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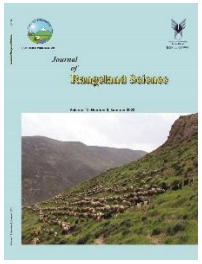

Research and Full Length Article:

Promotion of Seed Germination and Seedling Growth in *Zygophyllum atriplicoides* using Chemical, Mechanical, and Biological Priming Treatments

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Received on: 25/01/2020
Accepted on: 08/09/2021
DOI: 10.30495/RS.2022.684746

Abstract. Native palatable species are the most important plants for the restoration of arid areas. *Zygophyllum atriplicoides* is one of the useful species in restoring arid regions, but poor germination and seedling growth are the main problems in the establishment of this species. The objective of this study was to investigate the effect of biological, chemical, and mechanical priming treatments on seedling germination. The experiments were carried out in a completely randomized design with three replications in a laboratory (germinator) and tray culture mid-summer of 2018. Experimental treatments consisted of two chemical treatments including salicylic acid and gibberellic acid at three levels, five biological treatments consist of *Azotobacter chroococcum, Azospirillum lipoferum, Bacillus megaterium, Flavobacterium sp.* and *Pseudomonas fluorescens* and mechanical treatments including 24 kHz ultrasonic wave during 5 min. Seed germination and seedling growth traits were measured in different treatments. Analysis of variance showed significant differences between treatments for all traits in both experiments ($p<0.01$ and $p<0.01$). The result of the laboratory experiment showed the higher mean values of germination percent (38.33), germination rate (14.69), germination percent day (2.73) and germination index (0.54) in *Bacillus* treatments than other treatments. Also, *Azospirillum* increased seed vigor index (56.0), root length (1.33cm), seedling length (2.26cm), fresh weight Root (8.40g), root dry weight (1.20g) and shoot dry weight (1.90g) as compared to control. The maximum shoot length and root to shoot length ratio were obtained by salicylic acid and gibberellic acid 3000 ppm, respectively. *Bacillus* caused the highest root length (4.73cm), root to shoot ratio (2.20), root (6.50g) and shoot fresh weight (2.63g) and leaf area (11.37). Maximum seedling length and leaf fresh and dry weight were obtained by *Pseudomonas fluorescens*. According to the results of this study, the use of bacteria, especially *Azospirillum, Bacillus* and *Pseudomonas* were effective in better germination of seed.

Key words: Bio priming, Salicylic acid, Gibberellic acid, Ultrasonic, Germination

Introduction

Iran is centrally located in the arid and semi-arid regions of the Earth, with more than 70% of its land area being classed as arid and semi-arid (Ahmadi, 2012), which have many problems such as severe drought, low and irregular rainfall, and severe wind activity, which makes it hard to restore the arid and semi-arid areas naturally. The best way to improve vegetation conditions is to select suitable varieties for seed sowing and seedling and shrub cultivation. Resuscitation of degraded land and the establishment of seedlings in arid regions is difficult due to seed germination problems. Understanding the seed biological conditions of these species in these areas is essential due to the important role of seed germination in the seedling establishment (Commander *et al*., 2009). Among the plant species, the best species are those with high forage quality, soil stabilization, and adaptation to harsh environmental conditions (Azarnivand, 2003; Abdulsalam *et al*., 2019). The genus *Zygophyllum* belongs to the family Zygophyllaceae with 100 species; It is mainly found in the desert and steppe regions of South Africa, Australia, the Mediterranean, and Central Asia (Mozafarian, 2006).

It has a high resistance to drought, salinity, and extremely arid climatic conditions of desert areas (Shawky *et al*., 2019); it stabilizes sand flows and is effective in reducing wind erosion (Moghimi, 2006). Different species of Zygophyllum have medicinal applications (antimicrobial and antioxidant properties) (Shawky *et al*., 2019; Tigrine-Kordjani *et al*., 2011). *Zygophyllum atriplicoides* is a shrub specific to the steppe and desert regions of Iran, Russia, Pakistan, and Afghanistan. Its aerial organs contain the chemical constituents of terpenoids, petrocarpenes, and essential oils (Akhgar *et al*., 2015). Improved germination and breaking of seed dormancy can have an effective role in seedling survival and population expansion due to its increased resistance to drought and high temperature in the desert environment. Breaking seed dormancy plays an important role in the improvement of rangelands especially in arid and semi-desert areas (Sharififar *et al*., 2015).

According to Abdulsalam *et al*. (2019), the use of 50 mmol / L solution of gibberellic acid can break the seed dormancy of *Zygophyllum*. The effects of 42 kHz ultrasound for 1, 3, 5, 7, and 9 minutes on germination of *Atriplex lentiformis*, *Cuminum cyminum*, and *Z. atriplicoides* seeds were investigated. Among treatments, 5 and 7 min treatments had the highest germination percent and 9 minutes had the lowest percent (Sharififar *et al*., 2015). In the study, the effect of soaking priming in boiling water by 98% sulfuric acid for 5, 10, and 15 minutes, cold treatment and 0.2% potassium nitrate was investigated on germination traits of *Zygophyllum atriplicoides*. The highest percentages and rate of germination, shoot length and seed vigor index occurred in potassium nitrate treatment and the highest root length occurred in boiling water treatment (Soltanipour *et al*., 2011). In an experiment, the effect of priming of levels (100, 200, and 300 mg/L) of salicylic, ascorbic, and gibberellic acid (500, 250, and 150 ppm) levels under salinity stress were evaluated on germination and primary growth traits of *Zygophyllum atriplicoides*. All priming treatments increased seed germination under salinity stress. 250 ppm concentration of all treatments caused the highest germination traits under salinity stress (Rafatpour and Shahriari, 2013). Commander *et al*. (2009) investigated the effect of boiling water, steam, gibberellic acid, and carcinolide on the priming of 18 desert species, and

reported the positive effect of carcinolide on *Zygophyllum fruticulosum* seed as compared to other treatments. Based on the results of Abbasi Khalaki *et al*. (2015), among the treatments of potassium nitrate (0.2 and 0.1% concentration), sulfuric acid, and hot water, the highest germination percent, germination rate, and seedling weight were obtained using potassium nitrate 0.2% and concentrated sulfuric acid.

