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Exogenous application of growth promoting substances improves growth, yield and quality of spring maize (*Zea mays* L.) hybrids under late sown conditions

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ABSTRACT: The performance of spring maize hybrids are severely affected by high temperature at reproductive phase causing marked reduction in yield. Exogenous application of natural and synthetic plant hormones may induce tolerance against temperature constraints. Therefore, a field study was conducted to evaluate the performance of two maize hybrids i.e. PS525 (heat tolerant) and P1543 (heat sensitive) with exogenous application of growth promoting substances (3% moringa leaf extract (MLE), 75 mg L^{-1} kinetin, 85 mg L^{-1}, silver nitrate and 0.1 mg L^{-1} triacontanol). Plants without spray (control) and water spray were taken for comparison. Different agronomic, physiological and quality traits were measured using standard procedure. Both hybrids showed improved performance in response to foliar spray of growth promoting substances. But maximum results were observed in hybrid PS525 with foliar application of 0.1 mg L^{-1} triacontanol and followed by 3% MLE. Enhancement in maize growth and yield through foliar spray of growth promoting substances was attributed more likely due to improved chlorophyll and relative water contents, LAI and decreased cell membrane permeability.

Keywords: tricontanol, moringa, foliar application, late sown, maize hybrids

1. INTRODUCTION

Maize (*Zea mays* L.) is the significant food and feed crop of the earth planet. It is high yielding crop among all the cereals of the world (Witt and Pasuquin, 2007). In Pakistan during the year 2015-16, maize was grown on an area of 1144 thousand hectares with a total production of 4.920 million tons (Govt. of Pakistan, 2016). The potential yield of maize per unit land area is much higher than any other field crop under optimal environmental conditions. In Pakistan maize can be successfully cultivated twice a year in autumn and spring season (Perveen *et al*., 2011). However, maize plants are very susceptible to environmental fluctuations due to high temperature extremes. Due to these adverse environmental conditions on an average 15% to 20% world maize production potential is lost each year (Lobell *et al*. 2011). During spring plantation, a high day temperatures of 38°C at reproductive stage directly affect pollination and seed setting resulting in reduced grain yield (Wahid *et al*., 2007). High temperatures speed plant development, reducing the length of growth periods necessary for optimum development of plant and grain.

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Every hybrid has specific planting date and a higher divergence from that planting time result in extra yield loss (Berzsenyi and Lap, 2001). Delayed planting are often accompanied with high temperature that hastened crop growth and development leading to reduce production of biomass and kernel yield (Otegui and Melon, 1997). Currently there is no economical way to cope with theses temperature extremes to facilitate crop production under late sown conditions. However plantation of heat tolerant maize hybrids can be a promising approach. Crop stress tolerance can be improved by the use of osmoprotectants and growth promoting substances (Parida and Das 2005).

To cope with high temperature extremes through exogenous application of plant growth promoting substances is very effective technique (Ashraf *et al*., 2010). Moringa is gaining a lot of importance as natural source of plant growth regulators. It has been reported that 3% foliar spray of moringa leaves extract enhances the maize growth, physiological and biochemical attributes under stressful environmental conditions (Ali *et al*., 2011). Kinetin is also used to enhance the crop growth under diverse conditions of salinity (Salama and Awadalla, 1987), water-logging (Gadallah, 1995), and soil acidity (Gadallah, 1994). Foliar applied kinetin tends to combat with increased concentration of abscisic acid and hence delays the leaf senescence by decreasing the chlorophyll and protein degradation possibly due to increased leaf sugar contents (Ali *et al*., 2008). Silver nitrate is also very helpful to mitigate the adverse effects of stresses due to temperature extremes. $AgNO_3$ has been known to inhibit ethylene action which is produced during stress conditions faced by plant due to high temperature (Beyer, 1976). Triacontanol (TRIA) is also a very effective plant hormone that has been known to regulate various growth processes under normal or stress conditions (Verma *et al*., 2011). TRIA is a plant hormone that is naturally present in plant epicuticular waxes and act as plant growth promoter (Naeem *et al*., 2011). Its foliar application has been shown to influence the rate of photosynthesis in various crops such as wheat (Perveen *et al*., 2010), rice (Chen *et al*., 2003) and maize (Ries, 1991).

