Germination of Carrot (*Daucus carota* L.) Seeds in Response to Osmotic Priming

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ABSTRACT

Seed priming alleviates environmental problems such as water and salinity stress and hence improves seed germination and subsequent growth. An experiment was conducted to evaluate the effects of distilled water, sodium chloride (NaCl), potassium nitrate (KNO_3) and polyethylene glycol (PEG_{6000}) on the germination dynamics of six carrot cultivars. Experimental design was factorial based on completely randomized design (CRD) with four replications. Germination traits were assessed either just after treatments or 3 months after pretreating seeds at 5˚C and 45% relative humidity (RH). Results showed that the effects of priming treatment and cultivar were significant ($P \leq 0.01$) on germination percentage, mean germination time (MGT) and plumule and dry weight. 'Forto' and 'Baby finger' had the highest and the lowest germination percentage and MGT, respectively. PEG determined the highest germination percentage. The lowest germination percentage was noticed in the case of priming with distilled water. The variations of priming treatments and cultivars were significant ($P \leq 0.01$) for germination percentage, mean germination time and plumule and radical dry weight. Radicle length was improved with sodium chloride (NaCl) priming. 'Chanteny' and 'Baby finger' had the highest and the lowest radicle lengths, respectively. In total, priming treatments promoted germination related traits of carrot.

Keywords: Carrot, seed priming, KNO_3, PEG_{6000}, germination

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INTRODUCTION

Water and salinity stress are among main problems of crop production in most dry and semi-dry regions of the world (Bradford, 1986). These adverse conditions result in low water availability and hence hamper seed germination (Aazami and Hassanpouraghdam, 2009). Drought stress also leads to yield loss in most of field and horticultural crops (Ashrafi and Mehmoodi, 1990). Water deficit adversely affects germination dynamics, seedling establishment and ultimately biomass production. Seed priming in high osmotic solutions is a convenient way to overcome drought and salinity problems. Cellular, subcellular and molecular processes during priming enhance seed quality and make the seed and resulting plantlet ready to cope with stressful conditions like low water potential, low and high soil temperature (Farooq *et al.*, 2006), fluctuated soil water availability (Dean-Knix *et al.*, 1998; Ellis and Butcher, 2007) and saline soil. Osmotic priming of seed is the time dependent soaking of seeds in low potential inorganic salts or polyethylene glycol (PEG) for optimum water absorption (Amooaghaie, 2011). This technique consists of seed hydration in a solution whose osmotic potential is enough to allow initial germination events to occur, but not sufficient for radicle protrusion (Bradford, 1986;

Zlatica *et al.*, 2018). Advantageous effects from priming have been reported for several vegetable seeds included carrot. For many vegetable species and crops, priming increases seedling vigor and yield, resulting in greater incomes that explain the additional cost of these treatments (Aazami and Mohammadi, 2008; Draganic and Lekic, 2012; Delian and Lagunovschi-Luchian, 2015). The aim of the present experiment was to find out the suitable chemical priming agent for increasing germination dynamics of some carrot varieties. Thus, taking into consideration that the priming treatment are known to improve carrot seeds germination traits, the aim of this experiment was to find out the suitable priming agent in the case of different carrot varieties.

MATERIAL AND METHODS

Researches have been carried out in the Laboratory of Plant Physiology, Faulty of Horticulture, University of Maragheh in 2016. Six carrot cultivars (Forto, Touchan, Chanteny, Baby finger, Nantes and Imperial) were obtained from Hamilton Seed Company (Ontario, Canada).

In the first experiment, the priming treatments used were: distilled water as the control, 100 mM NaCl, 200 mM KNO_3 and 273 gL^{-1} PEG_{6000}. Osmotic potential of all treatments was set at -1 MPa for ease of comparison.

Priming was carried out at 15˚C for ten days followed by rinsing seeds with tap water and disinfecting with Thyram to prevent any fungal growth. Using distillated water fifty seeds were cultured in each 9 cm Petri dish on filter paper. Cultured seeds were incubated at 20˚C. During a 14 days period, number of germinated seeds (germination percentage) and MGT were recorded.

$$GP = \text{seeds germinated/total seeds} \times 100$$
$$MGT = \Sigma [n \times t] / \Sigma n$$

(where n is the number of germinated seeds in upcoming days from experiment commence, t, the days passed from the experiment start and Σn, the overall sum of germinated seeds).

At the end of the experiment, at the 14th day radicle length and plumule/radicle dry weight were also recorded. For radicle length, mean data from 10 plantlets were assessed. Plumule/radicle dry weight was measured after drying of the material at 72˚C for 48 hrs.

In the second experiment, primed seeds were stored at 5˚C for 3 months and then the same traits were recorded.

