leaves. They reduce the average transpiration rate by creating obstacles or barriers to water loss (whether mechanically or physiologically) and/or increase water use efficiency. These barriers do not cause damage after drying on the leaf, thus increasing crop productivity under conditions of insufficient water [3].Antitranspirants include natural substances such as kaolin clay, biochemicals, and paraffin wax, as well as many chemical compounds such as silicon [4] and [5]. The aforementioned studies confirmed the successful use of antitranspirants, demonstrating their positive effects, which extend beyond simply reducing transpiration and increasing water use efficiency. They also positively impact several physiological aspects. Hence, the importance of this study lies in achieving the following objectives:

- To regulate seasonal water consumption in corn under varying stress levels.

- To investigate the role of antitranspirants in mitigating the effects of water stress and its impact on yield.

Materials and Methods

The experiment was conducted in the Abi Ghosh District of Babylon province, approximately 10 km northwest of the city of Hilla, in autumn 2025.Maize cultivar Fajr 1 was grown under water stress condition from Agricultural Research Department/Abu Ghraim to investigate the effect of antitranspirants on growth parameters, specific physiological and anatomical parameters, grain yield and its components. The experiment consisted of 36 experimental units, using a split-plot design with three replications and a randomized complete block design (RCBD). The first factor included three levels of water stress: 50% depletion (control treatment), 65%, and 80% of the available water (S1, S2 and S3, respectively). There were plenty of them in the main plots. The second one consisted of four different doses of anti-transpirants: 15 ml of L^{-1} silicone, 6% kaolin, 1% paraffin wax and distilled water as control. These were used for the subplots. The antitranspirants were applied twice to balance the water level upstream and downstream, at 8 true leaves and when the male inflorescence emerged [6]. The plants were irrigated with a 16L backpack sprayer in the early morning until well irrigated. In setting up the experimental plot, the above-mentioned plan has been followed. The experimental unit was 3 x 3 m at a plant density of 66,666 plants/ha with 3 rows of plants in each experimental unit, with row to row and plant to plant distances of 75 cm and 20 cm, respectively. To avoid water run off, a 1.5 m distance was left between the duplicates and principal treatments. The seeds were sown on 22nd July 2025 and harvested on 12th November 2025.Random samples were taken to 40 cm depth before planting to evaluate some soil properties (Table 1). The urea fertiliser applied (46% N) was 300kg of N/ha for each, at the 6-leaf and at flower initiation stages, respectively. Before sowing and during field preparation, a single application of a triple superphosphate (46% P_2O_5) fertilizer was applied at 250 kg of P_2O_5/ha.[7]

The maize stem borer, *Sesamia cretica* L., was suppressed with granular diazinon at 5-6 leaf stage at a rate of 6 kg ha^{-1} to treat the soil surface and weeds were hand pulled when necessary.The correlation between the structural tension of the soil sample and its volumetric moisture content was used to assess the soil's capacity for water retention. The difference between Field capacity and the wilting point was used to determine the available soil water.

Method for measuring soil moisture content:

One day before and two days after irrigation, soil samples were taken at the depths of 20 and 40 cm using a trowel and soil moisture was estimated using the volumetric method. Samples were weighed in an aluminum container after being moistened. The specimens were then dried in the microwave oven with the power adjusted as suggested in the previous study [8]. Upon reevaluating the samples, the below equation was used to ascertain their moisture content:

$$Qv = Qw \times (\partial b / \partial w)$$

Where: Qw = Moisture content by weight($g.g^{-1}$), Qv = Moisture content by volume($cm^3.cm^{-3}$) , $\partial \omega$= Water density ($g\ cm^{-3}$) ∂b = Bulk density ($g\ cm^{-3}$)

Irrigation Method:

