EurAsian Journal of BioSciences
Eurasia J Biosci 12, 467-472 (2018)

Environmental evaluation of auxin priming and plant growth promoting rhizobacteria on yield and yield components of wheat under drought stress

Najmeh Bagheri [1], Omid Alizadeh [2*], Shahram Sharafzadeh [1], Farshid Aref [1], Kourosh Ordookhani [1]

[1] Department of Agriculture, Firoozabad Branch, Islamic Azad University, Firoozabad, IRAN
[2] Department of Agriculture, Shiraz Branch, Islamic Azad University, Shiraz, IRAN
*Corresponding author: alizadehomid51@yahoo.com

Abstract

This study was performed to the environmental evaluation of auxin and plant growth promoting rhizobacteria priming on yield and yield components of wheat under drought stress. Experiment was conducted as a Split plot in RCBD design with 3 replications. Main factor included drought stress (irrigation on base of 25, 50 and 75%FC) and sub plots were inoculation at 4 levels (control, azotobacter, pseudomonas and a combination of two bacteria), also sub plots were auxin priming at 4 levels (0, 1, 2 and 4 mg.L^{-1}). According to results, application of drought stress led to the reduction grain yield, so, the 50% and 75% water discharge treatments led to 9% and 37% the reduction of grain yield as compared to control, respectively. In relation to bacteria treatments, highest grain yield (4.35 t/ha) obtained by azotobacter inoculation. In relation to auxin application, the 4 mg.L^{-1} treatment led to 6%the increase of grain yield as compared to control. Highest means of grain yield (3.25 t/ha) under 75% discharge water observed by azotobacter inoculation. We concluded that priming with auxin and rhizobacteria, plays an important role in the induction of tolerance to drought and overcome limitations created by the drought stress on wheat.

Keywords: environmental evaluation, bacteria, plant regulator, priming, yield, wheat

Bagheri N, Alizadeh O, Sharafzadeh Sh, Aref F, Ordookhani K (2018) Environmental evaluation of auxin priming and plant growth promoting rhizobacteria on yield and yield components of wheat under drought stress. Eurasia J Biosci 12: 467-472.

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INTRODUCTION

Wheat is a stable food for 35% of the world population, and moreover, about 60% of land area on the globe belongs to arid and semiarid zone. More recently, drought stress is a worldwide problem especially in Middle East, seriously influencing plant productions. Water deficit is characterized by reduction of water content, turgor loss, diminished leaf water potential, decrease in cell enlargement, closure of stomata and growth (Sher *et al*. 2017). Drought resistance is a multi-gene controlling quantitative character and wheat final production in field is realized mainly by physiological regulation under the condition of multi-environmental factor interaction (HongBo et al. 2005). Many strategies are being practiced in the world to cope with water stress (Ashraf and Follad 2007); however, it has been suggested that, seed priming is cheapest approach to the decrease of abiotic stresses effects at different developmental stages of crop (Razzaq et al. 2013). Priming of seed is the induction of a particular physiological state in plants by the treatment of natural and synthetic compounds to the seeds before germination. In crop defense, priming is defined as a physiological process by which a plant prepares to the cope with abiotic stress more quickly or aggressively (Jisha et al. 2013). Abid et al. (2017) mentioned that pre-drought priming facilitated the wheat plants to sustain grain development against the post-anthesis drought stress by modulating the levels of growth hormones. The role of microorganisms in plant growth, nutrient management and biocontrol activity is very well demonstrated. These beneficial microorganisms colonize the rhizosphere/endo-rhizosphere of plants and promote growth of the plants through various direct and indirect mechanisms (Grover et al. 2011). It has been suggested that, the role of microorganisms in management of biotic and abiotic stresses is gaining importance. The possible explanation for the mechanism of plant drought tolerance induced by rhizobacteria include: (1) production of phyto hormones; (2) ACC deaminase to reduce the level of ethylene in the roots; (3) induced systemic tolerance by bacterial compounds; (4) bacterial exopolysaccharides (Kim et al.

