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UTILIZATION OF VEGETABLE WASTE BIOMASS TO ENHANCE SEEDLING EMERGENCE IN SPINACH (*SPINACIA OLERACEA* L.): A SUSTAINABLE APPROACH

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Abstract:

Spinach (Spinacia oleracea L.) is consumed for numerous health benefits, including improving blood glucose control in diabetes, reducing cancer risk, and enhancing bone health. It is notably rich in essential minerals, particularly potassium, which assists in blood pressure regulation, as well as carotene, folate, niacin, iron, ascorbic acid, and calcium. In the Marathwada region of Maharashtra state, vegetable crops are widely cultivated and generate substantial quantities of vegetable waste biomass (WBM). This study evaluates the utilization of vegetable waste biomass extracts as natural seed treatments and bio-fungicides to improve seed health and seedling emergence. Seeds of spinach (palak) were treated with 5% aqueous extracts obtained from the waste biomass of carrot (Daucus carota L.), radish (Raphanus sativus L.), onion (Allium cepa L.), fenugreek / methi (Trigonella foenum-graecum L.), spinach (Spinacia oleracea L.), cabbage (Brassica oleracea var. capitata L.), cauliflower (Brassica oleracea var. botrytis L.), tomato (Lycopersicon esculentum L.), and okra / bhendi (Abelmoschus esculentus L.). Treated seeds were evaluated for seedling emergence percentage, root length, and shoot length over a ten-day incubation period. Findings demonstrate that WBM extracts significantly influenced seed germination vigor, highlighting their practical potential as eco-friendly, sustainable seed-priming agents.

Keywords: *Spinach, Spinacia oleracea, Vegetable Waste Biomass, Seedling Emergence, Root Length, Shoot Length, Biocontrol.*

1. Introduction

Spinach (*Spinacia oleracea* L.) is an economically and nutritionally important leafy green vegetable that promotes skin, hair, and skeletal health. It contains significant reserves of vitamin K, crude dietary fiber, phosphorus, and thiamine, with its caloric content primarily derived from digestible proteins and carbohydrates. However, crop

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yield and seed quality are severely constrained by seed-borne and storage mycoflora. Vegetables and their propagation seeds naturally harbor an extensive diversity of phytopathogenic fungi during both field maturation and post-harvest storage, leading to progressive decay, damping-off, and rot diseases (1). Fungal biodeterioration severely impairs seed viability, frequently arresting germination entirely and degrading seed biochemical reserves (2).

To mitigate these losses, sustainable biocontrol agents derived from botanical by-products offer an effective alternative to synthetic agrochemicals. In the Marathwada region of Maharashtra, agricultural production yields massive volumes of unused vegetable waste biomass (WBM), encompassing discarded leaves, stems, and fibrous roots. Previous literature has established that botanical extracts and crop residues contain diverse secondary metabolites possessing antimicrobial, fungicidal, and growth-stimulatory properties, which suppress pathogenic seed mycoflora and enhance germination vigor across pulses, cereals, and vegetables (3–9). Specifically, investigations by Giridhar Singh *et al.* (10), Biligrami *et al.* (11, 12), Chary and Reddy (13), and allied researchers emphasize the sensitivity of seed-borne mycoflora and seedling development to botanical and microbial metabolites (14, 15).

Accordingly, the present investigation was undertaken to evaluate the bio-efficacy of waste biomass extracts derived from nine commonly cultivated regional vegetables on seed health, seedling emergence percentage, root elongation, and shoot growth in spinach (*Spinacia oleracea* L.).

2. Material and Methods

Healthy, uniform seeds of palak (*Spinacia oleracea* L.) were selected for experimental trials. Fresh waste biomass (WBM) components—comprising discarded leaves, stems, and roots—were collected from local agricultural markets for nine vegetable crops: carrot (*Daucus carota* L., leaf), radish (*Raphanus sativus* L., leaf), onion (*Allium cepa* L., leaf), methi (*Trigonella foenum-graecum* L., stem), palak (*Spinacia oleracea* L., stem), cabbage (*Brassica oleracea* var. *capitata* L., leaf), cauliflower (*Brassica oleracea* var. *botrytis* L., leaf), tomato (*Lycopersicon esculentum* L., root), and bhendi (*Abelmoschus esculentus* L., root).

