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Effect of Concentration and Duration of Osmopriming on Germination and Vigor of Aged Seed of Chickpea

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A B S T R A C T

To standardize the best concentration and duration of osmopriming of aged seed of chickpea variety, NBeG-3 with Polyethylene Glycol, an experiment was conducted in Factorial Completely Randomized Design with four replications. The seed was subjected to osmopriming with different concentrations of PEG 6000 *viz*., 0, -0.5, -1.0, -1.5 and -2.0 MPa for various durations *viz*., 3, 6, 9, 12 and 24 hours. The seed quality was assessed by testing for germination in between paper method and sand method. In both the methods of testing, concentration of PEG, duration of osmopriming and their interaction exhibited highly significant effect on germination, seedling length and seedling vigor index. Among all the concentrations used, seed primed with -0.5 MPa PEG recorded highest germination, root length, shoot length, seedling length, root / shoot ratio and seedling vigor index. Among the various durations, osmopriming for 6 hours showed highest improvement in seed quality. The interaction effect of seed priming with -0.5 MPa PEG for 6 hours also showed highest improvement in seed quality attributes.

Introduction

Bengalgram is a major pulse crop widely grown in India and accounts for nearly 40 % of the total pulse production. India is one of the major chickpea growing countries of the world, accounting for 62 % of the total world production.

One of the most important aspects for seed production is germination and rapid emergence. Seed priming has been successfully demonstrated to improve germination and emergence in seeds of many crops. Osmopriming is a method of controlled seed priming in which the amount of water available for seed is restricted by regulating the water potential of priming medium (Farahani *et al.*, 2011). The low water potential of the priming solution allows partial seed hydration so that pre-germination metabolic processes begin, but germination is inhibited.

One of the most common substances used for osmopriming is the polyethylene glycol 6000

(Oliveira and Gomes-Filho, 2016). Priming of seed in osmoticum such as polyethylene glycol (osmo-priming) and in water (hydro-priming) has been reported to be an economical, simple and a safe technique for increasing the capacity of seed to osmotic adjustment and enhancing seedling establishment and crop production under stressed conditions. This could be due to faster emergence of roots and shoots, more vigorous plants, better drought tolerance, earlier flowering, earlier harvest and higher grain yield under adverse conditions (Lee-suskoon *et al.,* 1998). Hence the present study was carried out to evaluate the effect of different concentrations and durations of osmopriming and to know the best combination of concentration and duration of osmopriming with PEG for chickpea variety, NBeG-3.

Materials and Methods

The present investigation was carried out during 2017-18 in the Department of Seed Science and Technology, Advanced Post Graduate Centre, Acharya N. G. Ranga Agricultural University, Lam, Guntur, Andhra Pradesh. Foundation seed of chickpea variety, NBeG-3, harvested during *rabi*, 2015-16 was obtained from Regional Agricultural Research Station, Nandyal.

In order to standardize the duration of soaking and optimum concentration of Poly Ethylene Glycol (PEG) 6000 for osmopriming, an experiment was conducted in factorial completely randomized design with four replications. The first factor was concentration of poly ethylene glycol consisting of five levels of PEG 6000 (0 MPa, -0.5 MPa, -1.0 MPa, -1.5 MPa and -2.0 MPa) and second factor was duration of priming including five durations (3 h, 6 h, 9 h, 12 h and 24 h).

The osmotic potential of PEG was calculated as described by Michel and Kaufmann (1973).

Water potential (bar index) = $- (1.18 \times 10^{-2}) C - (1.18 \times 10^{-4}) C^2 + (2.67 \times 10^{-4}) CT + (8.39 \times 10^{-7}) C^2T$

Where C is the concentration of PEG-6000 in g kg^{-1} H_2O,

T is the temperature in °C.

The PEG solution with desired osmotic potential (-0.5, -1.0, -1.5 and -2.0 MPa) were prepared by dissolving 212.6, 308.5, 382.1 and 444.2 g PEG L^{-1}, respectively.

