PLANT BREEDING AND SEED SCIENCE
Volume 71 2015

DOI: 10.1515/plass-2015-0025

Hamid-Reza Fallahi[1*], Golsoom Fadaeian[2], Marziyeh Gholami[3], Omolbanin Daneshkhah[2], Fatemeh Sadat Hosseini[2] , Mahsa Aghhavani-Shajari[4], Alireza Samadzadeh[1]

[1] Department of Agronomy and Plant Breeding, Faculty of Agriculture, University of Birjand, Birjand, Iran.; [2] Department of Agronomy and Plant Breeding, Sarayan Faculty of Agriculture, University of Birjand, Birjand, Iran; [3] Department of Seed Sciences and Technology, Faculty of Agriculture, Gorgan University of Agricultural Sciences &Natural Resources, Gorgan, Iran; [4] Department of Agronomy and Plant Breeding, Faculty of Agriculture, Ferdowsi University of Mashhad, Mashhad, Iran.; Corresponding author's e-mail: hamidreza.fallahi@birjand.ac.ir

GERMINATION RESPONSE OF GRASSPEA (*LATHYRUS SATIVUS* L.) AND ARUGULA (*ERUCA SATIVA* L.) TO OSMOTIC AND SALINITY STRESSES

ABSTRACT

The use of genetic potential of forgotten plants such as grasspea and arugula is an appropriate strategy for increasing of plants tolerance to environmental stresses. Therefore, in this laboratory study the effects of different levels of osmotic (0, -2, -4, -6, -8, -10, -12 and -14 bar caused by PEG) and salinity (0, 50, 100, 150, 200, 250, 300 and 350 mmol induced by NaCl) stresses were evaluated on germination indices of grasspea and arugula in four separate experiments. Arugula showed a suitable tolerance to osmotic stress, so that its germination percentage and rate at treatment of -10 bar were similar to control. Arugula had 79% germination at osmotic level of -14 bar, but its germination rate at this level was 60% lower than control. In addition, its radicle length until -8 bar and radicle dry weight up to -14 bar were higher than control treatment. However, all levels of salinity stress particularly treatments of more than 100-150 mmol decreased the germination indices of arugula. Germination percentage of arugula in 150 and 200 mmol treatments was 22 and 56% lower than control treatment, respectively. Grasspea had partially suitable tolerance to osmotic stress until -6 bar, but then intensified the reducing trends of its germination indices and finally reached to zero at -14 bar treatment. Moreover, salinity stress especially treatments of higher than 100 mmol decreased all germination indices of grasspea. Overall, arugula was a more tolerant plant especially to osmotic stress; therefore this forgotten plant can be used in agronomic and breeding programs in areas affected by drought stress.

Key words: environmental stresses, germination percentage, germination rate, polyethylene glycol, sodium chloride.

Communicated by Grzegorz Żurek

INTRODUCTION

During recent decades the diversity of food crops has reduced and the genetic uniformity of the few plants that provide food for human increased. Therefore, many plants that historically provided the local food needs of developing countries population are less used or have been forgotten (Rezvani-Moghaddam, 2012). Currently 75% of world food needs is derived from 12 plants and in the meantime 60% of calories and 50% proteins are derived only from rice, wheat and maize. This shows the vulnerability of agroecosystems and the weakness of the human diet. In addition, many neglected crops have valuable genes and are considered as a genetic resource for crop improvement especially in terms of environmental stresses like salinity and drought (Bala-Ravi *et al.*, 2010; Rezvani-Moghaddam, 2012).

Salinity is a major abiotic stress that affected nearly half of the irrigated lands and 20% of the world's cultivated lands (Fallahi *et al.*, 2013). Also, about one-third of the world lands is covered by arid and semi-arid areas that are faced to drought stress (Fallahi *et al.*, 2009). Recently, given the world's growing need for food, exploitation of the lands under abiotic stresses is considered. In these areas, the use of plants that are more resistant to environmental stresses, particularly in the germination and early seedling growth stage, is more important (Fallahi *et al.*, 2015).

