

Full Length Research Paper

Effect of halopriming treatment on seed germination and seedling emergence of Judas tree (*Cercis siliquastrum* L., Caesalpiniaceae) from Zanjan, Iran

Naser Norouzi Haroni^{1*}, Masoud Tabari¹ and Daniel Dey²¹Faculty of Natural Resources, University of Tarbiat Modares, NoorMazandaran, Iran.²USDA Forest Service, Northern Research Station, University of Missouri, Columbia, Missouri, United States of America.

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The effect of seed halopriming with potassium nitrate on germination and emergence traits of *Cercis siliquastrum* L seeds, in two experiments were evaluated, one in the laboratory and the other in a greenhouse. The studies were a completely randomized design and 4 replications. The treatments included non-priming and halopriming with potassium nitrate at one of four concentrations (0, 100, 250, 500 and 750 mM) for 48 h, for all treatments the seeds were boiled in water per 24 h. The results showed that seed halopriming with KNO₃ at the 750 mM concentration in the laboratory significantly increased several characteristics of germination. Emergence characteristics also were increased by pretreatment of seeds with potassium nitrate when planting in greenhouse. The highest emergence percentage (57%), speed of germination (1.54 seeds per day) emergence energy (44.8%) and lowest mean germination time (13.9 days) were showed in 100 mM treatment. The best halopriming level for seedling characteristics was detected in 100 mM KNO₃. However, haloprimed achenes resulted in maximum final emergence and shoot length, root length, collar diameter, shoot dry weight, root dry weight, number of leaves, leaf area and seedling quality index treated with primed techniques were increased and compared with non-prime treatment.

Key words: Afforestation, *Cercis siliquastrum*, germination, Potassium nitrate, regeneration, seedling quality index.

INTRODUCTION

Increasing global consumption of natural resources has caused ecological degradation in some area. The annual area has decreased with about 5.2 million hectares of forestlands worldwide over the past ten years (FAO, 2010). Therefore, restoration projects are very important in forest management with increasing forestlands, especially in arid and semi-arid areas. Last year, the

amount of forest degradation in Iran reached 2 million hectares according to FAO (Kouhgardi et al., 2012). Iran is a country with an arid and semi-arid climate and restoration of deforested and desertified areas have been done with native tree species such as (*Haloxylon persicum*), (*Quercus persica*), (*Pistacia atlantica*) and (*Olea europaea*) (Jazirei, 2001). Current interest is

*Corresponding author. E-mail: Norouzinaser88@yahoo.com. Tel: +98- 09363325136.

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increasing for using Judas tree (*Cercis siliquastrum* L.), a celsipeanacea species with ornamental-conservational importance, for restoration (Jazirei, 2001). Judas trees are also used for protection against soil losses caused by wind and water erosion (Gebre and Karam, 2004; Zahreddine et al., 2007). This deciduous species may also be used in reforestation of disturbed lands to improve the landscape. Judas trees occur most often on the borders of broadleaved or coniferous forests in valleys of streams and rivers in maquis communities (Boratynski et al., 1992).

Like many other woody plants, the artificial regeneration of Judas trees is most commonly by seed propagation, as this method is a cost-effective method (Pipinis et al., 2011). Cuttings are rarely used, but some varieties are propagated by grafting (Ana-Felicia, 1998). The seed of this species, as in many Leguminosae, has a hard seed coat that is impermeable to water, which causes a physical dormancy. Judas trees require a long growing season, have good drought tolerance and are sensitive to frost (Sabina and Cornelia, 2012). They are distributed in Thermo-Mediterranean zones at elevations up to 0-800 m, and on soils with pH above 7.5 (Sternberg, 2012). In Iran Judas tree grows in Giulan, Hamedan, Lorestan and Fars as wild plant. Tree growth is high in soils with gypsum and limestone. It is also resistant to drought and needs direct sunlight for growth (Sabety, 1994).

Nursery production of high quality seedlings is important in forestry for successful regeneration. *Cercis* seeds generally require pre-germination treatment to overcome dormancy, because of their impermeable seed coat and embryo dormancy (Hamilton and Carpenter, 1976; Geneve, 1991; Tipton, 1992; Jones and Geneve, 1995; Rascio et al., 1998). There are different methods for breaking seed dormancy such as thermo-stratification, acid exposure, scarification and chemical treatment (Kermode, 2011). Much research has been done on breaking the dormancy of Judas tree seeds. Geneve (1991) and Dirr and Heuser (1987) tried to break the dormancy of Judas tree seed by cold stratification to allow imbibitions of the hard seed coat, but this method requires a long exposure period to cold temperatures to improve germination efficiency. Judas seeds treated with sulfuric acid and follow stratification had high germination rates, but there were subsequent negative physiological side effects on seedling growth rate (Frett and Dirr, 1979; Liu et al., 1981). In addition, the method required a long time to complete the germinability.

