OPEN ACCESS Plant Health 02 (01) 2023. 09-15 DOI: 10.33687/planthealth.02.01.4782

Check for updates

Available Online at EScience Press
Plant Health
ISSN: 2305-6835
https://esciencepress.net/journals/planthealth

Effect of Foliar Application of Silicon Dioxide on Yield of Maize (*Zea mays* L.) under Different Water Regimes

Nadeem Akbar, Shakeel Ahmad Anjum, Shahid Nazeer*, Adnan Safdar, Bushra Safdar
Department of Agronomy, University of Agriculture Faisalabad, Pakistan.

ARTICLE INFO

Article History
Received: February 23, 2023
Revised: July 12, 2023
Accepted: July 29, 2023

Keywords
Maize
Water
Stress
Silicon
Yield

ABSTRACT

Maize is one of the most significant cereal crops of the world. Water shortage has damaging effects on food production. Efficient water utilization for crops appears to be quite effective in the current situation of water scarcity. Application of nutrients (Plant Growth Regulators) which increase tolerance to water stress can mitigate the negative effects of water stress. Among the plant growth regulators silicon can increase the tolerance in maize plant for water scarcity. Silicon minimizes the effect of water stress on maize crop particularly at reproductive stage. To evaluate the effect of silicon on yield of maize field experiment was conducted during 2021 at Agronomic Research Area, University of Agriculture, Faisalabad. The experiment was comprised of water stress conditions: no water stress, water stress at 5 leaf stage and water stress at milking stage and levels of foliar application of silicon: no spray, spray @ 40 $mgL^{-1}Si$, 80 $mgL^{-1}Si$, 100 $mgL^{-1}Si$. Randomized complete block design (RCBD) with split plot arrangement was used consisting of three replications. Data of growth, physiology, yield and yield attributes were recorded. The data was analyzed by using Fisher's Analysis of variance technique. The results of present study indicated water stress applied at milking stage significantly reduced the yield characters including cobs per plant, grains and grain rows per cob, grain weight (g), biological yield (t/ha), economical yield (t/ha) and harvest index (%). The foliar applied silicon @ 80mgL^{-1} significantly increased the yield and yield characters.

Corresponding Author: Shahid Nazeer
Email: nazeershahid46@gmail.com

INTRODUCTION

Maize is annual, summer season and cross-pollinated crop which belongs to family *poaceae*. Maize is a significant food crop not only for its consumption worldwide, also due to its nutrition value. Maize tends to provide more carbohydrates as compared with wheat and sorghum. Maize provides a lot of phosphorus and contains small traces of iron, calcium, thiamin and fat (Mboya *et al.,* 2011). Maize is ranked 3rd among cereal crops after wheat and rice in the world as well as in Pakistan according to food and agriculture organization (FAO, 2017). Maize is a determinate nature crop having separate vegetative and reproductive stages also belongs to efficient C_4 plants. Maize can be grown under wide range of edaphic and climatic conditions from clay soil to sandy and in tropical and temperate regions (Ahmad *et al.,* 2008). Maize is one of the most significant cereal crop across the world. Maize is staple food in many countries and comparable to rice and wheat in Asia. Maize, rice and wheat provide about 30 % calories to 4.5 billion people around the globe. Among these consumers about 900 million are poor people. The role of maize in terms of calorie share for human consumption varies significantly across regions (Maqbool, 2021). In Pakistan maize is grown at 3rd number after wheat and rice (area vise) and 98 % of which is cultivated in Punjab and

Khyber Pakhtunkhwa (Tahir *et al.,* 2008). It is cultivated on an area of 1.33 million hectares of Pakistan (Yousaf *et al.,* 2020). Maize is cultivated on an area of 197.19 million hectares worldwide and has a production of about 1134.75 million metric tons with an average of 5.75 metric tons per hectare (FAO, 2017). aize grain is a rich source of proteins, starch, vitamins and minerals. It contains 10 % protein, 3 % sugar, 72 % starch, 8.5 % fiber and 4.8 % oil (Tahir *et al.,* 2008). Maize is also a center of attention among farmers due to its multiple cultivations within a single year. Maize can be grown three times in a year under different climatic conditions. But in Pakistan mostly two seasons of maize are normally practiced (spring and autumn maize). Mostly maize is sown in spring season and less in autumn season (Hanif and Akhtar, 2020).

