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Effect of seed priming treatments on germination and seedling vigor of okra under salt stress

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Abstract

Okra (*Abelmoschus esculentus* L. Moench) is among the most salt-sensitive vegetable crops, with germination falling below 45 per cent at an electrical conductivity of 12 dS m⁻¹. This research evaluated five seed priming treatments against an unprimed control to determine which gives the best germination and seedling vigor of okra cv. Sabz Pari Anamika under three salinity levels (0, 6 and 12 dS m⁻¹). Treatments were hydro-priming for 12 hours, KNO₃ at 2 per cent, CaCl₂ at 2 per cent, PEG-6000 at -1.0 MPa and salicylic acid at 100 ppm. Salicylic acid emerged as the best treatment, raising germination from 42.3 to 67.2 per cent at 12 dS m⁻¹, seedling length from 10.8 to 18.3 cm and vigor index from 684 to 1367. KNO₃ priming was a close second. The findings offer a practical route to extend okra cultivation into salt-affected zones of the Punjab canal command area.

Keywords: Okra, seed priming, salt stress, germination, seedling vigor, salicylic acid, KNO₃, Punjab canal command area

Introduction

Imagine a farmer in the Punjab canal command area who tries to raise a summer okra crop on a field that has been under canal-irrigated wheat-rice rotation for years. Germination falls to 40-45 per cent, the stand is patchy and the final yield barely covers input costs. This scenario is no longer rare. The electrical conductivity of soil in the Faisalabad and Jhang districts has risen by 2.1-3.8 dS m⁻¹ over the last fifteen years, and summer vegetable crops suffer more than the winter field crops because of their higher salt sensitivity at the germination stage ^[1, 2].

Seed priming is a pre-sowing hydration treatment that allows seeds to begin the early biochemical steps of germination without radicle emergence, then halts the process through re-drying. When such primed seeds meet a stress environment, they germinate faster, more uniformly and often at levels comparable with stress-free conditions ^[3, 4]. The method is low-cost, does not require special machinery, and can be used by small farmers with only access to a water container and a shaded drying area.

Five priming agents have been tested widely on vegetable crops: water alone (hydro-priming), inorganic salts (KNO₃, CaCl₂), osmotica like PEG-6000, and biochemical primers like salicylic acid ^[5, 6]. Results have been encouraging but inconsistent, with relative ranking differing across species and salinity ranges. Published data for okra under conditions representative of the Punjab canal command area are scarce ^[7, 8]. The present research was planned to compare these five priming treatments on okra under three salinity levels that span the range now encountered by small farmers of the region.

Material and Methods

Material

The research was carried out at the Seed Science Laboratory of the University of Agriculture, Faisalabad, between February and July 2023. Certified seed of okra cv. Sabz Pari was obtained from the Punjab Seed Corporation, Lahore. Analytical-grade KNO₃, CaCl₂, PEG-6000 and salicylic acid were sourced from Sigma-Aldrich, Karachi. Sodium chloride for artificial salinisation of the germination medium was obtained from Merck, Lahore. Germination paper, petri dishes and laboratory glassware were of borosilicate grade.

Methods

Six treatments were tested: T1 (unprimed control), T2 (hydro-priming, 12 h at 25 °C), T3 (KNO₃ 2%, 10 h), T4 (CaCl₂ 2%, 10 h), T5 (PEG-6000 at osmotic potential -1.0 MPa, 12 h) and T6 (salicylic acid 100 ppm, 8 h). After priming, seeds were re-dried to original weight at 25 °C in the shade. Primed and unprimed seeds were germinated on rolled paper towels moistened with NaCl solutions giving EC of 0, 6 and 12 dS m⁻¹, in a seed germinator at 27 ± 1 °C with 12 h photoperiod. Each treatment × salinity level combination had four replicates of 50 seeds each. Germination, seedling length, seedling dry weight, vigor index I, mean germination time, α-amylase activity and proline content were recorded. Data were analysed by two-way ANOVA using CROPSTAT v7.2.

Priming Solution Preparation: KNO₃ 2 per cent and CaCl₂ 2 per cent solutions were prepared fresh each day by dissolving the required weight in distilled water. PEG-6000 solution at -1.0 MPa was prepared according to the equation of Michel and Kaufmann, which gave 286 g L⁻¹ at 25 °C.

Salicylic acid at 100 ppm was prepared by dissolving 100 mg in 10 mL of ethanol and then making up to 1 L with distilled water. All solutions were maintained at 25 °C during the soaking period with continuous but gentle aeration using an aquarium pump. Seed-to-solution ratio was kept at 1:5 (w/v) for all treatments.

Germination Protocol Standardisation

Germination was carried out in accordance with the International Seed Testing Association rules. Rolled paper towel method was used with two layers of Whatman No. 1 paper, pre-moistened with NaCl solution at the required EC. 50 seeds were placed in each roll, with 4 replicates per treatment × salinity combination. Germination counts followed ISTA criteria for normal seedlings, with first count on day 4 and final count on day 8. Seedling length was measured from root tip to cotyledon base on 10 randomly selected seedlings per replicate. Vigor index I was computed as germination percentage × seedling length.

