University of Birjand

تنشهای محیطی در علوم زراعی
Environmental Stresses In Crop Sciences

Journal homepage: https://escs.birjand.ac.ir

Vol. 15, No. 4, pp. 921-934 (Winter 2023)

http://dx.doi.org/10.22077/escs.2021.4167.1979

Original article

Increasing *Triticum aestivum* (var. Narin) yield with bacteria isolated from rhizosphere of *Seidlitzea rosmarinus*, *Atriplex lentiformis* and *Halostachys belangeriana* under salinity stress

A. Mosleh Arani[1*], A.R. Amini Hajiabadi[2, 3], S. Ghsemi[4], M.H. Rad[5]

1. Department of Environmental Sciences, Faculty of Natural Resources, Yazd University, Yazd, Iran
2. PhD Student, Faculty of Natural Resources, Yazd University, Yazd, Iran
3. Central Office of Natural Resources and Watershed Management, Yazd, Iran
4. Associate Proffessor, Department of Soil Science, Faculty of Natural Resources, Yazd University, Yazd, Iran
5. Assistant Prof, Forest and Rangeland Division, Yazd Agricultural and Natural Resource Research and Education Center, Agriculture Research Education and Extension Organization (AREEO), Yazd, Iran

Received 20 February 2021; Accepted 22 June 2021

Extended abstract

Introduction
Increasing world population, along with climate change and environmental stresses, has posed a serious challenge to adequate food supply. Salinity is one of the most important stresses affecting the reduction of agricultural products. In recent years, the use of new strategies for sustainable production of food products under salinity stress has been considered, including plant growth promoting rhizosphere bacteria. Due to the strategic importance of wheat in food security, this study was designed and conducted with the aim of increasing the salinity resistance of wheat (Var. Narin) using plant growth promoting rhizosphere bacteria isolated from the rhizosphere of several halophyte plants in Yazd province.

Materials and methods
Plant growth promoting traits such as ability to produce auxin, siderophore, hydrogen cyanide, and phosphate solubility and salinity resistance of isolated bacteria from rhizosphere of halophyte plants (*Atriplex lentiformis*, *Seidlitzea rosmarinus*, *Halostachys belangeriana* and *Tamarix ramossima*) in their habitats in Chahafzal in Yazd Province were investigated. Then, wheat seeds were inoculated with the best three bacteria in terms of plant growth-promoting traits and salinity resistance, and then was irrigated with water with salinities of 4, 8 and 16 ds m^{-1}. After the growth period, total biomass, seed weight and spike components and seed amylose and amylopectin were measured.

Results and discussions
The studied bacteria including *Bacillus safensis*, *B. pumilus* and *Zhihengliuella halotolerans* had the ability to produce auxin, siderophore, hydrogen cyanide, 1-aminocyclopropane-1-carboxylic acid deaminase (ACC deaminase) and phosphate solubility. The highest amount of auxin production was measured in B. safensis (29.72 µg ml^{-1}) and the highest amount of hydrogen cyanide production and phosphate solubility was in *Z. halotolerans*. The highest amount of ACC deaminase was measured in *B. pumilus* (8 µmol of α-ketobutyrate h^{-1} mg^{-1} protein). The results showed that increasing salinity levels

* Corresponding author: Asghar Mosleh Arani; E-Mail: amoleh@yazd.ac.ir

decreased spike length, spike weight, number of spikelets, number of florets, number of seed, seed weight, amylose and amylopectin content of seeds. The length and weight of spikes at salinity of 16 dS m^{-1} decreased by 36% and 18%, respectively, compared to the non-salinity control. Instead, *B. safensis*, *Z. halotolerans* and *B. pumilus* caused an average increase of 35, 22, and 17.6% of the spike length at salinity stress levels (4, 8, and 16 dS m^{-1}), respectively, compared to the uninoculated controls. Also, B. *safensis*, *B. pumilus* and *Z. halotolerans* bacteria caused an average increase of 69, 43 and 30% of spike weight in salinity stress levels compared to the uninoculated control, respectively. The number of spikelets and number of florets at salinity of 16 dS m^{-1} decreased by 27 and 43%, respectively, compared to the non-salinity control. In all salinity stress levels, *B. safensis*, *Z. halotolerans* and *B. pumilus* caused an average increase of 48, 26 and 13% of total biomass, and an average increase of 59, 23 and 7% of seed weight in all salinity stress levels compared to control. *B. safensis*, more than the other two bacteria, improved the total biomass and seed weight of wheat.

