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Original article

To Study the response of grain yield and some agronomical traits of foxtail millet (*Setaria italica* L.) to foliar application of growth regulators under drought stress condition

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Extended abstract

Introduction
Abiotic stresses are major constraints for many crop plants in specific areas over the globe which limits crop production. Drought, the occurrence of a substantial water deficit in the soil, is an alarming constraint to crop productivity and yield stability worldwide. Drought is the leading environmental stress in world agriculture, causing losses in crop yield. Drought stress adversely affects a variety of vital physiological and biochemical processes in plants, leading to reduced growth and final crop yield. One quick strategy to promote plant drought tolerance is exogenous application of various compounds, including organic solutes (organic osmolytes and plant growth regulators) and mineral nutrients. Recently, this strategy has gained considerable attention because of its efficiency, feasibility, and cost- and labor-effectiveness. In this experiment, we studied the roles of some plant growth regulators foliar application including putrescine, humic acid, salisylic acid and methanol, in foxtail millet response to drought stress in enhancing millet drought tolerance and alleviating the damaging effects of drought stress.

Materials and methods
In order to evaluate the effect of plant growth regulators on yield and morpho-phenological traits of foxtail millet under drought stress condition an experiment in split plot arranged in randomized complete block design with three replications conducted in two years of 2017 and 2018 at the Agricultural Research Center of Birjand branch, Islamic Azad University, Birjand. Experimental factors included drought stress as main factor in three levels (irrigation in 30, 70 and 100 percent of plant water requirement) and foliar application of plant growth regulators as sub plot in five levels (control and foliar application of putrescine, humic acid, salisylic acid and methanol). The water requirement was determined by FAO method using evaporation data from Class A pan with 80% efficiency for field water distribution (Hellen et al., 1998). In this method, FAO guidelines were used to determine the vegetative coefficient at different stages of growth. Foliar application of 1 mM salicylic acid, 1 mM putrescine, 1.5 kg.ha-1 humic acid, and 25% volumetric methanol were used in two stages (early stem elongation and early flowering). The averages of data statistically analyzed using analysis of variance

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(ANOVA) by using the SAS system for windows, version 9.1 (SAS Inst., 2001) and means were compared using Duncan Multiple Range Test at 0.05% probability.

Results

Results showed that drought stress led to significant reduction in plant height, peduncle length, number of panicle per meter square, number of grain per panicle, 1000 grain weight, grain yield and biomass while foliar application of plant growth regulators improved morphological traits, yield components and finally grain yield. The highest biomass and grain yield were obtained at 100% water requirement with 704.5 and 267.7 g.m-2, respectively. At 70% of water requirement these traits decreased by 20.2 and 25.2 percent and in 30% of water requirement they reduced by 51.2% and 58.4%, respectively. Foliar application of putrescine, humic acid, salisylic acid and methanol enhanced millet grain yield by 8.3, 23.9, 17.1 and 19.6 percent, respectively in contrast to control treatment. Investigation the interaction of year in irrigation on biomass and grain yield revealed that in both studied years, the highest values of these traits were obtained from 100% water requirement treatment and with increasing of stress intensity they reduced significantly.

Conclusions

Generally, results revealed that application of plant growth regulators improved foxtail millet grain yield under water stress. Application of humic acid under optimal irrigation condition and application of methanol in severe drought stress had the highest impact in improving grain yield.

Keywords: Drought Stress, Humic Acid, Salisylic Acid, Methanol, Putrescine

Table 1. Soil physicochemical properties of experiment site

K	P	N	EC	pH	Texture	Clay	Silt	Sand
---------ppm----------		%	$dS.m^{-1}$		لومی شنی	---------------%--------------		
156	13.4	0.014	4.97	8.01	Sandy loam	15	30	55

