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Mitigating the Drought Stress through Potassium Application in Corn

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ABSTRACT

A study was carried out to explore the impact of drought stress executed through out several growth phases of Corn (Zea mays L.) crop and reducing the deleterious effect of drought stress through Potassium (K^+) application. Corn hybrids, 32-F-10 and YH-1898 drought tolerant and sensitive respectively, were grown February 28, 2010 at Postgraduate Agricultural Research Station (PARS), Faisalabad. All the mandatory soil and water analysis were completed. All the standard methods were adopted to conduct the experiment. Drought stress was forced on various growth phases (no drought, at 5-leaf stage, at 10-leaf stage, at anthesis and at grain formation) along with two treatment of potassium fertilizer; no potassium and 100 mg/kg of soil application. Corn seeds two per hill were sown in pots filled with soil where irrigation was done through tap water in a controlled net house. soil field capacity was determined and drought stress treatments were maintained by using moisture meter. Measures related to cultural and protection were executed till the time of crop maturity. Before crop maturity all the compulsory data of parameters were gathered by adopting standard methods. Through analysis of data it was found that drought stress had deleterious impacts on plant height, leaf area, root shoot fresh and dry weights, relative water contents, leaf water potential, photosynthesis rate, grain weight per cob, 1000 grains weight, biological and grain yield depending on stress period of drought. While, on the other hand K^+ had significant promotive impact on growth and yield parameters of Corn crop. Nevertheless, additional research studies would be essential to examine deeply the K^+ role in reducing the negative impact of drought stress.

Key Words: Cell, differentiation, drought, enlargement, minerals, and shrinks volume.

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INTRODUCTION

Corn is usually cultivated in irrigated areas of Pakistan. Accessibility of irrigation water is reducing day by day. Corn is C_4 plant and produce highest yield being hybrid (FAOSTAT, 2009). A plant of Corn requires 500 to 800 mm of water for its whole life cycle of 80 to 110 days (Critchley and Klaus, 1991). However, hot and blowing wind weather enhance the water requirement of Corn up to 195 mm water for one month. Pakistan possesses semiarid nature of climate where Corn crop have to face severe moisture deficit. Corn growing regions in Pakistan get majority of rains during rainy season of monsoon. Additionally, artificial canal irrigation system in Pakistan doesn't have much capacity to irrigate the present cropping intensity. Hence, under the such scenario of water scarcity innovative strategies are mandatory to grow maize under limiting quantity of irrigation water (PILDAT, 2003). In this condition of water dearth high yielding and drought stress tolerant Corn hybrids could be important aspects to get high production of Corn (Cavalieri *et al*., 2011).

Drought stress is the deficit moisture contents situation that restrict plant growth and development and hazardous threat for crop production (Ludlow and Muchow, 1990; Sadras and Milory, 1996; Gaspar *et al.*, 2002; Zhu, 2002). Across the Globe, drought stress decreases yield of crop plants up to 50% (Wang *et al*., 2003). Extremities of drought stress results to; reduced leaf size, slow stem elongation and root penetration to rhizosphere. Such kind of disturbances in plant morphology interrupt the metabolism and efficiency of water consumption by the plant (Nonami, 1998; Lawlor and Cornic, 2002; Hussain *et al*., 2008; Farooq *et al*., 2009).

In growing plants cell division, enlargement and differentiation are important mechanisms and are much dependent drought stress that minimizes the cell turgor pressure (Taize and Zeiger, 2006). During the circumstances of drought stress cell tends to shrink and its total volume decreases that increases the viscosity of cell solute may be toxic to photosynthetic machinery (Hoekstra *et al*., 2001; Farooq *et al*., 2009). While, water scarcity in rhizosphere increases respiration of roots that resultantly use abundant quantity of carbon resources. This decrease in root respiration minimizes the production of adenosine triphosphate (ATP) and enhances the production of reactive oxygen species (ROS) and this oxidative damage to plant cells occurs (Farooq *et al*., 2009) that also disrupts the usual plant growth.

Corn is usually grown two times in a year. It is much delicate to water deficit / drought stress and yielded less production under drought stress (Lawlor, 2002). During the severe condition of drought stress plant growth and yield reduces severely. The research work done on Corn verifies that moisture deficit stress in rhizosphere decreases leaf area, leaf chlorophyll contents and photosynthetic functioning (Athar and Ashraf, 2005). Even though Corn is sensitive to drought stress but seedling with good vigor could develop plant stand and good yield. Corn plant develops more roots during seedling stage that develops to huge root mass and anchorage (Maiti *et al*., 1996; Mehdi and Ahsan, 1999).

