



RESEARCH ARTICLE

Organic seed production in okra (*Abelmoschus esculentus* L.): Standardising techniques for traditional and improved varieties

Keerthana D¹, Renugadevi J^{1*}, Jerlin R¹, Shoba T K², Raghu R³ & Sathiya B K⁴

¹Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India

²Department of Horticulture, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India

³Department of Plant Biotechnology, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India

⁴Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India

*Correspondence email - renugadevi.j@tnau.ac.in

Received: 01 November 2025; Accepted: 24 March 2026; Available online: Version 1.0: 11 May 2026

Cite this article: Keerthana D, Renugadevi J, Jerlin R, Shoba TK, Raghu R, Sathiya BK. Organic seed production in okra (*Abelmoschus esculentus* L.): Standardising techniques for traditional and improved varieties. Plant Science Today (Early Access). <https://doi.org/10.14719/pst.12548>

Abstract

In recent years, seed production using organic nutrients has gained significant interest, with researchers aiming to enhance seed germination, crop growth and yield. The potential of organic seed production techniques in improving seed germination, seedling vigour, growth and yield of traditional and improved okra varieties was evaluated in the present study. Seeds of okra varieties were primed with different organic formulations, along with hydropriming and control and the field experiment was conducted under different organic nutrient regimes. The results revealed that organic seed priming had a significant effect on seed quality parameters in both traditional and improved bhendi varieties. Seed priming with panchagavya at 3 % (T₆) emerged as the most effective treatment in both types, resulting in higher speed of germination, emergence energy value, germination percentage, germination potential, root and shoot lengths, dry matter production, allometric coefficient and vigour index I and II. The untreated control (T₀) showed the lowest values across all the physiological parameters. The interaction between variety and treatment was non-significant, suggesting that the effectiveness of panchagavya at 3 % (T₆) is independent of genotypic variation, supporting its broader adoption. Studies on growth and yield parameters revealed that application of panchagavya at 3 % (T₆) through soil and foliar application resulted in higher field emergence, greater plant height, increased chlorophyll content and improved fruit and seed yield traits compared to control. Therefore, seed priming with panchagavya at 3 % along with soil and foliar application is the most promising organic seed technique for enhancing seed germination, early seedling vigour, growth and yield of both traditional and improved varieties of okra.

Keywords: bhendi; improved and traditional variety; organic seed production; seed quality enhancement

Introduction

Okra (*Abelmoschus esculentus* L.) is a warm-season, annual herbaceous vegetable belonging to the family Malvaceae and is often cross-pollinated, with a diploid chromosome number of 2n = 130 (1). India is the leading producer of okra, producing 6.8 MT from a growing area of 0.5 M ha with a productivity rate of 12.5 t ha⁻¹ (2). Okra is an important vegetable crop owing to its high nutritional value and medicinal properties and it also possesses significant commercial importance with considerable export potential (3, 4).

Despite India's higher average okra productivity (12.26 t ha⁻¹) compared to the global mean (≈ 9.8 t ha⁻¹), its cultivation continues to face numerous challenges related to pests and diseases (5). Several high-yielding, disease-resistant varieties have been developed; however, the availability of quality seed is still one of the limiting factors in okra cultivation (6). Thus, to ensure the supply and production of quality seed, it is imperative to standardise the seed production techniques to improve seed yield with better quality. In general, low productivity in okra is mostly caused by a lack of adoption of improved varieties, suitable seed management

techniques, quality seed availability, hard seed occurrence and inadequate seed storage techniques (7). Additionally, the seed contains 20–40 % oil, which changes the permeability of the cell membrane due to lipid peroxidation (8). To maintain seed viability and enhance quality, appropriate seed invigouration techniques such as hydropriming, osmopriming, halopriming, biopriming, nutrient priming and seed coating are commonly employed.

Although the development of a number of soil and crop management systems aimed at maximising the establishment of robust seedlings, resource-poor farmers have yet to adopt the technologies due to their high cost or inaccessibility (9). By adopting low-risk, low-cost crop management practices such as crop rotation, resistant varieties, seed priming, biological pest control and timely cultural operations, resource-limited farmers can improve crop establishment, seed quality and yield in okra (10). For farmers with limited resources, one such strategy that can boost yields is organic seed priming along with organic seed production systems. As a pre-sowing method, seed priming involves treating seeds to start the germination process before field planting (11). It is the most promising method for invigourating seeds since it speeds up

germination, improves crop stand establishment and increases seedling vigour. Seed priming, a promising strategy, has been successfully used to solve the problem of poor germination and the unpredictable crop stand that followed under both normal and stressful conditions (12).

Okra crop yields, soil pH, total nutrient content and nutrient availability might all be enhanced by inorganic fertilisers (13). However, their use is restricted because of their scarcity, high cost, nutrient imbalance and acidity of the soil. Organic crop management techniques offer a sustainable solution to these problems by reducing soil erosion and ecotoxicity potential. In addition, organic farming results in more soil biodiversity and an abundant supply of macro and microorganisms, but, depending on the crops, it may result in lower yield, indicating a trade-off between agricultural productivity and environmental protection (14).

The proportion of land allocated for organic farming has consistently risen globally over the years, alongside the organic products industry. Organic products are more beneficial and environmentally safe and do not contain any residues compared to conventionally produced food (15). Therefore, a comprehensive and ecologically responsible approach to agriculture is provided by the use of conventional organic formulations. These formulations present a possible path toward creating ecologically friendly agricultural systems by encouraging microbial diversity, improving plant resilience to adverse conditions and supporting sustainable farming methods (16).

Nowadays, organic bhendi varieties are gaining importance due to their nutritional and medicinal value. Since the okra crop is widely used and many traditional varieties are available at present, the demand for quality seeds has increased. By assessing the demand for organic crops along with seed germination and the early growth of seedlings, this study aims to overcome the problem of slow and uneven germination of okra and improve the growth performance and yield through organic seed production techniques. The use of organic formulations such as panchagavya, vermiwash, jeevamrutha, fish amino acid and plant-based extracts in seed

production induces various biochemical changes that modify protoplasmic constituents and enhance the physiological activity of the embryo and its associated structures. These formulations contain only naturally occurring, organically produced elements and compounds, free from synthetic chemicals and genetically modified components. They improve soil structure, boost plant nutrient absorption, enhance soil fertility and help to retain moisture content in addition to increasing the emergence, establishment and yield (17).

Materials and Methods

Site description

Laboratory and field experiments aimed at enhancing the quality and yield of traditional and improved bhendi varieties through organic seed production techniques were conducted at the Agricultural Research Station, Tamil Nadu Agricultural University, Bhavanisagar, during 2023–24. This station is located at approximately 11.29° N, 77.80° E and falls under the Western Agro-Climatic Zone of Tamil Nadu. Complementary laboratory studies were carried out at the Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore, situated at about 11.02° N, 76.96° E, also within the Western Agro-Climatic Zone. The experimental soil was sandy clay loam. The soil was neutral in reaction (pH 7.86) with low electrical conductivity (0.07 dS m⁻¹), indicating non-saline conditions.

