Original Research Article

Enhancing okra [*Abelmoschus esculentus* L. (Moench)] performance: A comparative study of priming across varieties

Abstract

This study, titled **"**Enhancing okra performance: A comparative study of priming across varieties**,"** aimed to evaluate the effects of osmopriming with Poly ethylene Glycol (PEG) 6000 and biopriming with *Pseudomonas fluorescens* on five okra varieties—Aruna, Anjitha, Pusa-5, Salkeerthi, and Varsha Uphar. The initial seed quality parameters of all the five varieties were assessed immediately after these treatments**.** Variety Salkeerthi showed superiority for germination and vigour indices closely followed by Varsha Uphar. Both priming treatments had similar effects on initial seed quality parameters and showed superiority over the control. The research employed a Randomized Complete Block design with three replications to assess growth, fruit, and seed traits, revealing significant differences among varieties, treatments, and their interactions.Varsha Uphar exhibited the highest field emergence, plant height, early flowering, number of fruits per plant, and seed yield per plant. Pusa-5 achieved the highest fruit weight and fruit yield per plant. Among treatments, biopriming with *Pseudomonas fluorescens* (T2) excelled in field emergence, number of branches, and fruit traits, while osmopriming with PEG 6000 (T1) was superior for internodal length and seeds per pod. The Varsha Uphar × *Pseudomonas fluorescens* combination (V5 × T2) recorded the best performance in field emergence, days to 50 per cent flowering, plant height, and seed yield per plant. Meanwhile, Pusa-5 × PEG 6000 (V3 × T1) produced the highest fruit weight and fruit yield per plant.The findings indicate that priming, particularly biopriming with *Pseudomonas fluorescens*, significantly enhances seedling emergence, growth, and yield, highlighting its potential for improving okra productivity. This study underscores the value of adopting seed priming techniques to optimize performance in okra cultivation.

Key words: Okra, Priming, Osmopriming, Biopriming, Pseudomonas fluorescens, PEG 6000, Yield

1. Introduction

Okra (*Abelmoschus esculentus* L. Moench), a member of the Malvaceae family, is widely cultivated around the world, especially in tropical and subtropical regions, where it is valued for its rich nutritional content, including minerals, vitamins, and dietary fiber (Naveed et al, 2009). In India, okra is grown on approximately 5.55 lakh hectares with an annual production of 72 lakh tonnes. In Kerala, its cultivation spans about 1,140 hectares with a yield of 7,400 metric tonnes (Indiastat, 2023). However, its cultivation during the rainy season is limited, relying mainly on rain-fed conditions. To address this, the Kerala State Planning Board initiated the SubhikshaKeralam project to enhance vegetable production, recommending specific okra varieties like Salkeerthi, PusaMakhmali, and Kiran, as well as virus-resistant varieties such as Arka Anamika and Varsha Uphar, alongside seed treatment and priming to improve germination and vigour (Kerala State Planning Board, 2022).

Seed quality is pivotal for crop productivity, with okra seeds often exhibiting slow and inconsistent germination due to their hard seed coat and low permeability (Morris and Massa, 2003; Felipe et al., 2010). Seed priming, which improves germination speed and uniformity, can promote better seedling establishment and increase overall crop productivity (Badek et al, 2006; Chen et al, 2012). Among the priming techniques, osmopriming with PEG and biopriming with *Pseudomonas fluorescens* have shown promise in enhancing seedling growth and stress tolerance.

A previous study in the Department of Seed Science and Technology (Adheena,2022) demonstrated significant improvements in plant growth, pod development, and seed yield through priming treatments on a single variety, Arka Anamika . However, the study underscored the need for broader research across multiple varieties. The present study evaluates the effects of osmopriming with Poly Ethylene Glycol (PEG) 6000 and biopriming with *Pseudomonas fluorescens* across five okra varieties: Aruna, Anjitha, Pusa-5, Salkeerthi, and Varsha Uphar. These varieties were selected for their agronomic and regional significance. Aruna, Anjitha, and Salkeerthi, all released by Kerala

Agricultural University, are widely recommended due to their adaptability and proven performance in local conditions. Varieties like Aruna, Varsha Uphar, and Salkeerthi are part of the Kerala State Planning Board's strategy to double vegetable production, while Pusa-5 is chosen for its increasing popularity in North India due to its resistance to Yellow Vein Mosaic Virus (YVMV) and superior yield potential (Yadav and Tomar, 2019). Salkeerthi, although susceptible to YVMV, is high yielding. It is a purelineselection from germplasm of ICAR-National Bureau of Plant Genetic Resources (NBPGR),Thrissur (CDS, 2019),characterized by its long, white fruits, and is highly preferred in the northern districts, especially Kannur and Kasargod of Kerala (ICAR-CPCRI, 2021) The present study evaluates the effects of priming treatments on a range of okra varieties, focusing on their interaction effects. The objective is to identify effective strategies for enhancing field performance and productivity across different genetic backgrounds.

