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Effects of Seed Priming with PEG or K_3PO_4 on Germination and Seedling Growth in Lettuce

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Abstract: This study was conducted to improve late and unsynchronized germination and emergence under stressful conditions such as thermo-dormancy in lettuce seeds. Thermo-dormancy becomes especially important when the production is based on direct seeding. Lettuce seeds were treated with PEG-6000 (-5.1 bar) or K_3PO_4 (1%) both at 15°C either in an aerated bubble-column (BC) or in petri dishes. Standard germination and emergence tests (at 20°C), emergence under stressful conditions (at 15 and 35°C), emergence in the nurseries and in the direct seeded field have all been conducted with treated seeds in comparison with the non-treated control seeds. K_3PO_4 applied in BC was the most efficient method in improving germination and emergence in all tests. Emergence rate ($E_{\%}$) at 20°C was considerably improved (91%) and mean emergence time (E_{50}) reduced (2.74 days) by this treatment, which was 84.2% and 3.63 days in the control seeds, respectively. $E_{\%}$ at 15°C reached 90%, while remaining 71% in the control. E_{50} was also improved by 1.93 days. The most notable results were obtained in $E_{\%}$ at 35°C, which was 64.5% in the treated seeds, while being 1.25% in the control seeds. $E_{\%}$ was not affected in the field trials by this treatment, while E_{50} reduced to 6.32 days, while remaining at 11.27 days in the control. Total yield was also increased from 17.50 kg/parcel to 19.29 kg/parcel.

Key words: Lettuce, pre-sowing seed treatments, emergence, yield

INTRODUCTION

Lettuce production in Turkey is essentially based on the production through seedlings. Seeds are sown to the nurseries during July and August and transplanted to the open field when ready. This type of production, however, requires an additional step of seedling production phase in the nursery and hence, additional costs. However, production costs can be lowered when direct seeding is combined with proper soil preparation (Vural *et al*., 2000), which is not a general practice in lettuce in Turkey so far. Thermo-dormancy is one of the most important reasons for low germination and emergence rate at high soil temperatures, which can reach up to 35°C during this period (Cantliffe *et al*., 1981). Low emergence further results in non-uniform plant development (Spurr *et al*., 2002). These adverse effects become especially important when the production is based on direct seeding, where there is no chance to eliminate less developed seedlings as it is the case in the nurseries (Cantliffe *et al*., 1987; Demir *et al*., 1999; Parera and Cantliffe, 1992).

Osmotic adjustment or priming of seeds prior to sowing is known as an efficient way to increase germination and emergence rate in some species with e.g., small embryo or species with stepwise seed development (Sivritepe, 2000; Duman *et al*., 1995; Brocklehurst *et al*., 1987). Besides the efficiency of each solution a comparative view regarding various aspects of seed treatments such as time, level and type of treatment is also being severally reported (Brocklehurst and Dearman, 1987; Brocklehurst *et al*., 1987; Bujalski *et al*., 1990; Duman and Esiyok, 1998; Seale *et al*., 1994). Orzeszko and Podlaski (2003) reported that germination rate in sugar beet seeds can be similarly improved by rubbing or washing the seeds as compared to priming alone.

Harris *et al*. (2001) collaborated with farmers in a participatory programme in priming wheat seeds, which highlights it's simplicity when scientific results are practically and commercially extended and it's applicability in developing countries such as Turkey. Priming overnight prior to sowing resulted in faster, more complete emergence, more vigorous early growth, better tillering, earlier flowering, larger ears, earlier maturity and higher yields.

In addition, many farmers also reported that foliage in primed plots was a darker shade of green than that in non-primed plots, suggesting that primed plants may have been using nitrogen more efficiently.

The efficiency of seed priming for better germination and emergence is already severally reported in many vegetable, cereal and ornamental species (Cantliffe *et al*., 1987; Harris *et al*., 2001; Finnerty *et al*., 1992). However, an important lack in the literature appears when seed priming is used in direct seeded plants. Hence, studies do not concentrate on seedling emergence and the changes in yield and quality traits in the open field. This study was conducted to minimize the adverse effects of thermo-dormancy and stressful conditions to which the lettuce seeds are being subjected during the sowing period. The effects of the treatments to mean emergence time and rate and on final yield in both nursery seedlings and direct sown lettuce have been investigated.

