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THE INFLUENCE OF ABSCISIC ACID (ABA) ON GROWTH AND YIELD OF MAIZE UNDER DROUGHT STRESS

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Abstract

Background: *The highest-yielding cereal crop worldwide is maize (Zea mays L.). After wheat and rice, maize is the third-most important cereal crop in Pakistan. Maize can be used as cattle feed and fodder also. Throughout the world, Maize is a major feed crop for livestock and a food crop for humans. In Pakistan, it is grown for its grain and forage. The primary factor causing a decrease in crop productivity is drought. Abscisic acid is one of the key plant growth regulators that may help maize development and yield.*

Objective: *The goal of the current study is to assess the impact of abscisic acid on maize.*

Methodology: *The study was conducted at the agronomy research area at the Islamia University of Bahawalpur.T_0 = Control, T_1 = Drought, T_2 = 100 mg/L ABA + Drought, T_3 = 200 mg/L ABA + Drought, T_4 = 300 mg/L ABA + Drought and T_5 = 400 mg/L ABA + Drought. In all the treatments, drought was imposed at tasseling stage of maize. Different*

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agronomic parameters were observed in this experiment like plant height, cobs per plant, leaves per plant, leaf area, rows per cob, grains per row, cob length, cob weight, 1000 grain weight, grains weight per cob, stomatal conductance, photosynthetic rate, transpiration rate and total dry matter production.

Results: *It was revealed that treatment T_5=400mg/L ABA + Drought at tasselling stage significantly enhanced the grain per cob, number of grains per row, leaf area, 1000-grain weight, grain weight per cob, number of leaves, number of cobs per plant, cob weight, stomatal conductance, photosynthetic rate, transpiration rate, leaf length and total dry matter production.*

Conclusion: *It is concluded that the application of Abscisic acid @400 mg/L at tasselling stage significantly affected all growth and yield-related parameters of maize.*

INTRODUCTION

The Gramineae (Poaceae) family includes the major cereal crop known as maize (*Zea mays L.*). It is called "Makai" in Punjab. America is home to the maize plant, which is consumed by Americans. The history of maize begins in 1492, when Christopher Columbus discovered this novel crop in Cuba, when it was first domesticated for use in western civilization. It is thought to be 80,000 years old and was found in the western hemisphere. It was discovered in drill cores 200 feet beneath Mexico City (Umar, 2002).

A total of 1,653 thousand hectares of maize were planted in 2021–2022, an increase of 16.6% over the 1,418 thousand hectares that were cultivated in the previous year. The output of the maize crop was 10.635 million tonnes, a considerable increase of 19.0% over the 8.940 million tonnes produced the previous year. Maize contributes 0.8% to GDP and 3.3% to the value added of agriculture (Economic Survey of Pakistan 2020-2021). The increase in production was mostly brought on by larger areas that were sown, enhanced high-yield seed kinds, favorable weather and higher financial returns.

Specifically, a grain called maize (*Zea mays L.*), which is utilized for both human and animal consumption as well as animal feed, significantly contributes to global food security (Campos *et al.*, 2004). The demand for maize by the year 2020 had surpassed that of rice and wheat, having nearly doubled by that point in China, India and South Asia. Additionally, with an annual rise of 2.9%, maize demand outpaces that of all other cereal crops in developing nations (Timsina *et al.*, 2011). Additionally, with an annual rise of 2.9%, maize demand outpaced that of all other cereal crops in developing nations.

A range of crop development and management techniques are being created for the intensive and sustainable farming of maize to accomplish this. Drought is one of several obstacles to maize intensification that many nations across the world regard to be the main one. Due to drought, maize output in Africa has decreased by up to 70% and complete crop failure is not unusual (Ashraf 2010; Muoma*et al.*, 2010). Asia is affected, especially the southwest region as well as northwest of Bangladesh.

Because it is a short-duration, fast-growing crop that may theoretically provide a large quantity of grain per unit area and is ready for harvest in approximately 7 to 9 weeks after germination, maize can also be grown for green fodder (MUKOKA., 2022). Pakistan produces less maize than other wealthy nations, on average. Declining productivity is impacted by a variety of factors, including nutrient depletion in the soil, uneven fertilizer application, incorrect planting techniques, weed infestation and irrigation. Among these, irrigation and appropriate planting techniques are essential for boosting

maize growth and yield. Currently, the average yield of maize being acquired is lower than what our current varieties can produce, mostly due to the typical planting configuration's sub-optimal plant density (Rahman & Iqbal 2013). It is exclusively planted in Pakistan for food and fodder purposes or in conjunction with other forages (Saleem *et al.*, 2003).

After the importance of rice and wheat locally as well as international, *Zea mays L.*, a cereal crop with a high potential for production, is regarded as the third most extraordinary crop in the history of agriculture. According to (Alahdadi*et al.*, 2011) maize is a key component of human diets, animal feed and industrial raw materials. In 2014–2015, 124 thousand hectares of maize were planted, an increase of 8.2%. This increase in the cultivated area is the result of the area's switch from cotton to maize production (Govt. of Pakistan, 2015-16). Two important provinces account for the vast majority (97%) of the production (KPK and Punjab). 68% of overall output and 57% of the area are produced by KPK (PARC, 2007).

Many agro-based businesses now rely on maize as a commercial crop for basic ingredients (Iken and Amusa, 2004). According to the (Khawar *et al.*, 2007) assert that the multiple uses of maize and its presence of vitamins B, proteins and trace minerals. For the creation of glucose, protein and oil, it is essential (Niaz and Dawar, 2009). In terms of nutrition, among the crops, maize is important. A major proportion of food comes from forage maize to produce cattle, particularly in tropical regions where feedstuffs were insufficient to fulfil animal needs because of a variety of issues like low drought and soil fertility (Eltelib*et al.*, 2006).

A warm-season crop known as maize is farmed in a variety of climates, from tropical to temperate ones. This crop may be produced effectively in locations where the nighttime temperature does not go below 15 degrees Celsius since beyond this point, the crop stops growing. Early development phases of the maize crop are vulnerable to low temperatures. According to studies, low temperatures below 15°C impair the ability of maize seedlings to photosynthesize by destroying cellular membranes, photosynthetic apparatus and cellular enzymes (Farooq *et al.*, 2009). This may be due to a significant increase in reactive oxygen species (ROS), which causes poor establishment of seedling stands in agriculture.

