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ENHANCEMENT OF TOMATO SEED GERMINATION AND SEEDLING VIGOR BY OSMOPRIMING

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Fresh seeds of tomato cultivars Nagina, Pakit, Riogrande improved and Roma were subjected to osmopriming treatments with an objective to improve germination and seedling vigor by dormancy breakdown. For osmopriming seeds were soaked in –1.1 MPa aerated solution of polyethylene glycol (PEG-8000), NaCl and KNO_3 for 24 h. All the treatments resulted in improved germination and seedling vigor by dormancy breakdown compared with untreated seeds; however, highest vigor was observed in seeds subjected to KNO_3 followed by NaCl. In all the cultivars, all the seed treatments resulted in lower electrical conductivity of seed leachates than untreated seeds being lowest in seeds treated with KNO_3.

Key words: Osmopriming; tomato; electrical conductivity; seedling vigor; germination

Abbreviations: Mean germination time = MGT, Mean emergence time = MET, Speed of germination index = GI, Time taken for 50 % germination = T_{50}, Energy of germination = GE, Final germination percentage = FGP, Final emergence percentage = FEP, Electrical conductivity = EC, Polyethylene glycol = PEG

INTRODUCTION

The tomato is a major vegetable crop that has achieved tremendous popularity over the last century. It is grown practically in every country of the world in outdoor fields, greenhouses and net houses. Aside from being tasty, tomatoes are a very good source of vitamins A and C. Vitamin A is important for bone growth, cell division and differentiation, for helping in the regulation of immune system and maintaining surface linings of eyes, respiratory, urinary and intestinal tracts. Vitamin C is important in forming collagen, a protein that gives structures to bones, cartilage, muscles and blood vessels. It also helps maintain capillaries, bones and teeth and aids in the absorption of iron. Freshly harvested tomato seeds often fail to germinate due to presence of dormancy. Dormancy has also been reported even in one year old seeds. This all has resulted in problems to tomato production all over the world. Controlled hydration of seeds followed by drying (seed priming) is used to break dormancy, speed germination, and improve uniformity of radicle emergence (Liu *et al.*, 1996).

Osmopriming is a special type of seed priming that has been used to invigorate many horticultural (Bradford, 1986; Bray, 1995) and agronomic crops (Basra *et al.*, 2002, 2003, 2005; Farooq *et al.*, 2005). In osmopriming seeds are soaked in aerated low water potential solutions, which allow pre-germinative activities to proceed, followed by redrying before actual germination (Cheng and Bradford, 1999).

Osmotically primed tomato seeds showed improved stand establishment, early seedling growth and yield, seedlings from primed seeds emerged earlier and more uniformly than seedlings from untreated seeds. Seedlings from primed seeds maintained greater mean plant dry weights, leaf areas and ground cover percentages than untreated seedlings throughout the pre-flowering period (Alvardo and Bradford, 1987). In another study, Cayela *et al.* (1996) reported that priming of tomato seed with NaCl induces physiological changes in plants grown under salt stress. They concluded that tomato seedlings from primed seeds emerged earlier than non-primed seeds while shoot and root dry weight reduction was found in primed seeds at different harvest. Jumsoon *et al.* (1996) studied the effect of priming (150 mM KNO_3 at 20°C for 4 days) of tomato seeds under water or saline stress. They concluded that primed seeds had higher percentage germination than unprimed seeds at 15 or 20°C under both water and saline stress.

In another experiment, it was found that salt solution priming of tomato seeds was more beneficial to subsequent germination than PEG solution. Tomato seeds primed in solutions that contained KNO_3 had much shorter time spread of germination than those primed in solutions other than KNO_3 (Haigh and Barlow, 1987). Agerich and Bradford (1989) concluded that priming in salt solution (KH_2PO_4 + KNO_3) did not affect percentage germination of tomato seeds.

Freshly harvested tomato (*Lycopersicon esculentum* Mill. cv. Moneymaker) seeds were osmotically primed for 8 d in -1.0 MPa PEG-6000 solution and dried to about 6% water content for storage. Such so-called 'fresh PEG priming' enhanced seed germination and improved seedling performance as compared with the

untreated control. Fresh PEG priming neither alleviated seed dormancy nor promoted DNA replications as was the case when seeds were dried upon harvest and subsequently primed in PEG (normal PEG priming). However, the addition of 10 mM GA to the osmotic priming solution triggered replicative DNA synthesis of fresh-priming seeds and further enhanced the germination process. After 5 months of storage in ambient temperature conditions, fresh PEG-primed seeds maintained more positive effects gained from priming, whereas, normal PEG-primed seeds had lost the promoting effects on germination. Normal PEG-primed seeds were much more susceptible to controlled deterioration than fresh PEG-primed seeds (Liu *et al.*, 1996).