The results on primed lettuce seeds are expected to be useful in direct seeded lettuce production. It will also allow a comparison of direct seeding and seedling production in primed seeds, as well as their *per se* production costs. Additionally, the efficiencies of bubble-column and petri dish will also be compared.

MATERIALS AND METHODS

Experiments were conducted in the laboratories and fields of the Ege University, Faculty of Agriculture, Department of Horticulture, Izmir Province, latitude 38°28′ N, longitude 27°15′ E, altitude 25 m between March 2004 and May 2005. The seeds of the cv.'s Yedikule (Cos type) and Kıvırcık (Bunching type) lettuce cultivars were treated either with PEG-6000 (190 g L; -5.1 bar) or K_3PO_4 (% 1) (Bradford, 1986; Parera and Cantliffe, 1994; Duman *et al*., 1995). Treatments were made either in petri dishes or in aerated bubble column (BC). PEG application was made for 6 days, while K_3PO_4 application was made for 3 days at a constant of 15°C. Ten gram of seeds were used between two layers of filter paper in 100 cc solution in petri dishes with 15 cm diameter. The same amount of seeds was used in 250 cc solution in BC treatment with 2.5 mL min^{-1} humid air flow (Bujalski and Nienow, 1991; Parera and Cantliffe, 1994). At the end of the treatments the seeds were dried to their original weight and germination, emergence, emergence under stress (at 15°C and 35°C), emergence in the field and seed nurseries were all performed according to the ISTA rules in both treated and untreated control seeds (Cantliffe *et al*., 1981; Parera and Cantliffe, 1994; ISTA., 1999).

Seeds were sown to the seed nurseries and to the field on 1 August, while the seedlings were transplanted to the field on 5 September to 3.5 m^2 plots. The seedling were planted at 35×20 cm distances, while in direct seeding seeds were sown at 2-3 cm intervals to the rows (35 cm between row distance) and thinned to 20 cm within row distance thereafter. Each plot consisted of 50 plants. Average head weight, leaf number, early and total yield as number of heads/parcel and kg/parcel were all determined in the plots. Cultural practices and harvest in plants obtained by either seedlings or by direct seeding were done after Vural *et al*. (2000). The experimental design was a completely randomized block design with three replications. Germination rate ($G_{\%}$), emergence rate ($E_{\%}$), mean emergence time (E_{50}) and coefficients of uniformity of emergence (CUE) were all calculated form the collected data (Spurr *et al*., 2002). Statistical analyses were done using SPSS version 7.5 and significant groups were separated according to Duncan's multiple range test.

RESULTS

Germination and emergence: Treatments to improve germination and emergence in lettuce had little or no effect at the basis of cultivars (data not shown). In the standard emergence test at 20°C the treatments had statistically significant effects on $E_{\%}$ at $p \leq 0.05$ level and E_{50} and CUE at $p \leq 0.01$ level. The K_3PO_4-BC treatment was the most efficient treatment with 91% $E_{\%}$ and 2.74 E_{50}, which was 71% $E_{\%}$ and 6.98 E_{50}, in the control seeds respectively. The same treatment had the most uniform germination with 0.486 CUE, which remained 0.121 in the control (Table 1).

A similar effect to the standard tests was obtained under stress conditions at low temperatures (15°C). Depending on the treatments, statistically significant differences were detected in $G_{\%}$, E_{50} and CUE at $p \leq 0.01$ significance level. K_3PO_4-BC was again the most effective treatment with 90% $E_{\%}$, 5.05 days E_{50} and 0.379 CUE while control seeds had 84.25% $E_{\%}$, 3.63 days E_{50} and 0.179 CUE (Table 1). The effect of this treatment to E_{50} at 15°C is presented in Fig. 1. K_3PO_4-BC treatment decreased E_{50} in both cultivars. K_3PO_4-BC treatment resulted in E_{50}'s of 4 and 5 days in the cv.'s Kıvırcık and Yedikule, respectively, while this was approxinately. Seven days in the control seeds.