Abiotic stresses that are harmful include some of the following on crop development, output and grain quality include drought, hotter temperatures and salt. The most pervasive and important abiotic stressor for grain production is the water deficit. Additionally, the severity of the drought in the arid region is made worse by the heat stress (Urooge et al.2021; Kumar *et al.*, 2020). 1/3 of the world's farmed land has a limited water supply due to water scarcity. But the greatest ecological stress is dryness, which greatly hinders plant development and growth and eventually reduces plant productivity (Ihsan *et al.*, 2016).

The primary factor restricting the growth and output of major field crops has been a lack of water and its severity is getting worse over time (Passioura*et al.*, 2010). Water shortage for agricultural output was 40.39 MFA in 2000, according to the Government of Pakistan (2001; 107.80 MFA in 2013; a difference of around 2.8 times). The main threat to drought stress globally is changes in the yearly rainfall pattern and a drop in precipitation (Lobell *et al.*, 2011). According to a study that examined data from 1980 to 2015, Crop yields of wheat (*Triticum aestivum L.*) and maize (*Zea mays L.)* have decreased by up to 21 percent and 40 percent, respectively, because of the global water crisis (Daryanto *et al.*, 2016). According to stages of growth of plant as well as other ecological parameters, different species will react differently to the stress of dry spell (Demirevska*et al.*, 2009). The shortage of water supply causes our key field crops, like wheat, to yield less grain in the end, by 57%. (Balla *et al.*, 2011).

In line with the findings of (Kushiro et al., 2004) Abscisic acid controls both vegetative as well as reproductive development as well as how plants react to stress. In the process of ABA production,

the enzyme NCED (Nine-cis-epoxy carotenoid dioxygenase) is essential to produce ABA in response to the stress of drought spell. Phytohormone abscisic acid controls a variety of critical processes of a plant growing and developing (Tardieu *et al.*, 2010). Additionally, this molecule regulates the body's adaptive responses to difficult situations. A large buildup of ABA happens under conditions of low water supply, controlling stomatal opening and closure. Under stress, ABA buildup in leaves is crucial for lowering transpirational water loss (Liu *et al.*, 2005). Additionally, the enhanced transfer of ABA initiate especially in the roots in interaction with soil sample with dry natyre to shoot may be the significant cause of stomatal closure (Schachtman and Goodger 2008).

It seems that ABA is essential for drought resistance. When cold Stress was analyzed, (Aroca *et al.*, 2003) revealed that ABA treatment boosted resistance in some genotypes because they were more resilient to water shortages attributable to the reduction in stomatal conductivity under stress. There are few studies on the application of ABA and gas exchange in maize. The relationship between ABA treatment and maize genotypes that are drought-sensitive and resistant to drought is poorly understood. In genotypes resistant to droughts, ABA immensely improves the antioxidant enzymes activity (Kelloset *al.*, 2008). According to several research, abscisic acid may contribute to stress of oxidative phase in maize cells (Hu *et al.*, 2005). When ABA was administered to maize at varying concentrations, antioxidant enzymes became more active and produced more ROS (Jiang 2002 and Zhang 2004).

MATERIAL AND METHODS

Experimental site and conditions

The goal of the current study was to determine how abscisic acid affected the production and growth of maize (*Zea mays L.*) under drought circumstances. In Pakistan Bahawalpur, the Islamia University Faculty of Agriculture and Environmental Sciences, the experiment was conducted in August 2021 in the agronomic research area. The following observations were made throughout the entire study period and were documented. Prior to planting the crop, a physicochemical examination of the soil was performed.

Soil analysis

Before planting the crop, a soil physicochemical investigation was done. Using a soil augur, soil samples were obtained from depths of 0 to 15 cm and 15 to 30 cm. The labelled polythene bags containing the gathered samples were then sent to the regional agriculture research institution (RARI) Bahawalpur's soil and water testing facility for examination. The table below contains the results of the soil analysis Table 1.

Table 1: Soil Physical and Chemical characteristics of the experiment site

Characteristics	0-15cm	15-30cm
Organic substance (Percentage)	0.78	0.57
PH	8.4	8.6
EC (micro siemen per centimeter)	250	230
proportion of T.S.S.	0.7	0.9
Available-Phosphorus (ppm)	7.1	5.1
Available-Potassium (parts per million)	112	114
percentage of saturation	36	35
Soil Separates (Sand Percentage)	39	34
Silt Percentage	41	39
Clay Percentage	23	28
Textural class	Loam texture	Loam texture

pH of saturated soil paste

The pH of the soil was determined using a pH meter. The instrument was first calibrated using a standard buffer solution with pH values of 4, 7, and 9. When it was mixed into a paste containing dirt, the pH was then determined.

Water analysis

Analysis of water Prior to planting the crop, irrigation using tap water was employed to water it. Regional Agriculture Research Institute (RARI) Bahawalpur's soil and water testing facility received the gathered samples in marked plastic bottles for analysis Table 2.

Table 2: Quality of irrigation water used during the entire course of studies

Characteristics	Tube well water
EC (micro-Siemen per centimeter)	1104
pH	7.41
Ca^{2+}+Mg^{2+} (milli equivalent per liter)	7.91
Na^{+} (milli equivalent per liter)	3.11
CO_3^{2-} (milli equivalent per liter)	Nil
HCO_3^{-} ((milli equivalent per liter)	5.3
Cl^{-} (milli equivalent per liter)	3.2
SO_4^{2-} (milli equivalent per liter)	1.03
SAR (milli mol per liter)	1.58
RSC (milli equivalent per liter)	Nil

Climatic Data

Figures 3.1 and 3.2 provide information on environmental variables (temperature and rainfall) during the course of the period.

Temperature

The research's maximum and minimum temperatures, which ranged from August 2021 to November 2021, are depicted in fig.3.1. The month of August saw the highest temperature ever recorded (38°C), while the month of November saw the lowest temperature ever recorded (28°C) Figure 1.