Priming techniques has been reported to help in dormancy breakdown in many vegetable crops including tomato (Bradford, 1986; Liu *et al.*, 1996; Kester *et al.*, 1997).

The present study was therefore planned to evaluate the impact of osmopriming techniques (if any) on the germination and seedling vigor, and dormancy breakdown of tomato.

MATERIAL AND METHODS

Seed materials

Seeds of tomato cultivars Nagina, Pakit, Riogrande improved and Roma were used as medium of experiment. The seeds were obtained from Vegetable Research Institute, Faisalabad, Pakistan. The initial seed moisture contents were 8.04, 8.17, 8.35 and 8.43% in Nagina, Pakit, Riogrande improved and Roma, respectively on dry weight basis.

Osmopriming

The seeds were primed in the aerated solutions having 16.4 g L^{-1} NaCl, 30 g L^{-1} KNO_3 or 321 g L^{-1} Polyethylene Glycol-8000 (PEG-8000). The osmotic potential of all the solutions was –1.25 MPa. Seeds were soaked in the respective solution for 24 h. The ratio of seed weight to solution volume was 1:5 (g mL^{-1}) (Ruan *et al.*, 2002).

Post priming operations

After priming for prescribed duration, seeds were given three surface washings with distilled water (Khan, 1992) and redried to original weight with forced air under shade (Basra *et al.*, 2002). These seeds were then sealed in polythene bags and stored in refrigerator for further use.

Germination test

Seeds (15 in each) were sown in petri dishes between the layers of moist whatman 45 at 25°C in an incubator and were replicated four times. Germination was observed daily according to the AOSA method (AOSA, 1990). The time to get 50% germination (T_{50}) was calculated according to the following formulae of Coolbear *et al.* (1984) modified by Farooq *et al.* (2005):

$$T_{50} = t_i + \frac{\left(\frac{N}{2} - n_i\right)(t_j - t_i)}{n_j - n_i}$$

Where N is the final number of germination and n_i , n_j cumulative number of seeds germinated by adjacent counts at times t_i and t_j when $n_i < N/2 < n_j$.

Mean germination time (MGT) was calculated according to the equation of Ellis and Roberts (1981):

$$MGT = \frac{\sum Dn}{\sum n}$$

Where n is the number of seeds, which were germinated on day D, and D is the number of days counted from the beginning of germination.

Germination index (GI) was calculated as described in the Association of Official Seed Analysts (1983) as the following formulae:

$$GI = \frac{\text{No. of germinated seeds}}{\text{Days of first count}} + - - - - + \frac{\text{No. of germinated seeds}}{\text{Days of final count}}$$

Energy of germination was recorded 4th day after planting. It is the percentage of germinating seeds 4 days after planting relative to the total number of seeds tested (Ruan *et al.*, 2002).

Seedling Emergence

Control and treated seeds were sown in plastic pots (30 in each) having moist sand, replicated four times and were placed in net house. Mean daily temperature was 30°C during the course of investigation. Emergence was recorded daily according to the seedling evaluation Handbook of Association of Official Seed Analysts (1990). Mean emergence time was calculated according to the method described earlier.

Electrical conductivity of seed leachates

Seeds (5 g) were soaked in 50 mL distilled water at 25°C. Electrical conductivity of steep water was measured 0.5, 1.0, 1.5, 2.0, 6.0, 12.0 and 24.0 h after soaking using conductivity meter (Model Twin Cod B-173) and expressed as µS cm^{-1} g^{-1} (Basra *et al.*, 2005).

RESULTS

Osmopriming treatments significantly ($P < 0.05$) affected the germination vigor of all the tomato cultivars (Table 1). The response of all the cultivars to the osmopriming treatments was similar (Table 1). All the seed treatments resulted in lower T_{50} and MGT and, higher FGP, GI, GE, radicle and plumule length compared with untreated seeds (Table 1). In all the cultivars lowest T_{50} was noted in seeds osmoprimed with KNO_3 that was followed by NaCl in Nagina and Pakit and PEG in Riogrande improved and Roma (Table 1). Minimum MGT was noted in seeds subjected to KNO_3 in all the cultivars (Table 1). Maximum FGP, GI, GE, radicle and plumule length was noted in seeds osmoprimed with KNO_3 in all the cultivars (Table 1).