2. Materials and methods

2.1 Description of the Study Area

The experiment was conducted at the Department of Seed Science and Technology, located 40 meters above sea level (13°32'N, 76°26'E). Twenty three agro ecological units has been delineated for Kerala based on climatic variability, landform and soils as per National Bureau of Soil Survey and Land Use Planning (KAU, 2016).This study site which is in Thrissur falls under agro-ecological unit (AEU 10) Northern central laterites which represents mid laterite terrain with long dry periods. The area comes under upland where the soils are characterized as lateritic, strongly acidic, highly gravelly low activity clay soils and exhibit significant variability throughout the profile.Meteorological data were recorded during the study period from November 2023 to June 2024. A Randomized Complete Block Design (RCBD) was employed with three replications, comprising 15 treatment-varietal combinations derived from five varieties and three treatments.

2.2 Experimental Material

Two-month-old seeds of five okra (*Abelmoschus esculentus*) varieties—Aruna (V1), Anjitha (V2), Pusa-5 (V3), Salkeerthi (V4), and Varsha Uphar (V5)—were used. The seeds underwent two priming treatments: a wet treatment with polyethylene glycol (PEG 6000) at a concentration of 6000 ppm (-0.25 MPa) for six hours (T1) and a dry treatment with talc-based *Pseudomonas fluorescens* applied at 10 g/kg seed (T2). Untreated seeds served as the control (T3).The initial seed quality parameters were assessed immediately after these treatments. Subsequently the treated seeds along with untreated control (T3) were sown in the field and crop was raised according to the package of practicesKerala Agricultural University (KAU, 2016)

2.3 Initial seed quality parameters

The seeds from all five okra varieties both treated and untreated, were promptly analyzed under ambient laboratory conditions to assess initial seed quality, including germination percentage and vigour indices.

2.3.1 Germination (%)

Seed germination was assessed in sand medium following ISTA, (2010) guidelines .Four sets of 100 seeds from each treatment were placed on very fine moist sand (sieve size -0.80 mm). The number of normal seedlings was counted on the seventh day of germination and germination per cent was worked out using the formula as given hereunder.

$$\text{Germination (\%)} = \frac{\text{The number of seeds germinated}}{\text{Total no of seeds kept for germination}} \times 100$$

2.3.2 Vigour index I

The seedling vigour index I was calculated using the formula suggested by Abdul- Baki and Anderson (1973).

Vigour index I = Germination (%) x Seedling length (cm)

2.3.3 Vigour Index II

Vigour index II was computed as suggested by Abdul- Baki and Anderson (1973)

Vigour index-II = Germination (%) x Seedling dry weight (g)

2.3.4 Electric conductivity of seed leachate (μScm^{-1})

Five grams of stored seeds were surface sterilized using 0.1 % mercuric chloride ($HgCl_2$) for about one minute followed by rinsing with distilled water. Then these were soaked in 50 ml of distilled water for 24 hours. The electrical conductivity (EC) of seed leachate collected in beaker after decanting was measured with a digital conductivity meter (EUTECH CON-510) and the mean value was recorded as micro siemens per centimeter (μScm^{-1})

2.4 Data Collection

Data were recorded on growth, fruit, and seed characteristics from five randomly tagged plants in each plot. Field emergence was assessed as the percentage of seedlings on the seventh day after sowing. Plant height, measured in centimeters (cm), was recorded at 90 days from the collar to the tip of the plant. The number of branches per plant and the internodal length (cm) were also recorded during this period.Flowering was monitored, and the dates for first flowering and 50 per cent flowering were noted. Fruit length (cm) and weight (g) were determined by averaging values from ten randomly selected fruits per plant. The total number of fruits per plant and yield per plant (g) were also recorded.For seed characteristics, seeds were collected from the mature pods of five tagged plants in each plot. The number of seeds per pod was determined by averaging the counts from the harvested pods. The seed yield per plant (g) was calculated by weighing the seeds extracted from the dried pods. To determine the 100-seed weight (g), 100 seeds were randomly selected, weighed, and their average weight recorded.

