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EXOGENOUS APPLICATION OF GIBBERELLIC ACID IMPROVES THE MAIZE CROP PRODUCTIVITY UNDER SCARCE AND SUFFICIENT SOIL MOISTURE CONDITION

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ABSTRACT. Drought stress creates imbalance or deficiency of some growth regulators in plants, which leads toward reduced crop yield. Gibberellic acid is one of the most important growth regulators in plants, which improve drought tolerance in plants under optimum concentration. A field experiment was conducted under exogenous application of gibberellic acid under normal or drought condition and with or without gibberellic acid application. Crop growth and yield parameters were assesses during the experimentation. Study revealed that crop reduced growth in term of leaf area index (LAI), leaf area duration (LAD), crop growth rate (CGR), net assimilation rate (NAR) and total dry matter (TDM) under drought condition, while these parameters were improved with gibberellic acid application. Similary, improved growth rate resulted in better performance of yield attributes (cob length, cob diameter, grains per cob, grain weight and yield). Gibberellic acid application improved the crop performance at optimum irrigation, as well as under reduced irrigation. Although highest crop yield was recorded with gibberellic acid application under optimum irrigation level, while its application under drought stress improved crop tolerance and resulted in better crop yield, similar to optimum irrigation level. Exogenous application of gibberellic acid not only improved the drought tolerance in maize, but also increased the crop yield under normal condition.

Keywords: drought; growth regulator; crop growth; yield.

REZUMAT. Aplicarea exogenă a acidului giberelic la creşterea

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productivităţii culturii de porumb în condiţii de umiditate scăzută şi suficientă a solului. Stresul produs de secetă creează dezechilibre sau deficiențe ale unor regulatori de creștere în plante, ceea ce duce la o producție redusă. Acidul giberelic este unul dintre cei mai importanți regulatori de creștere în plante, care îmbunătățește toleranța la secetă la plante, la o concentrație optimă. Un experiment de câmp a fost realizat prin aplicarea exogenă a acidului giberelic în condiții normale sau de secetă și cu sau fără aplicarea acidului giberelic. Creşterea culturii și parametrii de producție au fost evaluați în timpul experimentării. Studiul a evidențiat o creștere redusă a culturii în ceea ce privește indicele suprafaţei frunzei, durata perioadei de creştere a frunzei, rata de creştere a culturii, rata de asimilare netă şi cantitatea totală de substanță uscată în condiții de secetă, în timp ce acești parametri s-au îmbunătățit prin aplicarea acidului giberelic. In mod similar, rata de creştere îmbunătățită a dus la o performanță mai bună a însuşirilor de randament (lungimea ştiuletelui, diametrul ştiuletelui, boabe pe ştiulete, greutatea bobului şi producţia). Aplicarea acidului giberelic a îmbunătățit performanța culturii la irigarea optimă, precum și la irigări reduse. Deși cel mai mare randament al culturilor a fost înregistrat la aplicarea acidului giberelic la un nivel optim de irigare, aplicarea acestuia în condiții de secetă a îmbunătățit toleranța culturilor și a dus la un randament mai bun al acestora, similar cu nivelul optim de irigare. Aplicarea exogenă a acidului giberelic nu numai că a îmbunătățit toleranța la secetă a porumbului, dar a crescut și randamentul culturii în condiții normale.

Cuvinte cheie: porumb; acid giberelic; secetă; creștere; randament.

INTRODUCTION

In Pakistan, maize is the fourth largest grown crop after wheat, rice and cotton, with an area of production of 1,144 thousand hectare with the total production 4.920 million tons. Demand for maize in Pakistan has increased in recent years due to expansion in poultry and livestock industry. It contributes 2.2% to the value added in agriculture and 0.4% to GDP of Pakistan (Pakistan bureau of statistics 2015-2016). Maize crop yield in Pakistan is less as compared with other developed countries. There are many reasons of this low productivity, but the most important one is the water deficiency. Irrigation water is shrinking day by day due to lesser storage and high conveyance losses. Drought stress at different growth stages seems a major challenge, which continuously leading to decrease yield (Jaleel *et al.,* 2009). Drought is worldwide problem and have produced challenging situations for arable field crop growth and food security. One third part of world arable land facing water shortage problem, which disturb the crop production (Aslam *et al.,* 2013). This reported that drought affects seedling establishment, vegetative growth, root growth, photosynthetic activity, radiation use efficiency (RUE), reproductive stage, pre anthesis, anthesis to silking interval, and finally on grain yield in maize crop. Maize is more resistant to drought stress at early stages of growth, as compared to fully developed stage (Khan *et al.,* 2001).

