

EFFECT OF SOME TREATMENTS ON GLOBE ARTICHOKE SEED PRODUCTION UNDER EGYPTIAN CONDITIONS.

B- Enhancement of Seed Germination by Seed Priming

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ABSTRACT

Artichoke seeds germination shows variation in germination percentage and speed with non-uniform seedlings. Two laboratory and nursery experiments were carried out during seasons of years 2011/2012 and 2012/2013 to investigate the enhancement role of seed priming agents on seed germination and seedling behavior of locally produced seeds of globe artichoke *Cynara scolymus* L (green globe CV.). Seeds were primed in 8 different priming agents (PEG 8000, KNO₃, K₂HPO₄, Na₂SO₄, NaCl, MgSO₄, KCl, or Mannitol.) plus the control treatment (without priming). Both germination under laboratory conditions and emergence under nursery conditions were evaluated.

Germination percentage, coefficient of velocity and germination performance index were significantly increased as a result of seed priming treatments. KNO₃, PEG and mannitol were found to be the best treatments in this regard. Priming artichoke seeds in different priming agents reduced mean germination time and time required to reach 50% germination.

KNO₃, PEG and mannitol significantly improved the seedling characters in terms of seedling length and seedling fresh and dry weights as well as amylase activity. However, K₂HPO₄ was the best treatment in activating the peroxidase enzyme.

Emergence and subsequent growth of seedling in trays responded positively to seed priming and KNO₃ was the superior in enhancing emergence percentage and seedling growth in terms of seedlings height, number of leaves and dry weights of shoots and roots.

It could be recommended that, priming local produced artichoke seeds in KNO₃, PEG and mannitol will enhance seed germination and subsequent seedling growth which in turn will lead to using seed as a new method for propagation and multiplication under Egyptian condition and subsequently the cultivated area with artichoke will increase.

Keywords: seed priming, germination, globe artichoke, *Cynara scolymus*, PEG, KNO₃

INTRODUCTION

Globe artichoke (*Cynara scolymus* L.) is a large immature flower rich in medicinal substances. It is considered one of the most important vegetable crops in the countries bordering the Mediterranean basin including Egypt.

Nowadays, in Egypt more attention is given to promote globe artichoke production to satisfy the increased demands of local consumption as well as for exportation. Subsequently the cultivated acreage was doubled two times and half between 2006 and 2011. According to Egyptian ministry of agriculture statistics, the total cultivated area was 8603 feddan in 2006 against 21450 feddan in 2011. Current and expected expansions in the cultivated area require more choices for farmers in terms of varieties and propagation methods.

Historically, globe artichoke fields have been cultivated vegetatively e.g., offshoots and stump sections from plants that have been cut down from older fields and this form of propagation remains the most spread among the countries dedicated to its cultivation.

This way of propagation occasioned problems as low rate of multiplication (Pecaut *et al.*, 1983), intensification of phytosanitary disorders associated to dissemination of fungal, bacterial and viral diseases (Moncousin, 1982), and high implantation costs (Mauromicale *et al.*, 1989; Ricceti *et al.*, 1996). All these disadvantages could be overcome by the use of sexual propagation, which in turn can allow the crop to be incorporated as an annual in rotations (Basnizki and Zohary, 1994), extend its cultivation to new regions, reach more plant stand uniformity (Pecaut, 1993; Basnizki and Zohary, 1994), and a higher rate of multiplication (Pecaut, 1993).

Recently, new seed-propagated cultivars have become commercially available. Seed-grown globe artichoke seems a promising technique and can represent a valid alternative to traditional methods all over the world (Welbaum, 1994; Pomares *et al.*, 2004; Foti *et al.*, 2005). It is believed that the use of seed-propagated cultivars would lead to an increase in yield due to the root system development, which explores and uses water and nutrients more efficiently than in vegetatively propagated materials. Garcia *et al.* (2012) recommended that when possible, it would be worth to change the propagation system towards seed-means; in order to achieve increased yield and precocity.