Plant growth-promoting Bacteria (PGPB) represent an attractive source to maintain yields with additional benefits in plant protection against biotic and abiotic stresses. The majority of PGPB comes from the Firmicutes and Proteobacteria. They engage in associative symbioses on plant root surfaces or as root endophytes without the development of specialized structures such as nodules (Drogue *et al*., 2012; Gray & Smith, 2005). Among PGPB, members of the genus *Azospirillum* have attracted particular attention since they are innocuous and can increase yields of many crop species including cereals (Pereg *et al*., 2016). Priming with ascorbic acid (AsA) improved the seed germination rate and morphological traits in seedling of *Taverniera cuneifolia (*Alvani *et al*., 2018). The objective of this study was to identify the effect of biological, chemical, and mechanical priming treatments on germination, vegetative traits and seedling production of *Zygophyllum atriplicoides*.

Materials and methods

In mid-summer 2018, seeds of Z. *atriplicoides* were collected from dry habitats in east of Semnan city (Ahuwan Mountain pass). This study was conducted in the Faculty of Desert Studies, Semnan University. Seeds were separated from the wings and sterilized for 30 seconds in 70% ethanol solution and 2% sodium hypochloride for 15 minutes (Khatibzadeh *et al*., 2013). The experiment was carried out in a completely randomized design in both laboratory (in germinator) and seedling trays medium (in the greenhouse). All the 13 treatments were; chemical priming (three levels of 1000, 2000, and 3000 ppm of gibberellic and salicylic acid for 24 hours), mechanical treatment (24 kHz wavelength of the ultrasonic device for 5 minutes) and biopriming (*Azotobacter chroococcum*, *Azospirillum lipoferum*, *Bacillus megaterium*, *Flavobacterium sp.* and *Pseudomonas fluorescens* inoculated for 15 minutes with a population of 5×10^7cfu of the bacteria). The treatment names and their abbreviation are presented in Table 1.

Table 1. Abbreviation of treatments

Abbr.	Treatmnt name	Abbr.	Treatmnt name
GA1	Gibberellic acid 1000ppm	SA1	Salicylic acid 1000ppm
GA2	Gibberellic acid 2000ppm	SA2	Salicylic acid 2000ppm
GA3	Gibberellic acid 3000ppm	SA3	Salicylic acid 3000ppm
AZ	*Azotobacter chroococcum*	UL	Ultrasonic
FL	*Flavobacterium sp*	AS	*Azospirillum lipoferum*
SO	*Pseudomonas fluorescens*	BA	*Bacillus megaterium*

Laboratory experiment

Acrylic plastic petri dishes with a diameter of 9 cm were selected for the experiment. About 70% ethanol solution was used to sterilize the petri dishes. Three replicates of 20 seeds from each treatment were placed on sterilized filter paper (Whatman No.1) in petri dishes, then moistened with distilled water so that about half the volume of each seed was immersed. The dishes were placed in the growth chamber for germination at 15-25°C (Al Khateeb *et al*., 2010).

Seedling trays

The trays were sterilized with 70% sodium hypochlorite solution. Then, they were filled with 10, 30, 30, 30 % vermicompost, perlite,

coco peat, and pit moss, respectively. In each tray, two seeds were sown in 10 small cells. Seeds were sown in cells after the priming treatments. Then, the seeds were covered with a thin layer of sand. The trays were kept at 25°C in the glasshouse. By the end of the experiment, the samples were irrigated with purified water with electrical conductivity about 371 µmohs/cm.

Data collection

Seeds were counted daily for germination evaluation. After three days of constant counting, counting the number of germinated seeds in petri dishes was stopped.

Seed germination percent was estimated by the equation 1 (Abdel-Haleem and El-Shaieny, 2015):

Equation 1: $GP = ({}^{n}/_{N}) * 100$

n, *N* and GP are the number of germinated seeds, seed number, and percentage of germination, respectively.

Root and shoot length and seedling growth were measured using a ruler. The fresh and dry weights of roots, shoots, and leaves were weighed.

Germination percent per day was calculated on the GPD using the equation 2,

Equation 2: $GPD = \frac{GP}{D}$

Where D is the number of days from the beginning of the experiment.

Mean germination time (MGT) was calculated using the following equation:

Equation 3: $MGT = \frac{\sum((n1*d1))}{n2}$

Where n1 is the number of seeds counted on day one, d1 is the day of seed count, and n2: final number of germinated seeds (Schelin *et al*., 2003).

The germination rate (GR) was obtained by equation 4 as follow:

Equation 4: $GR = \sum n2 \; / \sum(Dn2)$

Where n2 is the number of seeds germinated on day D, and D is the number of days from the beginning of the test (Hampton *et al*., 1995).

Germination index (GI). Calculated by the equation 5,

Equation 5: $GI = {}^{n}/_{D}$

Where n is the number of germinated seeds, and D is the number of days from the beginning of the test

Seed vigor index (SVI) was calculated by the equation 6 (Abdul-Baki and Anderson, 1973).

Equation 6: $SVI = SL * GP$

Where SL is the total root length and shoot length, and GP is the Germination percent.

Percentage Length Inhibition (PLI) was calculated using the equation 7 (Amoo *et al.*, 2008).

Equation 7: $PLI = \frac{R2 - R1}{R1} \times 100$

Where R1is the response of the control crop and R2 is the response of the test.

In this study, the leaf area of seedlings (tested in seedling trays) was estimated by a digitizer and Axio Vision SE64 Release 4.9.1. One-way ANOVA was used to analyze the data using SAS software version 9.1. Also, the Tukey test was used to compare the mean data.

Results

Laboratory

The result of ANOVA showed significant effects of different priming treatments on germination percent, mean germination time, germination percent day, germination index, root length, shoot length, seedling length, root length ratio, fresh and dry weight of root and shoot dry weight ($p<0.01$) and germination rate and seed vigor index ($p<0.05$) in different treatments. The effect of treatments on shoot fresh weight was not significant.

The highest germination percent (38.33%), germination rate (14.69), germination percent day (2.73), and germination index (0.54) were observed in *Bacillus*. Similarly, the maximum mean germination time (18.27) and (17.95) were

observed by *Azotobacter* and *Bacillus*, respectively. *Azospirillum* caused the highest values of seed vigor index (56.00), root length (1.33cm), seedling length (2.26cm), root fresh weight (8.40g), root dry weight (1.20g), and shoot dry weight (1.90g) than the other treatments. The maximum shoot length (1.03cm), and root to shoot length ratio (2.67) were obtained by Salicylic acid 3000 ppm and gibberellic acid 3000ppm, respectively (Table 2 and Fig.1).

