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Research Article

Effect of Foliar Application of Salicylic Acid on Yield of Maize (Zea mays L.) under different Water Regimes

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Abstract

Maize is the third most important cereal crop after wheat and rice in the world and plays a significant role in human nutrition. Its area and production have been substantially increased during recent years in Pakistan. Water contributes more than 70% in the composition of plant body and is important for all anabolic/catabolic processes. Among all the abiotic stresses the water shortage is the major one. To explore the efficacy of exogenously applied salicylic acid in mitigating the drought effects under different water regimes on maize growth and yield, a field experiment was conducted at Agronomic Research Area, University of Agriculture Faisalabad Pakistan, during autumn, 2021. The layout of experimental trial was comprised of randomized complete block design with split plot arrangement with gross plot size of 5 m × 3 m. There were two factors in this study; factor A comprised of different irrigation regimes such as no stress, skip irrigation at knee height, and skip irrigation at tasseling. Whereas the factor B comprised of salicylic acid treatments viz; 0 mg L-1, 100 mg L-1, 200 mg L-1, and 300 mg L-1. Water stress was applied at varying described stages. Drought stress influenced badly the physiological features and other growth and yield related attributes of maize crop and exogenous salicylic acid application was found helpful to enhance crop yield performance by increasing stress tolerance in maize. Salicylic acid as foliar application @ 300 mg L-1 was recorded best which ameliorated the moisture stress and improved the crop yield performance.

Keywords: Maize, salicylic acid, abiotic stress, water regimes, foliar application.

Introduction

The maize (Zea mays L.) is the most important cereal crop in Pakistan as well as in the world and it is most cultivated crop after wheat and rice according to food and agriculture organization. Maize is cross pollinated crop with determinate nature. It has great economic importance in livestock and poultry. The plants of maize are C4 in category and belongs to family Poaceae (Gramineae). Maize can grow on soil ranging from sandy to clayey and can be grown in tropical subtropical and temperate region. However, soil of moderate texture with pH of 6.5 to 7.5 suited well for maize (Ahmad et al., 2018).

Maize was cultivated on 1418 thousand hectares which was 1 percent more than last year. The yield of maize increases 8.465 million tons which was 7.4 percent more as compared to last year. The production was increases due to large area under cultivation, availability of better cultivars, more economic returns, and production technology. Maize production contributes 3.4 percent in agriculture and 0.6 percent in agriculture GDP. Maize is cultivated for various purpose such as food, feed, and fodder. While its consumption by human is decreases but consumption in wet milling industry and in feed is increases day by day.

Maize grows intensely in world due to this it is called "king of grain crops" (Tahir et al., 2008). Maize has great importance among farmers of Pakistan because it can grow three times in a year. However, most suitable seasons for cultivation of maize are spring and autumn. Maize is cultivated more in spring, than autumn season. The grains of maize are rich in necessary nutrients and possess 10% protein, 72% starch, 8.5% fiber, 4.8% oil, 3% sugar, and 1% ash (Hanif and Akhtar, 2020).

Water contributes more than 70% in the composition of plant body and is important for all anabolic/catabolic processes. Soil and climatic conditions of Pakistan are highly suitable and cultivars with high yield potential and resistant against disease are available but our yield per acre is low when we compare with developed countries like USA, Egypt, and Canada. The consumption of maize by human is about 8 to 10%. Water shortage is one of the emerging factors which affect the productivity and growth of plant, which appears to be more prevalent in arid regions. Water stress affect every developmental stage of maize, but it causes more disaster when water stress occurs at various stages of plant growth such as germination, seedling, flowering, root length initiation and shoot length initiation. Abiotic stress affects the yield of maize and can cause yield reduction up to 50% (Ahmad et al., 2018). Other than abiotic stress water shortage is a major limiting factor in maize production (Tariq and Iqbal, 2010). In response of water deficit plants become adapted to drought through various biochemical and phenological modifications (Manzoor et al., 2015). About 66% maize in our country has plenty of water for growth and development and remaining grow in rainfed region (Tariq and Iqbal, 2010). The increasing shortage of water worldwide and increasing cost of irrigation make world to develop modern methods that increase water use efficiency and decrease water loss (Burhan and Rehan, 2018).

Plant growth regulators are natural or synthetic chemical compounds that are used to regulate the plant growth such as reduced growth or increasing yield. Plant growth regulators are synthetic compounds that are used to reduce the unwanted growth of plant without having any effect on its productivity (Leolato et al., 2017).