2. MATERIALS AND METHODS

Performance of two maize hybrids i.e. PS525 (heat tolerant) and P1543 (heat sensitive) was evaluated at Agronomic Research Area, University of Agriculture Faisalabad, Pakistan under late sown conditions. Different foliar spray treatments of plant growth promoting substances were used like 3% moringa leaf extract (MLE), 75 mg L^{-1} kinetin, 85 mg L^{-1} , silver nitrate and 0.1 mg L^{-1} triacontanol. Plants without spray (control) and water spray were taken for comparison. The experiment was laid out in randomized complete block design (RCBD) with factorial arrangements having three replications using net plot size of 6.0 m × 3.0 m. Recommended seed rate of 25 kg ha^{-1} was used. Sowing was done on ridges by manual dibbling, maintaining plant to plant distance 25 cm with inter row distance of 75 cm and fertilizer N: P: K (250:120:100 kg/ha) was applied. All other agronomic and plant protection measures were kept uniform for all treatments.

2.1. PREPARATION OF SOLUTIONS

Extraction of moringa leaves was done with a locally designed machine and 3 mL was dissolved in 100 mL distilled water to prepare 3% solution of MLE (Basra *et al*., 2011). The solution of KIN was prepared by first dissolving in ethanol and required volume was obtained using distal water. SN and TRIA were prepared in hot distal water.1% tween-20 solution was used as surfactant.

2.2. FOLIAR APPLICATION

Foliar sprays of each growth promoting substance (as per treatments) were applied in three splits using Knapsack hand sprayer at knee height, tessling and grain filling stage. Four liters solution of respective growth promoting substances was prepared for three replications of each treatment at the time of foliar spray.

2.3. MEASUREMENTS

2.3.1. PHYSIOLOGICAL ATTRIBUTES

2.3.1.1. LEAF AREA INDEX (LAI)

It is the ratio of leaf area to land area and was measured by using formula given by Watson, (1947).

2.3.1.2. Cell MEMBRANE PERMEABILITY

Membrane stability was determined in terms of electrolyte leakage according to the method of Blum and Ebercon (1981) at silking stage. Six segments of ear leaf having equal size were immersed in distilled water for 12 h followed by the measurement of electrical conductivity (EC_1) of the solution with EC meter. Samples were then shifted to water bath for 60 minutes at 50 ºC and then cooled to room temperature. The electrical conductivity of killed tissues (EC_2) was again measured. Membrane permeability was calculated as the ratio between EC_1 and EC_2.

2.3.1.3. RELATIVE WATER CONTENTS (RWC)

Fresh leaves sample of 0.5 g (W_f) were rinsed in water until the weight of the leaves was constant. The saturated leaves were weighed (W_S) and then dried for 24 h at 80 ºC for determination of dry weigh (W_D). Relative water contents (RWC) was calculated by the following formula (Barr and Weatherley, 1962).

$$RWC\ (\%) = (W_F - W_D) / (W_S - W_d) \times 100$$

2.3.1.4. CHLOROPHYLL CONTENTS

The chlorophyll contents were measured with the help of chlorophyll tester (CT- 102). The chlorophyll tester calculates a numerical value which is proportional to the amount of chlorophyll present in the leaf.

2.4. AGRONOMIC AND YIELD ATTRIBUTES

Plants from each experimental unit were harvested at physiological maturity. Data of agronomic traits and yield components including number of grains per row, number of grains per cob, grain weight per cob, 1000-grain weight, grain yield, biological yield and harvest index were recorded following standard procedures.

2.5. STATISTICAL ANALYSIS

Data collected on all parameters were analyzed statistically by using Fisher's Analysis of Variance technique and least significant difference (LSD) test at 5% probability level was applied to compare the treatments' means (Steel *et al.*, 1997) using the computer statistical program Statistics 8.1.

3. RESULTS

Data regarding yield attributes of spring maize hybrids as affected by foliar spray of growth promoting substances under late sown conditions reveal that both the factors (spring maize hybrids and growth promoting substances) significantly improved yield related traits and interaction between them was also found significant (Table 1). Among various growth promoting substances, foliar spray of TRIA significantly increased, number of grains per row, number of grains per cob, grain weight per cob, 1000-grain weight, biological and grain yields of both hybrids. However, maximum number of grains per cob (502.67), number of grains per row (39.47), grain weight per cob