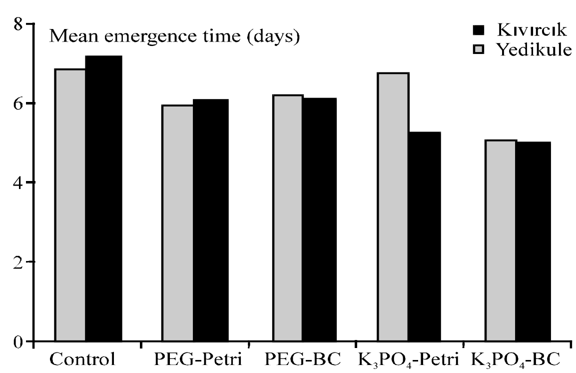

Fig. 1: The effects of the treatments on average emergence time (E_{50}) at 15°C in both lettuce cultivars

Table 1: The effects of the treatments on $E_{\%}$, E_{50} and CUE at various temperatures and field conditions in lettuce seeds

	15°C			20°C (standard)			Field conditions			35°C
Treatment	$E_{\%}$	E_{50} (days)	CUE	$E_{\%}$	E_{50} (days)	CUE	$E_{\%}$	E_{50} (days)	CUE	$E_{\%}$
Control	71.00c[x]	6.98c	0.121c	84.25c	3.63d	0.179d	82.50	11.27e	0.047cd	1.25c
PEG-Petri	82.75b	6.05b	0.347a	88.50ab	3.11bc	0.212c	86.60	8.85d	0.051c	13.50b
PEG-BC	86.00ab	6.12b	0.189b	90.50a	2.84ab	0.388b	89.90	7.89c	0.061bc	55.25a
K_3PO_4Petri	80.75b	6.09b	0.146bc	86.25bc	3.28cd	0.345b	87.40	7.18b	0.095ab	15.00b
K_3PO_4-BC	90.00a	5.05a	0.379a	91.00a	2.74a	0.486a	89.60	6.32a	0.119a	64.50a
Average	82.10**	6.05**	0.236**	88.10*	3.12**	0.322**	87.20ns	8.30**	0.074*	29.90**

x = duncan's multiple range test, Significant at $p \leq 0.01$ level (**), at $p = 0.05$ level (*) and none significant (ns)

Table 2: The effects of the treatments to head weight (g) at the basis of the cultivars and the growing method (direct sowing and production through seedlings)

		Treatment					
Cultivar	Growing method	PEG-Petri	PEG-BC	K_3PO_4-Petri	K_3PO_4-BC	Control	Average
Yedikule	Direct Seeding	678.73	687.57	687.43	706.23	555.40	663.07
(Cos type)	By Seedlings	667.93	672.37	670.67	695.70	677.87	676.91
	Average	673.33	679.97	679.05	700.97	616.63	669.99
Kıvırcık	Direct Seeding	367.47	383.27	369.90	408.30	353.87	376.56
(Bunching type)	By Seedlings	363.87	365.13	352.43	392.57	357.53	366.31
	Average	365.67	374.20	361.17	400.43	355.70	371.43
	General mean	519.5b[x]	527.08b	520.11b	550.70a	486.17c	520.71**

x = Duncan's multiple range test. **: Significant at p =0.01 level

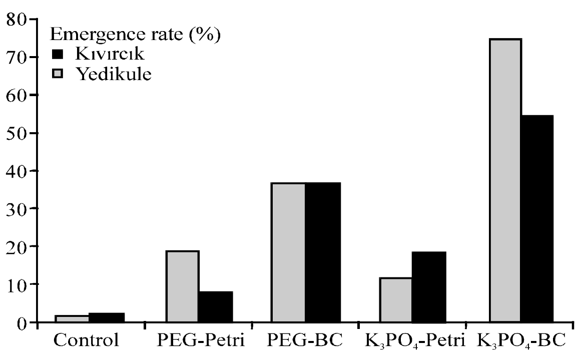

Fig. 2: The effects of the treatments on emergence rate ($E_{\%}$) at 35°C in both lettuce cultivars