Two discs of blotter paper were placed in petriplates which were moistened with approximately 30 mL of desired concentration of PEG solution in each petriplate. The aged seed of chickpea variety NBeG-3 was kept in petriplates for required duration on moistened blotter paper discs. The primed seed was surface washed twice with distilled water and dried to reach 9 % moisture content and was tested for seed quality by between paper method and sand method.

In between paper method, four replicates of 100 seed from each priming treatment were placed at uniform spacing in between two wetted germination paper towels. The paper towels were rolled, secured with rubber bands on both the sides and kept in plastic trays in upright position and the trays were incubated in germinator at 25 ± 2 °C and 95 % RH for 8 days.

For sand method also four replicates of 100 seed in each treatment were placed over moist sand with uniform spacing in plastic trays and covered with another layer of moist sand and the trays were placed in germinator at 25 ± 2 °C and 95% RH for 8 days.

Data on germination and other seed quality parameters were recorded after 8 days of test period as detailed below:

The number of normal seedlings were counted and expressed as germination (%) as per the formula:

$$\text{Germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Total number of seed sown}} \times 100$$

The root length, shoot length and seedling length were determined by randomly selecting ten normal seedlings in each replication and each treatment at the end of the germination count and expressed in centimeters. The root length was measured from the tip of the primary root to the base of the hypocotyl. Shoot length was measured from the tip of the primary leaf to the base of the hypocotyl. Seedling length was calculated by adding root and shoot lengths. The root / shoot ratio of the 10 seedlings was computed and their mean was expressed as root / shoot ratio.

Seedling vigor index was computed by adopting the following formula as suggested by Abdul-Baki and Anderson (1973) and was expressed in whole number:

Seedling Vigor index = Germination (%) x Seedling length (cm)

Statistical analysis

The data were subjected to Analysis of Variance (ANOVA) using SPSS software (version 16.0) at 1 % and 5 % level of significance. The primingal means were compared using Duncan's Multiple Range test ($P<0.05$).

Results and Discussion

The trend of variation observed in chickpea seed subjected to osmopriming with different concentrations of PEG and durations was almost similar in both the methods of germination testing.

The analysis of variance clearly indicated that germination, seedling length and seedling vigor index were significantly affected by the concentration of PEG, duration of osmopriming and their interaction in both the methods (Table 1). Root length and shoot length showed highly significant variation due to duration of osmopriming and interaction effect in both the methods of testing and due to the concentration of PEG in between paper method. In sand method, the concentration of PEG showed significant variation in root length and shoot length at 5 % level of significance. The root / shoot ratio varied significantly only at 5% level of significance due to duration of osmopriming in both the methods and due to the interaction effect in sand method (Table 1). An improvement in germination, root length, shoot length, seedling length and seedling vigor index was noticed with increase in concentration of PEG from 0 MPa upto -0.5 MPa and then declined gradually upto -2.0 MPa in aged seed. Similarly there was increase in the above characters with increase in duration of osmopriming from 3 hours to 6 hours followed by a gradual decrease upto 24 hours.

Germination

The concentration of PEG, duration of osmopriming and their interaction exhibited significant influence on germination in both between paper and sand methods. The highest and lowest germination percentages were recorded with -0.5 MPa and 0 MPa concentration of PEG (90.15 % and 86.35 % in between paper method and 90.35 % and 86.55 % in sand method, respectively) and 6 hours and 24 hours of osmopriming (91.10 % and 86.70% in between paper method and 91.30 % and 86.85 % in sand method), respectively. Interaction of concentration and duration of priming with PEG also showed highest germination with -0.5 MPa concentration of PEG and 6 hours of

osmopriming (92.25 %and 92.50 % in between paper and sand methods, respectively) and lowest germination with 0 MPa for 24 hours (78.00 % and 77.75 % in between paper and sand methods, respectively) (Table 2 and 3).