(130.57 g), 1000-grain weight (270.67 g), biological yield (14.98 tha^{-1}) and grain yield (6.75 tha^{-1}) were recorded in hybrid PS525 with foliar spray of TRIA and followed by MLE foliar spray treatment while lowest values were recorded in control treatment of hybrid P1543.
Likewise, higher values for leaf area index (Fig 1) were also recorded in plants of PS525 sprayed with TRIA followed by MLE. Table 2 represented that both hybrids and growth promoting substances significantly affected chlorophyll contents, cell membrane permeability and relative water contents. While the interactive effect of both the factors (spring maize hybrids and growth promoting substances) was found statistically non-significant. All growth promoting substances increased chlorophyll contents in both hybrids. However, maximum chlorophyll contents (Fig 2) were obtained in plants sprayed with TRIA as compared to control treatment. Performance of hybrid PS525 was better than P1543 regarding chlorophyll contents. Foliar spray of TRIA (0.1 mg L^{-1}) significantly reduced cell membrane permeability compared with control in which higher value for membrane permeability was recorded (Fig 3). High relative water contents were recorded in Hybrid PS525 and with foliar application of TRIA (0.1 mg L^{-1}) while minimum water contents were linked with control treatment of hybrid P1543 (Fig 4).

Table 1. Effect of hybrids and foliar spray of growth promoting substances on yield attributes of spring maize hybrids planted under late sown conditions

Foliar Spray	**Number of grains per cob**	**Number of grains per row**	**Grain weight per cob (g)**	**1000-grain weight (g)**	**Biological yield (tha^{-1})**	**Grain yield (tha^{-1})**
H_1T_0	391.00 g	30.13 g	106.20 cde	247.67 cde	13.197 de	4.74 f
H_1T_1	391.67 g	30.80 g	107.26 cde	246.67 def	13.743 c	4.88 f
H_1T_2	470.00 b	36.60 b	119.47 b	260.33 b	14.497 b	5.94 b
H_1T_3	447.00 c	33.53 cde	111.63 c	252.00 c	13.123 e	5.63 c
H_1T_4	442.00 cd	34.47 c	109.83 cd	247.67 cde	13.38 d	5.77 bc
H_1T_5	502.67 a	39.47 a	130.57 a	270.67 a	14.987 a	6.75a
H_2T_0	378.67 h	27.47 h	89.43 h	229.00 h	12.453 g	4.48 g
H_2T_1	379.33 h	27.87 h	91.20 gh	251.67 cd	12.5 g	4.51 g
H_2T_2	422.33 f	33.46 de	101.23 ef	241.67 f	12.793 f	5.56 cd
H_2T_3	428.00 ef	32.60 ef	97.87 fg	234.67 g	13.057 e	5.38 de
H_2T_4	429.33 ef	32.47 f	96.37 fgh	245.33 ef	13.007 ef	5.27 e
H_2T_5	436.33 de	33.80 cd	103.40 def	229.00 h	13.12 e	5.67 c
LSD at P=0.05 for Interaction	9.6541	0.9541	7.3632	5.1373	0.2398	0.2190
Hybrids (H_1=PS525, H_2=P1543,), Foliar spray treatments (T_0=control, T_1 Water spray ,T_2= Moringa leaf extract, T_3=Kinetin, T_4=Silver nitrate, T_5=Triacontanol)						

Table 2. Effect of hybrids and foliar spray of growth promoting substances on physiological attributes of spring maize hybrids planted under late sown conditions

Chlorophyll Contents	**Membrane Permeability**	**Relative Water Contents**

	PS525	P1543	Mean	PS525	P1543	Mean	PS525	P1543	Mean
T_0	1.90	1.52	1.71B	51.70	52.91	52.31 A	50.65	48.06	49.36 C
T_1	1.89	1.60	1.74B	50.15	50.89	50.52 AB	52.89	52.42	52.65BC
T_2	2.21	1.92	2.07A	28.58	38.74	33.66 CD	66.68	53.50	60.09AB
T_3	1.98	1.74	1.86B	40.54	42.95	41.74 BC	65.66	56.93	61.30 A
T_4	1.91	1.68	1.79B	33.60	43.33	38.46 C	61.69	64.27	62.98 A
T_5	2.29	1.99	2.14A	19.98	34.61	27.30 D	72.19	62.10	71.15 A
Mean	2.03A	1.75B		37.43 B	43.90A		61.63A	56.21B	
LSD at P=0.05 for Interaction= 0.2529 ,*Treatments*=0.1788, *Hybrids*=0.1032				*LSD at P=0.05 for Interaction*=13.923,Treatments =9.8453, *Hybrids*=5.6842			*LSD at P=0.05 for Interaction*= 11.543, *Treatments* =8.1621 , *Hybrids*=5.6842		