Received: July 2018
Accepted: October 2018
Printed: December 2018

2013, Timmusk et al. 2014, Vurukonda et al. 2016). Also Kumar et al. (2016) mentioned a significant improvement in the shoot diameter, shoot height, fruit yield and seed yield was evident in 18-month-old Jatropha plants under field conditions when azotobacter and arbuscular mycorrhizal fungi were co-inoculated. Ulfat et al. (2017) reported wheat seed hormone priming was able to overcome drought stress and increased yield and stress tolerance index was also improved by using hormonal priming. Based on Shariatmadari et al. (2017) results in chickpea, hormo-priming increased seed emergence and plant vigor. The general objective of this study was to investigate the response of wheat to drought stress. Other objectives were to check usefulness of phytohormones auxin as priming agents and plant growth promoting rhizobacteria to improve the wheat performance in terms of yield and yield contributing traits under drought and non-stressed control conditions.

MATERIALS AND METHODS

Statistical Design and Treatments

Experiment was conducted as a Split Split plot in RCBD design with 3 replications. Main factor included drought stress (irrigation on base of 25, 50 and 75%FC) and sub plots were priming at four levels (Control, Azotobacter, Pseudomonas and a combination of two bacteria). The experimental seeds were immersed in the inoculum for 12 hours and they were washed twice with distilled water and then dried, also sub sub plot were auxin priming at four levels (0, 1, 2 and 4 $mg.L^{-1}$).

Field Operations

The field was as fallow at before year. Field operation was done according to usual of region methods (plow, Disc land leveling and furrow). Fertilizer levels were determined after soil analysis. Each plot contained eight rows with two meters length and a distance of 0.2 m, with a constant density of 450 plants per square meter. In the stem extension stage of wheat, weeds chemical control were carried out using Granstar herbicide (for the control of grassy weeds) and Puma super (to fight broadleaf weeds).The first irrigation was done in full but other irrigations were done according to irrigation treatments (irrigation on base of 25, 50 and 75% FC). The final harvest was carried out at the time of drying the stems under the spike and reaching the seeds to hardening and moisture content of about 14%. At the end of the growth period, some properties measured such as yield, yield components (1000 seed weight, number of spikes per plant, number of seeds per spike), plant height, leaf number, harvest index, biological yield.

Data Analysis

Data were analyzed using the general linear model (GLM) procedure of the statistical analysis system, SAS. When analysis of variance showed significant treatment effects, Duncan's multiple range tests were applied to compare the means at $P < 0.05$.

RESULTS AND DISCUSSION

Plant Height and Leaf Number

According to the results, drought stress and bacteria had significant effects on plant height and leaf number at 1% statistically level but auxin only showed significant effect on plant height at 1% statistically level and interaction between three factors showed significant effect on leaf number at 1% statistically level. Application of drought stress led to the reduction in plant height and leaf number, so, the 50% and 75% water discharge treatments led to 8 and 14% the reduction of plant height and 13 and 31% the reduction of leaf number by the compare to control, respectively. In relation to bacteria treatments, highest plant height (74 cm) and leaf number (5.97 per plant) obtained by azotobacter and lowest means observed by combination of two bacteria treatment. In relation to auxin application, The 2$mg.L^{-1}$ treatment led to 3% the increase of plant height and the leaf number increased the 4% by application of 1 $mg.Lit^{-1}$, by the compare to control. Fahad et al (2015) reported exogenous application of various plant growth regulators assuaged the adverse effects of high temperature on rice. Hormone pretreatment is a commonly used priming strategy to improve seed germination and establishment of the plant in stressful conditions (Bhanuprakash and Yogeesha 2016, Masood et al. 2016, Li et al. 2016). For example, rye (Secale montanum) pretreated with gibberellic acid (GA3) increased plant height in water deficit conditions (Ansari et al. 2013). In pepper, Khan et al. (2009) showed that pretreatment with acetylsalicylic acid and salicylic acid resulted in greater establishment of seedlings and growth under high salinity. Contrary to the results of this work, azetobacter plays an important role in the induction of tolerance to drought and overcome limitations created by 75% discharge water treatment, values of plant height at 75% discharge water with azetobacter treatments were 75 cm, there was no significant differences between bacteria treatments at 50 and 75% discharge water treatments on leaf number. In relation to interaction between drought stress and auxin, it was founded that application of 2$mg.Lit^{-1}$ auxin priming had highest plant height at 50% and 75% discharge water treatments (74.9 and 61.9 cm, respectively). Application of 4$mg.L^{-1}$ at normal irrigation showed highest leaf number and lowest mean obtained by 0 auxin under 75% water discharge treatment.