These findings are in conformity with the findings of Sadeghi *et al.,* (2011) who reported that increase in osmopriming concentration and duration of soybean seed resulted in increased germination upto -1.2 MPa concentration and 12 hours duration which declined with further increase in PEG concentration and priming duration. Similar results were obtained in cotton by Papastylianou and Karamanos (2012) where osmopriming with mannitol at -0.5 MPa for six hours had positive effects on germination while at -1.5 MPa for 12 to 18 hours exhibited reduction in final germination. The possible reason for improved germination through priming may be the synthesis of proteins and leaching of growth inhibitors (Bray *et al.*, 1989) and repair of deteriorative DNA in seed (Girolamo and Barbanti, 2012).

Root length

Among the various concentrations of PEG, maximum and minimum root lengths were observed with-0.5 MPa and 0 MPa (15.03 cm and 14.01 cm, respectively) in between paper method and -0.5 MPa and -2.0 MPa (14.37 cm and 13.82 cm, respectively) in sand method. Similarly, due to duration of osmopriming, the maximum and minimum root lengths were observed with 6 hours and 24 hours (15.59 cm and 13.61 cm in between paper method and 15.02 cm and 13.39 cm in sand method), respectively. Among the interaction of concentration and duration of priming, seed priming with -0.5 MPa PEG for 6 hours recorded highest root length (17.05 cm and 16.19 cm in between paper and sand methods, respectively) and 0 MPa for 24 hours recorded lowest root length (10.78 cm and 11.28 cm in between paper and sand methods, respectively) (Table 2 and 3). Increased root length by osmopriming with PEG was also earlier reported in chickpea (Khadraji *et al.*, 2017). Faijunnahar *et al.,* (2017) concluded that the considerable increase in root length in the primed seeds of wheat might be due to increased metabolic activities in the primed seeds than non-primed.

Shoot length

Among the various osmopriming treatments, -0.5 MPa and 0 MPa recorded maximum and minimum shoot lengths (18.48 cm and 17.59 cm in between paper method and 19.62 cm and 19.17cm in sand method), respectively and the durations of 6 hours and 24 hours exhibited maximum and minimum shoot lengths (19.10 cm and 17.53 cm in between paper method and 20.19 cm and 18.79cm in sand method), respectively.

Seed primed with -0.5 MPa for 6 hours recorded highest shoot length (19.53 cm in between paper method and 20.63 cm in sand method), while lowest shoot length (15.10 cm in between paper method and 17.20 cm in sand method) (Table 2 and 3) was noticed with the seed primed with 0 MPa for 24 hours. Increase in shoot length due to osmopriming with PEG was also reported earlier in common bean (Amanpour-Balaneji and Sedghi, 2012) and chickpea (Khadraji *et al.*, 2017). Lee and Kim (2000) found that priming increased the metabolic activities of seed ultimately resulting in substantial increase in shoot length than non-primed seed.

Seedling length

The seedling length was obtained by adding root length and shoot length and hence showed similar trend of variation that was noticed for both these traits.

Table.1 Mean squares for germination and seed quality traits in aged seed of chickpea as affected by duration of osmopriming and concentration of PEG

Source	d.f	Germination (%)	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Root / shoot ratio	Seedling vigor index
Between paper method							
Duration	4	38.2124**	11.7297**	6.4838**	35.1196**	0.0010*	369136.3208**
Concentration	4	32.6013**	2.9019**	2.7166**	10.3084**	0.0003^{NS}	152049.6694**
Duration × Concentration	16	9.71057**	2.9864**	1.7116**	8.1277**	0.0006^{NS}	73203.6613**
Error	75	0.5501	0.6119	0.4283	0.9409	0.0004	5265.9445
Sand method							
Duration	4	38.9954**	7.7653**	6.0411**	27.1269**	0.0005*	459880.3000**
Concentration	4	30.4513**	0.9991*	0.9133*	3.6576**	0.0001^{NS}	122412.2000**
Duration × Concentration	16	11.6082**	2.4832**	1.4801**	5.5584**	0.0009*	105271.9000
Error	75	1.0106	0.3286	0.3370	0.8493	0.0002	8731.0000

* Significant difference at 5% probability level
** Significant difference at 1% probability level
NS: Non-significant

Table.2 Influence of concentration and duration of osmopriming with PEG 6000 on seed quality traits in aged seed of chickpea (Between paper method)

