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Evaluating relative efficacy of different priming treatments in brinjal (*Solanum melongena* L.)

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Abstract
The present experiment was conducted in a CRD with three replications to study the effect of different priming agents in improving the seed quality parameters in brinjal. Seeds of four brinjal varieties were treated with GA_3 (1 ppm), KNO_3 (5%), Na_2HPO_4 (2%), PEG (10%), $ZnSO_4$ (1%), Ascorbic Acid (50 ppm) and deionised H_2O for 24 hours and then dried to original moisture content under shade. Dry seeds were taken as control. Data were recorded on germination (%), seedling vigour index-I & II in both lab and field conditions. The results revealed that GA_3 ranked first in increasing germination percent, SV-I and field emergence percent (FEP) as compared to control; KNO_3 ranked first in increasing SV-II and of SV-I of seedling emerged in the field as compared to control; and $ZnSO_4$ ranked first in increasing SV-II of seedling emerged in the field as compared to control.

Keywords: Brinjal, priming, efficacy, cumulative germination index, cumulative seedling vigour index

Introduction
Brinjal or eggplant (*Solanum melongena* L.) is an important solanaceous vegetable of tropics and sub-tropics. It is also called aubergine (French word) in Europe. Brinjal is a very low calorie vegetable and has healthy nutrition profile. It contains good amount of many essential B- complex group of vitamins such as pantothenic acid (vitamin B5), pyridoxine (vitamin B6), thiamin (vitamin B1) and niacin (vitamin B3). It is a versatile crop adapted to different agro-climaic regions and can be grown throughout the year. The eggplants are very rich source of fiber and low soluble carbohydrates. Thus they are highly beneficial for regulation of blood sugar level and also to control the absorption of glucose.
The most important and feasible approach to enhance the productivity of these vegetable crops would be the production of quality seed and making its availability. Quality seed is the key for successful agriculture, which demands each and every seed should be readily germinable and produce vigorous seedlings ensuring high yield. The farmers always very much interested in the best seed management practices which are safe, environmentally sound and scientifically proven technologies. The quality of seed can be deteriorated due to many reasons as environmental conditions are not favourable at the time of seed formation, mishandling at the time of harvest, processing and storage and unfavourable storage conditions with high moisture and temperature which increases seed ageing.
The quality of the seed can be improved by seed quality enhancement technique. One of the quality enhancement techniques is priming. Seed priming is the physiological technique by which controlling the hydration level within the seed so that the metabolic activity necessary for germination could occur but radicle emergence is prevented. Seed priming ensures uniform germination rate and better seedling establishment. This is a technique that is followed to enhance seed quality notably with respect to rate and uniformity of germination (Taylor *et al*. 1998) [6], thereby improving seedling stand and enabling better crop establishment (Job *et al*. 2000) [2]. In the present investigation the effects of priming treatments on seed quality parameters of brinjal were studied to compare the relative efficacy of different priming treatments.

Materials and methods
Seed material
One year old seeds of four brinjal varieties (Utkal Jyoti, Utkal Keshari, Utkal Madhuri &

Utkal Anushree) were collected from All India Coordinated Research Project on Vegetable Crops, Bhubaneswar.

Seed priming procedure

Seeds of different varieties of brinjal were treated with GA_3 (1 ppm), KNO_3 (5%), Na_2HPO_4 (2%), PEG- 6000 (10%), $ZnSO_4$ (1%), Ascorbic Acid (50 ppm) and water for 24 hours. In case of hydro-priming the seeds were soaked in deionised H_2O. After priming for 24 hours the soaked seeds were removed and rinsed with distilled water for three times and re-dried to original moisture content under shade. These seeds were then sealed in polythene bags and stored in refrigerator for further use.