Weather data recorded during the experimental period are given in Fig. 1. The average weekly high temperature during the period of investigation ranged from 34.2–40.5 °C, with a mean of 36.3 °C, while the average weekly low temperature varied from 19.8 °C to 26.5 °C, with a mean of 23.1 °C. The total quantity of precipitation recorded was 218.6 mm, distributed over 7 rainy weeks during the cropping period. Rainfall was absent during the initial weeks (standard weeks 8–17), followed by the onset of precipitation from week 18 onwards, with peak rainfall observed during week 21 (117.6 mm).

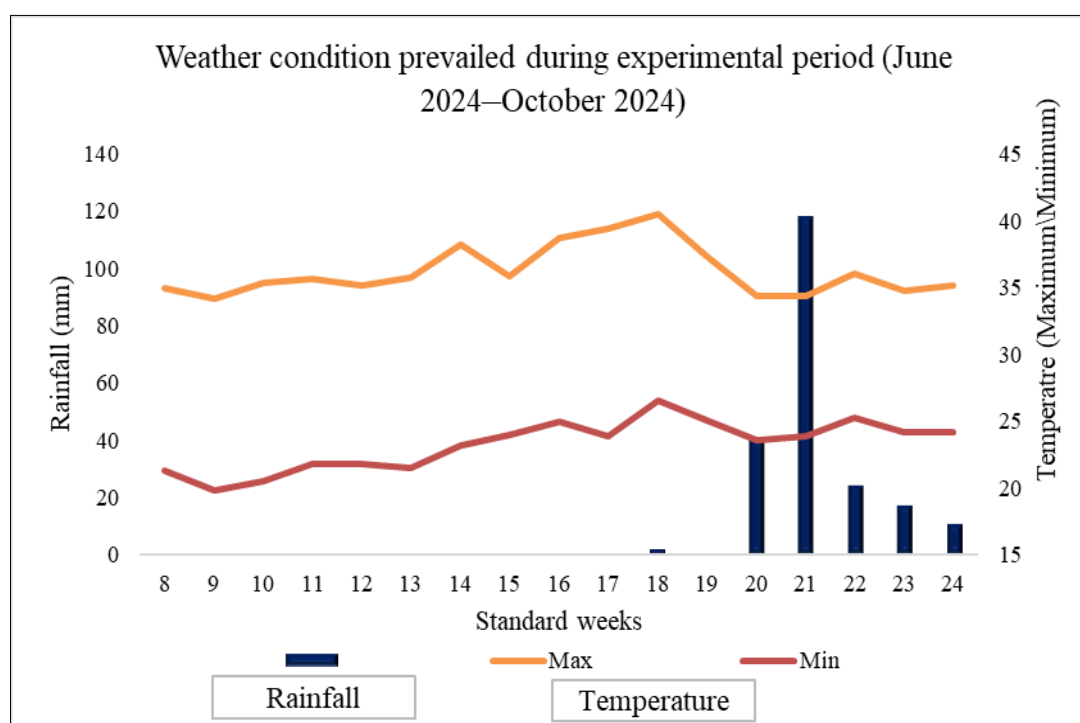


Fig. 1. Weather data recorded during the experimental period (June 2024–October 2024).

Improved variety (Arka Anamika, V₁) was collected from the Department of Vegetable Science, Tamil Nadu Agricultural University, Coimbatore and the traditional variety (double colour bulk okra, V₂) was collected from traditional vegetable growing farmers of Tamil Nadu.

Experimental design

Studies on the optimisation of seed priming, soil and foliar application with organic nutrients were carried out in the present study. Seeds of traditional and improved bhendi varieties were subjected to different organic priming treatments with the soaking duration of 12 hr using variable organic amendments along with hydropriming and unprimed seeds as control. After priming, the seeds were dried back to their original moisture content and subjected to evaluation of various physiological parameters. The experiment was conducted in a factorial completely randomised design and replicated thrice. The seeds were subjected to a germination test in paper medium at a temperature of 25 ± 2 °C and 95 ± 3 % RH with a germination period of 14 days (18). Seedlings were evaluated for germination, shoot length (cm), root length (cm), dry matter production per 10 seedlings (g), speed of germination, emergence energy value, germination potential, seedling vigour and allometric coefficient (19–23). The treatment details are as follows:

Treatment details

- T₀ : Control
- T₁ : Hydropriming
- T₂ : *Trichoderma asperellum* at 1 %
- T₃ : *Bacillus subtilis* at 1 %
- T₄ : Amuthakaraisal at 3 %
- T₅ : Vermiwash at 1 %
- T₆ : Panchagavya at 3 %
- T₇ : Sweet flag rhizome extract at 1 %
- T₈ : Moringa leaf extract at 1 %
- T₉ : Fish amino acid at 1 %
- T₁₀ : Aloe vera extract at 1 %

Field experiments were conducted during the kharif season of 2024 to determine the optimum soil and foliar application treatments using organic nutrient sources. The experiment was laid out in a factorial randomised block design with three replications. The experimental plots were 4 × 3 m in size with a spacing of 60 cm in between rows and 30 cm between plants. To standardise the soil and foliar application of organic nutrients, soil application was given as basal and foliar application was given twice at pre flowering and flowering stages of crop growth. Observations on field emergence, plant height, chlorophyll content, days to first flowering, days to 50 % flowering, number of fruits plant⁻¹, fruit length and weight at harvestable maturity, fruit yield plant⁻¹, number of seeds plant⁻¹, seed yield plant⁻¹, seed yield ha⁻¹ and seed recovery percentage were recorded in randomly selected plants. The treatment details are as follows:

Treatment details

- T₀ : Control
- T₁ : Soil application (2.5 kg/ha) + Foliar spray of *T. asperellum* (2 %)
- T₂ : Soil application (2.5 kg/ha) + Foliar spray of *B. subtilis* (2 %)

T₃ : Soil application 50 L/ha + Foliar spray of amuthakaraisal (5 %)

T₄ : Soil application 50 L/ha + Foliar spray of vermiwash (1 %)

T₅ : Soil application 50 L/ha + Foliar spray of panchagavya (3 %)

T₆ : Soil application 50 L/ha + Foliar spray of sweet flag rhizome extract (1 %)

Statistical analysis

The experimental data were statistically analysed by applying the analysis of variance (ANOVA) appropriate to the experimental design (24). The significance of treatment differences was tested using the *F*-test at 5 % level of probability. Whenever the *F*-test was found significant, the treatment means were compared using the critical difference (CD). All statistical analyses were performed using the SPSS software. The results were interpreted based on the standard error of difference (SEd) and critical difference (CD) values.