Application of K^+ could enhance the ability of Corn to stand against drought stress especially in semiarid areas of Pakistan. The absorption of mineral nutrient by roots and presence in plant stem and leaves establishes tolerance to drought stress. K^+ have important role to mitigate the adverse effects of drought stress (Marschner, 1995; Cakmak, 2005). Paucity of K^+ in plant body part is a huge nutritious disorder. It is mandatory for crop production and produce quality enhancement. The plant with K^+ deficiency under prevailing situation of drought stress are more vulnerable to high intensity light and convert to chlorotic and necrotic immediately. Damage in stomatal regulation, conversion of light energy to chemical energy, movement of assimilates to sink from sources and trouble in photosynthetic CO^2 fixation could be K^+ deficiency disorders.

Soil application of K+ to crop plants improves root encourage that enable the roots to absorb more water from rootzone (Saxena, 1985). Accordingly, K^+ presence in plant body in abundant quantity retard transpiration and conserve much quantity of water during drought stress (Umar and Moinuddin, 2002). Addition of K^+ in crop plants during water deficit situation establish tolerance to drought stress by consuming moisture contents more effectively as compare to K^+ deficient plants. K^+ in plants improves root growth that absorbs more mineral nutrients and moisture contents (Rama Rao, 1986). K^+ controls turgor and osmotic potential and functioning of stomata under water deficit stress (Umar *et al*., 1993). Cell sap pH of water deficit stress plants is also being regulated by K^+ in stroma of chloroplast. Additionally, K^+ also gives defense against photo-oxidative damage to chloroplast (Cakmak, 2005). The balanced biochemical functioning of plant is being regulated by K+ during drought stress (Cakmak and Engels, 1999). During drought stress chloroplast export off most of its potassium contents and slow down photosynthetic working (Sen Gupta and Berkowitz, 1987). Hence, K^+ is an important and vital mineral nutrient for proper functioning of photosynthesis and guard the plant from oxidative damage of ROS (Sen Gupta *et al*., 1989; Cakmak, 2005).

MATERIALS AND METHODS

In this research work K^+ was applied to reduce the adverse effects of drought stress on Corn crop. The research work was carried out in a controlled net house at PARS, University of Agriculture, Faisalabad, Pakistan. The geo coordinates of site were longitude 73°74 East, latitude 30°31.5 North. This site was 184 m high from sea level. The average monthly temperature, relative humidity, rainfall, sunshine period, potential evapotranspiration and wind speed during month of March, 2010 were 23.5^{o}C, 57.5%, 0.3 mm, 8.7 hrs, 3.4 mm and 3.6 km/hr and in April, 2010 were; 29.9^{o}C, 36.8%, 0.04 mm, 9 hrs, 6 mm, 5.8 km/hr and in May, 2010 were; 33.1^{o}C, 31.7%, 0.4 mm, 10.4 hrs, 5.7 mm, 6.2 km/hr respectively. The field capacity (FC) of soil used in experiment was calculated through gravimetric method (Nachabe, 1998).

Table 1 Analysis of soil used in pots

Parameter	Units	Values
Texture	--	Sandy loam
pH	--	8.3
EC	(dSm^{-1})	0.72

O. M.	(%)	0.39
Nitrogen	(%)	0.045
Available P	(ppm)	7.42
Extractable K	(ppm)	129.5
Sand	(%)	56
Silt	(%)	22
Clay	(%)	22
Field capacity	(%)	25.5
Wilting point	(%)	7.9
SAR	--	09

The experiment was designed with CRD (Factorial) replicated thrice. Following treatments applied;

Factor A: Corn Hybrids

1. 32-F-10 2. YH-1898

Factor B: Growth Phases to apply drought stress

1. No drought stress 2. Five leaf 3. Ten leaf 4. Anthesis 5. Grain formation

Factor C: Potassium Levels

1. 0 mg/kg of Soil 2. 100 mg/kg of soil

The fertilizer @ 250 Kg/ha of Nitrogen and 125 kg/ha of Phosphorous was applied to eight kilogram of pot soil while 1/3 portion of nitrogen was also applied at the time of sowing. The Corn hybrids 32-F-10 and YH-1898 were grown on February 28, 2010. One pot was sown with six seed of Corn and irrigated fully. On each day every pot was irrigated fully on the basis of visual observation. At four leaf stage plants thinning was completed and two plants in a pot kept maintained. Drought stress was maintained on given growth phases by maintaining 70% FC after 30% depletion in it by using moisture meter. The rest of 2/3 Nitrogen fertilizer was applied after 20 days of sowing. Fully matured crop was harvested and standard methods were adopted to collect the data.

Meter rod was used to measure plant height while leaf area meter (CI-203 Area meter, CID, Inc. USA) was used to measure the leaf area. Electric balance was used to weigh the plant shoot after cutting from base of stem. Plant roots were taken up and washed with water to remove soil and weighed through electric balance. Fresh shoots and roots were put in an oven for 48 hours at 70^{o}C. On drying weight of these samples was calculated.