Plant growth regulators were found to improve water use efficiency by closing stomata. They also have effect on increase of root to shoot ratio, and can also induce the accumulation of antioxidants, that protect plants at stress conditions (Baranyiova *et al.,* 2014). They function as chemical messengers for intercellular communication and active at very low concentration in plants (Bakhsh *et al.,* 2011; Aslam *et al.,* 2010). Foliar application of gibberellic acid to the shoot enhances the elongation of both shoot and root (Harberd *et al*., 2003). Gibberellic acids are involved in the natural process of breaking dormancy and other aspects of germination (Gupta & Chakrabarty, 2013). Ayyub *et al.* (2013) reported that exogenous application of gibberellic acid regulates growth processes, such as seed germination, stem elongation uniform flowering and increase number of flowering. Kaya *et al.* (2006) also studied foliar application of gibberellic acid on maize under water stressed and well water conditions with 25 mg L^{-1}, 50 mg L^{-1} concentrations of gibberellic acid, and reported physiological parameters and nutrients level similar to control. Keeping in views the importance of gibberellic acid, the present study was carried out to explore the importance of exogenous application of gibberellic acid under sufficient and scarce water condition and to determine the appropriate growth stage of maize at which exogenously applied gibberellic acid could effectively reduce the adverse effects of water stress.

MATERIALS AND METHOD

Experiment was conducted at postgraduate research area of Agronomy Department, Bahuddin Zakriya University Multan, Pakistan (71.43 E^o, 30.2 N^o). The climate of region was subtropical to semiarid and is characterized by mean annual precipitation 175 mm, mean annual temperature of 26.6°C.

Maize hybrids ICI9091 and P1543 were selected as test cultivars for this experiment. Crop was sown on 26th February 2016 with recommended seed rate and land was prepared by one deep ploughing and two cultivation, followed by planking. Ridges were made by ridger with a space of 75 cm. Sowing was done by hand on ridges with plan to plant distance 25 cm. The experiment was consisting of two factors: first factor include maize cultivars, while second factor was gibberellic acid under full and reduced irrigation conditions. Treatments were: Factor A (Cultivar-1: Hybrids ICI9091, Cultivar-2: Hybrid P1543) and Factor B: T_1: full irrigation, T_2: reduced irrigation, T_3: GA under full irrigation, T_4: GA under reduced irrigation. In treatment of full irrigation, water was applied at all critical growth stages, while in case of reduced irrigation treatment final irrigation was missed as terminal drought. Gibberellic acid (150 mg/L) was foliarly applied at 8-10 leaf stage and at silking stage. For weeds control recommended dose of Dual Gold (Syngenta) was applied as pre-emergence herbicide. The recommended dose of fertilizer was applied. All nutrients, except for nitrogen, were applied at time of sowing, nitrogen was applied in three splits in form of urea.

For observing growth behaviour maize crop, plant samples were collected after every 15 days interval. We cut only one plant from each treatment and fresh weight, height, stem diameter, number of leaves, and leaf area was measured by manually. Leaves were separated from each sample and then leaf and stem weight was taken separately. To calculate dry weight sample of 20 g was air dried and then placed into oven at 70^0C.

The following growth parameters were calculated by Hunt procedure (1978): LAI = Leaf area / ground area; LAD = $(LAI_1 + LAI_2) / (T_2 - T_1) /2$; CGR = $W2 - W1/T_2 - T_1$; NAR = $W_2 - W_1/LAD$.

The different yield parameters were also calculated. Plant height was measured by using meter rod from bottom of plant to the tip of panicle. The parameters were included number of cobs per plant, cob diameter, number of grains per row, average grain rows, number of grains per cob. Final, yield was calculated at end of experiment of each plot and also 1000 grain weight for each plot was calculated separately. The experiment was laid out on the basis of factorial experimental with randomized complete block design (RCBD). Each treatment was replicated three time. Statistic 8.1 was used for statistical analysis.

RESULTS

Leaf area index, leaf area duration, net assimilation rate and total dry matter

Leaf area index was progressively increased, reaching a maximum level prior to reproductive stage, i.e. up to 63 days after emergence then decreased gradually (*Fig. 1*). Crop significantly reduced crop growth rate in term of leaf area index (LAI), leaf area duration (LAD), crop growth rate (CGR), net assimilation rate (NAR) and total dry matter (TDM) under drought condition, while crop performance was improved with giberellic acid application upto its normal level of irrigation (*Fig. 2*). Similar results were recorded in treatment of optimum irrigation (T_1H_1, T_1H_2) and in treatment of reduced irrigation along with GA application (T_4H_1, T_4H_2). Accelerated crop growth rate was recorded in treatment of optimum irrigation along with GA application (T_3H_1, T_3H_2) in both hybrids (*Table 1*).

