Journal of Agricultural Technology 2011 Vol. 7(3): 611-622
Available online http://www.ijat-aatsea.com
ISSN 1686-9141

The improvememt of seed germination traits in canola (*Brassica napus* L.) as affected by saline and drought stress

Heshmat, O.[1*], Saeed, H.A.[2] and Fardin, K.[3]

[1] Department of Agronomy, Faculty of Agriculture, University of Shahed, Tehran, Iran.
[2] Department of Agronomy, Faculty of Agriculture, Tarbiat Modares University, Tehran, Iran.
[3] Seed and Plant Certification & Registration Resaerch Institute, Karaj, Iran.

Heshmat, O., Saeed, H.A. and Fardin, K. (2011). The improvement of seed germination traits in canola (*brassica napus* L.) as affected by saline and drought stress. Journal of Agricultural Technology 7(3): 611-622.

In many crop species, seed germination and early seedling growth are the most sensitive stages to stress. Salinity and drought may delay the onset, reduce the rate, and increase the dispersion of germination events, leading to reductions in plant growth and final crop yield. The adverse effects of salt-stress can be alleviated by various measures, including seed priming (a.k.a. pre-sowing seed treatment). The general purpose of seed priming is to partially hydrate the seed to a point where germination processes are begun but not completed. Most priming treatments involve imbibing seed with restricted amounts of water to allow sufficient hydration and advancement of metabolic processes but preventing germination or loss of desiccation tolerance. The objective of the study was to determine factors responsible for germination and early seedling growth due to salt toxicity or osmotic effect and to optimize the best priming treatment for these stress conditions. In this experiment treated seeds (control, KNO3 and hydropriming) of canola (*Brassica napus* L.) cultivar Okapi were evaluated at germination and seedling growth for tolerance to salt (NaCl) and drought conditions (PEG-6000) at the same water potentials of 0.0, −3, −6, −9 and −12bar. Electrical conductivity (EC) values of the NaCl solutions were 0, 3, 6, 9 and 12 dSm−1, respectively. Results discovered that germination delayed in both solutions, having variable germination with different priming treatments. Germination, root and shoot length were higher but mean germination time and unusual germination percentage were lower in NaCl than PEG at the same water potential. Seeds were able to germinate at all concentrations of NaCl but no seed germination was observed at −1.2MPa of PEG treatments. NaCl had less inhibitor effect on seedling growth than the germination. It was concluded that inhibition of germination at the same water potential of NaCl and PEG resulted from osmotic effect rather than salt toxicity. Hydro priming increased germination and seedling growth under salt and drought stresses.

Key words: Canola, salt and drought stress, seed treatment; germination

[*]Corresponding Author: Omidi Heshmat; e-mail: heshmatomidi@yahoo.com

Introduction

Canola (Brassica napus L.) is one of the most important oil seed crops in Iran. One of the major problems to high yield and production is the lack of synchronized crop establishment in canola due to poor weather and soil conditions (Mwale *et al.,* 2003). The seeds are occasionally sown in seedbeds having unfavorable moisture because of the lack of rainfall at sowing time (Heydecker and Coolbaer, 1977) which results in poor and unsynchronized seedling emergence (Mwale *et al.,* 2003).

Winter canola is a winter annual that is sown in late summer or fall. When commercial production was first considered in Iran, site location and equal vegetation percentage were thought to be the two most important cultural decisions. Since winter wheat is commonly grown in Iran, winter wheat areas were considered most likely to be well suited for winter canola. This has proven to be the case. Therefore, good sites for winter canola are easy for producers to identify through their experience with winter wheat production. The advantages that winter canola possesses include lower input costs compared to other broadleaf crops in the region; the same equipment used for solid seeded crops may be used; winter canola facilitates the return to traditional fall planted crops such as wheat. With the introduction of more winter hardy, drought tolerant varieties, the most critical factor in winter canola production becomes planting date (Mehmet *et al.,* 2006). Under the conditions of Iran, moisture content of soil at sowing time (Mid-April–Mid-May) is most often inadequate with significant variation in micro pockets of the same field; a condition that results in irregular seed germination and stand establishment.

