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Seed Priming Affects the Germination, Shoot Growth, and Mineral Composition of Four Herbal Microgreens

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Abstract

Seed priming has been widely used as a strategy to improve germination and promote uniform seedling growth in horticultural crops, yet its application in microgreen production remains relatively underexplored. This study evaluated the impact of four priming treatments—hydrogen peroxide, Kelpak Maxx (a seaweed extract), Continuum™ (a beneficial bacterial biostimulant), and hydropriming—on the germination, shoot growth, visual quality, coloration, and mineral nutrient composition of four herbal microgreen species compared with untreated raw seeds as a control treatment. Four species—chives (*Allium schoenoprasum*), dill (*Anethum graveolens*), scallion (*Allium fistulosum*), and shiso (*Perilla frutescens*)—were produced as microgreens under greenhouse conditions in two experiments in 2024 and 2025. Results revealed that early germination percentages at 3 days after treatment (DAT) in dill were increased by Kelpak Maxx, Continuum, and hydropriming by 11–18% in 2024 and by 20–40% in 2025, compared with increases for the control of 1% in 2024 and 5% in 2025. Germination percentages at 7 DAT in chives, scallion, and shiso all exceeded 88%, which were similar among priming treatments in 2024 and were not affected by priming in 2025. The four priming treatments resulted in similar fresh and dry shoot weights in chives, scallion, and shiso, but decreased fresh shoot weights in dill by 48.6% in 2024 and by 26.2% in 2025 compared with the control treatment. Species varied in mineral nutrient compositions. Priming altered concentrations of potassium, sulfur, magnesium, boron, and copper in certain species, but otherwise had minimal effects on mineral nutrient concentrations. Seed priming may potentially be used to enhance germination in slow-germinating species; however, it did not consistently improve shoot yield or mineral nutrient concentrations in the four tested microgreen species.

Keywords: dill; shiso; *Allium* species; chemical priming; biopriming



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1. Introduction

Rapid urbanization and limited access to arable land have necessitated research into resource-efficient farming methods capable of producing high-value, nutrient-rich crops in minimal space. Microgreens, tender edible seedlings harvested 7–21 days after germination, offer unique flavors, textures, and exceptional nutritional profiles, and can be produced

year-round in protected environments [1–4]. A number of species, including vegetables, herbs, grains, and weeds, from the families of Brassicaceae, Asteraceae, Amaranthaceae, Cucurbitaceae, Lamiaceae, and Fabaceae can be produced as microgreens [5–7]. North America accounts for nearly half of the rapidly-increasing global microgreen market [8,9]. The US microgreen market size is expected to grow from 1.57 billion USD in 2023 to 2.59 billion USD by 2028 [10]. Short production cycles and high market values (66–110 USD per kilogram) position microgreens as an economically viable cash crop with low startup cost [11].

Growing evidence supports the classification of microgreens as a functional food due to high levels of vitamins, minerals, and bioactive compounds including phenolics, flavonoids, carotenoids, ascorbic acid, tocopherols, and phyloquinone [12–18]. Microgreens have been shown to be 4–6 times more nutrient dense than mature plants [15,16,19,20]. Species vary significantly in nutrient profiles. *Brassica* microgreens are generally rich in potassium, calcium, iron and zinc [21], while amaranth (*Amaranthus tricolor*) contains high levels of magnesium and nitrates [22]. While the genotypic variations among species have been extensively compared, mineral nutrients and bioactive compounds in microgreens can also be substantially altered by cultural practices (e.g., fertilization, seeding density, substrate choice, etc.) and pre-sowing seed treatments, the effects of which remain largely unclear [23].

Fast seed germination and uniform seedling development are critical for successful production of microgreens due to short production cycles. Pre-sowing seed treatments such as seed priming have been used in the production of various horticultural crops to improve germination rate and enhance seedling vigor [24]. Seed priming is defined as controlled hydration which initiates the metabolic processes involved in germination without radicle protrusion [25]. Methods include hydropriming, chemical priming, osmotic priming, and biopriming [24], all aiming to achieve partial water imbibition, thereby improving germination quality [26]. However, the effects of seed priming on germination and seedling development have rarely been reported for microgreen production. Microgreen production success heavily depends on fresh shoot yield, visual quality, and mineral nutrient concentration. Therefore, these parameters require thorough investigation alongside germination quality as affected by priming.