Table 2. Comparison of the average effect of different priming treatments on seed germination of *Z. atriplicoides* in petri dish

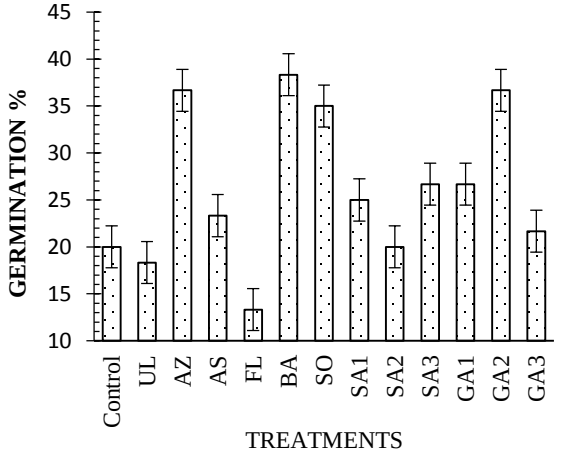
Treatments	Germination Percentage	Germination Rate	Mean germination time	Germination percentage day	Germination Index	Seed Vigor index
Control	20.00 de	11.39 bcd	8.53 de	1.42 de	0.28 de	27.67 abcd
Ultrasonic	18.33 de	11.31 bcd	9.01 de	1.30 de	0.26 de	12.33 d
Azotobacter chroococcum	36.67 ab	13.45 ab	18.27a	2.61 ab	0.52 ab	14.83 d
Azospirillum lipoferum	23.33 de	11.57 bc	11.07 bcde	1.66 de	0.33 de	56.00 a
Flavobacterium sp.	13.33 e	8.99 d	4.61 e	0.95 e	0.19 e	18.00 cd
Bacillus megaterium	38.33 a	14.69 a	17.95 a	2.73 a	0.54 a	21.00 bcd
Pseudomonas fluorescens	35.00 ab	13.99 ab	16.37abc	2.50 ab	0.50 ab	47.83 ab
Salicylic acid 1000ppm	25.00 cd	10.44 cd	9.48 de	1.78 cd	0.35 cd	10.80 d
Salicylic acid 2000ppm	20.00 de	9.718 cd	6.91 de	1.42 de	0.29 de	4.67 d
Salicylic acid 3000ppm	26.67 bcd	12.02ab	11.90 abcd	1.90 bcd	0.38 bcd	43.17 abc
Gibberellic acid 1000ppm	26.67 bcd	11.88 ab	12.55 abcd	2.61 ab	0.38 bcd	29.67 abc
Gibberellic acid 2000ppm	36.67 ab	14.00 ab	17.47ab	1.54 de	0.52 ab	13.67 d
Gibberellic acid 3000ppm	21.67 de	11.33 bcd	10.05 cde	1.54 de	0.30 de	13.30 d
F test	**	*	**	**	**	*

Table 2. Continue

Treatments	Root length (cm)	Shoot length (cm)	Root to shoot Length ratio	Seedling growth (cm)	Root fresh weight (g)	Root dry weight (g)	Dry shoot weight (g)
Control	0.60 b	0.70 abcd	1.17 bc	1.30 bcd	1.00b	0.20bc	0.67 bc
Ultrasonic	0.26 b	0.33 bcde	0.38 cd	0.60 cde	0.70b	0.17bc	0.10 bcd
Azotobacter chroococcum	0.33 b	0.07cd	0.33 cd	0.40e	1.00 b	0.23 bc	0.30 bcd
Azospirillum lipoferum	1.33 a	0.93 ab	1.41 bc	2.26 a	8.40 a	1.20 a	1.90 a
Flavobacterium sp.	0.36 b	0.60 bcde	0.81 bcd	0.96 bcde	0.60 b	0.33 bc	0.50 bcd
Bacillus megaterium	0.23 b	0.30 bcde	0.83 bcd	0.53 cde	0.60 b	0.10 c	0.13 cd
Pseudomonas fluorescens	0.60 b	0.83 ab	0.69 bcd	1.43 ab	0.90 b	0.37 bc	0.60 bc
Salicylic acid 1000ppm	0.23 b	0.16 cde	0.33 cd	0.43 de	0.50 b	0.20 bc	0.13 cd
Salicylic acid 2000ppm	0.23 b	0.03de	0.16 d	0.26e	0.60 b	0.13 bc	0.07 d
Salicylic acid 3000ppm	0.36 b	1.03a	0.62 bcd	1.56 ab	0.90 b	0.40 b	0.80 b
Gibberellic acid 1000ppm	0.26 b	0.73 ab	0.50 bcd	1.10 bcde	0.70 b	0.23 bc	0.30 bcd
Gibberellic acid 2000ppm	0.36 b	0.10 cde	1.66ab	0.36 e	0.40 b	0.10 c	0.10 cd
Gibberellic acid 3000ppm	0.36 b	0.16 cde	2.67a	0.53 cde	0.30 b	0.10 c	0.10 cd
F test	**	**	**	**	**	**	**

*,**= significant at 0.05 and 0.01 probability level, respectively

Means with the same letter are not significantly different from each other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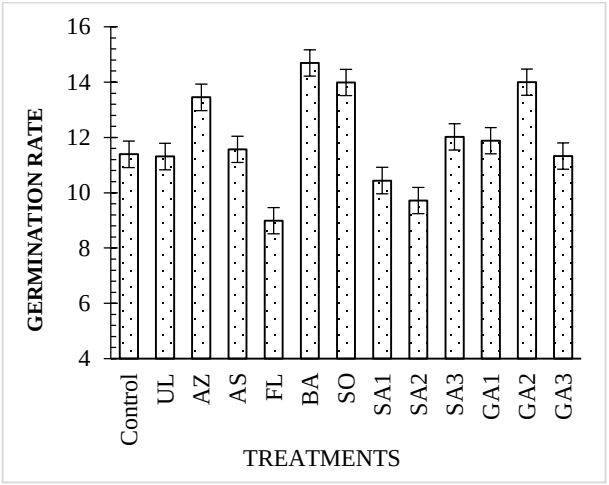
40
35
30
25
20
15
10
Control
UL
AZ
AS
FL
BA
SO
SA1
SA2
SA3
GA1
GA2
GA3
TREATMENTS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12
10
8
6
4
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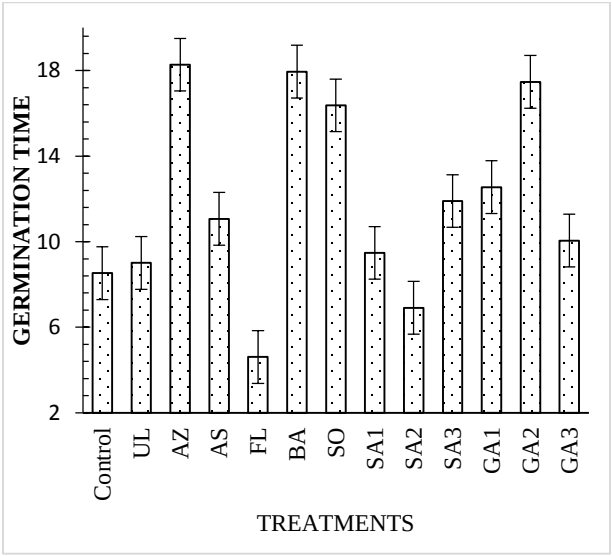
SA2
SA3
GA1
GA2
GA3
TREATMENTS