To regulate the volume of water determined by the reduction of the designated water content, the irrigation procedure was executed utilizing plastic tubing linked to a pump with a steady flow rate ($2.1\ L.S^{-1}$) and fitted with a meter to quantify the water supplied to each experimental unit. To ensure field emergence, identical quantities of water—50% of the available moisture—were provided to each plate at the time of planting. At depths of 20 and 40 cm, the vegetation was further irrigated after the depletion of 50%, 65%, and 80% of the available moisture. Equation [9] was used to determine the quantity of water that was included.

$$W = a.As\left(\frac{\%Pw^{F\ c} - \%Pw^{w}}{100}\right)\times\frac{D}{100}$$

Where:

W = Volume of water to be added during irrigation (m^3).

a = Irrigated area (m^2).

As = Apparent density ($Mg(m^3)^{-1}$).

$Pw^{F\ c}$ = Percentage of soil moisture based on weight at field capacity (after irrigation).

Pw^{w} = percentage of soil moisture before the irrigation date.

D = Soil depth at the desired root system (cm).

The collected and tabulated data were then analyzed using the GenStat V.20 statistical software, following the method used previously [10], according to the ANOVA table. Means were compared using the least significant difference test at a probability level of 0.05 [11].

Table (1) Some physical and chemical properties of field soil

No.	Properties	units	values
1	Electrical conductivity EC 1:1	$DS.m^{-1}$	2.45
2	Soil acidity (pH)		7.8
3	Available nitrogen	$mg.\ kg^{-1}$	21.10
4	Available phosphorus	$mg.\ kg^{-1}$	17.0
5	Available potassium	$mg.\ kg^{-1}$	582
6	Total carbonate	$g.\ kg^{-1}$	182
7	Organic matter	%	0.89
8	Sand content	$g.\ kg^{-1}$	244
9	Silver content	$g.\ kg^{-1}$	414
10	Clay content	$g.\ kg^{-1}$	342
11	Soil texture	$Mg.\ m^{-3}$	Clay-silty-loamy
12	Bulk density		1.24
13	Volumetric moisture content at field capacity		0.29
14	Volumetric moisture content at permanent wilting point		0.13
15	Available water		0.16

Studied traits:

Vegetative Growth traits:

- Leaf Area (cm^2): Calculated from the average of five plants using the equation: as per [12].

Leaf length under the ear leaf × 0.75 (one leaf).

- Chlorophyll Content (mg g^{-1} fresh weight): Estimated according to the Linchtenthaler method described in [13].

- Relative Water Content of Leaves%: Estimated from the following equation:

$$R.W.C = \frac{FW - DW}{TW - DW} \times 100$$

Where: FW = Fresh weight (g), DW = Dry weight (g), TW = Turgid weight (g).

From the center of a leaf below the ear, four 2 cm-diameter disks were removed. They were cut, weighed immediately and placed in nylon bags to prevent moisture loss. They were then stored at room temperature, with light and in distilled water for 12-14 hours. The leaves were then dried on blotting paper, weighed for total dry weight and dried in an oven at 85°C for 3 hours. Then, it was observed that the moist mass remained [14].

- Percentage of soluble sugars in the leaves: A weight of 0.20 g of finely ground leaves was taken and crushed with (10 ml) of distilled water. The solution was then centrifuged for 15 minutes at a speed of 3000 $rpm.m^{-1}$ The solution was filtered through filter paper, and

1 ml of the filtrate was withdrawn into a new test tube. Add 5 ml of 5% phenol and 5 ml of 99% concentrated sulfuric acid. After stirring and shaking, allow the tubes to cool. Then, after appropriate dilution, read the light absorption at a wavelength of 490 nm using a spectrophotometer. Determine the sugar concentration using the following equation:

$$C = \frac{Y}{(1000 * w)/100} * 100$$

Where:

C: Sugar content, Y: Instrumental reading correction, W: Sample weight.

Correcting the device reading= $\frac{R-0.0313}{8.8655}$ R: Device reading, according to [15]

Anatomical traits:

- Stomata Length and Width (µm): Calculated the average of five readings from leaves where the number of stomas was measured. The dimensions of the Stomata opening (length and width) were measured using an ocular micrometer after calibration.