Hydropriming, commonly referred to as seed soaking, is a widely practiced and cost-effective priming method in which seeds are soaked in water and allowed to dry back to their original moisture content before sowing [27]. This technique has been shown to improve germination timing in certain *Brassica* species compared to non-primed seeds, particularly at lower temperatures [28]. Similarly, Damalas et al. reported improved seedling vigor in fava beans (*Vicia faba* L.) following hydropriming [29]. Chemical and osmotic priming can improve plant growth and enhance tolerance to abiotic stresses, using agents such as choline, ethanol, putrescine, ZnSO₄, and CuSO₄ [30]. Biopriming involves the application of a living bacterial inoculum, such as plant-growth-promoting rhizobacteria (PGPR), which adheres to or enters the seeds before planting. Biopriming improves germination speed and uniformity, ensures rapid establishment of seedlings, and eventually increases crop growth and yield [31]. In addition, plant-derived biostimulants have been used as priming agents shown to increase the concentrations of phenolics and flavonoids in brassicaceous microgreens [32].

Microgreen species exhibit considerable variation in germination behavior and seedling establishment. The potential benefits of seed priming are likely to be species dependent, and can be affected by growth, environment, and cultural practices, the effects of which remain unclear. We hypothesized that herbal microgreen species may vary in germination and growth response to different priming treatments. Therefore, the objective

of this study was to evaluate the effects of four priming treatments on the germination, shoot growth, yield, and mineral nutrient compositions of four herbal microgreen species.

2. Materials and Methods

2.1. Seed Treatment and Experiment Setup

Four herbal microgreen species—chives (*Allium schoenoprasum*), dill (*Anethum graveolens*), scallion (*Allium fistulosum* ‘Evergreen Hardy White’) and shiso (*Perilla frutescens* var. *crispa*)—were evaluated for germination, shoot growth and mineral nutrient concentrations (Table 1). The four herbal species were selected based on popularity as well as suitability to be grown on hydroponic mats. Chives and shiso seeds were purchased from True Leaf Market (Salt Lake City, UT, USA). Scallion and dill seeds were purchased from Johnny’s Selected Seeds (Winslow, ME, USA). The study was carried out in a greenhouse located at Mississippi State University (33.4552° N, 88.7944° W). The greenhouse temperature was set at 25 °C day/night for the duration of the experiment with no supplemental lighting. This study contained two experiments: the first experiment was initiated on 24 October 2024 and repeated on 10 February 2025. The two experiments conducted in 2024 and 2025 were designed as independent repetitions to assess the consistency and reproducibility of seed priming effects on the selected microgreen species.

Table 1. Microgreen species, seed sowing, and harvest timing used in this study.

Common Name	Scientific Name	Seeding Rate ¹ (g·m ^{−2})	100 Seed Wt. (g)	Harvest Dates (DAP)
Chives	<i>Allium schoenoprasum</i>	211.6	0.13 ± 0.0035	18–19
Dill	<i>Anethum graveolens</i>	211.6	0.20 ± 0.0070	16–18
Scallion	<i>Allium fistulosum</i> cv. ‘Evergreen Hardy White’	211.6	0.24 ± 0.0046	18–19
Shiso	<i>Perilla frutescens</i> var. <i>crispa</i>	211.6	0.44 ± 0.0096	16–18

¹ Seeding rate was determined based on previous studies on similar microgreen species as well as recommendations from seed suppliers.