GERMINATION TIME
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14
10
6
2
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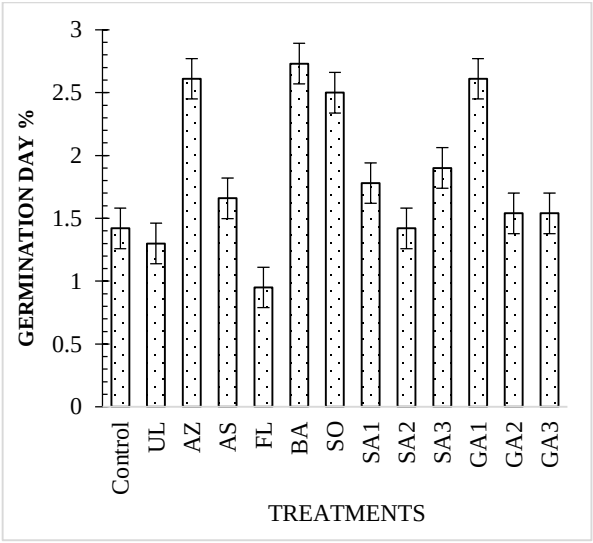
SA2
SA3
GA1
GA2
GA3
TREATMENTS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2
1.5
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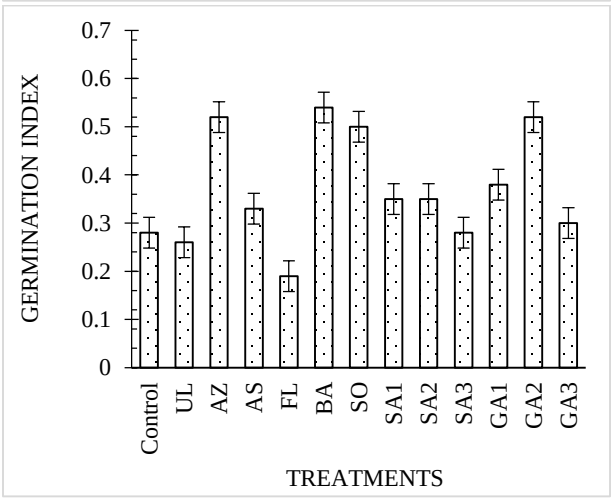
SO
SA1
SA2
SA3
GA1
GA2
GA3
TREATMENTS


GERMINATION INDEX
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0.6
0.5
0.4
0.3
0.2
0.1
0
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AZ
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SA1
SA2
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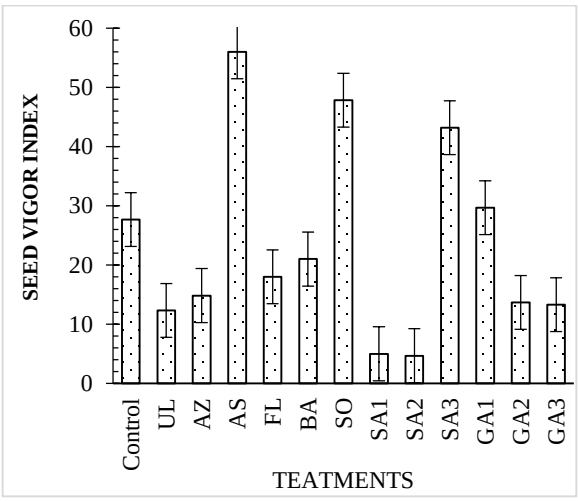
GA1
GA2
GA3
TREATMENTS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SO
SA1
SA2
SA3
GA1
GA2
GA3
TEATMENTS