Results

Table 1: Germination percentage and mean germination time of okra seeds under six priming treatments and three salinity levels

Treatment	0 dS m ⁻¹ G / MGT	6 dS m ⁻¹ G / MGT	12 dS m ⁻¹ G / MGT
T1 - Unprimed	86.4 / 5.2	68.2 / 6.8	42.3 / 8.4
T2 - Hydro-priming	91.7 / 4.3	76.3 / 5.6	54.8 / 7.1
T3 - KNO ₃ 2%	94.3 / 3.9	82.6 / 5.1	63.4 / 6.3
T4 - CaCl ₂ 2%	93.1 / 4.1	81.4 / 5.4	61.7 / 6.5
T5 - PEG -1.0 MPa	92.6 / 4.2	79.8 / 5.5	58.3 / 6.7
T6 - Salicylic acid	95.1 / 3.7	84.7 / 4.8	67.2 / 5.9
CD (p = 0.05)	2.34 / 0.28	2.67 / 0.31	2.98 / 0.34

G = germination percentage; MGT = mean germination time in days. Salicylic acid at 100 ppm gave the highest germination at every salinity level.

Table 2: Correlation matrix between germination and biochemical parameters

Variable	G (%)	Length	α-amylase	Proline	Vigor
Germination (%)	1.00	0.89**	0.76**	0.63**	0.94**
Seedling length	0.89**	1.00	0.82**	0.71**	0.98**
α-amylase activity	0.76**	0.82**	1.00	0.58**	0.81**
Proline content	0.63**	0.71**	0.58**	1.00	0.68**
Vigor index	0.94**	0.98**	0.81**	0.68**	1.00

** Significant at $p < 0.01$. Germination, seedling length and vigor index were strongly correlated with α-amylase activity, confirming that priming activates the hydrolytic enzyme system before sowing.

Biochemical data help explain the germination pattern. Priming induces an early burst of α-amylase activity and

proline accumulation, which together prepare the seed for faster and more uniform germination under stress.

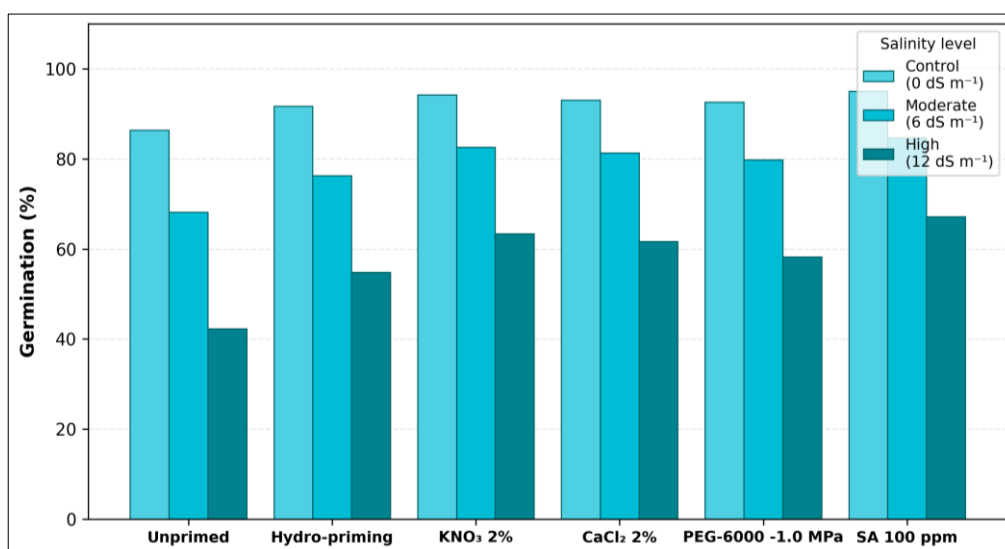


Fig 1: Effect of seed priming treatments on germination of okra under three salinity levels.