Water use efficiency in seed planted artichoke is higher than in vegetatively propagated fields and this is suitable with the current situation of water shortage which Egypt faces now. An irrigation trial was carried out in Sicily, Italy compared a seed grown cultivar with a traditional clonal cultivar. Transpiration and stomatal conductance in seed grown plants were , respectively, 46% and 49% higher and leaf water potential was 56% lower in the clonal cultivar (Cosentino and Mauromicale, 1990). They also observed that seed grown plants had deeper and better shaped root system.

Artichoke seeds have a lower rate of emergence than other vegetable crops due to the hard structure of their seed coat (Ellis *et al.*, 1985). Also, it is difficult to have a good stand establishment of globe artichoke when seeds are sown directly in open fields during summer in Mediterranean region (Mauromicale and Licandro, 2002).

Various methodologies were adapted from time to time to improve seed germination and emergence. Seed priming or osmoconditioning has proved to be an effective and successful method in increasing seed vigour in

most cases and it is the process of soaking seeds in osmotic solution. Seed priming is the induction of a particular physiological state in plants by the treatment of natural and synthetic compounds to the seeds before germination (Jisha *et al.* 2013). It is also widely used to synchronize the germination of individual seeds (Taylor and Harman 1990). Improved seed invigoration techniques are known to reduce emergence time, accomplish uniform emergence, and give better crop stand in many horticultural and field crops (Ashraf and Foolad 2005). Seed-priming technology has twofold benefits: enhanced, rapid and uniform emergence, with high vigor and better yields in vegetables (Bruggink *et al.* 1999). According to McDonald (2000), primed seeds acquire the potential to rapidly imbibe and revive the seed metabolism thus enhancing the germination rate.

Primed seeds usually exhibit an increased germination rate, greater germination uniformity, and at times, greater total germination percentage (Basma *et al.* 2005). These attributes have practical agronomic implications, notably under adverse germination conditions (McDonald 2000). Therefore, there is a strong interest in the seed industry to find suitable priming agent(s) that might be used to increase seed germination and early seedling growth and subsequently plants growth either under favorable or adverse field conditions (Job *et al.* 2000).

Few studies were carried out to examine the effectiveness of seed priming on seed germination of globe artichoke. It is found that seed priming seed globe artichoke in PEG improved germination under low temperatures (4 and 8 °C) in globe artichoke (Ierna *et al.*, 2004). Results of Saleh (2011) on artichoke showed positive effects for seed priming treatments either biologically with *Bacillus subtilis* or chemically with CaCl₂ in improving seed germination percentage compared to untreated seeds.

Thus, this work was planned with objective to examine would seed priming agents improve seed germination and subsequent seedling growth of locally produced globe artichoke seeds.

MATERIALS AND METHODS

These experiments on locally produced seeds of globe artichoke (*Cynara scolymus* L.) cultivar green globe were carried out during seasons of years 2011/2012 and 2012/2013. They were conducted at Mansoura Horticultural Research Station, and Mansoura Seed Technology Unit, Agricultural Research Center, Ministry of Agriculture, Egypt. Two experiments were designed to evaluate the effect of seed priming on artichoke seed germination in the laboratory, and to study the effect of seed priming on seedling growth and establishment under nursery conditions. Locally-produced artichoke seeds were subjected to 9 treatments (8 priming treatments + control treatment without priming).

Seed priming was done as follows: seeds (100 g each) were primed in eight aerated columns in different priming agents. Treatments were at -1.0 Mega Pascal (MPa) of (1) PEG 8000, (2) KNO₃, (3) K₂HPO₄, (4) Na₂SO₄, (5)

NaCl, (6) MgSO₄, (7) KCl, or (8) Mannitol. 0.2% Thiram was added to prevent fungal growth during the treatment (Zbitnew, 1984).