Yield attributes

Yield parameters showed that gibberellic acid application significantly improved the crop performance under drought, as well as under normal water condition. Tallest cobs were found in treatment of normal irrigation along with exogenous application of gibberellic acid (T_3H_1, T_3H_2), while the shortest cobs were recorded in drought treatment (T_2H_1, T_2H_2). Moreover, the gibberellic acid application improved the drought tolerance when it was applied under reduced irrigation treatment (T_4H_1, T_4H_2) and exhibited similar performance with normal irrigation treatment (T_1H_1, T_1H_2). Similar trend was found for cob diameter, number of grains per cob and 1000 grain weight. Crop yield is the commulative effect of growth, as well as yield attributes. Crop grown under normal condition along with GAs application significantly enhanced crop yield (T_3H_1, T_3H_2), while the minimum crop yield was recorded under treatment of drought stress (T_2H_1, T_2H_2). GAs application under drought stress improved the crop yield upto the yield of treatment at optimum irrigation level (*Table 2*).

Table 1 - Effect of folierly applied gibberellic acid on different growth parameters of maize

Treatments	LAI	LAD (days)	CGR gm^{-2} day^{-1}	NAR gm^{-2} day^{-1}	TDM gm^{-1}
T_1H_1	6.52 b	43.1 bc	20.5 bc	40.3 b	1646.7 b
T_2H_1	5.21 c	35.6 d	15.1 e	33.8 c	1147.3 c
T_3H_1	7.62 a	46.6 a	22.8 a	46.6 a	1813.3 a
T_4H_1	6.44 b	43.0 bc	20.2 c	36.9 c	1690.0 b
T_1H_2	6.46 b	42.2 c	22.3 ab	36.6 c	1620.0 b
T_2H_2	5.15 c	35.3 d	17.4 d	34.0 c	1275.3 c
T_3H_2	7.15 a	43.7 b	24.2 a	42.4 b	1790.0 a
T_4H_2	6.42 b	41.8 c	20.4 bc	36.0 c	1649.7 b
LSD	0.534	1.31	1.97	3.16	131.77

Table 2 - Effect of gibberellic acid foliar application on yield and yield attributes of maize crop

Treatments	Cob length (cm)	Cob diameter (cm)	No. of grains per row	Avg. no. of grains/cob	1000 grain weight (g)	Yield (kg/ha)
T_1H_1	20.9 b	14.1 bc	40.3 bc	496.3 b	496.3 a	6601.5 b
T_2H_1	15.1 d	11.3 d	33.3 e	396.3 c	396.3 b	5913.2 c
T_3H_1	23.4 a	15.3 b	43.3 a	530.6 a	530.6 a	6945.6 ab
T_4H_1	20.7 b	14.1 bc	39.6 c	477.6 b	477.6 a	6695.3 b
T_1H_2	18.5 c	15.2 bc	37.0 d	493.3 b	493.3 a	6701.7 b
T_2H_2	13.5 d	10.4 d	32.3 e	332.0 d	332.0 c	5897.5 c
T_3H_2	24.1 a	16.6 a	42.0 b	532.6 a	532.6 a	7121.1 a
T_4H_2	18.0 c	14.3 bc	36.0 d	478.6 b	478.6 a	6720.5 b
LSD	1.66	1.21	1.99	34.29	12.611	359.10

DISCUSSION

Application of various nutrients and cultivation of drought tolerant varieties are common farmer practice to manage drought condition. But, the impact of various growth regulators under drought stress is still missing among farmers. Although many reserchers have highlighted its significance to manage stress period in crop production (Nurunnaher *et al.,* 2014; Okuma *et al.,* 2000; Al.-Shaheen *et al.,* 2014; Afroz *et al.,* 2005; Shahram, 2015; Sardoei & Shahdadneghad, 2014). With reference of growth performance, maize crop showed accelerated growth with foliar application of gibberellic acid, in comparison with control treatment in which gibberellic acid was not applied. Various growth parameters, like LAI, LAD, NAR, and TDM, were reduced under drought stress and without growth enhancer. It has been previously reported that gibberellic acid is helpful in enhancing growth of wheat, maize, and tomato under water stress conditions (Kaya *et al.,* 2006; Maggio *et al.,* 2010). Improved growth might be due to optimum uptake of various nutrients, as gibberellic acid found to play an important role in enhancing the N, P, K, content (Soad, 2005; Sayed, 2001) (*Fig. 1*)

