Madras Agric. J., 98 (4-6): 124-128, June 2011
https://doi.org/10.29321/MAJ.10.100258

Effect of Priming on Stored Onion Seeds

K. Selvarani, R. Umarani and K. Sivasubramaniam*
Department of Seed Science and Technology
Agricultural College and Research Institute, Madurai - 625 104

Onion seeds were treated with water (hydropriming), sand (80% WHC) (Solid matrix priming), salts of KNO_3 and NaCl at 3% (halopriming) for 12 h and 24 h and PEG (-0.25 MPa) for 8h and 12 h (osmopriming). Seeds grouped into two lots and dried to 7% and 8% MC were packed in Aluminium foil pouch and cloth bag respectively and stored for four months under ambient conditions (33°C and 57% RH). Results of the storage experiment revealed that all the eight priming treatments imposed upon onion seeds increased the speed of germination, germination percentage, seedling length, protein content and enzyme activity but lowered the electrical conductivity of seeds when compared to control. Among the treatments, seeds hydro primed with 80% sand for 24 h bestowed supremacy over the rest of the treatments throughout the period of storage in both containers. Between the containers, seeds stored in Aluminium foil pouch recorded significantly improved percentage of radicle protrusion and germination throughout the period of storage.

Key words: Onion seed, hydropriming, sandmatrix priming, storage

Improving the seed quality is an approach which is likely to produce significant benefits in almost all circumstances without any significant increase in risk. The use of seed enhancement techniques is not new to agriculture and earlier practices have been described for such treatments (Kalyani *et al.,* 2009). Theophrastus (372-287 BC) recommended presoaking of cucumber seeds in milk or water to make them germinate quicker and better (Michael Evenari, 1984). Priming is a process in which seeds are imbibed either in water or osmotic solution or a combination of solid matrix carrier and water in specific proportions followed by drying before radicle emergence. In several studies, an increase in the nuclear DNA contents of radicle meristem cells from the G_1 to the S or G_2 phases of the cell cycle was noticed. An invigoration treatment should bring about qualitative improvement in the seed, which should persist after the treatment is stopped as the treatments are basically physiological in nature. In the last two decades, seed priming - an effective seed invigouration method - has become a common seed treatment method to increase the rate and uniformity of emergence that has been commercialized.

The recorded effects of priming treatments on the storability of seeds are some what contradictory. The advancement of the germination process during priming continuously consumes stored substances and consequently may shorten seed longevity. However, the repair of DNA damage will increase longevity (Osborne, 1983). The results obtained so far are few, limited, contrasting because of the variability of the response to treatments of cultivars and even seed lots (Bradford, 1986) which require a careful choice of the compounds to be used as osmoticum and standardization of the treatment conditions. With this point of view, the present investigation was conducted.

*Corresponding author email: seedmani@yahoo.com

Materials and Methods

Seeds of onion cv. CO5 were obtained from Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore. Onion seeds were primed with water (hydropriming), sand (80% WHC) (Solid matrix priming), salts of KNO_3 and NaCl at 3% concentration (halopriming) for 12 h and 24 h and PEG (-0.25 MPa) for 8h and 12 h (osmopriming). Based on the experimental results of the standardization of seed priming procedures two best durations in each method of priming was selected. The seeds were grouped into two lots and dried to 7% and 8% MC and packed in i) Aluminium foil pouch and (ii) cloth bag respectively. The containers were kept under ambient conditions (33oC and 57% RH) for four months.

Seed samples were drawn initially and subsequently at monthly intervals were subjected to germination test with four replicates of 100 seeds. The seeds were observed daily up to 14 days for radicle protrusion. The seeds showing less than 3mm radicle protrusion were alone counted. The speed of germination was calculated (Maguire, 1962). The number of normal seedlings were counted after 14 days and expressed as germination percentage. The length of the seedlings were measured and expressed in cm and vigour index

Table 1. Influence of storage containers, period of storage on radicle protrusion percentage of primed onion seeds