Infrared gas analyser (LCi Bioscientific Ltd) was used to measure the rate of photosynthesis (A). To measure relative water contents fresh weight of 0.5 g leaf was measured and soaked in test tube filled with water. Leaf portion was taken out from test tube after 24 hours. Water droplets present on surface of leaf were removed by using tissue paper and leaf weight was calculated. The leaf sample was then dried up in an oven for 24 hours at 80°C and dry weigh was calculated. The relative water contents were calculated by using the formula (Karrou and Maranville, 1995) given below;

RWC = (FW-DW)/ (TW-DW) x 100

Where FW is the fresh weight of sample, DW is the dry weight of sample and TW is the turgid/soaked weight of sample.

Leaf water potential (ψ_w) was measured by using Scholander type pressure chamber from third leaf (fully expanded youngest leaf) of Corn plant from the top that was removed between 6:30 am to 8:30 am.

RESULTS

Plant height (cm)

Increase ($p \leq 0.05$) in plant height of Corn hybrids 32-F-10 and YH-1898 was observed by application of K^+ in the current study (Table 2). The maximum height (160.9 cm) of Corn plant was noted in pot of 32-F-10 with well water irrigation and K^+ was also applied through soil that was followed by YH-1898. Long period of drought stress has to face by the treatment when drought was imposed from five leaf phase and in all other treatments drought stress period was reduced gradually and very less duration of drought stress was imposed to grain formation phase of Corn. Corn hybrids produced very low height under drought stress when imposed from five leaf phase a long duration of drought stress in this study.

Leaf area per plant (cm^2)

Significantly ($p \leq 0.05$) enhanced leaf area of hybrid Corn plant was observed in treatments with K^+ application under drought conditions imposed at different growth phases (Table 2). Reduced leaf area was observed in drought treatment at five leaf phases. Regarding establishment of leaf area, 32-F-10 was dominant over Yh-1898.

Number of leaves per plant

Application of K^+ increased ($p \leq 0.05$) the number of leaves per plant (Table 2) during full water application however, number of leaves reduced under drought stress with no K^+ application. Corn plants where drought stress was imposed at five leaf phases produced least number of leaves followed by treatment when drought was imposed at ten leaf phases. Number of leaves remained at par when no drought stress was imposed and when drought stress was imposed at grain filling stage.

Root fresh weight (g)

It was concluded after data analysis that potassium had significant ($p \leq 0.05$) impact (Table 2) on fresh weight of root grown under well water treatment and under drought stress. Drought tolerant Corn hybrids 32-F-10 developed more root fresh weight comparatively drought sensitive YH-1898 Corn hybrid. Drought stress from five leaf phase and ten leaf phases drastically reduced root fresh weight due to less availability of moisture contents to roots.

Table 2 Effect of potassium on plant height, leaf area per plant, number of leaves per plant and root fresh weight of maize hybrids grown under drought imposed from various growth stages.

Hybrids	Growth stages to impose drought	Plant height (cm)		Leaf area per plant (cm^2)		No. of leaves per plant		Root fresh weight (g)	
		0 mg/kg	100 mg/kg	0 mg/kg	100 mg/kg	0 mg/kg	100 mg/kg	0 mg/kg	100 mg/kg
32-F-10	No drought	143.53 e	160.72 a	2298.3 e	3015.0 a	14.46 c	16.43 a	34.45 b	38.52 a
	Five leaf stage	119.79 lm	130.04 i	1408.1 m	1811.2 j	11.38 f	12.36 e	26.21 fgh	28.35 defg
	Ten leaf stage	123.00 k	133.88 h	1669.3 k	2190.1 fg	12.44 e	13.30 d	28.01 defg	30.12 cde
	Anthesis	130.18 i	140.11 f	2232.6 ef	2529.0 d	14.36 c	15.39 b	30.36 cd	31.25 bcd
	Grain formation	137.21 g	154.24 c	2598.0 d	2898.9 b	16.41 a	16.42 a	32.24 bc	25.35 ghi
YH-1898	No drought	139.74 f	157.62 b	1993.4 h	2731.9 c	13.38 d	15.46 b	17.65 l	25.78 ghi
	Five leaf stage	115.63 n	126.19 j	1238.1n	1540.2 l	10.35 g	11.46 f	21.45 jk	19.66 kl
	Ten leaf stage	118.14 m	120.18 l	1464.5 lm	1931.3 hi	11.38 f	12.42 e	21.39 jk	22.67 ijk
	Anthesis	122.88 k	135.28 gh	1869.4 ij	2107.9 g	12.43 e	13.47 d	24.20 hij	27.08 efgh
	Grain formation	133.81 h	149.71d	2160.0 fg	2726.5 c	14.47 c	16.40 a	26.53 fgh	29.12 cdef
LSD ($P \leq 0.05$)		2.87		103.59		0.66		3.2	

Means followed by common letter (s) are not significantly different according to Fisher's protected LSD test at P = 0.05.

Shoot fresh weight (g)

Statistically significant ($p \leq 0.05$) shoot fresh weight was generated by Corn hybrid 32-F-10 as compare to Corn hybrid YH-1898. Shoot fresh weight per plant was improved where K+ was applied whereas drought stress imposed from various growth phases had adverse effect shoot fresh weight.