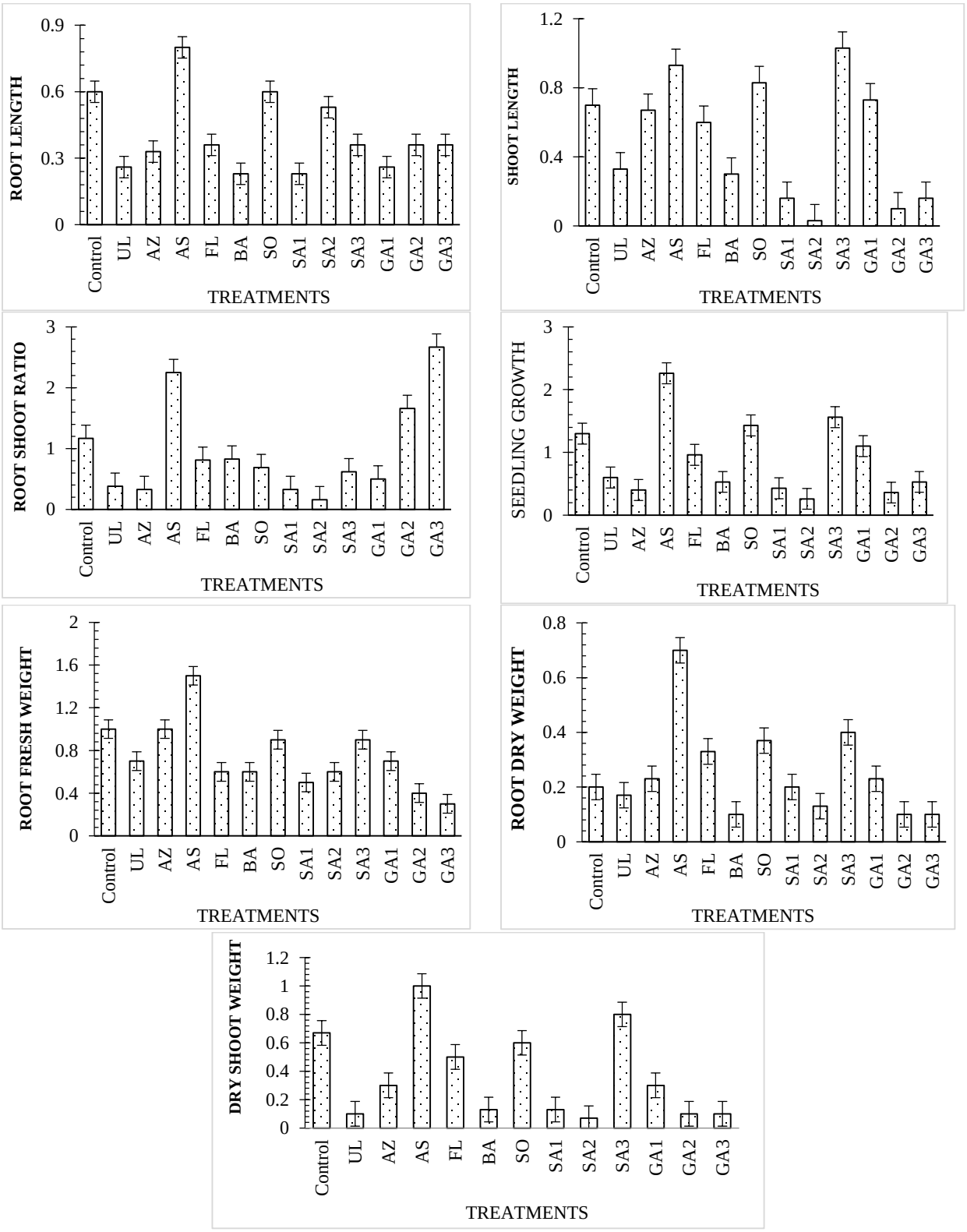


Fig. 1. Mean±Standard error of the different priming treatments on seed germination traits of *Z. atriplicoides* in the laboratory (The abbreviation of treatments is presented in Table 1)

Seedling trays

The result of ANOVA indicated that the treatments had significant effect on root and shoot length, root fresh weight, shoot fresh weight and leaf area ($p<0.01$), root to shoot ratio, seedling length, root, shoot and leaf dry weight and fresh leaf weight were significantly different ($p<0.05$). No seeds were germinated in the studied concentrations of salicylic acid and 3000 ppm gibberellic acid. Bacillus and Pseudomonas bacteria treatments had 4.73 and 5.13cm as the highest root length, respectively. Gibberellic acid treatment at 2000 and 1000ppm increased shoot length, shoot dry weight and root dry weight. Maximum root to shoot length ratio (2.20), root weight (6.50g) and shoot weight (2.63 g) were obtained in Bacillus bacteria treatments.

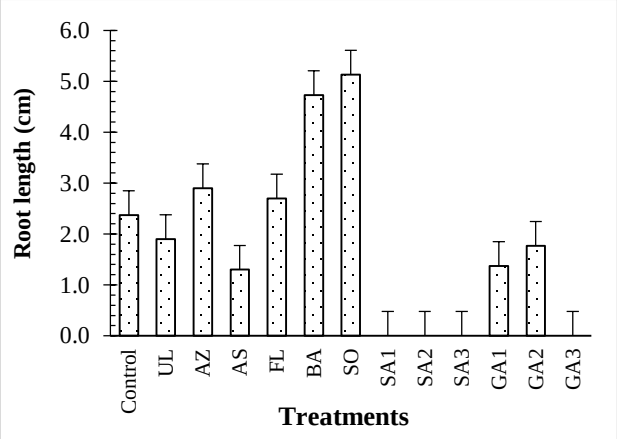
Pseudomonas caused the highest seedling length (8.03 cm) and leaf dry weight (0.43 g). The highest leaf fresh weight (3.64g) and (3.48g) was observed in ultrasonic treatment and Pseudomonas bacteria treatment, respectively. Maximum leaf area index (11.37) and (11.0) was created by Bacillus and Flavobacterium (Table 3 and Fig. 2).

Table 3. Comparison of the average effect of different priming treatments on seed germination of *Z. atriplicoides* in cultivating tray

Treatments	Root length (cm)	Shoot length (cm)	Root to shoot Length ratio	Seedling Length (cm)	Root fresh weight (g)	Root dry weight (g)	Shoot fresh weight (g)	Shoot dry weight (g)	Leaf fresh weight(g)	Leaf dry weight (g)	Leaf Area Index
Control	2.37cd	2.07b	1.16bcd	4.43cd	0.26d	0.03ab	0.42b	0.03bcd	0.34cd	0.21ab	0.14ef
Ultrasonic	1.90cd	1.37bc	1.55abc	3.27d	1.01bc	0.01b	0.37b	0.02bcd	3.64a	0.21ab	5.74cd
Azotobacter chroococcum	2.90b	2.70ab	1.21abcd	5.60bc	0.42cd	0.03ab	0.52b	0.04bc	2.34b	0.29ab	5.35cd
Azospirillum lipoferum	1.30de	1.83b	0.78bcd	3.13d	0.43cd	0.02ab	0.27b	0.01cd	0.80c	0.05b	3.02de
Flavobacterium sp.	2.70bc	2.20b	1.28abcd	4.90bcd	0.27d	0.02ab	0.46b	0.02bcd	2.51b	0.29ab	11.37a
Bacillus megaterium	4.73a	2.27b	2.20a	7.00ab	6.50a	0.02ab	2.63a	0.05ab	2.99ab	0.18ab	11.00a
Pseudomonas fluorescens	5.13a	2.90ab	1.79ab	8.03a	0.28d	0.04ab	1.73ab	0.06ab	3.48a	0.43a	10.29ab
Salicylic acid 1000ppm	0.00e	0.00e	0.00e	0.00e	0.00d	0.00b	0.00b	0.00d	0.00d	0.00b	0.00f
Salicylic acid 2000ppm	0.00e	0.00e	0.00e	0.00e	0.00d	0.00b	0.00b	0.00d	0.00d	0.00b	0.00f
Salicylic acid 3000ppm	0.00e	0.00e	0.00e	0.00e	0.00d	0.00b	0.00b	0.00d	0.00d	0.00b	0.00f
Gibberellic acid 1000ppm	1.37cde	2.63ab	0.52de	4.0cd	1.34b	0.09a	0.39b	0.03bc	0.58cd	0.03b	7.88bc
Gibberellic acid 2000ppm	1.77bcd	3.87a	0.46de	5.63bc	0.48cd	0.01b	1.03ab	0.08a	2.45cd	0.08b	1.67de
Gibberellic acid 3000ppm	0.00e	0.00e	0.00e	0.00e	0.00d	0.00b	0.00b	0.00d	0.00d	0.00b	0.00f
F test	**	**	*	*	**	*	**	*	*	*	**