Treatment	Period of storage (months)															
	Initial			1			2			3			4			Mean
	A	C	Mean	A	C	Mean	A	C	Mean	A	C	Mean	A	C	Mean	
Control	3	3	3	3	3	3	2	1	1.5	0	0	0	0	0	0	1.5
	(9.8)	(9.8)	(9.8)	(9.8)	(9.8)	(9.8)	(7.9)	(5.7)	(5.41)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(5.41)
Hydro 12 h	17	17	17	3	3	3	2	1	1.5	1	1	1	1	1	1	4.7
	(24.34)	(24.34)	(24.34)	(9.8)	(9.8)	(9.8)	(7.9)	(5.7)	(5.41)	(5.7)	(5.7)	(5.7)	(5.7)	(5.7)	(5.7)	(10.51)
Hydro 24 h	23	23	23	14	15	14.5	14	13	13.5	12	8	10	4	2	3	12.8
	(28.64)	(28.64)	(28.64)	(21.96)	(22.77)	(22.37)	(21.96)	(21.12)	(21.12)	(20.25)	(16.41)	(17.33)	(17.33)	(7.9)	(9.8)	(20.12)
Sand 80% 12 h	8	8	8	6	7	4	4	4	2	2	2	2	2	2	2	4.6
	(16.41)	(16.41)	(16.41)	(14.14)	(15.27)	(11.47)	(11.47	(11.47)	(7.9)	(7.9)	(7.9)	(7.9)	(7.9)	(7.9)	(7.9)	(11.84)
Sand 80% 24 h	29	29	29	22	21	21.5	16	14	15	12	11	11.5	6	4	5	16.4
	(32.58)	(32.58)	(32.58)	(27.96)	(27.27)	(27.62)	(23.57)	(21.96)	(22.76)	(20.25)	(19.35)	(19.80)	(14.14)	(11.47)	(12.87)	(23.11)
-0.25 MPa 8h	3	3	3	2	2	2	2	1	1.5	2	1	1.5	2	1	1	1.9
	(9.8)	(9.8)	(9.8)	(7.9)	(7.9)	(7.9)	(7.9)	(5.7)	(5.41)	(7.9)	(5.7)	(5.41)	(7.9)	(5.7)	(5.7)	(7.69)
-0.25 MPa 12h	4	4	4	3	2	3	3	3	3	3	2	2.5	2	2	2	2.8
	(11.47)	(11.47)	(11.47)	(9.8)	(7.9)	(9.8)	(9.8)	(9.8)	(9.8)	(9.8)	(7.9)	(8.9)	(7.9)	(7.9)	(7.9)	(9.49)
3% KNO3 12 h	11	11	11	6	6	6	6	5	5.5	5	5	5	2	2	2	5.9
	(19.35)	(19.35)	(19.35)	(14.14)	(14.14)	(14.14)	(14.14)	(12.87)	(11.85)	(12.87)	(12.87)	(12.87)	(7.9)	(7.9)	(7.9)	(13.59)
3% KNO3 24 h	7	7	7	6	6	6	5	4	4.5	5	5	5	2	0	0	4.7
	(15.31)	(15.31)	(15.31)	(14.14)	(14.14)	(14.14)	(12.87)	(11.47)	(12.19)	(12.87)	(12.87)	(12.87)	(7.9)	(0.2)	(0.2)	(11.73)
3% NaCl 12 h	5	5	5	2	2	2	2	2	2	1	1	1	2	2	2	2.4
	(12.87)	(12.87)	(12.87)	(7.9)	(7.9)	(7.9)	(7.9)	(7.9)	(7.9)	(5.7)	(5.7)	(5.7)	(7.9)	(7.9)	(7.9)	(8.53)
3% NaCl 24 h	3	3	3	1	2	1.5	1	1	1	0	0	0	0	0	0	1.1
	(9.8)	(9.8)	(9.8)	(5.7)	(7.9)	(5.41)	(5.7)	(5.7)	(5.7)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(4.61)
Mean	10	10	10	6.3	6.1	6.2	5.1	4.4	4.8	3.9	3.2	3.5	5.1	1.4	1.7	
	(17.33)	(17.33)	(17.33)	(13.25)	(13.15)	(13.20)	(11.96)	(10.88)	(11.42)	(9.46)	(8.67)	(9.07)	(7.27)	(5.82)	(6.54)	

