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Evaluation of Different Seed Priming on Seedling Growth, Yield and Quality Components in Two Sunflower (*Helianthus annuus* L.) Cultivars

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ABSTRACT

A laboratory study was conducted to evaluate the effect of seed priming using different priming agents with different concentrations (KNO_3, Polyethylene Glycol (PEG 6000), ascorbic acid, α-tocopherol, folic acid and seaweed extract) and hydropriming compared with unprimed seed on seed and seedling vigor of two sunflower (*Helianthus annuus* L.) cultivars i.e., Sakha 53 and Giza 102 during 2009 season. Also, field experiments were carried out to investigate the influence of the best concentration selected of each priming treatment from laboratory experiment on yield, its components and quality of the same two sunflower cultivars during 2009 and 2010 seasons. In most cases, seed priming treatments reduced the Mean Germination Time (MGT), increased Germination Percentage (GP), Germination Energy (GE) and Germination Index (GI) and improved Seedling Length (SL) and Seedling Dry Weight (SDW) in both cultivars under laboratory conditions. Data analysis in the field experiment observed that Sakha 53 significantly surpassed Giza 102 in yield, its components and seed oil percentage. While, Giza 102 surpassed Sakha 53 in seed protein content. The highest values of capitulum diameter, 100-seed weight and seed yield/ha were observed by the application of 75 mg L^{-1} ascorbic acid in both seasons. Also, the highest values of seed yield/plant and seed oil and protein% produced from seed primed with 15 mg L^{-1} folic acid in the second season. Sakha 53 was better than Giza 102 as an oil source because of its highest content of oleic acid and unsaturated fatty acids percentages. It may be concluded that seed priming agents can be used for improving the germination and seedling vigor of sunflower seeds. In addition, planting Sakha 53 cultivar and seed primed with 75 mg L^{-1} ascorbic acid or 15 mg L^{-1} folic acid can achieve high yield and oil quality of sunflower. So, seed priming can be used as a beneficial method to improve seed performance and plant traits of sunflower.

Key words: Priming, *Helianthus annuus* L., germination, seedling growth, yield, quality components

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the most important oil seed crops in Egypt. It is a short duration crop (90-110 days) and can be grown twice in a year. It is fully fit in Egyptian cropping system and can be grown without causing competition of any major crop (Ahmad *et al.*,

2009). In Egypt, the total production of 24 thousand tons ha^{-1} and an average yield of 2.4 tons ha^{-1} According to FAO (2010), sunflower crop has introduced in Egypt with the objective of bridging the gap between production and consumption of edible oil. Where, Egypt's production of edible vegetable oils has been suffering several problems. These problems which Egypt if suffered from could be summarized as follows; the cultivated area from oil crops is very small; the majority of Egyptian farmers has a lake knowledge alternative of winter and summer oil crops; slow of post harvest factoring process and marketing system and extra. The local production satisfies 5% only of the total requirements. For increasing the total production of edible oil, the area cultivated with oil crops such as sunflower should be increased by expanding in the newly reclaimed soil and planting high potential yield cultivars. From them, seed priming has been found a doable technology to enhance rapid and uniform emergence, high vigour and enhance overall plant growth and productivity in vegetable, flower species and some field crops (Basra *et al*., 2005; Hussain *et al*., 2006).

Singh and Rao (1993) stated that KNO_3 effectively improved germination, seedling growth and vigor index of the seeds of sunflower varieties with the low germination. Bailly *et al*. (2000) found that primed seeds of sunflower emerged 1-3 days earlier than non-treated seeds and it quickly became apparent that these early grains led to a range of later benefits. On bread wheat (Harris *et al*., 2001) and chickpea (*Cicer arietinum* L.) (Musa *et al*., 2001) both respond positively to "on-farm" seed priming with water. Besides better establishment, farmers have reported that primed crops grew more vigorously, flowered earlier and yielded higher. Basra *et al*. (2005, 2006) reported that primed seeds emerged 12 h earlier than non-primed seeds. Kaya *et al*. (2006) reported that hydroprimed seeds of sunflower and wheat could germinate faster and produced longer seedling as compared with untreated seeds but osmopriming with Polyethylene Glycol (PEG) was less effective method than other hydropriming for improving seed germination and Mean Germination Time (MGT). Mohammadi (2009) on soybean (*Glycine max* L.) in field and laboratorial studies, found that seed primed with potassium nitrate increased Germination Percentage (GP), Germination Rate (GR), Seedling Dry Weight (SDW), 1000-seed weight and yield as compared to control. Moradi and Younesi (2009) on sorghum (*Sorghum bicolor* L.) pointed out that Germination Percentage (GP), Germination Index (GI), Seedling Length (SL) and Weight (SW) increased significantly due to osmopriming with PEG.

Ascorbic acid (Vitamin C, ASA) and folic acid (vitamin B6; Fol), due to their inherent antioxidant potential, both vitamins can be used as priming agents for increasing seed vigour and phenolic elicitation. Exogenous application of Ascorbic Acid (ASA) has been found to induce mitotic activity in several systems, including white lupine (*Lupinus albus* L.) seedlings (Arrigoni *et al*., 1997). Both vitamins are water soluble with antioxidant potential (McCue *et al*., 2000). Ascorbic acid (ASA) is an important metabolite involved in many cellular processes, including cell division (De Gara *et al*., 2003).

In this concern, Wahid *et al*. (2008) on sunflower observed that seed priming with ASA reduced MGT and improved GE and final GP (6 days) as well as shoot and root dry weight. α-tocopherol (Vitamin E; Toc) interact with the polyunsaturated acryl groups of lipids, stabilize membranes and scavenge and quench various Reactive Oxygen Species (ROS) and lipid soluble by products of oxidative stress (Gadalla, 2009).