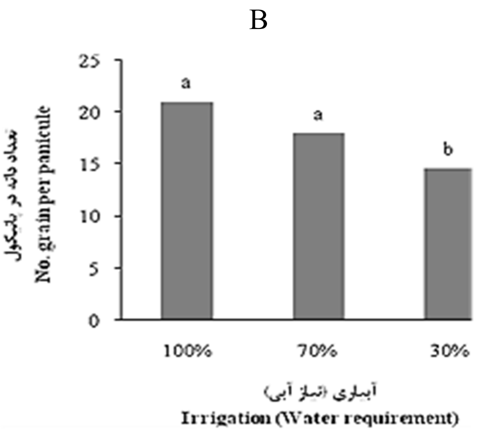
Table 2. Combine analysis of variance for phenological and morphological traits, grain yield and grain yield components of Bastan millet

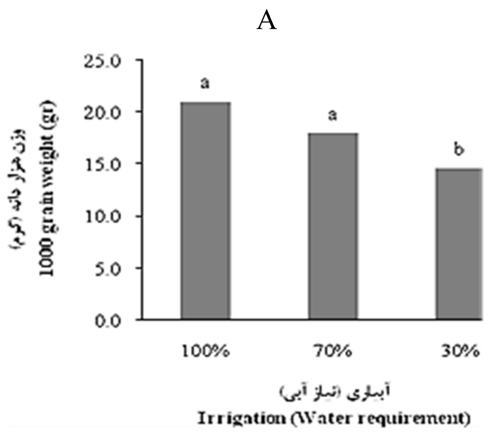
S.O.V.	Df	panicule emergence	Maturity	Grain filling	Plant height	Peduncle length	Panicule length
Year (Y)	1	220.90 ns	1224.71*	405.34 ns	69.34 ns	6.56 ns	0.00004 ns
Replication (Year)	4	11.79	26.36	11.21	78.67	15.70	1.50
Irrigation (I)	2	313.81 ns	928.30 ns	178.54 ns	5393.44*	310.37*	140.39 ns
Y × I	2	17.50**	85.54**	36.88**	145.76**	13.13**	18.12**
Error I	8	13.56	44.07	52.99	270.58	36.52	8.82
Foliar spray (F)	4	41.35 ns	113.53 ns	21.35 ns	498.12 ns	15.25*	12.57*
Y × F	4	21.15**	55.68**	15.48**	126.21**	1.51 ns	3.18*
I × F	8	3.20**	5.16**	4.52*	57.80*	1.57 ns	1.16 ns
Y × I × F	8	0.00 ns	0.85 ns	0.85 ns	14.16 ns	0.73 ns	0.55 ns
Error	48	7.22	20.76	20.09	43.17	6.20	3.50
C.V %		*5.08*	*4.97*	*11.55*	*8.44*	*13.95*	*11.95*

Table 2. Continued

S.O.V.	Df	No. fertile panicule	No. grain per panicule	1000 grain weight	Biomass	Grain yield	HI
Year (Y)	1	222.78 ns	92154 ns	1.330*	364750.8*	82065.5*	295.57 ns
Replication (Year)	4	31.46	11693	0.355	12463.5	2001.9	15.03
Irrigation (I)	2	9162.33**	897533*	1.292*	990970.8*	174690.3*	247.21 ns
Y × I	2	37.48 ns	9917.59 ns	0.034 ns	20088.8*	2610.7**	21.38 ns
Error I	8	97.27	5691.81	0.190	3225.1	1732.9	56.96
Foliar spray (F)	4	255.31 ns	30821**	0.058 ns	21223.3*	4535.2*	15.38 ns
Y × F	4	56.96*	674.65 ns	0.061 ns	3026.2 ns	343.9 ns	3.25 ns
I × F	8	48.20*	4789.95 ns	0.075 ns	6567.0 ns	1126.3*	28.54*
Y × I × F	8	10.89 ns	3999.01 ns	0.030 ns	2488.7 ns	218.9 ns	7.35 ns
Error	48	45.42	4725.01	0.166	2338.9	593.1	18.49
C.V%		*10.62*	*8.17*	*13.19*	*9.01*	*12.95*	*12.55*

ns: not significant; *and ** significant at 5% and 1% probability levels, respectively