Experimental design was factorial based on CRD with four replications. Data were subjected to variance analysis by MSTATC and SPSS 15 software (Statistical Package for the Social Sciences, SPSS Inc., Chicago, Ill.). Mean comparisons were carried out by Duncan's multiple range test at 5% probability level.

RESULTS AND DISCUSSION

RESULTS

First Experiment

Different chemical priming agents had significant effects on germination percentage of all cultivars (Table 1). PEG had the highest germination percentage for all cultivars. The lowest germination percentage belonged to the control ($P \leq 0.01$). The interactive effects of cultivar × priming were significant ($P \leq 0.01$) for MGT. The highest and lowest MGT gained by PEG and control treatments respectively. 'Forto' had the highest MGT versus 'Baby finger' with the most inferior MGT.

For radicle length, the effect of cultivar was significant ($P \leq 0.01$) (Table 1) and 'Chanteny' had the highest radicle length and 'Baby finger' the lowest. Effects of different priming agents and cultivars on plumule dry weight as well as their interactive effect were significant ($P \leq 0.01$). 'Baby finger' had the lowest amount for this trait. There was no significant difference between other treatments.

For radicle dry weight, cultivar × priming interactive effect found to be significant ($P \leq 0.01$) as well. PEG resulted in the highest radicle dry weight. Furthermore, among the cultivars, 'Forto' had the greatest amount for this trait.

Table 1 Effects of osmotic priming on germination-related traits of the seeds six carrot cultivars (not-pretreated)

	Germination Percentage (%)						MGT (day)						Radicle length (cm)					
	Forto	Touchan	Chanteny	Baby finger	Nantes	Imperial	Forto	Touchan	Chanteny	Baby finger	Nantes	Imperial	Forto	Touchan	Chanteny	Baby finger	Nantes	Imperial
Distill water	42.6	33.3	22.6	12.0	53.3	76.0	3.9	3.2	3.4	1.4	4.1	5.4	8.7	6.6	7.3	5.3	8.4	9.0
NaCl	84.0	37.3	69.3	26.6	69.3	29.3	6.4	3.6	4.8	3.1	4.9	2.8	7.0	7.6	11.4	6.2	8.3	7.7
PEG	98.6	62.6	74.6	30.6	70.6	72.0	7.2	4.6	5.1	3.6	4.9	5.1	8.7	7.2	10.0	5.2	7.2	6.3
KNO_3	86.6	49.3	44.0	36.0	33.3	57.3	6.8	4.3	4.4	3.9	2.9	4.6	8.2	8.9	9.8	4.4	5.3	8.7
Cultivars	79.12**						1.12^{ns}						0.71^{ns}					
Treat-ments	112.35**						8.83*						16.57**					
Cul.× Treat.	27.33**						3.17^{ns}						3.32^{ns}					

	Plumule dry weight (g)						Radicle dry weight (g)					
	Forto	Touchan	Chanteny	Baby finger	Nantes	Imperial	Forto	Touchan	Chanteny	Baby finger	Nantes	Imperial
Distill water	0.001	0.001	0.001	0	0.002	0.002	0.002	0.001	0.002	0	0.004	0.005
NaCl	0.003	0.002	0.003	0	0.004	0	0.003	0.002	0.003	0	0.004	0
PEG	0.003	0.002	0.004	0	0.004	0.002	0.008	0.004	0.004	0	0.007	0.005
KNO_3	0.003	0.001	0.002	0.001	0	0.002	0.007	0.004	0.004	0	0.002	0.005
Cultivars	16.53**						22.98**					
Treat-ments	19.009**						30.44**					
Cul.× Treat.	4.48*						7.87**					

MGT: Mean germination time, ns: Non-significant, *: Significant at ($P \leq 0.05$), **: Significant at ($P \leq 0.01$)

Table 2 Effects of osmotic priming on germination-related traits of the seeds six carrot cultivars (Pretreated)

