Seed Res. 50 (1): 21-27, June, 2022

Influence of Seed Priming Techniques for Enhancing Seed Quality in Sunflower (*Helianthus annuus* L.)

RAKSHITHA, HN[1], PARASHIVAMURTHY[1] AND HARISH MS*[2,1]

[1]Department of Seed Science and Technology, UAS, GKVK, Bengaluru, Karnataka, India
[2]Chaudhary Charan Singh Haryana Agricultural University, College of Agriculture, Bawal, Haryana, India

*harishseedtech@gmail.com

(Received November 2021; Revised March 2022; Accepted March 2022)

ABSTRACT: Seed priming is one of the economical and feasible technologies for rapid and uniform field emergence in most of the field crops. A laboratory experiment was conducted in the Seed Testing Laboratory, AICRP on Seed (Crops), NSP, University of Agricultural Sciences, GKVK, Bangalore. Out of 14 priming treatments, hydropriming for 18 h (T_3) recorded highest seed quality parameters like germination (81.80%), shoot length (17.80 cm), root length (13.92 cm), mean seedling length (31.09 cm), mean seedling dry weight (21.40 mg), SVI-I (2591) and SVI-II (1704). This was followed by priming with 2% KNO_3 for 18 h (81.0%, 16.60 cm, 13.86 cm, 29.65 cm, 21.09 mg, 2418 and 1673, respectively). Highest (1.16) dehydrogenase activity was recorded in seeds primed with 2% KNO_3 for 18 h. Hence, the seed subjected to hydropriming for 18 h and priming with 2% KNO_3 for 18 h are promising for sunflower cultivation.

Keywords: Sunflower, Seed priming and physiological parameters

INTRODUCTION

Oil seed crops occupy a very important role in agricultural economy of any country. In India, there is a large demand for vegetable oils both for edible and non-edible purposes. The urgent need to build up the economy of the country on self-supporting basis has promoted the search for non-traditional oilseed crops of our country such as sunflower, canola etc. During past 25 to 30 years, sunflower cultivation has helped to a great extent in achieving self-sufficiency in oil seed front in the country**.** Sunflower (*Helianthus annuus* L.) is a protein rich oil seed crop with high amount of unsaturated fatty acids oleic and linoleic acid, making it prone to deterioration at a faster rate, lowering its vigour and viability. The seed quality can be maintained by storing in a controlled condition, but storage of large quantities of seeds under controlled conditions is a costly affair, and hence seed treatments like priming before sowing are proposed for improving the vigour and hence the planting value of seeds.

Seed priming as a pre-sowing seed treatment in which seeds are hydrated in an osmotic solution that allows them to imbibe water and go through the first stages of germination but does not permit radical protrusion through the seed coat [1]. Rapid germination and emergence are important factors for successful stand establishment. It is reported that the seed priming can help rapid and uniform germination and emergence of seeds and increase tolerance to adverse environmental conditions upon sowing. Sunflower being an oil seed crop rich in unsaturated fatty acids, loses its vigour and viability rapidly, hence priming was attempted to improve the rate of germination, vigour and maintain a good plant population.

MATERIALS AND METHODS

A laboratory experiment was conducted to evaluate the effect of priming on seed quality parameters in sunflower hybrid KBSH-41 at STR Unit, AICRP on Seed (Crops), NSP, GKVK, Bangalore. Seed lots of different vigour levels were subjected to pre-sowing treatments for different durations. After the completion of treatment periods, the seeds were dried at room temperature. Treatment details were Factor A: Seed vigour levels (L_1 - Fresh seed lot (80.0% germination), L_2 - Old seed lot (55.0% germination); Factor B : Treatments (T_1 - Control (Untreated), T_2- Hydropriming for 12 h, T_3 - Hydropriming for 18 h, T_4 - Hydropriming for 24 h, T_5 - Priming 2% KNO_3 for 12 h , T_6 - Priming 2% KNO_3 for 18 h, T_7 - Priming 2% KNO_3 for 24 h, T_8 - Priming with 20% *Pseudomonas fluorescens* for 12 h, T_9 - Priming with 20% *Pseudomonas fluorescens* for 18 h, T_{10}- Priming with 20% *Pseudomonas fluorescens* for 24 h, T_{11}- Thermo invigoration at 35 °C