- Number of Stomas (stoma.cm^{-2}): Calculated the average of five readings from each experimental unit using a lens divided into squares of known area as follows:

Average number of stomas per cm² of epidermis = Average number of stomas divided by the area of the microscopic field [16].

Productive traits:

- cob Length (cm.cob^{-1}): Measured the length of ten ears randomly drawn from the random sample and calculated the average.

- Number of Grains per cob (grain.cob^{-1}): Ten ears were randomly drawn from the random sample, and the number of grains in each ear was counted and calculated the average.

- Weight of 500 grains (g): with 15.5% moisture: The moisture content was adjusted according to the following equation [17].

weight with moisture 15.5 $= \frac{\text{original moisture} - 100}{84.5} \times$ Original weight

- Total grain yield (Mg ha^{-1}): At 15.5% moisture content, the yield of the two middle rows was calculated, and the yield per plant was determined by dividing the total yield of the two middle rows by the number of harvested plants and multiplying by the number of plants per hectare for all experimental units.

Results and Discussion:

Leaf area (cm²):

Data in Table (2) showed significant differences due to antitranspirants, water availability depletion and interaction of antitranspirants and water availability depletion. The treatment with 50% available water depletion (S1) achieved the greatest average leaf area of 6319 cm², which showed no variation from the treatment with 65% available water depletion (S2). In contrast, the shortest growth period was seen in the 80% accessible water depletion treatment (S3) with a mean leaf area of 5475 cm².One possible explanation for the decrease in leaf area with a decrease in irrigation is that it makes the plant cells less turgid, which slows the rate of extension of the cells. The membranes have to be stretched when cells divide[18].

Application of anti-transpirant, greatly improves the leaf area of plants. Both kaolin and silicon spray treatments greatly out-performed the control (no spray) treatment which showed no significant difference from the paraffin wax spray treatment (5230 cm² leaf area on average) with average leaf areas of 6539 and 6509 cm².Antitranspirants applied to plants reduce water loss rates and prevent the development of leaf senescence as well as the reduction of leaf temperature induced by high temperatures. This is accomplished by increasing the capacity of stomata to control water loss and by providing a physical barrier which blocks direct water loss from the outer epidermis. The white clay particles of kaolin prevented a significant increase in leaf temperature, and the application was effective [19].

The effects of water stress and antitranspirants on average leaf area were significantly influenced by the combination of S1 and S2 with kaolin, with averages of 6635 and 6542 cm², respectively. This was not significantly different from the combination of S1 and S2 with silicon, with averages of 6611 and 6516 cm², respectively.Conversely, the lowest average leaf area was 4030 cm² with the S3 combination and the no-spray treatment. The excelled of these combinations is attributed to the fact that the availability of water combined with the presence of antitranspirants created a favorable environment for plant growth.

Table (2) Effect of water stress levels, antitranspirants, and their interaction on leaf area (cm²)

water tension	Antitranspirants				average
	control (without spraying)	Kaolin	Paraffin wax	Silicone	
S1	6010	6635	6021	6611	6319
S2	5650	6542	5850	6519	6139
S3	4030	6441	5031	6400	5475
average	5230	6539	5634	6509	
LSD	water tension 504		Antitranspirants 190		interaction 435

Leaf Chlorophyll Content (mg g⁻¹ fresh weight):

Table (3) indicates that the leaf chlorophyll level appreciably differed due to water stress, antitranspirants and interactions of water stress and antitranspirants. The leaf chlorophyll content was highest with the treatment of 50% available water depletion (S1), which did not significantly differ from the S2 treatment (39.04 mg g^{-1} fresh weight). The lowest average of chlorophyll content (35.59 mg g^{-1} fresh weight) was found in S3 treatment.The decrease in chlorophyll levels associated with increased water stress might be due to reduced irrigation and fertilizer inputs, thus limiting the roots' ability to uptake nitrogen. Nitrogen increases the amount of chlorophyll pigment; because of the role of nitrogen in the pyroferin cycle, which is part of the chlorophyll molecule[20].