Spikes Numbers per Plant and Seed Numbers per Spike

According to the results, drought stress and bacteria had significant effects on Spikes numbers per plant and seed numbers per spike at 1% statistically level but auxin only showed significant effect on seed numbers per spike at 5% statistically level. Interaction of stress with bacteria and interaction of stress with auxin had significant effect on spikes numbers per plant at 1%. Interaction between three factors showed significant effect on of seed numbers per spike at 5% statistically level. Application of drought stress led to the reduction in Spikes numbers per plant and of seed numbers per spike, so, the 50% and 75% water discharge treatments led to 14 and 20% the reduction of Spikes numbers per plant and 15 and 43% the reduction of seed numbers per spike by the compare to control, respectively. In relation to bacteria treatments, highest Spikes numbers per plant (13) and seed numbers per spike (43.89) obtained by azotobacter and pseudomonas, respectively. In relation to auxin application, the 4mg.L^{-1} treatment led to 4% and 3% the increase in Spikes numbers per plant and seed numbers per spike, by the compare to control, respectively. At 75% water discharge treatment, application of pseudomonas showed highest means of spikes numbers per plant and seed numbers per spike (12.16 and 29.92, respectively), so pseudomonas plays an important role in overcome limitations created by 75% discharge water treatment. The results of Naveed et al. (2014)suggested that *Burkholderia phytofirmans* strain PsJN could be effectively used to improve the growth, physiology and quality of wheat under drought conditions, also, Inoculation improved the ionic balance, antioxidant levels, and also increased the nitrogen, phosphorus, potassium and protein concentration in the grains of wheat. In relation to interaction between drought stress and auxin, it was founded that at 75% discharge water treatments highest spikes numbers per plant (12.58) was obtained by 2mg.L^{-1} auxin priming. Raheem *et al*, (2018) concluded that application of the drought tolerant rhizobacteria can help to overcome productivity losses in drought prone areas and for yield parameters and recorded 34% and 1 fold increases for spike length and seed weight, over respective control at 10% FC.

1000seed Weight and Seed Yield

According to the results, drought stress had significant effects on 1000seed weight and seed yield at 1% statistically level, also bacteria treatment showed significant effects on 1000seed weight and seed yield at 1 and 5% statistically level, respectively. Auxin showed no significant effect on 1000seed weight but had significant effect on seed yield at 5% statistically level. Application of drought stress led to the reduction in 1000seed weight and seed yield, so, the 50% and 75% water discharge treatments led to 27 and 48% the reduction of 1000seed weight and 9 and 37% the reduction of seed yield by the compare to control, respectively. Wang et al. (2017) mentioned that drought stress reduced wheat yield due to a reduction in grain number and seed size. In relation to bacteria treatments, highest 1000seed weight (29.12 g) and seed yield (4.35) obtained by pseudomonas and azotobacter, respectively. Barnawal et al. (2017) suggested that PGPR confer abiotic stress tolerance in wheat by enhancing IAA content, reducing ABA/ACC content, modulating expression of a regulatory component (CTR1) of ethylene signaling pathway and DREB2 transcription factor. Naveed et al. (2014) reported that grain yield was decreased when plants were exposed to drought stress at the tillering and flowering stage, but inoculation resulted in better grain yield (up to 21 and 18 % higher, respectively) than the respective uninoculated control. In relation to auxin application, the 4mg.L^{-1} treatment led to 6%the increase of seed yield, by the compare to control. Highest means of 1000seed weight (20.35 g) and seed yield (3.25) under 75% discharge water observed by pseudomonas and azotobacter, respectively.