Aqueous extracts of 5% concentration (w/v) were prepared from the respective waste biomass materials using sterile distilled water. Spinach seeds were pre-soaked separately in each 5% WBM extract for twenty-four hours at ambient laboratory temperature. Control seeds were simultaneously soaked in sterile distilled water under identical conditions. Following soaking, one hundred seeds per treatment were sown in plastic pots containing pre-sterilized potting soil. Pots were incubated in the laboratory under ambient conditions (room temperature) for ten days. At the conclusion of the ten-day incubation period, seedling emergence (SE, %), root length (RL, cm), and shoot length (SL, cm) were recorded. Experimental trials were conducted with proper replication.

3. Results and Discussion

The influence of vegetable waste biomass extracts on seedling emergence and biometric parameters of spinach (*Spinacia oleracea* L.) after ten days of sowing is presented in Table 1.

It is evident from the experimental findings presented in Table 1 that the waste biomass extracts of almost all evaluated vegetable species exhibited stimulatory effects on seedling emergence in palak relative to the control (50%). The maximum seedling emergence (80%) was achieved in seeds treated with stem extracts of *Spinacia oleracea* L. and leaf extracts of *Brassica oleracea* var. *botrytis* L., followed closely by leaf extracts of *Allium cepa* L. and root extracts of *Lycopersicon esculentum* L. (70% emergence each).

Table 1: Effect of waste biomass (WBM) of vegetable plants on seedling emergence and growth parameters of palak (Spinacia oleracea L.) after ten days of sowing

Sr. No.	Name of the Vegetable	WBM Plant Part	Seedling Emergence SE (%)	Root Length RL (Cm)	Shoot Length SL (Cm)
1.	*Daucus carota* L.	Leaf	60	1.2	1.3
2.	*Raphanus sativus* L.	Leaf	50	1.3	1.4
3.	*Allium cepa* L.	Leaf	70	1.2	1.3
4.	*Trigonella foenum-graecum* L.	Stem	40	1.5	1.4
5.	*Spinacia oleracea* L.	Stem	80	1.4	1.3
6.	*Brassica oleracea* var. *capitata* L.	Leaf	50	1.0	1.1
7.	*Brassica oleracea* var. *botrytis* L.	Leaf	80	1.3	1.2
8.	*Lycopersicon esculentum* L.	Root	70	1.1	1.0
9.	*Abelmoschus esculentus* L.	Root	60	1.2	1.3
–	**Control (sterile distilled water)**		50	1.3	1.3

Note: SE = Seedling Emergence, RL = Root Length, SL = Shoot Length.

Regarding seedling elongation, root and shoot responses varied according to the donor species. The highest root length (1.5 cm) and shoot length (1.4 cm) were observed in treatments with *Trigonella foenum-graecum* L., despite its lower emergence percentage. Stem extracts of *Spinacia oleracea* L. maintained robust root elongation (1.4 cm) and shoot growth (1.3 cm). Conversely, extracts of *Brassica oleracea* var. *capitata* L. and *Lycopersicon esculentum* L. demonstrated slight inhibitory effects on root and shoot extension (1.0–1.1 cm) compared to control values (1.3 cm each). These differential growth dynamics align with documented allelopathic and biochemical interactions reported in previous botanical seed-treatment investigations (14, 15).

Moderate enhancement was recorded with leaf extracts of *Daucus carota* L. and root extracts of *Abelmoschus esculentus* L. (60% emergence). In contrast, stem extracts of *Trigonella foenum-graecum* L. exhibited an inhibitory effect on seedling emergence (40%), while leaf extracts of *Raphanus sativus* L. and *Brassica oleracea* var. *capitata* L. showed no deviation from the control value (50%).

4. Conclusion

The present findings demonstrate that vegetable waste biomass (WBM), which is generated abundantly in agricultural production across the Marathwada region, can be utilized as an effective and sustainable resource for enhancing seedling emergence in spinach (*Spinacia oleracea* L.). In particular, stem extracts of spinach and leaf extracts of cauliflower significantly stimulated seed emergence up to 80% without detrimental effects on seedling morphology. Utilizing discarded vegetable by-products as natural seed-priming materials and bio-fungicidal agents represents an eco-friendly, cost-effective strategy to improve crop establishment, suppress seed-borne biodeterioration, and support organic agricultural practices.