2.5 Statistical Analysis

The field data, encompassing two factors—Factor A (Variety) and Factor B (Treatment)—were statistically analyzed using the General R-based Analysis Platform Empowered by Statistics (GRAPES) package, developed by Kerala Agricultural University (Gopinath et al., 2020). A Randomized Block Design (RBD) was employed for the analysis. The data collected from the field trial were subjected to analysis of variance (ANOVA). In line with the RBD framework, the effects of varieties, treatments, and their interactions were assessed. Plant performance in the field was further evaluated and ranked using Duncan's Multiple Range Test (DMRT).

2.6 Results and discussion

2.6.1 Effect of varieties, priming treatment and their interaction on initial seed quality of okra

The treatment as well as the varieties showed significant variation for all seed quality parameters (Table 1). Among the varieties, Salkeerthi (V4: 93.11%), recorded highest germination percentage comparable to Anjitha (V2: 93%) and Varsha Uphar (V5: 91.00 %). Salkeerthi reported highest seed vigour indices (Vigour I: 3062 and Vigour II: 52) followed by Varsha Uphar (Vigour I: 2902 and Vigour II: 45). Salkeerthi reported lowest electrical conductivity (277.44 μScm^{-1}) and it was followed by Varsha Upahar (322.22 μScm^{-1}). Both treatments had similar effects on initial seed quality parameters and showed superiority over the control.

Significant interaction effect was observed for all the characters except germination percentage as presented in Table 2. The combination Salkeerthi-*Pseudomonas fluorescens* showed superior performance for all initial seed quality parameters and was on par with Salkeerthi-PEG followed by Varsha Uphar- *Pseudomonas fluorescens*

2.6.2 Effect of varieties, priming treatment and their interaction on field performance of okra.

The analysis of variance indicated significant effects of both priming treatments and varieties on most traits in okra. Varietal differences were evident for all growth, fruit, and seed yield parameters, except for the number of branches per plant. Priming treatments significantly influenced all traits except plant height. The interaction between variety and treatment (V×T) was significant for most traits but not for internodal length, days to first flowering, and 100-seed weight.

2.6.2.1 Field Emergence (%):

Varsha Uphar recorded the highest field emergence (90.1%), while Aruna had the lowest (59.24%), reflecting genetic differences in seedling vigour (Sheferie et al, 2023). Priming treatments significantly improved emergence compared to the control, with *Pseudomonas fluorescens* (T2: 91.64%) and PEG (T1: 86.64%) outperforming the untreated control (66.63%) (Table3). Enhanced germination maybe attributed to metabolic activities like protein synthesis, DNA repair, and stress tolerance conferred by priming (Girolamo and Barbanti, 2012; Zhang et al, 2015). The highest emergence was in Salkeerthi-PEG (97.3%), followed by Varsha Uphar-*Pseudomonas fluorescens* (97.2%), while Aruna-control had the lowest (24.98%) as represented inTable 4

2.6.2.2 Growth Parameters:

Improved field emergence translated into better vegetative growth. Varsha Uphar exhibited the tallest plants (50.27 cm) and longest internodes (5.12 cm), while Salkeerthi showed the lowest values (29.12 cm and 4.15 cm, respectively). *Pseudomonas fluorescens* significantly boosted plant height and branching, with Varsha Uphar-*Pseudomonas fluorescens*recording the tallest plants (56.43 cm). This observation aligns with the findings of Bindu (2020), who studied the effect of biopriming on four okra varieties (Susthira, Arka Anamika, Aruna, and Salkeerthi) using two biopriming agents—*Pseudomonas fluorescens* (8 g/l) and *Trichoderma viride* (4 g/l). She reported increase in plant height in variety Arka Anamika treated with *Pseudomonas fluorescens* (144.32 cm). Similarly, Rai and Basu (2014) reported enhanced growth in eight okra varieties treated with the biopriming agents, highlighting the positive impact of *Pseudomonas fluorescens* priming in Variety Arka Anamika on plant height.(114.74 cm)

Branching also improved with priming, especially T2 (*Pseudomonas fluorescens*, 2.21 branches per plant), compared to the control (1.62). The highest branching occurred in Aruna-*Pseudomonas fluorescens* (2.46). Improved phosphorus availability and microbial growth-promoting substances likely contributed to these results (Sharma et al. 2018).

Internodal length followed a similar trend, with T1 (PEG: 4.93 cm) and T2 (*Pseudomonas fluorescens*: 4.82 cm) surpassing the control (4.27 cm). The consistency between higher emergence rates and improved growth parameters underscores the role of priming in enhancing early growth and overall plant vigour.