Laboratory germination test and seedling vigour

For germination test three hundred seeds were randomly taken from each treatment of each variety of brinjal. Three replicates of 100 seeds were germinated between double layered rolled germination paper along with control (dry seeds) and moistened with sterile distilled water, in an amount equivalent to 2.5 times the mass of dry substrate, made into rolls, and placed into a seed germinator at 25ºC. Germination was considered to have occurred when the radicles were 3 mm long. The seedlings with short, thick and spiral form hypocotyls and stunted roots were considered as abnormally germinated. Germination percentage was recorded on fourteenth day (final count). Observations were recorded on germination percent, root length, shoot length, and seedling dry weight.

Root and shoot length was measured on 14th days. At the end of germination test (14 days), the seedlings were dried in an oven at 100 ºC for 24 hours. The dried seedlings were weighted to the nearest milligram and then the mean seedling dry weight was determined. Vigour index I (seedling length x germination percentage) and vigour index II (seedling dry weight x germination percentage) were then calculated.

Field emergence

For field emergence test three hundred seeds were randomly taken from each treatment and each variety of brinjal. Three replicates of 100 seeds were sown in aluminium trays (100 cm x 90 cm size) having sandy loam soil and coconut coir pith. Field emergence (%) count was done on 14th days. Data were recorded on field emergence percent, root length, shoot length, seedling dry weight, SV-I and SV-II.

Experimental design and statistical analysis

Laboratory as well as field tests were carried out in a completely randomised design with three replications. Analyses of variance (ANOVA) of laboratory and field data were calculated using SAS 9.3 version.

Estimation of cumulative germination index and cumulative seedling vigour index

The efficacy of different priming treatments was judged in terms of cumulative germination index and cumulative seedling vigour index. These indices are calculated as follows. Using suitable class intervals, the range of variability with regard to a character is classified into three groups such as low, medium and high. The mean data (over varieties) for each character is scored as 0 for low value, 1 for medium value and 2 for high value. The cumulative germination index is calculated by adding the scored values of lab germination percent and field emergence percent; cumulative seedling vigour index is calculated by adding the scored values of lab SV-I & SV-II and field SV-I & SV-II.

Results and discussion

Effect of priming agents on seed quality parameters Germination

Analysis of variance for germination indicated significant differences among the priming treatments for all the brinjal varieties (Table 1). Germination response of the cultivars to priming treatments was found to follow a similar trend. In general all the treatments gave significantly higher germination than unprimed seeds. Variety Utkal Jyoti recorded the highest germination percent when primed with GA3 (92.33) followed by KNO_3 (88.0) but GA3 gave significantly higher germination than KNO_3 and all the treatments gave significantly higher germination than unprimed seeds. In Utkal Keshari germination percentage varied from 71.66% to 91.00% with an average of 83.04% and the highest being observed in GA3 which was at par with KNO_3. In Utkal Madhuri both GA3 (90.66%) and KNO_3 (90.00%) were at par in improving germination as compared to others and rest of the priming treatments positevely and significantly produced higher germination than control. In Utkal Anushree KNO_3 recorded the highest germination (92.00%) followed by GA3 (90.33%) and $ZnSO_4$ (90.00%) but they all were at par with each other. Rest of the treatments also gave significantly higher germination than unprimed seeds. From the mean effect of the treatments it was observed that GA3, KNO_3, Na_2HPO_4, PEG, $ZnSO_4$, Ascorbic Acid and deionised water produced higher germination by 24.07%, 22.6%, 16.8%, 12.7%, 16.7%, 12.7% and 8.75% respectively than control. This result indicated that GA3 and KNO_3 had better impact in improving germination of brinjal seeds.