Hussain *et al*. (2006) observed that seed priming techniques affected significantly seedling establishment, yield and quality of hybrid sunflower but seed oil content was not affected significantly by different seed priming. The variety Vedock was the better than Malabar cultivar

in growth, yield and its components characters under study (Ibrahim *et al.*, 2006). Abdel-Motagally and Osman (2010) observed that Sakha 53 significantly surpassed Giza 102 in head diameter, 100-seed weight, seed yield/plant and seed yield/ha, however, there was not significant effect on oil percentage. Ahmed *et al.* (2010) found that Vedock cultivar significantly exceeded Hysun 354 in head diameter, seed index, seed yield/ha and protein percentage, except oil percentage, Sadak *et al.* (2010) on sunflower indicate that soaking sunflower seeds in α-tocopherol or nicotinamide increased yield components of the two tested cultivars.

Therefore, the aims of the present study were: (1) to evaluate the effect of different seed priming agents with different concentrations on seed germination behavior and seedling vigor of each sunflower cultivar under laboratory conditions, (2) to evaluate the response of two sunflower cultivars to different seed priming agents and (3) to assess the impact of the best concentration of different seed priming agents which selected from laboratory experiment on yield and its components and oil quality components of two introduced sunflower cultivars under field conditions.

MATERIALS AND METHODS

Laboratory experiment was carried out at Seed Technology Research Unit Mansoura, Dakahlia Governorate, Department of Seed Technology Research, Field Crop Research Institute, Agricultural Research Center during 2009 season to evaluate the effect of different seed priming agents with different concentrations on inducing seed germination behavior and seedling vigor as compared with unpriming treatment of each sunflower cultivar. Each cultivar was designed in a completely randomized design with five replicates. Also, field experiments were conducted at the Experimental Farm of Department of Agricultural Botany, Faculty of Agriculture, Mansoura University, Egypt during 2009 and 2010 seasons. A factorial with two factors (cultivars and priming treatments) in randomized complete block design with three replications was used in each season to investigate the impact of the best concentration of different seed priming agents which selected from laboratory experiment on yield and its components and oil quality components of the same two introduced sunflower cultivars under field conditions.

Seed material: Two sunflower (*Helianthus annuus* L.) cultivars i.e., Sakha 53 and Giza 102 were obtained from Department of Oil Crop Research, Field Crop Research Institute, Agricultural Research Center, Egypt.

Seed treatments: Seeds of sunflower were surface-sterilized in 1.5% sodium hypochlorite solution (NaOCl) for 5 min, then rinsed by distilled water (20°C) three times(Chen and Wu, 1999). Then, sterilized seeds were priming in different solutions according to each treatment. Seed priming treatments were: (a) hydropriming, soaking seeds in aerated distilled water, (b) osmopriming, similar to hydropriming but in the presence of aerated solution of potassium nitrate (KNO_3) (250, 500 and 750 mg L^{-1}), Polyethylene Glycol (PEG) 6000 (0.1, 0.2 and 0.3 g mL^{-1} H_2O), (c) vitamin priming, soaking seeds in an aerated solution of Ascorbic Acid (ASA) (25, 50 and 75 mg L^{-1}), α-Tocopherol (Toc) (25, 50 and 75 mg L^{-1}) and folic acid (Fol) (5, 10 and 15 mg L^{-1}) and seaweed extract priming (SWE) (50, 100 and 150 mg L^{-1}). The following standard priming treatment was adopted in all experiments: a single layer of sunflower seeds was submerged in each priming solution or distilled water, to a depth of 1 cm above the top of the seeds, for 8 h at laboratory temperature in the dark (Wahid *et al.*, 2008). The ratio of seed weight to solution volume was 1:5 (g mL^{-1}) (Basra *et al.*, 2004). The treated seeds were surface-dried under forced air on filter

paper to their original moisture 8-10% (on dry weight basis). After drying, all the treated and non treated seeds were sealed in polyethylene bag and stored in refrigerator at 5°C till further use.

Laboratory experiment

Germination test: Primed and unprimed seeds of each cultivar were sown on a double layer of Whatman No.1 filter paper that was moistened with 15 mL distilled water in sterilized Petri-dishes (14 cm diameter). Each Petri-dish contained 20 seeds and five Petri-dishes kept close together and incubated at 25±2°C, with a 12 h photoperiod and 70% relative humidity. Distilled water was added as needed to compensate for evaporation loss, then five replications were used to evaluate subjected to standard germination test as the rules of International Seed Testing Association (ISTA, 1985). Counts of germinating seeds were taken daily up to ten days after the start of germination. Germination Index (GI), Germination Energy (GE) and Mean Germination Time (MGT) were determined in this experiment. GI was calculated as described in the Association of Official Seed Analysis (AOSA, 1983) by following formula:

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

GE was recorded on the fourth day after sowing. The percentage of germinating seeds at 4th day after sowing is relative to the total number of seeds tested (Ruan *et al*., 2002). MGT was calculated depending on the following equation of Ellis and Roberts (1981): $MGT = \Sigma Dn / \Sigma n$, Where n is the number of seed which were germinated on day D and D is number of days counted from the beginning of germination.

Germination % and seedling vigor: Primed and unprimed seeds of each cultivar were sown in 12×8 cm plastic pots (15 in each) having moist sand (780 g), five replicates and subjected to the same conditions of standard germination test. At the end of standard germination test after 10 days from sowing the following characters was determined: Germination % (GP), Seedling Length (SL, cm), Seedlings Dry Weight (SDW, mg) and Seedling Vigor Index (SVI). GP was expressed by the percentage of the total number of normal seedlings. SL (shoot length + root length) was determined from 10 normal seedlings taken at random from each replicate, then dried in a forced air oven at 70°C for 48 h to a constant weight and then weighed to obtain seedlings dry weight (mg). Seedling Vigor Index (SVI) was calculated by the following equation of ISTA (1985) Rules:

$$SVI = \text{Seedling length (cm)} \times \text{Germination percentage}$$

Field experiments: Seed priming treatments in this study were selected from laboratory experiment after statistical analysis of data. These were: (a) untreated seeds (b) hydropriming (c) osmopriming (750 mg L^{-1} KNO_3 and 0.1 g mL^{-1} H_2O PEG 6000) (d) vitamin priming (75 ASA, 50 Toc and 15 mg L^{-1} Fol) and finally (e) seaweed extract priming (100 mg L^{-1} SWE).