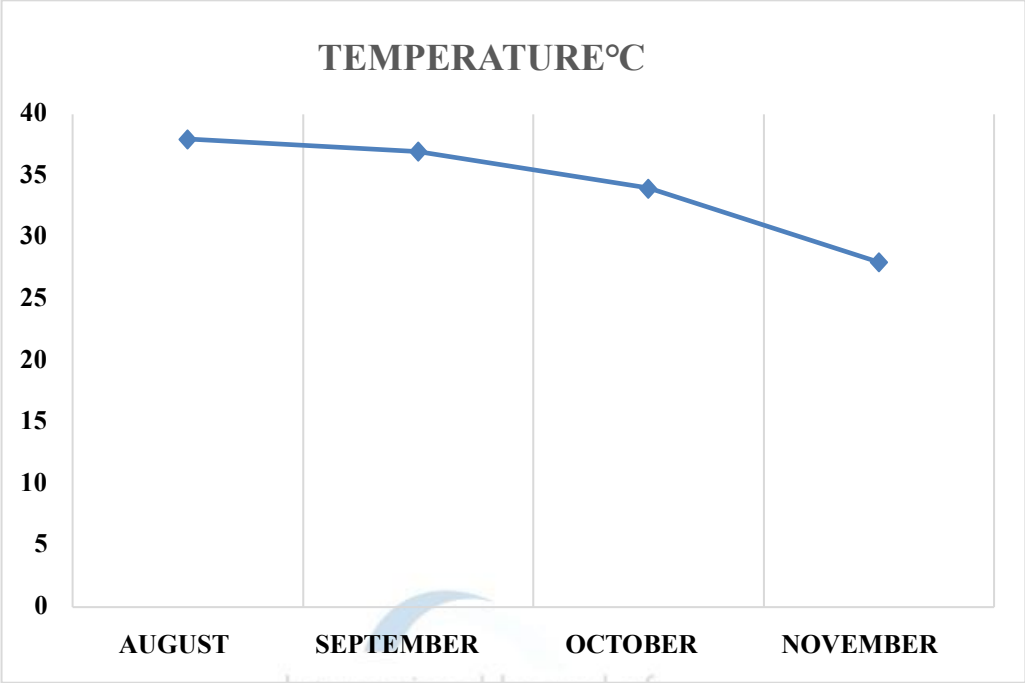


Figure 1: Mean average temperatures that were measured throughout the research period

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Rainfall

In Fig. 3.2, the maximum and minimum rainfall amounts observed during the research period (August 2021 to November 2021). The highest amount of rainfall (33 mm) was recorded in August, while the lowest amounts (October and November) (2 mm) Figure 2.

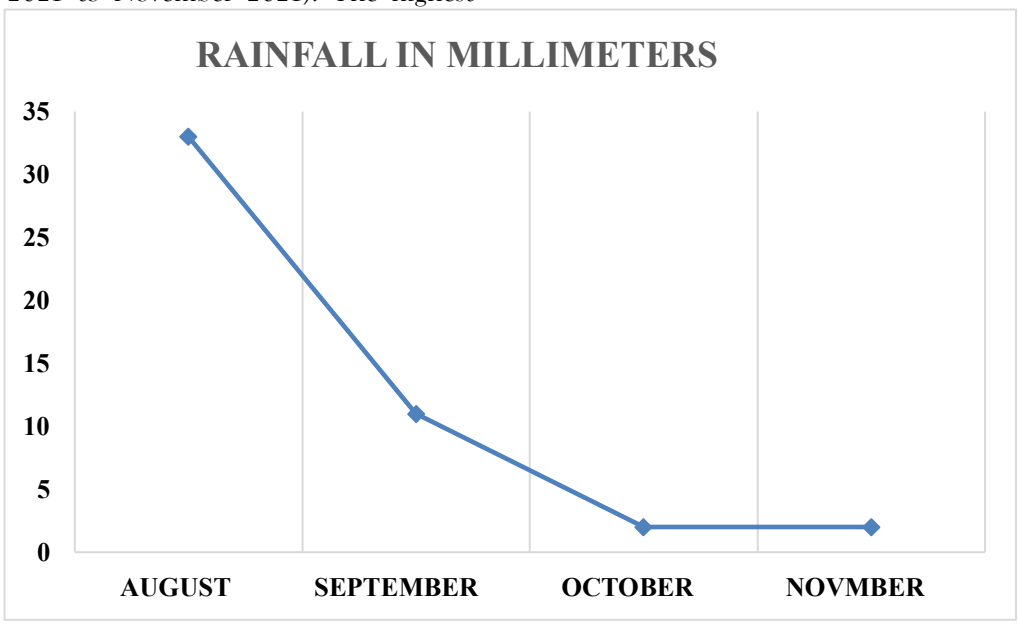


Figure 2: Mean average rainfall recorded during the research duration

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Treatments

The experiment included the following therapies.

- T_0= Control
- T_1= Drought
- T_2= Foliar application of ABA@100 mg/L + Drought
- T_3= Foliar application of ABA@200mg/L ABA + Drought
- T_4= Foliar application of ABA@300mg/L ABA + Drought
- T_5= Foliar application of ABA@400mg/L ABA+ Drought

In all the treatments, drought was imposed at tasseling stage of maize.

Crop Husbandry

The experiment had a net plot size of 5 m x 3 m and was set up using a randomized complete block design (RCBD). Utilizing a mould board plough and cultivator, the soil was prepared. The crop was planted in August 2021. Drilling by hand was used to sow. Fertilizer dosages that are suggested applying 255 kg ha^{-1} of nitrogen, 144 kg hdosagesus, and 90 kg ha^{-1} of potassium. For each treatment, the same agronomic procedures were used. Consistent plant protection practices were used to keep crops free of weeds, insects and illnesses.

Parameters Recorded

Utilizing standard techniques, the following parameters were recorded.

Agronomic and yield related parameters:

The data was recorded on the following traits:

- Plant height
- Number of cobs per plant
- Number of leaves per plant
- Leaf area
- Number of grains rows per cob
- Number of grains per row
- Cob length
- Cob length per plant (cm)
- Cob weight
- 1000 grain weight
- Grains weigh per cob
- Stomatal conductance
- Photosynthetic rate
- Transpiration rate
- Total dry matter production
-

Procedures to record the observation

Plant Height (cm)

Plant height of each plant was taken through meter rod, whose calibrations were in cm.

The meter rod was put adjacent to plant and reading was taken.

Number of Leaves

The numbers of leaves were counted from base of plant to top. The data was taken on weekly basis.

No. of grain rows per cob

After being harvested from the field, the rows per cob were counted.

Number of cobs per plant

From each plot, ten plants were chosen at random, and their cobs were counted. By dividing the total number of cobs by the number of plants, the average number of cobs per plant was computed.