Germination is one of the most critical phases during plant growth cycle that greatly influenced by salinity and drought stresses (Yazdani Biuki *et al.*, 2010; Fallahi and Khajeh-Hosseini, 2011; Amiri *et al.*, 2011). This phase is very determinant for crops yield, because seedling establishment affects the plant vigor during other growth phases and so plant density (Amiri *et al.*, 2011). Regards to the high proportions of lands under salinity and drought all over the worlds and taking into account the growing world population, combined with the reduction and degradation of soil and water resources, research on plants resistant to unfavorable environmental conditions is necessary (Fallahi *et al.*, 2009; Amiri *et al.*, 2010). In this regard the use of forgotten crops that a few decades ago had an important place in agro ecosystems is more important. So far, the resistance of some new and forgotten crops such as *Salvia scelarea* (Fallahi *et al.*, 2009), *Cynara scoolymus*, *Echinacea purpurea* (Amiri *et al.*, 2010), *Hyssopus officinalis* and *Chrysanthemum superbum* (Amiri *et al.*, 2011) has been studied to environmental stresses at early growth stage. Results shows that some of these plants have genetic potential for use is agronomic and breeding programs in areas affected by environmental stresses.

Arugula and grasspea are two forgotten plants that are considered partially resistant to some abiotic stresses. Arugula locally known as mandab is a fast growing, short production cycle, cool season crop (Jakse *et al.*, 2013). It is an important oilseed crop of the rapeseed-mustard group that grown on marginal lands with poor fertility. Moreover, due to its drought tolerant and adaptability to adverse environmental conditions, it is preferred over Brassica species under water scarce conditions (Jakhar *et al.*, 2010). Arugula (Taramira, Rocket) often grows in arid and semiarid regions and on severely salt-affected soils (Shannon and Grieve, 1999).

Grasspea also is an annual food and feed crop from fabaceae family. This short growth cycle plant is suitable for cool seasons and has high adaptability to unfavorable environmental factors especially drought stress (Mahdavi *et al.*, 2007; Talukdar, 2013). It is reported that grasspea has been grown successfully in areas with an average annual rainfall of 380 to 650 mm (Jiang *et al.*, 2013). Several *Lathyrus* species particularly grasspea have a great tolerance to drought and saline condition and research on them could improve our understanding of plant resistance mechanisms to environmental stress (Piwowarczyk *et al.*, 2014).

Regards to the role and importance of grasspea and arugula in past agricultural systems and lack of scientific information about these resistant forgotten crops, the aim of this study was to investigate the drought and salinity tolerance of them at germination and early seedling growth stage.

MATERIALS AND METHODS

In order to investigate the effects of osmotic and salinity stresses on germination indices of grasspea and arugula four separate experiments were conducted at seed research laboratory of Sarayan Faculty of Agriculture, University of Birjand, Iran during 2015. These experiments were evaluated using completely randomized design with four replicates of 20 seeds. In two experiments, the effects of drought levels (0, -2, -4, -6, -8, -10, -12 and -14 bar) and in two other ones the effects of salinity stress levels (0, 50, 100, 150, 200, 250, 300 and 350 mmol) were studied on germination indices of two studied plants. In addition, for confidence from results of osmotic stress on arugula that showed high tolerance to this stress, the test was repeated twice. For producing of different levels of osmotic and salinity stresses was used from polyethylene glycol (PEG 6000) and Sodium chloride (NaCl), respectively that were obtained from Merck Company. The amounts of PEG and NaCl used for each treatment are shown in Table 1.

Table 1

The amounts of polyethylene glycol and sodium chloride used for producing of different levels of osmotic and salinity stresses

Salinity levels (mmol)	0	50	100	150	200	250	300	350
Amount of NaCl (g Nacl /50g H_2O)	0	0.292	0.585	0.877	1.170	1.462	1.755	2.047
Osmotic stress (bar)	0	-2	-4	-6	-8	-10	-12	-14
Amount of PEG (g PEG/50g H_2O)*	0	5.75	8.64	10.87	12.76	14.42	15.93	17.32

* Calculated using Michel and Kaufman formula at temperature of 22 ºC (Amiri *et al.*, 2010)

Seeds were germinated in 9 cm diameter Petri-dishes with one Whatman No. 1 filter paper moistened with 6 ml of distilled water or the appropriate solutions. The trays containing Petri-dishes were supplied with ample water and were put into sealed plastic bags to prevent evaporation and therefore maintain approximately 100% relative humidity within each tray throughout the germination test (Fallahi and Khajeh-Hosseini, 2011). The trays containing Petri-dishes of salinity stress test were placed in the lab environment with temperature of 25ºC and the trays of osmotic stress were kept in an incubator with temperature of 22ºC.