Each plot consisted of 5 ridges 3.5 m long and 60 cm width, occupying an area of 10.5 m^2. The preceding winter crop was Egyptian clover (*Trifolium alexandrinum* L.) in both seasons. Primed and unprimed seeds were sown by hand with the usual dry method (Afir planting) on 6th and 2nd May in 2009 and 2010 seasons, respectively. Seeds were sown in hills spaced of 20 cm apart with two to three seeds/hill. The chemical analysis of the soil used were pH (7.82 and 7.75), EC

(1.64 and 1.70 dS m^{-1}), N (19 and 18 ppm), P (8 and 7 ppm), K (140 and 135 ppm), organic matter (2.69 and 2.80%) in both seasons, respectively and the soil texture was clayey. Phosphorus fertilizer was applied in the form of calcium superphosphate (15.5% P_2O_5) during soil preparation at the rate of 357 kg ha^{-1}. Nitrogen fertilizer was applied in the form of ammonium nitrate (33.5% N) in two equal doses at the rate of 71.4 kg N ha^{-1} (after thinning to one plant/hill and after 36 days from sowing), whereas potassium fertilizer in the form of potassium sulphate (48% K_2O) at the rate of 119 kg ha^{-1} as recommended was applied with the second portion of nitrogen fertilizer addition. The normal cultural practices for growing sunflower were conducted as recommended by Ministry of Agricultural and Land Reclamation.

At harvest time, a sample of ten randomly capitula (heads) of each experimental unit was taken and were separately harvested, bagged, cleaned from straw and other residues, dried under sunshine for two weeks, then the following characteristics were recorded; Capitulum diameter (cm), seed yield (g $plant^{-1}$) and 100-seed weight (g). Seed yield (ton ha^{-1}) was estimated by converting seed yield of the three medium ridges in each experimental unit to seed yield (ton ha^{-1}). Samples of seed were oven dried, ground finely and stored in small bags for chemical analysis. Seed oil percentage was determined after extraction with Soxhelt`s apparatus using hexane as an organic solvent according to AOAC (1990). Seed nitrogen percentage was estimated by using micro Kjeldahl apparatus and multiplied by the converting factor (6.25) to get seed protein percentage (Jackson, 1962).

Fatty acids profiling: The methyl esters of extracted crude oil were prepared according to the method described by Ludy *et al.* (1968). Gas liquid chromatography (Agilent 6890 GC, USA) was used for determination and identification of the fatty acids methyl esters, in Central Lab. of Food Tech. Rec. Institute, ARC, Egypt, according to Zygadlo *et al.* (1994).

Statistical analysis: The data was analyzed using analysis of variance technique (One-way ANOVA) under completely randomized design with five replicates for each cultivar (laboratory experiment) and factorial with two factor randomized complete block design with three replications (field experiments) for each season. All data were subjected to statistical analysis using "MSTAT-C" computer software package (Nissen *et al.*, 1985) as published by Gomez and Gomez (1984). Duncan's New Multiple Range Test at 5% level of probability was used to compare means which were indicated by alphabets on data sets (Waller and Duncan, 1969).

RESULTS AND DISCUSSION

Laboratory experiment: The Germination % (GP) and seedling measurements in sunflower cultivars significantly differed due to treatments (Table 1, 2). Application of priming treatments improved significantly GP in Sakha 53 cultivar. Meanwhile, all priming treatments except the moderate and high concentration of PEG increased significantly seed GP in Giza 102 cultivar. Seed priming treatments using SWE at 100 mg L^{-1} and ASA at 75 mg L^{-1} recorded the maximum GP in both cultivars (95.6 and 95.5% for Sakha 53 and 97.8 and 96.7% for Giza 102) respectively as compared with control seeds (64.4 and 82.2%) in both cultivars, respectively. GI and GE were increased significantly by using seed priming treatments as compared with control (unprimed seed) except the moderate and high PEG concentration which decreased GE in Giza 102 and GI in Sakha 53. The increase in GI and GE due to priming treatment was accompanied with a decreasing in

Table 1: Seed and seedling vigor characters of Sakha 53 cultivar as affected by seed priming

Treatments	Concentration (mg L^{-1})	GP	GI	GE	MGT	SL (cm)	10-SDW (mg)	SVI
Control		64.4^{g}	3.0^{gh}	65.6^{i}	4.9^{a}	20.6^{g}	567.7^{k}	13.3^{j}
Hydropriming		66.7^{fg}	3.5^{fgh}	72.3^{ghi}	3.9^{cd}	21.4^{fg}	626.3^{hij}	14.2^{j}
KNO_3	250.0	77.8^{de}	3.6^{efg}	73.9^{fgh}	3.7^{cdef}	23.4^{cdef}	612.0^{ijk}	18.2^{efgh}
	500.0	82.2^{cde}	4.1^{def}	75.5^{efgh}	3.3^{efgh}	25.2^{abcd}	608.7^{jk}	20.7^{cde}
	750.0	88.9^{abc}	4.5^{bcd}	80.0^{defg}	3.3^{efgh}	26.1^{ab}	671.3^{gh}	23.1^{abc}
PEG (g mL^{-1} H_2O)	0.1	73.3^{ef}	3.8^{ef}	77.8^{efg}	3.8^{cde}	26.6^{ab}	787.7^{bcd}	19.2^{defgh}
	0.2	68.9^{fg}	2.9^{gh}	76.2^{efgh}	4.1^{bc}	24.4^{abcde}	779.3^{bcd}	16.8^{hi}
	0.3	64.5^{g}	2.9^{h}	68.1^{hi}	4.4^{b}	21.7^{fg}	667.3^{ghi}	15.1^{ij}
ASA	25.0	73.3^{ef}	3.6^{efg}	77.3^{efg}	3.7^{cdef}	23.1^{def}	642.0^{hij}	16.9^{hi}
	50.0	84.4^{bcd}	4.2^{cdef}	86.4^{bcd}	3.4^{defgh}	24.2^{bcde}	771.0^{cde}	20.4^{def}
	75.0	95.5^{a}	4.7^{bc}	95.5^{a}	3.1^{ghi}	26.6^{a}	831.7^{b}	25.5^{a}
Toc	25.0	84.3^{bcd}	4.2^{bcde}	80.0^{defg}	3.4^{defgh}	23.6^{cdef}	676.3^{gh}	19.9^{defg}
	50.0	91.1^{abc}	4.9^{b}	93.3^{ab}	3.0^{hi}	25.5^{abc}	748.7^{def}	23.3^{abc}
	75.0	88.9^{abc}	4.7^{bc}	88.9^{abc}	3.1^{ghi}	23.4^{cdef}	709.0^{fg}	20.8^{cde}
Fol	5.0	77.8^{de}	4.7^{bcd}	82.2^{cdef}	3.6^{cdefg}	22.9^{def}	798.3^{bcd}	17.8^{fgh}
	10.0	82.2^{cde}	4.8^{bc}	83.0^{cde}	3.1^{ghi}	24.4^{abcde}	817.7^{bc}	20.1^{defg}
	15.0	93.3^{ab}	5.7^{a}	93.3^{ab}	2.6^{i}	25.7^{abc}	933.3^{a}	24.0^{a}
SWE	50.0	78.9^{de}	3.5^{efgh}	76.1^{efgh}	3.7^{cdef}	22.4^{efg}	719.3^{efg}	17.6^{gh}
	100.0	95.6^{a}	4.8^{bc}	93.3^{ab}	3.2^{fgh}	24.9^{abcd}	761.0^{cdef}	23.8^{ab}
	150.0	86.7^{abcd}	4.5^{bcd}	88.9^{abc}	3.3^{efgh}	24.6^{abcde}	744.0^{def}	21.3^{bcd}