Conclusions

Plant growth promoting rhizosphere bacteria in this experiment significantly improved the resistance of wheat to salinity stress. Comparison between the studied bacteria showed that *B. safensis* had a greater effect on the promotion of total biomass, yield and all traits of the studied components than *B. pumilus* and *Z. halotolerans*, due to the superiority of *B. safensis* in auxin production and increasing the ratio of potassium to sodium. It can be concluded that the auxin and the potassium are of key importance in increasing the reproductive performance of Narin cultivar. It is also concluded that the rhizosphere of halophytic rangeland plants can be a good source for the isolation of salinity-resistant bacteria to improve the resistance of wheat plants to salinity.

***Keywords*:** Amylopectin, Auxin, *Bacillus safensis*, Plant Growth Promoting Rhizobacteira

Table 1- Selected physical and chemical characteristics of the greenhouse experiment soil

Clay	Silt	Sand	Cu	Na	Mg	SP	pH	EC
-----------------	%	---------------	-----------------------	mg kg^{-1}	------------------	%		dsm^{-1}
8	19	73	0.72	10	204	31	7.2	2.9

Table 1. Continued

Ca	C	Mn	Fe	Zn	K	P	N
mg kg^{-1}	%	------------------------	------------------------	mg kg^{-1}	------------------------	------------------------	%
312	0.42	10.4	8.5	1.1	168	15.8	0.04

Table 2. Average production of Indole 3 Acetic Acid, Hydrogen Cyanide, Siderophore, ACC-deaminase and phosphate solubilization ability by studied Bacteria at non saline condition

Bacteria	Indole-3-acetic acid	Hydrogen cyanide	Siderophore	ACC deaminase	Phosphat Solubilization
	µg ml^{-1}	colour degree	halo to colony diameter, cm	µmol of α-ketobutyrate h^{-1} mg^{-1} protein	µg ml^{-1}
B. safensis	29.72 ^{a}	3 ^{b}	1.50 ^{a}	6 ^{b}	70.33 ^{b}
B. pumilus	22.57 ^{b}	3 ^{b}	0.50 ^{b}	8 ^{a}	116.33 ^{ab}
Z. halotolerans	26.82 ^{a}	5 ^{a}	0.14 ^{c}	6 ^{b}	162.08 ^{a}

Columns with same letters, dont have significant difference at 0.05 probability level.

Table 3. Mean square total biomass and yield components traits of wheat treated with different strains of bacteria at different levels of salinity

S.O.V	df	Biomass	Spike Length	Spike Weigth	Spikelet Number/ Plant	Floret Nunmber/ Plant
Salinity	3	0.443**	4.10**	0.12**	52.0**	2157**
Bacteria	3	0.147**	3.13**	0.08**	37.0**	1066**
Ba × Sa	9	0.053**	1.76**	0.03**	11.0*	230**
Error	32	0.005	0.38	0.005	4.95	74
CV%		*7.32*	*9.97*	*12.57*	*18.02*	*15.8*

Table 3. Continued

S.O.V	df	Seed Number/ Plant	Seed Weigth/ Plant	Amylose	Amylopectine
Salinity	3	119**	0.02**	46.9 **	1.6*
Bacteria	3	36.0**	0.02**	82.7 **	99.7 **
Sa×Ba	9	17.0*	0.006*	2.1 *	8.1 **
Error	32	6.41	0.002	0.795	0.457
CV%		*15.50*	*17.65*	*10.68*	*2.25*

**, *, Significant at P≤0.01, significant at P≤0.05 respectively

Table 4. Mean comparison of the effect of bacteria on total biomass and yield components of wheat at different salinity levels of irrigation water