Results

Organic seed priming treatments had a significant effect ($p < 0.05$) on all seed physiological quality parameters in improved (Arka Anamika) and traditional (double colour bulk okra) bhendi varieties. Among the treatments, T₆ (panchagavya at 3 %) exhibited the highest speed of germination (8.37) and emergence energy value (7.47), followed by T₉ (fish amino acid at 1 %) (8.04 and 7.31) and T₄ (amuthakaraisal at 3 %) (7.79 and 7.19) of speed of germination and emergence energy value respectively. In contrast, the control (T₀) showed the lowest values for both the traits (5.75 and 6.02), emphasising the efficacy of organic priming. Statistical analysis revealed significant effects for variety and treatment on both speed of germination and emergence energy value. However, the interaction between variety and treatment was non-significant, indicating that all treatments were similarly effective across both improved (V₁) and traditional (V₂) varieties. Notably, the improved variety V₁ showed a higher speed of germination (7.55) and emergence energy value (6.90) compared with the traditional variety V₂ (6.58 and 6.68 respectively), indicating inherent genetic differences in seed vigour (Table 1).

The germination percentage (94 %) and germination potential (47 %) were also high in T₆ (panchagavya at 3 %), followed by T₉ (fish amino acid at 1 %) (92 and 44 %) and T₄ (amuthakaraisal at 3 %) (91 and 41 %) respectively, indicating that these treatments were most effective in enhancing seed germination performance. The lowest values for both parameters were observed in the control (T₀) (76 and 27 % for germination percentage and germination potential respectively). Significant varietal differences were also observed; the improved bhendi variety (V₁) outperforms the traditional variety (V₂) in both seed germination (89 and 82 %) and germination potential (37 and 34 %) respectively, reflecting its relatively higher inherent vigour. However, the interaction was non-significant, suggesting that all treatments were similarly effective across both varieties. Overall, these results confirm that organic seed priming substantially enhances seed germination efficiency (Table 1).

For root length, the mean values ranged from 13.20 cm in T₀ (control) to 15.56 cm in T₆ (panchagavya at 3 %), followed by T₁₀ (aloe vera extract at 1 %) (15.32 cm) and T₉ (fish amino acid at 1 %) (15.05 cm), indicating that untreated seeds produced weaker root systems. Between varieties, V₁ (14.49 cm) exhibited slightly higher root length compared to V₂ (14.28 cm). Statistical analysis revealed that both variety and treatment effects were significant, while the

Table 1. Effect of organic seed priming in traditional and improved varieties of okra on speed of germination (SOG), emergence energy value (EEV), seed germination, germination potential (GPt) and vigour index I (VI I)

Treatments	SOG		Mean		EEV		Seed germination %		Mean	GPt %		Mean	VI I		Mean
Varieties	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂		V ₁	V ₂		V ₁	V ₂	
T ₀	6.15	5.35	5.75	6.12	5.92	6.02	80	72	76	29	25	27	2145	2034	2089
T ₁	6.90	6.20	6.55	6.48	6.62	6.55	86	80	83	32	30	31	2434	2394	2414
T ₂	6.58	5.78	6.18	6.35	6.10	6.23	83	74	79	30	28	29	2276	2137	2207
T ₃	6.72	5.92	6.32	6.54	6.28	6.41	86	77	82	33	30	32	2401	2269	2335
T ₄	8.40	7.18	7.79	7.36	7.02	7.19	94	87	91	42	40	41	2803	2758	2781
T ₅	7.86	6.90	7.38	7.28	6.94	7.11	93	85	89	40	37	39	2745	2655	2700
T ₆	8.98	7.76	8.37	7.58	7.36	7.47	96	92	94	48	46	47	3003	3036	3020
T ₇	7.48	6.65	7.07	6.96	6.82	6.89	89	84	87	38	35	37	2592	2572	2582
T ₈	7.10	6.42	6.76	6.72	6.50	6.61	88	79	83	35	33	34	2521	2394	2458
T ₉	8.72	7.36	8.04	7.44	7.18	7.31	95	90	92	45	42	44	2881	2898	2889
T ₁₀	8.15	6.82	7.48	7.10	6.70	6.90	91	81	86	38	33	36	2808	2574	2691
Mean	7.55	6.58	7.06	6.90	6.68	6.79	89	82	86	37	34	36	2601	2520	2560
	V	T	V × T	V	T	V × T	V	T	V × T	V	T	V × T	V	T	V × T
S. Ed.	0.048	0.112	0.158	0.049	0.114	0.162	0.593	1.391	1.967	0.212	0.498	0.704	14.77	34.64	48.99
CD (p=0.05)	0.096	0.225	NS	0.098	0.231	NS	1.195	2.803	NS	0.428	1.003	NS	29.77	69.82	NS

T₀: Control, T₁: Hydropriming, T₂: *T. asperellum* at 1 %, T₃: *B. subtilis* at 1 %, T₄: Amuthakaraaisal at 3 %, T₅: Vermiwash at 1 %, T₆: Panchagavya at 3 %, T₇: Sweet flag rhizome extract at 1 %, T₈: Moringa leaf extract at 1 %, T₉: Fish amino acid at 1 %, T₁₀: Aloe vera extract at 1 %, V₁: Arka Anamika, V₂: Double colour bulk okra.

interaction was non-significant, confirming that the treatments were uniformly effective across varieties. Similarly, the highest shoot length was recorded in T₆ (panchagavya at 3 %) (16.58 cm), followed by T₉ (fish amino acid at 1 %) (16.21 cm) and T₁₀ (aloe vera extract at 1 %) (16.00 cm). In contrast, the control treatment recorded the lowest shoot length (14.33 cm). Unlike other parameters, traditional variety (V₂) exhibited greater shoot length (16.39 cm) than the improved variety (V₁) (14.61 cm), suggesting a higher allocation of resources towards shoot growth. Their interaction remained non-significant (Fig. 2).

For the allometric coefficient, values ranged from 1.045 for T₁₀ (aloe vera extract at 1 %) to 1.092 for T₂ (*T. asperellum* at 1 %), with a mean of 1.079 across treatments. Although varietal differences

were significant, treatment and their interactions were non-significant, indicating that the shoot-root ratio remained largely stable across different priming treatments. Between varieties, V₂ (1.149) consistently showed higher allometric coefficient values compared to V₁ (1.009), suggesting relatively greater allocation of assimilates to shoot growth in V₂ (Fig. 2). T₆ (panchagavya at 3 %) recorded highest dry matter production (0.326 g), since the seedling length was high in T₆, closely followed by T₉ (fish amino acid at 1 %) (0.324 g) and T₁₀ (aloe vera extract at 1 %) (0.322 g) and the control (T₀) showed the lowest dry matter production (0.294 g), confirming the role of priming in enhancing biomass accumulation. Between varieties, V₂ (0.317 g) maintained a marginal advantage over V₁ (0.306 g). The non-significance of interaction indicates that both