Values within the same column followed by the same letters are not significantly different using Duncan's multiple range test at the level of 5% of probability. KNO_3: Potassium nitrate, PEG: Polyethylene glycol, ASA: Ascorbic acid; Toc: α-Tocopherol, Fol: Folic acid, SWE: Seaweed extract, GP: Germination %, GI: Germination index, GE: Germination energy; MGT: Mean germination time and SVI: Seedling vigor index, SL: Seedling length and SDW: Seedling dry weight

MGT, where priming treatments specially the moderate level of Toc (50 mg L^{-1}) in Giza 102 and high level of folic acid (15 mg L^{-1}) in Sakha 53 decreased significantly the time needed for germination of both cultivars.

The data in the same Tables indicate that all priming induced significantly seedling vigor represented as SL and 10-SDW as well as SVI as compared with unprimed control plants. Concerning Sakha 53 cultivar, it was observed from Table 1 that all priming treatments significantly increased, in most cases for all SV parameters. Higher SL (26.6) and SVI (25.5) were recorded at 75 mg L^{-1} ASA. Meanwhile, the highest 10-SDW (933.3 mg) was recorded at 15 mg L^{-1} folic acid as compared with unprimed seeds.

For Giza 102 cultivar, data in Table 2 indicate that all priming treatments significantly increased SV parameter but the difference between higher concentration of PEG (0.3 g mL^{-1} water) and control treatment in SVI was not significant. Among all the priming treatments, the highest SL (24.0 cm) was recorded at 50 mg L^{-1} Toc, meanwhile, 10-SDW (799.3 mg) and SVI (22.7) were recorded at 75 mg L^{-1} ASA as compared with the plants which resulted from unprimed seeds.

It could be concluded from the previous results that the responses of cultivars to priming treatments were different. This difference in germination by different varieties of various sunflower cultivars might be due to genetic potential of the variety (Khalil *et al*., 2003). The reason could be that water is a natural solvent which led to availablity of nutrients to the seedlings. The probable reason could be that presoaking cause's completion of pre-germinative metabolic activities of the seed, making the seed ready for radical protrusion and the seed get germinated soon. This may be also due to increase in activity of enzymes. These enzymes have great role in breakdown of

Table 2: Seed and seedling vigor characters of Giza 102 cultivar as affected by seed priming

Treatments	Concentration (mg L^{-1})	GP	GI	GE	MGT	SL (cm)	10-SDW (mg)	SVI
Control		82.2^{ef}	3.5^{f}	83.1^{ef}	4.6^{a}	17.0^{h}	407.7^{h}	13.9^{i}
Hydropriming		88.9^{abcdef}	4.0^{def}	90.9^{abcde}	3.5^{efg}	18.9^{fgh}	490.3^{efgh}	16.8^{fgh}
KNO_3	250.0	84.5^{def}	4.1^{cdef}	89.5^{bcde}	4.0^{bcd}	19.8^{defg}	487.7^{efgh}	16.7^{gh}
	500.0	93.3^{abcd}	4.5^{abc}	93.9^{abcd}	3.9^{bcde}	22.0^{abcd}	477.0^{efgh}	20.6^{abcd}
	750.0	95.6^{abc}	4.6^{ab}	96.0^{abc}	3.4^{fg}	21.8^{abcd}	541.7^{def}	20.9^{abcd}
PEG (g mL^{-1} H_2O)	0.1	88.9^{abcdef}	3.9^{def}	89.6^{bcde}	3.6^{defg}	23.4^{abc}	619.3^{cd}	20.7^{abcd}
	0.2	80.0^{f}	3.7^{ef}	80.6^{f}	4.0^{bcd}	21.8^{abcd}	465.3^{fgh}	17.5^{efgh}
	0.3	68.9^{g}	3.1^{g}	70.6^{g}	4.2^{abc}	19.3^{efg}	434.3^{gh}	13.2^{i}
ASA	25.0	86.7^{bcdef}	3.9^{def}	87.3^{def}	4.3^{ab}	21.0^{def}	517.0^{defg}	18.2^{defg}
	50.0	91.1^{abcde}	4.1^{cdef}	91.6^{abcd}	3.6^{defg}	21.4^{cde}	723.3$_{ab}$	19.5^{bcdef}
	75.0	96.7^{ab}	4.4^{abcd}	97.3^{ab}	3.4^{fg}	23.6^{abc}	799.3^{a}	22.7^{a}
Toc	25.0	85.6^{cdef}	4.2^{bcde}	86.2^{def}	4.3^{ab}	19.8^{defg}	448.7^{fgh}	16.9^{fgh}
	50.0	91.7^{abcde}	4.9^{a}	92.2^{abcd}	3.2^{g}	24.0^{a}	581.0^{cde}	22.0^{ab}
	75.0	91.1^{abcde}	4.4^{abcd}	93.9^{abcd}	4.2^{abc}	21.7^{bcd}	553.7^{cdef}	19.8^{bcde}
Fol	5.0	84.4^{def}	4.2^{bcde}	86.5^{def}	4.1^{bc}	20.2^{def}	491.0^{efgh}	17.0^{fgh}
	10.0	86.7^{bcdef}	4.4^{abcd}	88.3^{cdef}	3.4^{fg}	21.6^{bcd}	495.3^{efgh}	18.7^{cdefg}
	15.0	91.1^{abcde}	4.7^{ab}	91.6^{abcd}	3.2^{g}	23.7^{ab}	646.3^{bc}	21.6^{ab}
SWE	50.0	84.4^{def}	3.9^{def}	87.4^{def}	3.8^{cdef}	17.9^{gh}	464.3^{fgh}	15.2^{hi}
	100.0	97.8^{a}	4.6^{ab}	98.4^{a}	3.4^{fg}	21.7^{bcd}	609.7^{cd}	21.3^{abc}
	150.0	95.6^{abc}	4.5^{abc}	96.2^{abc}	3.3^{fg}	20.4^{def}	525.3^{defg}	19.5^{bcdef}