Germinated seeds (radicle length 2-3 mm) were counted daily for one week. On the final day germination percentage,c radicle length and plumule length were determined. Then plumules and radicles were isolated and dried in oven at 75ºC for 48 hours to determine their dry weights. In addition, Germination rate was calculated using formula by Maguire, 1962.

$$R_s = \sum_{i=1}^{n} \frac{S_i}{D_i}$$

where R_s is germination rate, S_i is daily seed germination, D_i is number of day to *n* computation and n is number of days computation.

Finally, statistical analysis of the four experiments results was made by the Duncan multiple ranges test at the 5% level of probability, using SAS 9.1.

RESULTS

Effect of osmotic stress on arugula germination

Osmotic stress affected significantly all germination and seedling growth indices of arugula (Table 2). Germination percentage of arugula did not reduce by increasing of osmotic stress level up to -10 bar and then decreased only by 7 and 16% in -12 and -14 bar, compared with control, respectively. Similar results obtained for germination rate, where the amount of this index in -10 bar treatment was only 9% lower than control, while this reduction for -12 and -14 bar treatments was 37 and 60%, respectively (Table 3). Unlike plumule, osmotic stress had an increasing effect on radicle length and dry weight of arugula. Radicle length showed an increasing trend until osmotic stress of -8 bar and then decreased by enhancement of stress severity. However, the effect of all levels of osmotic stress was negative on plumule length of arugula. Moreover, all osmotic stress levels increased the amount of radicle dry weight, while high levels of osmotic stress decreased the amount of plumule dry weight (Table 3).

Table 2

Analysis of variance (sum of squares) for effects of osmotic stress on germination indices of arugula

Sources of variation	DF	Germination percentage	Germination rate	Mean length of radicle	Mean length of plumule	Mean dry weight of radicle	Mean dry weight of plumule
Treatment	7	1064.0**	761.9**	73362.0**	11936.7**	4.79**	0.0000163**
Error	24	304.0	21.6	5252.4	131.9	1.36	0.0000005
Total	31	1368.0	783.5	78614.4	12068.7	6.15	0.0000168

ns: non-significant, ** and * significant at 1% and 5% levels of probability, respectively

Table 3

Effects of different levels of osmotic stress on germination indices of arugula

Osmotic levels (bar)	Germination percentage	Germination rate [day^{-1}]	Mean length of radicle [mm]	Mean length of plumule [mm]	Mean dry weight of radicle [g]	Mean dry weight of plumule [g]
0	95.0^{a}	22.64^{a}	72.57^{c}	54.37^{a}	0.00017^{d}	0.0009^{c}
-2	97.0^{a}	23.25^{a}	124.98^{a}	50.32^{b}	0.00065^{c}	0.0015^{b}
-4	94.0^{a}	22.70^{a}	137.85^{a}	29.07^{c}	0.00107^{b}	0.0014^{b}
-6	97.0^{a}	23.37^{a}	146.73^{a}	28.10^{c}	0.00143^{a}	0.0019^{a}
-8	94.0^{a}	21.93^{a}	103.38^{b}	17.67^{d}	0.00049^{cd}	0.0016^{b}
-10	96.0^{a}	20.52^{b}	44.68^{d}	12.42^{e}	0.00068^{c}	0.0004^{d}
-12	88.0^{b}	14.22^{c}	32.70^{ed}	0.00^{f}	0.00041^{cd}	0.0000^{e}
-14	79.0^{c}	09.16^{d}	12.28^{e}	0.00^{f}	0.00032^{cd}	0.0000^{e}

In each column means with the same letter(s) are not significantly different at 0.05 level of probability

Effect of salinity stress on arugula germination

Salinity had a significant effect on all germination and seedling growth indices of arugula (Table 4). Results of means comparison showed that with increase in salinity levels the amounts of germination percentage and rate reduced, but the considerable reduction obtained when salinity level increased from 150 to 200 mmol. So that, germination percentage and rate in 150 mmol treatment were 23 and 29% lower than control, while their reduction in 200 mmol compared to 150 mmol treatment were 47 and 70%, respectively. In addition, salinity had a negative effect on length and dry weight of radicle and plumule (Table 5).