In the experiments carried out under high temperature stress (at 35°C) treatments significantly effected emergence rate at $p \leq 0.01$ significance level (Table 1). Especially BC treatments showed a considerable improvement in $E_{\%}$. $E_{\%}$ was 55.25% in PEG-BC treatment and 64.5% in K_3PO_4-BC treatment, which was around 13-15% in petri treatments and was the lowest in the untreated control seeds. Interactions between cultivars and treatments were statistically not significant for $E_{\%}$ (data not presented). However, there were statistically significant differences at the basis of cultivars, where $E_{\%}$ values of cv. Kıvırcık and cv. Yedikule were 50 and 23%, respectively.

Both BC treatments were efficient in improving $E_{\%}$ depending on the cultivar used. PEG-BC improved $E_{\%}$ in cv. Kıvırcık (approx. 70%), while K_3PO_4-BC improved $E_{\%}$ in cv. Yedikule (approx. 65%), as compared to petri treatments where $E_{\%}$ was 10 and 15% for Yedikule and Kıvırcık, respectively (Fig. 2). Due to low $E_{\%}$ values obtained in the case of the untreated control seeds and the treatments in petri dishes extremely low values were obtained for E_{50} and CUE, which data are not presented here.

In the experiments at the nurseries, the effects of treatments to $E_{\%}$, E_{50} and CUE were statistically not significant (data not shown).

In direct seeding BC treatments were not effective in increasing $E_{\%}$, while the effects of the treatments to E_{50} and CUE were statistically significant at $p \leq 0.01$ and $p \leq 0.05$ level, respectively.

In K_3PO_4-BC treated seeds could reached E_{50} within 6.32 days, while this was extended to 11.27 days in the control seeds. The same treatment had the most uniform germination with 0.119 CUE, while emergence was less uniform in the control seeds (CUE = 0.047).

Yield and quality: The effect of the treatments to average head weight was found significant at $p \leq 0.01$ level (Table 2). Regardless of the effects of treatments, cv. Yedikule produced larger heads (669 g/head) then cv. Kıvırcık (371 g/head). K_3PO_4-BC was the most effective treatment in increasing head weight in both cultivars in direct seeded parcels. The control plants of the cv. Yedikule produced heads of 555 g, which was increased to 706 g by K_3PO_4-BC treatment. Similarly the head weight of the cv. Kıvırcık was also increased from 353 g (control), to 408 g. This is an increase of 27.2 and 15.6% for the cv.'s Yedikule and Kıvırcık, respectively. The same treatments remained quite ineffective when the production was done through seedlings. The effect of the treatments to average leaf number per head is presented in Table 3.

Table 3: The effects of the treatments to average leaf number/head at the basis of the cultivars and the growing methods (direct sowing and production through seedlings)

Cultivar	Growing Method	Treatment PEG-Petri	PEG-BC	K_3PO_4-Petri	K_3PO_4-BC	Control	Average
Yedikule	Direct seeding	46.07	49.80	44.20	52.43	41.23	46.75
(Cos type)	By seedlings	46.53	52.57	50.33	50.77	47.97	49.63
	Average	46.30	51.18	47.27	51.60	44.60	48.19
Kıvırcık	Direct seeding	38.33	38.10	37.43	41.37	31.07	37.26
(Bunching type)	By seedlings	37.87	38.13	36.83	38.60	36.47	37.58
Yedikule	Average	38.10	38.12	37.13	39.98	33.77	37.42
	General mean	42.20c[x]	44.65b	42.20c	45.79a	39.18d	42.81**

x = Duncan's multiple range test. **: Significant at $p \leq 0.01$ level

Table 4: The effects of the treatments to early yield (%) at the basis of the cultivars and the growing methods (direct sowing and production through seedlings)