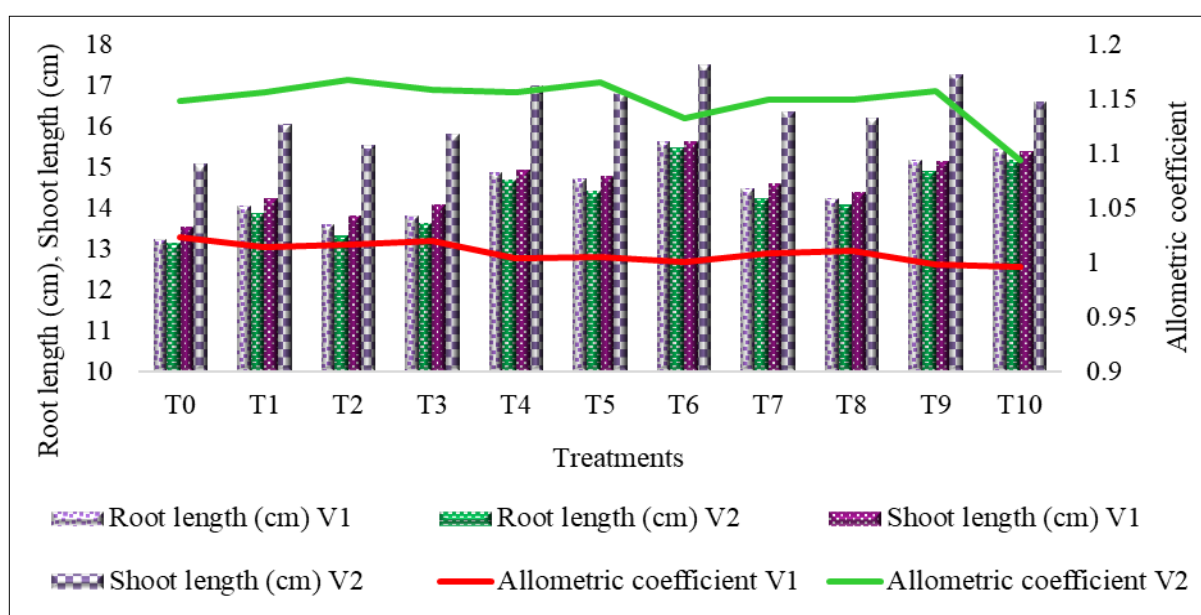


Fig. 2. Effect of organic priming in improved and traditional varieties of okra on root length, shoot length and allometric coefficient. T₀: Control, T₁: Hydropriming, T₂: *T. asperellum* at 1 %, T₃: *B. subtilis* at 1 %, T₄: Amuthakaraaisal at 3 %, T₅: Vermiwash at 1 %, T₆: Panchagavya at 3 %, T₇: Sweet flag rhizome extract at 1 %, T₈: Moringa leaf extract at 1 %, T₉: Fish amino acid at 1 %, T₁₀: Aloe vera extract at 1 %, V₁: Arka Anamika, V₂: Double colour bulk okra.

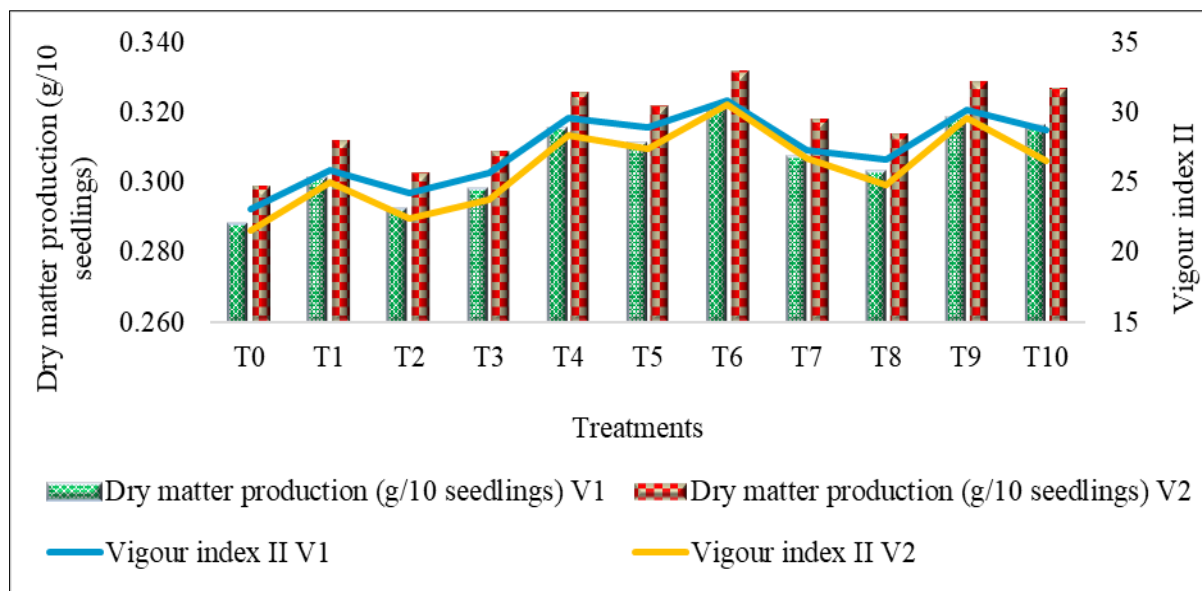


Fig. 3. Effect of organic priming in traditional and improved varieties of okra on dry matter production, vigour index I and vigour index II. T₁: Hydropriming, T₂: *T. asperellum* at 1 %, T₃: *B. subtilis* at 1 %, T₄: Amuthakaraisal at 3 % T₅: Vermiwash at 1 % T₆: Panchagavya at 3 %, T₇: Sweet flag rhizome extract at 1 %, T₈: Moringa leaf extract at 1 %, T₉: Fish amino acid at 1 %, T₁₀: Aloe vera extract at 1 %, V₁: Arka Anamika, V₂: Double colour bulk okra.

varieties responded similarly to priming (Fig. 3).

For vigour index I, the values ranged from 2089 in the control (T₀) to a maximum of 3020 in T₆ (panchagavya at 3 %), followed by T₉ (fish amino acid at 1 %) (2889) and T₄ (amuthakaraisal at 3 %) (2781), which indicates that priming with T₆ produced the most vigorous seedlings. Between varieties, V₁ (2601) slightly outperformed V₂ (2520), though the interaction between variety and treatment was found to be non-significant, suggesting consistent treatment effects across varieties. A similar trend was observed in vigour index II, with the highest value of 30.68 in T₆ (panchagavya at 3 %), followed by T₉ (fish amino acid at 1 %) (29.91) and T₄ (amuthakaraisal at 3 %) (28.99); the lowest value occurred in control (T₀) (22.29). Across varieties, V₁ (27.37) exhibited greater vigour compared to V₂ (26.05), again demonstrating inherent varietal differences. Variety and treatments were significant, while the interaction between them remained non-significant, confirming uniform benefits across both

traditional and improved bhendi varieties (Fig. 3).