(Figures in parenthesis indicate arcsine values) A - Aluminium foil pouch ; C- Cloth bag

	P1	P2	P3	P4	P5		C1	C2
P mean	10.2	6.2	4.8	3.5	1.7	C mean	5.5	5.1
	(17.34)	(13.20)	(11.42)	(9.07)	(6.54)		(11.85)	(11.17)
	T	C	P	TxP	P x C	TxC	T x P x C	
SEd	0.314	0.134	0.212	0.703	0.299	0.444	0.994	
CD (P=0.05)	0.619	0.264	0.417	1.386	0.591	0.876	NS	

was calculated using the Abdul - Baki and Anderson (1973) formula.

Biochemical evaluations were carried out before storage and four months after storage. The seeds were analyzed for electrical conductivity (Presley, 1958), -amylase activity (Simpson and Naylor, 1962) and protein content (Ali khan and Youngs, 1973).

The observations recorded were statistically analysed using methods described by Panse and Sukatme (1978).Wherever necessary the percentage values were converted into arcsine for easier interpretation.

Results and Discussion

The results of the storage experiment revealed that all the eight priming treatments imposed upon onion seeds increased the speed of germination, germination percentage, seedling length, protein content and enzyme activity and lowered the electrical conductivity of seeds when compared to control.

Significant differences in radicle protrusion were observed for seed treatment, period of storage and containers. Among the treatments the seeds primed with 80% sand matrix (24 h) (16.4%) or hydroprimed for 24 h (12.8%) recorded supremacy over the rest of the treatments throughout the period of storage in both containers. Between the containers, seeds stored in aluminium foil pouch recorded significantly improved radicle protrusion percentage through out the period of storage (Table 1). After 4 months of storage, except halopriming (3% NaCl, 24 h), all the others treatments recorded significantly higher speed of germination than the control. However, sand matrix priming (24 h) and hydropriming (24 h) recorded the highest speed of germination, with increase of 41 and 43% over the control (Table 2). Among the treatments, 80% sand matrix priming (24 h) recorded the mean maximum germination of 91 per cent, followed by hydropriming (24 h) (90%), while control registered the minimum of 85 per cent (Table 3). Significant differences in vigour index noticed among the seed treatments, period of storage, containers and their interactions. The results revealed that vigour index decreased with increase in the period of storage from 766 (initial) to 498 (fourth month) irrespective of treatments and containers. Among the treatments 80% sand matrix primed (24 h) seeds recorded highest vigour index (778) followed by hydropriming (24 h) (712) (Table 4).

Table 2. Influence of storage containers, period of storage on speed of germination of primed onion seeds

Treatment	Period of storage (months)															
	Initial			1			2			3			4			Mean
	A	C	Mean	A	C	Mean	A	C	Mean	A	C	Mean	A	C	Mean	
Control	19.1	19.1	19.1	18.05	18.57	18.31	15.03	14.34	14.69	14.50	15.31	14.90	14.96	13.82	14.39	16.28
Hydro 12 h	23	23	23	23.72	22.20	22.96	19.12	18.06	18.59	16.10	16.81	16.45	15.72	15.15	15.43	19.26
Hydro 24 h	23.77	23.77	23.77	23.57	23.61	23.59	21.50	21.50	21.50	21.53	20.30	20.92	20.62	20.61	20.61	22.08
Sand 80% 12 h	20.92	20.92	20.92	19.62	19.60	19.61	19.50	18.75	19.12	17.50	17.31	17.40	17.31	16.39	16.85	18.78
Sand 80% 24 h	24.6	24.6	24.6	24.2	24.13	24.16	22.37	22.17	22.27	22.8	22.6	22.7	20.82	19.81	20.31	22.82
-0.25 MPa 8h	21.5	21.5	21.5	20.17	19.81	19.99	18.22	18.22	18.22	15.78	15.50	15.39	15.12	14.01	14.56	17.93
-0.25 MPa 12h	22.07	22.07	22.07	21.72	20.20	20.96	20.16	19.95	20.01	17.78	17.20	17.49	17.01	17.01	17.01	19.52
3% KNO3 12 h	22.20	22.20	22.20	21.5	21.25	21.37	18.22	18.22	18.22	16.37	16.91	16.64	16.00	15.98	15.99	18.88
3% KNO3 24 h	21.08	21.08	21.08	20.05	20.17	20.11	18.87	17.22	18.04	14.10	14.07	14.08	14.07	14.01	14.04	17.47
3% NaCl 12 h	21.32	21.32	21.32	19.33	19.31	19.32	19.01	18.97	18.99	15.36	15.36	15.36	15.38	14.31	14.84	17.97
3% NaCl 24 h	20.73	20.73	20.73	18.50	18.97	19.23	16.77	15.12	15.94	13.50	13.75	13.52	13.12	12.15	12.63	16.33
Mean	21.85	21.85	21.83	20.95	20.71	20.83	18.98	18.41	18.69	16.80	16.84	16.81	16.38	15.75	16.06	