for 12 h, T_{12}- Thermo invigoration at 35 °C for 18 h, T_{13}- Thermo invigoration at 35 °C for 24 h, and T_{14}- Pre-chilling at 7.5 °C for a period of 7 days). The standard germination test was done as per the ISTA rules [2]. Electrical conductivity and TDH activity estimated following the method by [3,4] and Seedling vigour index was computed by using the formula [5].

Seedling Vigour Index- I = Germination (%) x Mean seedling length (cm)

Seedling Vigour Index -II = Germination (%) x Mean seedling dry weight (mg)

RESULTS AND DISCUSSION

Standardization of priming techniques for enhancing seed quality

The primed seeds across the treatments showed significantly higher germination percentage over Control (Table 1). Higher seed germination, shoot length, root length (87.69%, 17.91 cm and 14.01 cm), was recorded in fresh seed (L_1) lot as compared to old seed (L_2) lot (67.92%, 13.73 cm and 10.66 cm). Among the priming treatments, the highest germination, shoot and root lengths (81.80%, 17.80 cm and 13.92 cm) were recorded in T_3 (Hydropriming for 18 h-), followed by T6 (81.0%, 16.80 cm and 13.92 cm), i.e. priming with 2% KNO_3 (T6). Control (T_1) recorded the lowest germination, shoot length and root length (71.41%, 14.08 cm and 10.96 cm). Overall, the highest germination, shoot length and root length (91.48%, 20.92 cm and 16.14cm) were recorded in L_1T_3 and L_2T_3 (hydropriming for 18 h), followed by the interaction of L_1T_6 and L_2T_6 (90.24%, 19.16cm, 15.90, and 72.13%, 14.44 cm and 11.65 cm respectively).

Hydropriming for 18 h resulted in significantly higher germination compared to control. Soaking of sunflower seed leads to enhanced water imbibition may be attributed to enzyme activation, translocation and utilization of reserve food materials and increased respiration. Another possible action of priming is suggested to be leaching of germination inhibitors from seeds [6]. KNO_3 balances the hormones within the seed which reduces the ratios of germination inhibitors like abscisic acid. Similar results on effect of priming with KNO_3 were reported in bitter gourd seeds [7, 8]. Hydroprimed seeds produced the largest roots compared to other seed priming treatments in sunflower seeds [9]. It is stipulated that primed seeds are simultaneously subjected to processes of repair and deterioration and force between the two determines the success or failure of the treatment [10].

Among different seed vigour levels, effect of priming treatment was significant on the mean seedling length (Table 2), which varied from 32.07 cm and 24.38 cm in fresh seed lot (L_1) and old seed lot (L_2) respectively. Increase in mean seedling length (31.72 cm) was recorded in Hydropriming for 18 h (T_3), followed by 30.57 cm in T_6 (Priming with 2% KNO_3) in the low vigour seeds. While, lowest mean seedling length (25.04 cm) was recorded in unprimed seeds (T_1). The highest mean seedling length (37.04 and 26.29 cm respectively) was recorded in L_1T_3 and L_2T_3 (Hydropriming for 18 h) respectively. Thus, priming treatments positively influenced the mean seedling lengths irrespective of the vigour levels of seeds. Increase in mean seedling length might be due to faster emergence of seeds which led to production of vigorous seedlings as hydro primed seeds of sunflower and wheat are reported to have germinated faster and produced taller seedlings compared to untreated seed [11,12]. Different vigour levels and seed priming treatments significantly influenced the mean seedling dry weight too, which is an important indicator of the planting value of the seed (Table 2). Fresh seed lot (L_1) recorded the higher mean seedling dry weight (21.73 mg) than the old seed lot (L_2) (19.06 mg). Hydropriming for 18 h (T_3) recorded highest mean seedling dry weight (21.40 mg). This was followed by treatment T_6 (priming with 2% KNO_3) which recorded mean seedling dry weight of 21.09 mg. The control (T_1) recorded the lowest mean seedling dry weight (19.11 mg). The highest mean seedling dry weights (23.16 and 19.63 mg, respectively) were recorded in L_1T_3 and L_2T_3 (Hydropriming for 18 h) respectively, which was followed by L_1T_6 (22.95 mg) and L_2T_6 (19.21 mg). Faster and vigorous growth of seedlings in primed seeds is one of the reasons for increase in seedling dry weight. Hydropriming showed substantially higher growth with respect to root and shoot length in comparison with seedlings obtained from non-primed seeds in chickpea [13].