No. of grains per row

5 cobs from each treatment were selected randomizely. The grains per row were counted manually from each cob.

Cob weight (gm)

The cob weight was taken through meter rod.

Grains weight per cob(gm)

After threshing the grains from the cob, the grain weight per cob was measured. Then, weight is taken by placing all grains per cob on weight balance.

1000 grains weight (gm)
The 1000 grains are threshed from cob and counted manually by hand. Then, weight is taken by placing grains on weight balance.

Leaf Area(cm^2)
The leaf area was taken from the fourth and fifth leave from top. The width was taken at three points of plant leaf. And length is taken of whole leaf.
Leaf Area = Mean Width x Length

Stomatal conductance
The most popular tools for quantitatively measuring stomatal conductance are diffusion promoter and infrared gas analyzer (IRGAS), which may be employed in the field or the lab (Bell &squirre, 1981; Hirkham, 2005). Stomatal conductance of the two chosen plants' abaxial leaf surfaces were measured hourly using a porometer. At three different leaf locations, the center of each leaf was measured (upper, middle and lower).

Photosynthetic rate:
With the aid of an infrared gas analyzer, Monitoring is done of the CO_2 entering and exiting the leaf chamber. The difference provides the quantity of CO_2 from which we may compute the rate of photosynthesis.

Transpiration Rate
Transpiration was measured as sap flow using a heat balance approach and a sap flow sensor attached to the stems of maize plants. To counteract the impact of dirt, the guage was elevated 0.5 meters above the surface.

Leaf length
The plant leaf length and breadth may be quickly, precisely and conveniently measured with a leaf area meter.

STATICAL ANALYSIS
The statistical analysis of the data is done using the analysis of variance (ANOVA) approach. The least significant differences (LSD) test will be used to compare significant differences between the treatments' means at a 5% probability level.

RESULTS
The averages of the observations from each replication were statistically examined once the desired data from the current experiment had been collected. The results of maize following growth and yield metrics as affected by the application of abscisic acid are shown below (ABA).

Plant Height (cm)
Table 3a and 3b display information about plant height. Drought stress does not significantly affect the height of the plant of maize. Abscisic acid (ABA) application non significantly affected maize plant height (cm).

Table 3(a): Effect of various doses of abscisic acid on the height of the maize plant

Treatments	Means
T_0 = Control	181.11
T_1= Drought	180.97
T_2= Abscisic acid@100 mg/L + Drought	181.19
T_3= Abscisic acid@200 mg/L + Drought	181.10
T_4= Abscisic acid@300 mg/L + Drought	180.82
T_5= Abscisic acid@400 mg/L + Drought	180.75

Table 3(b): Analysis of variance table for the impact of various abscisic acid dosages on the height (in cm) of maize plants

Source	DF	SS	MS	F	P
Rep	2	2.44827	1.22427		
Treatment	5	213.946	42.7892	6.929	$0.4651^{N.S}$
Error	10	6.20228	6.20229	-	-
Total	17	213.946	-	-	-

N.S = non-significant

Number of Leaves

The information in table 4a and 4b. Which is based on data from the table, provides details about the number of leaves per plant of maize. The application of abscisic acids significantly affects the number of maize leaves. ABA which improved the tolerance in maize against dry spell period. Maximum numbers of maize leaves were observed in T_5= 400 mg/L abscisic acid at tasseling stage (18A) and T_1= Drought at tasseling stage showed the least number of maize leaves (7E).

Table 4(a): Effects of varying doses of abscisic acid on number of leaves per plant

Treatments	Means
T_0 = Control	10F
T_1= Drought	7 E
T_2= Abscisic acid@100 mg/L + Drought	13 D
T_3= Abscisic acid@200 mg/L + Drought	15 C
T_4= Abscisic acid@300 mg/L + Drought	17 B
T_5= Abscisic acid@400 mg/L + Drought	18 A

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Table 4(b): Analysis of the variance table for the effect of abscisic acid administration on the number of leaves per maize plant

Source	DF	SS	MS	F	P
Rep	2	2.22229	1.11129		
Treatment	5	142.500	28.5000	7.531	0.0000**
Error	12	3.81330	3.81331	-	-
Total	17	142.500	-	-	-

**** <0.01 = Highly Significant**

Leaf Area (cm^2)

Available statistics data regarding the area of leaf (cm^2) of maize which is represented in table 5a and 5b. The application of abscisic acids exhibits a remarkable effect on the maize's leaf area (cm^2). ABA improved the tolerance against the dry spell period in maize. Maximum leaf area of maize was recorded in T_5= 400 mg/L abscisic acid at tasseling stage (1515 cm^2) and the minimum leaf area (cm^2) of maize was observed in T_1= Drought at tasseling stage (889 cm^2).

Table 5a: Effects of various Abscisic Acid Concentrations on Maize leaf area (cm^2)

Treatments	Means
T_0 = Control	892 F
T_1= Drought	889 E
T_2= Abscisic acid@100 mg/L + Drought	1053 D
T_3= Abscisic acid@200 mg/L + Drought	1112 C
T_4= Abscisic acid@300 mg/L + Drought	1290 B
T_5= Abscisic acid@400 mg/L + Drought	1515A

Table 5b: Analysis of variance table for Influence of different doses of application of Abscisic acid on leaf area of maize

Source	DF	SS	MS	F	P
Rep					
Treatment	5	364.080	72.8160	44.9	0.0000**
Error	12	19.440	1.6200	-	-
Total	17	383.520	-	-	-

Leaf Length (cm)

The analytical data regarding the length of leaf of maize per plant shown in table 6a and 6b Applying of abscisic acids significantly affects the leaf length per plant of maize. Abscisic acid (ABA) improved the drought tolerance in maize. The maximum leaf length per plant of maize were recorded in T_5= 400 mg/L abscisic acid at tasseling stage (25.24cm) and the minimum leaf length per plant of maize were recorded in T_1= Drought at tasseling stage (10.7cm).