In many seeds, germination and subsequent seedling growth can be inhibited by mechanical restriction exerted by the seed coat (Sung and Chiu, 1995). Priming may be helpful in reducing the risk of poor stand establishment under drought and salt stress and permit more uniform growth under conditions of irregular rainfall and drought on saline soils. Parera and Cantliffe (1994) and McDonald (1999) emphasize that hydropriming is the simplest approach to hydrating seeds and minimizes the use of chemicals. However, if the seeds are not accurately hydrated, the rate of hydration cannot be exactly controlled.

Seedling establishment is a phenological stage at which drought could be particularly harmful to annual plants. Even though wheat is generally grown in water stress prone parts of the world, soil water potential strongly affects seedling emergence (Mehmet *et al.,* 2006).

Another major constraint to seed germination is soil salinity, a common problem in irrigated areas of Iran, with low rainfall (Kaya *et al.,* 2003). Salinity is the major environmental factor limiting plant growth and productivity (Allakhverdiev, 2000b). Soil salinity may affect the germination of seeds either

by creating an osmotic potential external to the seed preventing water uptake, or through the toxic effects of Na+ and Cl− ions on the germinating seed (Khajeh-Hosseini, 2003). Salt and osmotic stresses are responsible for both inhibition or delayed seed germination and seedling establishment (Almansouri *et al.,* 2003). Under these stresses there is a decrease in water uptake during imbibitions and furthermore salt stress may cause excessive uptake of ions (Asish and Anath, 2005; Mehmet *et al.,* 2006; and Murillo-Amador, 2002). Seed priming has been successfully demonstrated to improve germination and emergence in seeds of many crops, particularly seeds of vegetables and small seeded grasses (Angadi and Entz, 2002; Bradford, 1986). The beneficial effects of priming have also been demonstrated for many field crops such as wheat, sugar beet, maize, soybean and canola (Khajeh-Hosseini, 2003, Parera and Cantliffe, 1994; Sadeghian and Yavari, 2004; and Singh, 2004). Dharmalingam and Basu (1990) reported beneficial effect of a hydration-dehydration seed treatment on germination of canola. Rao *et al.* (1987) reports that primed Brassica seeds may reduce the risk of poor stand establishment in cold and moist soils. However, Singh and Rao (1993) stated that KNO3 effectively improved germination, seedling growth and seedling vigour index of the seeds of canola varieties with low germination. The aims of the present study were to determine factors responsible for failure of germination of canola seeds under saline conditions due to an osmotic barrier or due to the toxic effects of NaCl by comparing seed germination under a range of osmotic potentials due to NaCl and PEG. Furthermore, the study examined the possibilities to overcome salt and drought stresses by seed treatments with hydropriming or treatment with KNO3.

Materials and methods

This research was carrying out at the Department of Agronomy, Faculty of Agriculture, University of Shahed, Iran. Canola cultivar Okapi from Seeds Inc., which is commonly grown in semiarid and saline soils of Iran, was used as seed material. Germination and early seedling growth (10 days) of the cultivar were studied using distilled water (control) and under osmotic potentials of −3, −6, −9 and −12bar, for NaCl (Coon *et al.,* 1990) or polyethylene glycol (PEG 6000) (Michel, 1973). NaCl concentrations had the electrical conductivity (EC) values of 0, 3, 6, 9 and 12 dSm−1, respectively.

For hydropriming, canola seeds (5.5% seed moisture) were immersed in distilled water at 25◦C for 18 h under dark conditions. The hydropriming duration was determined by controlling seed imbibitions during germination. For KNO3 treatment, the seeds were immersed in 500 ppm KNO3 solution at 25◦C for 2 h in the dark (Singh and Rao, 1993). Thereafter, the seeds were

rinsed with tap water three times. The treated seeds were surface-dried and dried back to their original moisture content at room temperature (about 22◦C, 47% relative humidity) determined by changes in seed weight. Moisture content of untreated seeds (control, 5.5% moisture content), hydroprimed and KNO3 treated seeds was equilibrated at room temperature for 2 days.