Table 4

Analysis of variance (sum of squares) for effects of salinity stress on germination indices of arugula

Sources of variation	DF	Germination percentage	Germination rate	Mean length of radicle	Mean length of plumule	Mean dry weight of radicle	Mean dry weight of plumule
Treatment	7	45712.0**	2855.3**	22012.1**	7576.5**	2.16**	8.3986E-6**
Error	24	176.0	17.3	151.7	43.0	4.96	3.7648E-7
Total	31	45888.0	2872.7	22163.8	7619.5	7.21	12.151E-6

ns: non-significant, ** and * significant at 1% and 5% levels of probability, respectively

Table 5

Effects of different levels of salinity stress on germination indices of arugula

Salinity levels (mmol)	Germination percentage	Germination rate [day^{-1}]	Mean length of radicle [mm]	Mean length of plumule [mm]	Mean dry weight of radicle [g]	Mean dry weight of plumule [g]
0	94.0^{a}	22.70^{a}	68.95^{a}	39.75^{a}	0.00018^{a}	0.00084^{b}
50	87.0^{b}	20.80^{b}	56.22^{b}	34.42^{b}	0.00019^{a}	0.00117^{a}
100	80.0^{c}	18.97^{c}	12.60^{c}	15.40^{c}	0.00013^{b}	0.00123^{a}
150	72.0^{d}	16.07^{d}	2.92^{d}	6.20^{d}	0.00006^{c}	0.00048^{c}
200	38.0^{e}	4.72^{e}	1.97^{d}	0.00^{e}	0.00000^{d}	0.00000^{d}
250	06.0^{f}	0.28^{f}	1.12^{d}	0.00^{e}	0.00000^{d}	0.00000^{d}
300	03.0^{fg}	0.12^{f}	0.00^{d}	0.00^{e}	0.00000^{d}	0.00000^{d}
350	00.0^{g}	0.00^{f}	0.00^{d}	0.00^{e}	0.00000^{d}	0.00000^{d}

In each column means with the same letter(s) are not significantly different at 0.05 level of probability

Effect of osmotic stress on grasspea germination

Osmotic stress inserted a significant effect on all germination and early seedling growth traits of grasspea (Table 6). Germination percentage of grasspea did not reduce until -6 bar treatment, but more increase in osmotic stress severity decreased the amount of this index. The highest reduction in germination percentage observed in treatments higher than -8 bar, where the amount of this reduction with increase of stress severity from -8 to -10 bar was 78%. All levels of osmotic stress negatively affected the germination rate of grasspea and the highest negative impact obtained when the level of osmotic stress increased from -8 bar (Table 7). Drought stress had a deterrent effect on radicle and plumule length, but this impact on plumule growth was more, so that the length of radicle and plumule in -10 bar treatment were 61 and 95% lower than control, respectively. In addition, negative influence of osmotic stress levels was not considerable on mean dry weight of radicle, while plumule weight had a decreasing trend with increase in drought stress severity (Table 7).

Table 6

Analysis of variance (sum of squares) for effects of osmotic stress on germination indices of grasspea

Sources of variation	DF	Germination percentage	Germination rate	Mean length of radicle	Mean length of plumule	Mean dry weight of radicle	Mean dry weight of plumule
Treatment	7	54959.3**	910.0**	4607.9**	2633.7**	0.000099**	0.0000774**
Error	24	437.5	4.5	58.1	35.3	0.000001	0.0000003
Total	31	55396.8	914.5	4693.0	2669.1	0.000100	0.0000777

ns: non-significant, ** and * significant at 1% and 5% levels of probability, respectively