Table 6a: Impact of different levels of Abscisic acid on leaf length of maize

Treatments	Means
T_0 = Control	14.45cm
T_1= Drought	10.7cm
T_2= Abscisic acid@100 mg/L + Drought	17.10cm
T_3= Abscisic acid@200 mg/L + Drought	20.35cm
T_4= Abscisic acid@300 mg/L + Drought	22.72cm
T_5= Abscisic acid@400 mg/L + Drought	25.24cm

LSD =1.5

Table 6b: Analysis of variance table for Influence of application of Abscisic acid on the leaf length of maize

Source	DF	SS	MS	F	P
Rep	2	0.34	0.171		
Treatment	5	1144.72	228.948	1383.86	0.0000**
Error	10	1.65	0.165	-	-
Total	17	1146.72	-	-	-

** <0.01 = Highly Significant

Number of cobs per plant

According to the figures, which are shown in table 7a and 7b, the number of cobs per maize plant is represented. The quantity of cobs per maize plant is significantly impacted by the stress of a dry spell. Application of ABA has a considerable impact on the amount of corn cobs produced per plant. Abscisic acid (ABA) increased maize drought resistance. The highest number of corn cobs per plant was found in T_5= 400 mg/L abscisic acid at the tasseling stage (1.38A) and the lowest number of corn cobs per plant was found in T_1= Drought at the tasseling stage (1.27E).

Table 7a: Impact of different Abscisic acid levels on number of cobs per plant of maize.

Treatments	Means
T_0 = Control	1.29 F
T_1= Drought	1.27 E
T_2= Abscisic acid@100 mg/L + Drought	1.33 D
T_3= Abscisic acid@200 mg/L + Drought	1.35 C
T_4= Abscisic acid@300 mg/L + Drought	1.36 B
T_5= Abscisic acid@400 mg/L + Drought	1.38 A

LSD at 5%= 0.239

Table 7b: Analysis of the variance table for the effect of applying different doses of abscisic acid on the quantity of corn cobs produced by each plant.

Source	DF	SS	MS	F	P
Rep	2	6.65631	3.32831		
Treatment	5	0.02700	0.00540	7.329	0.0000**
Error	10	7.39632	7.39633	-	-
Total	17	0.02700	-	-	-

**** <0.01 = Highly Significant**

Cob length per plant (cm)

Data regarding cob length per plant table 8a and 8b show that the application of abscisic acids significantly affects cob length per plant of maize. Abscisic acid (ABA) improved the drought tolerance in maize. Maximum cob length per plant of maize were recorded in T_5= 400 mg/L abscisic acid at tasseling stage (27.5) and the minimum cob length per plant of maize were recorded in T_1= Drought at tasseling stage (13.6).

Table 8a: Impact of different levels of Abscisic acid on cob length per plant of maize

Treatments	Means
T_0 = Control	17.5 F
T_1= Drought	13.6 E
T_2= Abscisic acid@100 mg/L + Drought	20.8 D
T_3= Abscisic acid@200 mg/L + Drought	23.9 C
T_4= Abscisic acid@300 mg/L + Drought	25.7 B
T_5= Abscisic acid@400 mg/L + Drought	27.5 A

LSD =1.5

Table 8b: Analysis of variance table for Influence of application of Abscisic acid on cob length per plant of maize

Source	DF	SS	MS	F	P
Rep	2	6.36329	3.18229		
Treatment	5	262.000	52.4000	2.032	0.0000**
Error	10	2.63030	2.63031	-	-
Total	17	262.000	-	-	-

** <0.01 = Highly Significant

Cob weight (g)

Table 9a and 9b provide information regarding the weight of a cob of maize. The cob weight of maize is significantly impacted using abscisic acids. Abscisic acid (ABA) improved the drought tolerance in maize. Maximum Cob weight (gm)of maize was recorded in T_5= 400 mg/L abscisic acid at tasseling stage (149.3g), and the minimum Cob weight (gm)of maize were recorded in T_1= Drought at tasseling stage (83.2g).

Table 9a: Impact of different levels of Abscisic acid on cob weight (gm) of maize

Treatments	Means
T_0 = Control	85.3 E
T_1= Drought	83.2 D
T_2= Abscisic acid@100 mg/L + Drought	106.2C
T_3= Abscisic acid@200 mg/L + Drought	111.8C
T_4= Abscisic acid@300 mg/L + Drought	135.9B
T_5= Abscisic acid@400 mg/L + Drought	149.3A

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Table 9b: Analysis of variance table for Influence of application of Abscisic acid on cob weight of leaves per plant of maize

Source	DF	SS	MS	F	P
Rep	2	8.35308	4.17528		
Treatment	5	10615.5	2123.10	7.731	0.0000**
Error	10	2.76428	2.74629	-	-
Total	17	10615.5	-	-	-

** <0.01 = Highly Significant

Number of Grain Rows per Cob

The number of grain rows per maize cob is shown in Table 10a and 10b. Grain rows per maize cob is dramatically impacted using abscisic acids. Abscisic acid (ABA) increased maize ability to withstand drought. At the tasseling stage, maize exposed to T_5=400 mg/L abscisic acid had the maximum number of grain rows per cob (19), and the lowest concentration were shown in T_1 Drought during the tasseling stage (9).

Table 10a: Impact of different levels of Abscisic acid on number of grain rows per cob

Treatments	Means
T_0 = Control	11 F
T_1= Drought	9 E
T_2= Abscisic acid@100 mg/L + Drought	14 D

T_3= Abscisic acid@200 mg/L + Drought	16 C
T_4= Abscisic acid@300 mg/L + Drought	17 B
T_5= Abscisic acid@400 mg/L + Drought	19 A

Table 10b: Analysis of the variance table for the effects of various abscisic acid applications doses on the number of grains rows per cob of maize.

Source	DF	SS	MS	F	P
Rep	2	5.52929	2.630.29		
Treatment	5	31.8524	6.37049	1.032	0.0000**
Error	10	0.5463	0.04552	-	-
Total	17	32.3997	-	-	-

** <0.01 = Highly Significant

Number of grains per row

Table 11a and 11b provide statistical information on the number of grains per row of maize. The number of grains per row of maize is significantly impacted using abscisic acids. ABA improved the tolerance against the dry spell period of maize. T_5=400 mg/L abscisic acid showed the highest number of grain rows per row of maize at tasseling stage (26.50) and the minimum number of grain rows has been observed per row of maize in T_1= Drought at tasseling stage (14.08).