Recently, the priming method has been presented for breaking seed dormancy and improving seedling growth of crops and trees (Bradford, 1986). During osmotic priming (halopriming), ions in a potassium nitrate and sodium chloride solution accumulate within the seeds, increasing water absorption by reducing water potential (Parera and Cantliffe, 1994). Potassium nitrate as one of the main compounds in halopriming increases the

concentrations of potassium and nitrogen in seeds (Alevarado and Bradford, 1988; Bellti et al., 1993). Advantages of halopriming include high germination efficiency (Taylor et al., 1998), more rapid germination (Bhan and Sharma, 2011), enhanced growth rates (Geo et al., 2012), and more uniformity of germination that collectively result in higher seedlings quality (Basra et al., 2005).

There are increased opportunities for the application of such seed treatment method in forestry, especially in the restoration of arid and semi-arid lands. But there are many problems with Judas tree seed germination and seedling production that limit its use in restoration. The purpose of this research is to evaluate the effectiveness of treating Judas tree seed with boiling water and halopriming technique followed by soaking in a potassium nitrate solution to break the double dormancy and promote germination simultaneously. We also followed the seedlings in greenhouse conditions obtained from non-priming with primed seeds in order to determine how seedling characteristics are affected by priming treatments conducted by different KNO₃ concentrations.

MATERIALS AND METHODS

Seed characterization or traits

The seeds of Judas tree were received from the Central Seed Center of Caspian (Amol) for this research. The seeds were obtained from Zanjan (Iran), seed of physic-chemical characteristics such as weight, purity, humidity and viability was determined. Also, habitat characteristics of the seeds produced are given in Table 1.

Seed priming

The experiments were performed in College of Natural Resource, Tarbiat Modares University, Iran. The treatments included non-priming and halopriming with potassium nitrate at four concentrations (0, 100, 250, 500 and 750 mM) for 48 h and 4 replications. For all treatments, the seeds were boiled in water per 24 h. After boiling in water (sowing in water with 100°C), they were left up to 24 h until the water temperature reached ambient air temperature. For priming with Potassium nitrate, two hundred seeds were selected randomly for each concentration and were placed in a 10-cm diameter plastic Petri dish on a filterpaper (Whatman filter paper No. 1). The Petri dishes were covered by aluminum foil in order to prevent waste solution and were placed in a germinator (with a temperature of 20°C and in constant darkness). A period of 2 days was allocated to their growth. In order to wash off the solutions from the surface of the seeds, after the 2 days, seeds were rinsed in distilled deionized water for 2 min. Seeds were dried slowly at room temperature for 48 h to reach the initial moisture (control) (Demir and Mavi, 2004). Unprimed seeds (only sowed in boiling water) and control seeds (no seed handling) were used in research.

Seed germination in the laboratory

For seed germination analysis, four replicates of 25 seeds of non-primed, primed (potassium nitrate treatment) and control

Table 1. seeds features from Judas tree (*Cercis siliquastrum* L., Caesalpiniaceae) seeds originated from Zanjan (Iran) and commercialized by forest seed center from Central Seed Center of Caspian (Amol)

Description the area and laboratory characteristic										
Specie	Origin	Latitude	Longitude	Altitude (M)	Climate	Viability (%)	Humidity	Numbers of seed per kg	One thousand grain weight (g)	Purity (%)
<i>C. siliquastrum</i>	Zanjan	36.66° N	48.48° E	1663	Semiarid ultra cold	85	4.4	36630	27.7	97

Table 2. Seed germination measurements utilized to characterize seeds from Judas tree (*Cercis siliquastrum* L., Caesalpiniaceae) and their mathematical expressions.

Germination indices	Mathematical expressions
Germinability	$FG, FE = n/N \times 100$ (n- The total number of seeds germinated in the period N- The number of seeds planted)
Speed of germination, emergence (Maguire, 1962)	$SG, SE = N1/1 + n2/2 + \dots + nx/x = N$ (N1 = Nx are the no. of seed germinated on day 1 to day x, 1 = X are the no. of days)
Germination energy, emergence energy (Czabator, 1962)	$GE, EE = Mng/N \times 100$ (Mng- Accumulative maximum percentage of germinated seeds N- The number of seeds planted)
Mean germination time, Mean emergence time (Ellis and Roberts, 1981)	$MGT, MET = \sum D_n / \sum n$ (where n is the number of seeds which were germinated on day D)

treatments were placed on filter papers in Petri dishes and were kept moist daily (20 ml). The Petri dishes were transferred to a germinator where the temperature was maintained at 20°C, under the 16 h light and 8 h of dark, light intensity of 1000 Lux and 60% humidity (ISTA, 1985). The papers were replaced every 3 days to prevent fungal growth. Seed germination was recorded daily in a certain time. A seed was considered as germinated when its radicle emerged by about 2 mm in length (Mohammadi, 2009).