The table's results show that applying antitranspirants increased the amount of chlorophyll in maize leaves. The kaolin spray treatment resulted in an average of 43.32 mg g^{-1} fresh weight, while the lowest average in control treatment was 32.90 mg g^{-1} fresh weight. This increase may be due to the effectiveness of kaolin as a reflective antitranspirant with low heat conductivity. Its granules, of a specific size and shape, exhibit reflective properties and precipitation on the plant surface, allowing for gas exchange without stomata blockage. This property is crucial for enhancing photosynthesis, especially under water stress conditions.This leads to the regulation of thylakoid membranes, a group of membranes found in chloroplasts where photochemical reactions during photosynthesis take place.Thylakoids contain the photosynthetic pigments necessary for this function. Furthermore, kaolin reduces the formation of proteolytic enzymes such as The enzyme chlorophyllase is responsible for the breakdown of chlorophyll and damage to the photosynthetic system [21] and [22].

The results also showed that combinations S1 and S2 with kaolin spraying were significantly excelled, with averages of 45.36 and 44.24 mg g^{-1} fresh weight, respectively, compared to the lowest average in combination S3 with the control treatment (spraying with distilled water only), which averaged 30.86 mg g^{-1} fresh weight.

Table (3) Effect of water stress levels, antitranspirants, and their interaction on leaf chlorophyll content (mg g^{-1} fresh weight)

water tension	Antitranspirants				average
	control (without spraying)	Kaolin	Paraffin wax	Silicone	
S1	34.32	45.36	36.86	39.63	39.04
S2	33.53	44.24	35.24	38.53	37.89
S3	30.86	40.36	34.51	36.63	35.59
average	32.90	43.32	35.53	38.26	
LSD	water tension 2.57		Antitranspirants 1.63		interaction 2.84

Relative Water Content of Leaves (%):

The differences in the relative water content of leaves are significant due to the known differences in the amount of water available and the use of the antitranspirants as indicated in Table (4). The two drugs, however, did not show significantly interacting.The depletion treatment S1 (82.78%) was also statistically significantly more effective than S2 (80.64%) which showed no significant difference.This is compared with the lowest mean (71.59%) of the depletion treatment S3. As the moisture is being drawn from the leaves, the relative moisture content of the leaves decreases. This could be due to the reduction in soil water potential, which results in a reduction in water levels in plant tissues and interferes with the plants' water uptake.In addition, the difference between the transpiration and the absorption of water from the plant had a negative effect on the state of hydration of the plant [23].

There were no significant differences between the averages for kaolin, silicon and paraffin wax, which were 80.53%, 79.71% and 79.87%, respectively, but the lowest average was obtained with the control treatment (distilled water), at 73.25%, showing the effectiveness of the antitranspirants for this characteristic. This increase may be due to the role of the antitranspirants in the maintenance of the hydration equilibrium of the plant. This is done by decreasing transpiration rates of the plant and making it retain water, either by creating barriers or by decreasing water loss from the plant through physiological or mechanical means. These barriers have no effect on the effectiveness of carbon production, and do not harm the leaf after it is dry. They cool down the plant tissues, particularly the leaf surface, by forming a delicate, white film on the surface which reflects the incoming sun's rays. This reduces transpiration because it reduces the vapour pressure difference between the plants and the atmosphere. They also provide a significant amount of reflection of incoming light and are a barrier to direct water loss from the outer epidermis. This keeps plant tissue (especially leaves) from getting to high temperatures [24,25].