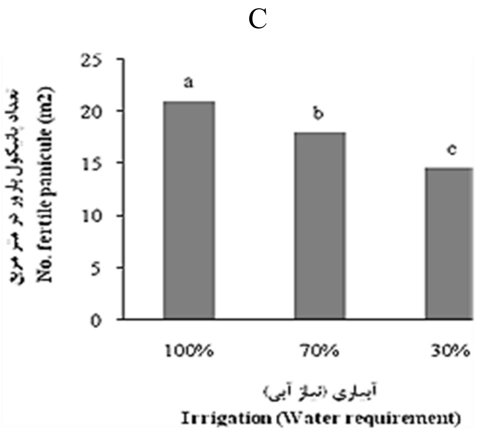


Fig. 1. The effect of irrigation on (A) 1000 grain weight (B) Number of grain per panicule (C) Number of fertile panicule

Table 3. Means comparison for year × irrigation and year× foliar application on phenological and morphological traits, grain yield and grain yield components

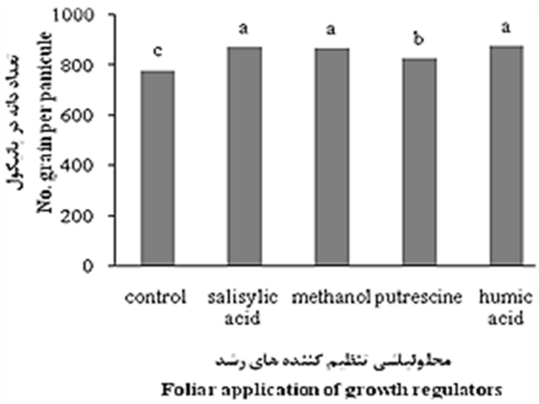
Year	Irrigation (Water requirement)	Panicule emergence	Maturity	Grain filling	Plant height	Peduncle length	Panicule length
		------------------Day---------------			----------------cm----------------		
1st	**100%**	53.9 b	92.1 c	38.2 b	87.7 b	20.1 b	16.9 b
	70%	51.1 c	87.7 d	36.7 c	82.6 c	18.4 c	15.9 c
	100%	48.9 e	84.1 e	35.2 d	60.6 f	14.2 f	14.1 d
2nd	**100%**	58.7 a	101.9 a	43.3 a	91.1 a	21.9 a	18.2 a
	70%	53.9 b	96.5 b	42.6 a	79.4 d	17.5 d	16.3 bc
	100%	50.7 d	87.7 d	36.9 c	65.7 e	14.9 e	12.4 e
Year	**Foliar spray**						
1st	**Control**	50.1 j	86.6 f	36.4 cd	71.1 f	16.0 c	14.9 c
	Salysilic Acid	51.9 f	89.9 d	38.0 b	76.0 de	17.6 b	15.4 bc
	Methanol	52.1 e	89.6 d	37.4 bc	80.1 cd	18.4 ab	15.8 ab
	Putrescine	51.6 g	87.0 f	35.4 d	76.7 cde	18.0 b	15.9 ab
	Humic Acid	50.8 h	86.9 f	36.1 d	80.9 bc	17.8 b	16.2 ab
دوم 2nd	**Control**	50.4 i	88.3 e	37.9 b	69.7 f	16.4 c	13.6 d
	Salysilic Acid	55.2 c	96.9 b	41.7 a	84.8 ab	18.6 ab	16.0 ab
	Methanol	55.4 b	97.6 ab	42.1 a	79.1 cd	18.3 ab	16.5 a
	Putrescine	53.9 d	95.8 c	41.9 a	73.1 ef	18.2 ab	15.5 bc
	Humic Acid	57.1 a	98.2 a	41.1 a	86.9 a	19.1 a	16.6 a