Three replicates of 25 seeds were germinated between double layered rolled Anchor germination papers with 10 ml of respective test solutions. The papers were replaced every 2 days to prevent accumulation of salts (Rehman *et al.,* 1996). The rolled paper with seeds was put into sealed plastic bags to avoid moisture loss. Seeds were allowed to germinate at 25±1◦C in the dark for 7 days. Germination was considered to have occurred when the radicles were 2mm long. Germination characters was recorded every 24 h for 7 days. To determine the toxic effects of the solutions on germination, non-germinated seeds in each treatment were transferred to distilled water and counted 3 days later. Mean germination time (MGT) was calculated to assess the rate of germination (Ellis and Roberts, 1980). The seedlings with short, thick and spiral formed hypocotyls and stunted primary root were considered as abnormally germinated (ISTA, 2003). Root length; shoot length and seedling fresh weights were measured after the 10th day. Three grams of the seeds from each seed treatment were placed in Petri dishes containing distilled water to determine water uptake of seeds necessary for germination. The water uptake was expressed as the percentage increase in moisture content on fresh weight basis.

The experimental plan was three factors factorial arranged in a completely randomized design; with three replications and 25 seeds per replicate. The first factor was seed treatments (control, KNO3 and hydropriming), the second, solutions (NaCl and PEG) and the third was osmotic potential levels (0, −0.3, −0.6, −0.9 and −1.2MPa for drought stress and 0, 3, 6, 9 and 12 dSm−1 for NaCl stress). The data were analyzed using the factorial procedure of the statistical analysis system, SAS (SAS Inst., Cary, Nc). The differences between the means were compared using LSD values ($P < 0.05$).

Results and discussion

Analysis of variance for different parameters is shown in Table 1. In main factors, barely Osmosis factor (water potential levels) on Mean germination time, Germination Coefficient, Root length, Shoot length, Fresh weight and Dry weight was significant ($P>0.01$) and water potential of -3 bar (-0.3Mpa) was the most (Tables 1 and 2: Fig. 1). Seed treatment (T) was interacted with Solution (S) in its effect on Mean germination time, Germination Coefficient, Fresh weight and Dry weight only (Tables 1 and 3). So Osmosis factor had interaction with Seed treatments (T) (Table 1 and 4) and Solution(S) (Table 1 and 5).

A significant three-way interaction (seed treatment, solution and stress) was found ($P < 0.05$, 60 df.) for all investigated characters (Table 1& 6). The mean germination time (MGT) increased with decrease in osmotic potential in both NaCl and PEG solution; however, PEG delayed it more compared to NaCl (Table 1). Both priming (seed treatments) shortened the time to seed germination. Hydropriming resulted in the accelerated germination for both NaCl and PEG, especially under low osmotic potential. Water uptake of primed seeds did not change significantly ($P<0.05$), while the time to seed germination for hydropriming, KNO3 and control was delayed by 12, 18 and 38 h, respectively (data not shown). Germination Coefficient was influenced by salt and osmotic stresses, but inhibition was greater in PEG.

Seeds were able to germinate at−1.2MPa of PEG.KNO3 showed more germination under all osmotic potential of NaCl solutions, but Germination Coefficient drastically declined and delayed with increase of osmotic stress due to PEG in MPa lower than −0.6. Considering seed treatments, KNO3 gave higher Germination Coefficient only in PEG solution. KNO3 and hydropriming diminished the abnormal germination in NaCl, while they failed to reduce it in PEG. Increased water stress was accompanied with increase of abnormal germination in both solutions (data not shown). Although root length was affected due to salt and osmotic stresses, significant and higher inhibition due to PEG was very evident ($P < 0.05$). At−0.9MPa, root growth stopped after emergence of root or primary root from the seed. Greater reduction in shoot length due to PEG compared to salt was very evident ($P < 0.05$) with no recorded shoot growth at −0.6MPa of PEG (Table 5). However, hydropriming enhanced shoot growth at −0.6MPa of PEG. Also, hydropriming exhibited higher shoot growth due to all concentrations of NaCl. Depending on decrease in shoot and root length, seedling fresh weight gradually declined with the decreasing osmotic potential of solutions (Table 6). Higher seedling fresh weights were recorded from NaCl compared to osmotic stress at −0.6MPa due to PEG and above.

Both seed treatments showed enhanced performance under stress conditions. Mean germination time was shortened by seed priming, but stress conditions delayed it considerably. Compared to PEG, MGT for NaCl was shorter at equivalent osmotic potential. This could be explained by more rapid water uptake in hydroprimed seeds because germination for hydropriming, KNO3 and control started at 12, 18 and 38 h, respectively (data not shown). It supports that hydropriming caused more rapid water uptake than the amount of

Table 1. Mean of Squares for germination characters of canola seeds treated with KNO3, hydropriming and control (untreated) at water stress of NaCl and PEG.