Increased seedling vigour index-I was recorded in primed seeds among the different seed vigour levels (Table 2). The fresh seed lot (L_1) was recorded significantly higher seedling vigour index-I (2763) whereas, the old seed lot (L_2) was noticed the lower seedling vigour index-I (1649). Hydropriming for 18 h (T_3) was recorded the highest seedling vigour index-I (2591) of all the treatments

Table 1. Influence of different seed vigour and seed priming treatments on germination, shoot length and root length in sunflower

Treatments	Seed germination (%)	Shoot length (cm)	Root length (cm)
Lots			
L_1 - Fresh lot	87.69	17.91	14.01
L_2 - Old lot	67.92	13.73	10.66
Mean	77.81	15.82	12.34
SEm ±	0.45	0.09	0.07
CD @ 1%	1.71	0.36	0.24
Treatments			
T_1 - Control (Untreated)	71.41	14.08	10.96
T_2 - Hydropriming for 12 h	76.07	16.07	12.61
T_3 - Hydropriming for 18 h	81.80	17.80	13.92
T_4 - Hydropriming for 24 h	77.86	16.455	13.05
T_5 - Priming 2% KNO_3 for12 h	77.87	15.97	12.22
T_6 - Priming 2% KNO_3 for18 h	81.00	16.80	13.77
T_7 - Priming 2% KNO_3 for 24 h	76.96	14.99	11.96
T_8 - Priming with 20% *Pseudomonas fluorescens* for 12 h	80.47	16.50	12.88
T_9 - Priming with 20% *Pseudomonas fluorescens* for 18 h	78.40	14.98	11.30
T_{10}- Priming with 20% *Pseudomonas fluorescens* for 24 h	75.20	14.96	11.46
T_{11}- Thermo invigouration at 35 ºC for 12 h	74.43	15.36	12.21
T_{12}- Thermo invigouration at 35 ºC for 18 h	78.47	15.36	12.06
T_{13}- Thermo invigouration at 35 ºC for 24 h	79.85	15.95	12.68
T_{14}- Pre-chilling at 7.5ºC for a period of 7 days	79.35	16.15	12.56
Mean	77.80	15.81	12.40
SEm ±	1.20	0.25	0.17
CD @ 1%	4.54	0.97	0.65
Interactions			
L_1T_1	86.42	15.97	12.80
L_1T_2	85.20	18.93	15.17
L_1T_3	91.48	20.92	16.14
L_1T_4	87.51	19.01	15.29
L_1T_5	88.20	17.83	13.43
L_1T_6	90.24	19.16	15.90
L_1T_7	86.36	16.42	13.64
L_1T_8	89.49	18.51	14.08
L_1T_9	87.54	16.34	12.96
L_1T_{10}	87.87	16.78	12.87
L_1T_{11}	84.96	17.35	13.70
L_1T_{12}	86.69	16.92	13.75
L_1T_{13}	87.83	17.81	14.31
L_1T_{14}	87.88	18.46	14.13
L_2T_1	56.41	12.20	9.11
L_2T_2	66.94	13.20	10.05
L_2T_3	72.51	14.68	11.82
L_2T_4	68.21	13.60	10.80
L_2T_5	67.55	14.11	11.00
L_2T_6	72.13	14.44	11.65
L_2T_7	67.55	13.57	10.27
L_2T_8	70.70	14.38	11.67
L_2T_9	69.26	13.63	9.63
L_2T_{10}	62.53	13.15	10.05
L_2T_{11}	63.90	13.36	10.72
L_1T_{12}	70.24	13.80	10.36
L_2T_{13}	72.07	14.09	11.04
L_2T_{14}	70.82	13.84	10.98
Mean	77.80	15.80	12.40
SEm ±	1.70	0.36	0.24
CD @ 1%	6.42	1.37	0.91
CV (%)	3.79	3.99	3.42