Seedling emergence in the greenhouse

Pots with 35 cm diameter contain silt loamy soil with 0.3 dS

m electrical conductivity was prepared. In each pot, twenty-five seeds were planted 2 cm in depth and irrigated when soil moisture was slightly below field capacity. There were four replications for each KNO₃ concentration. The experiment was conducted in a greenhouse where daily air temperatures averaged was 20 ± 10°C (ranging from 7 to 15°C at night), and natural light that varied from 6000-10000 lux during the day. Counts of germinating seeds were made daily, starting on the first day of stem emergence. The progress of seedling emergence was measured at 24 h intervals for 45 days. After 45 days of start of the experiment, final germination percentage and final emergence percentage (FGP, FEP), germination speed (GS), mean germination time and emergence time (MGT, MET), germination and emergence energy (GE, EE)

were calculated according to the equations (Table 2).

Measurement of growth characteristics in greenhouse

Seedlings obtained from greenhouse condition were planted in pots with dimensions 15 × 20 cm and were irrigated to field capacity once every 2 days for 4 months in greenhouse conditions listed above. Plants were randomly selected per replication in each treatment, a total of 8 plants for each treatment, to determine seedling growth characteristics such as the length of the shoot and root (to the nearest mm). Root collar diameter was measured with a caliper. Shoot and root dry weight, and leaf fresh weight were measured with a microbalance to

Table 3. Comparison of the mean (\pm standard deviation in parentheses) of seed germination and seedling emergence of Judas tree (*Cercis siliquastrum* L., Caesalpiniaceae) obtained of seeds from Laboratory and Greenhouse and primed with KNO₃ and non-primed seed.

Germination environment	Treatment	G, E (%)	GS, ES (seed per day)	GE, EE (%)	MGT, EGT (day)
Laboratory	Non-primed	18 (2.3) ^d	0.26 (0.04) ^e	2.6 (1.2) ^c	19.7 (1.6) ^a
	100 mM KNO ₃	39 (2) ^c	0.61 (0.06) ^d	12.12 (2.6) ^{bc}	19.2 (1.4) ^a
	250 mM KNO ₃	61 (6) ^b	1.16 (0.07) ^c	26.9 (14.4) ^{ab}	16.4 (1.6) ^b
	500 mM KNO ₃	70 (7.6) ^a	1.41 (0.17) ^b	33.8 (18.3) ^a	15.9 (0.7) ^b
	750 mM KNO ₃	72 (6.5) ^a	1.61 (0.05) ^a	35.2 (8.4) ^a	13.6 (0.58) ^c
	F value	72.61**	143.146**	6.48**	17.91**
Greenhouse	Non-primed	25 (3.8) ^d	0.24 (0.03) ^c	4.5 (1.5) ^c	26.3 (2.1) ^a
	100 mM KNO ₃	82 (9.2) ^a	1.8 (0.2) ^a	49.3 (11.8) ^a	12.4 (1) ^c
	250 mM KNO ₃	66 (6.9) ^b	1 (0.1) ^b	26.7 (7.5) ^b	17.7 (1.1) ^b
	500 mM KNO ₃	53 (3.8) ^c	0.89 (0.06) ^b	17.2 (8.8) ^b	17.3 (1.7) ^b
	750 mM KNO ₃	59 (3.8) ^c	0.97 (0.5) ^b	18 (7.5) ^b	18.8 (4.9) ^b
	F value	47.8**	67.8**	16.46**	25.05**

** P < 0.01; Means with different letters superscripts in a column to each environment indicate significant difference among seed treatment means according to Duncan's multiple range test (P < 0.01). G, E: Germinability, Emergency, GS, ES: Speed of germination, emergence, GE: Germination energy, emergence energy, MGT, MET: Mean germination time, Mean emergence time.

a precision of 0.001 gr. Leaf surface was measured with a CI202 Area meter, CID, Inc. For each plant, expanded leaf area of randomly selected leaves was measured and leaf number was counted by treatment. Leaf area was computed using the formula for specific leaf area (specific leaf area = leaf area (cm²) / leaf dry weight (gr)) according to Arias et al. (2007). Seedling quality (QI) was calculated for each seedling using the formula: $QI = TDW / ((SL / SD) + (SDW / RDW))$, where TDW is total dry weight, SL is shoot length, SD root collar diameter, SDW shoot dry weight and RDW is root dry weight (Mckay et al., 1999).