Shoot dry weight (g)

Soil applied K^+ increased ($p \leq 0.05$) shoot dry weight (Table 3) whereas in well water treatment

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(no drought stress) significantly highest shoot dry weight (35.52 g) was observed and least dry shoot weight was found in treatment where drought stress was imposed at five leaf phases. However, application of K^+ increased the shoot dry weight.

Root dry weight (g)

There was statistically significant ($p \leq 0.05$) difference of root dry weight among all the drought stress treatments (Table 3). Analysis of data concluded that K^+ application enhanced the root dry weight as compare to non-applied K^+. Dry matter production efficiency of drought tolerant Corn hybrid 32-F-10 was better as compare to drought sensitive Corn hybrids YH-1898. The highest root dry weight (4.54 g) was produced in well water treatment with K+ application and minimum were generated in treatment where drought stress was imposed at various growth phases with longer duration of drought stress. Drought stress imposed for shorter duration improved the efficiency of root dry weight production. During well-watered situation roots grow normally while under mild drought stress roots grow fast to get more water from root zone by getting more assimilates from leaves. However, severe drought stress reduced the capability of roots to generate dry matter.

Photosynthetic rate (µmolm^{-2}s^{-1})

Working of photosynthesis (Table 3) was improved ($p \leq 0.05$) by applied K^+ in well-watered treatment and even in drought stress conditions. However, rate of photosynthesis was retarded during drought was imposed at five leaf stage.

Table 3 Effect of potassium on shoot fresh weight, shoot dry weight, root dry weight plant^{-1} and photosynthetic rate of maize hybrids grown under drought imposed from various growth stages.

Hybrids	Growth stages to impose drought	**Shoot fresh weight (g)**		**Shoot dry weight (g)**		**Root dry weight (g) plant^{-1}**		**Photosynthetic rate (µmole m^{-2} s^{-1})**	
		0 mg/kg	100 mg/kg	0 mg/kg	100 mg/kg	0 mg/kg	100 mg/kg	0 mg/kg	100 mg/kg
32-F-10	No drought	164.16 e	215.36 a	26.06 f	35.52 a	4.05 cd	4.54 a	19.81 e	25.99 a
	Five leaf stage	100.58 m	129.37 j	15.96 m	20.54 j	3.09 ghij	3.34 fg	12.14 m	15.62 j
	Ten leaf stage	119.23 k	156.44	18.93 k	24.83 fg	3.29 fgh	3.54 ef	14.39 k	18.88 fg
	Anthesis	159.47 ef	180.64 d	25.31 fg	28.67 e	3.57 ef	3.68 e	19.25 ef	21.80 d
	Grain formation	185.61 d	207.06 b	29.46 de	32.87 b	3.79 de	2.99 hij	22.40 d	24.99 b
YH-	No drought	142.39 h	195.13 c	22.60 hi	31.65 bc	4.28 abc	3.81 de	17.19 h	23.55 c

Annals of R.S.C.B., ISSN:1583-6258, Vol. 26, Issue 1, 2022, Pages. 671 - 689
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1898	Five leaf stage	88.44 n	110.01 l	14.04 n	17.46 kl	2.96 ij	2.85 j	10.67 n	13.28 l
	Ten leaf stage	104.61 lm	137.95 hi	16.61 lm	21.90 ij	3.09 ghij	3.22 ghi	12.62 lm	16.65 hi
	Anthesis	133.53 ij	150.56 g	21.19 ij	23.90 gh	4.38 ab	3.66 e	16.12 ij	18.17 g
	Grain formation	154.29 fg	195.13 c	24.49 g	30.91 cd	3.68 e	4.08 bcd	18.62 fg	23.51 c
LSD (P≤0.05)		7.40		1.49		0.31		0.89	

Means followed by common letter (s) are not significantly different according to Fisher's protected LSD test at P = 0.05.

Relative water contents (%)

Application of K+ has statistically significant ($p \leq 0.05$) impact on decrease or increase of relative water contents of Corn hybrids during the drought situations (Fig. 1). Applied K+ improved relative water contents as compare to non-K+ applied treatments. Corn hybrid 32-F-10 was found better in conserving relative water contents as compare to YH-1898. Highest relative water contents were found in well-watered treatment as compare to drought treatments. However, reduced relative water contents were observed in drought stress treatments imposed at five leaf phases. Relative water contents steadily increased with drought treatments from five leaf phase to grain formation phase.