Table 1: Effect of priming treatments on lab germination count of brinjal varieties

Priming treatment	Utkal Jyoti	Utkal Keshari	Utkal Madhuri	Utkal Anushree
T1. GA_3 (1 ppm)	92.33 (73.98)	91.00 (72.60)	90.66 (72.24)	90.33 (71.88)
T2. KNO_3 (5%)	88.00 (70.06)	90.00 (71.57)	90.00 (71.81)	92.00 (73.57)
T3. Na_2HPO4 (2%)	84.00 (66.42)	85.66 (67.76)	86.00 (68.03)	87.33 (69.15)
T4. PEG (10%)	81.66 (64.68)	81.33 (64.43)	83.00 (66.48)	85.00 (67.21)
T5. $ZnSO_4$ (1%)	83.66 (66.20)	83.00 (65.67)	86.00 (69.53)	90.00 (71.57)
T6. Ascorbic Acid (50 ppm)	82.66 (65.43)	82.00 (64.90)	83.33 (65.96)	83.00 (65.65)
T7. Deionised H_2O	78.00 (62.03)	79.66 (63.21)	82.66 (65.41)	79.00 (62.73)
T8. Dry seed (Control)	73.66 (58.27)	71.66 (57.84)	74.00 (59.35)	74.33 (59.56)
CD (1%)	3.47	2.78	4.78	3.98
CV %	2.21	1.77	2.98	2.47

* Number inside the parenthesis indicates arcsine transformed value

Seedling vigour index-I

Non uniform response of brinjal varieties to priming treatments in respect of SV-I is presented in Table 2. In Utkal Jyoti SV-I was found to vary from 689.85 to 1028.45. The highest SV-I was achieved by Ascorbic Acid followed by GA3 (994.66). KNO_3, Na_2HPO_4 and ZnSO4 had significant positive effect in increasing SV-I. In Utkal Keshari the highest SV-I (1155.60) was obtained with KNO_3 followed by Na_2HPO_4 (1059.98) and GA3 (1026.60). This variety showed a positive response to all the priming treatments. In Utkal Madhuri SV-I ranged from 916.66 ($ZnSO_4$) to 1102.89 (Ascorbic Acid). GA3 (1095.02) and Ascorbic Acid were found to very much effective in increasing the SV-I value. Utkal Anushree showed a positive response to all the priming treatments and the maximum SV-I was being produced by $ZnSO_4$ (1128.14) followed by Na_2HPO_4 (1081.51) and KNO_3 (1076.77). From the mean effect of the treatments it is observed that priming with GA3, KNO_3, Na_2HPO_4, PEG, $ZnSO_4$, Ascorbic Acid and deionised water produced higher germination by 26.5%, 24.3%, 24.0%, 3.91%, 16.3%, 14.8% and 10.5% respectively than control. The mean effect of priming treatments revealed that GA3 was more potential in increasing SV-I value of fresh brinjal seeds.

Table 2: Effect of priming treatments on seedling vigour index-I of brinjal varieties

Priming treatment	Utkal Jyoti	Utkal Keshari	Utkal Madhuri	Utkal Anushree
T1. GA_3 (1 ppm)	994.66	1026.60	1095.02	1037.93
T2. KNO_3 (5%)	924.69	1155.60	924.54	1076.77
T3. Na_2HPO4 (2%)	946.68	1059.98	984.70	1081.51
T4. PEG (10%)	689.85	880.32	1008.72	833.85
T5. $ZnSO_4$ (1%)	863.31	911.11	916.66	1128.14
T6. Ascorbic Acid (50 ppm)	1028.45	808.52	1102.89	828.94
T7. Deionised H_2O	780.71	962.53	1021.76	863.22
T8. Dry seed(Control)	814.10	762.55	936.30	771.35
CD (1%)	79.89	73.95	111.6	115.86
CV %	3.81	3.28	4.69	5.10

Seedling vigour index-II

Seedling vigour index-II of brinjal varieties to priming treatments is presented in Table 3. In Utkal Jyoti SV-II was found to vary from 176.67 to 443.33. The highest SV-II was achieved with KNO_3 (443.33) followed by $ZnSO_4$ (417.67). All the priming treatments had positive effect in increasing SV-II. In Utkal Keshari the highest SV-II value was achieved when brinjal seeds were treated with PEG (810.67) followed by KNO_3 (810.0) and the lowest value was obtained in dry seeds. In Utkal Madhuri, SV-II ranged from 298.67 (control) to 897.33 (KNO_3). All the treatments had positive effect in increasing SV-II value. Utkal Anushree showed a very good response to GA3 that had recorded the highest SV-II value (1084.00). From the mean effect it is evident that $KNO_3$was more efficient than GA3 and other treatments.