Duration	Germination (%)						Root length (cm)						Shoot length (cm)					
	Concentration						Concentration						Concentration					
	0 MPa	-0.5 MPa	-1.0 MPa	-1.5 MPa	-2.0 MPa	Mean	0 MPa	-0.5 MPa	-1.0 MPa	-1.5 MPa	-2.0 MPa	Mean	0 MPa	-0.5 MPa	-1.0 MPa	-1.5 MPa	-2.0 MPa	Mean
3 hours	87.50	91.00	89.00	89.75	89.25	**89.30**	14.59	14.34	14.49	14.19	13.66	**14.25^{c}**	17.98	18.04	18.61	18.39	17.36	**18.07^{b}**
	(69.27)*	(72.53)	(70.61)	(71.31)	(70.84)	**(70.91)^{b}**												
6 hours	89.75	92.25	91.75	90.75	91.00	**91.10**	15.23	17.05	15.47	14.88	15.35	**15.59^{a}**	19.10	19.53	18.44	19.31	19.10	**19.10^{a}**
	(71.30)	(73.83)	(73.30)	(72.28)	(72.53)	**(72.65)^{a}**												
9 hours	88.25	90.00	90.00	89.00	88.75	**89.20**	15.52	14.78	14.93	14.54	14.37	**14.83^{b}**	17.90	18.69	18.32	18.27	18.09	**18.25^{b}**
	(69.93)	(71.55)	(71.55)	(70.61)	(70.39)	**(70.80)^{b}**												
12 hours	88.25	89.00	89.50	88.00	88.25	**88.60**	13.94	14.37	13.60	14.24	14.15	**14.06^{cd}**	17.86	18.03	18.53	17.94	17.96	**18.06^{b}**
	(69.93)	(70.61)	(71.07)	(69.71)	(69.94)	**(70.25)^{c}**												
24 hours	78.00	88.50	88.50	89.75	88.75	**86.70**	10.78	14.63	14.43	14.34	13.87	**13.61^{d}**	15.10	18.12	18.14	18.12	18.15	**17.53^{c}**
	(62.00)	(70.17)	(70.15)	(71.31)	(70.38)	**(68.80)^{d}**												
Mean	**86.35**	**90.15**	**89.75**	**89.45**	**89.20**	**88.98**	**14.01^{c}**	**15.03^{a}**	**14.58^{ab}**	**14.43^{bc}**	**14.28^{bc}**	**14.47**	**17.59^{b}**	**18.48^{a}**	**18.41^{a}**	**18.40^{a}**	**18.13^{a}**	**18.20**
	(68.48)^{d}	**(71.74)^{a}**	**(71.34)^{b}**	**(71.05)^{bc}**	**(71.00)^{c}**	**(70.68)**												
S Em ±	D 0.17		C 0.17		D × C 0.37		D 0.17		C 0.17		D × C 0.39		D 0.15		C 0.15		D × C 0.33	
CD (5%)	0.47		0.47		1.05		0.49		0.49		1.10		0.41		0.41		0.92	
CV (%)	1.05						5.41						3.60					

Table.2 Influence of concentration and duration of osmopriming with PEG 6000 on seed quality traits in aged seed of chickpea (Between paper method)