Table 2. Influence of different seed vigour and seed priming treatments on mean seedling length, mean seedling dry weight and seedling vigour index-I in sunflower

Treatments	Mean seedling length (cm)	Mean seedling dry weight (mg)	SVI-I
Lots			
L_1 - New lot	32.07	21.73	2763
L_2 - Old lot	24.38	19.06	1649
Mean	28.23	20.40	2206
SEm ±	0.15	1.05	16.95
CD @ 1%	0.57	3.98	63.94
Treatments			
T_1 - Control (Untreated)	25.04	19.11	1833
T_2 - Hydropriming for 12 h	27.88	19.97	2144
T_3 - Hydropriming for 18 h	31.72	21.40	2591
T_4 - Hydropriming for 24 h	29.48	20.49	2281
T_5 - Priming 2% KNO_3 for12 h	28.19	20.26	2256
T_6 - Priming 2% KNO_3 for18 h	30.57	21.09	2418
T_7 - Priming 2% KNO_3 for 24 h	26.93	20.34	2078
T_8 - Priming with 20% *Pseudomonas fluorescens* for 12 h	29.36	20.79	2376
T_9 - Priming with 20% *Pseudomonas fluorescens* for 18 h	26.26	20.41	2069
T_{10}- Priming with 20% *Pseudomonas fluorescens* for 24 h	26.41	20.19	2019
T_{11}- Thermo invigouration at 35 ºC for 12 h	27.56	20.12	2069
T_{12}- Thermo invigouration at 35 ºC for 18 h	27.41	19.98	2155
T_{13}- Thermo invigouration at 35 ºC for 24 h	28.62	20.92	2297
T_{14}- Pre-chilling at 7.5 ºC for a period of 7 days	28.72	20.43	2299
Mean	28.16	20.40	2206
SEm ±	0.40	2.78	44.86
CD @ 1%	1.50	10.52	169.17
Interactions			
L_1T_1	28.78	19.72	2477
L_1T_2	34.07	20.67	2756
L_1T_3	37.04	23.16	3307
L_1T_4	34.30	21.66	2923
L_1T_5	32.21	21.85	2822
L_1T_6	35.02	22.95	2941
L_1T_7	29.97	21.58	2551
L_1T_8	32.51	22.24	2909
L_1T_9	29.21	21.91	2523
L_1T_{10}	29.58	21.54	2599
L_1T_{11}	31.03	21.55	2613.
L_1T_{12}	30.61	20.64	2627
L_1T_{13}	32.09	22.86	2787
L_1T_{14}	32.63	21.74	2845
L_2T_1	21.30	18.49	1189
L_2T_2	23.17	19.26	1533
L_2T_3	26.29	19.63	1876
L_2T_4	24.32	19.32	1639
L_2T_5	25.12	18.66	1690
L_2T_6	26.23	19.21	1895
L_2T_7	23.89	19.11	1605
L_2T_8	26.20	19.34	1844
L_2T_9	23.31	18.91	1614
L_2T_{10}	23.24	18.83	1439
L_2T_{11}	24.09	18.69	1525
L_1T_{12}	24.21	19.33	1683
L_2T_{13}	25.15	18.87	1807
L_2T_{14}	24.80	19.12	1752
Mean	28.23	20.39	2206
SEm ±	0.56	3.99	63.44
CD @ 1%	2.13	14.89	239.25
CV (%)	3.49	3.35	4.97