The effect of soil and foliar application of organic nutrients showed significant differences among varieties and treatments for the growth and yield parameters, whereas their interaction effect was non-significant, indicating uniform response patterns of both varieties to the applied organic treatments. The soil and foliar application of panchagavya at 3 % (T₅) consistently outperformed all treatments, registering the highest field emergence (98 and 78 % in V₁ and V₂ respectively) (Fig. 4), maximum plant height (118.55 cm) (Table 2) and superior chlorophyll content (44.81) (Fig. 4), while also promoting earliest flowering (37.79 days to first flowering and 41.37 days to 50 % flowering) (Fig. 5) and this was followed by T₃ (soil and foliar application of amuthakaraisal at 5 %). These improvements are attributed to enhanced soil biological activity, sustained nutrient release and improved physiological efficiency under applied organic nutrients. Conversely, untreated control

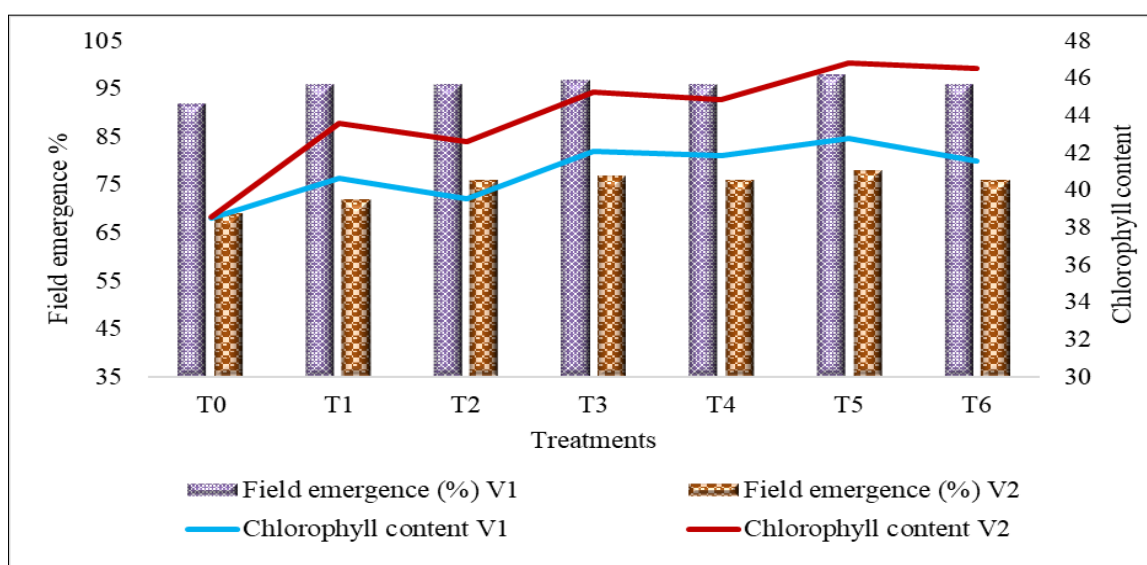
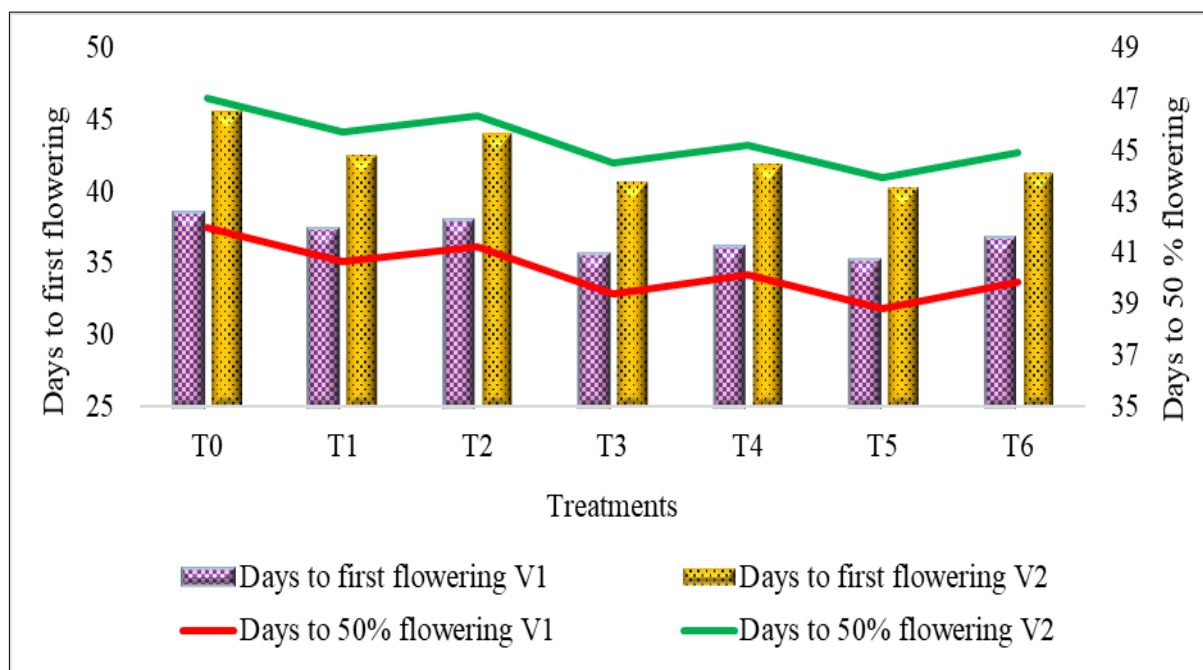


Fig. 4. Effect of soil and foliar application of organic nutrients on field emergence and chlorophyll content in traditional and improved okra varieties. T₀: Control, T₁: Soil application (2.5 kg ha⁻¹) + Foliar spray of *T. asperellum* (2 %), T₂: Soil application (2.5 kg ha⁻¹) + Foliar spray of *B. subtilis* (2 %), T₃: Soil application 50 L ha⁻¹ + Foliar spray of amuthakaraisal (5 %), T₄: Soil application 50 L ha⁻¹ + Foliar spray of vermiwash (1 %), T₅: Soil application 50 L ha⁻¹ + Foliar spray of panchagavya (3 %), T₆: Soil application 50 L ha⁻¹ + Foliar spray of sweet flag rhizome extract (1 %), V₁: Arka Anamika, V₂: Double colour bulk okra.

Table 2. Effect of soil and foliar application of organic nutrients on plant height, number of fruit plant⁻¹, fruit length at harvestable maturity (HM), fruit weight at harvestable maturity (HM) and fruit yield plant⁻¹ in traditional and improved okra varieties

Treatment	Plant height (cm)		Mean	Number of fruit plant ⁻¹		Mean	Fruit length (cm) at HM		Mean	Fruit weight (g) at HM		Mean	Fruit yield plant ⁻¹ (g)		Mean
	V ₁	V ₂		V ₁	V ₂		V ₁	V ₂		V ₁	V ₂		V ₁	V ₂	
T ₀	88.50	96.58	92.54	15.50	16.92	16.21	23.22	8.40	15.81	10.10	11.32	10.71	65.65	86.45	76.05
T ₁	97.44	107.45	102.44	16.72	18.08	17.40	24.08	10.08	17.08	11.06	12.28	11.67	84.70	105.5	95.10
T ₂	93.58	103.50	98.54	16.35	17.70	17.03	24.62	10.30	17.46	10.64	11.80	11.22	77.38	98.18	87.78
T ₃	108.52	118.54	113.53	18.05	19.42	18.74	26.30	11.74	19.02	12.22	13.40	12.81	109.80	130.60	120.20
T ₄	100.80	110.82	105.81	17.68	18.99	18.34	25.78	10.62	18.20	11.78	12.98	12.38	100.62	121.42	111.02
T ₅	113.64	123.46	118.55	18.36	19.67	19.02	26.88	11.90	19.39	12.62	13.82	13.22	117.18	137.98	127.58
T ₆	103.27	113.25	108.26	17.24	18.54	17.89	25.24	10.88	18.06	11.44	12.62	12.03	93.48	114.28	103.88
Mean	100.82	110.51	105.67	17.13	18.47	17.80	25.16	10.56	17.86	11.41	12.60	12.01	92.69	113.49	103.09
	V	T	V × T	V	T	V × T	V	T	V × T	V	T	V × T	V	T	V × T
S. Ed.	0.87	1.62	2.28	0.10	0.19	0.27	0.18	0.33	0.47	0.07	0.14	0.19	0.89	1.66	2.35
CD (p=0.05)	1.78	3.33	NS	0.21	0.39	0.55	0.36	0.68	0.96	0.15	0.28	0.39	1.83	3.42	4.83

