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Effect of salinity (NaCl) stress on seed germination and seedling vigour of okra (*Abelmoschus esculentus* L.) cultivars

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Abstract
Okra (*Abelmoschus esculentus* L.) is an annual herb and commercial vegetable crop belonging to the family Malvaceae. It is grown throughout the tropical and subtropical parts of the world. But its cultivation is hampered in saline and Sodic soils as it is sensitive to salinity. Among the different abiotic factor's salinity is one of the common factors that limits agricultural productivity. Germination under salt stress is the determining factor for most of the crops. The present experiment was carried out at College of Horticulture, Anantharajupeta to study the response of four okra cultivars *i.e.,* Arka Anamika, Pusa Sawani, Pusa Bhindi-5, Local variety under four concentrations of NaCl (2, 4, 6 and 8 dS m^{-1}) along with distilled water as control. It was found that with the increase in salinity concentration there was a significant reduction in the final germination percentage, radicle and plumule length, seedling vigour index while increase in salinity levels enhanced the time for 50% germination and mean germination time. Maximum germination percentage, radicle and Plumule lengths were obtained with distilled control treatment followed by 2,4 dS m^{-1} while minimum was recorded with high salt concentration (8 dS m^{-1}). Based on the results of the present experiment it was concluded that the cultivar Pusa Bhindi-5 showed the best results for germination and seedling vigour.

Keywords: Okra, salinity, NaCl, distilled water, germination, seedling vigour

Introduction
Okra (*Abelmoschus esculentus* L.) is a commercial vegetable crop belonging to the family Malvaceae with chromosome number 2n= 130 and it is commonly known as bhendi or ladies' finger, believed to have originated around Ethiopia. It is an especially important crop for farmers with small holdings as it provides higher income per hectare. Okra fruit is a major source of vitamins A, B, C, calcium, potassium, iron, iodine and other minerals which are often lacking in the human diet in developing countries. It is also a source of antioxidant compounds including phenols, flavonoid derivatives such as catechins and quercetin. The mucilage of okra helps to remove toxins from the body.

The most harmful environmental stress that destroy agriculture productions are saline irrigation and saline soil. Salinity is a worldwide problem that limits the growth and productivity of all vegetation and it is increasing day by day. More than 37% of world's agricultural land is under salinity (Shahbaz *et al*., 2012) [9]. It occurs due to the accumulation of calcium, magnesium, sodium and their anions such as sulphates, carbonates, bicarbonates as well as chloride ions. Of these salts, sodium chloride is the most common.

Rapid seed germination and subsequent seedling establishment are important factors affecting crop production under saline conditions where the seed germination is affected by a complex interaction of hormones, osmotic effects, specific ion effects and nutritional imbalances, which occur simultaneously depending upon stress nature and duration (Abbas *et al*., 2014) [1]. NaCl had a considerable inhibitory effect on seed germination of okra with Na+, sugar and phenols increased, while K+, starch, and amylase activity decreased significantly in the cotyledons of germinating seeds (Abid *et al*., 2002) [2]. Keeping all these issues in point of view, the present experiment was carried out with the objective to know the effects of salt stress (NaCl) on seed germination and seedling vigour of four okra cultivars.

Material and Methods
The present experiment was carried out at College of Horticulture, Anantharajupeta during *spring-summer* 2022 to study the response of four okra cultivars (C_1- Arka Anamika, C_2- Pusa Sawani, C_3-Pusa Bhindi-5, C_4- Local variety) under five concentrations of NaCl (S_1- distilled water control, S_2- 2 dS m^{-1}, S_3- 4 dS m^{-1}, S_4- 6 dS m^{-1} and S_5- 8 dS m^{-1}). The experiment was conducted in factorial completely randomized design with three replications and were subjected to analysis of variance at 5% level of significance. The germination tests were accomplished in petri plates that were sterilized by keeping in hot air oven at 180 °C for 30 minutes. Then the Petri plates were lined with blotting paper. For each treatment (in each petri plate) ten healthy and uniform seeds of each cultivar were placed. The blotting paper in each Petri plates was moistened with 5ml of distilled water and different concentrations of NaCl (2, 4, 6 and 8 dSm^{-1}) as per the treatments. The moisture content of the blotting paper was maintained regularly by pouring different NaCl concentrations and distilled water. An emergence of radicle was considered as seed germination and the number of seeds germinated was counted daily up to 10 days. The observations were recorded from five randomly selected seeds in each treatment.