Table (4) Effect of water stress levels, antitranspirants, and their interaction on the relative water content of leaves (%)

water tension	Antitranspirants				average
	control (without spraying)	Kaolin	Paraffin wax	Silicone	
S1	75.32	85.32	85.20	85.30	82.78
S2	73.22	83.13	83.11	83.11	80.64
S3	71.21	73.14	70.81	71.21	71.59
average	73.25	80.53	79.71	79.87	
LSD	water tension 3.57		Antitranspirants 1.27		interaction no

- Percentage of Soluble Sugars in Leaves%:

The results shown in Table (5) indicate significant differences in the percentage of sugars in leaves due to the depletion of available water, antitranspirants, and their interactions.The table data indicates a significant increase in the percentage of soluble sugars in leaves with increasing water stress. Plants treated with the S3 depletion treatment showed the highest average, reaching 51.94%.This is compared to the lowest average, which was observed in the S1 depletion treatment, at 44.04%. The reason for the increased percentage of soluble sugars formed in plants exposed to water stress conditions is The activity of certain enzymes, including amylase, which breaks down starch into simple sugars, and increased activity of invertase, which is responsible for splitting sucrose into hexoses (glucose and fructose). This serves as a defense mechanism to withstand water scarcity by raising the osmotic pressure within plant cells [26].

The results shown in the table indicate that spraying with antitranspirants led to a decrease in the percentage of soluble sugars in the leaves. The highest average soluble sugar content was observed in the control treatment (spraying with distilled water only), reaching 52.22%.Conversely, the lowest average soluble sugar content was observed in the silicone spray treatment, at 46.21%, with no significant difference compared to the paraffin wax spray treatment.The decrease in carbohydrate content following antitranspirant treatment may be attributed to improved plant metabolism. This improvement is achieved by reducing the water potential within the leaf due to increased water content, thereby enhancing the activity of carbohydrate metabolism, which converts monosaccharides into starch. [27].

A significant interaction was found between the depletion of available water and antitranspirants, with the S3 combination with all antitranspirants gave the highest averages.This is in comparison to the lowest averages, which were observed with the S1 combination with kaolin and silicon, at 40.11% and 42.30%, respectively. The increase in sugar content with increased water stress may be attributed to increased activity of starch-degrading enzymes as a defense mechanism to cope with water stress.

Table (5) Effect of Water Stress Levels, Antitranspirants, and Their Interaction on the Percentage of Soluble Sugars in Leaves%

water tension	Antitranspirants				average
	control (without spraying)	Kaolin	Paraffin wax	Silicone	
S1	47.53	40.11	46.22	42.30	44.04
S2	53.84	45.21	47.81	48.22	48.77
S3	55.53	51.84	50.21	50.21	51.94
average	52.22	45.72	48.08	46.21	
LSD	water tension 3.15		Antitranspirants 2.10		interaction 5.44

- Stomata length and width (µm):

The effects of depletion level and antitranspirants on stomatal size were found to be significant but the interaction between the two was not significant as shown in Tables 6 and 7. The results revealed that the stomatal length in the S1 depletion treatment was the highest (31.87 µm) and did not differ significantly from that obtained in S2 depletion treatment. Nonetheless, this characteristic was diminished in the S3 depletion therapy to an average of 27.52 µm. The results presented in the tables revealed that the S1 depletion treatment resulted in the highest stomatal width of 14.71 µm, which was not significantly different from the S2 depletion treatment. However, the average stomatal width decreased to 13.56 µm after DET in S3. The higher rate of depletion caused smaller and narrower stomata, which impacted on the uptake of the CO_2 and its incorporation into photosynthesis, and consequently on plant growth and yield[28].

