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Evaluation of seed priming techniques for improving germination under salinity stress in okra

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Abstract

Nearly 20% of irrigated farmland across South Asia is affected by soil salinity, and okra (*Abelmoschus esculentus* L. Moench) is among the vegetables most sensitive to salt stress during germination. This research evaluated six seed priming protocols for improving germination and seedling vigour of okra cultivar Arka Anamika under four salinity levels (0, 4, 8, and 12 dS/m NaCl). The experiment was conducted at the seed-testing laboratory of Bundelkhand University of Agricultural Sciences, Jhansi, during 2023, following a completely randomised factorial design with four replications. Treatments included hydropriming, osmopriming with PEG 6000 at -0.5 MPa, halopriming with KCl (1%) and KNO₃ (2%), hormonal priming with GA₃ (50 ppm), and an unprimed control. KNO₃ priming at 2% consistently gave the best performance across all salinity levels. At 12 dS/m, germination under KNO₃ priming reached 48.3% compared with 22.7% in the control. Vigour index I was 2.3 times higher in KNO₃-primed seeds at 8 dS/m. GA₃ priming ranked second, while PEG osmopriming showed the weakest improvement. A simple overnight soak in 2% KNO₃ offers an affordable approach to overcoming salt-induced germination failure in okra.

Keywords: Seed priming, germination, salinity stress, okra, *Abelmoschus esculentus*, halopriming, osmopriming, vigour index, NaCl, seed enhancement

Introduction

According to the Indian Council of Agricultural Research, roughly 6.73 million hectares of land in India are salt-affected, and the figure may rise to 16.2 million hectares by 2050 ^[1]. Soil salinity disrupts water uptake, creates ion toxicity, and triggers oxidative damage, all of which reduce germination ^[2]. Okra is particularly vulnerable to salt injury at germination because of its mucilaginous seed coat that absorbs excess sodium ^[3].

Seed priming, the controlled hydration of seeds followed by re-drying before sowing, has been explored as a low-cost countermeasure. The technique activates pre-germinative metabolic events without allowing radical emergence ^[4]. Several priming agents have been tested: hydropriming with water shows moderate success in wheat ^[5]; osmopriming with PEG regulates imbibition rate ^[6]; halopriming with KCl or KNO₃ provides both osmotic conditioning and a nutrient source ^[7]; and hormonal priming with GA₃ directly promotes embryo growth ^[8].

Comparative data for okra under graded salinity remain scarce. A few reports exist for okra under drought ^[9], but controlled comparisons under salinity are limited. The interaction between priming method and salinity level is especially important: a treatment effective at 4 dS/m may fail at 12 dS/m ^[10]. This research compared six seed priming protocols across four salinity levels to identify the agent offering the widest protection window for okra growers in salt-affected areas ^[11, 12].

Material and Methods

Material

Seeds of okra cultivar Arka Anamika were obtained from the Indian Institute of Vegetable Research, Varanasi (initial germination 92%, moisture 8.4%). Priming chemicals included PEG 6000 (Sigma-Aldrich), KCl and KNO₃ (Merck, analytical grade), and GA₃ (Loba Chemie, 90% purity). Saline solutions were prepared using NaCl (Merck). All germination

tests were conducted at 28 $\pm$ 1 deg C and 85 $\pm$ 5% relative humidity in thermostatic cabinets at Bundelkhand University of Agricultural Sciences, Jhansi.

Methods

Seeds were surface-sterilised with 0.1% mercuric chloride (2 min), rinsed, and primed: hydropriming in distilled water (12 h); osmopriming in PEG 6000 at -0.5 MPa (16 h); halopriming in 1% KCl (12 h) and 2% KNO₃ (12 h); and hormonal priming in 50 ppm GA3 (8 h). Seed-to-solution

ratio was 1:5 (w/v). After priming, seeds were air-dried to original moisture ^[13]. Germination tests used the between-paper method with 25 seeds per replicate across four NaCl levels (0, 4, 8, 12 dS/m) and four replications (96 rolls total). Counts were taken on days 7 and 14 following ISTA rules ^[14]. Vigour index I = germination % x seedling length; vigour index II = germination % x seedling dry weight ^[15]. Data were analysed as a factorial CRD using OPSTAT software; means separated by LSD at $p < 0.05$.