Statistical analysis

Experiments were set up in a completely randomized design. Data normality was explored by kolmogorov-smirnov Test. The mean and one-way ANOVA were calculated using SPSS (version 18) software. The mean separations were carried out using Duncan's multiple range tests (Duncan, 1955) and significance was determined at $p \leq 0.05$.

RESULTS

Germination in the laboratory

Control seeds (no seed handling) did not show germination in two substrates, Therefore, they were not involved in computing. The results indicated that halopriming treatments significantly ($P < 0.01$) affected all the measured parameters (Table 3). The largest improvement was achieved when seeds were primed with 750 mM KNO₃. Haloprimed seeds had significantly higher final germination percentage (64%), germination speed (1.34 seed per day), germination energy (32.6%) and mean germination time (6.1 day) compared to unprimed seeds.

Germination in greenhouse

Similar results to the laboratory experiment were observed when seeds were treated and the seedling emergence was evaluated in the greenhouse for 45 days in similar environmental conditions. The KNO₃ treatment had a significant effect on all the response variables (Table 3, $P < 0.01$). Maximum improvement was recorded when seeds were primed with 100 mM KNO₃. Seeds primed had a higher emergence percentage (57%) than those in the unprimed. The highest emergence speed was observed for seeds primed in the 100 mM KNO₃. For unprimed seeds, emergence energy was recorded at about 4.5% compared to about 49.3% for seeds primed with 100 mM KNO₃ (Table 3). Seeds primed with 100 mM KNO₃ had significantly shorter germination times than any other treatment.

Mean cumulative germination in the laboratory

Mean cumulative germination of *Cercis* seeds in the germinator showed that seeds primed in any of the KNO₃ concentrations had faster germination compared to seeds in the control (Figure 1). Seeds primed with 750 mM KNO₃ had the fastest germination start time among tree seeds, and the highest speed of germination. Germination began in non primed treatment later 7 days compared to primed treatment of 750 mM.

Mean cumulative emergence in greenhouse

Similarly, mean cumulative emergence of *C. siliquastrum* seeds grown in the greenhouse germinated faster for

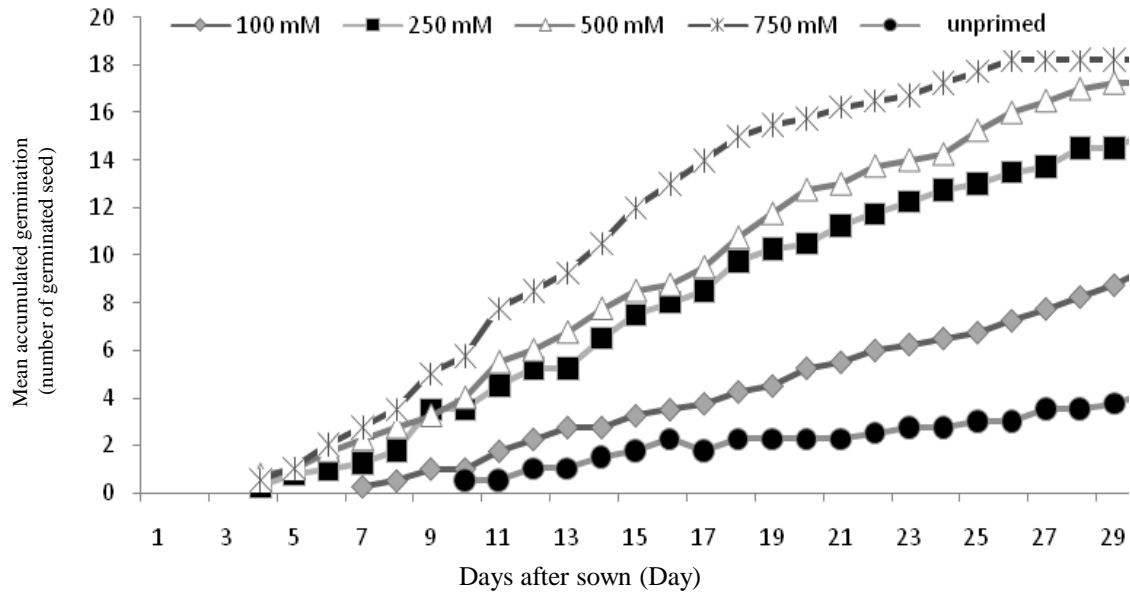


Figure 1. Cumulative mean of seed germination in the laboratory for *C. Siliquastrum L.* seed obtained from from Zanjan (Iran) in 2011.