Duration	Root / shoot ratio						Seedling length (cm)						Seedling vigor index					
	Concentration						Concentration						Concentration					
	0 MPa	-0.5 MPa	-1.0 MPa	-1.5 MPa	-2.0 MPa	Mean	0 MPa	-0.5 MPa	-1.0 MPa	-1.5 MPa	-2.0 MPa	Mean	0 MPa	-0.5 MPa	-1.0 MPa	-1.5 MPa	-2.0 MPa	Mean
3 hours	0.81	0.80	0.78	0.77	0.79	**0.79**	32.57	32.38	33.10	32.58	31.02	**32.33^{c}**	2256	2349	2337	2323	2197	**2292^{c}**
	(1.35) **	(1.34)	(1.33)	(1.33)	(1.34)	**(1.34)^{ab}**												
6 hours	0.80	0.87	0.84	0.77	0.81	**0.82**	34.33	36.58	33.91	34.19	34.45	**34.69^{a}**	2448	2701	2486	2471	2499	**2521^{a}**
	(1.34)	(1.37)	(1.36)	(1.33)	(1.34)	**(1.35)^{a}**												
9 hours	0.87	0.79	0.82	0.80	0.80	**0.81**	33.42	33.47	33.26	32.80	32.46	**33.08^{b}**	2337	2394	2379	2316	2284	**2342^{b}**
	(1.37)	(1.34)	(1.35)	(1.34)	(1.34)	**(1.35)^{a}**												
12 hours	0.78	0.80	0.73	0.80	0.79	**0.78**	31.80	32.40	32.13	32.18	32.10	**32.12^{c}**	2224	2287	2283	2244	2245	**2256^{c}**
	(1.33)	(1.34)	(1.32)	(1.34)	(1.34)	**(1.33)^{b}**												
24 hours	0.71	0.81	0.80	0.79	0.76	**0.78**	25.88	32.75	32.58	32.45	32.03	**31.14^{d}**	1605	2298	2285	2314	2254	**2151^{d}**
	(1.31)	(1.34)	(1.34)	(1.34)	(1.33)	**(1.33)^{b}**												
Mean	**0.79**	**0.81**	**0.79**	**0.79**	**0.79**	**0.80**	**31.60^{c}**	**33.51^{a}**	**32.99^{ab}**	**32.84^{b}**	**32.41^{b}**	**32.67**	**2174^{d}**	**2406^{a}**	**2354^{b}**	**2334^{bc}**	**2296^{c}**	**2313**
	(1.34)	**(1.35)**	**(1.34)**	**(1.34)**	**(1.34)**	**(1.34)**												
S Em ±	D 0.005		C 0.005		D × C 0.010		D 0.22		C 0.22		D × C 0.49		D 16.23		C 16.23		D × C 36.28	
CD (5%)	0.013		NS		NS		0.61		0.61		1.37		45.73		45.73		102.27	
CV (%)	1.517						2.97						3.14					

*Values in the parenthesis indicate arc-sine transformed values

**Values in the parenthesis indicate square root transformed values

NS: Non significant

The values in the same column/row for each treatment with the same alphabetical letter are not significantly different (P < 0.05).

Table.3 Influence of concentration and duration of osmopriming with PEG 6000 on seed quality traits in aged seed of chickpea (Sand method)

Duration	Germination (%)						Root length (cm)						Shoot length (cm)					
	Concentration						Concentration						Concentration					
	0 MPa	-0.5 MPa	-1.0 MPa	-1.5 MPa	-2.0 MPa	Mean	0 MPa	-0.5 MPa	-1.0 MPa	-1.5 MPa	-2.0 MPa	Mean	0 MPa	-0.5 MPa	-1.0 MPa	-1.5 MPa	-2.0 MPa	Mean
3 hours	87.50	90.75	89.00	90.00	88.75	**89.20**	13.10	13.41	14.42	13.97	13.30	**13.64^{cd}**	19.30	19.72	18.75	18.35	19.40	**19.11^{cd}**
	(69.27)*	(72.28)	(70.63)	(71.55)	(70.39)	**(70.82)^{b}**												
6 hours	90.00	92.50	92.50	90.75	90.75	**91.30**	15.33	16.19	14.86	14.39	14.31	**15.02^{a}**	20.12	20.63	20.59	19.82	19.79	**20.19^{a}**
	(71.54)	(74.08)	(74.08)	(72.32)	(72.28)	**(72.87)^{a}**												
9 hours	89.00	89.25	89.50	88.75	88.25	**88.95**	14.69	14.24	13.96	13.94	13.92	**14.15^{b}**	20.13	19.47	19.53	19.69	19.70	**19.70^{b}**
	(70.60)	(70.84)	(71.08)	(70.39)	(69.96)	**(70.57)^{b}**												
12 hours	88.50	89.75	89.00	89.00	88.25	**88.90**	14.81	14.02	13.82	13.60	13.54	**13.96b^{c}**	19.10	19.18	19.32	19.66	18.79	**19.21^{c}**
	(70.15)	(71.31)	(70.61)	(70.64)	(69.98)	**(70.54)^{b}**												
24 hours	77.75	89.50	88.50	88.75	89.75	**86.85**	11.28	14.00	13.46	14.16	14.05	**13.39^{d}**	17.20	19.13	19.84	19.41	18.37	**18.79^{d}**
	(61.83)	(71.09)	(70.15)	(70.39)	(71.30)	**(68.95)^{c}**												
Mean	**86.55**	**90.35**	**89.70**	**89.45**	**89.15**	**89.04**	**13.84^{b}**	**14.37^{a}**	**14.10^{ab}**	**14.01^{ab}**	**13.82^{b}**	**14.03**	**19.17^{b}**	**19.62^{a}**	**19.61^{a}**	**19.39^{ab}**	**19.21^{b}**	**19.40**
	(68.68)^{c}	**(71.92)^{a}**	**(71.32)^{ab}**	**(71.06)^{b}**	**(70.78)^{b}**	**(70.75)**												
S Em ±	D 0.22		C 0.22		D × C 0.50		D 0.13		C 0.13		D × C 0.29		D 0.13		C 0.13		D × C 0.29	
CD (5%)	0.63		0.63		1.42		0.36		0.36		0.81		0.37		0.37		0.82	
CV (%)	1.42						4.09						2.99					