Results

Table 1: Germination percentage of okra at four salinity levels under different priming treatments

Treatment	0 dS/m	4 dS/m	8 dS/m	12 dS/m	Mean	% change*
Control	89.3	72.1	41.3	22.7	56.4	-
Hydropriming	91.7	79.4	58.6	34.2	66.0	17.0
KCl 1%	90.2	81.3	62.8	38.9	68.3	21.1
KNO ₃ 2%	93.1	86.7	71.4	48.3	74.9	32.8
PEG -0.5 MPa	88.9	78.2	55.1	31.6	63.5	12.6
GA3 50 ppm	92.4	84.1	66.3	42.7	71.4	26.6
CD ($p < 0.05$)	3.1	3.8	4.6	5.2	-	-

*Percentage change over control at 12 dS/m

Germination declined progressively with salinity, but the magnitude varied sharply among priming methods. At 0 dS/m, differences were small. At 8 and 12 dS/m, KNO₃-primed seeds maintained germination at 71.4% and 48.3%,

while unprimed seeds dropped to 41.3% and 22.7%. The priming x salinity interaction was significant ($p < 0.01$). Vigour index I under KNO₃ at 12 dS/m was 627, roughly 2.8 times the control value of 227.

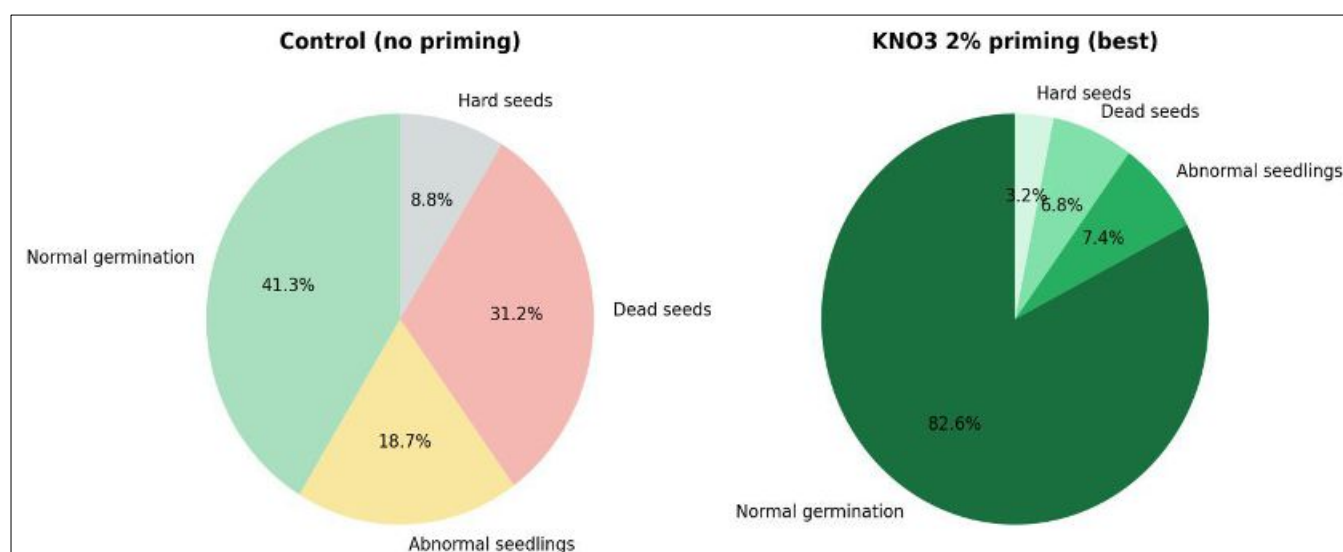


Fig 1: Seed lot composition (%) under control and KNO₃ 2% priming at 12 dS/m salinity