Table 7

Effects of different levels of osmotic stress on germination indices of grasspea

Osmotic levels [bar]	Germination percentage	Germination rate [day^{-1}]	Mean length of radicle [mm]	Mean length of plumule [mm]	Mean dry weight of radicle [g]	Mean dry weight of plumule [g]
0	95.0[a]	15.82[a]	40.27[a]	26.80[a]	0.0045[b]	0.0040[a]
-2	98.7[a]	11.02[b]	30.87[b]	19.72[b]	0.0066[a]	0.0037[b]
-4	95.0[a]	7.37[c]	26.65[c]	10.67[c]	0.0048[b]	0.0020[c]
-6	92.5[a]	7.10[c]	22.12[d]	11.37[c]	0.0047[b]	0.0020[c]
-8	62.5[b]	3.42[d]	18.00[e]	07.17[d]	0.0035[d]	0.0005[d]
-10	13.7[c]	0.75[e]	15.52[e]	01.50[e]	0.0039[c]	0.0000[e]
-12	05.0[d]	0.25[ef]	07.75[f]	0.00[e]	0.0040[c]	0.0000[e]
-14	00.0[d]	0.00[f]	0.00[g]	0.00[e]	0.0000[e]	0.0000[e]

In each column means with the same letter(s) are not significantly different at 0.05 level of probability

Effect of salinity stress on grasspea germination

Effect of salinity stress was significant on all germination and seedling growth traits of grasspea (Table 8). Reducing effect of salinity on germination percentage started when the severity of stress proceed from 50 mmol and the highest reduction obtained with increase of salinity level from 200 to 250 mmol. Germination rate of grasspea showed a continuous reducing trend with increase in salinity stress levels. In addition, salinity stress reduced the amounts of radicle and plumule length and dry weight, especially when the salt concentration was higher than 100 mmol (Table 9).

Table 8

Analysis of variance (sum of squares) for effects of salinity stress on germination indices of grasspea

Sources of variation	DF	Germination percentage	Germination rate	Mean length of radicle	Mean length of plumule	Mean dry weight of radicle	Mean dry weight of plumule
Treatment	7	43246.5**	1157.9**	7302.0**	2506.8**	0.0000948**	0.0000897**
Error	24	455.3	6.9	36.5	10.5	0.0000005	0.0000006
Total	31	43701.8	1164.8	7338.6	2517.4	0.0000953	0.0000904

ns: non-significant, ** and * significant at 1% and 5% levels of probability, respectively

Table 9

Effects of different levels of salinity stress on germination indices of grasspea

Salinity levels [mmol]	Germination percentage	Germination rate [day^{-1}]	Mean length of radicle [mm]	Mean length of plumule [mm]	Mean dry weight of radicle [g]	Mean dry weight of plumule [g]
0	93.1^a	16.90^a	45.22^a	23.22^a	0.0044^a	0.0038^a
50	93.7^a	13.90^b	30.95^b	19.95^b	0.0043^a	0.0041^a
100	85.6^b	8.10^c	15.00^c	12.55^c	0.0027^b	0.0024^b
150	67.5^c	5.15^d	7.75^d	6.32^d	0.0013^c	0.0007^c
200	46.3^d	3.37^e	7.35^d	1.95^e	0.0011^d	0.0001^d
250	14.3^e	0.67^f	2.65^e	0.00^f	0.0003^e	0.0000^d
300	8.1^e	0.32^f	1.57^{ef}	0.00^f	0.0000^f	0.0000^d
350	0.6^f	0.02^f	0.00^f	0.00^f	0.0000^f	0.0000^d

In each column means with the same letter(s) are not significantly different at 0.05 level of probability

DISCUSSION

Osmotic stress had a negative effect on germination and seedling growth indices of arugula and grasspea. This phenomenon is a consequence of hampered water and nutrient absorption because of reducing in water potential or suppressed cell elongation as a result of the low turgor pressure (Piwowarczyk *et al.*, 2014). However, stress tolerance of two studied plants was significantly different. Arugula was tolerated up to osmotic stress of -10 bar and had 79% germination even in -14 bar treatment (Table 3), while grasspea showed 2.5, 55, 45 and 57% reduction in germination percentage, germination rate, radicle and plumule length, respectively only up to -6 bar and even these reductions were more accelerated in -8 bar stress severity (Table 7).