S.O.V	Degree .of freedom	Mean germination time	Germination Coe	Root length	Shoot length	Fresh weight	Dry weight
Seed Treatment(T)	2	0.264	0.004	0.195	0.027	0.001	0.018
Solution(S)	1	0.607	0.007	0.387	0.000	0.002	0.001
Stress(O)	4	7.640**	0.025**	1.265**	0.439**	0.001**	0.254**
TS	2	0.523**	0.003**	0.497	0.436	0.001**	0.067**
PO	8	1.397**	0.003**	0.263**	0.334**	0.003**	0.066**
SO	4	0.315**	0.002**	0.137**	0.074**	0.002**	0.077**
TSO	8	0.778**	0.001**	0.236**	0.074**	0.002**	0.058**
Error	60	0.209	0.006	0.337	0.030	0.003	0.053

Ns, * and **: not significant, significant at the 5 and 1 % levels of probability, respectively.

Table 2. Mean comparisons of germination characters of canola seeds treated and untreated.

Stress	Germination Time(day)	Germination Coe	Root length (Cm)	Shoot length (Cm)	Fresh weight (gr)	Dry weight (gr)
0	2.504 c	0.402ab	3.914 ab	1.162b	0.035b	1.933c
-3	2.487c	0.411a	4.244 a	1.422a	0.041a	2.106b
-6	2.622 bc	0.389 ab	4.176a	1.373a	0.040a	2.133ab
-9	2.834 b	0.364 b	4.012a	1.153b	0.040a	2.267a
-12	3.271a	0.318 c	3.571ab	1.058b	0.033b	2.122ab

Mean followed by the same letters in each column are not significantly different (LSD test 5%).

Table 3. Mean comparisons for germination characters of canola seeds treated with KNO3, hydropriming and control (untreated) at solution under water stress of NaCl and PEG.

Seed treatment	Solution (S)	Germination Time(day)	Germination Coe	Root length (Cm)	Shoot length (Cm)	Fresh weight (g)	Dry weight (g)
Control	NaCl	2.883a	0.362ab	4.123a	1.253a	0.038ab	2.187a
	PEG-6000	2.535b	0.400a	3.967a	1.233a	0.036b	2.087a
KNO3	NaCl	2.659ab	0.386ab	3.909a	1.220a	0.036b	2.047a
	PEG-6000	2.684ab	0.384ab	4.117a	1.296a	0.037ab	2.127a
Hydropriming	NaCl	2.934a	0.354b	3.721a	1.227a	0.041a	2.093a
	PEG-6000	2.765ab	0.374ab	4.062a	1.172a	0.034b	2.133a

Mean followed by the same letters in each column are not significantly different (LSD test 5 %)

Table 4. Mean comparisons for germination characters of canola seeds treated with KNO3, hydropriming and control (untreated) at water potential levels.

Seed treatment	Stress	Germination Time(day)	Germination Coe.	Root length (Cm)	Shoot length (Cm)	Fresh weight (g)	Dry weight (g)
Control	0	2.682 bcd	0.374 abc	4.042 abc	1.227cde	0.035def	2.067abcde
	-3	2.428 d	0.416 a	4.087 abc	1.428ab	0.041abc	2.050bcde
	-6	2.642 bcd	0.387 ab	4.433 a	1.345abc	0.042abc	2.167abc
	-9	2.803 bcd	0.373 abc	3.825 abcd	1.113def	0.035def	2.200abc
	-12	2.985 abc	0.354 abcd	3.838 abcd	1.100def	0.032ef	2.200abc
KNO3	0	2.440 d	0.412 a	3.948 abcd	1.078def	0.036cdef	1.900de
	-3	2.447 d	0.412 a	4.248 ab	1.488a	0.037cde	2.100abcd
	-6	2.517 cd	0.403 a	4.082 abc	1.443ab	0.039bcd	2.167abc
	-9	2.618b cd	0.387 ab	4.257 ab	1.218bcd	0.037cde	2.317a
	-12	3.337 a	0.311 cd	3.532 cd	1.008f	0.035def	1.950cde
Hydropriming	0	2.392 d	0.420 a	3.752 bcd	1.180cdef	0.035def	1.833e
	-3	2.585 bcd	0.404 a	4.340 ab	1.350abc	0.044ab	2.167abc
	-6	2.707 bcd	0.377 abc	4.013 abcd	1.330abc	0.039bcd	2.067abcde
	-9	3.075 ab	0.331 bcd	3.955 abcd	1.073def	0.045a	2.283ab
	-12	3.490 a	0.287 d	3.343 d	1.065ef	0.031f	2.217ab

Mean followed by the same letters in each column are not significantly different (LSD test 5 %).