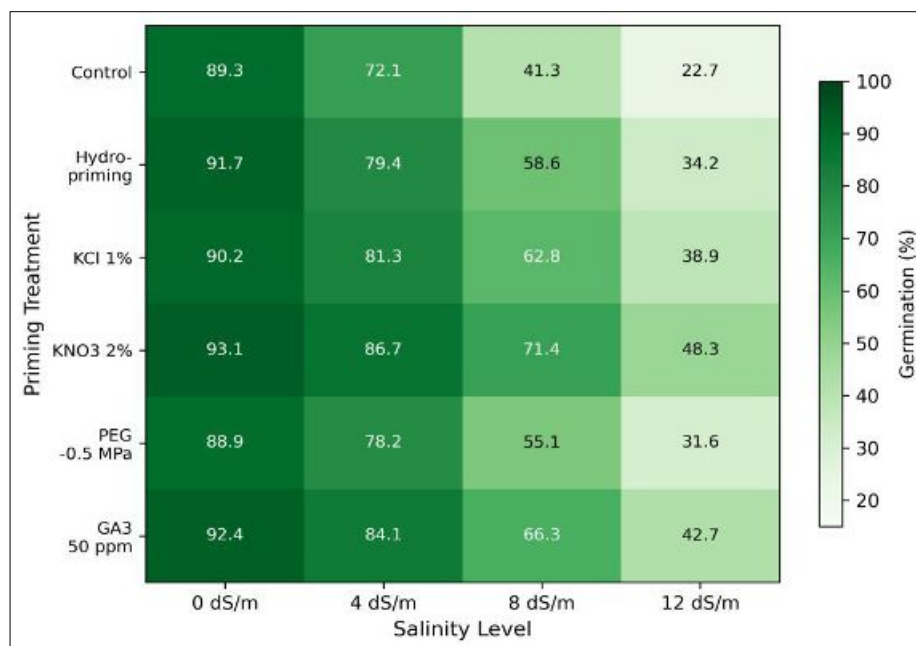


Fig 2: Heatmap of germination percentage across priming treatments and salinity levels

The pie charts (Figure 1) contrast seed fate at 12 dS/m: without priming, dead seeds and abnormal seedlings accounted for nearly half the lot, whereas KNO₃ shifted the balance toward normal germination. The heatmap (Figure 2) confirms KNO₃ 2% as the greenest row across all columns, while PEG osmopriming appears almost indistinguishable from hydropriming at higher salinities.

Discussion

The strong performance of KNO₃ priming agrees with Nawaz *et al.* [7] in wheat and Basra *et al.* [16] in hot pepper. Potassium nitrate likely confers a dual benefit: potassium ions counteract sodium entry through competitive inhibition at membrane transport sites, while nitrate ions serve as a nitrogen source for early enzymatic activity [17]. The reasonable performance of KCl supports the view that the potassium ion is the main driver of protection.

GA₃ priming ranked second. Gibberellic acid stimulates alpha-amylase and other hydrolytic enzymes that supply the embryo with sugars and amino acids [8]. But GA₃ costs several times more than KNO₃, limiting its appeal for smallholder growers. The weak PEG response was unexpected; Farooq *et al.* [6] cautioned that PEG can clog seed coat pores in mucilaginous species, and okra's abundant mucilage production may explain this finding.

One practical implication: the priming advantage was greatest at 8 dS/m and declined at 12 dS/m. Even the best treatment only lifted germination to 48% at 12 dS/m, which may be too low for commercial stands. Seed priming should therefore be part of a broader salinity management package that includes soil amendments and salt-tolerant varieties [18, 19].

Conclusion

This research demonstrated that seed priming can substantially improve okra germination under salinity stress. Among six treatments, halopriming with 2% KNO₃ for 12 hours was the most effective, raising germination at 12 dS/m from 22.7% to 48.3% and lifting vigour index I by 2.8-fold. GA₃ priming ranked second, followed by KCl and

hydropriming. PEG osmopriming was weakest, possibly because of mucilage-PEG interactions.

The priming x salinity interaction was significant: at low salinity most methods worked similarly, but at 8-12 dS/m only KNO₃ and GA₃ kept germination above 40%. KNO₃ is inexpensive, widely available, and requires no specialised equipment, making it suitable for smallholder adoption. Future work should validate these results under field conditions across salt-affected regions of the Indo-Gangetic plain.

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