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Full Length Research Paper

Response of winter rapeseed (*Brassica napus* L.) cultivars to salt priming of seeds

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Laboratory tests and a field experiment were carried out to evaluate the effects of salt priming (0.8% NaCl with electrical conductivity of 15.3 dsm^{-1} and 0.8% KNO_3 with electrical conductivity of 12.5 dsm^{-1} for 8 h at 20 ± 1°C) on seed invigoration and field performance of three winter rapeseed cultivars (Okapi, Opera and Talayeh). The field experiment was arranged as split plot factorial based on RCB design in three replicates, with irrigation regimes (I1, I2 and I3: irrigation after 80, 120 and 160 mm evaporation from class A pan) in main plots and cultivars and salt priming treatments in sub-plots. Salt priming, particularly KNO_3 priming, decreased mean germination time and increased seedling size, compared with non-primed seeds. Irrigation treatments had no significant effect on yield and yield components of rapeseed cultivars in the field, suggesting that this crop was well-performed even under the limited irrigation regimes. Although response to salt priming varied among rapeseed cultivars, seed priming generally increased grain yield per unit area through enhancing rate and percentage of seedling establishment, pods per plant and grains per plant. The highest improvement in grain yield per unit area was observed for seeds primed with KNO_3 (31.5%) followed by those primed with NaCl (22.5%).

Key words: Cultivar, grain yield, rapeseed, salt priming, seed germination, seedling emergence.

INTRODUCTION

Rapeseed (*Brassica napus* L.) has some good characteristics such as suitable placement in crop rotation, desirable quality, high value of oil (40 - 45%) and protein (39%) that has changed it to an important crop. In the semi-arid regions, crops often fail to establish quickly and uniformly, leading to decreased yields because of low plant populations. Constraints to good establishment include poor seedbed preparation (Joshi, 1987), low quality seed and lack of soil moisture (Gurmu and Naylor, 1991), high temperature (Weaich et al., 1992) and crust formation (Townend et al., 1996). Rapid and uniform field emergence is an essential prerequisite to reach the yield potential, quality and ultimately profit in annual crops (Parera and Cantliffe, 1994). Out of many constraints regarding low production of oilseeds, seed quality is the prime importance. Oilseeds are deteriorated more rapidly during storage, which reduces the quality of seeds (Afzal et al., 2004). Seed priming is a pre-sowing strategy for improving seedling establishment by modulating pre-germination metabolic activity prior to emergence of the radicle and generally enhances germination rate and plant performance (Bradford, 1986; Taylor and Harman, 1990; Ghassemi-Golezani et al., 2008a, b). Priming allows seed hydration to initiate the early events of germination, but not permit radicle emergence, followed by drying to initial moisture (McDonald, 2000; Ashraf and Foolad, 2005). There are reports that seed priming permits early DNA replication, increase RNA and protein synthesis, enhances embryo growth, repairs deteriorated seed parts and reduces leakage of metabolites (McDonald, 2000). Seed priming is seen as a viable technology to enhance rapid and uniform emergence, high vigor and better yields mostly in vegetable and flower species (Dearman et al., 1987; Parera and Cantliffe, 1994; Bruggink et al., 1999) and some field crops (Basra et al., 1988; Hartz and Capril, 1995; Harris et al., 1999; Chiu et al., 2002; Giri and Schillinger, 2003; Murungu et al., 2004; Ghassemi-Golezani et al., 2008b). Methods of seed priming include osmo-priming, salt-priming, hydro-priming, matrix-priming and thermo-priming (Khan, 1992; McDonald, 2000). Previous studies on tomato (Cano et

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Table 1. Effects of salt priming and cultivar on mean germination percentage, germination time and seedling dry weight of winter rapeseed in the laboratory.

