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Original article

Effects of growth regulators and proline amino acid on yield and yield components of single cross 704 maize under drought stress conditions in Isfahan province

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Extended abstract

Introduction

Corn (Zea mays L) is an annual cereal crop adapted to various ecological conditions. Corn with wheat and rice are three strategic agricultural products in the world. Drought stress is the crucial factor to limit the production of corn among abiotic stresses. Drought stress in corn reduces photosynthesis, and consequently grain yield by reducing the leaf chlorophyll level. Many external and internal factors are effective in plant growth. The most important internal factors are hormones and the most important external factors are light and temperature. Hormones regulate Plant Growth Regulators (PGRs) and coordinate the processes occurring in different parts of the plant body. Plant Growth Regulators (PGRs) increase plant tolerance to various environmental stresses, such as drought, salinity, cold, and heat, and this increase in tolerance to environmental stresses depends on the production of transcripts of anti-stress genes, such as heat shock genes and LEA genes. It is possible to divide the products of genes induced under drought stress conditions into two categories: (1) Those playing a direct protective role against stresses; (2) Those controlling gene expression and message transmission. The Rab-17 gene is one of the genes whose expression increases during drought stress following an increase in ABA. This gene belongs to second group LEA proteins. Several gene products identical to Rab17-encoded proteins have been identified in different plants. Studies indicate that LEA proteins act as water-binding molecules in grains and protect other proteins against the negative effects of drought, including ion separation from macro molecules and membrane protection against freezing damage. This study was conducted to examine the effect of the foliar application of proline amino acid and growth regulators, including benzyl adenine, gibberellic acid, as well as the combination of benzyl adenine and gibberellic acid and proline amino acid on the growth, yield and expression of the Rab-17 gene in corn (*Zea mays* L) (Single Cross 704) under drought stress.

Material and methods

This study was conducted as a split plot on the base of randomized complete block design with three replications in 2015 and 2016. Three irrigation treatments were considered, including after 70 (control), 90, and 100 mm evaporation from the surface of standard Class A evaporation pan as the main agent. Phytohormones BA6, GA (3+ 7), proline amino acid, BA6+ GA (3+ 7) +AA and pure water as control were considered five levels of the sub-factor. The plants were irrigated every 10 days before water stress was applied. Mild and severe stress treatments were applied 45 days after planting and in the 12-leaf

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stage. Afterward, foliar Plant Growth Regulators (PGRs) and proline were applied in the stem elongation stage of corn.

Results and discussion

The results and analysis of the data indicate that all the measured traits decreased with drought stress; however, the proline content increased by increasing the drought stress. For example, drought stress reduced forage yield by 46%. Corn yield was 1.3 times of the control treatment under severe drought stress with foliar application of proline amino acid. In the genetic experiments, increase of drought stress did not increase the PCR response to the Rab-17 gene due to the increased secretion of abscisic acid (ABA) and susceptibility of single cross 704 to drought stress.

Conclusions

According to the results, the foliar application of proline amino acid and Plant Growth Regulators (PGRs) can improve the growth and yield of corn under drought stress by improving plant physiological and genetic responses. Furthermore, the change in the expression of a number of genes appears to be occurred in response to drought stress. The results indicate that gene expression plays a vital role in the drought tolerance of corn; hence, it is suggested to be highly examined in further studies. It is possible that the current results draw our attention to the effects of tested Plant Growth Regulators (PGRs) on the physiology and genetic contents of corn in drought conditions to use the regulators at the right time to deal with environmental stresses in addition to perform proper management in the field, and to increase the efficiency of roots to uptake nutrients.

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***Keywords*:** Drought stress, Gene expression, Growth Regulators, Proline

Table 1. Application used for the thermocycler

Temperature stage	Temprature (℃)	Time (s)	Period
The initial opening of two strings	90	180	1
The final opening of the two strings	90	15	40
Connection	60-70	30	40
String reconstruction	72	45	40

Table 2. Composite analysis of variance of the effect of year, irrigation levels and foliar application on studied traits in corn (Zea mays L) single cross 704

S.O.V	df	Forage yield	Cob yield	Prolin	LAI	RWC
Year (Y)	1	39.085*	0.011	0.053	0.444**	359.680*
Error a	4	5.628	0.010	2.388	0.010*	33.280
Irrigation (I)	2	893.530**	0.592**	184.769**	0.095**	12863.845**
Y * I	2	11.526	0.062*	14.095*	0.016*	175.035*
Error b	8	4.120	0.009	3.099	0.002	38.881
Spraying (S)	4	88.672**	0.044**	20.123**	0.003	41.965
Y * S	4	9.351	0.011	6.778**	0.007	22.249
S * I	8	16.549	0.025**	2.224	0.003	142.101**
Y * I *S	8	9.163	0.016**	3.171*	0.005	50.134*
Error c	48	13.324	0.005	1.096	0.008	18.874