Significant effect ($P < 0.05$) of osmopriming treatments on the seedling vigor of all the tomato cultivars was observed (Table 2).

All the seed treatments resulted in lower MET compared with control except PEG in Riogrande improved, Nagina and Roma, which behaved similar to that of untreated seeds (Table 2). In all the cultivars, all the seed treatments resulted in higher FEP, root and shoot length, and seedling dry weight compared with control (Table 2). Tomato seeds subjected to KNO_3 osmopriming resulted in highest FEP, root and shoot length, and seedling dry weight compared with all other treatments including control. However, none of the priming treatments resulted in improved seedling fresh weight than that of control (Table 2).

In all the tomato cultivars under study, highest EC of seed leachates was noted in untreated seeds followed by PEG priming (Fig. 1). Electrical conductivity of seed leachates from seeds treated with PEG was similar to that of NaCl in Nagina and Pakit (Fig. 1a, 1b). Minimum EC of seed leachates in all the cultivars was recorded in seeds treated with KNO_3 that was similar to that of NaCl in Riogrande improved and Roma (Fig. 1c, 1d).

Table 1. Effect of osmopriming on the germination ability of tomato cultivars.

Treatments		T_{50} (days)	MGT (days)	FGP (%)	GI	GE (%)	Radicle length (mm)	Plumule length (mm)
Nagina	Control	5.50 a	6.90 a	45.33 c	15.50 d	14.25 d	35.90 c	33.76 c
	Osmopriming (PEG)	4.47 b	5.18 b	66.67 b	22.50 c	24.57 c	45.50 b	41.73 b
	Osmopriming (NaCl)	3.97 c	5.23 b	70.00 b	25.50 b	35.45 b	59.41 a	44.54 b
	Osmopriming (KNO_3)	2.27 d	4.60 c	83.33 a	31.00 a	45.28 a	62.34 a	51.66 a
	LSD at 0.05	0.204	0.188	12.36	2.33	8.23	4.24	6.06
Pakit	Control	5.87 a	6.92 a	45.33 c	15.50 d	16.05 d	38.90 d	33.76 c
	Osmopriming (PEG)	3.53 b	5.21 b	76.67 b	22.50 c	24.57 c	47.50 c	43.73 b
	Osmopriming (NaCl)	3.06 c	5.23 b	72.00 b	25.55 b	35.15 b	54.41 b	44.54 b
	Osmopriming (KNO_3)	2.27 d	4.56 c	83.33 a	31.20 a	45.28 a	63.34 a	55.66 a
	LSD at 0.05	0.211	0.178	10.26	2.13	7.13	4.04	5.06
Riogrande improved	Control	5.50 a	6.30 a	45.33 c	16.50 c	16.65 d	37.90 d	34.76 c
	Osmopriming (PEG)	3.07 c	5.17 b	65.67 b	24.50 b	24.57 c	43.50 c	42.73 b
	Osmopriming (NaCl)	3.77 b	5.13 b	74.00 a	25.50 b	37.45 b	55.41 b	47.54 b
	Osmopriming (KNO_3)	2.17 d	4.10 c	83.33 a	32.00 a	46.28 a	64.34 a	58.66 a
	LSD at 0.05	0.221	0.148	12.36	2.43	8.03	4.24	7.06
Roma	Control	5.15 a	6.70 a	48.33 c	16.50 d	15.25 c	33.90 c	30.76 c
	Osmopriming (PEG)	3.57 c	5.01 c	64.67 b	23.50 c	25.57 b	44.50 b	42.73 b
	Osmopriming (NaCl)	3.87 b	5.23 b	72.00 a	27.50 b	37.45 a	50.11 a	45.54 b
	Osmopriming (KNO_3)	2.87 d	4.60 d	78.33 a	33.00 a	44.08 a	54.34 a	53.66 a
	LSD at 0.05	0.254	0.188	11.36	2.33	9.13	4.24	5.06

Figures not sharing the same letters in a column differ significantly at p 00.05

DISCUSSION

Osmopriming had significant effect on the germination, seedling vigor and electrical conductivity of seed leachates in tomato cultivars used in the present investigation (Tables 1, 2; Fig. 1). Response of all tomato cultivars to different osmopriming treatments was similar (Tables 1, 2; Fig. 1).

Table 2. Effect of osmopriming on the seedling vigor of tomato cultivars.