*,**= significant at 0.05 and 0.01 probability level, respectively

Means with the same letter are not significantly different from each other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5.0
4.0
3.0
2.0
1.0
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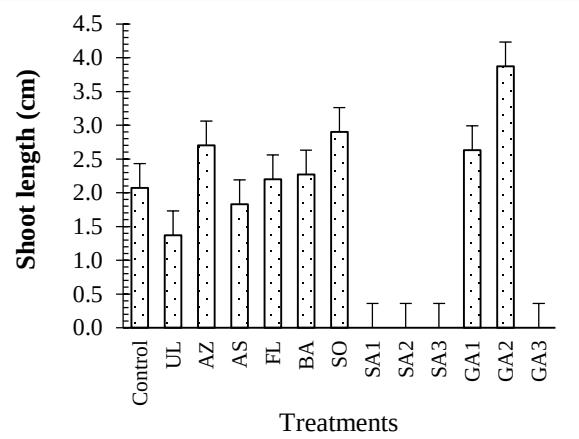
AZ
AS
FL
BA
SO
SA1
SA2
SA3
GA1
GA2
GA3
Treatments


Shoot length (cm)
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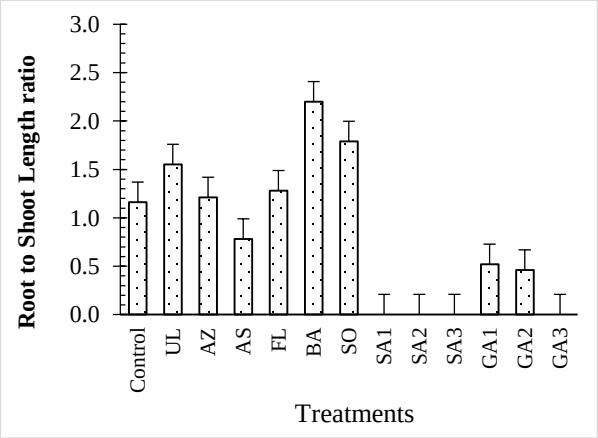
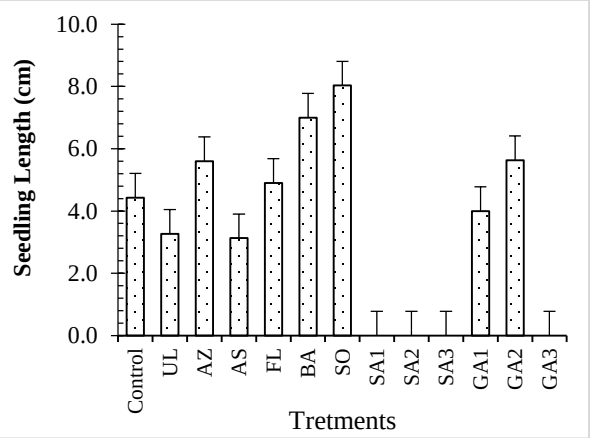
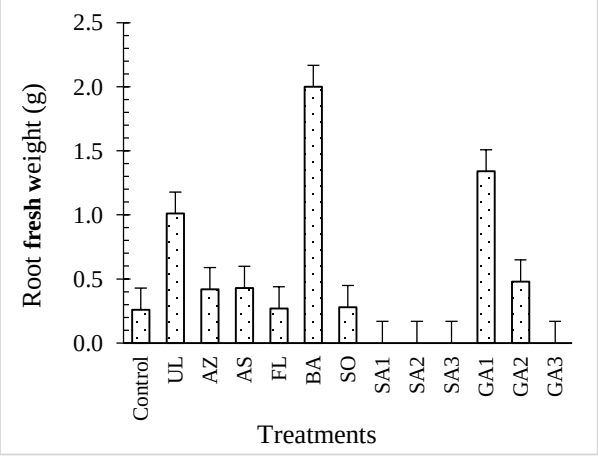
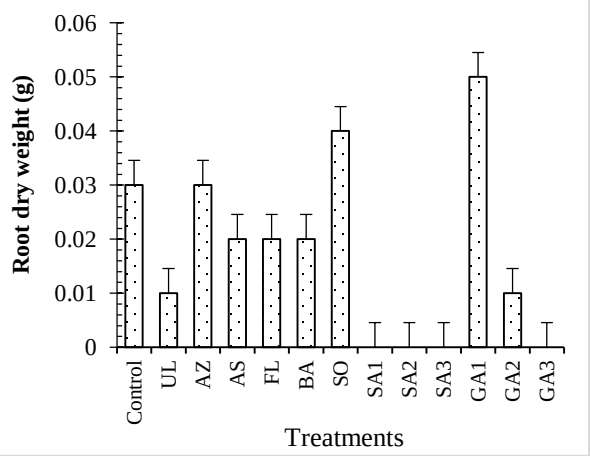
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Control
UL
AZ
AS
FL
BA
SO
SA1
SA2
SA3
GA1
GA2
GA3
Treatments


Root to Shoot Length ratio
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Control
UL
AZ
AS
FL
BA
SO
SA1
SA2
SA3
GA1
GA2
GA3
Treatments


Seedling Length (cm)
10.0
8.0
6.0
4.0
2.0
0.0
Control
UL
AZ
AS
FL
BA
SO
SA1
SA2
SA3
GA1
GA2
GA3
Tretments


Root fresh weight (g)
2.5
2.0
1.5
1.0
0.5
0.0
Control
UL
AZ
AS
FL
BA
SO
SA1
SA2
SA3
GA1
GA2
GA3
Treatments