2.6.2.3 Days to first and 50 per cent flowering

Varsha Uphar (V5) exhibited the earliest flowering among the varieties, with days to first and 50 per cent flowering recorded at 34.77 and 50.44 days, respectively, followed by Anjitha (V2: 37.89 and 53.11 days) and Pusa-5 (V3: 38.56 and 54.33 days). Salkeerthi (V4) showed the latest flowering, taking 42.55 days for the first flowering and 64.55 days for 50 per cent flowering. Among treatments, T2 (*Pseudomonas fluorescens*: 37.80 and 56.06 days) and T1 (PEG 6000: 38.06 and 56.46 days) significantly reduced the time to both first and 50% flowering compared to the control (T3: 40.46 and

60.46 days). The quickest 50 per cent flowering was observed in the combination Varsha Uphar-PF (V5×T2: 48.33 days), while the longest was in Salkeerthi-control (V4×T3: 66.66 days).

These findings underline the genetic diversity among varieties, influencing their response to priming. The enhanced flowering observed with priming treatments is attributed to improved seedling emergence, metabolic repair, osmotic adjustments, and accumulation of germination-related metabolites during priming (Bray et al., 1989). Faster flowering and fruit maturity also resulted from better vegetative growth induced by primed seeds (Sheferie et al, 2023).

2.6.2.4 Fruityield and component characters

The impact of variety and seed priming treatment on fruit yield and component characters like number of fruits per plant, fruit length (cm), fruit weight (g) are furnished in Table 5. The interaction effect of variety and priming treatment on fruit characters are presented in Table6. Effect of variety, priming treatment and their interaction was found to be significant for all the fruit characters in okra.

Varsha Uphar (V5) recorded the highest number of fruits per plant (11.00), followed by Pusa-5 (V3: 10.68), while Salkeerthi (V4: 8.28) had the lowest, highlighting significant genetic variations among varieties, as also reported by Chada et al. (2014) and Kumar et al. (2021). Among treatments, T2 (*Pseudomonas fluorescens*: 11.04) outperformed T1 (PEG 6000: 10.12) and T3 (Control: 8.36). The findings align with Rai et al. (2019), who demonstrated that bio-priming with *Trichoderma viride* and *Pseudomonas fluorescens* significantly enhanced the number of fruits per plant across eight okra varieties compared to unprimed seeds. Among these, the variety Arka Anamika recorded the highest pods per plant (21.85) when treated with *Pseudomonas fluorescens*

Salkeerthi (V4: 14.21 cm) demonstrated the longest fruits, attributed to its genotype, followed by Pusa-5 (V3: 13.81 cm) and Varsha Uphar (V5: 10.82 cm). Among treatments, T2 (*Pseudomonas fluorescens*13.70 cm) resulted in the longest fruits, consistent with findings of Sharma et al. (2018). Salkeerthi-PF (V4×T2: 15.46 cm) showed the highest fruit length, while Varsha Uphar-Control (V5×T3: 10.70 cm) had the shortest.

Pusa-5 (V3: 16.86 g) recorded the highest fruit weight, while Varsha Uphar (V5: 11.91 g) had the lowest. *Pseudomonas fluorescens*(T2: 15.40 g) outperformed T1 (PEG 6000: 13.21 g) and T3 (12.96 g). Notably, Pusa-5 × PEG (V3×T1: 21.59 g) achieved the highest fruit weight, while Varsha Uphar-Control (V5×T3: 10.90 g) reported lowest fruit weight

Pusa-5 (V3: 179.08 g) exhibited the highest fruit yield per plant, followed by Anjitha (V2: 152.78 g) whereas Salkeerthi (V4: 111.16 g) being the lowest. The two treatments T2 (*Pseudomonas fluorescens*: 162.90 g) and T1 (PEG 6000: 149.38 g) significantly outperformed the control (107.0 g), aligning with findings by Sharma et al. (2014) who reported the enhanced fruit yield per plot (16.4 kg) in okra seeds of variety Hisar Unnat treated with PEG 6000 13.5 % (-0.25 MPa) compared to unprimed seeds. Kaur et al.(2015) also reported that the seeds treated with PEG 5 % for 24 h reported highest fruit yield (126.23 g)compared to hydroprimed and unprimed seeds. The combination Pusa-5 × PEG (V3×T1: 239.98 g) recorded the highest yield, demonstrating the synergistic effects of genotype and priming.