Experiment A: Laboratory Germination

Laboratory germination tests were done on four replications of 100 seeds each. Seeds were sown in Petri dishes (9 cm) containing 2 moistened sheets of filter paper (Whatman 3). Each Petri dish contained twenty seeds. The Petri dishes were held for 21 days in a germination cabinet at a temperature of 20°C.

A complete randomized block design with 4 replicates was followed and the following data were recorded.

1. Germination percentage (GP) was measured according to the ISTA rules (ISTA, 2011).
2. Mean time to germination in days (MGT) was calculated according to the formula $MGT = \sum d/N$ where n is the number of germinated seed on each day, d the number of days from the beginning of the test, and N the total number of germinated seeds (Edwards and Sundstrom, 1987).
3. Time to reach 50% germination (T50), days required to 50% germination.
4. Coefficient of velocity was calculated according to the formula Coefficient of velocity = $1 / MGT \times 100$ where MGT is mean time to germination in days (Edwards and Sundstrom, 1987).
5. Germination performance index (GPI) was calculated according to the formula $GPI = GP/MGT$ where GP is germination percentage and MGT is mean time to germination in days (Pill and Fieldhouse, 1982)
6. Seedling length (cm) was measured on ten seedlings randomly taken from each replicate and the mean length of seedlings was calculated.
7. Seedling fresh weight (mg) was measured on ten seedlings randomly taken from each replicate, weighed, and the average fresh weight per seedling was calculated.
8. Seedling dry weight (mg) measurement used the same seedlings taken for the determination of fresh weight. They were oven-dried at 70°C until constant weight was reached. The average weight per dried seedling was calculated.
9. Amylase activity
10. Peroxidase activity

Experiment B: Nursery Trays

The tray experiment was done to measure seedling formation under nursery conditions on four replications of 100 seeds each. Seeds were sown in seedling polyesterene trays. . Seeds were sown in a peat-vermiculite-perlite mix (2:1:1, v/v/v). Trays were covered with plastic for 3 days, and then moved to raised beds where they remained for six weeks. Seedlings were watered every 2-4 days. A soluble fertilizer (20-10-10) was applied every 4 days after seedling emergence.

A complete randomized block design with 5 replicates was followed and the following data were recorded emergence percentage (EP), seedling height, number of leaves, and dry weight of shoots and roots.

The obtained data were subjected to analysis of variances, and the significant differences among treatment means were determined by Duncan's multiple range test at $P < 5\%$ as published by Duncan (1965).

RESULTS AND DISCUSSION

1-Effect of seed priming on germination behavior of artichoke

Germination percentage was significantly increased by osmoconditioning artichoke seeds with different priming agents (Table 1). Priming in PEG and KNO_3 recorded the highest values, followed by mannitol, KCl , K_2HPO_4 , MgSO_4 , NaCl and Na_2SO_4 . The lowest germination percentage was obtained from non-primed seeds. PEG treatment germinated 46.55% and 43.33% higher than the control during the first and second season, respectively, while KNO_3 treatment gave 42.52% and 40.0%, respectively, for the two seasons.

Data presented in the same table showed that seeds primed in -1.0 MPa of different priming treatments were characterized by a progressive reduction in MGT as compared with non-primed seeds. PEG 8000, KNO_3 , and mannitol treatments almost halved MGT, while other priming treatments reduced MGT by different periods. Sodium salts (NaCl and Na_2SO_4) treatments were less effective in this regard.

Seed priming caused a significant reduction in T50 as compared with the control in both seasons (Table 1). It appears that we can easily place priming agents into 3 groups according to their potential for reducing T50. The first group included PEG, KNO_3 and mannitol, the second group included K_2HPO_4 , MgSO_4 and KCl , and the third group included Na_2SO_4 and NaCl .

Table (1) showed that coefficient of velocity of germinated artichoke seeds tended to increase with priming treatments. There were significant differences among treatments means. The highest values in both seasons were recorded by PEG, KNO_3 and Mannitol treatments, while the lowest were obtained from Na_2SO_4 and NaCl treatments. K_2HPO_4 , MgSO_4 and KCl gave moderate results in improving artichoke coefficient of velocity.