Salicylic acid is well known signal modulating molecule that modulate the plant response to environmental stress. It is white odorless powder having chemical formula $C_7H_6O_3$, work in plant in maintenance of plant growth hormone and enzyme. Salicylic acid may cause a vital role in photosynthesis, plant water relations, stomatal regulation, and growth. Salicylic acid also involves in enhancing the resistance against pathogens. It is already known that salicylic acid can alter the production of ethylene in maize (Németh et al., 2002). Foliar application of salicylic acid may promote growth of some crops by reducing the water stress that inhibit the growth (Burhan and Rehan, 2018).

Methodology

The practical demonstration of this planned study was done at student research area, Agronomic research farm, university of Agriculture Faisalabad, Punjab, Pakistan. which was situated at the latitude 31° north and 73° south longitudes with elevation of the land beyond the sea level about 184 m. The research conduction was during autumn growing season of the year 2021. The climate of the site is semi-arid and subtropical. Average rainfall and temperature data during crop season showed in figure 1 and 2 respectively. The report of soil analysis of experimental site showed in table 1. The design of this study was randomized complete block design with split plot arrangement. Each treatment was repeated three times and net plot size was used 3.0 × 4.0 m. Maize hybrid used for research was DS-555. The seeds were sown on ridges by dibbling using R×R 75 cm distance and recommended seed rate 25kg ha^{-1} was used. N. P. K. fertilizers were applied at the rate of 202-114-90 NPK kg ha^{-1}, utilizing Urea, DAP and MOP for N. P. K, respectively as fertilizer sources. Fertilizers containing potassium and phosphors were provided as a whole at the time of planting, but the application of nitrogen was divided in three equal splits 1st dose (1/3 of the total amount) was applied at sowing time, 2nd at 35 days after sowing (vegetative stage) and 3rd dose was applied at reproductive stage. All the agronomic practices including thinning, hoeing, pesticide application and other plant protection measures were practiced uniformly, keeping treatment variables under consideration from sowing up to the maturity of the crop. Different concentrations of salicylic acid were used at different growth stages of maize. The details of all treatments are following Factor A: Water Regimes (W), Wo = No stress (Control), W1 = Skip irrigation at knee height, W2 = Skip irrigation at tasseling; Factor B: Salicylic Acid (C), So = 0 mg L-1, S1 = 100 mg L-1, S2 = 200 mg L-1, and S3 = 300 mg L-1. At maturity observation were taken for the calculation of different parameters for yield. The LSD test at the rate of 5 % probability were applied to compare means (Steel et al., 1997).

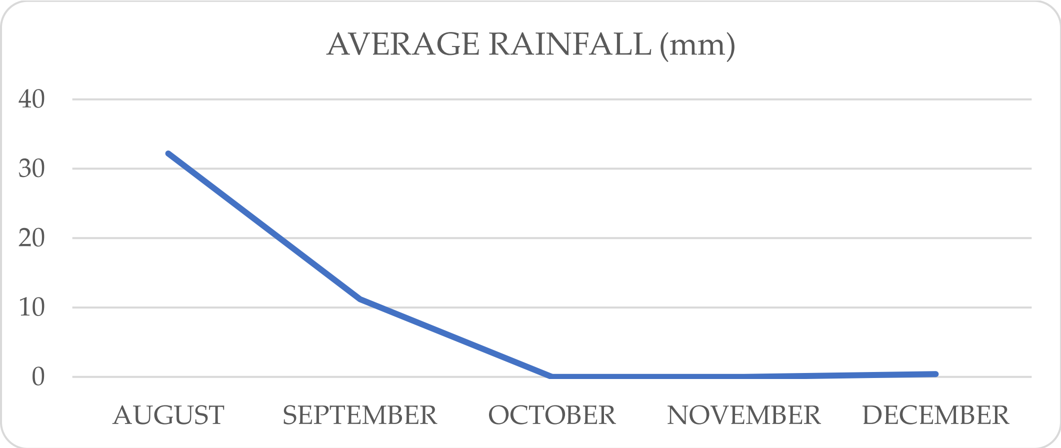

Figure 1. Graphically demonstration of average monthly rainfall.