Final germination percentage

$$FGP = \frac{\text{Total seeds germinated at end of the trial}}{\text{Number of seeds used}} \times 100$$

The mean germination time

$$MGT = \frac{\sum (Dn)}{\sum n}$$

Where, n is the number of seeds germinated on each day and D is the day of counting.

Seedling vigour index
Seedling vigor index = (Root length + Shoot length) X Germination percentage

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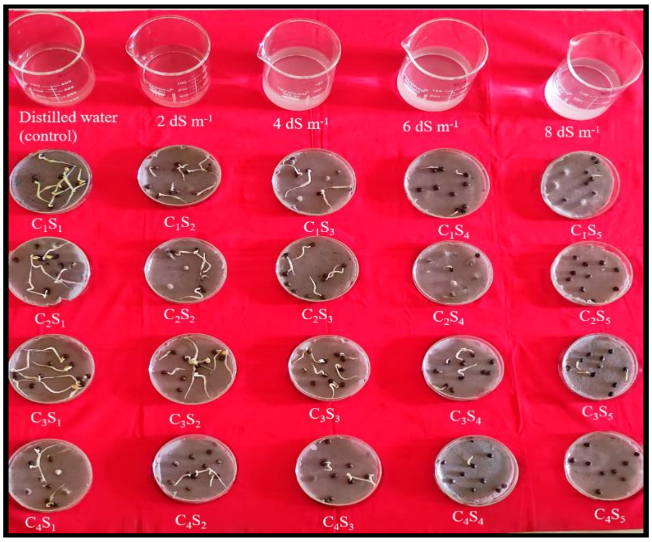

Fig 1: Germination studies of okra cultivars under different salinity stress levels at 10th day of experiment.

Results and Discussion

Table 1: Effect of different salinity stress levels (NaCl) on days to 50% germination of okra cultivars.

Cultivar	Days to 50% germination					
	Salinity stress level					
	S_1	S_2	S_3	S_4	S_5	Mean
C_1	3.50 (2.12)	4.50 (2.35)	5.00 (2.45)	0.00 (1.00)	0.00 (1.00)	2.60 (1.78)
C_2	4.30 (2.30)	5.00 (2.45)	5.60 (2.57)	0.00 (1.00)	0.00 (1.00)	2.98 (1.86)
C_3	3.00 (2.00)	3.50 (2.12)	4.00 (2.24)	0.00 (1.00)	0.00 (1.00)	2.10 (1.67)
C_4	4.50 (2.19)	5.30 (2.51)	6.30 (2.70)	0.00 (1.00)	0.00 (1.00)	3.22 (1.91)
Mean	3.83 (2.19)	4.58 (2.36)	5.23 (2.49)	0.00 (1.00)	0.00 (1.00)	
	S.Em±			CD at 5%		
C	0.00			0.01		
S	0.01			0.01		
CXS	0.01			0.03		

*The data in parenthesis indicates transformed values

The data presented in table 1 represents days to 50% germination of okra cultivars as influenced by different salinity stress levels. Significantly all the cultivars took minimum number of days to 50% germination with control treatment. As the salinity stress level is increased, cultivars took more number of days to 50% germination over the control. Among the interaction effects significantly minimum days for 50% germination (3.00) was recorded in C_3S_1 (Pusa Bhindi-5 with control) followed by C_3S_2 (Pusa Bhindi-5 at 2 dS m^{-1}) and C_1S_1-Arka Anamika with control (3.50 days). The results showed significant increase in number of days for 50% germination with the increase in salinity stress level. This might be due to excessive entry of toxic ions (Na and Cl) into the seed tissues which inhibit the germination of seeds by reducing the water absorption capacity of the seeds thus by increasing the time for 50% germination.

Table 2: Effect of different salinity stress levels (NaCl) on mean germination time of okra cultivars.