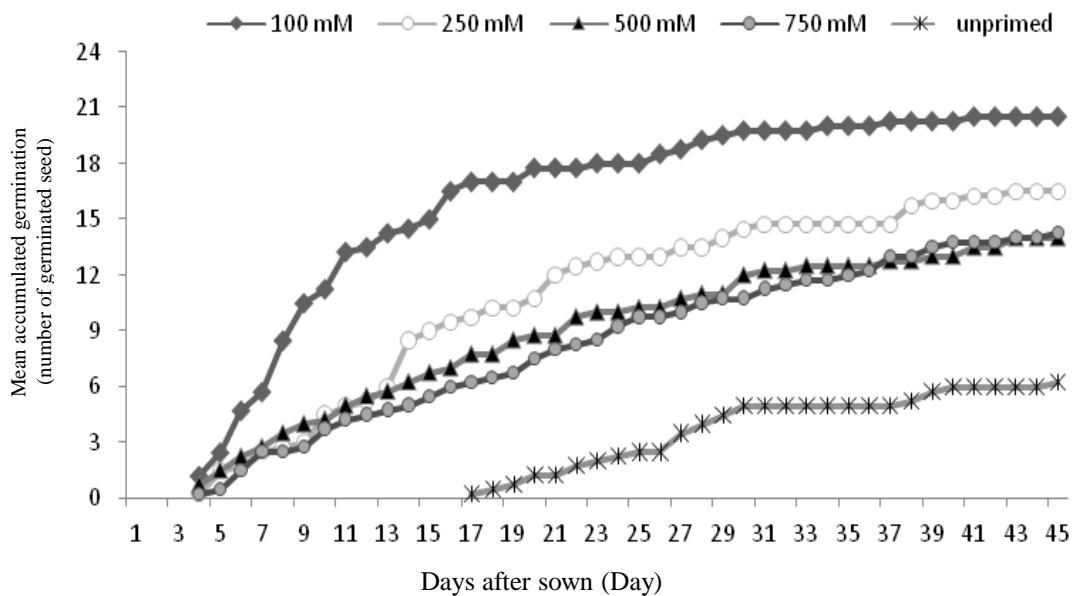


Figure 2. Effects of various concentrations of KNO_3 under seedling emergence of Judas tree (*Cercis siliquastrum L.*, Caesalpinaceae) seed obtained from from Zanjan (Iran) in 2012.

primed seeds compared to those in the control. Seeds primed in each of the KNO_3 solutions had the fastest emergence. Seed in the 100 mM KNO_3 treatment had the fastest emergence start time in any of the treatment, also it completed the emergence period sooner than seed in any other treatments. Seeds in the boiling water of treatment were the most delayed in initiating emergence in 17 days (Figure 2).

Growth characteristics in greenhouse

Halopriming with KNO_3 affected the growth characteristics compared to non-primed seeds, significantly. Seed priming increased shoot, root length and collar diameter seedlings as compared to unprimed seedling. Also 100 mM concentrate indicated the highest length of shoot, root and highest collar diameter compared to unprimed

Table 4. Comparison of the seedling growth characteristics of Judas tree (*Cercis siliquastrum* L., Caesalpiniaceae) obtained of seeds from Greenhouse and primed with KNO₃ and non-primed seed.

Treatments	100 mM	250 mM	500 mM	750 mM	Non-primed	F
Shoot length (mm)	24.7(5.9) ^a	19.1(3.6) ^b	17.3(3.5) ^{bc}	14.6(3.2) ^{cd}	11.7(1.7) ^d	12.88**
Root length (mm)	27.7(6.2) ^a	20.8(6.0) ^b	20.7(5.7) ^b	19.2(4.9) ^b	12.0(0.9) ^c	9.43**
Collar diameter (mm)	1.7(0.5) ^a	1.2(0.3) ^b	1.1(0.3) ^{bc}	1.2(0.4) ^{bc}	0.84(0.2) ^c	5.64**
Shoot fresh weight (g)	1.84(0.5) ^a	0.78(0.5) ^{ab}	0.66(0.4) ^{bc}	0.79(0.4) ^{ab}	0.31(0.1) ^c	4.28**
Root fresh weight (g)	1.21(0.5) ^a	0.58(0.3) ^b	0.44(0.1) ^b	0.54(0.2) ^b	0.29(0.1) ^b	11.14**
Root dry weight (g)	0.32(0.1) ^a	0.21(0.1) ^{ab}	0.15(0.1) ^{bc}	0.26(0.1) ^{ab}	0.07(0.04) ^c	4.98**
Shoot dry weight (g)	0.51(0.03) ^a	0.16(0.05) ^b	0.23(0.03) ^b	0.16(0.06) ^b	0.07(0.03) ^c	13.16**
No. of leaves	9.1(1.2) ^a	6.2(1.9) ^b	5.1(1.3) ^{bc}	5.6(1) ^b	3.8(0.8) ^c	19.83**
Leaf area (cm ²)	6.06(2) ^a	5.11(1.1) ^{ab}	3.8(1.4) ^b	4.3(1) ^b	3.8(0.7) ^b	3.90**
Specific leaf area (cm ² /g)	117.7(36.4) ^b	127.8(53.7) ^b	148.4(58.7) ^b	128.2(35.2) ^b	417.3(98.88) ^a	35.45**
Seedling quality index	0.0061(0.003) ^a	0.0026(0.001) ^{bc}	0.0029(0.002) ^b	0.0039(0.002) ^{bc}	0.0011(0.0007) ^c	5.33**