Table.3 Influence of concentration and duration of osmopriming with PEG 6000 on seed quality traits in aged seed of chickpea (Sand method)

Duration	Root / shoot ratio						Seedling length (cm)						Seedling vigor index					
	Concentration						Concentration						Concentration					
	0 MPa	-0.5 MPa	-1.0 MPa	-1.5 MPa	-2.0 MPa	Mean	0 MPa	-0.5 MPa	-1.0 MPa	-1.5 MPa	-2.0 MPa	Mean	0 MPa	-0.5 MPa	-1.0 MPa	-1.5 MPa	-2.0 MPa	Mean
3 hours	0.68	0.68	0.77	0.76	0.69	**0.72**	32.40	33.13	33.17	32.32	32.70	**32.74^{cd}**	2835	3006	2953	2909	2903	**2921^{c}**
	(1.30)**	(1.30)	(1.33)	(1.33)	(1.30)	**(1.31)^{b}**												
6 hours	0.76	0.78	0.72	0.73	0.72	**0.74**	35.45	36.82	35.46	34.20	34.10	**35.20^{a}**	3191	3406	3279	3105	3094	**3215^{a}**
	(1.33)	(1.34)	(1.31)	(1.31)	(1.31)	**(1.32)^{a}**												
9 hours	0.73	0.73	0.71	0.71	0.71	**0.72**	34.82	33.70	33.49	33.63	33.61	**33.85^{b}**	3099	3008	2998	2985	2965	**3011^{b}**
	(1.32)	(1.32)	(1.31)	(1.31)	(1.31)	**(1.31)^{b}**												
12 hours	0.78	0.73	0.72	0.69	0.72	**0.73**	33.91	33.20	33.14	33.26	32.33	**33.17^{c}**	3001	2980	2950	2960	2853	**2949^{c}**
	(1.33)	(1.32)	(1.31)	(1.30)	(1.31)	**(1.31)^{ab}**												
24 hours	0.66	0.73	0.68	0.73	0.77	**0.71**	28.48	33.13	33.30	33.58	32.43	**32.18^{d}**	2214	2965	2947	2979	2910	**2803^{d}**
	(1.29)	(1.32)	(1.30)	(1.32)	(1.33)	**(1.31)^{b}**												
Mean	**0.72**	**0.73**	**0.72**	**0.72**	**0.72**	**0.72**	**33.01^{b}**	**33.99^{a}**	**33.71^{a}**	**33.40^{ab}**	**33.03^{b}**	**33.43**	**2868^{d}**	**3073^{a}**	**3025^{ab}**	**2988^{bc}**	**2945^{c}**	**2980**
	(1.31)	**(1.32)**	**(1.31)**	**(1.31)**	**(1.31)**	**(1.31)**												
	D		C		D × C		D		C		D × C		D		C		D × C	
S Em ±	0.003		0.003		0.006		0.21		0.21		0.46		20.89		20.89		46.72	
CD (5%)	0.008		NS		0.017		0.58		0.58		1.30		58.89		58.89		131.68	
CV (%)	0.921						2.76						3.14					