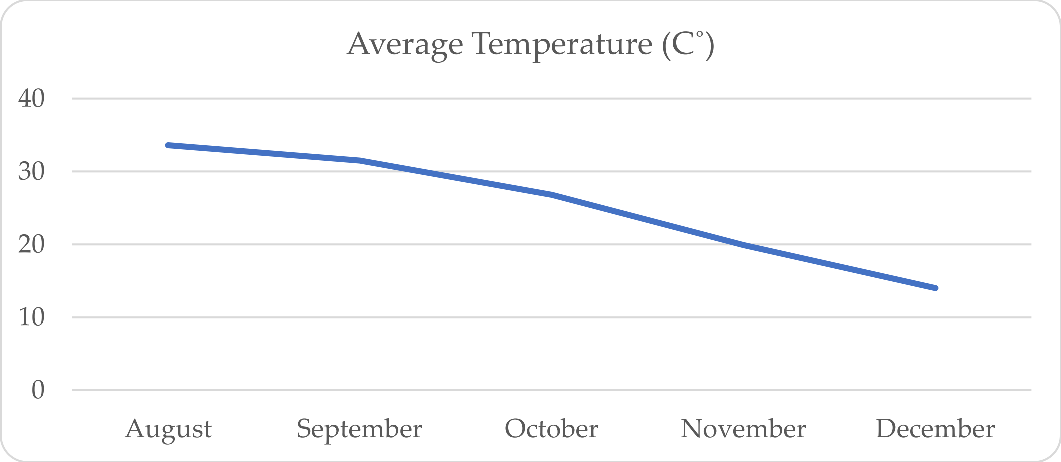

Figure 2. Graphically demonstration of average monthly temperature.

Table 1. Soil analysis for physical properties.

Determination	Value
Clay (%)	33.80 %
Sand (%)	34.20 %
Silt (%)	32.04 %
Textural class	Clay loam

Result and Discussion

Relative Water Contents (%)

Relative water content (RWC) is probably the most appropriate measure of plant water status in terms of the physiological consequence of cellular water deficit. Water potential as an estimate of the energy status of plant water is useful in dealing with water transport in the soil-plant-atmosphere continuum. Relative water contents are the actual amount of water in plant leaf at a given time, relative to the maximum amount of water that a plant leaf can hold in fully turgid conditions. Mean comparison revealed negative impact of drought stress on relative water contents applied at both stages of crop growth. Statistically, maximum relative water contents (74.66%) were noted in control treatment (Wo). while minimum relative water contents (62.57 %) were observed when hold irrigation at tasseling stage (W2) (table 2). The maximum relative water contents (72.75 %) were reported in treatment S3 (foliar application @ 300 mg L-1). The minimum relative water contents (69.23%) in treatment S1 (foliar application @ 100 mg L-1) (table 3). On the other hand, minimum water content was noted in So where no salicylic acid was applied, and moisture stress given at time of reproductive stage.

Moisture stress caused substantial reductions in relative water contents of plants which further influenced growth badly (Zhang et al., 2007; Elgamaal and Maswada, 2013). In our study, around 6 percent increase was observed in treatment where salicylic acid was applied both as foliar spray, compared to the treatment where salicylic acid was not provided. Similarly, it was found that moisture stress is a reducing factor for relative water contents of plants (Jiang and Huang, 2002; Unyayar et al., 2004; Efeoglu et al., 2009). Our results were supported by Latif et al. (2016) as they reported decline in relative water contents under drought conditions and improvement due to salicylic acid application on maize crop. Another study also described salicylic acid as beneficial entity to alleviate drought impact in maize crop (Rao et al., 2012; Maswada et al., 2018).

No of Leaves Per Plant

Number of leaves/plant plays a significant role in plant growth and development because leaves are the factories of food synthesis process. Data regarding number of leaves showed that drought stress applied at knee height and tasseling stage both significantly affect the amount of leaves/plant. Data showed that there was minimum number of leaves in W2 where stress applied at tasseling and maximum number of leaves was noted in Wo (table 2) where no water stress was applied.

The salicylic acid was reported an effective compound to improve this parameter in both stress and non-stress conditions. Statistically maximum no of leaves/plant (17.15) was noted in treatment S3 (foliar application @ 300 mg L-1 of salicylic acid) and minimum no of leaves (15.89) was noted when no salicylic acid application was done (table 3).

The results regarding the effect of drought stress on number of leaves per plant were found significant. Drought stress may cause the death of leaves (Kochaki and Sarmadnia, 2005), but the numbers remain same, and these results are in agreement with that of Ali et al. (1999) who described that deficit moisture had slightly effect on number of leaves per plant of maize crop.