Biological Yield and Harvest Index

Analysis of variances showed that drought stress and auxin had significant effect on biological yield at 1% statistically level, but showed no significant effect on harvest index. Application of drought stress led to the reduction in biological yield. So, the 50% and 75% water discharge treatments led to 10 and 33% the reduction of biological yield. In relation to auxin application, the 2mg.L^{-1} treatment led to 9% the increase of biological yield as compared to control. Shi et al. (2014) demonstrated that auxin might participate in the positive regulation of drought stress resistance, through regulation of root architecture, ABA-responsive genes expression, ROS metabolism, and metabolic homeostasis, at least partially.

CONCLUSION

This study was performed to evaluation of auxin priming and plant growth promoting rhizobacteria on yield and yield components of wheat under drought stress. Application of drought stress led to the reduction seed yield, so, the 50% and 75% water discharge treatments led to 9% and 37% the reduction of seed yield as compared to control, respectively. In relation to bacteria treatments, highest seed yield (4.35) obtained by azotobacter. In relation to auxin application, the 4mg.Lit^{-1} treatment led to 6%the increase of seed yield as compared to control. Highest means of grain yield (3.25) under 75% discharge water observed by azotobacter. We concluded that priming with auxin and rhizobacteria plays an important role in the induction of tolerance to drought and overcome limitations created by the drought stress on wheat.

Table 1. Analysis of variance for the effect of experimental treatments on height, number of leaves, number of spikes per plant and number of seeds per spike

Source of variation	Freedom degree	Means of square			
		height	number of leaves	number of spikes per plant	Seeds per spike
Block	2	13/450	0/895	0/187	10/225
Drought stress (a)	2	4445/984**	51/437**	106/270**	6426/326**
Error (a)	4	5/275	0/333	1/427	13/665
Bacteria (b)	3	145/213**	1/555**	4/803**	109/761**
b × a	6	151/389**	*0/854	4/317**	27/423**
Auxin (c)	3	38/913**	0/5000^{ns}	1/747^{ns}	13/733*
c × a	6	3/276^{ns}	1/076**	3/706**	3/670^{ns}
c × b	9	5/301^{ns}	0/346^{ns}	2/513**	13/573**
a × b ×c	18	6/538^{ns}	0/801**	1/628	5/696^{ns}
Error	90	8/873	0/328	0/828	4/712
Coefficient of variation		4/18	9/96	7/18	5/10
Block	2	27/045	3/346	1/067	16/407
Drought stress (a)	2	3711/511**	323/036**	44/737**	36/868^{ns}
Error (a)	4	11/240	1/588	0/309	18/086
Bacteria (b)	3	48/745**	1/161^{ns}	0/417*	10/878^{ns}
b ×a	6	39/017**	4/204**	0/304*	7/880^{ns}
Auxin (c)	3	1/900^{ns}	10/889**	*0/467	12/296^{ns}
c × a	6	1/394 ^{ns}	1/073^{ns}	0/103^{ns}	7/303^{ns}
c × b	9	2/142^{ns}	1/333	0/274*	7/656^{ns}
a × b ×c	18	2/313^{ns}	0/635^{ns}	0/082^{ns}	5/334^{ns}
Error (c)	90	4/266	0/600	0/137	7/066
Coefficient of variation		7/48	6/00	8/69	8/08

ns, * and ** show non-significant and significant at 5 and 1%

Table 2. Effects of drought stress on studied traits

	Plant height (cm)	Leaf number	Spikes numbers per plant	seed numbers per spike	1000seed weight	seed yield	biological yield	harvest index
25% water discharge	79.63^{a}	6.72^{a}	14.33^{a}	52.88^{a}	36.7223^{a}	5.0213^{a}	15.0663^{a}	33.1408^{a}
50% water discharge	73.35^{b}	5.85^{b}	12.92^{b}	44.72^{b}	26.9398^{b}	4.5806^{b}	13.6175^{b}	33.6363^{a}
75% water discharge	60.73^{c}	4.66^{c}	11.43^{c}	30.05^{c}	19.1742^{c}	3.1729^{c}	10.0273^{c}	31.9325^{a}