Treatments		MET (days)	FEP (%)	Root length (cm)	Shoot length (cm)	Seedling fresh weight (mg)	Seedling dry weight (mg)
Nagina	Control	7.51 a	31.41 d	45.05 d	34.88 d	1.45 a	21.29 d
	Osmopriming (PEG)	7.13 a	44.03 c	52.45 c	47.77 c	1.09 b	26.77 c
	Osmopriming (NaCl)	5.11 b	66.19 b	62.52 b	59.29 b	1.07 b	30.03 b
	Osmopriming (KNO_3)	4.05 c	74.97 a	74.17 a	74.75 a	1.02 b	34.05 a
	LSD at 0.05	0.515	5.342	6.212	5.326	0.201	0.712
Pakit	Control	7.61 a	35.41 c	45.05 d	30.88 d	1.35 a	19.29 d
	Osmopriming (PEG)	6.33 b	58.03 b	52.45 c	49.77 c	1.03 b	27.77 c
	Osmopriming (NaCl)	5.65 c	60.19 b	61.52 b	67.29 b	1.04 b	29.03 b
	Osmopriming (KNO_3)	4.95 d	72.97 a	74.87 a	74.75 a	1.07 b	31.05 a
	LSD at 0.05	0.475	4.342	6.152	5.126	0.234	0.714
Riogrande improved	Control	7.51 a	31.41 d	45.05 d	30.88 d	1.47 a	20.29 d
	Osmopriming (PEG)	7.33 a	54.03 c	54.45 c	49.77 c	1.19 b	27.77 c
	Osmopriming (NaCl)	5.15 b	62.19 b	64.52 b	69.29 b	1.17 b	30.03 b
	Osmopriming (KNO_3)	4.55 c	74.97 a	77.87 a	76.75 a	1.12 b	36.05 a
	LSD at 0.05	0.595	4.342	6.112	5.126	0.221	0.712
Roma	Control	7.91 a	43.41 d	43.05 d	34.88 d	1.49 a	21.29 d
	Osmopriming (PEG)	7.13 a	54.03 c	54.45 c	49.77 c	1.13 b	27.77 c
	Osmopriming (NaCl)	5.45 b	62.19 b	62.52 b	64.29 b	1.02 b	30.03 b
	Osmopriming (KNO_3)	4.75 c	74.97 a	76.87 a	73.75 a	1.12 b	37.05 a
	LSD at 0.05	0.575	4.232	6.112	5.126	0.213	0.714

Figures not sharing the same letters in a column differ significantly at p 00.05

Earlier and synchronized germination and emergence was observed in the treated seeds compared with that of control as depicted by lower MET, T_{50} and MGT, and higher GI, GE, FEP, FGP in treated seeds compared with untreated ones (Tables 1, 2), which is primarily attributed to dormancy breakdown as fresh seeds were used and dormancy has been reported in freshly harvested tomato seeds (Liu *et al.,* 1996). Higher radicle and plumule length, root and shoot length as well as seedling dry weight as observed in treated seeds might be the result of earlier germination and emergence (Tables 1, 2). Osmopriming has been found to improve germination rate and speed in tomato especially when freshly harvested seeds are used (Liu *et al.,* 1996). Osmotically primed tomato seeds showed improved stand establishment, early seedling growth and yield, seedlings from primed seeds emerged earlier and more uniformly than seedlings from untreated seeds (Alvardo *et al.,* 1987). Enhanced seed germination and improved seedling performance has also been recorded in freshly harvested tomato seeds compared with the untreated control (Liu *et al.,* 1996). KNO_3 primed jalapeno pepper seeds resulted in significantly earlier germination and accelerated vegetative seedling development but priming in PEG appeared to retard jalapeno vegetative seedling development (Rivas *et al.*, 1984). The earlier and better synchronized germination is associated with increased metabolic activities in the osmoprimed seeds (Alvardo *et al.,* 1987; Liu *et al.,* 1996). Faster emergence rate after osmopriming may be explained by an increased rate of cell division in the root tips as previously found for wheat (Bose and Mishra, 1992). In earlier studies, it was observed that seedlings from primed tomato seeds maintained greater mean plant dry weights, leaf areas and ground cover percentages than untreated seedlings throughout the pre-flowering period (Alvardo *et al.,* 1987). Highest invigoration was observed in seeds subjected to KNO_3 which is in support to the earlier findings of Alvardo *et al* (1987) and Liu *et al* (1996) who reported better performance of KNO_3 priming than PEG priming in tomato. The beneficial aspects of priming are primarily due to pre-enlargement of the embryo (Khan, 1992), and improvement of germination rate (Gray and Steckle, 1977).