	Germination Percentage (%)						MGT (day)						Radicle length (cm)						Plumule dry weight (g)						Radicle dry weight (g)					
	Forto	Touchan	Chanteny	Baby finger	Nantes	Imperial	Forto	Touchan	Chanteny	Baby finger	Nantes	Imperial	Forto	Touchan	Chanteny	Baby finger	Nantes	Imperial	Forto	Touchan	Chanteny	Baby finger	Nantes	Imperial	Forto	Touchan	Chanteny	Baby finger	Nantes	Imperial
Distill water	22.6	8.6	8.0	2.3	29.3	53.3	3.3	1.3	1.1	0.8	3.4	4.9	3.4	3.3	2.6	1.7	4.9	5.0	0.001	0	0	0	0.002	0.002	0.001	0	0	0	0.004	0.004
NaCl	73.3	25.3	52.0	10.0	38.6	53.0	6.1	2.6	4.3	1.1	3.9	4.8	5.6	4.3	6.0	2.4	4.1	2.5	0.003	0.001	0.003	0	0.004	0	0.004	0.002	0.006	0	0.004	0
PEG	86.6	56.0	61.3	9.3	40.6	68.0	6.9	3.9	4.9	1.7	4.3	5.1	5.9	5.5	6.0	2.3	3.8	5.0	0.004	0.003	0.004	0	0.004	0.002	0.006	0.005	0.006	0	0.004	0.005
KNO_3	70.6	29.3	40.0	12.0	20.0	48.0	5.8	2.8	3.7	1.3	2.8	4.1	5.5	3.4	5.9	2.7	3.1	4.5	0.003	0.001	0.002	0	0.002	0.022	0.005	0.002	0.005	0	0.002	0.004
Cultivars			60.81**						8.33*						11.18**						27.27**						39.85**			
Treat-ments			72.75**						20.44**						29.09**						20.44**						33.15**			
Cul.× Treat.			16.68**						5.62*						7.35**						4.41*						9.97**			

MGT: Mean germination time, * ($P \le 0.05$), **($P \le 0.01$)

Second Experiment

Cultivar × priming effect was considerable ($p \leq 0.01$) on germination percentage (Table 2). PEG owned the greatest germination percentage vs. the control with the lowest amount. 'Forto' had the highest and 'Baby finger' possessed the lowest germination percentage. In total, not-pretreated seeds showed higher germination percentage compared with pretreated seeds.MGT was also affected by cultivar × priming interactive effect ($P \leq 0.01$). Like all other traits, PEG showed the highest values for this trait. 'Forto' had the highest MGT in contrast with 'Baby finger' with the lowest one.

Radicle length was influenced by cultivar and priming as well as by their interactive effect (Table 2). The effects of priming on radicle length of cultivars were positive except for 'Nantes' and 'Imperial'. PEG had the greatest radicle length. However, NaCl treatment influenced the radicle length of 'Chanteny' at the highest value. Overall, 'Chanteny' illustrated the greatest radicle length, while that of 'Baby finger' was the lowest. Furthermore, 'Forto' and PEG had the highest means for plumule/ radicle dry weight ($P \leq 0.01$).

DISCUSSION

Time course between seed sowing and seedling establishment is a main and critical step of plant life cycle. Homogeneous and high rate of germination and emergence are main positive criteria especially for direct seeded plants, which affect the yield and quality of crops (Bradford, 1986). Osmotic priming accordingly influenced the germination dynamics depending upon plant species and experiment conditions (Mauromicale and Cavallaro, 1995; Moreno *et al.*, 2018). Arvin and Kazemipour (2003) in their study on onion noted that priming effect on germination percentage was cultivar dependent. In this experiment, 'Forto' had the greatest germination percentage and MGT. The lowest amounts for these traits were recorded for 'Baby finger'. This variation is due to the diverse germination potential of cultivars. This in turn shows that different environmental and growing condition influence the potential response of different seeds to priming treatments. Storage period significantly reduced germination response of carrot seeds compared with non-stored counterparts. The same results have been reported for onion (Arvin and Kazemipour, 2003), salvia (Dean-Kinx *et al.*, 1998) and alfalfa (Amooaghaie, 2011). Drew *et al.* (1997) reported that germination percentage of carrot, leek and onion primed seeds were not influenced by storage period. Meanwhile, prolonged storage period statistically increased abnormal seedlings. Priming agents had significant effects on germination-related traits with PEG having the most positive effect (Baque *et al.*, 2018). Promotive effects of PEG on germination dynamics of seeds have been reported for sunflower (Demir Kaya *et al.*, 2006), onion (Caseiro *et al.*, 2004; Ellis and Butcher, 2007) carrot (Aazami and Mohammadi, 2008; Aazami and Hassanpouraghdam, 2009), pepper (Namjun *et al.*, 1997), watermelon (Demir and Oztokat, 2003) and tomato (Mauromicale and Cavallaro, 1995; Cuartero *et al.*, 2006).

There are some reports revealing that the single and combined effects of chemicals had diverse effects on germination traits and oxidative stress of different plant species (Draganic and Lekic, 2012). Cayela *et al.* (1996) reported that NaCl pretreatments of tomato seeds significantly enhanced plantlets emergence. Furthermore, in most case and for the majority of plant species, priming treatments positively influence germination-related traits and concomitantly reduce abnormal seedlings. Ultimately, these positive responses improve seeds tolerance to stressful germination beds and condition and resultantly plants yield and quality (Namjun *et al.*, 1997; Shekari *et al.*, 2000; Ellis and Butcher, 2007; Mansouri and Omidi, 2018).

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