Values within the same column followed by the same letters are not significantly different using duncan's multiple range test at the level of 5% of probability. KNO_3: Potassium nitrate, PEG: Polyethylene glycol, ASA: Ascorbic acid, Toc: α-tocopherol, Fol: Folic acid, SWE: Seaweed extract, GP: Germination%, GI: Germination index, GE: Germination energy, MGT: Mean germination time and SVI: Seedling vigor index, SL: Seedling length and SDW: Seedling dry weight

macromolecules such as amylase, protease and lipase for growth and development of embryo that ultimately resulted in early and higher seedling emergence and better synchronized germination. These results are agreed with those reported by Singh and Rao (1993) and Wahid *et al.* (2008).

Primed seeds usually exhibit increased germination rate, greater germination uniformity and sometimes-greater total germination percentage (Basra *et al.*, 2005). Hydropriming improved SV of sunflower as indicated by GP and seedling growth in laboratory experiment (Table 1, 2). Priming may improve germination by accelerating imbibition which in turn would facilitate the emergence phase and the manipulation of radical cells (McDonald, 1999). It is obvious that hydro-primed seeds can rapidly imbibe and revive the seeds metabolism, enhancing GR which can lead to the production of large and uniform seedlings (McDonald, 2000). The earlier germination might be attributed to increased metabolic activities in the hydroprimed seeds (Basra *et al.*, 2002). Similar results were stated by Kaya *et al.* (2006) and Wahid *et al.* (2008).

The greater efficiency of osmohardening with potassium nitrate is possibly related to the osmotic advantage that K^+ has in improving cell water status. Also in that, they act as cofactors in the activities of numerous enzymes (Taiz and Zeiger, 2006). These results are partially in line with those reported by Singh and Rao (1993).

Seed priming with PEG decreased speed of emergence and vigor index as compared with non-primed and primed seeds. This negative effect of high PEG concentration which led to reduce the oxygen concentration in the solution due to the viscous nature of PEG which in turn may, has negative effects on both protein synthesis and degradation and hamper respiration processes during the seed germination. Also, the negative effect of high PEG solution may be due to its effect

in reducing seed water imbibitions as compared with distilled water (Ahmadi *et al*., 2007) due to its osmotic effect. Similar results were reported by Kaya *et al*. (2006) and Moradi and Younesi (2009).

Concerning vitamin priming, results indicated that vigour response was indeed higher in response to Fol and ASA treatments. In the case of ASA, the highest concentration was most effective in terms of enhanced vigour response and in folic acid the lowest concentration was most effective. ASA is an important metabolite involved in many cellular processes, including cell division (De Gara *et al*., 2003). There are many reports indicate that seed priming with ASA improved performance from wheat seeds treated with ascorbate (Basra *et al*., 2006). Similar results were confirmed by Wahid *et al*. (2008). This study found that ascorbic acid increased SL in treated seed. The effect of additional ascorbic acid on plant survival is associated with the partial inhibition of a few interactions in reactive oxygen species production (Gadalla, 2009). These results proved that priming reduced MGT and improved GE and GP as well as increased 10- SDW. To our knowledge, there are not information about the influences of folic acid and seaweed extract priming techniques on seed germination, seedling growth and vigor and need more and more experiments.

Field experiments

Yield and its components: With respect to cultivars performance, it was found that the two tested cultivars significantly differed in yield, its components and quality in both seasons (Table 3). Sakha 53 gave the highest values of capitulum diameter (22.5 and 21.3 cm), 100-seed weight (8.8 and 8.2 g), seed yield/plant (64.2 and 61.1g), seed yield ha^{-1} (3.98 and 3.83 ton) and seed oil content (39.8 and 40.4%) in the first and second seasons, respectively. However, Giza 102 gave the highest seed protein content (21.0%) in the first season only. But, there is no significant difference between Sakha 53 and Giza 102 in protein % in the second season. The variation between the two sunflower cultivars might be due to the genetic background and their differences in capitulum diameter and yield components that resulted in differences in seed yield ha^{-1}. The present results are in agreement with those of Abdel-Motagally and Osman (2010) and Ahmed *et al*. (2010).