A - Aluminium foil pouch ; C- Cloth bag

	P1	P2	P3	P4	P5		C1	C2
P mean	21.8	20.8	18.7	16.8	16.1	C mean	18.99	18.71
	T	C	P	TxP	P x C	TxC	T x P x C	
SEd	0.028	0.0123	0.0195	0.0646	0.0275	0.0409	0.0914	
CD (P=0.05)	0.057	0.0243	0.0384	0.0127	0.0543	0.0806	0.1803	

The highest EC value was recorded by untreated control (0.071 dSm^{-1}) and PEG - 0.25 MPa (8h) (0.070 dSm^{-1}) while the lowest value was registered by 80% sand matrix priming for 24 h (0.062 dSm^{-1}). Over the storage period these treatments also recorded the maximum protein content (20.12%) followed by hydropriming (24 h) seeds (20.02%) and untreated control seeds recorded the minimum value of 19 per cent, which was on par with halo priming (3% KNO_3, 24 h) (19.05%) irrespective of

Table 3. Influence of storage containers, period for storage on germination of primed onion seeds

Treatment	Period of storage (months)															
	Initial			1			2			3			4			Mean
	A	C	Mean	A	C	Mean	A	C	Mean	A	C	Mean	A	C	Mean	
Control	90	90	90	90	90	90	86	86	84	84	84	78	77	77	77	85
	(17.57)	(17.57)	(17.57)	(17.57)	(17.57)	(17.57)	(69.03)	(69.03)	(66.43)	(66.43)	(66.43)	(62.03)	(61.34)	(61.34)	(61.34)	(67.85)
Hydro 12 h	90	90	90	91	90	90	88	87	87	89	88	88	79	77	78	86
	(71.57)	(71.57)	(71.57)	(72.56)	(71.57)	(71.57)	(69.90)	(69.73)	(69.73)	(70.64)	(69.90)	(69.90)	(62.73)	(61.34)	(62.03)	(69.03)
Hydro 24 h	93	93	93	93	93	93	91	90	90	91	90	90	86	85	85	90
	(74.66)	(74.66)	(74.66)	(74.66)	(74.66)	(74.66)	(72.56)	(71.57)	(71.57)	(72.56)	(71.57)	(71.57)	(68.58)	(67.85)	(67.85)	(72.21)
Sand 80% 12 h	91	91	91	92	90	91	87	87	87	86	86	86	84	84	84	87
	(72.56)	(72.56)	(72.56)	(73.57)	(72.21)	(72.56)	(69.73)	(69.73)	(69.73)	(68.56)	(68.58)	(68.58)	(66.43)	(66.43)	(66.43)	(69.73)
Sand 80% 24 h	93	93	93	94	93	93	91	91	92	91	91	91	88	86	87	91
	(74.66)	(74.66)	(74.66)	(75.55)	(74.66)	(74.66)	(72.56)	(72.56)	(72.56)	(72.56)	(72.56)	(72.56)	(69.90)	(68.58)	(69.73)	(72.88)
-0.25 MPa 8h	90	90	90	90	90	90	88	87	87	86	86	86	85	84	84	87
	(71.57)	(71.57)	(71.57)	(71.57)	(71.57)	(71.57)	(69.90)	(69.33)	(69.33)	(65.58)	(68.58)	(68.58)	(67.85)	(66.43)	(66.43)	(69.46)
-0.25 MPa 12h	92	92	92	92	92	92	89	90	89	87	86	86	84	83	83	88
	(73.57)	(73.57)	(73.57)	(73.57)	(73.57)	(73.57)	(76.64)	(71.57)	(70.64)	(69.33)	(65.58)	(68.58)	(66.43)	(66.43)	(66.43)	(70.55)
3% KNO3 12 h	92	92	92	92	91	91	89	89	89	88	88	88	82	82	82	88