In addition, climate change is making droughts and heat waves more severe and prolonged, and water supplies more difficult to obtain. This makes it more difficult for crops to survive in extreme conditions caused by water scarcity. Maize is generally tall and broad-leaved, and a severe drought during the seedling or growing period causes leaf curling and stunted growth (Effendi *et al*., 2019). Water shortage disturbs morphological and physiological traits of plants (Kaya *et al.,* 2006). Climate changes now a days predict the prolong periods of drought in near future so crop plants should develop a mechanism of tolerance or some alternate methodology to cop up with these variations. Drought stress when occur at grain forming stage it hampers the yield. Water scarcity also shortens the grain filling period especially in maize (Gamez *et al.,* 2019). Among the various stresses water stress is gaining prominence due to its prevalence. Limiting water availability affects the morphological and physiological traits of plant.

The primary obstacle to maize production remaining sustainable is water scarcity. The performance of the crop in maize is significantly impacted by water deficiency situations throughout the pre-flowering and grain filling periods due to the indefinite function of the characteristics. Numerous components of the crop are impacted, including an increase in blooming days, a delay in maturity, anthesis, silk interval, and leaf count. The 300-500 mm of precipitation required for good yields of maize is grown in many regions (Parveen And Ashraf, 2010). Plant growth regulators are those chemical compounds which either occur naturally or made synthetically that affect metabolic and developmental processes specially when added in low doses. Plant hormones are used in various type of plants and directly affect the metabolic functions of plants. (Rademacher, 2015). Application of nanocompounds and plant growth regulators improves plant and soil health. It is presumed that nano-compounds (PGR) used in agriculture practices may improve rhizospheric microbiota, nature of root exudates and soil health. The introduction of various chemicals, such as pesticides and fertilizers, into the soil system can have a significant impact on soil health. It is proved by research that micronutrients can help in the overall output enhancement (Nazeer *et al*., 2020). Disturbance in soil enzymatic activities can be linked to the soil's microbiological state.

Silicon is the 2nd most abundant element present on earth surface. Although silicon is not included in the essential micronutrients, it is thought one of the beneficial elements for plant growth. Amount of silicon varies from soil to soil. Generally, it ranges from 1% to 45 %. It is present in different forms in the soil but the most absorbable form is Silicic Acid $Si(OH)_4$. Silicon is one of the most important micro molecules that perform its function as recovering plants against many abiotic stresses. It acts as a healer against different stresses and pathogens. Silicon can improve the condition of soil which is toxic and contain heavy metals. Silicon reduces toxicity of Al, Mn and Fe. Silicon can increase the availability of P and encourages salt reclamation and drought tolerance in plants through developing silicified tissues in plants (Parveen and Ashraf, 2010). Silicon supply enhanced osmotic potentials only in the leaves, but not in the roots. A significant rise in the solubility of sugars was also recorded in tobacco (Hajiboland *et al.,* 2017). The major objective of recent research is to investigate the effect of Silicon Dioxide application on yield and yield attributes of Maize and which growth stage of Maize is sensitive to moisture stress.

MATERIALS AND METHODS

During the autumn season of the year 2021, the experiment was conducted at the Agronomic Research Area, University of Agriculture, Faisalabad. The weather prevailing in this geographical area is mostly semi-arid and is classified as subtropical. The trial region used for the present study purpose is situated at a longitude of 73.090 towards East, at latitude of 31.25° towards North and at an elevation of about 184.4 meters above Sea level. Soil property of experimental site is discussed in Table 1.

Table 1. Soil analysis result for physical and chemical characteristics (Normal soil).

Determination	Value	Status
Clay (%)	33.89	
Sand (%)	34.21	
Silt (%)	33.02	
Textural Class	Clqay Loam	
Determination	Value	
Saturation (%)	38.5	
pH	7.8	Slightly Alkaline
EC (dSm^{-1})	1.2	Medium
Organic matter (%)	1.05	Medium
Total Nitrogen (%)	0.046	Low
Available phosphorus (ppm)	88.5	Medium
Available Potassium (ppm)	132.49	Sufficient

ppm= parts per million

The meteorological data was taken from Department of Agronomy Crop Physiology section, University of Agriculture, Faisalabad. The detail of climatic data of entire trial duration is given in Figures 1 and 2.