* and ** significant at the 0.05 and 0.01 level, respectively

Table 3. Comparison of the mean interaction of experimental treatments on the measured traits of corn

Year	Irrigation level	Spraying	Cob yield	Prolin	RWC
		Proline amino acid	16.37^{a}	5.58^{defgh}	89.3^{ab}
		BA_6	10.35^{bcdef}	3.90^{hijk}	94.60^{a}
	70	Control	8.35^{efghij}	1.90^{l}	92.64^{a}
		GA_{3+7}	13.30^{abcd}	2.60^{jkl}	88.60^{ab}
		$AA+BA_6+GA_{3+7}$	16.65^{a}	4.34^{ghijk}	82.40^{bc}
		Proline amino acid	8.02^{efghij}	7.22^{cde}	76.35^{cd}
		BA_6	7.5^{fghijk}	4.08^{hijk}	65.79^{e}
2015	**90**	Control	6.35^{ijklmn}	3.21^{ijkl}	79.39^{cd}
		GA_{3+7}	9.35^{defg}	4.21^{hijk}	72.49^{de}
		$AA+BA_6+GA_{3+7}$	6.65^{ghijkl}	5.18^{fghi}	72.38^{de}
		Proline amino acid	8.65^{efghi}	10.10^{a}	45.94^{hi}
		BA_6	$6.35^{hijklmn}$	10.03^{a}	44.32^{hi}
	110	Control	$6.65^{ghijklm}$	7.5^{bcd}	41.05^{i}
		GA_{3+7}	5.85^{jklmn}	10.76^{a}	43.87^{hi}
		$AA+BA_6+GA_{3+7}$	4.45^{mn}	9.19^{ab}	49.20^{ghi}
		Proline amino acid	14.68^{ab}	5.26^{efgh}	88.24^{ab}
		BA_6	13.83^{abc}	4.62^{fghij}	93.50^{a}
	70	Control	9.98^{cdef}	4.18^{hijk}	90.90^{a}
		GA_{3+7}	10.33^{bcdef}	2.54^{kl}	89.60^{ab}
		$AA+BA_6+GA_{3+7}$	14.77^{ab}	4.04^{hijk}	77.42^{cd}
		Proline amino acid	10.93^{bcde}	6.33^{defg}	79.65^{cd}
		BA_6	9.05^{efgh}	6.34^{defg}	76.50^{cd}
2016	**90**	Control	7.48^{fghijk}	6.55^{def}	80.70^{cd}
		GA_{3+7}	15.69^{a}	4.14^{hijk}	73.35^{de}
		$AA+BA_6+GA_{3+7}$	10^{cdef}	5.5^{defgh}	89.20^{ab}
		Proline amino acid	4.28^{n}	9.56^{a}	54.99^{fg}
		BA_6	5.05^{lmn}	9.92^{a}	57.80^{f}
	110	Control	5^{lmn}	5.69^{defgh}	50.03^{gh}
		GA_{3+7}	13.87^{ghi}	7.97^{efghi}	5.56^{defgh}
		$AA+BA_6+GA_{3+7}$	16.35^{efghi}	5.27^{klmn}	8.84^{abc}

In each column means followed by same letters do not differ significantly

Table 4. Comparison of the mean interaction of the year on irrigation level on the measured traits of corn (Zea mays L)

Year	Irrigation	LAI
2015	70	3.21[c]
	90	1.99[d]
	110	1.82[d]
2016	70	4.18[a]
	90	3.66[b]
	110	3.38[bc]

In each column means followed by same letters do not differ significantly

Table 5. Analysis of variance of the effect of irrigation and foliar application levels on the genetic contents of maize (related to 2016)

S.O.V	df	Gene expression rate
Block	2	0.152
Irrigation (I)	2	38.497**
Error a	4	0.569
Spraying (S)	4	0.949
I * S	8	18.142**
Error b	24	0.710

* and ** significant at the 0.05 and 0.01 level, respectively

Table 6. Comparison of the mean interaction of experimental treatments on the genetic contents of corn (related to 2016)

Irrigation	Spraying	Number of reactions PCR
70	**Proline Amino acid**	27.18[a]
	BA_6	23.38[efg]
	Control	25.58[b]
	GA_{3+7}	25.39[bc]
	$AA+BA_6+GA_{3+7}$	25.12[bcd]
90	**Proline Amino acid**	24.85[bcde]
	BA_6	23.90[cdef]
	Control	20.88[h]
	GA_{3+7}	23.56defg
	$AA+BA_6+GA_{3+7}$	22.27[gh]
110	**Proline Amino acid**	17.49[i]
	BA_6	22.50[fg]
	Control	24.54bcde
	GA_{3+7}	22.16[gh]
	$AA+BA_6+GA_{3+7}$	24.44[bcde]

In each column means followed by same letters do not differ significantly