The relationship between initial seed quality parameters and field performance revealed distinct patterns across okra varieties and treatments. Although Salkeerthi (V4) demonstrated superior initial seed quality, its field performance was comparatively lower, highlighting the role of environmental factors and genotypic traits in bridging the gap between seed quality and productivity. Additionally, the soil in the field study, characterized by more parameters such as soil fertility, presence of organic matter and soil moisture, differed significantly from the sandy medium employed in laboratory germination tests. This variation in soil properties, including texture and nutrient availability, likely influenced seed emergence and overall field performance, emphasizing also the importance of soil quality in determining the success of seedling establishment and productivity.

In terms of variety, Varsha Uphar exhibited the highest number of fruits per plant, which contributed to its overall productivity, though its fruit weight and fruit length were comparatively lower. Conversely, Pusa-5 (V3), which recorded the highest fruit weight and substantial fruit length achieved the highest fruit yield per plant, showcasing the direct influence of fruit weight and size on yield aligning with the findings of Veeresh et al. (2023). Salkeerthi (V4) demonstrated its genotypic predisposition for larger fruit length, but its lower number of fruits per plant and reduced fruit weight limited its total fruit yield.A comparison of correlation and path analyses revealed that fruit weight, number of fruits per plant, and harvest period showed significant positive correlations and direct effects on fruit yield per plant(Farooqkhanet al. 2024).

Priming treatments significantly improved all traits compared to the control. *Pseudomonas fluorescens* (T2) consistently outperformed PEG 6000 (T1) and the control (T3) across all varieties. T2 (*Pseudomonas fluorescens*) enhanced the number of fruits per plant, fruit length, and fruit weight, leading to the highest fruit yield. Studies have shown that the growth-promoting ability of microbes is often specific to plant species, cultivars, and genotypes (Bashan, 1998; Gupta et al, 2000; Lucy et al, 2004). This specificity, combined with mechanisms like induced systemic resistance, nutrient solubilization, nitrogen fixation, and stress tolerance, underscores the effectiveness of *Pseudomonas fluorescens* in enhancinggrowth and yield**.**

2.6.2.5 Seed characters

The influence of variety and seed priming on seed traits, including seeds per pod, seed yield per plant, and 100-seed weight, is presented in Table 7. Varietal effects were significant for all seed traits, while treatment effects as well as interaction effect were significant except for 100-seed weight as presented in Table 8.

Salkeerthi (V4) recorded the highest seeds per pod (45.67), followed by Varsha Uphar (V5: 44.03), while Aruna (V1: 34.32) had the lowest. Among treatments, T1 (PEG 6000: 44.27) and T2 (*Pseudomonas fluorescens*: 43.25) outperformed the control (38.59). The highest seeds per pod were in Salkeerthi-PEG (V4×T1: 51.03), while the lowest was in Aruna-control (V1×T3: 27.8). Maximum 100-seed weight was recorded in Salkeerthi (V4: 5.86 g), on par with Pusa-5 (V3: 5.63 g).

Varsha Uphar (V5: 32.50 g) recorded the highest seed yield, while Salkeerthi (V4: 20.3 g) had the lowest. T2 (28.36 g) and T1 (25.68 g) reported superiority over control (24.69 g). The combination Varsha Uphar-PF (V5×T2: 35.93 g) showed the highest seed yield, while Salkeerthi-control (V4×T3: 18.53 g) recorded the lowest. Bio-priming with *Pseudomonas fluorescens* enhanced seed yield through improved root function, nutrient uptake, and plant growth, consistent with findings by Rai and Basu (2014), and Adheena et al, (2022).

Table 1: Effect of varieties and treatments on the initial seed quality of okra immediately after treatment

Variety	Germination (%)	Vigour index I	Vigour index II	Electrical conductivity (μScm^{-1})
Aruna	90.444[b]	2610[c]	43[bc]	326.22[b]
Anjitha	93.000[a]	2488[d]	41[c]	348.00[a]
Pusa 5	90.333[b]	2479[d]	43[bc]	354.11[a]
Salkeerthi	93.111[a]	3062[a]	52[a]	277.44[c]
Varsha Uphar	91.000[b]	2902[b]	45[b]	322.55[b]
C.D	1.71	60.01	2.30	12.57
S.E (d)	0.84	29.38	1.128	6.15
S.E (m)	0.59	20.77	0.79	4.35
Treatment	**Germination (%)**	**Vigour index I**	**Vigour index II**	**Electrical conductivity (μScm^{-1})**
PEG	93.13[a]	2777[a]	47[a]	310.20[b]
PF	92.33[a]	2795[a]	47[a]	317.0[b]
Control	89.26[b]	2553[b]	40[b]	349.81[a]
C.D	1.32	46.48	1.78	9.74
S.E (d)	0.65	22.76	0.87	4.77
S.E (m)	0.46	16.09	0.61	3.37