	(73.57)	(73.57)	(73.57)	(73.57)	(72.56)	(72.56)	(70.64)	(70.64)	(70.64)	(69.90)	(69.90)	(69.90)	(64.89)	(64.89)	(64.89)	(70.38)
3% KNO3 24 h	91	91	91	90	90	90	89	89	89	86	87	86	80	80	80	87
	(72.56)	(72.56)	(72.56)	(71.57)	(71.57)	(71.57)	(70.64)	(70.64)	(70.64)	(65.58)	(69.33)	(68.58)	(63.43)	(63.43)	(63.43)	(69.33)
3% NaCl 12 h	91	91	91	90	90	90	88	88	88	88	87	87	84	82	83	88
	(72.56)	(72.56)	(72.56)	(71.57)	(71.57)	(71.57)	(69.90)	(70.64)	(69.90)	(69.90)	(69.33)	(69.33)	(66.43)	(64.89)	(66.43)	(69.69)
3% NaCl 24 h	91	91	91	90	89	89	87	86	86	84	84	84	82	81	81	86
	(72.56)	(72.56)	(72.56)	(71.57)	(70.64)	(70.64)	(69.33)	(68.58)	(68.58)	(64.43)	(64.43)	(64.43)	(64.89)	(64.16)	(64.16)	(68.58)
Mean	91	91	91	91	90	91	88	88	88	87	87	87	82	81	82	
	(72.56)	(72.56)	(72.56)	(72.56)	(71.57)	(72.56)	(69.90)	(69.90)	(69.90)	(69.33)	(69.33)	(69.33)	(64.89)	(64.16)	(64.89)	

(Figures in parenthesis indicate arcsine values) A - Aluminium foil pouch ; C- Cloth bag

	P1	P2	P3	P4	P5		C1	C2
P mean	91.3	91	88.4	87.1	82.4	C mean	88	87
	(72.85)	(72.54)	(70.69)	(68.95)	(65.20)		(69.90)	(69.33)
	T	C	P	TxP	P x C	TxC	T x P x C	
SEd	0.147	0.063	0.099	0.330	0.141	0.209	0.467	
CD (P=0.05)	0.291	0.136	0.196	0.652	0.278	0.412	0.922	

Table 4. Influence of storage containers, period of storage on vigour index of primed onion seeds

Treatment	Period of storage (months)															
	Initial			1			2			3			4			Mean
	A	C	Mean	A	C	Mean	A	C	Mean	A	C	Mean	A	C	Mean	
Control	673	673	673	599	584	592	512	422	467	448	446	447	445	384	415	517
Hydro 12 h	823	823	823	683	662	673	635	610	622	611	454	532	443	475	459	621
Hydro 24 h	912	912	912	803	754	778	729	731	730	637	572	605	545	525	535	712
Sand 80% 12 h	865	865	865	732	624	678	607	511	559	510	425	468	446	430	438	601
Sand 80% 24 h	952	952	952	796	891	844	848	788	818	655	655	655	634	612	623	778
-0.25 MPa 8h	635	635	635	649	618	634	599	593	596	554	552	553	546	539	543	592
-0.25 MPa 12h	706	706	706	673	639	656	648	628	638	671	522	596	547	565	556	630
3% KNO3 12 h	744	744	744	684	602	643	628	562	595	568	532	550	517	483	500	606
3% KNO3 24 h	681	681	681	661	661	661	556	562	559	516	522	519	480	440	460	576
3% NaCl 12 h	726	726	726	744	663	704	643	636	640	607	559	583	564	508	536	637
3% NaCl 24 h	704	704	704	509	474	492	446	422	434	446	412	429	419	430	425	496
Mean	766	766	766	684	652	667	623	588	605	566	514	539	508	490	498	