Seeds of each microgreen species were subject to four priming treatments, with the control consisting of non-primed raw seeds. The four priming treatments are summarized in Table 2, including chemical priming with hydrogen peroxide (H₂O₂) and the seaweed extract Kelpak Maxx (Kelp Products Ltd., Simon’s Town, South Africa), biopriming with the microbial biostimulant ContinuumTM (Impello Biosciences, Loveland, CO, USA), and hydropriming with deionized water. Kelpak Maxx is a seaweed concentrate derived from the large brown kelp species *Ecklonia maxima*. ContinuumTM is a plant-growth-promoting rhizobacteria (PGPR) biostimulant containing four bacterial species: *Paenibacillus chitinolyticus* (1 × 10⁶ CFU/mL), *Bacillus subtilis* (1 × 10⁶ CFU/mL), *Bacillus pumilus* (1 × 10⁶ CFU/mL), and *Bacillus amyloliquefaciens* (1 × 10⁶ CFU/mL). For each priming treatment, 14 g of seed for a given species were treated with 50 mL of priming solution for 6 hours and were agitated hourly. The 6-hour duration was determined based on previous literature and a preliminary experiment to ensure sufficient seed hydration without radicle protrusion. Primed seeds were then rinsed with deionized water for 30 seconds to terminate the priming process. Prior to planting, microgreen seeds were spread into plastic weighing trays and allowed to dry at room temperature for approximately 48 hours until original dry weight was achieved. No chemical seed sanitizers were applied to the control or primed seeds.

Table 2. Seed priming treatments applied to the four herbal microgreen species.

Priming Method	Priming Agent ¹	Solution Concentration ²
Control	None	N/A ³
Chemical	Hydrogen Peroxide	3 mL·L ⁻¹
Chemical	Kelpak Maxx	5 mL·L ⁻¹
Biological	Continuum TM	0.528 mL·L ⁻¹
Hydropriming	Deionized Water	N/A

¹ Kelpak Maxx is a liquid chemical priming agent derived from the brown kelp species *Ecklonia maxima*. ContinuumTM is a PGPR biostimulant. ² Concentrations of priming solutions were determined based on manufacturer's recommendations and previous reports. ³ N/A signifies that the solution concentration is not applicable as the control was applied as only deionized water.

Microgreens were grown on a hydroponic mat made from jute fibers (True Leaf Market, Salt Lake City, UT, USA). The jute fiber mats were precut and measured 25 cm by 25 cm to fit into 10-inch growing trays that measured 25.72 cm by 25.72 cm with a depth of 6.03 cm and lacked drainage holes (T.O. Plastics, Inc., Clearwater, MN, USA). The jute mats were hydrated by being soaked in tap water for approximately five minutes before use. Excess water was allowed to drain, and the saturated mats were placed in trays for planting. Microgreen seeds were manually sown by spreading the seeds evenly over the moist substrate surface. After seed sowing, growing trays were all covered with another black plastic tray to provide a dark environment beneficial for germination and then removed approximately 6 to 7 days after planting (DAP). Irrigation requirements fluctuated with the greenhouse microenvironment and the growth stage of microgreens within the experiment duration. Therefore, microgreens were inspected twice per day and were manually irrigated with a handheld sprayer once or twice as needed. This was to maintain adequate moisture in the substrate without causing excessive saturation. Fertilization in microgreen production is often considered optional, as seeds have nutrient reserves for germination and initial seedling growth. To avoid confounding effects from fertilization on mineral compositions, microgreens were not fertilized within the two experiments.

2.2. Germination Test

Prior to growing the microgreens in the greenhouse, a germination test was conducted to determine the germination percentage of each species, as affected by the four priming treatments described above. In total, 100 seeds of a given species subject to the four priming treatments or unprimed raw seeds as the control treatment were placed onto moist filter paper in a petri dish (Thermo Fisher Scientific Inc., Waltham, MA, USA). The seeds were then placed in a dark environment at 20 °C for germination. The germination test was conducted with five replications. Each 100 seeds in one petri dish served as a replication, totaling five hundred seeds used in each priming treatment or the control per species. Germination percentage was determined at three days and seven days after treatment (DAT), respectively [33].

2.3. Data Collection and Shoot Harvest

Microgreens were harvested with expanding cotyledons or the first pair of true leaves. Prior to harvest on the same day, shoot height was measured from the surface of the jute substrate to the tallest point of shoot growth for each tray. A visual quality rating was given to each tray by assessing microgreen shoot coverage over the growing area using a scale from 1 to 5 with 20% increments: 1 suggests 20% or less shoot coverage, 2 suggests 20 to 40% coverage, 3 suggests 40 to 60% coverage, 4 suggests 60 to 80% coverage and 5 suggest greater than 80% coverage with healthy shoot growth. Microgreens were also assessed for shoot coloration. Specifically, three color readings were collected from each

growing tray from a representative area using a chroma meter (CR-400, Konica Minolta Sensing Americas Inc., Ramsey, NJ, USA). After non-destructive data collection including shoot height, color and visual rating, microgreens were then harvested manually by cutting the microshoots close to the substrate surface with a pair of clean scissors. The fresh shoot weight from each tray was measured immediately after harvest. Fresh shoot samples were then dried in an oven at 60 °C until a constant weight was observed. Dry shoot weights were then determined.