Germination performance index (GPI) was calculated to integrate mean time to germination (MGT) and germination percentage (GP). The greater the GPI value, the greater the seed germination performance. Data tabulated in Table (1) showed that seed priming treatments significantly increased GPI in both seasons. PEG increased GPI almost 3.45-fold over the control, while KNO_3 increased GPI around 2.9-fold over the control and mannitol increased GPI around 3.33-fold over the control. The lowest values obtained from priming artichoke seeds was from Na_2SO_4 and NaCl solutions. These results are in harmony with those reported by Lanteri *et al.* (2000), who worked with pepper and Ierna *et al.*, 2004 Saleh 2011 on globe artichoke.

Germinating seeds typically exhibit a triphasic pattern of water uptake that starts with rapid imbibitions (phase I), followed by a plateau or lag phase in which there is little change in water content (phase II) and finally, an increase in water content coinciding with radical growth (phase III) (Bewley

and Black, 1994). During phase II, physiological and anatomical changes occur. These changes prepare the seed for later expansive growth. Thus, phase II serves as the major control point for germination of seeds (Bradford, 1990). Seed priming is a controlled hydration procedure followed by redrying. During priming, seeds progress through phase I and phase II. Seeds do not progress to phase III, because the uptake of additional water needed for the initiation of expansive embryo growth is blocked. Evidence suggests that many of the physiological and anatomical changes that characterize phase II are largely completed during priming, this causing seeds to germinate faster upon rehydration. Seed priming appears to be an effective physiological treatment to improve germination behaviour. It also results in better homogeneity of germination. The positive effects of priming on germination performance have been attributed to the induction of biochemical repair mechanisms. Metabolic events such as synthesis of protein, RNA and DNA are initiated within minutes of seed hydration (Osborne, 1983). Mitochondria increased in number during leek priming (Bray, 1995).

2-Effect of seed priming on Seedling characteristics and enzymatic activity of artichoke

Data presented in Table 2 indicated that significant differences occurred between treatment means in seedling length. KNO_3 was the superior treatment in this regard, followed by PEG priming treatment. In this character, mannitol, K_2HPO_4 and Na_2SO_4 had more positive effect than, KCl, NaCl and MgSO_4 priming treatments.

Concerning seedling fresh weight, data pertaining to the effect of seed priming on artichoke seedling fresh weight (Table 2) showed that significant differences were obtained between control and seed priming treatments, in addition to significant differences among priming agents themselves. KNO_3 recorded the highest value in seedling fresh weight with only slight difference from that of mannitol and PEG. While KCl recorded the lowest value among priming treatments for both seasons.

Seedling dry weight was also significantly affected by seed priming treatments. During the both seasons of study, KNO_3 gave the best results in seedling dry weight followed by mannitol and PEG. The differences between priming treatment were slight.

Our results are in line with those of Alvarado *et al.* (1987) on tomato, and those of Sundstrom and Edwards (1989) and Bradford *et al.* (1990) on pepper.

Tabulated data in Table (2) revealed that the amylase activity in both years was activated significantly by priming artichoke seeds in KNO_3 , PEG or mannitol treatments. Amylase activity exhibited different responses in relation to year and priming agents. Concerning peroxidase activity, the results in the same table showed that peroxidase activity in both years was enhanced significantly in seedlings obtained from seed primed in K_2HPO_4 .

These results are in agreement with those of Zuo *et al.* (1988), who reported that amylase activity during germination of primed pea and tomato seed, and peroxidase activity of primed tomato and spinach seed, were higher than non-primed seeds.