Cob Length

Cob length is an important yield indicator and was measured to check the effect of stress and salicylic acid on maize crop. Cob length decides the number of grains per cob. An increase in cob length results a greater number of grains per cob. Results of collected data were marked highly significant regarding the effect of salicylic acid on cob length.

It was revealed from mean comparisons that drought stress at tasseling stage (W2) put its negative effects on cob length and minimum cob length was observed (15.75 cm). Statistically, maximum cob length (16.69 cm) was recorded in (Wo) where no water stress applied (table 2).

Salicylic acid caused significant enhancement in cob length under both drought and no drought situations. The maximum cob length (17.56 cm) was noted in S3 treatment where salicylic acid was applied as foliar application @ 300 mg L-1 and minimum cob length (14.96 cm) was noted in So treatment where there was no salicylic acid was applied (Table 3).

Foliar spray of salicylic acid @ 300 mg L-1 in combination with drought stress at tasseling W2 was found better for growth and developmental parameters except. The cobs are reproductive parts and decline in their size and weight can be related with the disturbed translocation of photo assimilates towards these parts due to drought stress and hence decreasing their length, diameter and weight. Anjum et al. (2011) also found a decline in cob length of maize under water deficiency.

Yield Components

Some of important parameters like number of cobs per plant, number of rows per cob, and 100-grain weight has considerable contribution in final yield of maize crop. No of cobs per plant influence the economical yield, no of grains rows influence the weight and size of grains.

Results showed that these parameters were maximum when there was no stress like in Wo and these were minimum when we applied moisture stress at tasseling stage of crop development W2 (table 2). Similarly maximum value of yield components (number of cobs per plant, number of rows per cob, and 100-grain weight) was recorded in S3 treatment where application of salicylic acid was done as foliar application @ 300 mg L-1 and minimum value of these yield components were recorded where no salicylic acid application was done (table 3).

The negative influence of an external stress on these attributes can be clearly seen in the form of decreased final yield. It can be observed from our study findings that yield and yield related components are sensitive to be affected and severely hampered by externally imposed moisture stress, but salicylic acid application @ 300 mg L-1 reduce the negative effect of drought. Data of current study is in accordance with the results of Zahedi et al. (2014) who reported significant increase in yield and yield attributes due to salicylic acid application at different stages of growth in maize crop. Our results also resemble to Zamaninejad et al. (2013) who stated that there was significant decrease in yield and yield attributes due to moisture stress applied on maize during different growth stages of maize.

Biological Yield

Biological yield is the main parameter and represents the total biomass produced by all parts of plants i.e., sum of grain yield and straw yield. It is affected by management practices and all the other environmental factors.

Our results revealed that maximum biological yield (16.53 t ha-1) was reported under control (Wo) where no moisture stress applied and minimum (14.73 t ha-1) was found in depleted moisture conditions at tasseling stage (W2) (table 2). Similarly salicylic acid revealed its pronounced effect by increasing biological yield and maximum biological yield (16.98 t ha-1) was observed in S3 treatment where salicylic acid was applied as foliar application @ 300 mg L-1 and minimum (14.71 t ha^1) was noted in So (no salicylic acid application) (Table 3).

These results were supported with research of Abdulai et al. (2007) described that production of more biological yield is related with the normal availability of water required by crop.

Grain Yield

Grain yield is one of the major attributes of crop production and determines the output of economic produce. It is influenced by management activities and different type of stress factors. Results of data regarding grain yield were found highly significant under the application of salicylic acid.

Significant improvement in grain yield by salicylic acid application was found under both normally water and stressed situations. S3 treatment (foliar application @ 300 mg L-1 of salicylic acid) produced maximum grain yield (8.70 t ha-1) while, economical yield produced by So treatment where there was no salicylic acid application, was minimum (7.27 t ha-1) recorded (Table 3).

Our results were similar with (Burhan and Rehan, 2018) who got the similar increase in grain yield when apply 300mg/l salicylic acid. Who stated increase in grain yield might be due to the influence of irrigation and SA application on a number of growth parameters such as grain rows ear-1, grains ear-1, 1000 grains weight by producing more vigorous growth and development. Amin et al. (2013) found the salicylic acid as effective compound to enhance final yield of maize crop due to improvement of all features related to yield.

Harvest Index

Harvest index is the percentage of economical yield over biological yield. It tells about the conversion efficiency of synthesized photosynthates into economic parts or assimilation of food into seeds.

Harvest index was decreased severely due to water stress at knee height stage and maximum harvest index (54.51 %) was observed in no stress (W2) while, minimum harvest index (50.97 %) was observed in (W1) stress situations (table 2).