The data in the table shows that the stomatal size was significantly decreased by the use of antitranspirants, with no significant difference between the different antitranspirants, compared with control (no application) which yielded the highest stomatal length (30.38 µm) and stomatal width (14.97 µm) averages. It was observed that each treatment resulted in a decrease in the size of the stomatal apertures.This resulted in a reduction of water loss via transpiration and enhanced water use efficiency by establishing barriers or limitations to water loss thru physical or physiological methods. The measures do not injure the leaf during the drying process, allowing water potential to be maintained and providing a more drought resistant leaf by increasing the relative water content[29], without reducing the efficiency of carbon assimilation.In addition, the kaolin white clay in the soil and the wax present on the leaves reflect some of the solar radiation, which helps to control leaf temperature, and helps to maintain water balance within the plant cell, including stomatal closure. Silicon plays a role in reducing water stress through antioxidant defense mechanism, such as upregulation of enzymes such as SOD, POD, and CAT.It also helps maintain cell membrane permeability and thus minimize oxidative damage to functional molecules within the cells under water stress caused by the production of ROS. Under stress conditions, various physiological responses of a stressed plant can decrease the stomatal area as a defense measure to prevent damage to the plant cells due to water stress [30].

Table (6) Effect of water stress levels, antitranspirants, and their interaction on Stomata length (μm).

water tension	Antitranspirants				average
	control (without spraying)	Kaolin	Paraffin wax	Silicone	
S1	32.64	31.63	31.88	31.31	31.87
S2	29.64	28.63	28.64	27.63	28.64
S3	28.86	27.21	27.34	26.66	27.52
average	30.38	29.16	29.29	28.53	
LSD	water tension 3.52		Antitranspirants 0.94		interaction no

Table (7) Effect of water tension levels, antitranspirants and the interaction between them on the width of the stoma opening (μm)

water tension	Antitranspirants				average
	control (without spraying)	Kaolin	Paraffin wax	Silicone	
S1	15.45	14.21	14.63	14.54	14.71
S2	15.10	14.11	14.34	14.34	14.47
S3	14.36	13.01	13.63	13.21	13.56
average	14.97	13.77	14.20	14.03	
LSD	water tension 1.06		Antitranspirants 0.63		interaction no

- Number of stomata (stomata.cm^{-2}):

The depletion and antitranspirant treatments acting together show no significant effect but the information in tab (8) shows a significant effect on stomatal count. In the table the change in the mean number of stomata per leaf is shown as a consequence of the depletion treatments. No significant difference was found between the S1 and S2 depletion treatments with the former averaging 42.50 stomata.square centimeters and the latter 41.59 stomata.square centimeters. The S3 depletion therapy gave the lowest average reading with 40.33 stomata. square centimeters.This loss of stomatal number with lower water levels could be related to the decrease in flag leaf area (Table 2) and thus a potential loss of stomata. The decrease might be related to plant water status and stomatal responses to chemical signals, such as the production of ABA by roots in response to water deficiencies[31].

The results also showed the impact of the different antitranspirant spray treatments that were applied in the form of spray, with no difference in the mean number of stomas observed between the different treatments. All the treatments had showed decrease in the mean number of stomata per leaf, the control treatment (using only distilled water) had the highest mean of 43.26 stomata.centimeters squared.This decrease can be due to the use of so-called "anti-transpirants", which form a thin layer over the stoma and cause it to close or change shape, thereby decreasing the amount of stoma. This result corroborates that of [32] and [33] which reported that a significant reduction in the number of stomas in maize leaves was observed when using antitranspirants under dry conditions.

Table (8) Effect of water stress levels, antitranspirants, and their interaction on the number of stomas (stomas.cm^{-2})

water tension	Antitranspirants				average
	control (without spraying)	Kaolin	Paraffin wax	Silicone	
S1	44.36	41.36	41.68	42.63	42.50
S2	43.21	40.99	40.83	41.33	41.59
S3	42.22	39.36	39.51	40.21	40.33
average	43.26	40.57	40.67	41.39	
LSD	water tension 1.30		Antitranspirants 1.95		interaction no

Cob length (cm.cob^{-1}):