Cultivar	Mean Germination Time (days)					
	Salinity stress level					
	S_1	S_2	S_3	S_4	S_5	Mean
C_1	3.12	3.36	3.72	4.11	4.32	3.73
C_2	3.51	3.59	4.10	4.25	4.47	3.99
C_3	3.01	3.15	3.46	3.92	4.01	3.51
C_4	3.96	3.82	4.07	4.57	4.93	4.27
Mean	3.40	3.48	3.84	4.21	4.43	
	S.Em±			CD at 5%		
C	0.03			0.08		
S	0.03			0.08		
CXS	0.06			0.17		

Among the cultivars significantly lowest mean germination time (3.51 days) was recorded in Pusa Bhindi-5 followed by Arka Anamika (3.73 days), while highest was recorded with Local variety (4.27 days). As the salinity stress levels increased, days to mean germination was found to be increasing. Minimum mean germination time (3.40 days) was recorded in distilled water control followed by 2 dS m^{-1} and 4 dS m^{-1} (3.48 and 3.84 days) respectively, while maximum (4.43 days) was recorded with 8 dS m^{-1}. Among the interactions minimum mean germination time (3.01 days) was recorded in C_3S_1 (Pusa Bhindi-5 with control) followed by C_1S_1- Arka Anamika with control (3.12 days), while maximum mean germination time (4.93 days) was recorded in C_4S_5 (Local variety at 8 dS m^{-1}).

Table 3: Effect of different salinity stress levels (NaCl) on final germination percentage of okra cultivars.

Cultivar	Final germination percentage					
	Salinity stress level					
	S_1	S_2	S_3	S_4	S_5	Mean
C_1	86.7	83.3	70.0	43.3	20.0	60.7
C_2	80.0	73.3	63.3	30.0	13.3	52.0
C_3	93.3	90.0	83.3	53.3	23.3	68.7
C_4	80.0	70.3	50.0	13.3	10.3	45.4
Mean	85.0	80.0	66.7	35.0	16.7	
	S.Em±			CD at 5%		
C	0.51			1.47		
S	0.57			1.64		
CXS	1.14			3.28		

Among the four cultivars under study Pusa Bhindi-5 recorded maximum final germination percentage (68.7%) followed by Arka Anamika (60.7%). While Local variety recorded lowest final germination percentage (45.4%). With the increase in NaCl level, final germination was drastically reduced from 85% to 16.7%. however, among the interactions, highest final germination percentage (93.3) was observed in C_3S_1 (Pusa Bhindi-5 with control) followed by C_3S_2 (90.0), while the lowest (10.3) was observed in C_4S_5 (Local variety at 8 dS m^{-1}) which was statistically on par with C_2S_5- Pusa Sawani at 8 dS m^{-1} (13.3). The reduction in the final germination percentage of seeds with the increasing salinity levels might be due to salt stress which limits the seed germination by reducing the water absorption capacity of seeds, inducing ion toxicity and ionic imbalance, unbalanced nutrient uptake within the cell cytoplasm which disturbs the protein activity of seeds grown under high levels of salinity.

Table 4: Effect of different salinity stress levels (NaCl) on radicle length of okra cultivars.

Cultivar	Radicle length (cm)					
	Salinity stress level					
	S_1	S_2	S_3	S_4	S_5	Mean
C_1	5.80 (2.61)	5.20 (2.49)	4.60 (2.37)	2.11 (1.76)	1.07 (1.44)	3.76 (2.13)
C_2	5.62 (2.57)	4.81 (2.41)	4.21 (2.28)	1.93 (1.71)	0.00 (1.00)	3.31 (2.00)
C_3	6.83 (2.80)	6.21 (2.69)	5.40 (2.53)	2.12 (1.77)	1.31 (1.52)	4.37 (2.26)
C_4	5.66 (2.58)	4.45 (2.33)	4.32 (2.31)	1.64 (1.63)	0.00 (1.00)	3.22 (1.97)
Mean	5.98 (2.64)	5.17 (2.48)	4.63 (2.37)	1.95 (1.72)	0.60 (1.24)	
	S.Em±			CD at 5%		
C	0.01			0.02		
S	0.01			0.02		
CXS	0.02			0.04		

Table 5: Effect of different salinity stress levels (NaCl) on Plumule length of okra cultivars.