The fundamental processes concerned with seed germination include the change of stored insoluble materials into soluble materials, through respiration and hormones in endosperm and cotyledons. The soluble food and hormones are translocated to the rapidly-dividing meristems, where they are utilized for making new cells and for the liberation of kinetic energy. Therefore, germination is entirely a food utilization process (Edmond *et al.*, 1977). This change of course needs the involvement of different enzyme systems. Amylase as one of them has two aspects, the first as being dominant in seeds, and the second is formed *de novo* to be activated by some minerals.

3-Effect of seed priming on emergence and growth of artichoke tray seedlings

Data in Table 3 indicated that priming artichoke seeds with PEG, KNO_3 , K_2HPO_4 , Na_2SO_4 , NaCl , MgSO_4 , KCl , and mannitol increased emergence percentage by 62, 58, 46, 36, 40, 48, 42, 54 %, respectively, in the first season, and by 58.8, 56.9, 45, 37.25, 41.18, 45.1, 43.14, 52.9 %, respectively, during the second season. Non-primed seeds (control) had the lowest final emergence percentage in comparison with all priming treatments. Priming improves seedling emergence possibly because of decreased electrolyte leakage and faster germination rate, which reduce the window of opportunity for fungal attack (Taylor *et al.*, 1985 and Bradford *et al.*, 1988).

Concerning seedling height, seed priming significantly increased seedling height over that of the control (Table 3). PEG, KNO_3 and mannitol were superior and the best treatments during both seasons. However, no significant differences were recorded between the other priming agents.

Data in Table 3 showed that seed priming in KNO_3 , PEG mannitol or K_2HPO_4 significantly increased seedling leaf number over the non-primed control of artichoke seedlings. However, priming in NaCl , Na_2SO_4 , MgSO_4 or KCl did not show statistically significant differences in both seasons.

Shoot dry weight followed the same trend in both seasons (Table 3). It is clear that seed priming significantly increased shoot dry weight over that of the control non-primed treatment. KNO_3 , PEG and mannitol were the best treatments, and recorded high values in shoot dry weight. However, MgSO_4 recorded the lowest value. As for root dry weight, data in Table 3 indicated that during both seasons, seed priming in KNO_3 , PEG or had a significant promotion effect on root dry weight. However, no significant differences were observed between the remaining priming agents.

Generally, seedlings from primed seeds achieved a higher emergence percentage, and earlier canopy expansion than unprimed control seedlings, resulting in greater shoot and root weights. These results agree with those of Wolfe and Sims (1982) on tomato and Saleh *et al.* (1996) on pepper.

Our results showed that, all seed priming treatments increased emergence percentage. This may be due to the advancement of physiological and molecular processes during priming. Generally the significant improvement in vegetative growth of artichoke seedlings after priming process may be attributed to earlier emergence caused by seed priming treatments, which is indicated by its specific efficiency in stimulating growth.

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تأثير بعض المعاملات على إنتاج بذور الخرشوف تحت الظروف المصرية
(ب) تشجيع الإنبات باستخدام مهثيات الإنبات
على محمد مغازى، حمدينو محمد إبراهيم أحمد وأسامة محمد سيف الدين
أقسام بحوث الخضر- معهد بحوث البساتين- مركز البحوث الزراعية - مصر

أجريت هذه الدراسة بهدف استخدام مهثيات الإنبات لتحسين إنبات بذور الخرشوف المنتجة محليا و تم إختبار كفاءة ٨ مواد للتهئية هي ١- البولى اثيلين جليكول ٢- نترات البوتاسيوم ٣- فوسفات ثنائى البوتاسيوم ٤- كبريتات الصوديوم ٥- كلوريد الصوديوم ٦- كبريتات الماغنسيوم ٧- كلوريد البوتاسيوم ٨- المانيتول علاوة على معاملة الكنترول (بدون تهئية) و كان أهم النتائج المتحصل عليها هي:-