Germination percentage of arugula and grasspea was 88 and 5% in the osmotic stress level of -12 bar, respectively (Table 3 and 7). In similar studies the amounts of germination percentage in osmotic stress of -12 bar was 16% for *Cynara scoolymus,* 0% for *Echinacea purpurea* (Amiri *et al.*, 2010), 2% for *Brassica rapa* (Keshavarz Afshar *et al.*, 2012), 0% for *Salvia sclarea* (Fallahi *et al.*, 2009), 6% for average of ten genotypes of *Carthamus tinctorius* (Zebarjadi *et al.*, 2012) 0% for *Triticum aestivum* (Yazdani *et al.*, 2010), 0% for *Hyssopus officinalis* and *Chrysanthemum superbum* (Amiri *et al.*, 2011) and so 31% for *Cuminum syminum* in -8 bar (Rahimi, 2013). This comparisons shows that arugula could be a good candidate for crop production in areas affected by drought stress. In addition, grasspea had medium tolerance to osmotic stress. It has been reported that this plant is probably the most drought tolerant legume crop (Yang and Zhang, 2005). As in a study concluded that greater accumulation of proline and soluble sugars alleviated damages of osmotic stress produced by polyethylene glycol in grasspea compared with pea (Jiang *et al.*, 2013).

Mean dry weight of radicle increased in two studied plants in particular arugula at drought stress condition (Table 3 and 7). It has been reported that higher dry matter accumulation is a desir-able trait under water stress and is correlated with drought tolerance of grasspea (Piwowarczyk *et al.*, 2014). More weight of underground organs under stress condition appears to be an adaptation strategy, resulting in more efficient water and nutrient absorption. This allows to plant tolerate stress via up taking water by more extended subterranean organs for less extended part of upper organs (Fallahi *et al.*, 2009; Fallahi and Khajeh-Hosseini, 2011).

Effect of salinity stress was deterrent on germination indices of arugula and grasspea (Table 5 and 9). Salinity affects seeds germination and seedling growth either by creating an osmotic potential external to the seed preventing water uptake, or through the toxicity of Na^+ and Cl^- ions for germinating seed (Shannon and Grieve, 1999; Kaya *et al.*, 2006; Fallahi and Khajeh-Hosseini, 2011). Reduction of storage substrates decomposition and disturbance in synthesis of storage proteins are two other main deterrent impacts of salinity on seed germination (Fallahi *et al.*, 2013).

Unlike osmotic stress, the difference in resistance of arugula and grasspea to the salinity stress was lower. The amounts of germination percentage reduction in 100 and 150 mM salinity treatments were 14 and 24% for arugula and 7 and 26% for grasspea, respectively. In addition, these reductions about germination rate were 16 and 29% for arugula and 52 and 69% for grasspea, respectively. Moreover, germination percentage of arugula and grasspea in 200 mM salinity stress treatment was 38 and 46%, respectively (Table 5 and 9). In similar studies the amounts of germination percentage in salinity stress of 200 mM was 6% for *Cynara scoolymus*, 2% for *Echinacea purpurea* (Amiri *et al.*, 2010), 88% for

Salvia sclarea (Fallahi *et al.*, 2009), on average 28% for ten ecotypes of halophytic plants of *Agropyron elongatum* and *A. pectiniforme* (Abbasian and Moemeni, 2013), 5% in *Brassica oleraseae* var. Italica (Esfandiari *et al.*, 2014) and 90% in halophyte *Salsola ferganica* (Chenopodiaceae) (Wang *et al.*, 2013). These comparisons show the considerable salt tolerance of arugula and grasspea at initial stage of growth cycle. One of the reasons of higher germination indices of halophytes than conventional crops is because of salinity declines the germination of halophytes usually through only osmotic effect, but non-halophytes are more likely to exhibit additional ion toxicity (Fallahi and Khajeh-Hosseini, 2011).

Results of current experiment and some other ones show that grasspea is resistant to moderate salinity (Yang and Zhang, 2005). In similar study the amount of grasspea germination in 0, 6, 12 and 18 $dS.m^{-1}$ (~equals to 0, 60, 120 and 180 mM) salinity stress was 93, 93, 85, 67 and 46%, respectively (Mahdavi *et al.*, 2007), that are near to our findings (Table 9). However, in another study on grasspea the germination percentage for 0, 5, 9 and 15 $dS.m^{-1}$ salt stress was 100, 82, 22 and 0%, respectively (Tsegay and Gebreslassie, 2014). Therefore, response of grasspea to salinity stress is genotype oriented as in a study on six grasspea genotypes under NaCl stress significant variations observed among them and even between growth stages of a particular genotype for growth parameters (Talukdar, 2013). Similar results reported by Talukdar (2011) on eight different grasspea genotypes and concluded that the treatment of 150 mM NaCl can be considered as critical salt concentration to most of the grasspea genotypes.