Treatments	Germination (%)	Germination time (day)	Seedling dry weight (mg)
Cultivar			
Okapi	95.0[a]	4.03[a]	3.42[c]
Opera	88.3[b]	4.31[a]	4.01[a]
Talayeh	97.3[a]	3.61[b]	3.70[b]
Priming			
Non-primed	92.0[a]	4.47[a]	3.54[b]
NaCl	93.6[a]	3.99[b]	3.80[a]
KNO_3	95.0[a]	3.49[c]	3.78[a]

Different letters indicating significant difference at p≤0.01.

al., 1991; Cayuela et al., 1996) and melon (Sivritepe, 2003) showed that salt priming improves seed germination, seedling emergence and growth under saline conditions. Salt priming (3% KNO_3 for 3 days and 1% NaCl for 2 days at 20°C) of cucumber seeds that were harvested 25, 35 and 45 days after anthesis, increased emergence and growth of seedlings. Maximum advantage of priming was observed in seeds harvested at 25 days after flowering and in all cases, KNO_3 priming was more effective than NaCl priming (Ghassemi-Golezani and Esmaeilpour, 2008). Rapeseed yield is very low as compared to its production potential (Taylor et al., 1988). To date, the beneficial effects of salt priming on field performance of rapeseed under water stress are not well understood. Therefore, this research was carried out to investigate the effects of salt priming on seed invigoration, seedling emergence and grain yield of rapeseed cultivars under different irrigation regimes.

MATERIALS AND METHODS

Seeds of three winter rapeseed (*Brassica napus* L.) cultivars including Okapi, Opera and Talayeh (with 4.45, 5.02 and 4.66 g 1000 seed weight, respectively) were obtained from Agricultural Jihad Organization in Eastern Azerbaijan Province, Iran. These seeds were divided into three sub–samples. A sub–sample was kept as control (unprimed) and the two other sub–samples were prepared for priming treatments. Seeds of a sub–sample were soaked in 0.8% NaCl solution with electrical conductivity of 15.3 dsm^{-1} and seeds of another sub–sample were pretreated by 0.8% KNO_3 solution with electrical conductivity of 12.5 dsm^{-1} for 8 h. Priming treatments were performed in an incubator adjusted on 20±1°C under dark conditions. After priming, seeds were washed with tap water for 1 min and then dried back to primary moisture at room temperature of 20 -22°C. All the seeds were treated with Benomyl at a rate of 2 g kg^{-1} before testing. Laboratory tests were carried out as factorial with CR design at Seed Technology Laboratory of the University of Tabriz, Iran. Four replicates of 25 seeds were placed between moist filter papers and germinated in an incubator at 10°C for 10 days. Germination (protrusion of radicle by 2 mm) was recorded in daily intervals. Mean germination time for each treatment was calculated according to Ellis and Roberts (1980). At the end, percentage of normal seedlings and seedling dry weight were determined. The field experiment was conducted in a farm located at the east of Makue (latitude 39° 15°E, longitude 44º 44° N, Altitude 955 m above sea level), Iran. Soil type was sediment loam with an EC of 1.6 dsm^{-1} and a pH of 8.2. The mean annual precipitation and maximum and minimum temperatures in this region were 290 mm, 16.3 and 5.6°C, respectively. Seeds were hand sown in about 1.5 cm depth with a density of 100 seeds m^{-2} on 16 September 2007. Each plot consisted of 8 rows with 3 cm length, spaced 25 cm apart. The experiment was arranged as split plot factorial based on RCB design with three replications, with irrigation regimes (I_1, I_2 and I_3: irrigation after 80, 120 and 160 mm evaporation from class A pan) in main plots and cultivars and salt priming treatments in sub-plots. All plots were irrigated immediately after sowing. Irrigation treatments were applied after seedling establishment. Weeds were controlled by hand weeding during crop growth and development. The number of emerged seedlings in an area of 1 m^2 within each plot was counted in daily intervals until seedling establishment stabilized. Method of Ellis and Roberts (1980) was applied to calculate mean emergence time. At maturity, plants of 1 m^2 in the middle part of each plot were harvested and the number of pods per plant, grains per pod, 1000 grain weight and grain yield per unit area were recorded. Analysis of variance of the data appropriate to the experimental design and comparison of means at p≤0.05 were done using MSATAC software.

RESULTS

Effects of salt priming on germination time and seedling dry weight were significant (P≤0.01), but it has no significant effect on germination percentage (P≥0.05). The seeds primed with KNO_3 germinated earlier than those primed with NaCl and control. Mean germination time for NaCl priming was significantly lower than that for control. Salt primed seeds were also produced larger seedlings, compared with non-primed seeds (Table 1). Germination percentage, germination time and seedling dry weights of winter rapeseed were significantly affected by cultivar (P≤0.01). The highest germination percentage was obtained for Talayeh, which was not significantly different from Okapi. Germination percentage of Opera was significantly lower than that of Talayeh and Okapi. Seeds of Talayeh germinated faster than those of Okapi and Opera. Mean germination time of latter cultivars was

Table 2. Analysis of variance of the effects of irrigation and salt priming on field performance of winter rapeseed cultivars.