كان واضحا فى عامي الدراسة تحسن سلوك إنبات بذور الخرشوف المنتجة محليا نتيجة استخدام مهثيات الإنبات وكان البولى اثيلين جليكول ونترات البوتاسيوم و المانيتول هم أحسن المعاملات فى زيادة نسبة الإنبات و تقليل عدد الأيام التى تستغرقها عملية الانبات و تقليل عدد الأيام اللازمة للوصول إلى ٥٠% إنبات و زيادة معامل سرعة الانبات و زيادة دليل كفاءة الانبات. إزدادت معنويا قياسات البادرات و النشاط الإنزيمى فوق معاملة الكنترول نتيجة استخدام مهثيات الانبات. وكانت نترات البوتاسيوم هى أكفأ المواد فى زيادة فى طول البادرة ووزنها الطازج والجاف و نشاط إنزيم الأميليز أما نشاط إنزيم البيروكسيداز ف سجل أعلى القيم عند تهئية البذور فى محلول فوسفات ثنائى البوتاسيوم

تحسنت صفات الشتلات فى صوانى الإنبات نتيجة استخدام مهثيات الإنبات وكان البولى اثيلين جليكول ونترات البوتاسيوم و المانيتول هم الأكفأ فى هذا الصدد حيث إزدادت نسبة الإنباتاق و طول الشتلة و عدد الأوراق على الشتلة و الوزن الجاف للمجموع الخضرى و الجذرى للشتلة. و بصفة عامة أظهرت مهثيات الإنبات كفاءة فى تحسين إنبات بذور الخرشوف و يمكن التوصية بتهئية بذور الخرشوف المنتجة محليا فى نترات البوتاسيوم أو البولى اثيلين جليكول أو المانيتول حيث أن التهئية ستزيد و تشجع الإنبات و نمو الشتلات و الذى بدوره سيؤدى إلى إستخدام البذور كوسيلة جديدة للتكاثر و الزراعة تحت الظروف المصرية و بالتالى ستزداد المساحة المنزرعة بالخرشوف.

Table (1): Germination behavior of globe artichoke seeds in the laboratory as influenced by priming treatments during 2011/2012 and 2012/2013 seasons.

Treatments	Germination Percentage (GP %)		Mean germination time (MGT) days		Time to reach 50% germination (T50)		Coefficient of velocity (CV)		Germination performance index (GPI)	
	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013
Control	58.00 e	60.00 e	7.850 a	7.950 a	7.000 a	6.750 a	12.74 g	12.58 g	7.390 e	7.550 e
PEG 8000	85.00 a	86.00 a	3.390 d	3.250 d	2.880 e	3.250 e	29.50 a	30.77 a	25.07 a	26.46 a
KNO ₃	82.66 b	84.00 b	3.560 d	3.620 d	3.250 e	3.330 e	28.09 b	27.62 b	23.22 a	20.20 b
K ₂ HPO ₄	81.00 bc	82.00 bc	4.750 c	4.970 c	4.000 d	3.130 d	21.05 c	20.12 c	17.05 b	16.5 b
Na ₂ SO ₄	76.00 d	77.00 d	6.350 b	6.830 b	5.750 b	6.630 b	15.75 f	16.64 3	11.97 d	11.27 d
NaCl	77.00 d	78.00 d	6.010 b	6.410 b	5.750 b	6.000 b	16.64 e	15.60 f	12.81 d	12.17 d
MgSO ₄	80.00 c	81.00 c	4.990 c	5.310 c	4.13 cd	4.500 cd	20.04 cd	18.83 cd	16.03 b	15.25 b
KCl	80.00 c	80.00 c	5.250 c	5.370 c	4.580 c	5.000 c	19.05 d	18.62 d	15.24 bc	14.90 bc
Mannitol	82.00 bc	83.00 bc	3.600 d	3.850 d	3.250 e	3.330 e	26.78 b	26.50 b	22.78 a	21.56 a

Values within the same column followed by the same letters are not significantly different, using Duncan's Multiple Range Test at 5% level

Table (2): Seedling characteristics and enzymatic activity of 2 weeks-old globe artichoke seedlings as influenced by priming treatments during 2011/2012 and 2012/2013 seasons.