Cultivar	Growing method	Treatment PEG-Petri	PEG-BC	K_3PO_4-Petri	K_3PO_4BC	Control	Average
Yedikule	Direct seeding	65.17	68.87	62.20	77.07	56.67	65.99
(Cos type)	By seedling	54.13	56.90	60.03	61.27	57.57	57.98
	Average	59.65	62.88	61.12	69.17	57.12	61.99
Kıvırcık	Direct seeding	71.37	74.47	70.40	81.37	70.63	73.65
(Bunching type)	By seedling	69.23	71.47	69.77	70.97	67.87	69.86
	Average	70.30	72.97	70.08	76.17	69.25	71.75
	General mean	64.98 bc[x]	67.93 b	65.60 bc	72.67 a	63.18 d	66.87 **

x = Duncan's multiple range test. **: Significant at $p \leq 0.01$ level

Table 5: The effects of treatments on total yield for both cultivars in both growing methods (kg/parcel)

Cultivar	Growing Method	Treatment PEG-Petri	PEG-BC	K_3PO_4-Petri	K_3PO_4-BC	Control	Average
Yedikule	Direct seeding	20.63	20.43	19.47	21.90	18.40	20.17
(Cos type)	By seedling	19.20	18.93	19.13	21.23	19.00	19.50
	Average	19.92	19.68	19.30	21.57	18.70	19.83
Kıvırcık	Direct seeding	14.77	16.47	14.07	17.63	17.10	16.01
(Bunching type)	By seeding	14.57	16.93	15.40	16.40	15.50	15.76
	Average	14.67	16.70	14.73	17.02	16.30	15.88
	General mean	17.29b[x]	18.19ab	17.02b	19.29a	17.50b	17.86*

x = Duncan's multiple range test. *: Significant at $p \leq 0.05$ level

The treatments were more effective in direct seeded plants rather than in plants produced by seedlings. The cv. Yedikule had 41 leafs per head in the control seedlings and the cv. Kıvırcık 31, which was increased by K_3PO_4-BC treatments to 52 and 41, respectively. PEG-BC treatments formed statistically the second group, while petri treatments formed the third group after the control. Early yield explains the proportion of the first yield within the total yield. The treatments had a significant effect on early yield in direct seeded plots (Table 4).

Early yield was increased by K_3PO_4-BC treatments from 56 to 77% in cv. Yedikule and from 70 to 81% in cv. Kıvırcık. PEG-BC also resulted in an increase in early yield of Yedikule and Kıvırcık to 68 and 74%, respectively. The results on the total head yield (kg/parcel) are presented in Table 5. Total head weight per parcel was higher in direct seeded parcels in both cultivars when compared to parcels produced through seedlings. K_3PO_4 and PEG-BC treatments were the most effective treatments in increasing total head yield in both cultivars to an average of 19.3 and 18.2 kg/parcel, respectively, as compared to the control parcels with average 17.5 kg/parcel yield.

DISCUSSION

Results obtained here are in accordance with similar researchers, which aimed to improve emergence under field and stress conditions. Pre-sowing seed treatments have severally been reported to be effective in improving emergence in vegetable crops. Emergence time or emergence rate have been reported to be improved in lettuce seeds treated either in bubble column (Cantliffe *et al.*, 1987; Cantliffe, 1991; Seale *et al.*, 1994) or in petri dishes (Duman *et al.*, 1995). Brocklehurst *et al.* (1987) reported similar results with a number of other vegetable crops such as celery, leek, onion, carrot and tomatoes treated in petri dishes. Similar to these results, Nascimento and West (1999) tested germination of muskmelon seeds under laboratory conditions, where primed seeds germinated earlier than nonprimed seeds at 17°C, a similar temperature as under stressful conditions provided in this study. However, the authors further reported that priming caused no beneficial effect on shoot and root development neither in laboratory conditions nor during transplant production in the greenhouse.

Hardening and solid matrix priming (SMP) were used by Podlaski *et al.* (2003), where seed pre-sowing treatments increased percentage, speed and synchrony of seedling emergence as was the case in this study. Contradictory results, where seed priming was of no effectiveness were also reported by Mwale *et al.* (2003) and Giri and Schillinger (2003). In the case of Mwale *et al.* (2003), seed priming of the parental lines of sunflower has helped to improve field emergence and establishment of the male lines but had no influence on growth and flowering date of the crop. Consequently, seed priming in sunflower may not be a solution to the present obstacle of lack of good flowering synchronization in hybrid seed production at least in Zambia. Similarly Giri and Schillinger (2003) reported that seed priming has limited practical worth for enhancing emergence and yield of winter wheat since none of the seed priming media favored field emergence or subsequent grain yield in either cultivar compared with checks.