The data of Table (9) indicate a significant effect of depletion therapies, antitranspirants and their combinations on cob length (cm.cob^{-1}).The tabulated results showed that water stress treatment S1 had significantly superior cob length, with an average of 23.36cm.cob-1 which was not significantly different from water stress treatment S2 (21.32cm.cob^{-1}). This is not the same as water stress treatment S3, which resulted in the shortest average cob length of 18.16 cm.cob^{-1}.This contraction in cob length might be linked to a drop in several development parameters owing to insufficient water supply. This deficiency resulted in the reduced source capacity and reduced carbon transport rate from the source to the outlet which in turn affected the cob length.[34]

The results showed that there was no significant difference between the kaolin spray and silicone spray treatments, while both treatments had higher average measurements (22.50 and 22.09 cm.cob^{-1}, respectively) than the control treatment (18.78 cm.cob^{-1}).This may be due to the ability of the antibiotics to reduce the stress-induced damage and increase numerous growth traits such as leaf area (Table 2), chlorophyll content in leaves (Table 3) and enhanced relative water content in leaves (Table 4). This maintained intracellular hydration led to better production and transport of metabolites of carbon metabolism from the leaves to other parts of the plant such as the cob.[35]

The outcomes also showed that the kaolin and silicon spray treatments (S1) gave the highest average lengths (24.86 and 24.66 $cm.cob^{-1}$ respectively) when compared to the S3 spray treatment (control: distilled water alone) with the lowest average length of 15.13 $cm.cob^{-1}$.

Table (9) Effect of water tension levels, antitranspirants, and their interaction on cob length ($cm.cob^{-1}$)

water tension	Antitranspirants				average
	control (without spraying)	Kaolin	Paraffin wax	Silicone	
S1	21.61	24.86	22.31	24.66	23.36
S2	19.63	22.32	21.31	22.01	21.32
S3	15.13	20.32	17.56	19.62	18.16
average	18.78	22.50	20.39	22.09	
LSD	water tension 2.06		Antitranspirants 0.93		interaction 0.53

- Number of grains per cob (grain. cob^{-1}):

The results shown in Table (10) indicate a significant effect of available water depletion and antitranspirants, and their interaction, on the average number of grains per cob. depletion treatment S1 achieved the highest average for this trait, with no significant difference from tension treatment S2, resulting in averages of 500.88 and 493.68 grains. cob^{-1}, respectively.This is in contrast to depletion treatment S3, which had the lowest average of 392.47 grains. cob^{-1}.The decrease may be attributed to insufficient fertilization due to the adverse effects of water stress during this stage, coupled with the accompanying high temperature. These conditions may have affected the fertilization rate due to pollen drying.Alternatively, it may be due to flower abortions during the flowering stage and disruption of plant physiological processes resulting from insufficient water reaching the ovaries. This, in turn, leads to reduced dry matter accumulation and insufficient supply of assimilated materials to the grain sites, causing the abortion of pollinated grains and contributing to a reduction in the number of grains [36].

The results also showed that the kaolin spray treatment was superior to the silicone spray treatment, with averages of 511.92 and 496.84 grains . cob^{-1}, respectively, compared to the control treatment (spraying with distilled water only), which gave the lowest average for this trait at 385.41 grains. cob^{-1}.Spraying plants with antitranspirants improves their water status, reducing water stress during cell division. This ensures adequate water content throughout the growing season, positively impacting leaf area and chlorophyll content (Tables 2 and 3).Furthermore, it increases the products of carbon metabolism, effectively supplying new germination sites during the plant's reproductive phase with their required synthetic nutrients, thus increasing the number of grains per cob.

We also observe the superiority of combinations S1 and S2 with kaolin and silicon spraying, with no significant difference between them, compared to combination S3 and the control treatment (spraying with distilled water only), which had the lowest average of 323.24 grains $.cob^{-1}$.