Effect of different water regimes on yield components of maize (*Zea mays* L.) is discussed in Table 2. The experimental trial was carried out utilising the standardised experimental design Randomized Complete Block Design (RCBD) in accordance with split plot arrangement with three replications. The current study was designed to look into the effect of foliar silicon on yield of maize under water-stress conditions. Mean Comparison of foliar applied silicon dioxide on maize yield for silicon levels are discussed in Table 3. Recommended dose of fertilizers are NPK 202:114:90 kg/ha. Sources of fertilizers were Urea CH_4N_2O, DAP (Diammonium Phosphate) $(NH_4)_2HPO_4$ and MOP (Muriate of Potash) KCl. Full dose of DAP and MOP was applied at time of sowing. About 1/3rd concentration of urea was applied at time of sowing, 1/3rd with first irrigation and remaining dose was applied with third irrigation.

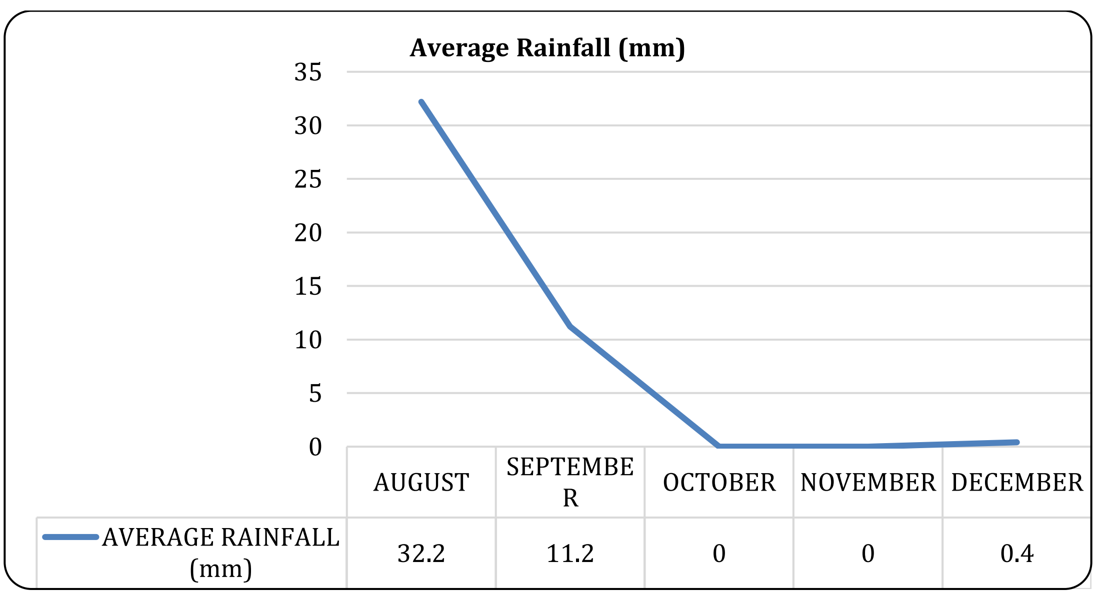

Figure 1. Graphically demonstration of mean monthly rainfall.

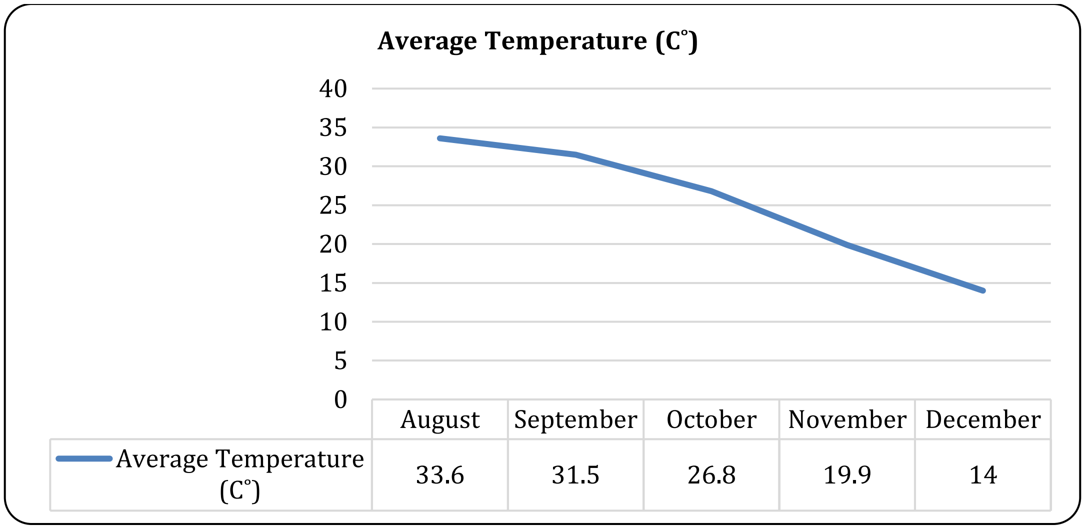

Figure 2. Graphically demonstration of mean monthly temperature.