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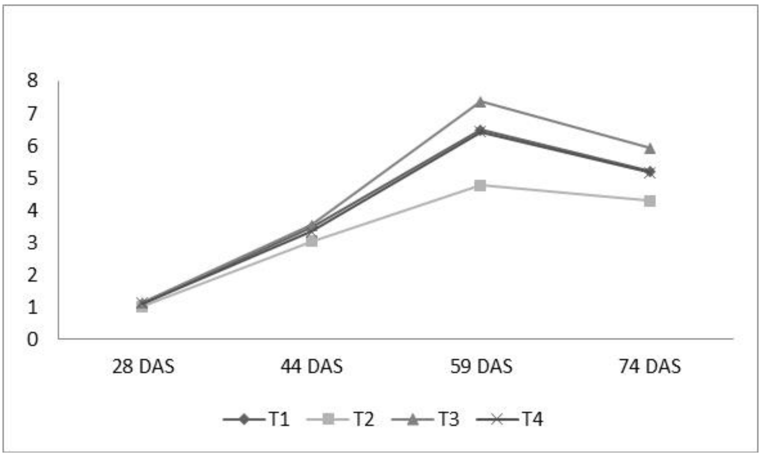

Figure 1 - Effect of folierly applied gibberellic acid on leaf area index (day)

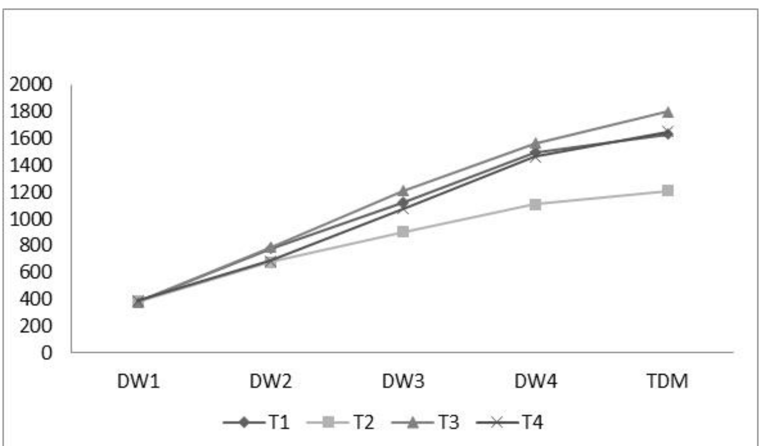

Figure 2 - Effect of folierly applied gibberellic acid on dry matter (g/m^2) of maize

The well-watered and gibberellic acid foliar application plants showed maximum increase in dry matter accumulation throughout the experiment. Data of total dry matter accumulation shows that drought stress induced reduction in dry matter accumulation, but a quick recovery was found in treatment with gibberellic acid foliar application under drought stress. Hoque *et al.* (2007) and Ashraf *et al.* (2002) observed that exogenously applied hormone during early stage growth might have caused enhanced accumulation of exogenous phytohormone under water stress conditions, which not only protects enzymes, 3D structures of proteins and organelle membranes, but it also supplies energy for growth and survival thereby helping the plant to tolerate stress. It is also reported in previous studies gibberellic acid can enhance drought tolerance of plants through increase in protein synthesis (Ei-Meleigy *et al.,* 1999). Exposure of maize plants to drought stress at reproductive stage was more detrimental to yield and yield attributes, as compared to vegetative stage (*Fig. 2*).

Many investigations have pointed out that drought stress increased the embryo abortion and loss of seed weight, which resulted in the reduction of yield and harvest index (Çakir, 2004; Kamara *et al.,* 2003, Monneveux *et al.*, 2006). Imbalance in the endogenous hormone under drought-stress conditions is known to aid embryo abortion and low fruit set, therefore, exogenous application of hormones can enhance the balance of endogenous hormones. Here exogenous application of gibberellic acid 150 mg/L at vegetative stage produced improvement in cob length, cob diameter, number of grains, 1000 grain weight and per hectare yield. The study of Alexopoulos *et al.* (2008) highlighted the significant impact of gibberellic acid on the length of ears and cobs of maize plant. Mean comparison of treatments indicated that rate of grain yield, 1000 grain weight and other yield attributes were highest in case of gibberellic acid foliar application, while lowest belongs to plants under drought stress condition without foliar gibberellic acid application.

CONCLUSION

Exogenous application of gibberellic acid not only improved the drought tolerance in maize, but also improved the crop growth and yield under normal, as well as in scarce water condition.

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