*Values in the parenthesis indicate arc-sine transformed values

**Values in the parenthesis indicate square root transformed values

NS: Non-significant

The values in the same column/row for each treatment with the same alphabetical letter are not significantly different (P < 0.05).

The highest and lowest seedling lengths were observed with -0.5 MPa and 0 MPa concentration of PEG (33.51 cm and 31.60 cm in between paper method and 33.99 cm and 33.01 cm in sand method) and 6 hours and 24 hours duration of osmopriming (34.69 cm and 31.14 cm in between paper method and 35.20 cm and 32.18cm in sand method), respectively. The interaction effect of concentration and duration of priming showed highest and lowest seedling lengths by seed priming with -0.5 MPa for 6 hours (36.58 cm and 36.82 cm in between paper and sand methods) and0 MPa for 24 hours (25.88 cm and 28.48 cm in between paper and sand methods), respectively (Table 2 and 3). Improvement in seedling length by osmopriming with PEG was reported earlier in cluster bean (Jat *et al.,* 2015) and chickpea (Kumar *et al.,* 2016).Seed priming causes pronounced increase in □-amylase activity and total soluble sugar contents under normal and drought conditions which results in better germination and faster growth compared with that in control (Zheng *et al.,* 2015).

Root/shoot ratio

No significant variation was observed in the root / shoot ratio due to the concentration of PEG in both between paper and sand methods. The duration of osmopriming showed significant effect on root/shoot ratio at 5 % level of significance in both the methods. The highest and lowest root/shoot ratios were recorded in seed subjected to osmopriming for 6 hours and 12 hours and 24 hours (0.82 and 0.78 in between paper method and 0.74 and 0.71 in sand method), respectively. The effect of interaction of concentration and duration of priming with PEG on root / shoot ratio was noticed to be non-significant in between paper method but significant in sand method. In sand method, the highest and lowest root/shoot ratios were recorded by seed primed with -0.5 MPa PEG for 6 hours (0.78) and 0 MPa PEG for 24 hours (0.66), respectively (Table 2 and 3). These findings are in accordance with the results obtained by Lemrasky and Hosseini (2012) in wheat where root / shoot ratio increased over control by treatment with PEG.

Seedling vigor index

The seedling vigor index was computed from germination and seedling length and hence this trait exhibited a similar trend of variation that was observed in case of germination and seedling length.

Seed primed with -0.5 MPa and 0 MPa concentration showed highest and lowest seedling vigor indices (2406 and 2174 in between paper method and 3073 and 2868 in sand method), respectively. Osmopriming for 6 hours and 24 hours recorded highest and lowest seedling vigor indices (2521 and 2151 in between paper method and 3215 and 2803 in sand method), respectively. The highest and lowest seedling vigor indices due to interaction of concentration and duration of priming with PEG were noticed in seed primed with -0.5 MPa PEG for 6 hours and 0 MPa PEG for 24 hours (2701 and 1605 in between paper method and 3406 and 2214in sand method), respectively (Table 2 and 3). Enhancement of seedling vigor index by priming with PEG was earlier documented in soybean (Sadeghi *et al.,* 2011) and chickpea (Kumar *et al.,* 2016). The improvement in germination and vigor might probably be due to the reserve mobilization of food material, activation and re-synthesis of some enzymes, DNA and RNA synthesis started during osmotic priming (Sadeghi *et al.,* 2011).

From the present study it can be concluded that osmopriming with Poly Ethylene Glycol has a positive effect on germination behavior of aged seed of chickpea. Osmopriming of aged seed with -0.5 Mpa PEG for 6 hours was

found to be the best for chickpea variety NBeG-3.

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