Sowing of crop was on ridges with row-to-row distance of about 75 cm and DS-555 hybrid variety of maize was cultivated. The net plot size was 4m*3m. Suggested seed rate of maize is 25kg/ha. All cultural practices were kept constant. The details of all treatments are: W_0 = No stress (Normal irrigations), W_1 = Skip irrigation at 5 leaf stage (30 days after sowing), W_2 = Skip Irrigation at milking stage (60 days after sowing), S_0 = Silicon 0 mg/L, S_1 = Si 40 mg/L, S_2 = Si 80 mg/L, S_3 = Si 120 mg/L. At maturity, equal sized area from each treatment was harvested for the calculation of different parameters regarding yield and quality. The sample that was gathered for the experimental observations was assessed from that sample using the LSD test at the 5 % confidence level. (Steel *et al*., 1997).

RESULTS

Impact of Water Deficit and Silicon Foliar Application on Crop Growth and Yield Attributes

In the current study, it was discovered that drought had a negative impact on the growth and yield characteristics of maize hybrids, including plant height, stem diameter, leaf number, cob length, number of grains per cob, 100 grain weight, grain yield, and biological yield.

Impact of Water Deficit and Silicon Foliar Application on Relative Water Content (RWC)

Mean comparison Table 2 showed water deficit has negative influence on RWC foliar application of silicon significantly improved the RWC under no stress and water stress condition. The maximum relative water contents (80.14 %) were recorded in no stress conditions with silicon application while minimum RWC (54.14 %) were recorded in water stress conditions. Silicon fertilization proved to be effective to improve the RWC.

Impact of Water Deficit and Silicon Foliar Application on Plant Height

Plant height is an important parameter of plant which directly refers to the yield of plant. Plant height is directly proportional to the final yield of plant. More the height of plant indicare good plant health and ultimately more yield. Mean comparison table showed water deficit has negative influence on plant height of maize crop. Foliar application of silicon significantly improved the water use efficiency of plants and indirectly influenced the plant height of maize crop. The maximum plant height (235.42 cm) was recorded under stress conditions and a minimum of (212 cm) plant height. When foliar application of silicon was done then the maximum plant height (242 cm) and a minimum of (215.45) were recorded.

Impact of Water Deficit and Silicon Foliar Application on Cob Length (cm)

Analysis of variance showed that drought stress applied at milking stage significantly reduced the cob length of maize crop under water deficit conditions. Mean comparison table showed water deficit negatively affect the cob length). The maximum cob length (17.68 cm) was recorded under no stress while minimum cob length (15.48 cm) was recorded under water stress conditions. Foliar application of silicon significantly increased the cob length both under no stress and water stress condition. Maximum cob length (18.40 cm) was recorded with silicon application while minimum cob length (15.57) was recorded under control conditions.

Table 2. Effect of different water regimes on yield components of maize (*Zea mays* L).

Treatments	Relative Water Content (%)	Plant Height (cm)	No. of cobs per plant	Cob Length (cm)	Cob Diameter (cm)	No of Grains per Cob	100-grain weight (g)	Biological yield (t ha-1)	Economical Yield (t ha-1)	Harvest index (%)
W_0=(Contro) Normal irrigations	72.92	226.91	1.75	17.46	4.02	521.25	25.91	17.44	7.09	40.80
W_1=Skip irrigation at 5 leaf stage	62.28	214.58	1.65	16.73	3.75	537.72	27.30	16.15	6.71	41.29
W_2=Skip irrigation at Milking Stage	74.49	219.99	1.63	16.82	3.68	495.38	27.01	15.41	6.24	40.11
LSD0.05	5.6681	3.1056	0.1000	0.0660	0.1830	7.6121	0.3766	0.2836	0.6120	3.8689

dSm^{-1}= deciSiemens per metre; %= percentage

Impact of Water Deficit and Silicon Foliar Application on Cob Diameter (cm)

Analysis of variance showed that drought stress applied at 50 % tasseling stage negatively affected the cob diameter of maize crop under water deficit conditions. Mean comparison table showed water deficit significantly reduced the cob diameter. Maximum cob diameter (4.10 cm) was recorded in no stress conditions while minimum cob diameter (3.59 cm) was recorded in water stress conditions. Foliar application of silicon proved to be effective to increase cob diameter under both no stress and water stress conditions. The maximum cob diameter (4.16 cm) was recorded under silicon application while minimum cob diameter (3.61 cm) was recorded with no silicon foliar application.