Root dry weight (g)
0.06
0.05
0.04
0.03
0.02
0.01
0
Control
UL
AZ
AS
FL
BA
SO
SA1
SA2
SA3
GA1
GA2
GA3
Treatments

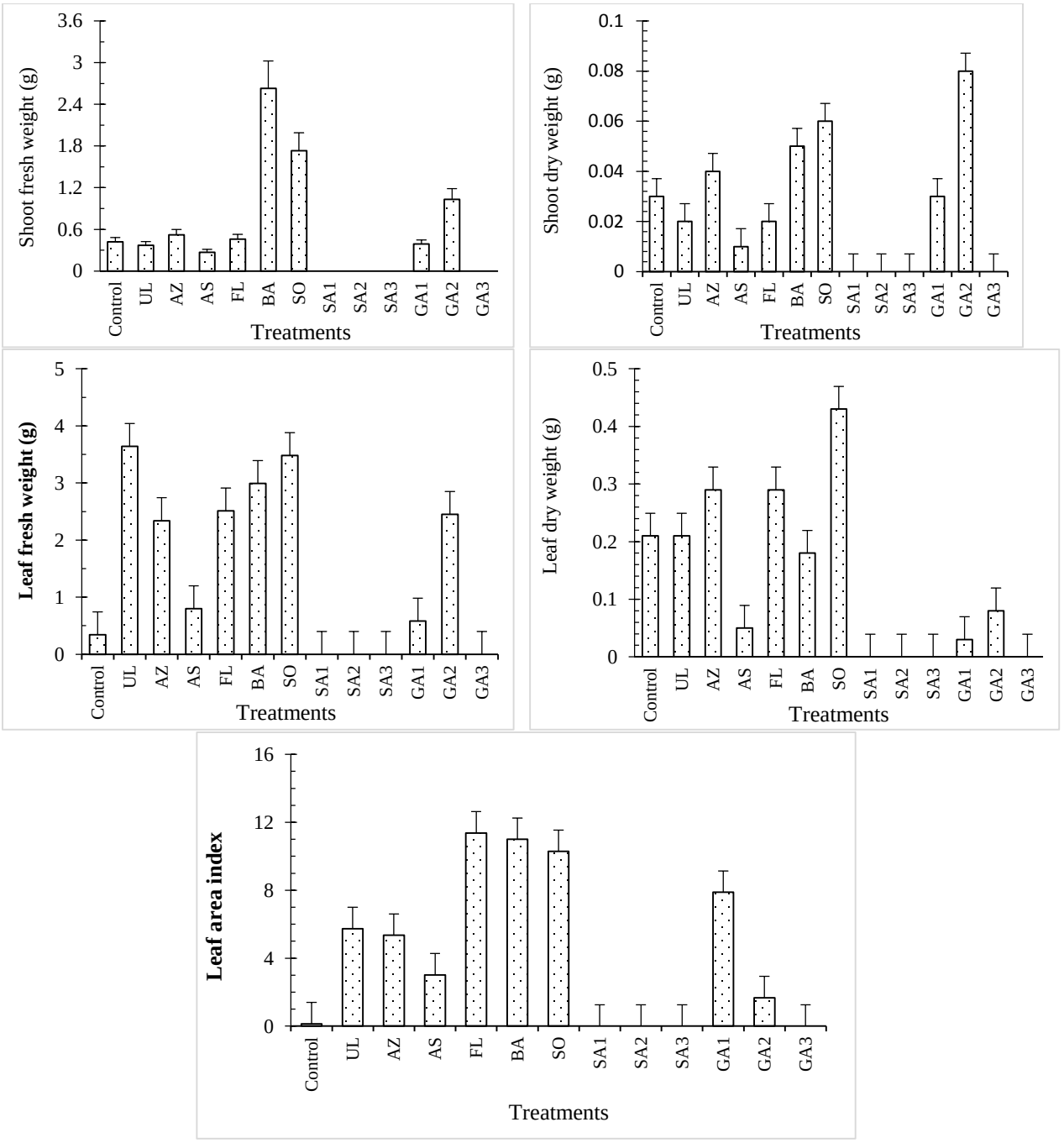


Fig. 2. Mean±Standard error of the different priming treatments on seed germination traits of *Z. atriplicoides* in cultivating tray (The abbreviation of treatments is presented in Table 1)

Discussion

Bacillus significantly increased germination percent, germination rate, germination percent day, mean germination time, and germination index in laboratory in comparison to control. Also, in the seedling tray, the highest root length, root to shoot length ratio, root and shoot fresh weight, and leaf area index than control occurred in Bacillus and root length, seedling length and leaf fresh and dry weight in Pseudomonas. Flavobacterium increased leaf area index. Similar results were seen in some research that can be mentioned in the following. Azotobacter increased mean germination time in petridish. Sabeti *et al*. (2019a) investigated the effect of rhizobacteria on plant growth of *Astragalus ovinus* under drought stress. Drought stress consisted of 0, -0.2, -0.4, and -0.8 MPa levels. According to their results, *B. cereus* and *P. aeruginosa* increased germination percent, germination rate, seed vigor, fresh and dry weight, root and shoot length, chlorophyll a, chlorophyll b, and carotenoid. Mishra *et al*. (2019) in a study of the effect of microbial inoculants on cumin found that Bacillus bacteria has a significant effect on germination and vegetative traits of the seed of this species. According to Sabeti *et al*. (2019b), biopriming of *B. cereus* and *A. lipoferum* had increased root length, germination percent, shoot fresh weight, and seedling of *Astragalus caragana* seed under drought stress. In laboratory, *Azospirillum* bacteria had significant effect on seed vigor, root, and shoot length, fresh and dry weight of root and shoot dry weight than that for control. In an experiment by Seyed Sharifi and Khawazi (2011), using bio priming of *Azotobacter crocorum* and *Azospirillum lipofrom* on four maize hybrids, it was found that *Azospirillum* increased root and shoot length and root to shoot length ratio.

Rozier *et al.* (2019) using *Azospirillum lipoferum* CRT1 on seed germination traits of maize found that bacterial inoculation of the seeds led to a 6–8 h acceleration of radicle emergence, increased surface bacterial counts and increased photosynthetic yield, and root surface area of maize.