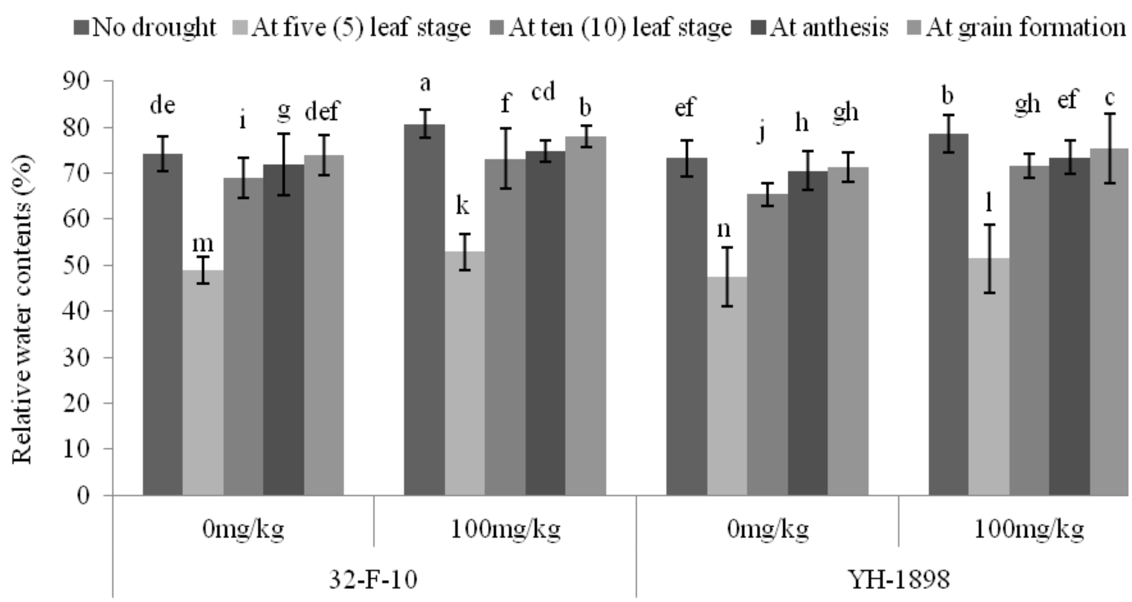

Fig. 1. Effect of potassium on the relative water contents of maize hybrids under drought imposed from various growth stages Leaf water potential (-MPa)

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K+ significantly ($p \leq 0.05$) improved leaf water potential even under drought stress (Fig. 2). It is indicated in given graph that K+ increased the leaf water potential as compare to non-K+ applied plots. Corm hybrid 32-F-10 established good status of leaf water potential while poor leaf water potential was developed by YH-1898. Well-watered plots and plots with drought stress at grain filling phase maintained statistically at par leaf water potential. Drought stress imposed at five leaf stage established limited leaf water potential. However, good status of leaf water potential was found in other drought treatments.

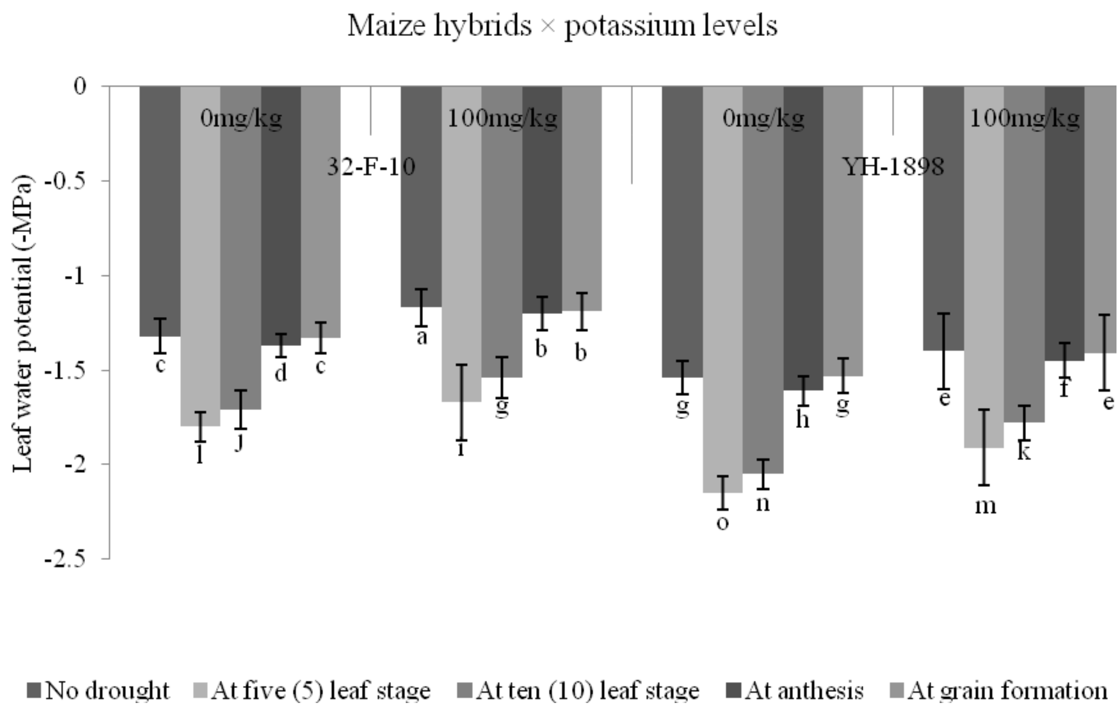

Fig. 2. Effect of potassium on the leaf water potential of maize hybrids under drought imposed from various growth stages.