Arugula also has a considerable salt tolerance but the yield and relative growth rate of the arugula populations can be different, so that lines collected from salt-affected arias are more tolerant. The salt tolerance feature appears to be associated with exclusion of Na^{+}, high K/Na selectivity and high Ca^{+2} uptake. In addition, more tolerant populations of arugula usually have higher amounts of sugars, proline and amino acids in their leaves than the non-tolerant ones (Shannon and Grieve, 1999).

CONCLUSIONS

Arugula had a considerable tolerance to osmotic stress at germination and early seedling growth stage. Germination indices of this plant were favorable up to -10 bar stress severity and even had 79% germination at level of -14 bar. In addition, arugula appropriately germinated up to salinity level of 100 mmol. Moreover, grasspea germination and seedling growth was satisfactory until drought stress of -6 bar and salinity stress of 100 mmol. Totally, arugula showed a better growth especially under osmotic stress; therefore it seems to be a suitable candidate for breeding programs.

REFERENSES

Abbasian A., Moemeni J. 2013. Effects of salinity stress on seed germination and seedling vigor indices of two halophytic plant species (*Agropyron elongatum* and *A. pectiniforme*). International Journal of Agriculture and Crop Sciences 5(22): 2669-2676.

Amiri M.B., Rezvani-Moghaddam P., Ehyaei H.R., Fallahi H.R., Aghhavani-Shajari M. 2010. Effect of osmotic and salinity stresses on germination and seedling growth indices of artichoke (*Cynara scoolymus*) and purple coneflower (*Echinacea purpurea*). Environmental Stresses in Crop Sciences 3(2): 165-176.

Amiri M.B., Rezvani-Moghaddam P., Ehyaei H.R., Fallahi H.R., Aghhavani-Shajari M. 2011. Response of germination and seedling growth of Hyssop (*Hyssopus officinalis*) and Marguerite (*Chrysanthemum superbum*) medicinal plants to water stress. Plant Ecophysiology 3: 65-77.

Bala-Ravi S., Hrideek T.K., Kishore Kumar A.T., Prabhakaran T.R., Mal, B., Padulosi S. 2010. Mobilizing neglected and underutilized crops to strengthen food security and alleviate poverty in India. Indian Journal of Plant Genetic Resources 23(1): 110-116.

Esfandiari A., Babalar M., Hashemi J., Mostufi Y. 2014. Effect of salicylic acid and salt stress on seed germination and functional antioxidant in broccoli sprout. Journal of Horticultural Science 28(3): 388-398.

Fallahi H.R., Ebadi M.T., Ghorbani R. 2009. The effects of salinity and drought stresses on germination and seedling growth of Clary (*Salvia scelarea*). Environmental Stresses in Agricultural Sciences 1(1): 57-67.

Fallahi H.R., Khajeh-Hosseini M. 2011. Effects of applying various levels of nitrogen on parent plants on the resistance to salinity stress in achieved seeds in *Triticum aestivum* L. cv. Gaskojen at germination period. Journal of Agricultural Technology 7(6): 1743-1754.

Fallahi H.R., Rezvani Moghaddam P., Nassiri Mahallati M., Behdani M.A., Aghhavani Shajari M., Amiri M.B. 2013. Influence of seed nitrogen content and biofertilizer priming on wheat germination in salinity stress conditions. Archives of Agronomy and Soil Science 59(6): 791-801.

Fallahi H.R., Rezvani-Moghaddam P., Amiri M.B., Aghhavani-Shajari M., Yazdani Biuki R. 2015. The study of nutritional management of mother plant and seed priming by biofertilizers on improve salinity tolerance of wheat (*Triticum aestivum L.*) cv. Sayonz at germination period. Journal of Agroecology 6(4): 689-700.