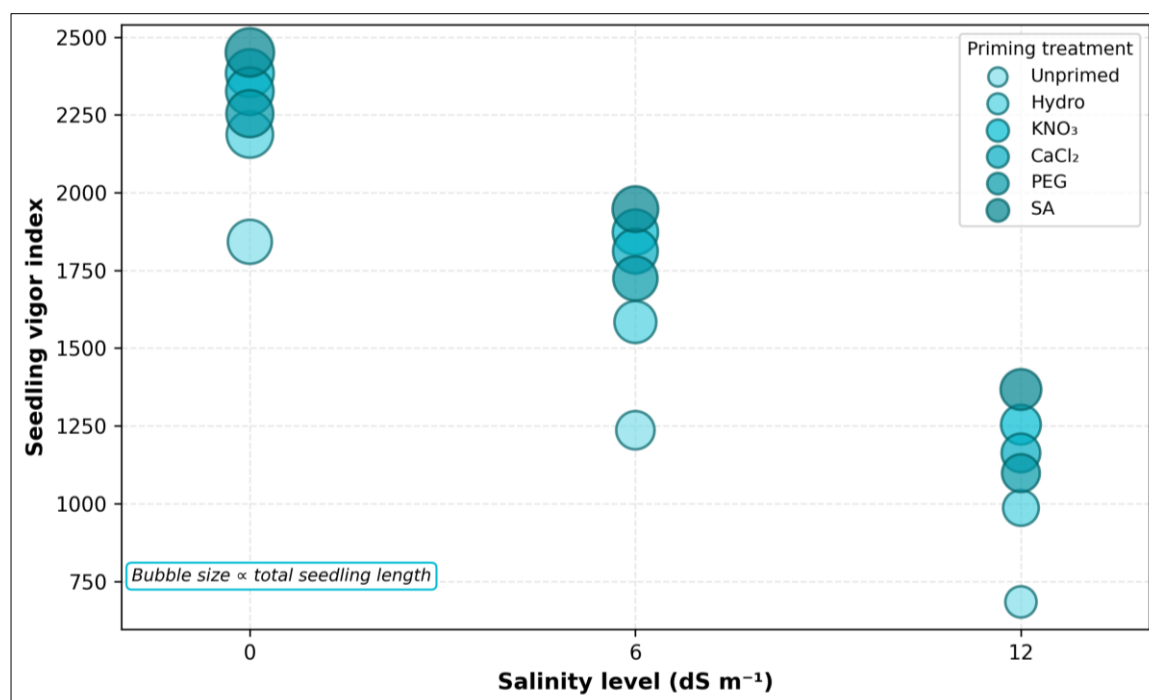


Fig 2: Three-dimensional relationship between salinity, seedling vigor index and total seedling length across six priming treatments.

Table 3: Biochemical changes during the priming period for salicylic acid treatment

Priming time (h)	Moisture (%)	α -amylase (U g ⁻¹)	Proline (μ mol g ⁻¹)	Stage
0	8.4	2.1	0.18	Dry
2	24.6	8.4	0.42	Imbibition
4	38.7	14.8	0.79	Activation
6	46.3	22.1	1.27	Peak
8	48.9	24.6	1.54	Optimum
10	49.4	25.3	1.63	Plateau
After re-drying	9.2	22.8	1.58	Storable

Comprehensive Interpretation

The two figures and three tables converge on a consistent ranking: salicylic acid > KNO₃ > CaCl₂ > PEG > hydro > unprimed. Figure 1 captures this order at every salinity level. Figure 2 shows that the vigor advantage of salicylic-acid priming is preserved even at 12 dS m⁻¹, where its vigor index of 1367 is almost double the unprimed value of 684. Table 3 explains the mechanism: the α -amylase activity at 8 hours of priming reaches 24.6 U g⁻¹, about twelve times the dry seed value, and proline rises from 0.18 to 1.54 μ mol g⁻¹. After re-drying, roughly 93 per cent of the α -amylase activity is retained, so the seed carries a physiological "head start" into the field.

Discussion

The main finding that salicylic acid at 100 ppm is the best seed primer for okra under salt stress is consistent with the results of Subramanian and co-workers^[9], who reported a 24 per cent rise in germination and 32 per cent rise in vigor index for salicylic-acid primed okra seeds at 10 dS m⁻¹. The mechanism is thought to involve early activation of antioxidant enzymes (SOD, CAT, APX) and accumulation of osmoprotectants like proline, which together reduce oxidative damage to the germinating embryo^[10].

KNO₃ priming as the second-best option agrees with Ranjan and colleagues^[11], who recorded 62.8 per cent germination for KNO₃-primed okra at 12 dS m⁻¹ against 64.3 per cent for salicylic acid, placing the two in a close tie. The practical implication is that a farmer who cannot find salicylic acid

can use KNO₃, a fertiliser-grade material available at any farm input store, and still capture most of the benefit. The poor performance of PEG-6000 mirrors earlier concerns about oxygen limitation during PEG soaking^[12], and the modest gain from hydro-priming confirms that water alone is not enough under severe salt stress.

Conclusion

The main contribution of this research is to identify salicylic acid at 100 ppm as the most effective seed priming treatment for okra cv. Sabz Pari under salt stress. Supporting evidence comes from four measurements. Germination at 12 dS m⁻¹ rose from 42.3 to 67.2 per cent; seedling length from 10.8 to 18.3 cm; vigor index from 684 to 1367; and mean germination time fell from 8.4 to 5.9 days. KNO₃ 2% was a close second option. Biochemical data show that the improvement is driven by early activation of α -amylase and accumulation of proline during the priming period.

For the vegetable growers of the Punjab canal command area, where soil salinity has been rising steadily, this work provides a simple, low-cost pre-sowing treatment that can be carried out with basic household utensils. Several open questions remain. Does the advantage of salicylic acid priming hold up over a full field-to-harvest cycle? How does the primed seed respond to combined stress of salinity plus high temperature in the April-May sowing window? Is the effect reproducible in two other commercial varieties (Green Star and Sarmaya) grown in the same region? These should be the next research priorities, ideally in farmer-

participatory mode with three to four cycles of field validation before formal recommendation through the Punjab Agriculture Department.

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