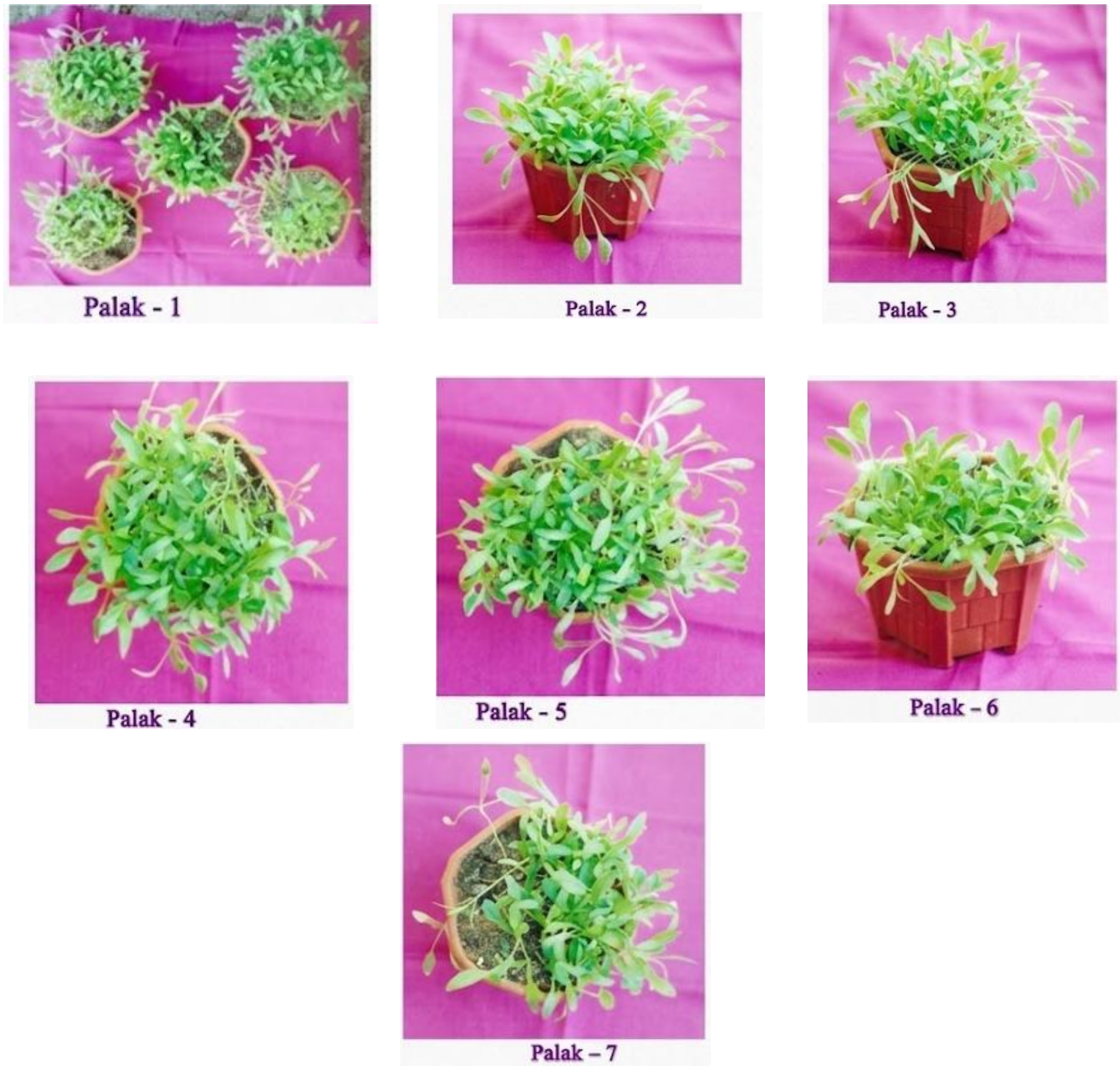

Figure 1: Visual evaluation of seedling emergence and growth of palak (Spinacia oleracea L.) treated with vegetable waste biomass (WBM) extracts

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