Jakhar M.L., Jajoria R.N., Sharma K.C., Ram S. 2010. Genetic divergence in Taramira (*Eruca sativa* Mill.). Journal of Oilseed Brassica 1(2): 79-83.

Jakse M., Hacin J., Kacjan Marsic N. 2013. Production of rocket (*Eruca sativa* Mill.) on plug trays and on a floating system in relation to reduced nitrate content. Acta Agriculturae Slovenica 101(1): 59- 68.

Jiang J., Su M., Chen Y., Gao N., Jiao C., Sun Z., Li F., Wang C. 2013. Correlation of drought resistance in grass pea (*Lathyrus sativus*) with reactive oxygen species scavenging and osmotic adjustment. Biologia 68(2): 231-240.

Kaya M.D., Okcu G., Atak M., Cıkılı Y., Kolsarıcı O. 2006. Seed treatments to overcome salt and drought stress during germination in sunflower (*Helianthus annuus* L.). European Journal of Agronomy 24: 291-295.

Keshavarz Afshar R., Keykhah M., Chaeichi M.R., Ansari M. 2012. Effect of different levels of salinity and drought stress on seed germination characteristics and seedling growth of forage Turnip (*Brassica rapa* L.). Iranian Journal of Field Crop Science 43(4): 661-671.

Mahdavi B., Modarres Sanavy S.A.M., Balouchi H.R. 2007. Effect of sodium chloride on germination and seedling growth of Grasspea cultivars (*Lathyrus sativus*). Iranian Journal of Biology 20(4): 363-374.

Maguire J.D. 1962. Speed of germination- Aid in selection and evaluation for seedling emergence and vigor. Crop Science 2: 176-177.

Piwowarczyk B., Kamińska I., Rybiński W. 2014. Influence of PEG generated osmotic stress on shoot regeneration and some biochemical parameters in *Lathyrus* culture. Czech Journal of Genetics and Plant Breeding 50: 77-83.

Rahimi A. 2013. Seed priming improves the germination performance of cumin (*Cuminum syminum* L.) under temperature and water stress. Industrial Crops and Products 42: 454- 460.

Rezvani-Moghaddam P. 2012. New crops and forgotten plants, pp. 476-511 in Koocheki A., Khajeh-Hosseini M. (Ed.) Modern Agronomy. Jahade Daneshgahi Publication, Mashhad, Iran.

Shannon M.C., Grieve C.M. 1999. Tolerance of vegetable crops to salinity. Scientia Horticulturae 78: 5-38.

Talukdar D. 2011. Morpho-physiological response of grasspea (*Lathyrus sativus*) genotypes to saly stress at germination and seedling stage. Legume Research 34(4): 232- 241.

Talukdar D. 2013. Growth responses and leaf antioxidant metabolism of grass pea (*Lathyrus sativus* L.) genotypes under salinity stress. International Scholarly Research Notices Agronomy 13: 1-15.

Tsegay B.A., Gebreslassie B. 2014. The effect of salinity on germination and early seedling growth of *Lathyrus sativus* and *Pisum sativum* var. abyssinicum. African Journal of Plant Science 8(5): 225-231.

Wang Y., Qiang Jiang G., Nan Han Y., Meng Liu M. 2013. Effects of salt, alkali and salt–alkali mixed stresses on seed germination of the halophyte *Salsola ferganica* (Chenopodiaceae). Acta Ecologica Sinica 33: 354-360.

Yazdani Biuki R., Rezvani-Moghaddam P., Koocheki A., Amiri M.B., Fallahi H.R., Deyhimfard R. 2010. Effects of seed nourished by different levels of nitrogen, biofertilizers and drought stress on germination indices and seedling growth of wheat (*Tritium aestivum*) cv. Sayonz. Journal of Agroecology 2(2): 266-276.

Yang H.M., Zhang X.Y. 2005. Considerations on the reintroduction of grass pea in China. Lathyrus Lathyrism Newsletter 4: 22-26.

Zebarjadi A.R., Soheilikhah Z.H., Ghasempour H.R., Vaisipour A. 2012. Effect of drought-induced stress by PEG6000 on physiological and morphological traits of Safflower (*Carthamus tinctorius*) seed germination in order to selection of drought tolerant genotypes. Iranian Journal of Biology 25(2): 252-263.