The data in Table 3 indicated that all priming treatments significantly increased in most cases for yield and its components as well as quality of sunflower in both seasons. The minimum increase was obtained under the hydropriming as compared with unprimed control plants which was similar to that of control. Using of 75 mg L^{-1} ASA priming produced the highest capitulum diameter (22.3 and 21.3 cm), 100-seed weight (9.8 and 9.1 g) and seed yield ha^{-1} (3.86 and 3.76 ton) in both seasons, respectively, as well as seed yield/plant (61.5 g) and seed protein percentage (22.9%) in the first season only. Maximum oil % recorded at 15 mg L^{-1} Fol or 100 mg L^{-1} SWE priming (40.0 or 39.5 and 40.5 or 40.6%) in both seasons, respectively. Also, the highest seed yield/plant (58.5 g) and protein % (23.2%) produced from 15 mg L^{-1} Fol priming in the second season only. There is no significant between ASA and Fol priming in seed protein % in the second season. The lowest values of all previous characters resulted from unprimed seed (control). Improved seed yield from primed seeds seems the result of improved yield contributing factors i.e., capitulum diameter and 100-seed weight. The increase in seed yield due to seed priming treatments, in particular, ASA or Toc may be the results of their responding increase in potassium content which enhanced photosynthetic pigments, leading to enhanced dry matter accumulation (Gadalla, 2009) and growth parameter which may reflected as improvement in plant fruiting performance and seed yield (Farouk, 2010). Moreover, the same author proved that application of both vitamins enhancing protein synthesis and delaying senescence and/or might be related to increase in

Table 3: Yield and its components, oil and protein % of Sakha 53 and Giza 102 cultivars as affected by seed priming during 2009 and 2010 seasons

	Characters											
	Capitulum diameter (cm)		100-Seed weight (g)		Seed yield (g plant^{-1})		Seed yield (ton ha^{-1})		Oil (%)		Protein (%)	
Treatments	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Cultivars												
Sakha 53	22.5	21.3	8.8	8.2	64.2	61.1	3.98	3.83	39.8	40.4	20.6	21.0
Giza 102	18.9	17.3	8.3	7.5	51.2	47.7	3.20	3.06	37.0	37.3	21.0	21.4
F. test	**	**	**	**	**	**	**	**	**	**	**	NS
Seed priming												
Control	18.1^{d}	16.1^{c}	6.8^{e}	6.2^{e}	51.9^{d}	48.9^{c}	3.11^{c}	2.93^{d}	36.3^{c}	36.4^{d}	18.6^{e}	18.0^{d}
Hydropriming	19.1^{cd}	17.5^{bc}	8.0^{d}	7.2^{d}	53.4	50.6^{bc}	3.25^{c}	3.12^{cd}	37.6^{b}	37.2^{cd}	18.8^{e}	18.8^{d}
KNO_3 (750 mg L^{-1})	20.3^{bc}	19.3^{ab}	8.2^{d}	7.4^{d}	55.7^{c}	52.7^{abc}	3.49^{b}	3.35^{bc}	37.6^{b}	38.5^{bc}	19.9^{d}	20.7^{c}
PEG (0.1 g mL^{-1} H2O)	21.4^{ab}	19.6^{ab}	8.9^{bc}	8.3^{bc}	59.2^{ab}	54.1^{abc}	3.72^{a}	3.59^{ab}	38.2^{b}	39.0^{abc}	21.1^{c}	21.7^{abc}
ASA (75 mg L^{-1})	22.3^{a}	21.3^{a}	9.8^{a}	9.1^{a}	61.5^{a}	57.0^{ab}	3.86^{a}	3.76^{a}	39.9^{a}	39.2^{ac}	22.9^{a}	23.3^{a}
Toc (50 mg L^{-1})	21.3^{ab}	19.4^{ab}	8.4^{cd}	7.8^{cd}	58.7^{b}	56.0^{ab}	3.73^{a}	3.60^{ab}	38.1^{b}	39.5^{ab}	20.8^{c}	21.2^{bc}
Fol (15 mg L^{-1})	21.3^{ab}	20.8^{a}	9.0^{bc}	8.7^{ab}	60.4^{ab}	58.5^{a}	3.82^{a}	3.68^{ab}	40.0^{a}	40.5^{ab}	22.4^{b}	23.2 a
SWE (100 mg L^{-1})	22.0^{ab}	20.6^{a}	9.2^{ab}	8.6^{ab}	60.6^{ab}	57.3^{ab}	3.70^{ab}	3.52^{ab}	39.5a	40.6^{a}	21.9^{b}	22.5^{ab}
Interaction												
A×B	NS	NS	**	**	**	NS	NS	NS	**	NS	**	NS

Values within the same column followed by the same letters are not significantly different using Duncan's multiple range test at the level of 5% probability. Hydro: Hydropriming, KNO_3: Potassium nitrate, PEG: Polyethylene glycol, ASA: Ascorbic acid, Toc: α-tocopherol, Fol: Folic acid and SWE: Seaweed extract, **: High significant and NS: Non significant

photosynthetic products which constitute an improved supply source for sinks leading to increase in seed yield. Similar results were obtained by Harris *et al.* (2001) and Hussain *et al.* (2006). Moreover, seaweed extract priming improved yield of sunflower may be due to high contents of cytokinin (Zhang and Ervin, 2004) which reduce ethylene production, leading to increasing fruit number per head and consequently increased seed yield per plants.

There are some few studies interested with application of some vitamins on improving protein content in the seeds. In this concern, some paper reveal that, application of ascorbic acid significantly increased nitrogen content in sunflower seeds (El-Gabas, 2006) which reflected to increase seed protein content as compared with untreated plants.

All interactions had no significant effect on seed yield, its components and quality in the second season, except for the interaction between cultivars and seed priming treatments in 100-seed weight seed yield/plant, seed oil and protein percentages (Table 3). Data in Table 4 cleared that the interaction between sunflower cultivars and seed priming had a highly significant effect on 100-seed weight (in both seasons), seed yield/plant and seed oil and protein percentages in the first season only. Maximum 100-seed weight (10.2 g) produced from Giza 102 and seed primed with 75 mg L^{-1} ASA in the first season. In addition, the highest value of 100 - seed weight (in the second season), seed yield/plant (67.6 g) and oil % (42.6%) in the first season only resulted from Sakha 53 and using 15 mg L^{-1} Fol priming as compared with unprimed seed. Maximum protein % was obtained from Giza 102 and using of 75 mg L^{-1} ASA in 2009 season only (23.8%). There is no significant between 15 mg L^{-1} Fol and 100 mg L^{-1} SWE in oil % of Sakha 53 and Giza 102 in 2009 season. The minimum increased was obtained due to hydropriming which in most cases the differences were not significant as compared with unprimed seeds, where in Sakha 53 cultivar which having more oil percentage as compared with Giza 102 cultivar.