		MS					
Source of variation	**d. f**	**Pods per plant**	**Grains per pod**	**Grains per plant**	**1000 grain weight**	**Grain yield per plant**	**Grain yield**
Replication	2	424.92^{ns}	3.77^{ns}	273762.82^{ns}	0.075^{ns}	8.13*	80304.46^{ns}
Irrigation (I)	2	1120.06^{ns}	3.46^{ns}	985956.67^{ns}	0.122^{ns}	1.81^{ns}	793.36^{ns}
Error	4	1328.06	3.27	1005813.84	0.187	0.79	25892.42
Cultivar (C)	2	3415.49*	59.26**	3821614.09**	4.942**	6.93^{ns}	19683.83^{ns}
I × C	4	1169.02^{ns}	3.38^{ns}	819140.48^{ns}	0.079^{ns}	0.79^{ns}	8074.18^{ns}
Salt priming (P)	2	3078.65*	6.28^{ns}	1807146.69*	0.048^{ns}	1.10^{ns}	67181.57*
I × P	4	189.15^{ns}	7.57^{ns}	60070.74^{ns}	0.059^{ns}	5.28^{ns}	28821.24^{ns}
C × P	4	1891.64^{ns}	11.94^{ns}	1637558.10*	0.063^{ns}	4.86^{ns}	13847.79^{ns}
I × C × P	8	502.69^{ns}	9.77^{ns}	462704.30^{ns}	0.059^{ns}	3.31^{ns}	21326.53^{ns}
Error	48	926.54	6.18	668825.46	0.198	5.62	17229.16
C.V%		33.35	10.22	36.49	10.46	35.95	36.14

^{ns},* and * *: No significant and significant at p≤0.05 and p≤0.01, respectively.

statistically similar. The highest and the lowest seedling dry weight were recorded for Opera and Okapi, respectively (Table 1). Priming × cultivar interaction was only significant for seedling dry weight (P≤0.01). Seedling weight of Okapi and Talayeh improved as a result of salt priming. However, priming had no significant effect on seedling dry weight of Opera (Figure 1).

Analysis of variance of the field data showed that seedling emergence percentage was significantly affected by cultivar and salt priming (P≤0.01). The effect of salt priming on emergence time was also significant (P≤0.01), but cultivar had no significant effect on this trait (P□0.05). Cultivar and salt priming significantly influenced the number of pods and grains per plant. The effects of cultivar on grains per pod and 1000 grain weight and the effect of salt priming on grain yield per unit area were also significant (Table 2). In contrast, yield components and grain yields per plant and per unit area were not significantly affected by irrigation. Cultivar had no significant effects on grain yields per plant and per unit area, while salt priming had no significant effects on grains per pod, grain yield per plant and 1000 grain weight. The interaction of salt priming × cultivar was only significant for grains per plant. However, the other interactions of the treatments were not significant for any traits (Table 2). Mean emergence percentage for Talayeh was significantly higher than that for Okapi and Opera, but differences in mean emergence time among cultivars were not statistically significant. The highest emergence percentage and the lowest emergence time were achieved by salt-priming with KNO_3, followed by NaCl priming. Seedlings from non-primed seeds emerged later and were less than those from salt-primed seeds (Table 3). Opera produced the least number of pods per plant and grains per pod and per plant, but the largest grains, compared with other cultivars. Although Okapi had the highest number of pods per plant, the number of grains per pod and plant was statistically similar for Okapi and Talayeh. Mean number of pods per plant, grains per plant and grain yield per unit area increased due to salt priming. The highest improvement in these traits was achieved by KNO_3 priming (Table 3). Salt priming enhanced the number of grains per plant in Okapi and Talayeh, but had no effect on this trait in Opera (Figure 2).