Table 10: Effect of water stress levels, antitranspirants, and their interaction on the number of grains per cob (grain $.cob^{-1}$).

water tension	Antitranspirants				average
	control (without spraying)	Kaolin	Paraffin wax	Silicone	
S1	422.63	545.36	492.30	543.21	500.88
S2	410.36	540.13	488.11	536.10	493.68
S3	323.24	450.26	385.16	411.22	392.47
average	385.41	511.92	455.19	496.84	
LSD	water tension 73.20		Antitranspirants 28.32		interaction 78.30

- Weight of 500 grains (g):

The results in Table (11) show a significant effect of the antitranspirant treatments only, while the water tension treatments and their interaction showed no significant difference.The paraffin wax spray treatment was significantly excelled, with an average weight of 92.51 g, and no significant difference compared to the silicone spray treatment, which had an average weight of 91.19 g.This is compared to the control treatment (spraying with distilled water only), which had an average weight of 89.38 g. The superiority of the paraffin wax treatment may be attributed to the decrease in other yield components under this treatment.An increase or decrease in one yield component corresponds to a decrease or increase in other yield components, based on the principle of physiological compensation [37].

Table (11) Effect of water tension levels, antitranspirants, and their interaction on the weight of 500 grains (g)

water tension	Antitranspirants				average
	control (without spraying)	Kaolin	Paraffin wax	Silicone	
S1	90.63	91.36	92.61	92.36	91.74
S2	89.88	90.63	93.62	91.21	91.34
S3	87.63	89.63	91.31	90.01	89.65
average	89.38	90.54	92.51	91.19	
LSD	water tension no		Antitranspirants 1.58		interaction no

Total grain yield ($Mg.ha^{-1}$):

Table 12 shows a significant effect of water tension coefficients, antitranspirants, and their interaction on the average grain yield.Treatments S1 and S2 showed no significant difference, with average yields of 7.23 and 6.78 $Mg.ha^{-1}$, respectively, compared to treatment S3, which had an average yield of 4.53 $Mg.ha^{-1}$.The decrease in grain yield under soil water stress conditions may be attributed to the significant reduction in cob length, number of grains per cob, and 500-grain weight (Tables 9, 10, and 11).This decrease is also a result of the negative impact of water stress on vegetative growth traits, including leaf area, leaf chlorophyll content, and relative water content (Tables 2, 3, and 4), which can lead to reduced carbon uptake and dry matter accumulation.This finding is consistent with the results of [38], who found that water stress on corn plants led to a decrease in grain yield.

The results also showed a significant advantage of the kaolin spray treatment, with no significant difference compared to the silicon treatment, with average concentrations of 6.84 and 6.72 $Mg.ha^{-1}$, respectively, compared to the control treatment (spraying with distilled water only), which averaged 5.20 $Mg.ha^{-1}$.This advantage reflects its superiority in cob length, number of grains per cob, and grain weight (Tables 9, 10, and 11), all of which resulted in increased grain yield.The anti-saturating agents helped mitigate the negative effects of water stress by regulating the filling of guard cells, which leads to water movement, partial stomata closure, stimulation of CO_2 synthesis, and a reduction in plant temperature. They then facilitated the translocation of carbon dioxide products to the fertilized grains, thus increasing grain yield.

The interaction also showed a significant effect, as the water tension treatments S1 and S2 outperformed the kaolin and silicone spray treatments, with no significant difference between them, compared to the S3 combination and the control treatment (spraying with distilled water only), which gave the lowest average of 3.98 $Mg.ha^{-1}$.

Table (12) Effect of water tension levels, antitranspirants, and their interaction on total grain yield ($Mg.ha^{-1}$)

water tension	Antitranspirants				average
	control (without spraying)	Kaolin	Paraffin wax	Silicone	
S1	6.31	7.96	6.88	7.87	7.23
S2	5.32	7.72	6.45	7.63	6.78
S3	3.98	4.83	4.63	4.66	4.53
average	5.20	6.84	5.98	6.72	
LSD	water tension 0.63		Antitranspirants 0.37		interaction 0.70

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