Sheikh Ghahfrokhi (2014) indicated that Azotobacter, Bacillus, Pseudomonas increased seed germination, mean germination time, germination rate, and relative germination coefficient and vigor index of evergreen flower of Calendula. The use of bacteria, especially *Azospirillum*, improved the germination and vegetative properties of the plant and can be a good alternative to chemical fertilizers (Rozier *et al*., 2019; Shirinzadeh *et al*., 2013). Bacteria stimulate and increase the growth of different parts of plant organs by producing phytohormones (plant hormones), production of iron-chelating siderophore, and phosphate solubilization (Kloepper *et al*., 1986; Shimon *et al*., 2004).

In laboratory, the maximum shoot length and root shoot length ratio were obtained by 3000 ppm of salicylic and gibberellic acid, respectively. In the seedling tray, no seeds were geminated using different concentrations of salicylic acid and 3000 ppm gibberellic acid. Application of 1000 ppm gibberellic acid increased root dry weight and 2000 ppm gibberellic acid increased length and dry weight of shoot. Similar to our result, Yanik *et al*. (2018) found no effect of 1000 mMoles salicylic acid on seed germination of *Secale cereale*. Also, in a study by Sanginabadi *et al*. (2016), gibberellic acid prevented germination of *Lavandula stricta* seed. Also, Janda *et al*. (1999) reported that some concentrations of salicylic acid have negative effect on seed germination traits. In contrast, Balaguera-López *et al*. (2008) by application of the effect of 300, 600, and 900 ppm gibberellic acid on tomato showed that the seed germination was improved under all concentrations. The highest positive effect was reported at a concentration of 900 mg/L). The 50 mmol/L solution of gibberellic acid breaks the seed

dormancy and improves seed germination of *Zygophyllum kaschgaricum* (Abdulsalam *et al*., 2019). According to Rafatpour and Shahriari (2013), seed priming of *Zygophyllum atriplicoides* with gibberellic acid and salicylic acid significantly improved germination and vegetative traits. Sijmilarly, Salicylic acid also had a positive effect on germination and growth *Trigonella Foenum* (Moghaddam *et al*., 2018).

Considering the results of this study, it can be concluded that the use of growth-promoting bacteria, especially *Azosporilium*, *Bacillus* and *Pseudomonas* in pre-treatment of *Zygophyllum* seed can save the seed and seedling and shrub cultivation and production. Also, using the results of this study can have a positive effect on rangeland improvement by cultivation of this species.

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بهبود صفات جوانه‌زنی و رویش بذر قیچ *Zygophyllum atriplicoides* با استفاده از تیمارهای پرایمینگ زیستی، شیمیایی و مکانیکی

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چکیده. احیای مناطق خشک و نیمه خشک با گونه‌های بومی و سازگار، امکان موفقیت بیشتری نسبت به سایر روش‌های احیا دارد. قیچ *Zygophyllum atriplicoides* از گونه‌های بومی مفید در احیای مناطق خشک کشور است که محدودیت‌های در جوانه زنی، تولید نهال و استقرار دارد. امکان بهبود ویژگی‌های جوانه‌زنی و استقرار نهال‌ها با استفاده از روش‌های مختلف پرایمینگ زیستی، شیمیایی و مکانیکی آزمون شد. این تحقیق در دو شرایط آزمایشگاه (اتاقک رشد) و سینی کشت (شرایط گلخانه) در قالب طرح کاملا تصادفی، با سه تکرار در سال ۱۳۹۷ انجام شد. تیمارهای آزمایش شامل دو تیمار شیمیایی (سالیسیلیک اسید و جیبرلیک اسید هر کدام در سه سطح (۱۰۰۰، ۲۰۰۰ و ۳۰۰۰ *ppm*)) و عامل زیستی (پنج باکتری *Azotobacter chroococcum*، *Azospirillum lipoferum*، *Bacillus megaterium*، *Flavobacterium sp.* و *Pseudomonu flourescens*) و عامل مکانیکی (طول موج ۲۴ کیلوهرتز دستگاه اولتراسونیک به مدت ۵ دقیقه) بود. صفات جوانه‌زنی و رویشی بذر، اندازه‌گیری شد. نتایج تجزیه واریانس در هر دو محیط بیانگر اختلاف معنی‌دار در سطح احتمال ۵ و ۱٪ برای کلیه صفات بود. مقایسه میانگین صفات در شرایط آزمایشگاه، بیانگر بیشترین درصد جوانه‌زنی(۳۸/۳۳٪)، درصد جوانه‌زنی در روز (۲/۷۳٪)، و شاخص جوانه‌زنی (۰/۵۴) در تیمار باکتری باسیلوس نسبت به سایر تیمارها بود. همچنین باکتری آزوسپریلیوم سبب افزایش شاخص بنیه بذر (۵۶/۰)، طول ریشه‌چه (۱/۳۳ سانتی‌متر)، وزن تر ریشه‌چه (۸/۴ گرم)، وزن خشک ریشه‌چه (۱/۲۰ گرم) و وزن خشک ساقه‌چه (۱/۹۰ گرم) نسب به تیمار شاهد شد. بیشترین طول ساقه‌چه (۱/۰۳ سانتی‌متر) و نسبت ریشه‌چه به ساقه‌چه (۲/۶۷) به ترتیب در تیمارهای سالیسیلیک اسید و جیبرلیک اسید ۳۰۰۰ ppm ایجاد شد. در حالی‌که در شرایط سینی نشا، در هیچکدام از تیمارهای سالیسیلیک اسید و جیبرلیک اسید۳۰۰۰ ppm جوانه‌زنی مشاهده نشد. باکتری باسیلوس سبب ایجاد بیشترین طول ریشه (۴/۷۳ سانتی‌متر)، نسبت ریشه‌چه به ساقه‌چه (۲/۲۰)، وزن تر ریشه‌چه (۶/۵۰ گرم) و ساقه‌چه (۲/۶۳ گرم) و سطح برگ (۱۱/۳۷) شد. بیشترین رشد گیاهچه (۸/۰۳ سانتی‌متر) و وزن تر (۳/۴۸ گرم) و خشک (۰/۴۳ گرم) برگ در اثر باکتری سودوموناس ایجاد شد. باتوجه به نتایج این پژوهش، استفاده از باکتری‌ها به‌ویژه *Azospirillum lipoferum* و*Bacillus megaterium* در جوانه‌زنی بهتر این بذر موثر بود.

کلمات کلیدی: پرایمینگ زیستی، اولتراسونیک، سالیسیلیک اسید، جیبرلیک اسید، جوانه‌زنی