Harvest index was significantly enhanced by salicylic acid application in both non-stress and stressed situations. The maximum value of harvest index (54.75 %) was recorded in S1 treatment (Foliar spray @ 100 mg L-1 of salicylic acid) and minimum (49.5%) was recorded in So treatment where there was no salicylic acid application (Table 3).

A considerable decrease in grain yield of maize was reported by Zhang et al. (2007) and this decrease in maize yield may be due to less absorption of radiations by canopy and reduced harvest index (Earl and Davis, 2003).

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

Treatments	Relative water content (%)	No of leaves per plant	Cob length (cm)	No of cobs per plant	No of grain rows per cob	100 grain weight (g)	Biological yield (t/ha)	Grain yield (t/ha)	Harvest index (%)
W_0 (no water stress)	74.66 a	17.39 a	16.69 a	1.8 a	15.44 a	27.74 a	16.53 a	8.44 a	51.12
W_1 (water stress at knee height)	72.95 a	17.14 a	16.40 a	1.7 a	15.14 a	26.11 b	16 03 a	8.15 a	50.97
W_2 (water stress, tasseling stage)	62.57 b	15.20 b	15.57 b	1.4 b	13.58 b	25.14 b	14.73 b	8.04 b	54.51
LSD value	5.14	0.7035	0.8819	0.2478	0.6078	1.4431	0.9932	0.5174	1.8038

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Treatments	Relative water content (%)	No of leaves per plant	Cob length (cm)	No of cobs per plant	No of grain rows per cob	100 grain weight (g)	Biological yield (t/ha)	Grain yield (t/ha)	Harvest index (%)
S_0 (no salicylic acid application)	66.75 b	15.89 b	14.94 d	1.6 b	13.85 c	24.75 b	14.71 c	7.27 b	49.50
S_1 (salicylic acid applied @ 100mg/l)	69.23 ab	16.44 ab	15.74 c	1.6 ab	14.55 b	25.96 ab	15.34 bc	8.36 a	54.75
S_2 (salicylic acid applied @ 200mg/l)	71.52 a	16.82 a	16.65 b	1.7 ab	14.82 b	26.50 ab	16.02 b	8.50 a	53.18
S_3 (salicylic acid applied @ 300mg/l)	72.75 a	17.15 a	17.56 a	1.8 a	15.67 a	28.11 a	16.98 a	8.70 a	51.37
LSD value	4.42	0.7178	0.2773	0.1448	0.6061	2.1705	0.7890	0.2898	3.5692

Conclusion and Policy Recommendations

Exogenously applied salicylic acid proved itself most efficient compound and revealed a reasonable impact on maize growth and final yield by boosting up stress tolerance. So, it is concluded that application of salicylic acid as foliar spray @ 300 mg L-1 diminishes drought stress effects on maize crop and increase productivity.

References

Abdulai, M.S., Sallah, P.Y.K. and Safo-Kantanka, O., 2007. Maize grain yield stability analysis in full season lowland maize in Ghana. Int. J. Agric. Biol, 9(1), pp.41-45.

Ahmad, H., Khan, I., Liaqat, W., Jan, M.F. and Ahmadzai, M.D., 2018. Effect of salicylic acid on yield and yield components of maize under reduced irrigation. Int J Environ Sci Nat Res, 9(3), pp.1-5.

Ali, M.A., Sarwar, A.K.M.G. and Prodhan, A.K.M.A., 1999. Effect of water stresses on the growth features of different maize (Zea mays L.) cultivars. Pak. J. Bot, 31(2), pp.455-460.

Amin, A.A., El-Kader, A.A., Shalaby, M.A., Gharib, F.A., Rashad, E.S.M. and Teixeira da Silva, J.A., 2013. Physiological effects of salicylic acid and thiourea on growth and productivity of maize plants in sandy soil. Communications in soil science and plant analysis, 44(7), pp.1141-1155.

Din, B.U. and Rehan, W., 2018. Yield and Yield Components of Maize as Influenced by Salicylic Acid under Reduced Irrigation. Middle East J, 7(2), pp.331-338.

Earl, H.J. and Davis, R.F., 2003. Effect of drought stress on leaf and whole canopy radiation use efficiency and yield of maize. Agronomy journal, 95(3), pp.688-696.

Efeoğlu, B., Ekmekçi, Y.A.S.E.M.I.N. and Çiçek, N.U.R.A.N., 2009. Physiological responses of three maize cultivars to drought stress and recovery. South African journal of botany, 75(1), pp.34-42.