Table 2: Interaction effect of variety and treatment on seed quality parameters immediately after treatment

V X T	Germination (per cent)	Vigour index I	Vigour index II	Electrical conductivity (μScm^{-1})
V1XT1	90.66	2692^{cd}	45^{bcd}	305.00^{f}
V1xT2	90.67	2635^{d}	43^{cde}	311.66^{ef}
V1xT3	90.00	2503^{e}	40^{e}	350.00^{b}
V2xT1	89.23	2523^{e}	47^{bc}	309.33^{ef}
V2xT2	94.66	2595^{de}	42^{de}	344.66^{bc}
V2xT3	89.33	2347^{f}	35^{f}	390.00^{a}
V3xT1	91.00	2510^{e}	43^{cde}	338.00^{bc}
V3xT2	92.00	2600^{de}	48^{b}	347.00^{bc}
V3xT3	88.00	2326^{f}	36^{f}	377.33^{a}
V4xT1	95.66	3186^{a}	55^{a}	283.00^{g}
V4xT2	93.66	3206^{a}	55^{a}	254.66^{h}
V4xT3	90.00	2795^{c}	47^{bc}	294.66^{fg}
V5xT1	93.33	2972^{b}	46^{bc}	315.66^{def}
V5xT2	90.66	2940^{b}	46^{bcd}	327.00^{cde}
V5xT3	89.00	2794^{c}	42^{de}	337.00^{bcd}
C.D	NS	103.94	3.98	21.78
S.E (d)	1.45	50.89	1.95	10.66
S.E (m)	1.02	35.98	1.38	7.54

Table 3: Effect of varieties and treatments on growth characters of okra

Varietal effect (V)	Field emergence (%)	Plant height (cm)	Number of branches per plant	Inter nodal length (cm)
Aruna	59.24[b]	47.94[ab]	1.82	4.91[a]
Anjitha	86.08[a]	43.94[b]	1.97	4.85[a]
Pusa 5	90.61[a]	37.36[c]	1.71	4.35[b]
Salkeerthi	81.45[a]	29.12[d]	1.86	4.15[b]
Varsha Uphar	90.71[a]	50.27[a]	1.93	5.12[a]
C.D	12.27	4.91	NS	0.47
S.E (d)	5.99	2.40	0.11	0.23
S.E (m)	4.23	1.69	0.08	0.16
Treatment (T)	**Field emergence (%)**	**Plant height (cm)**	**Numberof branchesper plant**	**Inter nodal length (cm)**
PEG	86.64[a]	40.47	1.74[b]	4.93[a]
PF	91.64[a]	44.30	2.21[a]	4.82[a]
CONTROL	66.63[b]	40.41	1.62[b]	4.27[b]
C.D	9.507	NS	0.18	0.36
S.E (d)	4.64	1.85	0.09	0.17
S.E (m)	3.28	1.31	0.06	0.12

V1-Aruna,V2-Anjitha,V3-Pusa-5,V4-Salkeerthi,V5-Varsha Uphar, T1-(PEG 6000 13.5% (-0.25 MPa 6 hours), T2-*Pseudomonas fluorescens* -10 g/kg seed, T3-Control

Table 4: Interaction effect of variety and priming treatments on growth characters of okra

V X T	Field emergence (%)	Plant height (cm)	Number of branches per plant	Inter- nodal length (cm)
V1 X T1	69.43^{bc}	48.33^{bcd}	1.93^{bcd}	5.20
V1xT2	83.31^{ab}	52.86^{ab}	2.46^{a}	5.06
V1xT3	24.98^{d}	42.63^{de}	1.66^{cde}	4.46
V2xT1	80.55^{ab}	40.66^{def}	2.06^{abc}	5.16
V2xT2	91.63^{a}	44.33^{cd}	2.26^{ab}	4.86
V2xT3	86.06^{ab}	46.83^{bcd}	1.60^{e}	4.53
V3xT1	91.63^{a}	44.56^{bcd}	1.93^{bcd}	4.93
V3xT2	91.66^{a}	34.93^{efg}	1.73^{cde}	4.10
V3xT3	88.83^{ab}	32.60^{fg}	1.46^{f}	4.03
V4xT1	97.3^{a}	28.33^{g}	2.26^{ab}	4.30
V4xT2	94.40^{a}	30.96^{g}	2.33^{ab}	4.16
V4xT3	52.76^{c}	28.06^{g}	1.92^{bcd}	3.98
V5xT1	94.40^{a}	52.23^{abc}	1.80^{cd}	5.06
V5xT2	97.20^{a}	56.43^{a}	2.26^{ab}	5.93
V5xT3	80.53^{ab}	48.16^{bcd}	1.73^{cd}	4.36
C.D.(0.05)	21.25	8.51	0.41	NS
S.E (d)	10.37	4.15	0.20	0.39
S.E (m)	7.33	2.94	0.14	0.28