Table 3. Effect of foliar application of different silicon levels on yield components of maize (*Zea mays* L).

Treatments	Relative Water Content (%)	Plant Height (cm)	No. of cobs per plant	Cob Length (cm)	Cob Diameter (cm)	No of Grains per Cob	100-grain weight (g)	Biological yield ($t\ ha^{-1}$)	Economical Yield ($t\ ha^{-1}$)	Harvest index (%)
S_0 = 0mg/L silicon Application	66.89	205.33	1.67	16.63	3.72	14.44	26.22	16.26	6.82	39.74
S_1 = 40mg/L Silicon Application	69.16	218.88	1.60	17.07	3.77	14.59	26.11	16.18	7.04	40.67
S_2 = 80 mg/L Silicon Application	71.08	230.59	1.76	17.16	3.91	15.19	27.60	16.55	7.4	41.66
S_3 = 120mg/L silicon Application	72.58	227.18	1.69	17.14	3.84	14.52	27.02	16.34	7.08	40.87
LSD 0.05	4.6468	2.9707	0.1452	2.0381	0.0311	0.2087	0.2840	0.2750	0.2215	1.4410

DISCUSSION

The current trial's findings indicated that physiological (relative water content and water potential), developmental, and (leaf fresh weight, leaf dry weight, LAI (Leaf Area Index) etc) and yield related parameters (number of grains per cob, grain rows per cob, grain weight per cob etc.) of maize crop are expressively affected by water deficit conditions. Water scarcity severely affected the growth and yield attributes of the maize plants. Silicon treatment cause buildup of solutes so water moves into the cell from nearby, this led to improvement in leaf potential of plant in moisture stress (Abobatta , 2020). When applied silicon at 5 leaf stages then it was determined that leaf water potential increased. Relative water contents are the actual amount of water that a plant leaf can have when tis fully turgid. It is the ratio of water and the dry matter present in the leaf more the water present in the leaves more will be its relative content. This also indicates the vegetative growth of the plant. Moisture efficiently decreased the RWC of the maize crop. Drop in relative water content of plant leaves in moisture deficit conditions might be because of inaccessibility of water in the soil. Liang et al. (2007) revealed that due to accumulation polar mono-silicic acid in the epidermis cell walls water molecules may escape less effectively from the lea surface. This led to increase in plant water status. Ali *et al*. (2019) suggested that silicon application in wheat improved the numerous plant attributes like plant height, 1000-grain weight, kernel per spike economical yield biological yield and HI (harvest index). Plant height was considerably affected in maize hybrid when plants were grown under the water scarcity and treated with silicon. Cob length directly contributes to grain yield. An increase in cob length results in increased in number of grains per cob and grain yield. Cob length specifies the vegetative as well as the reproductive growth of the plant. It is an important parameter contributing towards the harvest index of the plant. Cob diameter is an important parameter of maize which directly contributes to final yield of maize crop. Cob diameter generally contributes to the number of grain rows per cob. More the number of grain lines more will be the grain number and grain weight. So it directly affects the economical yield and harvest index of plant. However, the use of silicon dramatically enhanced these plant characteristics. (Amin, Muhammad, *et al*., 2018).

CONCLUSION

It is concluded that with the application of different plant growth regulators especially Silicon has significant effect on grain yield and yield components. Silicon has positive response against limited water supply or water shortage. The lowest values of yield attributes were obtained from S_0 (no Silicon application) from where no application of any plant growth regulators. Maximum yield and components of yield was obtained from S_2 (Silicon 80 mg/L).

ACKNOWLEDGEMENT

Present research work was done during my M.Sc (Hons.). I am very thankful to my worthy supervisor and all the authors who contributed during my research and paper writing.

CONFLICT OF INTEREST

The authors have not declared any conflict of interests.

REFERENCES

Abobatta W.F. 2020. Plant responses and tolerance to combined salt and drought stress. In Salt and drought stress tolerance in plants, 4: 17-52.

Ahmad H.A.H., E.E. Harb, M.A. Higazy and S.H. Morgan. 2008. Effect of silicon and boron foliar application on wheat plants grown under saline soil conditions. International Journal of Agricultural Research, 3:1-26.