Table 5. Interaction mean comparisons for germination characters of canola seeds treated with KNO3, hydropriming and control (untreated) under water potential levels.

Solution (S)	Stress	Germination Time(day)	Germination Coe.	Root length (Cm)	Shoot length(Cm)	Fresh weight (g)	Dry weight(g)
NaCl(dSm−1)	0	2.542bc	0.399ab	3.779abc	1.162cde	0.036bcd	1.889c
	-3	2.668bc	0.386ab	4.179ab	1.463a	0.042a	2.067bc
	-6	2.690bc	0.382ab	4.242ab	1.318abc	0.040ab	2.078bc
	-9	2.946ab	0.352bc	3.971ab	1.236bcd	0.041ab	2.367a
	-12	3.300a	0.317c	3.418c	0.988f	0.032e	2.144b
PEG-6000(bar)	0	2.484c	0.405ab	4.049ab	1.161cde	0.035bcd	1.978bc
	-3	2.306c	0.435a	4.309a	1.381ab	0.040ab	2.144b
	-6	2.553bc	0.396ab	4.110ab	1.428a	0.040ab	2.189ab
	-9	2.722bc	0.376b	4.053ab	1.070ef	0.037bcd	2.167ab
	-12	3.241a	0.318c	3.723bc	1.128def	0.034de	2.100bc

Mean followed by the same letters in each column are not significantly different (LSD test 5 %).

water for germination. Sung and Chiu (1995) observed that MGT was accelerated by hydropriming without changing amount of water uptake in watermelon. Hydropriming clearly improved both rate of germination and mean germination time both under salt and drought stress conditions. Furthermore, hydropriming resulted in increase of normal germination. The results are in line with the findings of Thornton and Powell (1994) in Brassica, Srinivasan *et al.* (1993) in mustard and Fujikura *et al.* (1993) indicated the beneficial effects of hydropriming on aged or unaged seeds with respect to germination and percentage of normal seedlings in cauliflower. Furthermore, Sadeghian and

Table 6: Mean comparisons of interaction for germination characters of canola seeds treated with KNO3, hydropriming and control (untreated) at solution under water stress of NaCl and PEG.

Seed treatment	Solution (S)	Stress	Germination Time(day)	Germination Coe.	Root length (Cm)	Shoot length (Cm)	Fresh weight (g)	Dry weight (g)
KNO3	NaCl(dSm−1)	0	2.677cdef	0.375abcde	3.910abcdef	1.207cdefg	0.035defghji	2.000cde
		-3	2.587cdef	0.391abc	4.183abcde	1.370abcde	0.040bcdefg	2.067bcde
		-6	2.800abcdef	0.370abcde	4.707a	1.300abcdef	0.044ab	2.233abcd
		-9	3.103abcde	0.344bcde	4.157abcde	1.360abcde	0.039bcdefg	2.467a
		-12	3.250abc	0.329cde	3.657bcdef	1.027fgh	0.031hij	2.167abcde
	PEG-6000(bar)	0	2.687cdef	0.372abcde	4.173abcde	1.247bcdefg	0.036cdefghi	2.133abcde
		-3	2.270f	0.441ab	3.990abcdef	1.487abc	0.042bcd	2.033bcde
		-6	2.483def	0.404abc	4.160abcde	1.390abcde	0.039bcdefg	2.100abcde
		-9	2.513cdef	0.403abc	3.493def	0.868h	0.030ij	1.933cde
		-12	2.720cdef	0.379abcde	4.017abcdef	1.173efg	0.034fghij	2.233abcd
Control	NaCl(dSm−1)	0	2.500def	0.403abc	3.983abcdef	1.127efgh	0.039bcdefg	1.867de
		-3	2.497def	0.405abc	3.913abcdef	1.460abcd	0.040bcdef	2.067bcde
		-6	2.510cdef	0.404abc	4.110abcde	1.370abcde	0.036cdefghi	2.033bcde
		-9	2.653cdef	0.382abcdd	4.030abcdef	1.170efg	0.031hij	2.233abcd
		-12	3.137abcd	0.337cde	3.510cdef	0.973gh	0.033ghij	2.033bcde
	PEG-6000(bar)	0	2.380ef	0.421abc	3.913abcdef	1.030fgh	0.034fghij	1.933cde
		-3	2.397def	0.419abc	4.583ab	1.517ab	0.033fghij	2.133abcde
		-6	2.523cdef	0.401abc	4.053abcde	1.517ab	0.042bcde	2.300abc
		-9	2.583cdef	0.393abc	4.483abc	1.370abcde	0.041bcdef	2.400ab
		-12	3.537a	0.337cde	3.510bcdef	1.043fgh	0.037bcdefgh	1.867de
Hydropriming	NaCl(dSm−1)	0	2.397def	0.420abc	3.443ef	1.153efg	0.035defghij	1.800e
		-3	2.920abcdef	0.363abcde	4.440abcd	1.560a	0.045ab	2.067bcde
		-6	2.760bcdef	0.371abcde	3.910abcdef	1.283abcdef	0.039bcdefg	1.967cde
		-9	3.080abcde	0.331cde	3.727bcdef	1.177defg	0.051a	2.400ab
		-12	3.513a	0.265e	3.087f	0.963gh	0.033ghij	2.233abcd
	PEG-6000(bar)	0	2.387ef	0.421abc	4.060abcde	1.207cdefg	0.034efghij	1.867de
		-3	2.250f	0.447a	4.353abcde	1.140efgh	0.043abc	2.267abc
		-6	2.653cdef	0.383abcd	4.117abcde	1.377abcde	0.038bcdefg	2.167abcde
		-9	3.070abcde	0.331cde	4.183abcde	0.970gh	0.039bcdefg	2.167abcde
		-12	3.468ab	0.290de	3.600cdef	1.167efg	0.029j	2.200abcd