Table 3. Continued

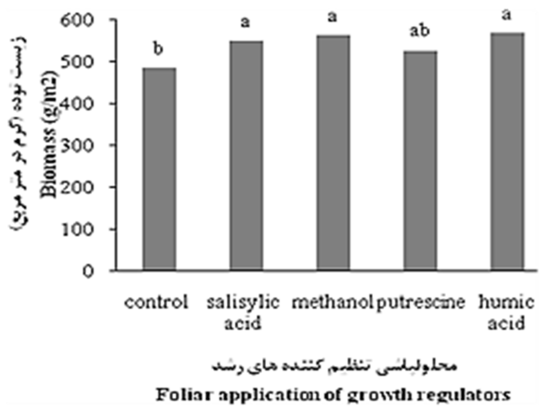
Year	Irrigation (Water requirement)	No. fertile panicule	No. grain per panicule	1000 grain weight	Biomass	Grain yield	HI
				g	---------kg/ha--------		%
	100%	79.3 ^{a}	958.0 ^{b}	3.06 ^{b}	6266 ^{b}	2236 ^{b}	35.7 ^{b}
1st	70%	64.0 ^{c}	867.2 ^{c}	3.08 ^{b}	5283 ^{c}	1754 ^{c}	33.2 ^{c}
	100%	42.3 ^{e}	601.2 ^{e}	2.77 ^{c}	2643 ^{e}	74.5 ^{e}	28.5 ^{d}
	100%	80.3 ^{a}	1022.3 ^{a}	3.31 ^{a}	7823 ^{a}	2977 ^{a}	38.2 ^{a}
2nd	70%	66.9 ^{b}	894.7 ^{c}	3.39 ^{a}	5959 ^{b}	2145 ^{b}	36.0 ^{ab}
	100%	47.8 ^{d}	701.4 ^{d}	2.94 ^{b}	4230 ^{d}	1425 ^{d}	34.0 ^{bc}
Year	Foliar spray						
	Control	59.0 ^{ef}	752.8 ^{d}	3.02 ^{cdef}	4409 ^{c}	1410 ^{f}	31.5 ^{d}
	Salysilic Acid	61.0 ^{def}	835.7 ^{bc}	3.01 ^{def}	4767 ^{bc}	1612 ^{de}	33.3 ^{bcd}
1st	Methanol	63.3 ^{cd}	827.7 ^{bc}	2.92 ^{ef}	4875 ^{bc}	1616 ^{de}	32.2 ^{cd}
	Putrescine	60.6 ^{def}	793.2 ^{cd}	2.86 ^{f}	4620 ^{c}	1498 ^{ef}	31.2 ^{d}
	Humic Acid	65.4 ^{bc}	834.7 ^{bc}	3.04 $^{c-f}$	4982 ^{bc}	1754 ^{cd}	34.2 $^{a-d}$
	Control	57.4 ^{f}	799.9 ^{cd}	3.09 ^{bcde}	5245 ^{b}	1893 ^{c}	36.0 ^{ab}
	Salysilic Acid	68.5 ^{ab}	900.1 ^{ab}	3.21 ^{abc}	6180 ^{a}	2257 ^{a}	36.7 ^{a}
2nd	Methanol	67.7 ^{ab}	898.7 ^{ab}	3.27 ^{ab}	6368 ^{a}	2336 ^{a}	36.3 ^{ab}
	Putrescine	61.4 ^{de}	851.5 ^{abc}	3.20 $^{a-d}$	5877 ^{a}	2083 ^{b}	34.8 ^{abc}
	Humic Acid	69.9 ^{a}	913.8 ^{a}	3.31 ^{a}	6351 ^{a}	2342 ^{a}	36.5 ^{ab}

Means followed by the same letters in each column are not significantly different at 5% probability level (Duncan·s multiple range test)

B



A



C

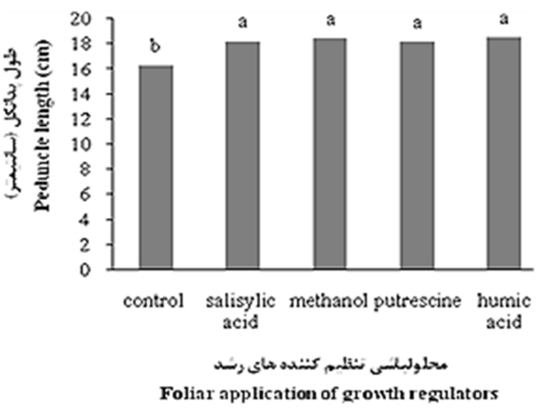


Fig. 2. The effect of foliar application on (A) Biomass (B) Number of grain per panicule (C) Panicule length