Table 11a: Impact of different levels of Abscisic acid on number of grains per row of maize

Treatments	Means
T_0 = Control	16.07 F
T_1= Drought	14.08 E
T_2= Abscisic acid@100 mg/L + Drought	18.04 D
T_3= Abscisic acid@200 mg/L + Drought	22.33 C
T_4= Abscisic acid@300 mg/L + Drought	24.10 B
T_5= Abscisic acid@400 mg/L + Drought	26.50 A

Table 11b: Analysis of variance table for Influence of different doses of application of Abscisic acid on number of grains per row of maize

Source	DF	SS	MS	F	P
Rep	2	1.52028	7.59929		
Treatment	5	355.838	71.1676	4.731	0.0000**
Error	10	1.52529	1.52530	-	-
Total	17	355.838	-	-	-

** <0.01 = Highly Significant

1000 Grains Weight (g)

Available numeric data regarding maize of 1000 grains weight (gm) is presented in table 412a and 12b. Applying abscisic acids shows a remarkable effect of 1000 grains weight of maize. Abscisic acid (ABA) improved the drought tolerance in maize. Maximum 1000 grains of maize weight were recorded in T_5= 400 mg/L abscisic acid at

tasseling stage (237.07g) and the minimum 1000 Grain weight of maize were recorded in T_1= Drought at tasseling stage (178.26g).

Table 12a: Impact of different levels of Abscisic acid on 1000 grains weight of maize

Treatments	Means
T_0 = Control	180.28 F
T_1= Drought	178.26 E
T_2= Abscisic acid@100 mg/L + Drought	188.78 D
T_3= Abscisic acid@200 mg/L + Drought	192.12 C
T_4= Abscisic acid@300 mg/L + Drought	199.85 B
T_5= Abscisic acid@400 mg/L + Drought	237.07 A

Table 12b: Analysis of variance table for Influence of different doses of application of Abscisic acid on 1000 grains weight of maize

Source	DF	SS	MS	F	P
Rep	2	1.62926	8.14527		
Treatment	5	6938.89	1387.78	2.131	0.0047**
Error	10	6.73228	6.73229	-	-
Total	17	6938.89	-	-	-

**** <0.01 = Highly Significant**

Grains Weight per Cob (g)

Table 13a and 13b provide information on the grains weight per cob of maize. Applying abscisic acids shows significant grain weight per cob of maize. Abscisic acid (ABA) improved the drought tolerance in maize. Maximum grains weight per cob of maize were recorded in T_5= 400 mg/L abscisic acid at tasseling (111.9g) and the minimum grains weight per cob of maize were recorded in T_1= Drought at tasseling stage (51.2g).

Table 13a: Impact of different levels of Abscisic acid on grains weight per cob of maize

Treatments	Means
T_0 = Control	53.4 F
T_1= Drought	51.2 E
T_2= Abscisic acid@100 mg/L + Drought	82.8 D
T_3= Abscisic acid@200 mg/L + Drought	87.5 C
T_4= Abscisic acid@300 mg/L + Drought	95.5B
T_5= Abscisic acid@400 mg/L + Drought	111.9 A

Table 13b: Analysis of variance table for Influence of application of Abscisic acid on grains weight per cob of maize

Source	DF	SS	MS	F	P
Rep	2	1.89327	9.46628		
Treatment	5	8574.21	1714.84	4.531	0.0000**
Error	10	3.78728	3.78729	-	-
Total	17	8574.21	-	-	-

**** <0.01 = Highly Significant**

Total dry matter (t ha^{-1})

Available data regarding the total dry matter production of maize is shown in table 14a and 14b applying of abscisic acids significantly affects the total dry matter of maize plant. Abscisic acid (ABA) improved the drought tolerance in maize. The maximum total dry matter (8.94 t ha^{-1}) was recorded in T_5= 400 mg/L abscisic acid at tasseling stage, and the minimum was observed in T_1= Drought at tasseling stage (7.12 t ha^{-1}).

Table 14a: Impact of different levels of Abscisic acid on total dry matter of maize

Treatments	Means
T_0 = Control	9.65
T_1= Drought	7.12
T_2= Abscisic acid@100 mg/L + Drought	7.55
T_3= Abscisic acid@200 mg/L + Drought	8.31
T_4= Abscisic acid@300 mg/L + Drought	8.59
T_5= Abscisic acid@400 mg/L + Drought	8.94

LSD=1.5

Table 14b: Analysis of the variance table for the impact of abscisic acid application on the total dry matter of maize

Source	DF	SS	MS	F	P
Rep	2	0.34	0.171		
Treatment	5	1144.72	228.948	1383.86	0.0000**
Error	10	1.65	0.165	-	-
Total	17	1146.72	-	-	-

**** <0.01 = Highly Significant**

Stomatal Conductance

Data regarding stomatal conductance of maize per plant table 15a and 15bshows that the application of abscisic acids significantly decreases the stomatal conductance per plant of maize. Maximum stomatal conductance per plant of maize were recorded in T_0= Control (125.82) and the minimum stomatal conductance of maize were recorded in T_5= 400 mg/L Abscisic acid at tasseling stage (102.18).

Table 15a: Impact of different levels of Abscisic acid on stomatal conductance of maize

Treatments	Means
T_0 = Control	125.82 A
T_1= Drought	106.77 B
T_2= Abscisic acid@100 mg/L + Drought	104.89 CD
T_3= Abscisic acid@200 mg/L + Drought	105.50 C
T_4= Abscisic acid@300 mg/L + Drought	104.36 D
T_5= Abscisic acid@400 mg/L + Drought	102.18 E

LSD =1.5

Table 15b: Analysis of the variance table for Abscisic acid application effects on maize stomatal conductance

Source	DF	SS	MS	F	P
Rep	2	0.34	0.171		

Treatment	5	1144.72	228.948	1383.86	0.0000**
Error	10	1.65	0.165	-	-
Total	17	1146.72	-	-	-

** <0.01 = Highly Significant

Photosynthetic Rate (µmol m^{-2} g^{-1})

Statistical table data regarding the photosynthetic rate of maize plants shown in table 16a and 16brevealed that the application of abscisic acids significantly decreases the photosynthetic rate per plant of maize. The maximum photosynthetic rate per plant of maize were recorded in T_0= Control (14.81) and the minimum photosynthetic rate of maize were recorded in T_5=400 mg/L abscisic acid at tasseling stage (11.54).