Table 5: Effect of varieties and treatments on flowering duration and fruit characters of okra

Varietal effect (V)	Days to 1st flowering	Days to 50 % flowering	Number of fruits per plant	Fruit length (cm)	Fruit weight (g)	Fruit yield per plant (g)
Aruna	40.11[b]	60.77[b]	9.20[c]	13.51[b]	14.35[bc]	129.17[c]
Anjitha	37.89[c]	56.33[c]	10.05[b]	12.71[c]	15.31[b]	152.78[b]
Pusa 5	38.56[c]	56.22[c]	10.68[a]	13.81[ab]	16.85[a]	179.08[a]
Salkeerthi	42.55[a]	64.55[a]	8.28[d]	14.21[a]	13.29[c]	111.16[d]
VarshaUphar	34.77[d]	50.44[d]	11.00[a]	10.82[d]	11.91[d]	128.11[c]
C.D	1.40	2.38	0.46	0.52	1.24	16.17
S.E (d)	0.68	1.16	0.22	0.25	0.60	7.89
S.E (m)	0.48	0.82	0.16	0.18	0.42	5.58
Treatment (T)	**Days to first flowering**	**Days to 50% flowering**	**Number of fruits per plant**	**Fruit length (cm)**	**Fruit weight (g)**	**Fruit yield per plant (g)**
PEG	38.06[b]	56.46[b]	10.12[b]	13.21[b]	14.67[a]	149.38[b]
PF	37.80[b]	56.06[b]	11.04[a]	13.70[a]	15.40[a]	162.90[a]
Control	40.46[a]	60.46[a]	8.36[c]	12.16[c]	12.96[b]	107.90[c]
C.D	1.09	1.84	0.36	0.40	0.96	12.53
S.E (d)	0.53	0.90	0.17	0.19	0.47	6.11
S.E (m)	0.37	0.63	0.12	0.13	0.33	4.32

Table 6: Interaction effect of variety and priming treatment on flowering fruit characters of okra

V X T	Days to 1st flowering	Days to 50 % flowering	Number of fruits per plant	Fruit length (cm)	Fruit weight (g)	Fruit yield per plant (g)
V1 X T1	40.00	61.33^{bcd}	9.20^{gh}	13.66^{de}	12.40^{efg}	114.01^{fgh}
V1xT2	38.00	55.00^{efg}	10.20^{efg}	13.83^{bcde}	16.65^{b}	161.10^{cd}
V1xT3	42.33	66.00^{a}	8.20^{i}	13.03^{ef}	14.02^{cde}	112.40^{gh}
V2xT1	37.66	56.67^{ef}	10.47^{de}	12.26^{f}	13.89^{cde}	140.06^{defg}
V2xT2	36.33	54.00^{de}	11.30^{c}	13.73^{cde}	16.91^{b}	190.92^{b}
V2xT3	39.66	58.33^{de}	8.40^{hi}	12.31^{f}	15.14^{bcd}	127.36^{efgh}
V3xT1	37.00	51.66^{ghi}	11.10^{cd}	14.58^{abc}	21.59^{a}	239.98^{a}
V3xT2	39.00	58.66^{cde}	12.43^{a}	14.51^{bcd}	15.57^{bc}	183.05^{bc}
V3xT3	39.66	58.33^{de}	8.533^{hi}	12.33^{f}	13.38^{def}	114.23^{fgh}
V4xT1	41.33	62.66^{abc}	8.46^{hi}	14.73^{ab}	12.93^{efg}	109.50^{hi}
V4xT2	42.33	64.33^{ab}	9.13^{gh}	15.46^{a}	15.56^{bc}	141.20^{def}
V4xT3	44.00	66.66^{a}	7.26^{j}	12.43^{f}	11.40^{fg}	82.78^{i}
V5xT1	34.33	50.00^{hi}	11.40^{bc}	10.80^{g}	12.53^{efg}	143.35^{de}
V5xT2	33.33	48.33^{i}	12.16^{ab}	10.96^{g}	12.30^{efg}	138.24^{defg}
V5xT3	36.66	53.00^{fgh}	9.43^{fg}	10.70^{g}	10.90^{g}	102.75^{hi}
C.D	NS	4.12	0.80	0.90	2.15	28.02
S.E (d)	1.18	2.01	0.39	0.44	1.05	13.68
S.E (m)	0.84	1.42	0.27	0.31	0.74	9.67