Table 3. Influence of different seed vigour and seed priming treatments on seedling vigour index-II, electrical conductivity and total dehydrogenase activity in sunflower

Treatments	SVI-II	EC (μScm^{-1})	TDH (A@480nm)
Lots			
L_1 - Fresh lot	1896	206.46	1.10
L_2 - Old lot	1267	266.669	0.61
Mean	1581	236.56	0.86
SEm ±	10.37	2.09	0.01
CD @ 1%	39.12	7.88	0.03
Treatments			
T_1 - Control (Untreated)	1423	277.23	0.70
T_2 - Hydropriming for 12 h	1538	229.52	0.78
T_3 - Hydropriming for 18 h	1704	195.02	1.14
T_4 - Hydropriming for 24 hour	1480	209.32	0.73
T_5 - Priming 2% KNO_3 for12 hour	1582	234.67	0.78
T_6 - Priming 2% KNO_3 for18 hour	1673	215.84	1.16
T_7 - Priming 2% KNO_3 for 24 hour	1575	255.12	0.77
T_8 - Priming with 20% *Pseudomonas fluorescens* for 12 hour	1635	228.16	0.99
T_9 - Priming with 20% *Pseudomonas fluorescens* for 18 hour	1624	247.92	0.74
T_{10}- Priming with 20% *Pseudomonas fluorescens* for 24 hour	1555	243.95	0.73
T_{11}- Thermo invigouration at 35 ºC for 12 hour	1506	258.26	0.84
T_{12}- Thermo invigouration at 35 ºC for 18 hour	1590	241.68	0.89
T_{13}- Thermo invigouration at 35 ºC for 24 hour	1635	237.17	0.90
T_{14}- Pre-chilling at 7.5ºC for a period of 7 days	1619	238.14	0.73
Mean	1581	236.58	0.85
SEm ±	27.44	5.53	0.02
CD @ 1%	103.50	20.86	0.08
Interaction			
L_1T_1	1822	234.35	0.92
L_1T_2	1789	199.97	1.02
L_1T_3	2009	164.70	1.44
L_1T_4	1930	177.94	0.92
L_1T_5	1912	200.12	0.86
L_1T_6	1959	178.54	1.51
L_1T_7	1869	212.58	0.91
L_1T_8	1902	206.58	1.42
L_1T_9	1944	225.75	0.97
L_1T_{10}	1953	211.06	0.94
L_1T_{11}	1833	226.87	1.15
L_1T_{12}	1827	218.89	1.29
L_1T_{13}	1911	226.80	1.19
L_1T_{14}	1878	206.21	0.79
L_2T_1	1025	320.11	0.48
L_2T_2	1287	259.05	0.55
L_2T_3	1398	225.33	0.84
L_2T_4	1030	240.72	0.57
L_2T_5	1253	269.22	0.70
L_2T_6	1388	253.13	0.82
L_2T_7	1282	297.65	0.63
L_2T_8	1368	249.72	0.57
L_2T_9	1303	270.08	0.51
L_2T_{10}	1156	276.83	0.52
L_2T_{11}	1180	289.65	0.53
L_1T_{12}	1353	264.46	0.49
L_2T_{13}	1359	247.53	0.60
L_2T_{14}	1360	270.06	0.67
Mean	1581	236.57	0.85
SEm ±	38.81	7.82	0.03
CD @ 1%	146.38	29.50	0.11
CV (%)	4.24	5.73	5.77

followed by T_6 (2418). Unprimed seeds (T_1) was recorded the lowest seedling vigour index-I (1833). The highest seedling vigour index-I (3307 and 1876 respectively) were noted in L_1T_3 and L_2T_3 (hydropriming for 18 h) followed by L_1T_6 and L_2T_6 (Priming with 2% KNO_3) interaction which has recorded seedling vigour index-I of 2941 and 1895. Soaking of seeds in water for 18 h caused a significant increase in the seedling vigour index compared to other priming periods and non-primed seeds. Increase in seedling vigour index-I is due to increase in germination per cent and mean seedling length. Hydropriming improved the germination traits especially the vigour index of okra seeds and priming induces faster and more uniform seed germination and seedling vigour index [14].