Elgamaal, A.A. and Maswada, H.F., 2013. Response of three yellow maize hybrids to exogenous salicylic acid under two irrigation intervals. Asian Journal of Crop Science, 5(3), pp.264-274.

Hanif, N.Q. and Akhtar, N., 2020. Nutritional Evaluation of Maize Plant Fodder Grown in Spring and Autumn Season in Punjab, Pakistan. Journal of Bioresource Management, 7(1), p.9.

Jiang, Y. and Huang, B., 2002. Protein alterations in tall fescue in response to drought stress and abscisic acid. Crop Science, 42(1), pp.202-207.

Kochaki, A. and G. Sarmadnia. 2005. Crops physiology. Mashhad Jehad Daneshgahi Press (Translated in Persian).

Latif, F., Ullah, F., Mehmood, S., Khattak, A., Khan, A.U., Khan, S. and Husain, I., 2016. Effects of salicylic acid on growth and accumulation of phenolics in Zea mays L. under drought stress. Acta Agriculturae Scandinavica, Section B—Soil & Plant Science, 66(4), pp.325-332.

Leolato, L.S., Sangoi, L., Durli, M.M., Panison, F. and Voss, R., 2017. Growth regulator and maize response to the increase in plant density. Pesquisa Agropecuária Brasileira, 52, pp.997-1005.

Manzoor, K., Ilyas, N., Batool, N., Ahmad, B. and Arshad, M., 2015. Effect of Salicylic Acid on the Growth and Physiological Characteristics of Maize under Stress Conditions. Journal of the Chemical Society of Pakistan, 37(3).

Maswada, H.F., Abd El-Razek, U.A., El-Sheshtawy, A.N.A. and Elzaawely, A.A., 2018. Morpho-physiological and yield responses to exogenous moringa leaf extract and salicylic acid in maize (Zea mays L.) under water stress. Archives of Agronomy and Soil Science, 64(7), pp.994-1010.

Németh, M., Janda, T., Horváth, E., Páldi, E. and Szalai, G., 2002. Exogenous salicylic acid increases polyamine content but may decrease drought tolerance in maize. Plant Science, 162(4), pp.569-574.

Rao, S.R., Qayyum, A., Razzaq, A., Ahmad, M., Mahmood, I. and Sher, A., 2012. Role of foliar application of salicylic acid and l-tryptophan in drought tolerance of maize. J. Anim. Plant Sci, 22(3), pp.768-772.

Shakeel, A.A., Xiao-yu, X., Long-chang, W., Muhammad, F.S., Chen, M. and Wang, L., 2011. Morphological, physiological and biochemical responses of plants to drought stress. African journal of agricultural research, 6(9), pp.2026-2032.

Steel, R.G.D., J.H. Torrie and D.A. Dicky. 1997. Principals Procedure of Statistics. 3rd Ed. Mc.Graw Hill Book Co. Inc., New York.

Tahir, M., Tanveer, A., Ali, A., Abbas, M. and Wasaya, A., 2008. Comparative yield performance of different maize (Zea mays L.) hybrids under local conditions of

Faisalabad-Pakistan. Pak J Life Soc Sci, 6(2), pp.118-120.

Tariq, M. and Iqbal, H., 2010. Maize in Pakistan–an overview. Agriculture and Natural Resources, 44(5), pp.757-763.

Ünyayar, S., Keleþ, Y. and Ünal, E., 2004. Proline and ABA levels in two sunflower genotypes subjected to water stress. In Bulg. J. Plant Physiol.

Yaghoubian, H., Moghadam, H.R.T., Kasraie, P. and Zahedi, H., 2014. Effect of foliar application of salicylic acid on physiological and biochemical characteristics of corn (Zea mays L.) under withholding irrigation at different growth stages. Journal of Applied Science and Agriculture, 9(9), pp.27-34.

Zamaninejad, M., Khorasani, S.K., Moeini, M.J. and Heidarian, A.R., 2013. Effect of salicylic acid on morphological characteristics, yield and yield components of corn (Zea mays L.) under drought condition. European Journal of Experimental Biology, 3(2), pp.153-161.

Zhang, L.X., Li, S.X., Zhang, H. and Liang, Z.S., 2007. Nitrogen rates and water stress effects on production, lipid peroxidation and antioxidative enzyme activities in two maize (Zea mays L.) genotypes. Journal of Agronomy and Crop Science, 193(6), pp.387-397.