Table 4: Effect of the interaction between sunflower cultivars and seed priming on 100-seed weight (2009 and 2010 seasons), seed yield/plant, oil and protein % during 2009 season

	Characters									
	100-seed weight (g)				Seed yield/(g/plant)		Oil %		Protein %	
	2009		2010		2009		2009		2009	
Treatments	Sakha 53	Giza 102	Sakha 53	Giza 102	Sakha 53	Giza 102	Sakha 53	Giza 102	Sakha 53	Giza 102
Control	7.3^{g}	6.3^{h}	6.8^{fg}	5.5^{h}	60.4^{d}	43.3^{i}	36.6^{de}	35.9^{e}	18.6^{i}	18.6^{i}
Hydropriming	8.5^{cdef}	7.4^{fg}	7.7^{defg}	6.6^{g}	61.6^{cd}	45.3^{i}	38.8^{bc}	36.5^{de}	18.8^{hi}	18.7^{i}
KNO_3 (750 mg L^{-1})	8.6^{cde}	7.8^{efg}	7.8^{cdef}	7.0^{efg}	62.3^{bcd}	49.1^{h}	38.5^{bc}	36.7^{de}	19.6^{gh}	20.3^{fg}
PEG (0.1g mL^{-1} H_2O)	8.7^{cde}	9.2^{abcd}	8.0^{cde}	8.5^{bcd}	64.4^{abc}	53.9^{efg}	38.9^{bc}	37.4^{cde}	20.7^{ef}	21.5^{de}
ASA (75 mg L^{-1})	9.4^{abc}	10.2^{a}	8.8^{abc}	9.5^{ab}	66.0^{a}	57.0^{e}	41.9^{a}	37.8^{bcd}	22.1^{cd}	23.8^{a}
Toc (50 mg L^{-1})	8.5^{bcde}	8.0^{efg}	8.3^{cd}	7.2^{efg}	65.4^{ab}	52.0^{gh}	39.4^{b}	36.7^{de}	20.6^{f}	21.0^{ef}
Fol (15 mg L^{-1})	9.8^{ab}	8.2^{defg}	9.7^{a}	7.7^{defg}	67.6^{a}	53.2^{fg}	42.6^{a}	37.3^{cde}	23.3^{ab}	21.5^{de}
SWE (100 mg L^{-1})	9.2^{abcd}	9.2^{abcd}	8.7^{abcd}	8.4^{bcd}	65.6^{ab}	55.7^{ef}	41.6^{a}	37.5^{cde}	20.9^{ef}	22.8^{bc}

Values within the same column followed by the same letters are not significantly different using Duncan's multiple range test at the level of 5% probability. Hydro, Hydropriming: KNO_3: Potassium nitrate, PEG: Polyethylene glycol, ASA: Ascorbic acid, Toc: α-tocopherol, Fol: Folic acid and SWE: Seaweed extract

Considering that over 30 reactions are required to convert acetyl-Co A to TAG (Stymne and Stobart 1987). The regulatory or metabolic factors that influence, the wide range of oil accumulation in seeds are currently unknown (Ohlragge and Jaworski 1997). Activities of a number of lipid-synthetic enzymes parallel oil accumulation in oilseeds. From these results we can conclude that in most cases all priming treatments may be improved oil percentage especially in Sakha 53 cultivar in both seasons. In this concern there are well known that ASA, Toc, SWE and Fol served as a natural antioxidants.

It could be concluded that the field traits improvement may be due to the enhancement of the laboratorial traits resulted from priming treatments. In other words, increase germination percentage and seedling dry weight due to the seed priming treatment led to the earlier establishment of sunflower cultivars and production a developed crop canopy on the soil surface. This can be attributed to the better seed performance resulted from the seed priming process. According to Halmer (2004) typical responses to priming are faster and closer spread of times to emergence overall seedbed environments and wider temperature range of emergence, leading to better crop stands and hence improved yield and quality.

Fatty acids composition of extracted crude oil: Regarding Sakha 53 cultivar, the data in Table 5 indicate that the highest value of total monounsaturated fatty acids percentage was obtained from seed primed with folic acid (50.12%) followed by hydropriming (49.71%). ASA priming gave the lowest value (34.58%) but it still above the control (32.75%). Meanwhile, the highest value of total polyunsaturated fatty acids (57.06%) was obtained from unpriming seed followed by ASA priming (54.69%). While, the lowest percentage of total polyunsaturated a fatty acid was obtained by folic acid priming (39.25%). The minimum ratio between oleic to linoleic acid was obtained from control (0.57). Vice versa, the maximum ratio was recorded from folic acid priming (1.27) followed by hydropriming (1.23) as compared with control. All priming treatments except for hydopriming and potassium nitrate priming showed the highest saturated fatty acids percentage, meanwhile enhanced the ratio between unsaturated and saturated fatty acids.