At each column, means with similar alphabet show no significant differences (Duncan 5%)

Table 3. Effects of Bacteria treatments on studied traits

	Plant height (cm)	Leaf number	Spikes numbers/plant	seed numbers/spike	1000seed weight (g)	seed yield (t/ha)	biological yield(t/ha)	harvest index
Control	70.21^{bc}	50.75^{a}	12.72^{a}	43.63^{ab}	26.335^{c}	4.20611^{ab}	12.9939^{ab}	32.3556^{a}
Azotobacter	74.01^{a}	5.97^{a}	13.00^{a}	42.62^{b}	27.2486bc	4.35417^{a}	13.0486^{a}	33.1833^{a}
Pseudomonas	71.33^{b}	50.80^{a}	12.86^{a}	43.90^{a}	29.1228^{a}	4.34111^{a}	12.9275^{ab}	33.5289^{a}
Pseudomonas + Azotobacter	69.41^{c}	5.47^{a}	12.16^{b}	40.06^{c}	27.7419^{b}	4.13167^{b}	12.6447^{b}	32.545^{a}

At each column, means with similar alphabet show no significant differences (Duncan 5%)

Table 4. Effects of auxin treatments on studied traits

	Plant height (cm)	Leaf number	Spikes numbers/plant	seed numbers/spike	1000seed weight (g)	Grain yield (t/ha)	biological yield(t/ha)	harvest index
Control	70.81^{b}	5.67^{a}	12.53^{ab}	41.81^{b}	27.56^{a}	4.18806^{b}	12.5881^{b}	33.0261^{a}
1	71.07^{b}	5.89^{a}	12.75^{ab}	42.55^{ab}	27.779.^{a}	4.19583^{b}	12.6453^{b}	33.2178^{a}
2	72.74^{a}	5.64^{a}	12.97^{a}	43.03^{a}	27.798.^{a}	4.42778^{a}	13.7275^{a}	32.0461^{a}
4	70.35^{b}	5./81^{a}	12/.50^{b}	42.95^{a}	27.306.^{a}	4.22139^{b}	12.6539^{b}	33.3228^{a}

At each column, means with similar alphabet show no significant differences (Duncan 5%)