Germination and emergence in stressful environmental conditions have been investigated in high temperatures in lettuce (Guedes and Cantliffe, 1980), leek (Parera and Cantliffe, 1992) and pepper (Demir *et al.*, 1999); and in high and low temperatures in watermelon (Demir and Van De Venter, 1999). Sivritepe (2000) additionally tested onion seeds under salinity conditions, where it turned out that 1% NaCl treatment resulted in an increase in the tolerance of onion seeds against salinity stress. Hardegree and Van Vactor (2000) further reported that seed priming may enhance establishment success of cool-season range grasses. Similarly, Orzeszko and Podlaski (2003) reported that primed seeds were most resistant to different moisture conditions during germination. According, the success of K_3PO_4-BC treatments would make earlier plantings possible in lettuce seeds since the adverse effects of stressful conditions (15°C) are eliminated by this treatments.

Similar results have been reported by various authors that pre-sowing seed treatments not only affect germination rate and mean germination time but also early and final yield. This is true especially in direct seeded lettuce (Guedes and Cantliffe, 1980; Seale *et al.*, 1994), carrot (Duman and Eoiyok, 1998) and leek (Parera and Cantliffe, 1992). Podlaski *et al.* (2003) further reported root yield increases in parsley due to seed pre-treatment with similar methods. Better growth attributes of roots and shoot, increased seed yield per plant were recorded for sesame as well, when similar seed-priming techniques were applied Singh *et al.* (2002).

CONCLUSIONS

The commercial production of primed seeds is not being done in any of the vegetable seeds in Turkey so far, but may be of interest in the future especially due to increasing number of fields where direct sowing is practiced. K_3PO_4 applied in a bubble column was proven to be the most efficient application to improve emergence in both field and stress conditions in lettuce, which also highlights its success when used in direct sowing where stress conditions can prevail at critical periods. Besides emergence rate and mean emergence time, which were significantly improved by this treatment, further plant development was also favored by increasing head weight, leaf number, early and total yield. The ineffectiveness of K_3PO_4 in the production through the seedlings is less of importance, since this type of production needs an additional production step and hence additional costs. As in many other vegetable crops such as tomatoes and onions, direct seeding might also be suggested in lettuce in combination with pre-sowing seed treatments and may find application especially in direct seeded onion in growing areas across Turkey.

REFERENCES

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

Brocklehurst, P.A. and J. Dearman, 1987. A comparison of different chemical for osmotic treatment of vegetable seed. Ann. Applied Biol., 105: 391-398.

Brocklehurst, P.A., J. Dearman and R.L.K. Drew, 1987. Recent developments in osmotic treatment of vegetable seeds. Acta Hortic., 215: 193-200.

Bujalski, W., A.W. Nienow and D. Gray, 1990. Establishing the large scale osmotic priming of onion seeds by using enriched air. Ann. Applied Bio1., 1581: 171-176.

Bujalski, W. and A.W. Nienow, 1991. Large-scale osmotic priming of onion seeds: A comparison of different strategies for oxygenation. Sci. Hortic., 46: 13-24.

Cantliffe, D.J., K.D. Shuler and A.C. Guedes, 1981. Overcoming seed thermodormancy in a heat sensitive romaine lettuce by seed priming. Hortscience, 16: 196-198.

Cantliffe, D.J., M. Elbella, A. Guedes, G.B. Odell, P. Perkins-Veazie, J.R. Schultheis, D.N. Seale, K.D. Shuler, I. Tanne and J.T. Watkins, 1987. Improving stand. Establishment of direct seeded vegetable in Florida. Pro. Flor. State. Hortic. Soc., 100: 213-216.