T₀: Control, T₁: Soil application (2.5 kg ha⁻¹) + Foliar spray of *T. asperellum* (2 %), T₂: Soil application (2.5 kg ha⁻¹) + Foliar spray of *B. subtilis* (2 %), T₃: Soil application 50 L ha⁻¹ + Foliar spray of amuthakaraial (5 %), T₄: Soil application 50 L ha⁻¹ + Foliar spray of vermiwash (1 %), T₅: Soil application 50 L ha⁻¹ + Foliar spray of panchagavya (3 %), T₆: Soil application 50 L ha⁻¹ + Foliar spray of sweet flag rizhome extract (1 %), V₁: Arka Anamika, V₂: Double colour bulk okra.

**Fig. 5.** Effect of soil and foliar application of organic nutrients on days to first flowering and days to 50 % flowering in traditional and improved okra varieties. T₀: Control, T₁: Soil application (2.5 kg ha⁻¹) + Foliar spray of *T. asperellum* (2 %), T₂: Soil application (2.5 kg ha⁻¹) + Foliar spray of *B. subtilis* (2 %), T₃: Soil application 50 L ha⁻¹ + Foliar spray of amuthakaraial (5 %), T₄: Soil application 50 L ha⁻¹ + Foliar spray of vermiwash (1 %), T₅: Soil application 50 L ha⁻¹ + Foliar spray of panchagavya (3 %), T₆: Soil application 50 L ha⁻¹ + Foliar spray of sweet flag rizhome extract (1 %), V₁: Arka Anamika, V₂: Double colour bulk okra.

plants (T₀) recorded the lowest values for all parameters, reflecting inferior growth due to a lack of external nutrient supplementation. Among varieties, V₂ exhibited better vegetative performance, while V₁ was superior for earliness in flowering.

The combined effect of applied panchagavya at 3 % through soil and foliar application (T₅) exhibited maximum productivity with highest number of fruits plant⁻¹ (19.02), maximum fruit length (19.39 cm), greatest fruit weight (13.22 g) and superior individual plant yield (127.58 g), followed by T₃ (soil and foliar application of amuthakaraial at 5 %). The untreated control (T₀) showed the

lowest performance across parameters. The improvement under T₅ may be associated with enhanced nutrient mineralisation and efficient translocation towards reproductive structures, leading to better sink strength and fruit development. Between varieties, V₂ produced higher yield and fruit yield compared to V₁, confirming its greater responsiveness to organic nutrient supply (Table 2).

For seed yield parameters, among the different nutrient regimes soil and foliar application of panchagavya at 3 % (T₅) recorded the highest number of seeds fruit⁻¹ (56.04), maximum seed yield plant⁻¹ (82.33 g) and superior seed yield ha⁻¹ (2342 kg), along

with the highest seed recovery (81 %), which was statistically followed by soil and foliar application of amuthakaraial at 5 % (T₃). The untreated control (T₀) recorded the minimum values for all seed yield traits. The substantial improvement in seed productivity under T₅ is attributed to effective nutrient supply, better pollination efficiency and enhanced assimilate partitioning towards seed formation under enriched organic inputs. Between the two varieties, V₂ consistently outperformed V₁ for seed yield, reflecting its better adaptability to different organic nutrient regimes (Table 3).

Discussion

Okra's significance lies not only in its nutritional value but also in its adaptability to diverse environmental conditions. However, reduced germination, poor seedling vigour and seed-borne diseases often constrain okra productivity. To overcome these limitations, seed priming has emerged as a sustainable, low-cost pre-sowing technique that enhances germination, seedling vigour and stress tolerance.

Primed seeds perform better with higher vigour and result in rapid germination (25). Priming enhances the accumulation of germination metabolites such as soluble sugars, amino acids and organic acids, promotes metabolic repair and accelerates the mobilisation of food reserves to developing seedlings, thereby reducing germination time (9). Organic priming triggers early metabolic activation in seeds, facilitating the biochemical processes essential for seed germination (26). Panchagavya is a highly effective plant growth stimulant that increases seed vigour by boosting biological efficiency due to the rich composition of plant growth-promoting hormones such as indole acetic acid (IAA) and gibberellic acid (GA) and stimulates the activity of key enzymes involved in germination, including amylases and proteases, which facilitate the mobilisation of stored nutrients (27).

The improved seedling growth parameters observed in seeds primed with 3 % panchagavya may be attributed to accelerated enzymatic activity and enhanced mobilisation of stored

food reserves. Similarly, seeds of *Jatropha curcas* and *Pongamia pinnata* primed with 2 % panchagavya recorded higher germination percentage, which may be due to synergistic effects of beneficial microorganisms and plant growth regulators (GA₃ and IAA) present in the organic formulation (28). Germination percentage of *Andrographis paniculata* (kalamegha) and *Withania somnifera* (ashwagandha) seeds primed with 10 % kunapajala and panchagavya showed significant improvement over unprimed control (29). Enhancement in seedling growth parameters and vigour due to seed priming with liquid organic formulations has also been reported in chickpea (30).

Organic inputs enhance soil microbial activity, improve nutrient availability and support balanced plant growth, while also minimising environmental problems such as nutrient loss and soil degradation. However, their effectiveness largely depends on the appropriate concentration, method of application and crop variety. The application of organic nutrients through both soil and foliar methods promotes overall growth and development of crops by regulating various physiological, biochemical and molecular activities. Research indicates that seed treatment with panchagavya at 4 % improved the growth and yield parameters of lentil (31). The effect of foliar application of panchagavya and vermiwash resulted in improved yield and quality of bitter melon (32). Research indicates that panchagavya showed enhanced plant immunity, confers resistance against pests and diseases and provides various beneficial metabolites produced by microorganisms (33). Panchagavya at different concentrations on brinjal increased the growth and yield parameters due to growth hormones in the cow with increased cell division within the apical meristem in plants (34).