Table 4. Means comparison for irrigation × foliar application on phenological and morphological traits, grain yield and grain yield components

Irrigation (Water requirement)	Foliar Spray	Panicule emergence	Maturity	Grain filling	Plant height	Peduncle length	Panicule length
		---Day---			---cm---		
100%	Control	54.3 d	92.0 ef	37.7 de	83.8 c	18.4 b	15.9 e
	Salysilic Acid	56.8 b	99.2 a	42.3 a	91.0 b	21.5 a	17.7 abc
	Methanol	56.8 b	98.0 ab	41.2 ab	86.0 bc	21.9 a	17.6 abc
	Putrescine	56.3 c	97.5 b	41.2 ab	87.8 bc	21.5 a	17.8 ab
	Humic Acid	57.0 a	98.3 ab	41.3 ab	98.4 a	21.8 a	18.6 a
70%	Control	48.7 l	87.5 g	38.8 cd	70.6 e	16.7 c	14.4 f
	Salysilic Acid	53.2 f	93.7 d	40.5 b	84.4 c	18.2 b	16.2 e
	Methanol	54.2 e	95.3 c	41.2 ab	84.9 c	18.3 b	16.7 cde
	Putrescine	52.0 g	91.0 f	39.0 c	78.3 d	18.0 b	16.2 de
	Humic Acid	54.3 d	93.0 de	38.7 cd	87.0 bc	18.6 b	17.2 bcd
30%	Control	47.8 m	82.8 i	35.0 g	56.7 f	13.7 e	12.4 h
	Salysilic Acid	50.7 h	87.3 g	36.7 ef	65.9 e	14.7 de	13.2 gh
	Methanol	50.3 j	87.3 g	37.0 ef	68.1 e	14.9 d	14.2 fg
	Putrescine	49.8 k	85.7 h	35.8 fg	58.8 f	14.7 de	13.2 gh
	Humic Acid	50.5 i	86.3 gh	35.8 fg	66.3 e	14.9 d	13.4 gh

Table 4. Continued

Irrigation (Water requirement)	Foliar Spray	No. fertile panicule	No. grain per panicule	1000 grain weight	Biomass	Grain yield	HI
				g	---kg/ha---		%
100%	Control	73.6 cd	943.6 abc	3.03 c-f	6476 bc	2307 c	35.5 b-e
	Salysilic Acid	81.7 b	1010.5 ab	3.08 b-e	7507 a	2619 b	34.9 b-f
	Methanol	77.3 bc	973.7 abc	3.26 abc	6966 ab	2536 b	36.2 a-d
	Putrescine	79.0 b	992.2 abc	3.19 a-d	6823 abc	2616 b	38.5 ab
	Humic Acid	87.5 a	1030.8 a	3.35 a	7452 a	2955 a	39.8 a
70%	Control	59.4 f	780.0 e	3.19 a-d	4784 f	1652 e	34.4 c-g
	Salysilic Acid	67.2 e	912.8 cd	3.29 ab	5368 ef	2028 d	37.9 abc
	Methanol	69.1 de	942.8 abc	3.21 abc	6125 cd	2198 cd	35.7 b-e
	Putrescine	62.5 f	844.1 de	3.24 abc	5652 de	1797 e	31.5 fgh
	Humic Acid	69.1 de	925.3 bcd	3.26 abc	6177 cd	2071 d	33.4 d-g
30%	Control	41.8 i	605.4 f	2.94 def	3220 g	996 fg	31.4 fgh
	Salysilic Acid	45.3 hi	680.4 f	2.96 def	3546 g	1157 fg	32.2 e-h
	Methanol	50.1 g	673.1 f	2.80 fg	3774 g	1196 f	30.9 gh
	Putrescine	41.6 i	630.9 f	2.65 g	3271 g	959 g	29.1 h
	Humic Acid	46.4 gh	666.7 f	2.91 ef	3371 g	1119 fg	32.7 d-h

Means followed by the same letters in each column are not significantly different at 5% probability level (Duncan's multiple range test)