Cultivar	Plumule length (cm)					
	Salinity stress level					
	S_1	S_2	S_3	S_4	S_5	Mean
C_1	5.82 (2.61)	4.96 (2.44)	4.28 (2.30)	2.21 (1.79)	1.62 (1.62)	3.78 (2.15)
C_2	5.86 (2.62)	4.23 (2.29)	4.16 (2.27)	1.19 (1.48)	0.00 (1.00)	3.09 (1.93)
C_3	6.23 (2.69)	5.89 (2.63)	4.29 (2.30)	2.31 (1.82)	1.86 (1.69)	4.12 (2.23)
C_4	5.32 (2.51)	4.13 (2.27)	3.26 (2.06)	0.57 (1.25)	0.00 (1.00)	2.66 (1.82)
Mean	5.81 (2.61)	4.80 (2.41)	4.00 (2.23)	1.57 (1.59)	0.87 (1.33)	
	S.Em±			CD at 5%		
C	0.00			0.01		
S	0.01			0.01		
CXS	0.01			0.03		

The data presented in table 4 and 5 represents the length of radicle and plumule of okra cultivars under different salinity stress levels. Among the cultivars significantly highest radicle and plumule length (4.37 and 4.12 cm) was recorded in C_3-Pusa Bhindi-5, while the lowest (3.22 and 2.66 cm) was recorded in Local variety. Among the various salinity stress treatments, maximum radical and plumule length (5.98 and 5.81 cm) was recorded in distilled water control followed by 2 dS m^{-1} (5.17, 4.80 cm), while minimum (0.60, 0.87 cm) was recorded in 8 dS m^{-1}. Among the interaction effects, C_3S_1 followed by C_3S_2 recorded highest radicle and plumule length. However, in the treatments C_2S_5 and C_4S_5 the length of radicle and plumule was zero because there was no differentiation of radicle and plumule in these seeds as their growth has been stopped after germination.

Table 6: Effect of different salinity stress levels (NaCl) on seedling vigour index of okra cultivars

Cultivar	Seedling vigour index					
	Salinity stress level					
	S_1	S_2	S_3	S_4	S_5	Mean
C_1	1,006.20 (31.74)	846.63 (29.11)	621.60 (24.95)	187.18 (13.72)	53.80 (7.40)	543.08 (21.38)
C_2	916.80 (30.29)	662.16 (25.75)	529.43 (23.03)	93.60 (9.73)	0.00 (1.00)	440.40 (17.96)
C_3	1,213.29 (34.85)	1,088.10 (33.00)	807.46 (28.43)	236.25 (15.40)	73.95 (8.66)	683.81 (24.07)
C_4	878.40 (29.65)	716.43 (26.78)	379.10 (19.50)	29.45 (5.52)	0.00 (1.00)	400.68 (16.49)
Mean	1,003.67 (31.63)	828.33 (28.66)	584.40 (23.98)	136.62 (11.09)	31.94 (4.52)	
	S.Em±			CD at 5%		
C	0.08			0.24		
S	0.09			0.27		
CXS	0.19			0.54		

The data pertaining to seedling vigour index was presented in table 6 showed significant difference among the cultivars, different salinity levels and their interactions. Maximum seedling vigour index (683.81%) was observed in PusaBhindi-5 followed by Arka Anamika (543.08%), while minimum (400.68%) was observed in the Local variety. Among different salinity stress treatments, maximum seedling vigour index (1003.67%) was recorded with control followed by 2 dS m^{-1} (828.33%) and 4 dS m^{-1} (136.62%), while minimum (31.94%) was recorded in 8 dS m^{-1}. Among the interaction effects C_3S_1 (1213.29%) followed by C_3S_2 (1088.10%) and C_1S_1 (1006.20%) recorded significantly maximum seedling vigour index, while C_4S_5 and C_2S_5 recorded lowest (0.00) indicating very poor seedling vigour index at elevated stress levels. Increased levels of salinity significantly reduced the length of the radical, plumule and ultimately seedling vigour index. This might be due to the inhibition of the enzymatic activity in seeds and delay in the development of the radical and plumule.

Conclusion

From this experiment it was concluded that increase in level of salinity (NaCl) significantly decreased the seed germination percentage and seedling vigour. Among the four cultivars under study Pusa Bhindi-5 recorded the highest germination values followed by Arka Anamika, while lowest was recorded in Local variety.

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