Salinity	Bacteria	Biomass	Spike Length	Spike Weigth	Spikelet Number/ Plant	Floret Nunmber/ Plant
ds m^{-1}		G	mm	g		
Control	**Non-inoculated**	1.07^{bc}	67^{ab}	0.50^{c}	11.0^{cdef}	53^{cde}
	B. Safensis	1.07^{bc}	62^{ab}	0.40^{c}	9.0^{ef}	45^{def}
	B. Pumilus	1.14^{b}	65^{ab}	0.44^{c}	11.0^{cdef}	44^{defg}
	Z. halotolerans	1.30^{a}	68^{a}	0.49^{c}	12.0^{bcdef}	42^{efg}
4	**Non-inoculated**	0.86^{de}	63^{ab}	0.49^{c}	11.0^{cdef}	53^{cde}
	B. Safensis	1.38^{a}	70^{a}	0.80^{a}	18.0^{a}	85^{a}
	B. Pumilus	1.08^{b}	67^{ab}	0.75^{ab}	15.0^{abc}	75.0^{ab}
	Z. halotolerans	0.94^{cd}	70^{a}	^{b}0.65	14.0^{abcd}	60.0^{bcd}
8	**Non-inoculated**	0.73^{fg}	47^{cd}	^{c}0.42	10.0^{def}	51.0^{cde}
	B. Safensis	1.15^{b}	67^{ab}	0.75^{ab}	16.0^{ab}	81.0^{a}
	B. Pumilus	1.03^{bc}	55^{bc}	^{b}0.64	14.0^{abcd}	60.0^{bcd}
	Z. halotolerans	0.88^{de}	70^{a}	^{b}0.65	15.0^{abc}	62.0^{bc}
16	**Non-inoculated**	0.64^{g}	43^{d}	^{c}0.41	8.0^{f}	30.0^{fg}
	B. Safensis	0.77^{ef}	70^{a}	0.68^{ab}	13.0^{bcde}	59.0^{cde}
	B. Pumilus	0.70^{fg}	58^{ab}	0.51^{c}	12.0^{bcde}	44.0^{defg}
	Z. halotolerans	0.70^{fg}	47^{cd}	^{c}0.42	8.0^{f}	29.0^{g}

Table 4. Continued

Salinity	Bacteria	Seed Number/ Plant	Seed Weigth/ Plant	Amylose	Amylopectine	K/Na
ds m^{-1}			g	%	%	
Control	**Non-inoculated**	15^{def}	0.24^{cdef}	7.50^{c}	29.0^{e}	5.52^{c}
	B. Safensis	12^{ef}	0.19^{ef}	7.40^{c}	28.3^{e}	8^{b}
	B. Pumilus	13^{def}	0.21^{def}	13.67^{a}	30.5^{d}	5.6^{c}
	Z. halotolerans	15^{def}	0.23^{cdef}	11.00^{b}	33.8^{a}	8.8^{a}
4	**Non-inoculated**	16^{cde}	0.25^{cdef}	7.20^{c}	28.0^{e}	0.33^{gh}
	B. Safensis	25.0^{a}	0.37^{a}	7.56^{c}	28.5^{e}	0.91^{ef}
	B. Pumilus	20.0^{bc}	0.30^{abcd}	11.50^{b}	33.0^{abc}	1.24^{d}
	Z. halotolerans	18.0^{cd}	0.28^{bcde}	11.00^{b}	30.6^{d}	0.75^{f}
8	**Non-inoculated**	15.0^{def}	0.24^{cdef}	5.00^{d}	26.0^{f}	0.24^{h}
	B. Safensis	22.0^{ab}	0.34^{ab}	7.49^{c}	28.3^{e}	0.99^{e}
	B. Pumilus	18.0^{bcd}	0.26^{bcde}	11.10^{b}	33.5^{ab}	0.44^{gh}
	Z. halotolerans	18.0^{cd}	0.26^{bcde}	11.24^{b}	32.4^{bc}	0.54^{g}
16	**Non-inoculated**	11.0^{f}	0.16^{f}	2.72^{e}	24.0^{g}	0.25^{h}
	B. Safensis	15.0^{def}	0.32^{abc}	4.00^{de}	28.6^{e}	0.79^{ef}
	B. Pumilus	15.0^{cdef}	0.24^{cdef}	7.17^{c}	33.4^{ab}	0.41^{gh}
	Z. halotolerans	13.0^{ef}	0.16^{f}	8.00^{c}	32.1^{c}	0.49^{g}

Columns with same letters, dont have significant difference at 0.05 probability level