** P < 0.01; Means with different letters superscripts in a line indicate significant difference among seed treatment means according to Duncan's multiple range test (P < 0.01).

treatment, 13, 15.7 cm and 0.86 mm, respectively. Halopriming increased fresh weight shoot and root of seedling (P < 0.01) compared to unprimed seedling, and 100 mM treatment had the highest fresh weight shoot and root compared to other concentrations and non-primed treatments, 1.53 and 0.92 g, respectively. Similar trend was observed in weight of dry shoot and root in seedlings. Particularly, concentrate of 100 mM was better than other concentrates and unprimed treatment (Table 4). Halopriming increased the number of leaves and leaf area for seedlings, significantly (P < 0.01).

However, the seedlings primed by 100 mM KNO₃ had highest number of leaf and leaf area for seedlings, compared to unprimed seedlings, 5.3 and 2.2 cm², respectively.

Although, unprimed treatment had the highest specific leaf area, the Seedlings primed by 100 mM concentration had highest seedling quality index among other concentrate and unprimed treatment (Table 4).

DISCUSSION

Germination characteristics of holoprimed seed in germinator

The required time for emergence of seedlings has an important role in survival and for competitiveness with other plants; and delays in seedling germination can affect total biomass and sapling growth, especially under competitive conditions (Ross and Harper, 1972). A dormant seed is one that is unable to germinate in a specified period of time under a combination of environmental factors that are normally suitable for the germination of the non-dormant seed (Baskin and Baskin, 1998). Dormancy is a mechanism to prevent germination during unsuitable ecological conditions, when the probability of seedling survival is low (Bewley and Black, 1994). Affordable methods that can improve seed germination and increase the chance of seedling success in establishment and

dominance in regeneration are valuable. Priming treatments have much promise to improve seed germination and emergence of hard to regenerate species such as the Judas tree (Heydecker and Coolbear, 1977); these two traits, germination and rapid early growth, are important parameters that determine seedling competitiveness and ability to dominate in regeneration (Alizadeh and Jafari, 2006).

In this study, we hypothesized that enhancing germination and early growth of Judas trees can be achieved with the seed halopriming technique. We observed that Halopriming with KNO₃ caused increased seed germination percentage, speed, and energy, while decreasing mean germination time. In the laboratory study, the highest rate of germination occurred when seed was treated with a 750 mM KNO₃ solution, and the highest germination in the greenhouse was in the 100 mM KNO₃ treatment. These results are consistent with other studies (Afzal et al., 2009; Khan et al., 2009; Bhan and Sharma, 2011; Guo et al., 2012).

Increased germination percentage may be due to the effect of KNO_3 on biochemical changes involving hydrolysis and increased synthesis of enzyme activity that increases cell wall elasticity, thus promoting germination.

Another biochemical mechanism of seed priming is the increased activity of endopectinase enzymes that act to weaken cell walls, permitting rapid emergence of the rootlet (McDonald, 1999). Increased germination speed in seed treated by halopriming may be related to the production and of metabolites important to germination (Lee and Kim, 2000; Basra et al., 2005), or it may be associated with the synthesis of DNA, RNA and proteins during priming (Bray et al., 1989). For seed in the laboratory experiment, germination energy of the seed that was haloprimered was significantly larger than it was for seed treated with boiling water only. This may be due to the effect of boiling water on dormancy breaking of the seed coat and removing endosperm dormancy and decomposition of Frulic acid layer surrounding the endosperm (Christine et al., 1992). Halopriming effect on seed germination energy showed significant improvement in comparison with control in both experiments, however, the increase in seed germination energy was higher in the greenhouse study perhaps due to the amount of nitrogen in the soil pots compared to the filter paper medium in the laboratory study (Sivritepe et al., 2003). It may also be related to differences in nutritional elements such as NO_2^- in the soil, the uptake of nutrients, and the rate of seedling growth during the germination period (Wang et al., 2003).