A - Aluminium foil pouch ; C- Cloth bag

	P1	P2	P3	P4	P5		C1	C2
P mean	766	668	605	540	499	C mean	629	601
	T	C	P	TxP	P x C	TxC	T x P x C	
SEd	0.601	0.256	0.405	1.343	0.573	0.849	1.900	
CD (P=0.05)	1.184	0.505	0.798	2.648	1.129	1.675	3.745	

period of storage.α-amylase content differed significantly among treatments, period of storage and their interactions. The treatment 80% sand matric priming 24 h recorded the highest -amylase content (5.05 mm) followed by hydropriming 24 h (4.8 mm) while the control seeds recorded the lowest of 3.4 mm irrespective of periods (Fig 1).

Over the four months of storage the initial advantage obtained was maintained well in primed seeds. Among the priming treatments imposed on onion seeds, sand matrix priming (80% WHC) for 24 h recorded superiority over the other priming methods and methodology throughout the storage period with respect to all the parameters studied.

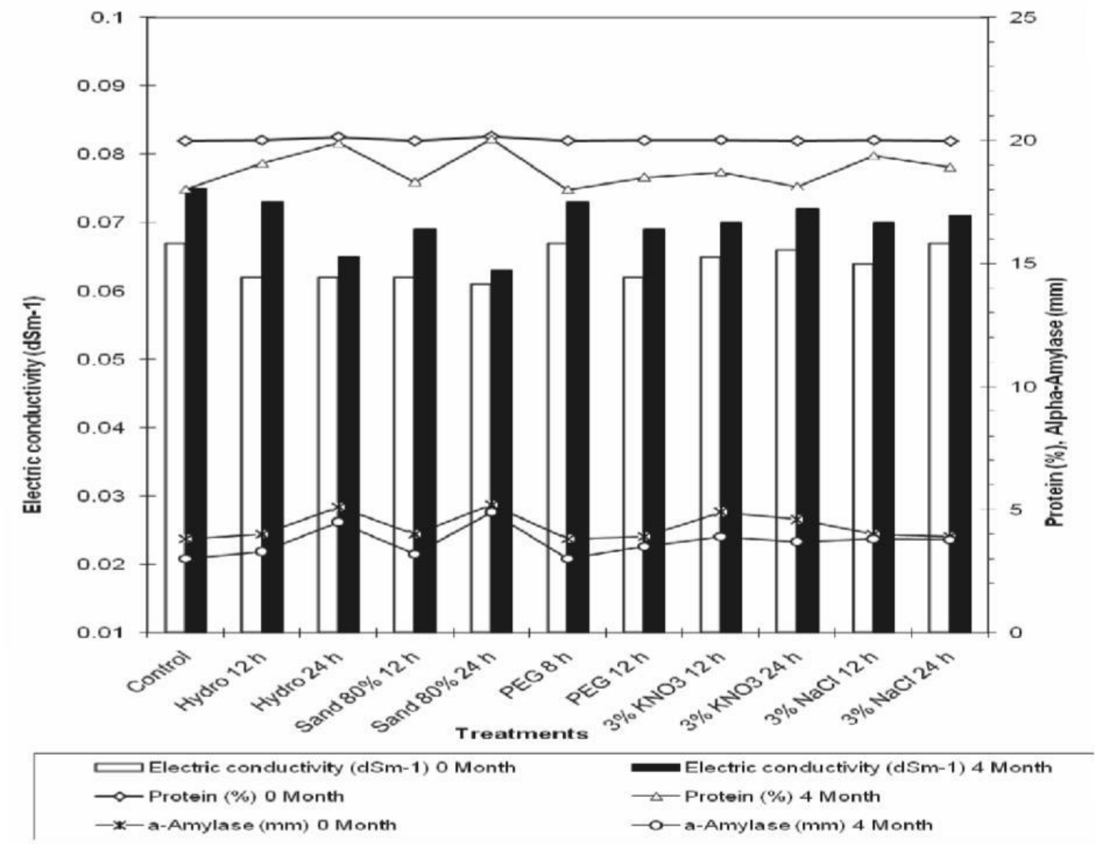

Fig. 1. Effect of seed priming of onion seeds on Electrical Conductivity , protein content and Alpha -amlayse activity