Traditional varieties maintained by small-scale farmers constitute an important reservoir of genetic diversity (35). In developed countries, traditional varieties, with few exceptions, are no longer cultivated and are conserved *ex-situ* in gene banks. Indeed, traditional varieties have been progressively replaced by modern hybrid cultivars. The main reason for abandoning traditional varieties and adopting hybrids was the low yield of these varieties

Table 3. Effect of soil and foliar application of organic nutrients on the number of seeds fruit⁻¹, seed yield plant⁻¹, seed yield ha⁻¹ and seed recovery in traditional and improved okra varieties

Treatment	Number of seeds fruit ⁻¹		Mean	Seed yield plant ⁻¹ (g)		Mean	Seed yield ha ⁻¹ (kg)		Mean	Seed recovery (%)		Mean
	V ₁	V ₂		V ₁	V ₂		V ₁	V ₂		V ₁	V ₂	
T ₀	46.74	56.74	51.74	41.80	79.88	60.84	1520	1720	1620	65	68	67
T ₁	48.14	58.14	53.14	47.33	88.61	67.97	1645	1845	1745	70	70	70
T ₂	48.74	58.74	53.74	46.38	87.13	66.76	1738	1938	1838	74	74	74
T ₃	50.44	60.44	55.44	56.63	101.06	78.85	2034	2234	2134	78	79	79
T ₄	49.64	59.64	54.64	51.96	96.27	74.12	1970	2170	2070	77	78	78
T ₅	51.04	61.04	56.04	60.44	104.22	82.33	2142	2542	2342	80	82	81
T ₆	49.34	59.34	54.34	51.89	94.17	73.03	1825	2025	1925	76	76	76
Mean	49.15	59.15	54.15	50.92	93.05	71.98	1839	2068	1953	74	75	75
	V	T	V × T	V	T	V × T	V	T	V × T	V	T	V × T
S. Ed.	0.49	0.91	1.29	0.63	1.19	1.68	17.40	32.55	46.03	0.64	1.20	1.69
CD (p=0.05)	1.00	1.87	2.65	1.30	2.44	3.45	35.76	66.90	94.61	1.31	2.46	3.47

T₀: Control, T₁: Soil application (2.5 kg ha⁻¹) + Foliar spray of *T. asperellum* (2 %), T₂: Soil application (2.5 kg ha⁻¹) + Foliar spray of *B. subtilis* (2 %), T₃: Soil application 50 L ha⁻¹ + Foliar spray of amuthakaraial (5 %), T₄: Soil application 50 L ha⁻¹ + Foliar spray of vermiwash (1 %), T₅: Soil application 50 L ha⁻¹ + Foliar spray of panchagavya (3 %), T₆: Soil application 50 L ha⁻¹ + Foliar spray of sweet flag rizhome extract (1 %), V₁: Arka Anamika, V₂: Double colour bulk okra.

compared to hybrids (36). Moreover, the production of traditional varieties is challenged by many factors, including the unavailability of quality seeds and poor germination (37). Despite these constraints, their inherent adaptability to marginal and stress-prone environments makes them highly valuable for sustainable agriculture and future crop improvement. In the present investigation, traditional varieties exhibited a response to organic seed priming comparable to that of improved varieties, particularly under seed priming with panchagavya at 3 % (T₀), which recorded superior germination and seedling vigour. This comparable performance is noteworthy, as it demonstrates that the limitations of traditional varieties related to seed quality can be effectively mitigated through organic priming interventions. Research indicates that organic seed priming can act as a viable strategy to enhance the performance of traditional varieties without compromising their genetic integrity (38). Therefore, the positive response of traditional varieties to priming not only improves their immediate agronomic performance but also provides a practical pathway for their revitalisation, wider adoption and long-term conservation of valuable genetic resources.

Conclusion

The results obtained from the present study reveal that seed priming along with soil and foliar application of organic amendments were effective in improving the seed germination, establishment and yield of improved and traditional bhendi varieties. In particular, seed priming combined with soil and foliar application of panchagavya at 3 % showed promising results under controlled conditions. Therefore, we conclude that seed priming together with soil and foliar application of panchagavya at 3 % is an effective and environmentally friendly technique for enhancing seed germination, early seedling vigour, establishment, growth and yield of both traditional and improved varieties of okra.

Acknowledgements

The authors acknowledge the support of Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.

Authors' contributions

KD experimented and prepared the original draft of the manuscript. RJ conceptualised the research problem. RR and STK supervised the work, drafted and reviewed the manuscript. JR and SBK structured, supervised the experiments, edited and critically reviewed the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

References

- Kumar J, Chaurasia AK, Bara BM. Effect of organic priming on germination and vigour of cotton (*Gossypium hirsutum* L.) seed. *J Pharmacogn Phytochem*. 2017;6(3):815–19.
- Akbar M, Aslam N, Khalil T, Akhtar S, Siddiqi EH, Iqbal MS. Effects of seed priming with plant growth-promoting rhizobacteria on wheat yield and soil properties under contrasting soils. *J Plant Nutr*. 2019;42(17):2080–91. <https://doi.org/10.1080/01904167.2019.1655041>
- Gupta S, Kaushal R, Spehia RS, Pathania SS, Sharma V. Productivity of capsicum influenced by conjoint application of isolated indigenous PGPR and chemical fertilizers. *J Plant Nutr*. 2017;40(7):921–27. <https://doi.org/10.1080/01904167.2015.1093139>
- Chandra MS, Naresh RK, Lavanya N, Varsha N, Chand SW, Chandana P, et al. Production and potential of ancient liquid organics panchagavya and kunapajala to improve soil health and crop productivity: A review. *J Pharmacogn Phytochem*. 2019;8(6):702–13.
- Padhiyar D, Kanzaria DR, Gondaliya BR, Purohit VL. Effect of different sowing time and planting distance on growth, yield and quality of okra (*Abelmoschus esculentus* (L.) Moench). *Plant Arch*. 2025;25:54–60. <https://doi.org/10.51470/PLANTARCHIVES.2025.SP.ICTPAIRS-011>
- Devi OR, Verma O, Laishram B, Anbarasan S, Debnath A, Panotra N, et al. Effect of seed priming and foliar application of organic liquid manure on germination, growth, yield and quality of late-sown wheat. *Emirates J Food Agric*. 2025;37:1–13. <https://doi.org/10.3897/ejfa.2025.126915>
- Harris D, Breese WA, Rao JK. The improvement of crop yield in marginal environments using 'on-farm' seed priming: Nodulation, nitrogen fixation and disease resistance. *Aust J Agric Res*. 2005;56(11):1211–18. <https://doi.org/10.1071/AR05079>
- Habibi N, Terada N, Sanada A, Koshio K. Alleviating salt stress in tomatoes through seed priming with polyethylene glycol and sodium chloride combination. *Stresses*. 2024;4(2):210–24. <https://doi.org/10.3390/stresses4020012>
- Farooq M, Hussain M, Imran M, Ahmad I, Atif M, Alghamdi SS. Improving the productivity and profitability of late sown chickpea by seed priming. *Int J Plant Prod*. 2019;13:129–39. <https://doi.org/10.1007/s42106-019-00041-z>
- Harisha SM, Tomar BS, Yadav RK, Singh N. Effect of time of planting and spacing on the quality seed production of okra cv. Pusa Bhindi-5. *Veg Sci*. 2022;49(1):86–90. <https://doi.org/10.61180/vegsci.2022.v49.i1.13>
- Kaviyarasu P, Sujatha K, Murugesan P, Albert VA, Ragavan T, Anand G, et al. Advanced seed invigoration technologies in okra (*Abelmoschus esculentus* L. Moench). *J Environ Biol*. 2025;46(1):1–9. <https://doi.org/10.22373/jeb/46/1/MRN-5297>
- Jarret RL, Wang ML, Levy IJ. Seed oil and fatty acid content in okra (*Abelmoschus esculentus*) and related species. *J Agric Food Chem*. 2011;59(8):4019–24.
- Yuvasri EA, Anandham R, Balachandar D, Senthilkumar M, Thiyageshwari S, Vincent S. Harnessing the power of traditional organic formulations for crop growth and microbial harmony. *Front Biosci Elite*. 2024;16(2):14. <https://doi.org/10.31083/j.fbe1602014>
- Bawa SEH, Badrie N. Nutrient profile, bioactive components and functional properties of okra (*Abelmoschus esculentus* (L.) Moench). In: *Fruits, vegetables and herbs*. London: Academic Press; 2016. p. 365–409. <https://doi.org/10.1016/B978-0-12-802972-5.00018-4>
- Azarbad H. Conventional vs. organic agriculture—which one promotes better yields and microbial resilience in rapidly changing climates? *Front Microbiol*. 2022;13:903500. <https://doi.org/10.3389/fmicb.2022.903500>
- Golijan-Pantovic J, Secanski M, Gordanic S. Seed health treatments in organic seed production. *Agric For*. 2022;68(4):41–57. <https://doi.org/10.17707/AgricForest.68.4.04>
- Kumar CS, Singh G. Role of organic liquid formulations in agriculture: A review. *J Emerg Technol Innov Res*. 2021;8:250–55.
- ISTA. International rules for seed testing. *Seed Sci Technol*. 1999;27:25–30.
- Maguire ID. Speed of germination aid in selection and evaluation for seedling emergence and vigour. *Crop Sci*. 1962;2:176–77.