Table 3: Effect of priming treatments on seedling vigour index-II of brinjal varieties

Priming treatment	Utkal Jyoti	Utkal Keshari	Utkal Madhuri	Utkal Anushree
T1. GA_3 (1 ppm)	277.33	546.00	452.67	1084.00
T2. KNO_3(5%)	443.33	810.00	897.33	832.00
T3. Na_2HPO4 (2%)	252.00	705.00	516.00	960.00
T4. PEG (10%)	326.67	810.67	416.00	510.00
T5. $ZnSO_4$(1%)	417.67	498.00	431.67	720.00
T6. Ascorbic Acid(50 ppm)	332.67	410.00	836.00	748.67
T7. Deionised H_2O	233.67	637.33	496.00	396.33
T8. Dry seed(Control)	176.67	357.33	298.67	370.33
CD(1%)	28.44	56.15	36.61	72.83
CV %	3.88	3.95	2.83	4.35

Field emergence percent (FEP)

There were significant differences among the priming treatments for field emergence percent of all brinjal varieties (Table 4). In Utkal Jyoti all the priming treatments produced significantly higher seedling emergence than control. The highest FEP was observed with GA3 (91.33%) followed by KNO_3 (87.33%). In Utkal Keshari GA3 recorded the highest FEP (89.33%) followed by KNO_3 (86.33%) and Na_2HPO_4 (84.0%) but these three treatment were statistically at par. Amongst the priming treatments hydropriming recorded the lowest FEP (77.33%) but it was at par with Na_2HPO_4, PEG, $ZnSO_4$ and Ascorbic Acid. In Utkal Madhuri priming with GA3 showed the greatest effect in enhancing FEP (88.0%) and it was at par with KNO_3 and Na_2HPO_4 and Ascorbic Acid. Amongst the priming treatments hydropriming recorded the lowest FEP (80.0%) but it was at par with Na_2HPO_4, PEG, $ZnSO_4$, and Ascorbic Acid. Priming response of Utkal Anushree was the highest with Na_2HPO_4 (89.66%) followed by GA3. Comparing the mean effect of all the treatments on FEP it was found that FEP increased by 25.8%, 23.1%, 17.5%, 14.1%, 17.3%, 13.08% and 9.03% when seeds were primed with GA3, KNO_3, Na_2HPO_4, PEG, $ZnSO_4$, Ascorbic Acid and deionised water respectively as compared to unprimed seeds. This result indicated that GA3, KNO_3 and Na_2HPO_4 were efficient priming agents in increasing FEP as compared to others.

Table 4: Effect of priming treatments on field emergence percent of brinjal varieties

Priming treatment	Utkal Jyoti	Utkal Keshari	Utkal Madhuri	Utkal Anushree
T1. GA_3 (1 ppm)	91.33 (72.92)	89.33 (71.11)	88.00 (69.83)	89.00 (70.74)
T2. KNO_3 (5%)	87.33 (69.24)	86.33 (68.97)	87.00 (68.88)	89.66 (71.26)
T3. Na_2HPO4 (2%)	82.00 (65.52)	84.00 (66.77)	83.00 (65.70)	85.00 (67.79)
T4. PEG (10%)	81.66 (67.37)	80.00 (63.55)	80.66 (63.97)	82.00 (65.34)
T5. $ZnSO_4$ (1%)	80.00 (63.45)	81.66 (65.05)	84.33 (66.91)	87.66 (69.50)
T6. Ascorbic Acid (50 ppm)	78.33 (62.34)	79.00 (62.88)	82.33 (65.27)	81.66 (65.13)
T7. Deionised H_2O	76.33 (60.89)	77.33 (62.33)	80.0 (63.47)	76.33 (61.04)
T8. Dry seed (Control)	69.66 (56.89)	72.33 (58.32)	71.00 (57.51)	71.33 (57.68)
CD (1%)	5.70	7.85	5.62	8.42
CV %	7.52	8.01	6.00	7.28