Table 7: Effect of varieties and treatments on seed characters of okra

Variety	Number of seeds per pod	Seed yield per plant (g)	100 seed weight (g)
Aruna	34.32[c]	23.81[d]	5.36[b]
Anjitha	43.80[ab]	25.33[c]	5.39[b]
Pusa 5	42.35[b]	29.28[b]	5.63[ab]
Salkeerthi	45.67[a]	20.30[e]	5.54[b]
Varsha Uphar	44.03[ab]	32.50[a]	5.86[a]
C.D	2.50	0.77	0.30
S.E (d)	1.22	0.37	0.15
S.E (m)	0.86	0.26	0.10
Treatment (T)	**Number of seeds per pod**	**Seed yield per plant**	**100 seed weight**
PEG	44.27[a]	25.68[b]	5.62
PF	43.25[a]	28.36[a]	5.63
Control	38.59[b]	24.69[c]	5.41
C.D	1.93	0.59	NS
S.E (d)	0.94	0.29	0.11
S.E (m)	0.66	0.20	0.08

Table 8: Interaction effect of variety and priming on seed characters of okra

V X T	No. of seeds per pod	Seed yield per plant	100 seed weight
V1 X T1	39.16^{fg}	23.40^{fgh}	5.43
V1xT2	36.00^{g}	24.73^{f}	5.66
V1xT3	27.80^{h}	23.30^{gh}	5.00
V2xT1	43.30^{cdef}	24.36^{fg}	5.30
V2xT2	47.90^{ab}	27.13^{e}	5.42
V2xT3	40.22^{efg}	24.50^{fg}	5.46
V3xT1	44.10b^{cde}	29.46^{d}	5.56
V3xT2	42.21^{cdef}	31.36^{bc}	5.76
V3xT3	40.76^{def}	27.03^{e}	5.56
V4xT1	51.03^{a}	19.73^{i}	5.66
V4xT2	44.63^{bcd}	22.63^{h}	5.36
V4xT3	41.36^{cdef}	18.53^{i}	5.60
V5xT1	43.76^{bcde}	31.46^{b}	6.16
V5xT2	45.53^{bc}	35.93^{a}	5.95
V5xT3	42.80^{cdef}	30.10^{cd}	5.46
C.D	4.33	1.33	NS
S.E (d)	2.11	0.65	0.25
S.E (m)	1.49	0.46	0.18

Conclusion.

The study revealed that seed priming treatments significantly influenced growth, fruit yield, and seed yield traits across different okra varieties.Despite Salkeerthi (V4) showing high initial seed quality, its field performance was lower, suggesting the influence of environmental factors and genetic traits. Varsha Uphar (V5) demonstrated superior field emergence, plant height, early flowering, number of fruits per plant, and seed yield per plant, while Pusa-5 achieved the highest fruit yield per plant. Among the treatments, T_2 (*Pseudomonas fluorescens* at 10 g/kg of seed) consistently enhanced growth, fruit, and seed traits across all varieties. The combination Varsha Uphar-*Pseudomonas fluorescens* (V5×T2) recorded the highest growth parameters and number of pods per plant and seed yield per plant whereas Pusa-5-PEG (V3×T1) showed the highest fruit weight and yield per plant.These results emphasize the efficacy of *Pseudomonas fluorescens* as a cost-effective and practical seed priming treatment to boost okra productivity. Further investigation into the physiological responses of okra varieties to PEG priming, especially its impact on water uptake, enzyme activation, and stress tolerance, is suggested to refine its use for enhancing seed performance under varying environmental conditions.

Acknowledgement

The authors are grateful to Kerala Agricultural University for financial support. It is thankful to the Department of Seed Science and Technology and the Department of Plant Pathology College of Agriculture, Vellanikkara, Thrissur for technical support

Disclaimer (Artificial intelligence)

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Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1. CHAT GPT FOR PROPER SENTENCE CONSTRUCTION

2.

3.

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