Treatments	Seedling length (cm)		Seedling fresh weight (mg)		Seedling dry weight (mg)		Amylase activity		Peroxidase activity	
	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013
Control	5.250 f	5.600 f	46.40 h	46.85 g	2.970 b	3.35 e	39.75 h	45.45 g	7.110 e	7.280 f
PEG 8000	7.800 b	8.45 b	51.60 c	54.00 b	3.270 a	3.880 ab	59.78 c	62.90 b	7.51 d	8.060 de
KNO ₃	8.670 a	10.35 a	52.20 a	54.87 a	3.330 a	3.930 a	77.06 a	74.40 a	7.870 c	8.270 c
K ₂ HPO ₄	6.650 c	7.750 c	52.40 a	55.01 a	3.350 a	3.980 a	45.88 g	49.70 f	8.550 a	9.270 a
Na ₂ SO ₄	6.610 c	7.100 c	49.50 f	49.50 e	3.160 ab	3.490 de	46.05 f	54.30 e	7.550 d	8.150 d
NaCl	5.980 d	6.350 d	50.50 e	50.10 d	3.200 a	3.600 cd	57.11 d	56.20 c	7.410 d	7.880 e
MgSO ₄	5.500 ef	6.100 de	50.80 d	52.20 c	3.240 a	3.720 bc	46.11 f	54.80 d	7.480 d	7.910 e
KCl	5.800 de	6.000 de	48.85 g	49.10 f	2.990 b	3.490 de	50.15 e	56.19 c	8.120 b	8.820 b
Mannitol	6.450 c	6.650 c	51.95 b	54.10 b	3.320 a	3.880 ab	64.70 b	62.80 b	7.860 c	8.230 cd

Values within the same column followed by the same letters are not significantly different, using Duncan's Multiple Range Test at 5% level

Table (3): Emergence percentage, seedling height, number of leaves and dry weight of shoots and roots of 6 weeks-old globe artichoke seedlings as influenced by priming treatments during 2011/2012 and 2012/2013 seasons.

Treatments	Emergence percentage (EP%)		Seedling height (cm)		Number of leaves		Shoot dry weight (gm)		Root dry weight (gm)	
	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013
Control	50.00 d	51.00 d	19.60 c	20.30 c	4.000 d	4.330 d	1.950 e	2.200 e	1.010 d	1.050 d
PEG 8000	81.00 a	81.00 a	27.30 a	29.40 a	7.000 ab	7.330 ab	3.500 ab	3.520 ab	1.750 a	1.820 a
KNO ₃	79.00 ab	80.00 a	28.20 a	30.50 a	7.330 a	7.660 a	3.800 a	3.600 a	1.790 a	1.840 a
K ₂ HPO ₄	73.00 c	74.00 bc	24.30 b	25.60 b	6.000 bc	6.330 bc	3.150 bc	3.200 bc	1.350 bc	1.420 bc
Na ₂ SO ₄	68.00 c	70.00 c	23.20 b	24.50 b	5.660 cd	5.660 cd	3.050 bc	3.100 bc	1.300 bc	1.340 bc
NaCl	70.00 c	72.00 c	22.50 b	24.00 b	5.000 cd	5.330 cd	2.930 cd	3.000 cd	1.200 cd	1.260 bc
MgSO ₄	74.00 bc	74.00 bc	22.40 b	23.50 b	5.000 cd	5.330 cd	2.470 d	2.880 c	1.210 cd	1.200 bc
KCl	71.00 c	73.00 bc	23.00 b	24.30 b	5.330 cd	5.330 cd	2.900 cd	3.000 cd	1.280 bc	1.330 bc
Mannitol	77.00 bc	78.00 ab	26.50 a	28.60 a	6.000 bc	6.330 bc	3.25 bc	3.320 bc	1.430 b	1.480 b

Values within the same column followed by the same letters are not significantly different, using Duncan's Multiple Range Test at 5% level