* Number inside the parenthesis indicates arcsine transformed value

SV-I of Field emerged seedling (FES)

SV-I of field emerged seedling of brinjal varieties is presented in Table 5. Significant differences were observed among the treatments with respect to this character in all the varieties. In Utkal Jyoti SV-I of FES varied from 363.83 (control) to 678.36 (GA3). Utkal Jyoti responded positively to all priming treatments. In Utkal Keshari priming with GA3 showed the greatest effect (645.94) in enhancing SV-I of FES followed by PEG (628.45). In Utkal Madhuri $ZnSO_4$ recorded the highest SV-I of FES (645.99) followed by KNO_3 (641.75). In Utkal Anushree SV-I of FES varied from 470.97 (control) to 676.77 (KNO_3). Seeds primed with GA3, KNO_3, Na_2HPO_4, PEG, $ZnSO_4$, Ascorbic Acid and deionised water enhanced the SV-I of FES by 44.2%, 49.3%, 42.0%, 38.8%, 42.7%, 34.6% and 27.4% respectively. This result revealed that KNO_3 has better impact on SV-I of FES in brinjal.

Table 5: Effect of priming treatments on SV-I of field emerged seedling of brinjal varieties

Priming treatment	Utkal Jyoti	Utkal Keshari	Utkal Madhuri	Utkal Anushree
T1. GA_3 (1 ppm)	678.36	645.94	554.61	640.81
T2. KNO_3(5%)	663.56	628.09	641.75	676.77
T3. Na_2HPO4 (2%)	641.55	621.87	614.91	604.45
T4. PEG (10%)	627.85	613.87	556.91	626.92
T5. $ZnSO_4$(1%)	580.00	628.45	645.99	639.21
T6. Ascorbic Acid (50 ppm)	591.65	569.39	630.07	561.87
T7. Deionised H_2O	563.67	515.43	598.07	549.71
T8. Dry seed(Control)	363.83	477.57	435.50	470.97
CD (1%)	66.50	65.33	66.76	53.22
CV %	4.74	4.66	4.79	3.74

SV-II of Field emerged seedling (FES)

SV-II of field emerged seedling of brinjal varieties is presented in Table 6. In Utkal Jyoti SV-II of FES varied from 182.92 (GA3) to 490.30 (PEG). Utkal Jyoti responded positively to all priming treatments except GA3. In Utkal Keshari priming with KNO_3 showed the greatest effect (1035.50) in enhancing SV-II of FES followed by $ZnSO_4$ (979.50) and the lowest was being observed in control (448.67). In Utkal Madhuri PEG recorded the highest SV-II of FES (1291.83) followed by $ZnSO_4$ (1191.73). In Utkal Anushree SV-II of FES varied from 297.27 (control) to 1068.80 (GA3).The mean effect reflected the efficiency of $ZnSO_4$ in increasing SV-II of FES followed by PEG.