DISCUSSION

Salt-priming improved seed germination and seedling vigor of winter rapeseed cultivars as indicated by rapid germination and high seedling dry weight in the laboratory. The highest improvement in seed germination was achieved by KNO_3 priming (Table 1). According to McDonald (2000), primed seeds can rapidly imbibe and revive the seed metabolism, enhancing germination rate and uniformity. Enhancement in seedling size due to salt priming was more evident in Talayeh, compared with other cultivars (Figure 1). This indicates that rapeseed cultivars respond differently to salt priming. Since Opera with the lowest germination percentage and the highest germination time produced the largest seedlings (Table 1), variation in seedling size of rapeseed cultivars could be also attributed to differences in seed size and genetic constitution. Rapid germination of salt primed seeds led to early and enhanced emergence of rapeseed seedlings in the field. The highest benefit of priming was observed for seeds primed with KNO_3 (Table 3). Therefore, salt priming can ensure satisfactory stand establishment of rapeseed cultivars in the field. Similar effects of salt priming on seedling establishment were reported for lentil (Ghassemi - Golezani et al., 2008a), cucumber

Table 3. Means of field traits for winter rapeseed affected by salt priming and cultivar.

Treatments	Seedling emergence (%)	Emergence time (day)	Pods per plant	Grains per pod	Grains Per plant	1000 grain weight (g)	Grain yield (g/plant)	grain yield (gm^{-2})
Cultivar								
Okapi	52.67^{b}	5.84^{a}	104.21^{a}	25.56^{a}	2667.49^{a}	3.83^{c}	6.918^{a}	343.17^{a}
Opera	51.56^{b}	6.09^{a}	85.68^{b}	22.67^{b}	1955.47^{b}	4.69^{a}	6.854^{a}	352.43^{a}
Talayeh	65.56^{a}	5.70^{a}	83.90^{b}	24.70^{a}	2100.80^{ab}	4.25^{b}	6.011^{a}	393.87^{a}
Priming								
Non-primed	49.78^{b}	6.28^{a}	80.79^{b}	24.11^{a}	1966.10^{b}	4.23^{a}	6.538^{a}	307.8^{b}
NaCl	59.26^{ab}	5.85^{ab}	90.87^{ab}	24.85^{a}	2278.09^{ab}	4.30^{a}	6.426^{a}	376.9^{ab}
KNO_3	60.74^{a}	5.50^{b}	102.14^{a}	23.95^{a}	2479.57^{a}	4.23 ^{a}	6.818^{a}	404.7^{a}

Different letters indicating significant difference at p≤0.05 and p≤0.01.

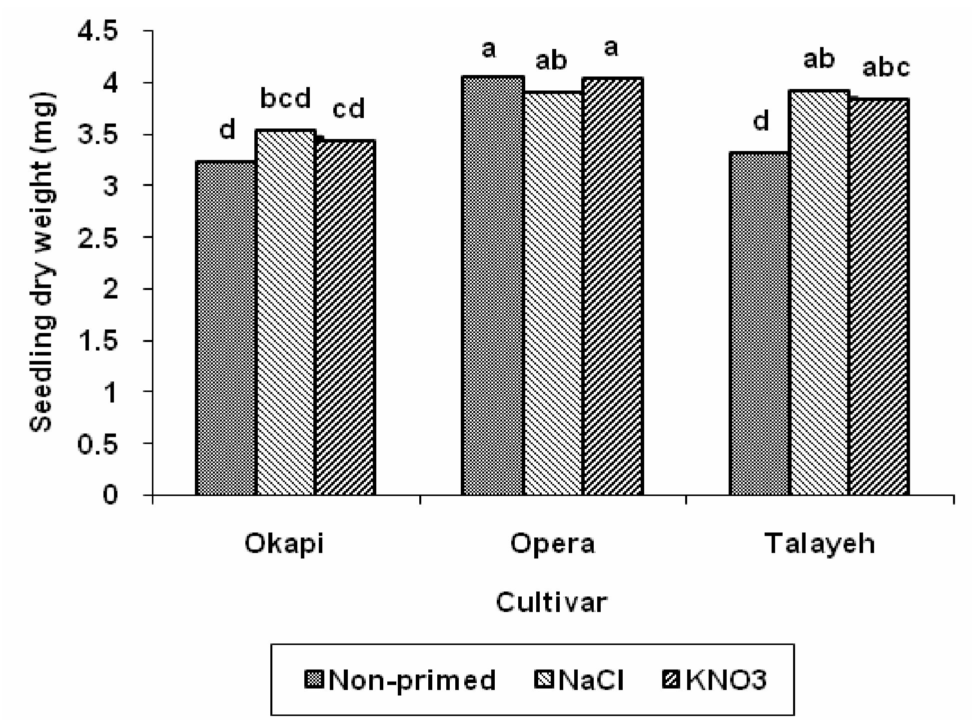

Figure 1. Mean seedling dry weight of winter rapeseed cultivars affected by salt priming in the laboratory. Different letters indicating significant difference at p≤0.01.