2.4. Mineral Nutrient Analyses

To determine the mineral nutrient concentrations of the microgreens, dry shoot samples were ground to pass through a 1 mm sieve with a grinder (Wiley mini-Mill, Thomas Scientific, Swedesboro, NJ, USA). Combustion analysis, using 0.25 g of dry plant material and an elemental analyzer (vario MAX cube; Elementar Americas Inc., Long Island, NY, USA), was conducted to determine total nitrogen (N) concentration. Dry samples were also tested for phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), and boron (B) using inductively coupled plasma optical emission spectrometry (SPECTROBLUE; SPECTRO Analytical Instruments, Kleve, Germany). Mineral nutrient analyses of microgreen samples were conducted at the Mississippi State University Extension Service Soil Testing Laboratory. Concentrations of macronutrient ($\text{mg}\cdot\text{g}^{-1}$) and micronutrients ($\mu\text{g}\cdot\text{g}^{-1}$) were presented on a dry weight basis. Mineral nutrients were only analyzed during the 2025 experiment.

2.5. Experimental Design and Statistical Analysis

This study was conducted in a randomized complete block design with a factorial arrangement of treatments and five replications for both experiments. The two experimental factors included microgreen species (4) and the priming treatment (5), resulting in 20 treatment combinations. Each growing bench in the greenhouse served as a block or replication. Within each replication, all treatment combinations were randomized, with each growing tray being considered as an experimental unit. The significance of any main effect and or the interaction between the main effects were determined by analysis of variance (ANOVA) using the PROC GLIMMIX procedure in SAS (version 9.4, SAS Institute, Cary, NC, USA). Means were separated using Tukey's honest significance difference (HSD) test at $\alpha = 0.05$. All statistical analyses were conducted using SAS. Data from the two experiments were analyzed independently as different trends were found on measured variables in the two experiments.

3. Results

3.1. Germination Percentage

Germination percentage was affected by the interaction between microgreen species and priming treatment at 3 days after treatment (DAT) and 7 DAT in the 2024 experiment (Figure 1) and at 3 DAT in the 2025 experiment (Figure 2). At 7 DAT in 2025, germination percentage varied among species and was not affected by priming treatment (Figure 2).

At 3 DAT in 2024, shiso had the highest germination percentage, ranging from 91% to 95%, while dill had the lowest germination percentage, ranging from 1% to 23% among priming treatments within the species (Figure 1A). Scallion and chives produced intermediate germination percentages, ranging from 74 to 79% and 58 to 75%, respectively. The four priming treatments resulted in similar germination percentages to the control in scallion and shiso. All four priming treatments significantly increased germination percentage in dill compared with control, with hydrogen peroxide producing the highest germination percentage of 23%. In chives, the two biostimulants Kelpak Maxx (75%) and Continuum (74%)

both increased germination compared with control (63%), whereas hydrogen peroxide (58%) and hydropriming (70%) resulted in similar germination percentages to the control.