Highest EC of seed leachates was recorded in untreated seeds. All the seed treatments resulted in lower EC of seed leachates. (Fig. 1) that might be the result of membrane repair during the hydration process as earlier reported by Rudrapal and Nakamura (1998) in radish and eggplant, Pen aloza and Eira (1993) in tomato and Basra *et al.,* (2003) in fine rice.

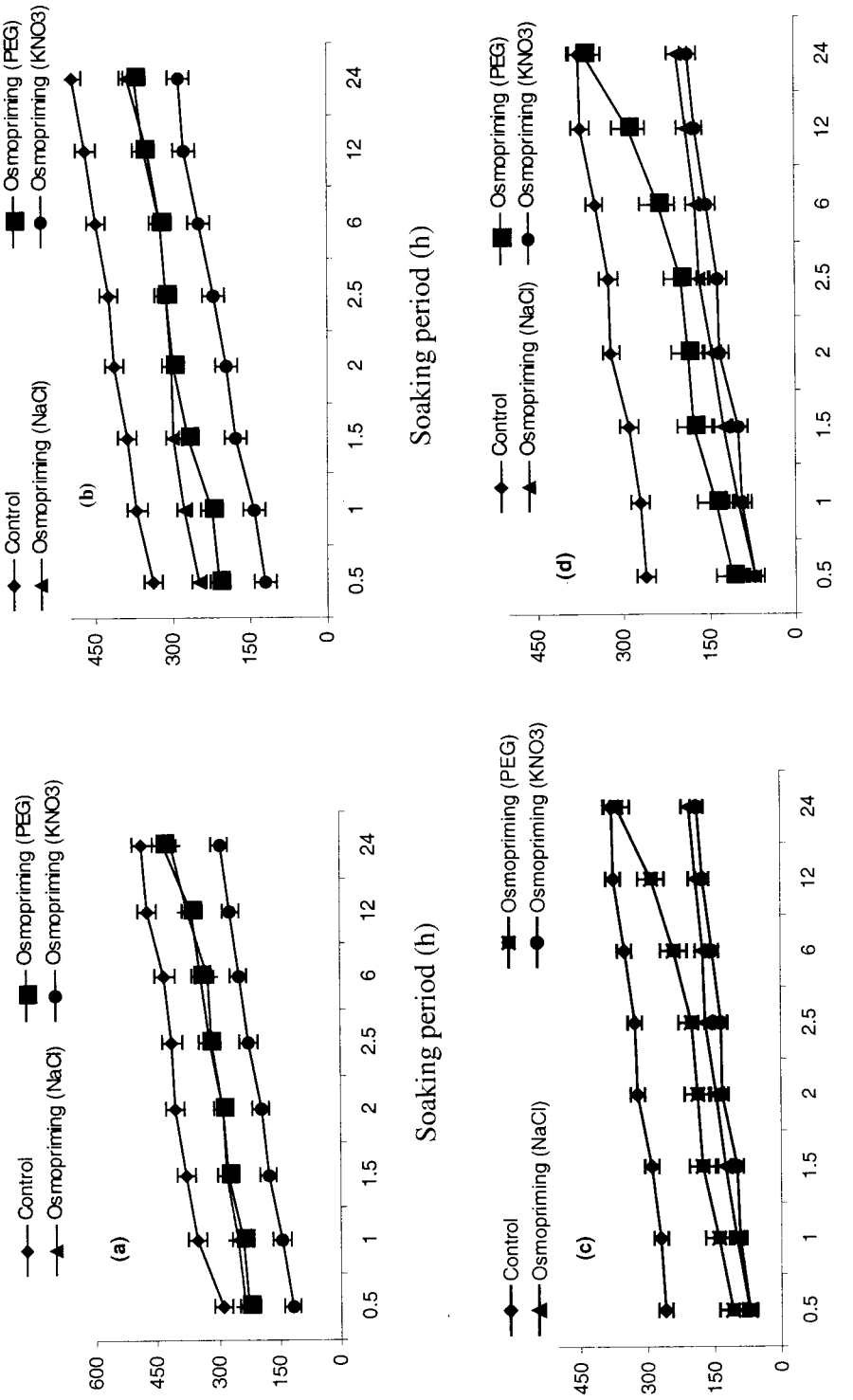

Fig. 1. Effect of osmopriming treatments on the electrical conductivity of seed leachates ($\mu S\ cm^{-1}\ g^{-1}$) of tomato cv. (a) Nagina (b) Pakit (c) Riogrande improved (d) Roma

From the present investigation it may be concluded that germination and seedling vigor can be enhanced by osmopriming treatments in different tomato cultivars by dormancy breakdown. However salt priming was more effective that PEG priming.

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