Ali S., M. Rizwan, A. Hussain, M.Z. ur Rehman, B. Ali, B. Yousaf, L. Wijaya, M.N. Alyemeni and P. Ahmad. 2019. Silicon nanoparticles enhanced the growth and reduced the cadmium accumulation in grains of wheat (*Triticum aestivum* L.). Plant Physiology and Biochemistry, 140: 1-8.

Amin M., R. Ahmad, A. Ali, I. Hussain, R. Mahmood, M. Aslam and D.J Lee. 2018. Influence of silicon fertilization on maize performance under limited water supply. Silicon, 10: 177-183.

Effendi R., S.B. Priyanto, M. Aqil and M. Azrai, 2019. Drought adaptation level of maize genotypes based on leaf rolling, temperature, relative moisture content, and grain yield parameters. IOP Conference Series: Earth and Environmental Science, 270.

FAO L.F.A.D. and UNICEF. 2017. The state of food security and nutrition in the world 2017. Building Resilience for Peace and Food Security (Food and Agriculture Organization, Rome).

Gámez A.L., D. Soba, A.M. Zamarreño, J.M. García-Mina, I. Aranjuelo and F. Morales. 2019. Effect of water stress during grain filling on yield, quality and physiological traits of Illpa and Rainbow quinoa (*Chenopodium quinoa* Willd.) cultivars. Plants, 8:

173-174.
Hajiboland R., L. Cherghvareh and F. Dashtebani. 2016. Effect of silicon supplementation on wheat plants under salt stress. Journal of Plant Process and Function, 5: 1-12.
Hanif N.Q. and N. Akhtar. 2020. Nutritional Evaluation of Maize Plant Fodder Grown in Spring and Autumn Season in Punjab, Pakistan. Journal of Bioresource Management, 7: 9-10.
Kaya C., L. Tuna and D. Higgs. 2006. Effect of silicon on plant growth and mineral nutrition of maize grown under water-stress conditions. Journal of Plant Nutrition, 29: 1469-1480.
Liang Y., W. Sun, Y.G. Zhu and P. Christie. 2007. Mechanisms of silicon-mediated alleviation of abiotic stresses in higher plants: a review. Environmental Pollution, 147: 422-428.
Maqbool M.A., A.B. Issa and E.S. Khokhar. 2021. Quality protein maize (QPM): Importance, genetics, timeline of different events, breeding strategies and varietal adoption. Plant Breeding, 140: 375-399.
Mboya R., P. Tongoona, J. Derera, M. Mudhara and A. Langyintuo. 2011. The dietary importance of maize in Katumba ward, Rungwe district, Tanzania, and its contribution to household food security. African Journal of Agricultural Research, 6: 2617-2626.
Nazeer S., M. Tahir, M. Sajjad, M. Idrees, M.A. Saleem, A. Shehzad and M.U. Hameed, 2020. Response of Different Micronutrients (Zn, Cu and Mn) Soil Application on Yield and Quality of Late Sown Wheat (*Triticum aestivum* L.) under Faisalabad.
Nusrat P. and A. Muhammad. 2010. Role of silicon in mitigating the adverse effects of salt stress on growth and photosynthetic attributes of two maize (*Zea mays* L.) cultivars grown hydroponically. Pakistan Journal of Botany, 42: 1675-1684.
Parveen N. and M. Ashraf. 2010. Role of silicon in mitigating the adverse effects of drought stress on growth and photosynthetic attributes of two maize (*Zea mays* L.) cultivars grown hydroponically. Pakistan Journal of Botany, 42: 1675-1686.
Rademacher W. 2015. Plant growth regulators backgrounds and uses in plant production. Journal of plant growth regulation, 34: 845-87.
Tahir M., A. Tanveer, A. Ali, M. Abbas, and A. Wasaya. 2008. Comparative yield performance of different maize (*Zea mays* L.) hybrids under local conditions of Faisalabad-Pakistan. Pakistan Journal of Life and Social Sciences, 6: 118-120.
Yousaf M.I., K. Hussain, S. Hussain, A. Ghani, A. Shehzad, A. Mumtaz, M.A.A. Mehmood, M.U. Khalid, N. Akhtar and M.H. Bhatti. 2020. Seasonal influence, heat unit accumulation and heat use efficiency in relation to maize grain yield in Pakistan. Maydica, 64:.9-15.