Noticeable difference was observed between different seed vigour levels for seedling vigour index-II as influenced by seed priming treatments (Table 3). The fresh seed lot (L_1) was recorded the highest seedling vigour index-II (1896), whereas the old seed lot (L_2) was recorded the lowest seedling vigour index-II (1267). Hydropriming for 18 h was recorded the highest seedling vigour index-II (1704) followed by T_6 (1673). Control was recorded the lowest seedling vigour index-II (1423). The highest seedling vigour index-II (2009 and 1398) were noted in L_1T_3 and L_2T_3 (hydropriming for 18 h). L_1T_6 and L_2T_6 (Priming with 2% KNO_3) showed seedling vigour index-II of 1959 and 1388, which were comparable to L_1T_3 and L_2T_3, respectively. Faster germination, uniform seedling emergence and increased shoot length and root length of seedlings observed in primed seed might be due to the induction of different metabolic activities in the seed embryo which leads to increase in seedling dry weight [15,16].

Various seed priming treatments had a significant influence on the electrical conductivity among different seed vigour levels in sunflower (Table 3). Fresh seed lot (L_1) was recorded the lowest (206.46 µS cm^{-1}) electrical conductivity and old seed lot (L_2) was recorded the highest electrical conductivity (266.66 µS cm^{-1}). The least electrical conductivity (195.02 µS cm^{-1}) was observed in hydropriming for 18 h (T_3). The control (T_1) was recorded the highest electrical conductivity (277.23 µS cm^{-1}). The lowest electrical conductivity (164.70 and 225.33 µS cm^{-1} respectively) were recorded in L_1T_3 and L_2T_3 (hydropriming for 18 h) this was followed by 178.54 µS cm^{-1} in L_1T_6 (priming with 2% KNO_3). Electrolyte leakage was decreased for all priming treatments. Improvement of membrane repair occur in primed seeds which might cause the better performance because of lower leakage of electrolytes from the cells of seeds [17].

There was a significant difference between the different seed priming treatments for total dehydrogenase activity among different seed vigour levels (Table 3). The fresh seed lot (L_1) was recorded the highest (1.10) total dehydrogenase activity, whereas the old seed lot (L_2) was recorded the lowest (0.61) total dehydrogenase activity. Priming with 2% KNO_3 (T_6) recorded the highest (1.16) total dehydrogenase activity followed by T_3 (1.14). While, the Unprimed seeds (T_1) was recorded the lowest (0.70) total dehydrogenase activity. The highest total dehydrogenase activity (1.51 and 0.84 respectively) was noticed in L_1T_6 and L_2T_6 (Priming with 2% KNO_3), respectively. L_1T_3 and L_2T_3 (hydropriming for 18 h) showed total dehydrogenase activity of 1.44 and 0.84, which were on par with L_1T_6 and L_2T_6, respectively. Increased TDH activity might be an index of increased cellular biosynthetic activities like DNA and RNA synthesis that in turn indicate the higher protein and energy production necessary for germination and seedling emergence. dehydrogenase activity increased in pea cotyledon tissues during imbibition. Dehydrogenase activity indicates metabolic activity on the part of cells and increases the catalysation of amino acids [18].

CONCLUSION

It is concluded that hydropriming for 18 h with or without inorganic salt KNO_3 had significant positive effect on most of seed quality parameters like germination percentage, shoot length, root length, mean seedling length, mean seedling dry weight, SVI-I, SVI-II, EC, TDH in different vigour levels, however the highest improvement in seed quality was recorded in hydropriming for 18 h. These seed quality parameters enhancement techniques are simple, eco-friendly and easy to carry out by the farmers and could be used for enhancing crop performance and quality of different vigour seed lots of sunflower.