4. DISCUSSION

Yield contributing attributes are the most important factors that have direct contribution toward economic yield. In present study high temperature stress reduced the growth and yield of controlled plants in both the hybrids. Though foliar application of growth promoting substances increased grain yield and its attributes in each hybrid but maximum improvement was observed in PS525 where foliar spray of TRIA and MLE was applied. This was might be the impact of its genetic character and more response to growth promoting substances under heat stress conditions in late sown crop. The experimental units of spring maize hybrid PS525 exhibited improved performance almost in all attributes. Maximum number of grain rows per cob, number of grains per cob, number of grains per row, thousand grain weight, biological and grain yields were observed by foliar application of TRIA followed by MLE. Similar trend was observed in plants sprayed with MLE regarding thousand-grain weight and number of grain rows per cob.

The results of current study are in line with many other researchers who reported that TRIA application increased yield and production of many crops for example 16% increase in the production of rice was achieved (Kawashima *et al*., 1987), 12% in winter wheat and 20% in maize (Ries, 1985). This increase in yield might be due to the improved crop growth and development as a result of foliar spray of TRIA and MLE. Shahbaz *et al*. (2013) reported that TRIA is a potential plant growth regulator which has been reported to significantly affect plant growth and development ,exogenously applied TRIA has been shown to enhance growth of many crops including wheat, maize, rice (Naeem *et al*., 2009; Perveen *et al*., 2010; 2011). All the foliar spray with growth promoting substances significantly improves crop growth attributes such as leaf area index of both hybrids under late sown condition. A periodic increase was examined in maize growth and development by the exogenous application of growth enhancers in the farm of improved leaf area index of both hybrids (Fig 1). TRIA (0.1 mg L^{-1}) and 3% MLE sprays significantly improved growth and development in both hybrids even under temperature stress condition due to late sown crop and this increase might be due to higher accumulation of assimilates in the grain (Foidle *et al*., 2001; Basra *et al*., 2011). Improved physiological parameters by foliar spray of growth promoters in both hybrids might be the result of enhanced tolerance toward heat stress that result in reduced cell membrane permeability, higher relative water contents and chlorophyll contents as compared to control. Maintenance of higher RWC has been considered to be drought resistance rather than drought escape mechanism and it is consequence of adaptive characteristics such as osmotic adjustment (Grashoff and Ververke, 1991).