Mean followed by the same letters in each column are not significantly different (LSD test 5 %)

Yavari (2004) reported that increasing drought stress resulted in increasing abnormal seedlings in sugar beet. It is concluded that superiority of hydropriming on germination could be due to soaking time effects rather than KNO3 treatment. Because, hydroprimed seeds compared to KNO3 treated seeds were allowed to imbibe water for a longer time and went through the first stage of germination without protrusion of radicle. Akinola *et al.* (2000) reported that higher duration of exposure to seed treatment resulted in higher cumulative germination in wild canola. Caseiro *et al.* (2004) found that hydropriming was the most effective method for improving seed germination of onion, especially when the seeds were hydrated for 96 h compared to 48 h. The beneficial effects of KNO3 on germination were found in this study.Hydropriming shortened MGT, however, final germination was higher from KNO3, suggesting nontoxicity of KNO3 due to ion accumulation in the embryo (Demir *et al.,* 1999).

Seeds always germinated better in NaCl than PEG at the equivalent water potential in line with earlier observations made for soybean by (Khajeh-Hosseini *et al.*, 2003). This may be due to the uptake of Na+ and Cl− ions by the seed, maintaining a water potential gradient allowing water uptake during seed germination. Lower germination percentage obtained from PEG compared with NaCl at equivalent water potential in each priming method suggest that adverse effects of PEG on germination were due to osmotic effect rather than specific ion accumulation. These results agree with Murillo-Amador *et al.* (2002) in cowpea (Demir and Van De Venter, 1999). In watermelon, they affirmed that drought or salinity may influence germination by decreasing the water uptake. Moreover, the present study revealed that PEG had no toxic effect since all seeds germinated when PEG stress was removed. Mehra *et al*. (2003); and Michel (1983) indicated that PEG molecules do not enter the seed and Khajeh-Hosseini *et al.* (2003) found that there was no toxicity of PEG. Under salt stress, Na+ and Cl− may be taken up by the seed and toxic effect of NaCl might appear. However, our findings at high salinity concentration showed that decrease in germination characters was not significant. The main effect of seed treatments was an increase in Germination Coefficient; however, post-germination growth was also increased. Hydropriming improved seedling fresh weight under osmotic stress. Considering both seed treatments, it was concluded that hydropriming improved root growth and gave the highest root length in both solutions. El-Midaoui *et al.* (2000b) reports that root and shoot growth significantly decreased by osmotic stress at −0.6 MPa and above induced by PEG 6000. Murillo-Amador *et al.* (2002) found that seedling growth of cowpea was inhibited by both NaCl and PEG, but higher inhibition occurred due to PEG. Sung and Chiu (1995) proposed that emergence force and

seedling growth were strengthened by hydropriming in watermelon. Seedling growth severely diminished with increased drought stress and genetic differences were found in sugar beet (Sadeghian and Yavari, 2004).