Table 5: Oil constituents (Fatty acids composition %) of Sakha 53 cultivar as affected by seed priming during 2010 season

	Treatments							
Fatty acids (%)	Control	Hydro	KNO_3	PEG	ASA	Toc	Fol	SWE
Monounsaturated								
Palmitoleic (16:1)	0.12	0.10	0.10	0.11	0.11	0.10	0.11	0.12
Oleic (18:1)	32.42	49.34	46.03	38.96	34.27	38.18	49.79	35.58
Gadolic (20:1)	0.21	0.27	0.20	0.21	0.20	0.21	0.22	0.20
Total	32.75	49.71	46.33	39.28	34.58	38.49	50.12	35.90
Polyunsaturated								
Linoleic (18:2)	56.99	40.23	43.49	50.29	54.62	50.63	39.17	53.65
Linolenic (18:3)	0.07	0.09	0.06	0.08	0.07	0.07	0.08	0.08
Total	57.06	40.32	43.55	50.37	54.69	50.70	39.25	53.73
Totalunsaturated	89.81	90.03	89.88	89.65	89.27	89.19	89.37	89.63
Olic/linoleic	0.57	1.23	1.06	0.77	0.63	0.75	1.27	0.66
Saturated								
Myristic (14:0)	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.06
Palmitic (16:0)	5.66	4.92	5.13	5.34	5.62	5.24	5.08	5.69
Margaric (17:0)	0.04	0.03	0.04	0.04	0.04	0.04	0.03	0.04
Stearic (18:0)	3.25	3.48	3.58	3.60	3.57	3.89	3.86	3.27
Arachedonic (20:0)	0.29	0.33	0.29	0.30	0.30	0.33	0.39	0.28
Behenic (22:0)	0.66	0.79	0.73	0.74	0.77	0.88	0.86	0.70
Lignoceric (24:0)	0.15	0.30	0.26	0.26	0.28	0.32	0.31	0.27
Total	10.11	9.91	10.08	10.33	10.63	10.75	10.58	10.31
Unsaturated/saturated	8.88	9.08	8.92	8.68	8.40	8.30	8.45	8.69

Hydro: Hydropriming, KNO_3: Potassium nitrate, PEG: Polyethylene glycol, ASA: Ascorbic acid, Toc, α-tocopherol, Fol: Folic acid and SWE: Seaweed extract

Concerning Giza 102 cultivar, the data in Table 6 indicated that priming treatments (hydropriming, potassium nitrate, folic acid) gave the highest values of total monounsaturated fatty acids percentage, meanwhile the lowest values of total monounsaturated fatty acids percentage produced from the other priming treatments (PEG, ASA, Toc and SWE) as compared with unprimed seed (control) (29.79%). The highest value of total monounsaturated fatty acids was obtained with hydropriming (39.15%) followed by folic acid (31.39%) and KNO_3 (31.26%). All priming treatments increased total polyunsaturated fatty acids except for hydropriming, folic acid priming and seaweed extract priming which decreased the percentage as compared with untreated seeds. The maximum value (62.01%) was obtained in Toc-priming followed by ASA-priming (61.36%). Concerning total unsaturated fatty acids, the data in the same table indicate that all priming treatments decreased clearly total unsaturated fatty acids. The ratio between oleic to linoleic acid have the same trend as monounsaturated fatty acids. The highest values of saturated fatty acids percentage was obtained due to hydropriming (19.02%) followed by ASA priming (11.80) as compared with unprimed seeds (10.25%) but gave the lowest ratio between unsaturated and saturated fatty acids. Generally Sakha 53 is better than Giza 102 as an oil source because of its highest content of oleic acid as well as unsaturated fatty acids percentages.

The previous research has demonstrated that fatty acids composition of sunflower oil may be affected by genetic and environmental conditions (Skoric *et al*., 2008). Moreover, Fatty acid composition and the proportions of different fatty acids of the seed oil due to seed priming treatments are dependent on the degradation rate of different fatty acids which convert to each other (Muangkaeo *et al*., 2005).

Table 6: Oil constituents (Fatty acids composition %) of Giza 102 cultivar as affected by seed priming during 2010 season

	Treatment							
Fatty acids (%)	Control	Hydro	KNO_3	PEG	ASA	Toc	Fol	SWE
Monounsaturated								
Palmitoleic (16:1)	0.12	0.57	0.11	0.11	0.15	0.12	0.11	0.11
Oleic (18: 1)	29.47	38.37	30.94	27.72	26.28	26.30	31.04	28.49
Gadolic (20:1)	0.20	0.21	0.21	0.21	0.34	0.24	0.24	0.19
Total	29.79	39.15	31.26	28.04	26.77	26.66	31.39	28.79
Polyunsaturated								
Linoleic (18:2)	59.81	41.58	57.62	60.78	61.21	61.89	57.45	59.88
Linolenic (18:3)	0.08	0.19	0.11	0.11	0.15	0.12	0.13	0.09
Total	59.89	41.77	57.73	60.89	61.36	62.01	57.58	59.97
Total unsaturated	89.68	80.92	88.99	88.93	88.13	88.67	88.97	88.76
Olic/linoleic	0.49	0.92	0.54	0.46	0.43	0.42	0.54	0.48
Saturated								
Myristic (14:0)	0.07	0.29	0.07	0.06	0.08	0.07	0.07	0.07
Palmitic (16:0)	6.14	13.88	6.11	6.31	6.73	6.55	6.10	6.25
Margaric (17:0)	0.04	0.05	0.04	0.04	0.05	0.05	0.04	0.04
Stearic (18:0)	2.85	3.70	3.40	3.37	3.26	3.39	3.49	3.55
Arachedonic (20:0)	0.23	0.29	0.29	0.29	0.41	0.31	0.32	0.28
Behenic (22:0)	0.66	0.59	0.75	0.68	1.08	0.67	0.70	0.72
Lignoceric (24:0)	0.26	0.22	0.28	0.24	0.19	0.24	0.26	0.26
Total	10.25	19.02	10.94	10.99	11.80	11.28	10.98	11.17
Unsaturated/saturated	8.75	4.25	8.13	8.09	7.47	7.86	8.10	7.95

Hydro: Hydropriming, KNO_3: Potassium nitrate, PEG: Polyethylene glycol, ASA: Ascorbic acid, Toc: α-tocopherol, Fol: Folic acid and SWE: Seaweed extract

From this study, it may be concluded that seed priming agents can be used for improving the germination and seedling vigor of sunflower seeds. In addition, planting Sakha 53 cultivar and seed primed with 75 mg L^{-1} ascorbic acid or 15 mg L^{-1} folic acid can achieve high yield and oil quality of sunflower. So, seed priming can be used as a beneficial method to improve seed performance and plant traits of sunflower.

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