Table 16a: Impact of different levels of Abscisic acid on photosynthetic rate

Treatments	Means
T_0 = Control	14.81A
T_1= Drought	12.52 B
T_2= Abscisic acid@100 mg/L + Drought	12.31 C
T_3= Abscisic acid@200 mg/L + Drought	12.27 D
T_4= Abscisic acid@300 mg/L + Drought	11.72 E
T_5= Abscisic acid@400 mg/L + Drought	11.54 F

LSD =1.5

Table 16b: Analysis of variance table for Influence of application of Abscisic acid on the photosynthetic rate of maize

Source	DF	SS	MS	F	P
Rep	2	0.00001	0.00004		
Treatment	5	20.7814	4.15628	57548.43	0.0000**
Error	10	0.0007	0.0007	-	-
Total	17	20.7822	-	-	-

** <0.01 = Highly Significant

Transpiration Rate (E=µ mol m^{-2} s^{-1})

The information given about the transpiration rate of corn that each plant transpires is shown in table 17a and 17b revealed that the applying abscisic acids significantly decrease the transpiration rate per plant of maize. The maximum transpiration rate of maize was recorded in T_0= Control (2.76) and the minimum transpiration rate per plant of maize were recorded in T_5= 400 mg/L abscisic acid at tasseling stage (1.12).

Table 17a: Impact of different levels of Abscisic acid on transpiration rate of maize

Treatments	Means
T_0 = Control	2.76 A
T_1= Drought	1.91 B
T_2= Abscisic acid@100 mg/L + Drought	1.70 C
T_3= Abscisic acid@200 mg/L + Drought	1.52 D
T_4= Abscisic acid@300 mg/L + Drought	1.32 E

T_5= Abscisic acid@400 mg/L + Drought	1.12 F

LSD =1.5

Table 17b: Analysis of the variance table for Abscisic acid application's effects on maize transpiration rate

Source	DF	SS	MS	F	P
Rep	2	2.22931	1.11531		
Treatment	5	5.03045	1.00685	1.4903	0.000**
Error	10	6.75632	6.75663	-	-
Total	17	5.03425	-	-	-

** <0.01 = Highly Significant

DISCUSSION

In drought conditions, abscisic acid (ABA), which was thought to be crucial for plant form and growth, had a striking effect on the growth and yield characteristics of maize crops. The height of plantsis one of the most important elements in growing a biomass of plants. Plant height is a crucial morphological characteristic that depends on a plant's genetic make-up, the amount of nutrients in the soil and the environment in which it is cultivated. Many studies favor applying abscisic acid (ABA) non-significant effect the plant height of maize. Drought stress reduced plant height and internode length in maize plants. Other crops also showed these negative impacts of drought stress (Manivannan *et al.*, 2007). However, adding ABA and GA3 significantly lessens the negative impacts of dry spell period by lengthening internodes and growing plant height. Under conditions of water scarcity, tomato, wheat, and maize development are improved by abscisic acid and gibberellic acid (GA3) (Ashraf *et al.*, 2002; Kaya *et al.*, 2006). Abscisic acid (ABA) application non significantly affected maize plant height.

The number of leavesis also a vital growth parameter. The higher the plant leaves, the higher the chance of more production of the photosynthetic products. Leaves are essential for the availability of stomata and chlorophyll. More leaves can increase the chance of enhancing plant growth. More numbers of leaves in maize are an indicator of higher crop production. The balance between water and its transpiration is maintained by leaves. The quantity of maize leaves is considerably impacted using abscisic acids. At the tasseling stage, T_5=400 mg/L abscisic acid revealed the most maize leaves (18) and a minimum number of leaves of maize was observed in T_1= Drought at tasseling stage (7).

Most of the portion of green leaf tissue regarding one-sided area per unit amount of land which is occupied by a crop is its leaf area. An important indication of precipitation, interception, radiation, energy conversion and water balance is the leaf area index. Because leaf surfaces serve as the major boundary for energy and mass exchange, leaf area is also essential for photosynthesis. Higher leaf area causes an increased photosynthesis rate, resulting in higher crop production. The application of abscisic acids significantly affects the maize leaf area. The maximum leaf area of maize was observed in T_5= 400 mg/L abscisic acid at tasseling stage (1515 cm^2) and the minimum leaf area of maize was observed in T_1= Drought at tasseling stage (889 cm^2).

A lengthy distal blade and a stem-clinging proximal sheath are linked by an auricle and a membrane ligule to form the maize leaf. The blade and supporting midrib may bend away from the stem thanks to this area that resembles a hinge, which has an impact on the structure and productivity of the plant. The functions of ligule less (lg) genes in creating the blade-sheath border have been extensively studied in ligule less mutants, but their downstream targets are still mostly unknown. Variations in leaf size and shape are significantly affected by a variety of

extreme conditions of environment, including transpiration, thermoregulation and photosynthesis. Altitude causes a reduction in leaf size due to a drop in mean annual rainfall, mean annual temperature and soil quality (McDonald *et al.*,2003). Moreover, drought stress decreased the cob leaf length of maize plants. Application of abscisic acids (ABA) significantly affects the leaf length per plant of maize. Abscisic acid (ABA) improved the drought tolerance in maize. The maximum leaf length per plant of maize was observed in T_5= 400 mg/L abscisic acid at tasseling stage (25.24cm) and the minimum leaf length per plant of maize was observed in T_1= Drought at tasseling stage (10.7cm).

Applying different abscisic acid levels also affected the number of cobs per plant. Water limited conditions decrease the grains and the growth of the maize plants. Corn plants produce fewer corn cobs per plant while under drought stress. According to our findings, the largest number of cobs per plant was seen in T_5= 400 mg/L abscisic acid at tasseling stage (1.38) and a reduced yield of cobs per plant were noted (1.27) in T_1= Drought at the selling stage.

Cob length per plantis related to plant growth and all internal functions of the plants. Plant cell growth is damaged due to the water potential and cell turgidity. Cob length is related to the growth hormone production in the plant. Drought stress also reduced the cob length of maize plants. Application of abscisic acids (ABA) significantly affects cob length per plant of the maize. The maximum cob length per plant of maize was observed in T_5= 400 mg/L abscisic acid (ABA) at tasseling stage (27.5cm) and cob length per plant of maize minimum was observed in T_1= Drought at tasseling stage (13.6cm).

Cob weight is important for the maize crop's biological and yield of the grain of the maize crop. Cob is central core of an ear of corn. It is the part of the ear on which the kernels are grown. Our research shows that abscisic acid (ABA) application considerably impacts the weight of maize grain cobs. The maximum maize cob weight was observed in T_5= 400 mg/L abscisic acid (ABA) at tasseling stage (149.3 g) and the minimum cob weight of maize was observed in T_1= 100 mg/L abscisic acid (ABA) at tasseling stage (83.2 g).