20. Bahuguna VK, Pyarelal, Dhawan VK. Standardisation of nursery techniques (seed sowing methods and watering schedules) of *Eucalyptus* FRI-4 under North Indian moist tropical climatic conditions. Indian For. 1987;113:541–49.
21. Liu D, Yang J, Tao L, Ma Y, Sun W. Seed germination and seedling growth influenced by genetic features and drought tolerance in a critically endangered maple. Plants. 2023;12(17):3140. <https://doi.org/10.3390/plants12173140>
22. Abdul-Baki AA, Anderson JD. Physiological and biochemical deterioration of seeds. In: Kozlowski TT, editor. Seed biology. Vol. 2. New York: Academic Press; 1973. p. 283–315.
23. Abbasi Khalaki M, Ghorbani A, Dadjou F. Influence of nano-priming on *Festuca ovina* seed germination and early seedling traits under drought stress in laboratory condition. Ecopersia. 2019;7(3):133–39.
24. Panse VC, Sukhatme PV. Statistical methods for agricultural workers. In: Rev ed. New Delhi: ICAR; 1978. p. 361.
25. Rehman H, Iqbal H, Basra SM, Afzal I, Farooq M, Wakeel A, et al. Seed priming improves early seedling vigor, growth and productivity of spring maize. J Integr Agric. 2015;14(9):1745–54. [https://doi.org/10.1016/S2095-3119\(14\)61000-5](https://doi.org/10.1016/S2095-3119(14)61000-5)
26. Yesmin MS, Sikder MSI, Hossain MS, Hasan MM, Howlader NC. Effect of organic seed priming on yield and yield attributing traits of chickpea (*Cicer arietinum* L.) in drought prone area. Agric Ext Dev Ctries. 2023;1(1):38–42. <https://doi.org/10.26480/aedc.01.2023.38.42>
27. Kumar S, Hariprabha S, Kamalakannan S, Sudhagar R, Sanjeevkumar K. Effect of panchagavya on germination and seedling growth of balsam (*Impatiens balsamina*). Plant Arch. 2020;20(1):3735–37.
28. Srimathi P, Mariappan N, Sundaramoorthy L, Paramathma M. Efficacy of panchagavya on seed invigoration of biofuel crops. Sci Res Essays. 2013;8(41):2031–37. <https://doi.org/10.5897/SRE2013.5629>
29. Ramesh AS, Rai PK, Nagar S. Influence of chemicals, botanicals and growth regulator treatments on plant growth and yield attributing traits of lentil (*Lens culinaris* L.) variety K-75. Int J Plant Soil Sci. 2021;33(19):124–29.
30. Gajjela S, Chatterjee R. Effect of foliar application of panchagavya and vermiwash on yield and quality of bitter gourd (*Momordica charantia* L.). Int J Chem Stud. 2019;7(3):218–24.
31. Kumar P, Khan N, Singh PD, Singh A, Yadav V. Panchagavya: A low-cost organic input in organic farming—A review. Int J Chem Stud. 2018;6(6):575–77.
32. Bhavyasree RK, Vinothini N. Enhancement of seed quality through orgoprimer in brinjal (*Solanum melongena* L.). Int J Chem Stud. 2019;7:242–44.
33. Ankad GM, Hiremath J, Patil RT, Pramod HJ, Hedge HV. Nutrient analysis of kunapajala and panchagavya and their evaluation on germination of ashwagandha and kalamegha seeds: A comparative study. J Ayurveda Integr Med. 2017;9(1):13–19. <https://doi.org/10.1016/j.jaim.2017.01.011>
34. Kala BK, Eswari REA. Effect of panchagavya on seed germination, seedling growth and nutrient content of some leafy vegetables. Int J Sci Res Biol Sci. 2019;6(6):56–60.
35. World Flora Online. *Zea mays* subsp. *mays* [Internet]. WFO; 2025 [cited 2026 Mar 27]. Available from: <http://www.worldfloraonline.org/taxon/wfo-0001096778>
36. Gouesnard B, Diaw Y, Gay L, Ronfort J, David J. Seed management and selection in ancient maize landraces from the French Pyrenees: Ethnobotanical survey and selection experiment. Genet Resour Crop Evol. 2025;1–21. <https://doi.org/10.1007/s10722-025-02555-0>
37. Dube P, Struik PC. Seed germination and morphological characterization of traditional leafy vegetables. Afr J Agric Res. 2021;17(4):598–603. <https://doi.org/10.5897/AJAR2018.13173>
38. Vivekanandhan S, Karuppanan T, Ashokkumar K. Evaluation of salinity tolerance in Tamil Nadu and Kerala's popular traditional rice varieties during germination and early growth stages. J Curr Opin Crop Sci. 2024;5(1):41–47. <https://doi.org/10.62773/jcocs.v5i1.232>

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonpublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonpublishing.com/journals/index.php/PST/indexing_abstracting

Copyright: © The Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited (<https://creativecommons.org/licenses/by/4.0/>)

Publisher information: Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.