REFERENCES

1. HEYDECKER W, J HIGGINS AND RL GULLIVER (1973). Accelerated germination by osmotic seed treatment. *Nature*, **246**(5427): 42-44.
2. Anonymous (2009). International Rules of Seed Testing. *Seed Sci. Technol.*, **27**: 25-30.
3. MILOSEVIC MM, D VUJAKOVIC AND KARAGIC (2010). Vigour tests as indicators of seed viability. *Genetika*, **42**(1): 103-118.

4. PERL MJ AND H GELMOND (1978). Biochemical changes in sorghum seeds officials in Accelerated aging. *J. of expt. Bot.*, **29**: 497-50.

5. ABDUL-BAKI AA AND JD ANDERSON (1973). Vigour determination of soybean seeds by multiple criteria. *Crop Sci.*, **13**: 630-633.

6. HEYDECKER W AND P COOLBEAR (1978). Seed treatments for improved performance survey and attempted prognosis. *Seed Sci. Technol.*, **5**: 353–427.

7. GASHI B, K ABDULLAI, V MATA AND E KONGJIKA (2012). Effect of gibberellic acid and potassium nitrate on seed germination of the resurrection plants *Ramondaserbica* and *Ramondanathaliae*. *African J. Biotechnol.*, **11**(20): 4537-4542.

8. FONSEKA HH AND RM FONSEKA (2009). Studies on deterioration and germination of bitter gourd seed (*Momordica charantia* L.) during storage. In *V International Symposium on Seed, Transplant and Stand Establishment of Horticultural Crops,* **898**: 31-38.

9. KATHIRESAN KV, KALYANI AND JL GNANARETHINAM (1984). Effect of seed treatments on field emergence, early growth and some physiological processes of Sunflower *Helianthus annuus* L. *Field Crop Res.*, **9**: 215–217.

10. MC DONALD MB (2000). Seed priming. In: Seed technology and biological basis. Sheffield Academic Press, Sheffield, UK, 287-325.

11. KAYA MD, G OKCU, M ATAK, Y CIKILI AND O KOLSARICI (2006). Seed treatments to overcome salt and drought stress during germination in sunflower (*Helianthus annuus* L.). *European J. Agron.*, **24**(4): 291-295.

12. BASRA SMA, I AFZAL, RA RASHID AND A HAMEED (2006). Inducing salt tolerance in wheat by seed vigour enhancement techniques. *Int. J. Agril. Biol.*, **2**(1): 173-179.

13. KAUR S, AK GUPTA AND N KAUR (2002). Effect of osmo- and hydropriming of chickpea seeds on seedling growth and carbohydrate metabolism under water deficit stress. *Plant Growth Regulation*, **37**(1): 17-22.

14. NASCIMENTO WM (2005). Vegetable seed priming to improve germination at low temperature. *Horticulturae Brasileira*, **23**: 211-214.

15. MOGHANIBASHI M, H KARIMMOJENI, P NIKNESHAN AND D BEHROZI (2012). Effect of hydropriming on seed germination indices of sunflower (*Helianthus annuus* L.) under salt and drought conditions. *Plant Knowledge J.*, **1**(1): 10-15.

16. GHASSEMI-GOLEZANI K, AA ALILOO, M Valizadeh and M Moghaddam (2008). Effects of hydro and osmo-priming on seed germination and field emergence of lentil (*Lens culinaris*Medik.*). Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, **36**(1): 29-33.

17. CHIU KY, SJ CHUANG AND JM SUNG (2006). Both anti-oxidation and lipid-carbohydrate conversion enhancements are involved in priming-improved emergence of *Echinacea purpurea* seeds that differ in size. *Scientia Horticulturae*, **108**(2): 220-226.

18. MASTERSON C, A BLACKBURN AND C WOOD (2000). Acyl – CoA dehydrogenase activity in pea cotyledon tissue during germination and initial growth. *Biochem. Society Transaction,* **28**(6): 760-762.