1000 grain weight (g)

Grain size is much dependent variable of yield of any crop. More transportation of photosynthetic assimilated from leaves to seed increased yield abundantly. Potassium plays an important role in transportation of photosynthetic assimilates to seed. In this research K+ has significantly ($p \leq 0.05$) increased 1000 grain weight in well-watered and in drought stress treatment (Table 4). Duration of drought stress has clear significant impact on 1000 grain weight, longer duration had more while shorter had less impact on 1000 grain weight. Maximum 1000 grain weight (265.11 g) was calculated in well-watered treatment with application of K+.

Grain weight per cob (g)

K+ has influential significant impact ($p \leq 0.05$) on the increase of grain weight per cob while drought stress reduced grain weight per cob imposed at five leaf phases to minimum. Grain

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weight per cob was reduced with enhanced duration of drought. Corn hybrid 32-F-10 generated more grain weight per cob while YH-1898 produced the least. K+ applied plots had enhanced grain weight per cob as compare to non-applied K+.

Biological yield (g/plant)

Biological yield of Corn significantly ($p \leq 0.05$) reduced by drought stress however, application of K+ increased it (Table 4). Here in this research work drought tolerant Corn hybrids generated more biological yield while less biological yield was produced by drought sensitive Corn hybrid. Longer duration of drought stress reduced biological yield however with the reduction in drought stress duration biological yield increased. Application of K+ also had positive impact on increase of biological yield as compare to non-applied K+ plots. Soil K+ applied treatment with well-watered treatment produced maximum biological yield (202.73 g/plant). On the other hand, minimum biological yield (94.68 g/plant) was produced by plots where drought stress was imposed from five leaf phase with non-application of K+.

Grain yield (g/plant)

Corn hybrid 32-F-10 generated maximum grain yield (84.73 g/plant) under no drought stress and with K+ potassium application (Table 4). Data shows that 32-F-10 performance regarding production of grain yield was better that YH-1898 with K+ application and without K+ application. K+ had good impact on enhancing grain yield.

Table 4 Effects potassium on 1000 grain weight, grain weight per cob, biological yield and grain yield of maize hybrids grown under drought imposed from various growth stages.

Hybrids	Growth stages to impose drought	1000 grain weight (g)		grain weight per cob (g)		biological yield (g/plant)		grain yield (g/plant)	
		0 mg/kg	100 mg/kg	0 mg/kg	100 mg/kg	0 mg/kg	100 mg/kg	0 mg/kg	100 mg/kg
32-F-10	No drought	202.09 e	265.11 a	61.42 e	80.57 a	159.95 d	202.73 a	69.27 bc	84.73 a
	Five leaf stage	125.69 m	159.27 j	37.63 m	48.41 j	94.68 m	121.79 j	39.05 hi	48.95 fg
	Ten leaf stage	146.78 k	192.58 fg	44.61 k	58.53 ef	112.25 k	147.27 ef	44.38 gh	68.17 bc
	Anthesis	196.31 ef	222.38 d	59.66 e	67.58 d	150.12 e	170.06 c	55.23 de	72.26 bc
	Grain formation	225.19 d	254.90 b	69.44 d	77.47 b	173.10 c	194.92 a	71.15 bc	73.58 b

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YH-1898	No drought	175.29 h	237.20 c	53.27 gh	73.01 c	134.04 gh	183.69 b	67.32 c	71.74 bc
	Five leaf stage	110.47 n	135.43 l	33.09 n	41.16 l	83.25 n	103.56 l	38.15 i	39.55 hi
	Ten leaf stage	128.78 lm	169.81 hi	39.14 lm	51.61 hi	98.48 lm	129.86 hi	48.84 fg	46.63 fg
	Anthesis	164.38 ij	185.35 g	49.95 ij	55.37 g	125.70 ij	141.74 fg	50.83 ef	60.63 d
	Grain formation	189.93 fg	236.47 c	55.99 fg	69.38 d	145.24 ef	183.34 b	60.49 d	71.53 bc
LSD ($P \leq 0.05$)		9.09		0.89		8.04		6.20	

Means followed by common letter (s) are not significantly different according to Fisher's protected LSD test at P = 0.05.

DISCUSSION

During drought stress application of K+ enhanced the plant height while enhancing the duration of drought stress plant height reduced gradually in the present research work and these findings are in accordance with Ali *et al.* (2011) whose concluded that by increasing drought stress plant was reduced. Additionally, impact of drought stress on plant height was also related to the findings of Itoh and Kumara (1986), Hamada and Al-Hakimi (2001) and Liu *et al.* (2004). This reduction in plant height might have shifted photosynthates to roots for their extension to draw more water to stand against drought stress. At the initial stage of drought stress Corn plants stated to transport all the photosynthates to stem and then to roots for their active and extensive soil proliferation to absorb water but K+ applied plots increased plant height even with drought stress as K+ activated many enzymes to promote growth effectively.