It was observed that hydropriming practically ensured rapid and uniform germination accompanied with low abnormal seedling percentage in line with Shivankar *et al.* (2003) and Singh (1995). They emphasize that it has high potential in improving field emergence and ensures early flowering and harvest under stress conditions especially in dry areas. Our findings revealed that inhibition of germination at equivalent water potential of NaCl and PEG resulted from osmotic effect rather than salt toxicity. Both seed treatments gave better performance than control (untreated) under salt and drought stresses with clear effectiveness of hydropriming in improving the germination percentage at low water potential. In commercial production of canola in Iran, seed costs are a major input price, often exceeding $200–$360 ha−1 since canola seed was priced from $10 to $17 kg−1 in 2006. To achieve a uniform plant density in case of drought, growers tend to sow 16 kg ha−1 of seed while only 8 kg ha−1 is needed. Hydrated seeds with higher germination percentage under drought and salt stresses represent a potential saving of $125–$212 ha−1. It also increased tolerance of seeds to salt and water stress. In addition, reported protocol is simple, cheap and does not require expensive chemicals and sophisticated equipment. The protocol has practical importance and could be recommended to farmers to achieve higher germination and uniform emergence under field conditions.

Acknowledgements

We wish to thank the workforce of the Dr H. Torabi and et al (Agro Dep, Sha U, Iran) for providing logistic help and Laboratory assistance during the collecting data. This study was supported by a grant from Dr H.Omidi; project.

References

Akinola, J.O., Larbi, A., Farinu, G.O., Odunsi, A.A. (2000). Seed treatment methods and duration effects on germination of wild canola. Exp. Agric. 36: 63–69.

Allakhverdiev, S.I., Sakamoto, A., Nishiyama, Y., Inaba, M., Murata, N. (2000b). Ionic and osmotic effects of NaCl-induced inactivation of photosystems I and II in Synechococcus sp. Plant Physiol 123: 1047–1056.

Almansouri, M., Kinet, J.M., Lutts, S. (2001). Effect of salt and osmotic stresses on germination in durum wheat (Triticum durum Desf.). Plant Soil 231: 243–254.

Angadi, S.V., Entz, M.H. (2002). Water relations of standard height and dwarf canola cultivars. Crop Sci. 42: 152–159.

Asish Kumar Parida, Anath Bandhu Das. (2005). Salt tolerance and salinity effects on plants: a review. Ecotoxicology and Environmental Safety 60: 324–349

Bradford, K.J. (1986). Manipulation of seed water relations via osmotic priming to improve germination under stress conditions. Hort. Sci. 21: 1105–1112.

Caseiro, R., Bennett, M.A., Marcos-Filho, J. (2004). Comparison of three priming techniques for onion seed lots differing in initial seed quality. Seed Sci. Technol. 32: 365–375.

Coons, M.J., Kuehl, R.O., Simons, N.R. (1990). Tolerance of ten lettuce cultivars to high temperature combined with NaCl during germination. J. Am. Soc. Hort. Sci. 115: 1004–1007.

Demir, I., Van De Venter, H.A. (1999). The effect of priming treatments on the performance of watermelon (Citrillus lanatus (Thunb.) Matsum. & Nakai) seeds under temperature and osmotic stress. Seed Sci. Technol. 27: 871–875.

Dharmalingam, C., Basu, R.N. (1990). Maintance of viability and vigour in canola. Seed Res. 18: 15–24.

Ellis, R.H., Roberts, E.H. (1980). Towards a rational basis for testing seed quality. In: Hebblethwaite, P.D. (Ed.), Seed Production. Butterworths, London, pp. 605–635.

El-Midaoui, M., Serieys, H., Griveau, Y., Benbella, M., Talouizte, A., Berville, A., Kaan, F. (2003). Effects of osmotic and water stresses on root and shoot morphology and seed yield in canola (Helianthus annuus L.) genotypes bred for Morocco or issued from introgression with H. argophyllus T.&G. and H. debilis Nutt. Helia, 26: 1–16.