(Ghassemi-Golezani and Esmaeilpour, 2008) and sunflower (Hussain et al., 2006).

Variations in seedling emergence time and percentage among rapeseed cultivars (Table 3) are closely associated with differences in initial quality of their seed lots (Table 1). Better germination of Talayeh seeds in the laboratory resulted in the highest seedling establishment of this cultivar in the field, compared with Okapi and Opera. Poor stand establishment of the latter cultivars was largely compensated by production of more, but smaller grains by Okapi and larger grains by Opera. Consequently, grain yield per unit area did not differ significantly among cultivars (Table 3). No significant effect of irrigation treatments on yield and yield components of rapeseed cultivars (Table 2) suggested that this crop can well-tolerate irrigation intervals up to 160 mm evaporation from class A pan. The effects of salt priming on increasing seedling establishment and production of pods and grains per plant led to considerable improvement in grain yield per unit area (Table 3).

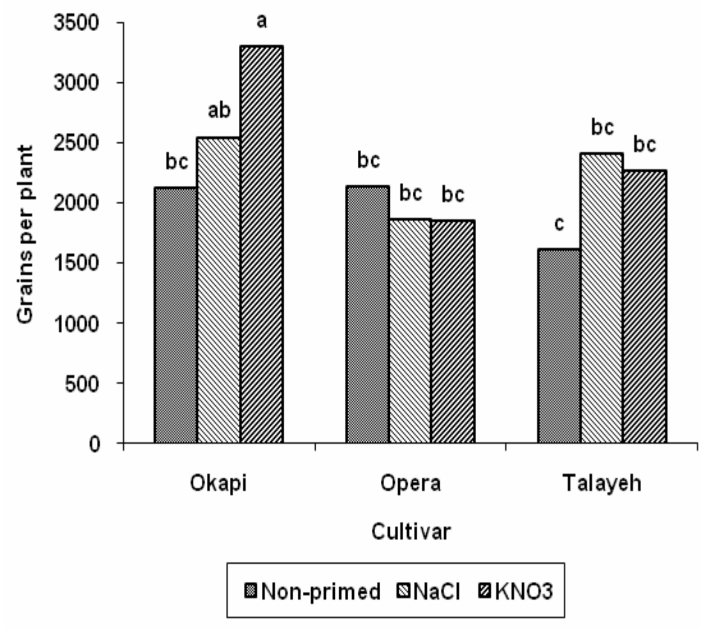

Figure 2. Mean grains per plant of winter rapeseed cultivars affected by salt priming. Different letters indicating significant difference at p≤0.05.

enhancement in number of grains per plant, due to salt priming, was only observed in Okapi and Talayeh (Figure 2). The highest improvement in grain yield per unit area was achieved by KNO3 priming (31.5%), compared with NaCl priming (22.5%). The superiority of KNO_3 priming over NaCl priming was also reported for watermelon (Sachs, 1977; Nerson, et al., 1985; Demir and Van de Venter, 1999; Demir and Ozokat, 2003), muskmelon (Bradford, 1985) and cucumber (Ghassemi-Golezani and Esmaeilpour, 2008). This superiority is related to more nitrogen and potassium accumulation in seeds treated with KNO_3 (Alevarado and Bradford, 1988; Bellti et al., 1993).

Conclusion

Rapeseed cultivars can well-tolerate irrigation intervals up to 160 mm evaporation from class A pan. There are variations among rapeseed cultivars in response to salt priming. Nevertheless, Salt priming generally improves grain yield of rapeseed cultivars through enhancing seed germination rate, seedling emergence rate and percentage, pods per plant and grains per plant. The highest benefit of salt priming can be obtained from seeds primed with KNO_3.

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