Leaf area of Corn hybrids was reduced by drought stress and there was a clear difference of leaf area among all the drought treatments in the present study that was might be due the increased leaf senescence and reduced provision of moisture contents. Such kind of findings are supported by earlier studies that drought stress retarded leaf area, radiation use efficiency and harvest index of Corn crop by disturbing the membrane structures and reactive oxygen species production resulted to leaf senescence (Nogues and Baker, 2000; Earl and Davis, 2003). Lindhauer (1985) found that K+ application increased the dry mass production and improved leaf area development and conservation of moisture contents in plant tissues under drought stress conditions.

In the present research work, number of leaves produced on Corn plants were reduced due to drought stress. Early formed leaves may die due to drought stress. However, other research shows that drought stress had little impact on number of leaves of Corn plant (Ali *et al*., 1999). On the other hands, application of potassium might have good effect on increasing number of leaves on a plant under drought stress. It was studied by de Souza *et al*., 1997 that Corn plant growing in water deficit stress face adverse effect on initiation of new leaves and it would might be due to disturbance in plant growth mechanisms. Bajji *et al.* (2001) studied that water deficit stress might have deleterious affect on leaf initiation in wheat crop plants. He elaborated that application of K+ increased the number of leaves in Corn plants. Hence, K+ has its role in increasing number of leaves. It was found by Rohbakhsh, 2013 that under well-watered conditions application of K+ increased number of leaves on a plant.

Root fresh weight was increased significantly ($p \leq 0.05$) by application of K+ in the present research work that was might be due to role of K+ for increasing root proliferation length. K+ has also its role in vegetative growth and development. K+ is lavishly exists in plant as a cation (Marschner, 1995). Drought is a single climatic agent that is reducing agriculture crop production due to reduced water nutrient uptake through roots. K+ ions paly its role in osmotic potential of cell vacuole under water deficit conditions in root elongation. Dry soil during plant growing period less inhibited the growth of roots as compare to shoot growth (Sharp and Davies, 1989). Sustainable root growth during drought stress could be an important factor for sustainable water supply to the plant (O'Toole and Bland, 1987; Sponchiado *et al*., 1989).

Water is an important raw material of photosynthesis for generation of plant biomass. In the current research work, drought stress has significant effect on root fresh weight where longer duration of drought stress produced less biomass accordingly that might be due the Corn plant adaptation to drought stress. It has already been studied that on beginning of drought stress plant reduced shoot growth by reducing growth of leaf, stem and resultantly increase root growth (Schuppler *et al.*, 1998).

Water and minerals are being absorbed by roots through various kinds of mechanisms. Root grow normally under well-watered conditions while under mild drought stress all the assimilates moves towards roots from leaves and roots grow more efficiently in search of water. However, during sever drought stress root growth reduces drastically. The same was found the present study where root fresh weight was affected more by long period of drought stress

Roots absorb water mineral nutrients from soil root zone by exploiting various mechanisms. Under normal supply of water roots grow normally while under mild water deficit situation roots obtain photosynthates from leaves and grow more in search of water contents. During severe drought stress roots grow slowly. During the present study root fresh weight was disturbed more with increasing the drought intensity. Enhancing the root fresh weight of Corn during mild drought stress is the adaptive capability of plant to consume assimilates for improving root growth and root respiration efficiency (Fitter and Hay, 2002; Hamayun *et al.,* 2010). During severe drought stress retarded root growth might be due to soil hardness that hinders in root penetration the soil and also reduced root respiration efficiency (Borrell and Hammer, 2000; Thomas and Howarth, 2000).

Depth of root anchorage is significantly variant among K+ applied Corn field and Corn fields without K+ applied as studied in previous research work under drought stress conditions. K+ has

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good ability to enable plants to approach longer root length under conditions of drought stress. Our results of this study are similar to the results of Rosolem *et al*. (2005) and Ashraf *et al*. (2003).

The impact of drought stress on crop plants is very complex and variant. The simple deleterious effect of drought stress on plant is reduction in biomass generation in grasses and Corn (Ashraf and Yasmin, 1995) and maize (Abrechit and Carberry, 1993) while similar results were observed in present study. However, under drought stress application of K+ has enhanced the biomass production capacity of plant that was might be due to the enhanced photosynthetic activity and enzyme activation. In the previous studies, it has been found that under normal application of irrigation water maximum shoot fresh biomass was produced by application of K+ (Rohbakhsh, 2013).