Table 6: Effect of priming treatments on SV-II of field emerged seedling of brinjal varieties

Priming treatment	Utkal Jyoti	Utkal Keshari	Utkal Madhuri	Utkal Anushree
T1. GA_3 (1 ppm)	182.92	716.07	703.60	1068.80
T2. KNO_3(5%)	349.20	1035.50	1043.53	717.53
T3. Na_2HPO4 (2%)	327.73	707.77	830.80	1020.20
T4. PEG (10%)	490.30	640.00	1291.83	820.20
T5. $ZnSO_4$(1%)	319.67	979.50	1191.73	877.83
T6. Ascorbic Acid(50 ppm)	310.33	579.33	823.17	653.00
T7. Deionised H_2O	312.87	635.33	493.43	623.77
T8. Dry seed(Control)	274.07	448.67	426.07	297.27
CD(1%)	31.50	61.02	85.87	84.80
CV %	4.12	3.57	4.23	4.68

Evaluating efficacy of different priming treatments

The present study indicates that all seed quality parameters were not equally influenced by a single priming treatment i.e. the response of different varieties of brinjal in respect of seed quality parameters is different in different priming treatments. Hence the efficacy of a priming treatment in improving seed quality parameters could not be judged on the basis of its effect on a single parameter. It would be better to consider all the parameters together in order to decide the efficiency of a priming treatment. In this investigation the efficacy of priming treatments was judged in following way as given below.

The efficacy of priming treatments was determined on the basis of two parameters i.e. cumulative germination index (CGI; obtained by adding the coded value of germination count in lab and field) and cumulative seedling vigour index (CSVI; obtained by adding the coded value of SV-I, SV-II in lab and SV-I, SV-II of field emerged seedlings). CGI value of

treatments varied from 2 to 6 where as CSVI value varied from 4 to 11. T1 (GA3), T2 (KNO_3), T3 (Na_2HPO_4) and T4 (PEG) have above average cumulative germination index (> 4.5) and cumulative seedling vigour index (> 8.75; Table 7). These four priming treatments are similar in their efficacy and better than rest of the treatments. Among these four treatments, the treatments having low cost could be recommend for farmer's use. $ZnSO_4$(1%) has high CSVI value but low CGI value. In Ascorbic Acid (50 ppm) and hydro priming both CSVI value and CGI values are low.

Table 7: Coded value of seed quality parameters, CGI & CSVI value of priming treatments

Treatment	Lab test			Field test			CGI	CSVI
	Germination	SV-I	SV-II	FEP	SV-I	SV-II		
T1	3	3	2	3	3	3	6	11
T2	3	2	3	3	3	3	6	11
T3	3	3	2	3	3	3	6	11
T4	3	2	3	3	3	3	6	11
T5	2	2	3	2	3	2	4	10
T6	2	2	1	2	2	2	4	7
T7	1	1	2	1	1	1	2	5
T8	1	1	1	1	1	1	2	4

*(Note: T1 = GA3 (1 ppm), T2 = KNO3 (5%), T3 = Na_2HPO_4 (2%), T4 = PEG (10%), T5 = $ZnSO_4$ (1%), T6 = Ascorbic Acid (50 ppm), T7 = deionised water, T8 = Dry seeds)

Demir *et al.* (1994) [1] studied the effects of GA_3, KNO_3 and PEG on germination of two year old eggplant seeds. They showed that GA_3 and KNO_3 in particular and unlike the control, significantly influenced germination percentage and germination rate. In the present study these two priming treatments showed high germination and seedling vigour. Trigo *et al*. (1999) [7] observed that the priming in water and KNO_3 is efficient to improve germination of eggplant seeds. Nascimento and Lima (2008) [4] reported that priming of eggplant seeds in PEG decreased germination, while the use of KNO_3 provided the best result. Reis *et al*. (2012) [5] suggested that priming in water or KNO_3 improved germination in brinjal. Trigo *et al*. (1999) [7] commented that the advantage of priming with KNO_3 may be related to the fact that this may act as an additional source of potassium and nitrogen during seed germination. Moreover potassium nitrate solution has long been known as a suitable chemical approach for promoting germination in various plant species and generally as a priming agent or germination media (Mc Donald, 2000) [3]. The results of the present investigation revealed that GA_3, KNO_3, Na_2HPO_4 and PEG have pronounced effect on seed quality parameters of brinjal.

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