The initial increment in seed vigour obtained through the different priming methods was reflected in the seed vigour after four months of storage.

Biochemical manifestations of seed priming has not been studied extensively. Protein, sugar and RNA were found to increase in PEG treated seeds of cauliflower (Fujikura and Karsen 1992). Enzyme activities of catalase, peroxidase, amylase and invertase increased in PEG treated seeds (Sing *et al.,* 1985).

These results on enzyme activity and protein synthesis are consistent with the results of the present study where, primed seeds showed higher levels of amylase enzymes and protein synthesis. Priming attributed germination increase might be due to priming - enhanced repair of membranes which were disrupted during maturation drying. This is indirectly supported by the reduced leakage of electrolytes from primed seeds, since electrolyte leakage is in part a result of damaged cell membranes.

The present study consistently revealed that initial advantage obtained through priming gained in the initial stage also persisted even after 4 months of storage. The study also underscored the conjecture that the seed viability was better maintained in primed seeds of onion than in unprimed seeds. Pill (1995) after an extensive review on seed priming concludes that since viability and germination rate were enhanced by priming both before and after seed storage, priming was involved in both delaying the ageing process and in repairing seed deterioration. These well standardized priming techniques can very well serve farmers as well as industry as a no cost technique to increase the seed germination, vigour and storability.

References

Abdul-Baki, A.A. and Anderson, J.D. 1973. Vigour deterioration of soybean seeds by multiple criteria. *Crop. Sci.,* **13**: 630-633.

Ali-khan, S. T. and Youngs, C. G. 1973. Variation in protein content of field peas. *Can. J. Pl. Sci.*, **53**: 37-41.

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

Fujikura, Y. and Karsen, C.M. 1992. Effects of controlled deterioration and osmo priming on protein synthesis of cauliflower during early germination. *Seed Sci. Res.*, **2**: 23-31.

Kalyani Srinivasan, Jain, S.K, Sanjeeve Saxena, Radhamani, J. and Manju Uprety. 2009. Seed Priming and Fortification. *Seed Res.,* **37**: 1-13

Maguire, J. D. 1962. Speed of germination: Aid in selection and evaluation for seedling emergence and vigour. *Crop. Sci.,* **2**: 176-177.

Michael Evenari. 1984 . Seed Physiology: Its History from antiquity to the beginning of the 20th century. *The Botanical Review.,* **50**: 119-142.

Osborne, D. J. 1983. Biochemical control systems operating in the early hours of germination. *Canadian J. Bot.,* **61**: 3568-3577.

Panse, V.G. and Sukhatme P.V. 1978. Statistical Methods for Agricultural Workers. ICAR publication. New Delhi.

Pill, W.G. 1995. Low water potential and presowing germination treatments to improve seed quality. In: Seed Quality: Basic mechanisms and agricultural implications (Ed. A. S. Basra), New York, Food Product Press, 319-359 p.

Presley, J.T. 1958. Relationship of protoplast permeability of cotton seed viability and predisposition of seedling disease. *Pl. Dis. Rep.,* **42**: 582.

Simpson, G.M. and Naylor, J. M. 1962. Dormancy studies in seeds of *Avena testa*. 3. A relationship between maltase, amylase and gibberellins. *Canadian J. Bot.,* **40**: 1659-1673.

Singh, H, Morss, S and Orton, T. J. 1985. Effects of osmotic pretreatment and storage on germination of celery seed. *Seed Sci. & Technol.,* **13**: 551-558.

Received: February 10, 2011; Accepted: June 20, 2011