In this study, we found that increases in the germination percentage, germination speed and germination energy of haloprimered seed can short the seed germination period, thus decreasing mean germination time. Decreased mean germination time in Judas tree seed may be also due to water absorption that promotes earlier germination. Similar results were reported by Afzal et al. (2009) who investigated the effect of halopriming treatments on seed germination of marigold. Also, others have reported that the mean of seed germination time was improved in halopriming treatments with KNO_3 (Afzal et al., 2009; Guo et al., 2012). Results of mean cumulative seed germination of Judas tree showed that using the halopriming technique quickened the initiation of germination and reduced the overall germination period compared to non-haloprimered seed. More rapid onset and completion of germination may be due to the priming effect on seed condition, Seed priming improves the performance of heterogeneous seeds and uniformity of germination (Olouch and Welbaum, 1996).

Most previous research done on breaking dormancy in Judas tree seed had emphasized treatments of chemical scarification with sulfuric acid for 20 to 30 min and cold stratification for a period of 90 to 120 days (Piotto et al., 2004; Pipinis et al., 2011; Zenkirkiran et al., 2010).

We found that seed dormancy could be broken using the halopriming technique with potassium nitrate salt so that in a 30 days period in laboratory conditions or 45 days in the greenhouse germination was complete, thus shortening the time required compared to the other chemical and cold stratification methods.

Using a solution of 750 mM KNO_3 to haloprime Judas tree seed in the laboratory increased average germination by 54%, germination speed by 1.35 and germination energy by 32.6% over germination performance in the unprimed.

Seed germination and seedlings characteristics in greenhouse

In the greenhouse study, use of the halopriming technique with a solution of 100 mM KNO_3 increased the average germination percentage by 57%, germination speed by 1.56, germination energy by 44.8%, and decreased the average time of germination by nearly 14 days compared to seed in the control treatment (without halopriming). Our results indicated that by halopriming seed of the Judas tree that germination increased significantly, and also, the length of the main and secondary roots were increased, which may increase root fresh and dry biomass of emerging seedlings. Halopriming also reduced the mean duration of germination by 6.1 days. Halopriming with KNO_3 may affect root nutrition and enhance growth. Increases in leaf number and area in seedlings from haloprimered seed can improve the absorption of nitrogen compared to seedlings from unprimed seed (Rouhi et al., 2012).

The overall effect of potassium nitrate is to stimulate the growth and development of roots by improved nutrition and higher absorption capacity, which enhances the growth and establishment of Judas tree seedlings. Hadinezhad et al. (2013) studied the effect of potassium nitrate on seedling emergence and improvement in growth of *Quercus castaneifolia*. They observed properties of KNO_3 that could improve germination and seedling growth when seeds were haloprimered compared with no-primed seed.

Other studies have reported that halopriming with boiling water and KNO_3 increased the speed of germination and growth (Riggio-Bevilacqua et al., 1985; Rascio et al., 1998; Smiris et al., 2006; Afanasiev, 1944; Frett and Dirr, 1979; Liu et al., 1981; Zencirkiran, 2010; Gebre and Karam, 2004). The authors found positive effects of stratification with boiling water and halopriming with KNO_3 on Judas tree seed germination and seedling development. Finally, it can be concluded that halopriming with KNO_3 salt solution can improve and invigorate the germination of Judas tree seed, thus increasing growth potential of seedlings and improving seedling competitiveness in a shorter time compared with non-haloprimered seed.

Conflict of Interest

The authors have not declared any conflict of interests.