Cantliffe, D.J., 1991. Benzyladenine in the Priming Solution Reduces Thermodormancy of lettuce Seeds. Hortic. Technol., 1: 95-97.

Duman, İ., D. Eşiyok and E. Düzyaman, 1995. Effects of presowing seed treatments on germination emergence yield and some quality properties in lettuce (*Lactuca sativa* cv. Saladin) production. Ege Univ. Fac. Agric., 32: 99-106.

Duman, I. and D. Eoiyok, 1998. Effects of pre-sowing PEG and KH_2PO_4 treatments on germination emergence and yield of carrot. Turk. J. Agric. For., 22: 445-449.

Demir, İ., Ö. Güçlü, K. Demir and M. Özçoban, 1999. Use of presowing seed treatments in order to break thermodormancy in pepper. III. National Horticultural Congress, Ankara, Turkey, pp: 515-518.

Demir, İ. and H.A. Van De Venter, 1999. The effect of priming treatments on the performance of watermelon (*Citrullus lanatus*) seeds under temperature and osmotic stress. Seed Sci. Technol., 27: 871-875.

Finnerty, T.L., J.M. Zajicek and M.A. Hussey, 1992. Use of seed priming to bypass stratification reguirements of three aquilegia species. Hortscience, 27: 310-313.

Giri, G.S. and W.F. Schillinger, 2003. Seed priming winter wheat for germination, emergence and yield. Crop Sci., 43: 2135-2141.

Guedes, A.C. and D.J. Cantliffe, 1980. Germination lettuce seeds at high temperature after seed priming. J. Am. Soc. Hortic. Sci., 105: 777-781.

Hardegree, S.P. and S.S. Van Vactor, 2000. Germination and emergence of primed grass seeds under field and simulated-field temperature regimes. Ann. Bot., 85: 379-390.

Harris, D., B.S. Raghuwanshi, J.S. Gangwar, S.C. Singh, K.D. Joshi, A. Rashid and P.A. Hollington, 2001. Participatory evaluation by farmers of on-farm seed priming in wheat in India, Nepal and Pakistan. Exp. Agric., 37: 403-415.

ISTA., 1999. International rules for seed testing. Seed Sci. Technol., 27: 501-505.

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

Nascimento, W.M. and S.H. West, 1999. Muskmelon transplant production in response to seed priming. Hortic. Technol., 9: 53-55.

Orzeszko-Rywka, A., S. Podlaski, 2003. The effect of sugar beet seed treatments on their vigour. Plant Soil Environ., 49: 249-254.

Parera, C.A. and D.J. Cantliffe, 1992. Priming leek seed for improved germination and emergence at high temperature. Hortscience, 27: 1077-1079.

Parera, C.A. and D.J. Cantliffe, 1994. Presowing Seed Priming. In: Horticultural Reviews, Volume 16, Janick, J. (Ed.). John Wiley and Sons, Oxford, UK., pp: 109-141.

Podlaski, S., Z. Chrobak and Z. Wyszkowska, 2003. Effect of parsley seed treatment on root yield. Plant, Soil Environ., 49: 213-217.

Seale, D.N., D.J. Cantliffe and P.J. Stoffella, 1994. Lettuce stand establishment in response to soil amendments and direct-seeding treatments. Hortic. Sci., 29: 22-24.

Singh, B., S. Singh, J. Singh and A. Kumar, 2002. Seed-priming techniques in sesame (*Sesamum indicum*). Indian J. Agric. Sci., 72: 319-321.

Spurr, C.J., D.A. Fulton, P.H. Brown and R.J. Clark, 2002. Changes in seed yield and quality with maturity in onion (*Allium cepa* L., cv.'Early Cream Gold'). J. Agron. Crop Sci., 188: 275-280.

Sivritepe, H.Ö., 2000. The Effects of Osmotic Conditioning Treatments on Salt Tolerance of Onion Seeds. III. National Symp. on Vegetable Production, Isparta, Turkey, pp: 475-481.

Vural, H., D. Eşiyok and İ. Duman, 2000. Cultivated vegetables (vegetable growing). Ege University. Agricultural Faculty, İzmir, Turkey, pp: 440.