Table 5. Effects of drought stress and bacteria interaction on studied traits

		Plant height (cm)	Leaf number	Spikes numbers/plant	seed numbers/spike	1000seed weight (g)	seed yield (t/ha)	biological yield(t/ha)	harvest index
25% water discharge	Contril	78.88^{ab}	6.75^{ab}	13.92^{bc}	55.51^{a}	34.35^{b}	4.7733^{c}	14.41^{b}	33.26^{ab}
	Azotobacter	78.45^{b}	7.00^{a}	14.50^{b}	53.47^{b}	34.99^{b}	5.1367^{ab}	15.5892^{a}	32.49^{ab}
	Pseudomonas	80.07^{ab}	6.83^{a}	15.25^{a}	52.31^{b}	38.16^{a}	5.3275^{a}	15.8142^{a}	33.41^{ab}
	Pseudomonas + Azotobacter	81.12^{a}	6.33^{bc}	13.67^{c}	50.23^{c}	39.39^{a}	4.8475^{bc}	14.4517^{b}	33.403^{ab}
50% water discharge	Contril	73.15^{c}	5.83^{cd}	12.50^{d}	44.00^{e}	25.61^{d}	4.6033^{cd}	14.1967^{bc}	32.462^{ab}
	Azotobacter	75.03^{c}	5.83^{cd}	12.33^{d}	44.45^{e}	28.40^{c}	4.6733^{cd}	13.4258^{d}	34.781^{a}
	Pseudomonas	72.72^{c}	6.25^{c}	11.92^{de}	47.13^{d}	28.85^{c}	4.6208^{cd}	13.2608^{d}	34.807^{a}
	Pseudomonas + Azotobacter	72.525^{c}	5.50^{de}	12.42^{d}	43.32^{e}	24.90^{d}	4.425^{d}	13.5867^{cd}	32.496^{ab}
75% water discharge	Contril	58.60^{f}	4.66^{fg}	11.75^{de}	31.38^{fg}	19.0517^{ef}	3.2417^{e}	10.375^{e}	31.345^{b}
	Azotobacter	68.55^{d}	5.08^{ef}	12.16^{de}	29.92^{g}	18.3625^{f}	3.2525^{e}	10.1308^{e}	32.279^{ab}
	Pseudomonas	61.20^{e}	4.33^{g}	11.41^{e}	32.24^{f}	20.3567^{e}	3.075^{e}	9.7075^{e}	32.37^{ab}
	Pseudomonas + Azotobacter	54.58^{g}	4.58^{g}	10.41^{f}	26.64^{h}	18.9258^{ef}	3.1225^{e}	9.8958^{e}	31.736^{b}

At each column, means with similar alphabet show no significant differences (Duncan 5%)

Table 6. Effects of drought stress and auxin interaction on studied traits

		Plant height (cm)	Leaf number	Spikes numbers/plant	seed numbers/spike	1000seed weight (g)	seed yield (t/ha)	biological yield(t/ha)	harvest index
25% water discharge	Control	79.368^{ab}	6.417^{b}	14.500^{ab}	52.715^{a}	36.82^{a}	4.99^{ab}	14.5967^{b}	33.973^{ab}
	1	79.688^{ab}	6.583^{ab}	14.667^{a}	52.599^{a}	37.35^{a}	4.91^{abc}	14.6825^{b}	33.396^{abc}
	2	81.375^{a}	6.917^{a}	13.833^{b}	53.595^{a}	36.59^{a}	5.22^{a}	16.2908^{a}	31.539^{bc}
	4	78.093^{b}	7.000^{a}	14.333^{ab}	52.619^{a}	36.12^{a}	4.94^{ab}	14.695^{b}	33.655^{ab}
50% water discharge	Control	72.418^{c}	6.083^{bc}	12.083^{c}	43.393^{c}	26.85^{b}	4.48^{de}	13.1958^{c}	34.018^{ab}
	1	72.915^{c}	6.167^{b}	12.333^{c}	44.667^{bc}	26.86^{b}	4.61^{cde}	13.4492^{c}	34.338^{a}
	2	74.908^{c}	5.500^{d}	12.500^{c}	45.117^{bc}	27.14^{b}	4.78^{bcd}	14.4933^{b}	32.821^{abc}
	4	73.198^{c}	5.667^{cd}	12.250^{c}	45.719^{b}	26.90^{b}	4.44^{e}	13.3317^{c}	33.368^{abc}
75% water discharge	Control	60.638^{d}	4.500^{e}	11.000^{d}	28.935^{d}	19.02^{c}	3.08^{f}	9.9717^{d}	31.088^{c}
	1	60.598^{d}	4.917^{e}	11.250^{d}	30.371^{d}	19.12^{c}	3.06^{f}	9.8042^{d}	31.919^{abc}
	2	61.930^{d}	4.500^{e}	12.583^{c}	30.374^{d}	19.65^{c}	3.27^{f}	10.3983^{d}	31.778^{bc}
	4	59.775^{d}	4.750^{e}	10.917^{d}	30.514^{d}	18.89^{c}	3.27^{f}	9.935^{d}	32.945^{abc}

At each column, means with similar alphabet show no significant differences (Duncan 5%)

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