REFERENCES

- Afanasiev M (1944). A study of dormancy and germination of seeds of *Cercis canadensis*. J. Agric. Res. 69(10):405-420.
- Afzal I, Ashraf S, Qasim M, Basra SMA, Shahid M (2009). Does halopriming improve germination and seedling vigour in marigold (*Tagetes* spp.). Seed Sci. Technol. 37(2):436-445.
- Alevarado AD, Bradford KJ (1988). Priming and storage of tomato (*Lycopersicon esculentum*) seeds, effect of storage temperature on germination rate and viability. Seed Sci. Technol. 16:601-612.
- Arias D, Calvo-Alvarado J, Dohrenbusch A (2007). Calibration of LAI-2000 to estimate leaf area index (LAI) and assessment of its relationship with stand productivity in six native and introduced tree species in Costa Rica. For. Ecol. Manage. 247(1-3):185-193.
- Baskin CC, Baskin JM (1998). Seeds: ecology, biogeography, and evolution of dormancy and germination. Academic press. San Diego, P. 666.
- Basra SMA, Afzal I, Anwar S, Shafique M, Haq A, Majeed K (2005). Effect of different seed invigoration techniques on wheat (*Triticum aestivum* L.) seeds sown under saline and non-saline conditions. J. Seed Technol. 28:36-45.
- Bergmark CL, Jackson WA, Volk RJ, Blum U (1992). Differential Inhibition by Ferulic Acid of Nitrate and Ammonium Uptake in *Zea mays* L. Plant Physiol. 98(2):639-645.
- Bewley JD, Black M (1994). Seeds. Physiology of Development and Germination. Second Edition. New York, Plenum Press P. 445.
- Bhan S, Sharma NC (2011). Effect of seed stratification and chemical treatments on seed germination and subsequent seedling growth of wild apricot (*Prunus armeniaca* L.). Res. J. Agric. Sci. Technol. 2.1:13-16.
- Boratynski A, Browicz K, Zielinski J (1992). Chorology of Trees and Shrubs in Greece. Polish Academy of Sciences. Institute of Dendrology, Sorus, Poznan-Kornik. P. 286.
- Bradford KJ (1986). Manipulation of seed water relations via osmotic priming to improve germination under stress conditions. Hortic. Sci. 21:1105-1112.
- Bray CM, Davison PA, Ashraf M, Taylor RM (1989). Biochemical changes during osmopriming of leek seeds. Ann. Bot-London 36:185-193.
- Demir I, Mavi K (2004). The effect of priming on seedling emergence of differentially matured watermelon seeds. Scient. Hortic. 102(4):467-473.
- Dirr MA, Heuser Jr CW (1987). The reference manual of woody plant propagation: From seed to tissue culture. Varsity Press, P. 239.
- Duncan DB (1955). Multiple range and multiple F tests. Biometrics 11(1):1-42.
- Frett JL, Dirr MA (1979). Scarification and stratification requirements for seed of *Cercis canadensis* L. (redbud), *Cladrastis lutea* (Michx. F) C. Koch (yellowwood) and *Gymnocladus dioica* (L.) C. Koch (Kentucky Coffee Tree). Plant Propag. 25(2):4-6.
- Gebre GH, Karam NS (2004). Germination of *Cercis siliquastrum* seeds in response to gibberellic acid and stratification. Seed Sci. Technol. 32(1):255-260.
- Geneve RL (1991). Seed dormancy in eastern redbud (*Cercis canadensis*). J. A. Soc. Hortic. Sci. 116(1):85-88.
- Guo S, Wang Y, Wang W (2012). Effects of priming treatments on germination and biochemical characteristics of *Pinus bungeana* seeds. For. Stud. China 14(3):200-204.
- Hadinezhad P, Payamenur V, Mohamadi J, Ghaderifar F (2013). The effect of priming on seed germination and seedling growth in *Quercus castaneifolia*. Seed Sci. Technol. 41(1):121-124.
- Hamilton DF, Carpenter PL (1976). Regulation of seed dormancy in *Elaeagnus angustifolia* by endogenous growth substances. Can. J. Bot. 54(10):1068-1073.
- Heydecker W, Coolbear P (1977). Seed treatments for improved performance-survey and attempted prognosis. Seed Sci. Technol. 5(35):3-425.
- ISTA (1985). International Rules for Seed Testing Rules. Seed Sci. Technol. 13:299-255.
- Jazirei MH (2001). Aforestation in dryland. Tehran University Publication 447 p.
- Jones RO, Geneve RL (1995). Seedcoat structure related to germination in eastern redbud (*Cercis canadensis* L.). J. A. Soc. Hortic. Sci. 120(1):123-127.
- Kouhgard E, Akbarzadeh M, Shahrokhi S (2012). How plantations can affect sustainable forest management in Iran. Int. Proc. Chem. Biol. Environ. Eng. 41:4-8.
- Lee SS, Kim SONG (2000). Total sugars, α -amylase activity, and germination after priming of normal and aged rice seeds. Korean J. Crop Sci. 45:108-111.
- Liu NY, Khatamian H, Freta TA (1981). Seed coat structure of three woody legume species after chemical and physical treatments to increase seed germination. J. A. Soc. Hortic. Sci. 106 (5):691- 694.
- McDonald MB (1999). Seed deterioration: physiology, repair and assessment. Seed Sci. Technol. 27(1):177-237.
- McKay HM, Jinks RL, McEvoy C (1999). The effect of desiccation and rough-handling on the survival and early growth of ash, beech, birch and oak seedlings. Ann. For. Sci. 56:391-402.
- Mohammadi GR (2009). The influence of NaCl priming on seed germination and seedling growth of canola (*Brassica napus* L.) under salinity conditions. Am. Eur. J. Agric. Environ. Sci. 5(5):696-700.
- Olouch MO, Welbaum GE (1996). Effect of post-harvest washing and post-storage priming on viability and vigor of 6-year old muskmelon (*Cucumis melo* L.) seeds from eight stages of development. Seed Sci. Technol. 24:195-209.
- Parera CA, Cantliffe DJ (2010). Presowing seed priming. Hortic. Rev. 16:109-141.
- Piotto D, Viquez E, Montagnini F, Kanninen M (2004). Pure and mixed forest plantations with native species of the dry tropics of Costa Rica: a comparison of growth and productivity. For. Ecol. Manage. 190:359-372.