Fujikura, Y., Kraak, H.L., Basra, A.S., Karssen, C.M. (1993). Hydropriming, a simple and inexpensive priming method. Seed Sci. Technol. 21: 639– 642.

Heydecker, W., Coolbaer, P. (1977). Seed treatments for improved performance survey and attempted prognosis. Seed Sci. Technol. 5: 353–425.

ISTA., International Seed Testing Association. ISTA Handbook on Seedling Evaluation, (2003) 3rd ed.

Kaya, M.D., ˙Ipek, A., O¨ zturk, A. (2003). Effects of different soil salinity levels on germination and seedling growth of safflower (Carthamus tinctorius L.). Turk. J. Agric. For. 27: 221–227.

Khajeh-Hosseini M., Powell A.A., Bingham I.J. (2003). The interaction between salinity stress and seed vigour during germination of soybean seeds. Seed Sci. Technol. 31, 715–725.

McDonald, M.B. (1999). Seed deterioration: physiology, repair and assessment. Seed Sci. Technol. 27: 177–237.

Mehmet Demir Kayaa, Gamze, Okc¸u , Mehmet, Atak, Yakup, C¸ ıkılı, O¨ zer Kolsarıcı. (2006). Seed treatments to overcome salt and drought stress during germination in sunflower (Helianthus annuus L.). Europ. J. Agronomy. 24: 291–295

Mehra, V., Tripathi, J., Powell, A.A. (2003). Aerated hydration treatment improves the response of Brassica juncea and Brassica campestris seeds to stress during germination. Seed Sci. Technol. 31: 57–70.

Michel, B.E. (1983). Evaluation of the water potentials of solutions of polyethylene glycol 8000 both in the absence and presence of other solutes. Plant Physiol. 72: 66–70.

Michel, B.E., Kaufmann, M.R. (1973). The osmotic potential of polyethylene glycol 6000. Plant Physiol. 51: 914–916.

Murillo-Amador, B., Lopez-Aguilar, R., Kaya ,C., Larrinaga-Mayoral, J., Flores-Hernandez, A. (2002). Comparative effects of NaCl and polyethylene glycol on germination, emergence and seedling growth of cowpea. J. Agron. Crop Sci. 188: 235–247.

Mwale ,S.S., Hamusimbi, C., Mwansa, K. (2003). Germination, emergence and growth of canola (Helianthus annuus L.) in response to osmotic seed priming. Seed Sci. Technol. 31: 199–206.

Parera, C.A., Cantliffe, D.J. (1994). Presowing seed priming. Hort. Rev. 16: 109–141.

Rao, S.C., Aker, S.W., Ahring, R.M. (1987). Priming Brassica seed to improve emergence under different temperatures and soil moisture conditions. Crop Sci. 27: 1050–1053.
Rehman, S., Harris, P.J.C., Bourne, W.F., Wilkin ‚J. (1996). The effect of sodium chloride on germination and the potassium and calcium content of Acacia seeds. Seed Sci. Technol. 25: 45–57.
Sadeghian, S.Y., Yavari, N. (2004). Effect of water-deficit stress on germination and early seedling growth in sugar beet. J. Agron. Crop Sci. 190: 138–144.
Shivankar, R.S., Deore, D.B., Zode, N.G. (2003). Effect of pre-sowing seed treatment on establishment and seed yield of canola. J. Oilseeds Res. 20: 299–300.
Singh, B.G. (1995). Effect of hydration-dehydration seed treatments on vigour and yield of canola. Indian J. Plant Physiol. 38: 66–68.
Singh, B.G., Rao, G. (1993). Effect of chemical soaking of canola (Helianthus annuus L.) seed on vigour index. Indian J. Agric. Sci. 63, 232–233.
Srinivasan, K., Saxena, S., Singh, B.B. (1999). Osmo- and hydropriming of mustard seeds to improve vigour and some biochemical activities. Seed Sci. Technol. 27: 785–793.
Sung, J.M., Chiu, K.Y. (1995). Hydration effects on seedling emergence strength of watermelon seed differing in ploidy. Plant Sci. 110: 21–26.
Thornton, J.M., Powell, A.A. (1992). Short term aerated hydration for the improved of seed quality on Brassica oleracea. Seed Sci. Res. 2: 41–49.

(Recieved 29 July 2010; accepted 18 March 2011)