Water-limited conditions decrease the grains and the growth of the plants. Grain yields were reduced by drought stress to 90% in the reproductive stage. Drought stress increased seed weight loss and embryo abortion, which decreased harvest and yield index (Cakir 2004; Monneveux*et al.* 2006). Our results show that abscisic acid (ABA) administration has a considerable impact on the number of grains per cob of maize. T1= Drought at tasseling stage had the fewest grain rows per maize cob (9), while T_5= 400 mg/L abscisic acid (ABA) at tasseling stage had the highest rows of grain per cob of corn (19).

The number of grains per row per cob in the maize crop serves as a measure of crop productivity as every agronomist strives to increase crop yield. Higher grain production is the need of time. The decline in grain yield caused by drought stress has been attributed to the smaller and fewer seeds per cob. A hormone imbalance or disproportionality is familiar with term to induce abortion of embryo and fruit setting in a poor way under drought-stress circumstances 1983's Nunez-Elisea and Davenport. Our research shows that the number of grains per maize cob is considerably impacted using ABA. At the tasseling stage, the largest number of grain rows per cob of maize were observed in T5=400 mg/L abscisic acid (ABA) (26.50) and the least number of grain rows per cob of maize was observed in T1=Drought (14.08).

One quantitative characteristic of maize that directly influences yield is its 1000 grains weight. Grains weight per spike has a direct impact on the harvest index and is critical in yield creation. Our finding indicates that abscisic acid (ABA) significantly affects the 1000 grains weight of the maize. The largest grains weight of 1000 grains of maize were recorded in T_5= 400 mg/L abscisic acid (ABA) at tasseling stage (237.07g) and a

minimum 1000 grains weight of maize was observed in T_1= Drought at tasseling stage (178.26g).

The number of ears produced and the average grain weight per cob determine maize grain yield. The yield of grains was significantly impacted by the drought, although the output of straw was less affected. The maize's pre-cob grain weight is greatly impacted by the application of abscisic acid. The maximum grain size for maize before to cob was noted in T_5= 400 mg/L abscisic acid at tasseling stage (111.9g) and minimum grain weight per cob was observed in T_1= Drought at tasseling stage (51.2g).

The production of dry matter, which is generally regarded as a complex process, and plant dry weight, which is measured at a given date and from which the initial weight of the planting material and the mean relative growth rate are the major constituents over the period of growth, are both complex characteristics. Among the crops, Maize is specifically grown for grain yield and for cob and not for leaves and stem. At the time of harvesting, the target dry matter level of the whole crop is about 30%. Application of abscisic acids (ABA) significantly affects the total dry matter of maize plants. Abscisic acid (ABA) improved the tolerance against the drought in maize. The maximum quantity of total dry matter (8.94 t ha^{-1}) was observed in T_5= 400 mg/L abscisic acid at tasseling stage, and the minimum was observed in T_1= Drought at tasseling stage (7.12 t ha^{-1}).

Stomatal conductance measures the extent of stomatal opening and serves as a gauge for the water status of plants. Abscisic acid, a stress hormone, accumulates in response to several biotic and abiotic stimuli. By shutting stomata, ABA often reduces transpirational water loss in leaves. Since they are unable to walk away from stressful situations, plants must react promptly to them. Abiotic factors such as biotic factors or (drought, salinity, cold and extreme temperature) (pathogens, insects, herbivores). To deal with these circumstances, plants developed a variety of adaption techniques.

Stomatal closure is a classic illustration, which reduces water loss and prevents pathogens from entering the leaves (Melotto*et al.*, 2008). Abscisic acid, a hormone, builds up in plants. ABA accumulation closes stomata while activating genes that help plants regulate their osmotic pressure in order to conserve water (Lim *et al.*, 2015). Increased ABA levels in plants have an impact on how they cross-adapt to fight off diseases, drought, and insect herbivores (Lee et al., 2012; Nguyen *et al.*, 2016). Applying abscisic acid significantly decreases the stomatal conductance of the maize plants. In our experiment, we observed that Maximum stomatal conductance per plant of maize was observed in T_0= Control (125.82) and the minimum stomatal conductance of maize was observed in T_5= 400 mg/L abscisic acid at tasseling stage (102.18).

The rate of photosynthesis is a general indication of how rapidly a plant receives solar energy and fixes it in organic carbon molecules. The application of abscisic acids significantly decreases the photosynthetic rate per plant of the maize. Abscisic acid decreases Photosynthesis in maize.

The amount of water lost by a plant over a specific time is measured by the rate of transpiration. By closing off the stomata, abscisic acid, which is produced naturally by maize plants in response to dry conditions, reduces the amount of water lost through transpiration. As a result, by minimizing water loss, retail plants' shelf lives can be increased with ABA. In drought-stricken situations, abscisic acid is administered to maize plants. It causes the guard cells to respond by either closing the stomata or keeping them from opening when it builds up in the leaves, which lowers transpiration (Mahdieh and Mostajeran, 2009; Milborrow, 1974). Particularly, tissues at the root tips, cortex and stele start to create ABA when a plant is exposed to less moisture in the soil. Application of abscisic acid is significantly decreasing the transpiration rate per plant of maize. The minimum transpiration rate per plant of maize was observed in T_5= 400 mg/L abscisic acid at

tasseling stage (1.12 E=μ mol m^{-2} s^{-1}) and the maximum transpiration rate of maize was observed in T_0=Control (2.76 E=μ mol m^{-2} s^{-1}).

CONCLUSION

Abscisic Acid applied to maize leaves results in a strikingly large increase in yield and other maize growth metrics. The application of ABA at a level of concentration of 400 mg/L during the tasseling stage of the experiment under drought conditions outperformed the other treatments. Because of this, the development and yield of maize improved with the use of abscisic acid (ABA). Abscisic Acid (ABA) has a substantial impact on the development and production of maize under drought conditions.

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Author Contributions

SI is researcher and author of manuscript. NI, AY and SU supervised study conducted. HU, AA and HA guided to conduct research in laboratory. FQ, YA and QUAA helped in formal analysis. SU, AK, and MA helped in manuscript writing review and editing.

Conflict of Interest

The authors declared that there is no conflict of interest regarding the publication of this research

Data Availability

The original data of study is available.

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