During mild drought stress, increasing the dry matter in Corn is an important aspect for adaption of Corn plants to drought stress by using assimilates of photosynthesis to increase root growth to proliferate more area for water uptake (Fitter and Hay, 2002; Hamayun *et al.,* 2010). Whereas, severe drought stress reduced the root growth that was might be due to soil compactness that also reduced root respiration and dry matter as studied by Borrell and Hammer, 2000; Thomas and Howarth, 2000. It can be concluded that K+ is an important essential element for plant growth and development and is abundant cation in plants (Marschner, 1995).

During drought stress the role of K+ is related to protective function for stress injuries (Pier and Berkowitz, 1987; Sen Gupta *et al.*, 1989). During drought stress photosynthesis activity reduction is due to dehydration of chloroplast (Sen Gupta and Berkowitz, 1987; Berkowitz and Kroll, 1988) and chloroplast loses most of its K+. Hence, application of K+ is mandatory for maintenance of proper photosynthesis activity. It was studied by Pier and Berkowitz (1987) that application of K+ to wheat improved the photosynthetic rate up to 66-113% in plants as compare where high level of K+ reversed the dehydration. Existence of K+ in plants is very important for improving yield and dought tolerance of plants during drought stress. It was studied by Waraich *et al*. (2011) that during water deficit conditions application of K+ to crop plants increases the tolerance to drought stress in the plants by absorbing more moisture contents actively as compare to K+ deficient plants.

K+ is an important mineral nutrient for various kind of biochemical process i.e. enzyme activation, synthesis of protein, photosynthesis functioning, osmoregulation, stomatal functioning, phloem transport, electrical counterbalancing, membrane potential regulation, sugar transport and stability of maintenance of action-anion in vacuole and in cytoplasm. It was studied by that K+ ions significantly contribute in osmotic potential of vacuole during drought stress. Adequate supply of K+ to plants may enable osmotic adjustment that further maintain turgor pressure at lower leaf water potentials and improve capability of plants to tolerate drought stress (Mengel and Arneke, 1982; Lindhauer, 1985). K+ is beneficial element for proper plant growth

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and development as found in many studies by Davidson, 1969 but very little information is available about the effect of K+ on drought resistance of plants. Thus, optimum level of K+ fertilizer that may impose drought resistance in Corn plants is still lacking.

It has been reported by Khan *et al*., 2001 that drought stress reduced the quantity of grain. K+ has its role in water use efficiency (WUE), plant growth improvement and cell division enhancement, hydrocarbon and protein formation and then their transportation towards grain (Marschner, 1995). K+ application enhanced 1000 grain weight as studied by Kolcar (1975). In the current study 1000 grain weight was also enhanced by K+ application. A contradictory study was conducted by Mahmood *et al*. (1999) where he found that there was not any impact of K+ on grain weight however, sometimes K+ had significantly increased the grain weight per cob in Corn. K+ has its role in photosynthetic assimilates transportation from leaves to grain through phloem where rate at which grain fills and period of its filling increased by K+ fertilizer application in Corn and this increasing grain weight increases Corn yield (Farooqi *et al*., 2012).
In the present study application of K+ increased biological yield per plant as compare to plots without K+ application that was might be due increased growth due to K+ application. These results indicate that forage crops should be harvested during holding high potassium contents without loss in dry matter (Ketterings *et al.*, 2005). These biological yield related results are in accordance with research findings of Nasri *et al.* (2010) and Abdulai *et al.* (2007) and they argued that maximum biological yield could be obtained from proper application of essential fertilizer nutrients with adequate supply of irrigation water.
K+ is an important macro-nutrient that is essential for plant growth and development and is vital ion in the plant water relations physiology. Management practices could be adopted to improve availability of Phosphorous, Potassium and Sulphur as studied by Hickman, 2002 while quality of soil can be elaborated through the presence or absence of mineral nutrients. Whereas K+ being a soil aggregating mineral nutrient have positive impact on crop growth and yield (Hamza and Anderson, 2003). The recommendation for Phosphorous, Potassium and Sulphur were made by Wortmann *et al*. (2009) by using 34 irrigated Corn trials. Earl and Davis (2003) abridged these three key tools through which Corn yield is decreased by soil drought stress: (i) Less absorption of incident photosynthetically active radiation by canopy, (ii) reduction in radiation use efficiency, and (iii) reduction in harvest index.

CONCLUSION

The valuable results from this extraordinary research work on drought stress that was conducted on Corn crop generated valued knowledge to investigate the impact of K+ fertilizer nutrients on the plants response to drought stress. Specifically, drought stress levels directly reduced the plant growth attributes such as; plant height, leaf area, fresh and dry matter yield, relative water contents, leaf water potential photosynthesis rate, grains weight per cob, biological and grain yield whereas; application of K+ fertilizer progressively alleviated deleterious effects of drought stress on plant growth. In short, the results from current study ensured the recovery effect of K+ on Corn plants during drought stress situations.

Authors' Contributions

Muhammad Aslam: Conducted research work
Muhammad Shahid Ibni Zamir:Main Supervisor
Irfan Afzal: Co supervisor
Muhammad Amin: Write up and proof reading

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