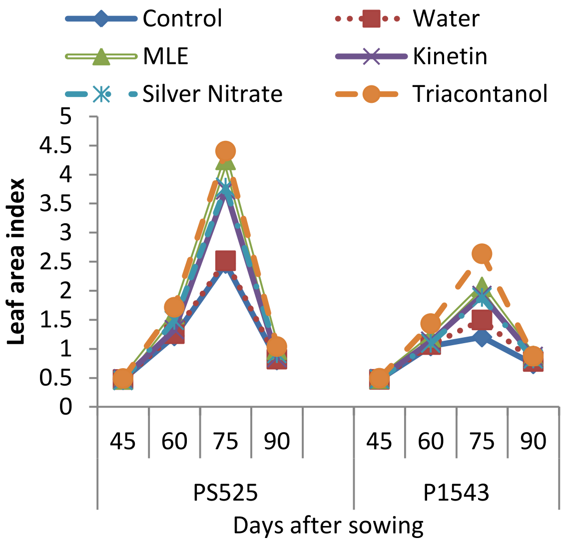

Fig 1.Leaf area index

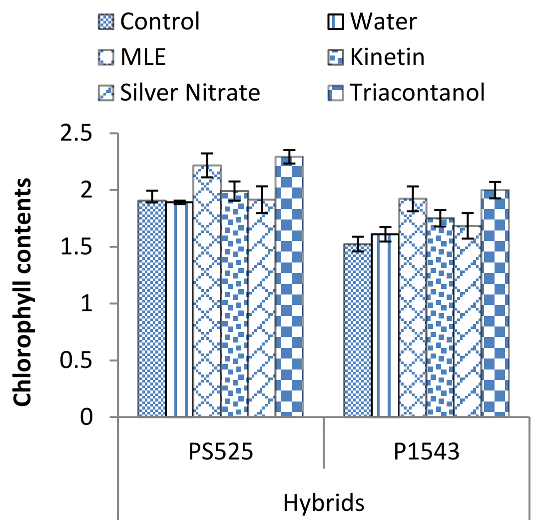

Fig 2. Chlorophyll content

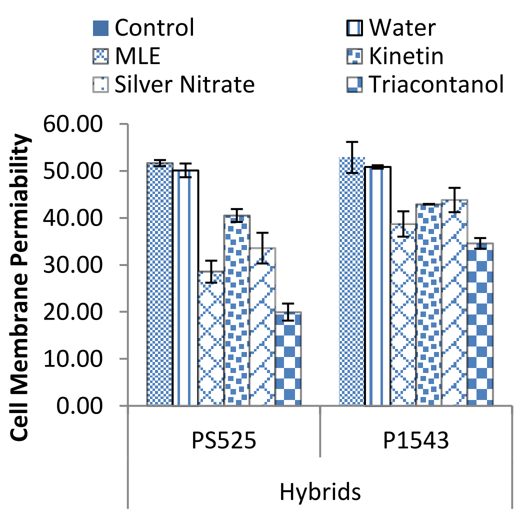

Fig 3. Cell membrane permeability

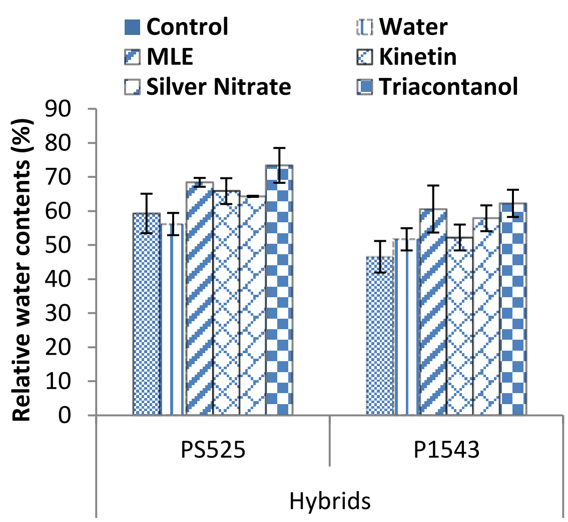

Fig.4 Relative water contents

Improved relative water contents and reduced membrane permeability in spring maize hybrids as a result of foliar application of TRIA and MLE might be due to maintenance of higher tissue water contents carbohydrate metabolism and anti-oxidation activities. These results are in accordance with previous studied done by (Farooq *et al*., 2008). Recorded observations of chlorophyll contents revealed that all foliar application of growth promoting substances substantially increased chlorophyll contents in spring maize hybrids under late sown conditions however a poor performance was observed in unsprayed maize plants. Obtained results are in accordance with those of exogenously applied TRIA increased the chlorophyll contents and photosynthetic activity in various crops (Borowski *et al*., 2000).

TRIA application not only enhanced yield but also quality characteristics of crops as observed in wheat, tomato, cotton, etc. (Ries, 1985; Naeem *et al.,* 2009). This increase in yield might be due to the effect of TRIA because Chen *et al*. (2002) reported that a large number of the TRIA responsive genes were associated with photosynthesis. These genes were up regulated and the stress related genes were down regulated by TRIA. Because of this it enhances the metabolism and growth processes of plants by influencing the enzymes involved in carbohydrate metabolism (Ries *et al*., 1977). The result of this study are also in correspondence with (Shing 1981) who reported that foliar application of TRIA has been shown to increase in yield attributes of rose-scented geranium, foliar and seed treatment with TRIA at 0.05 and 0.10 mg L^{-1} increased the yield of cotton by 12 and 31%, respectively. The results also support the findings of Yaseen *et al*. (2012; 2013) who reported that exogenous application of MLE improved grain weight and yield under stress full environment.

5. CONCLUSIONS

From the above study it can be concluded that foliar spray of natural and synthetic growth promoting substances enhanced grain yield by improving growth and development and inducing thermo tolerance in both hybrids under late sown conditions. Moreover, 0.1 mg L^{-1} foliar spray of TRIA (0.1 mg L^{-1}) and 3% MLE are found to be very effective regarding improved performance of spring maize hybrids under late sown conditions.

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