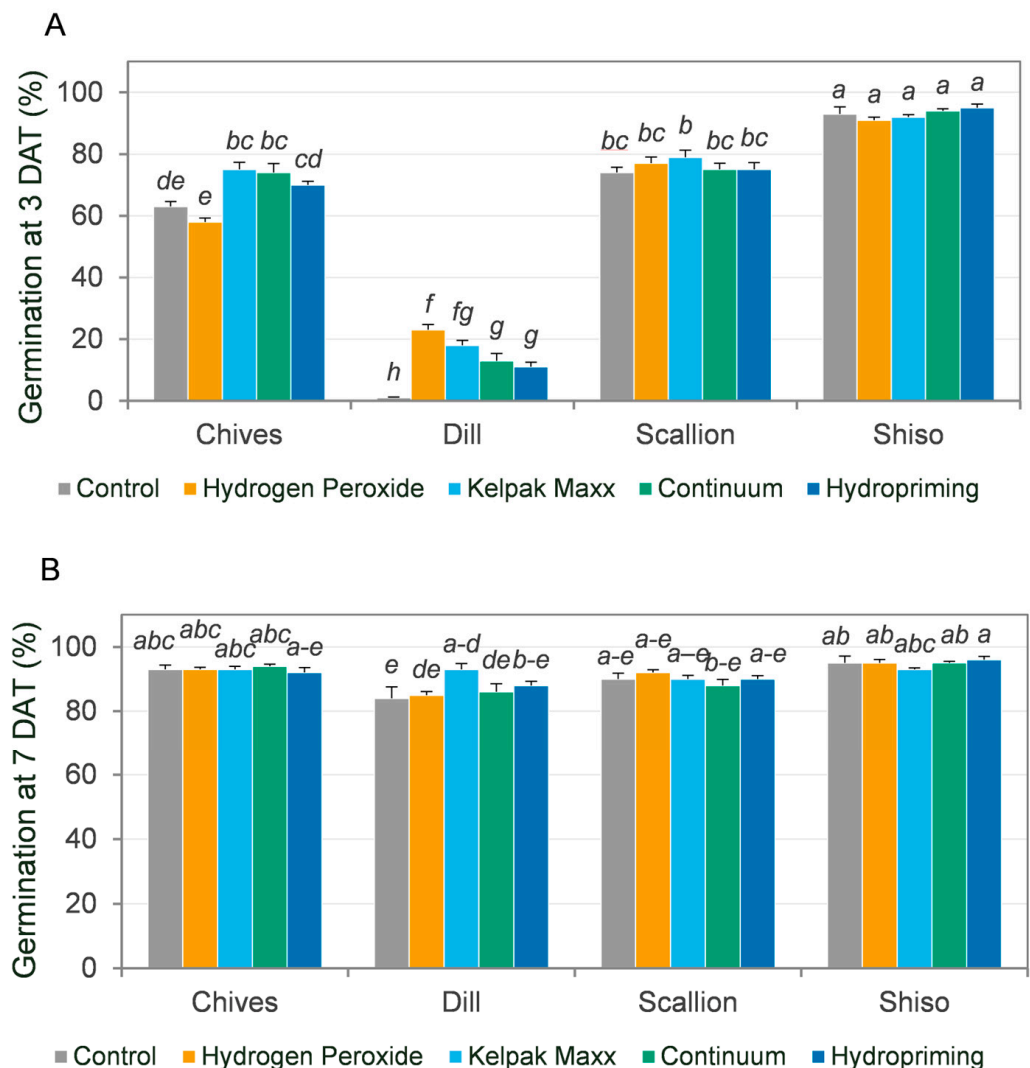


Figure 1. Germination percentages at 3 DAT (A) and 7 DAT (B) in the 2024 experiment were affected by the interaction between microgreen species and priming treatment. Different lower-case letters on top of a bar suggest significant differences among all means, as indicated by Tukey's HSD at $p < 0.05$.

At 7 DAT in 2024, chives, scallion and shiso achieved generally similar germination percentages, ranging from 88% to 96% regardless of priming treatment. Kelpak Maxx significantly improved germination in dill by 9% compared to the control, with a germination percentage of 84%. The other three priming treatments—hydrogen peroxide, continuum, and hydropriming—resulted in similar germination to the control (Figure 1B).

At 3 DAT in 2025, the highest germination percentages were found in chives treated with Kelpak Maxx, hydropriming, or control, in scallion treated with hydrogen peroxide, Kelpak Maxx, hydropriming, and control, and in shiso treated with hydrogen peroxide and Kelpak Maxx, ranging from 73 to 84% (Figure 2A). However, species varied in their response to priming treatments. Kelpak Maxx and hydropriming increased germination percentages in chives and dill compared with hydrogen peroxide or Continuum. In scallion, Continuum reduced germination percentage compared with control or hydropriming, while all treatments resulted in similar germination in shiso. At 7 DAT, chives had the highest germination percentage of 95% compared to all other species. The lowest germination

percentage was produced by shiso at 79%. The two species, dill and scallion, produced similarly intermediate germination percentages of 89% (Figure 2B).

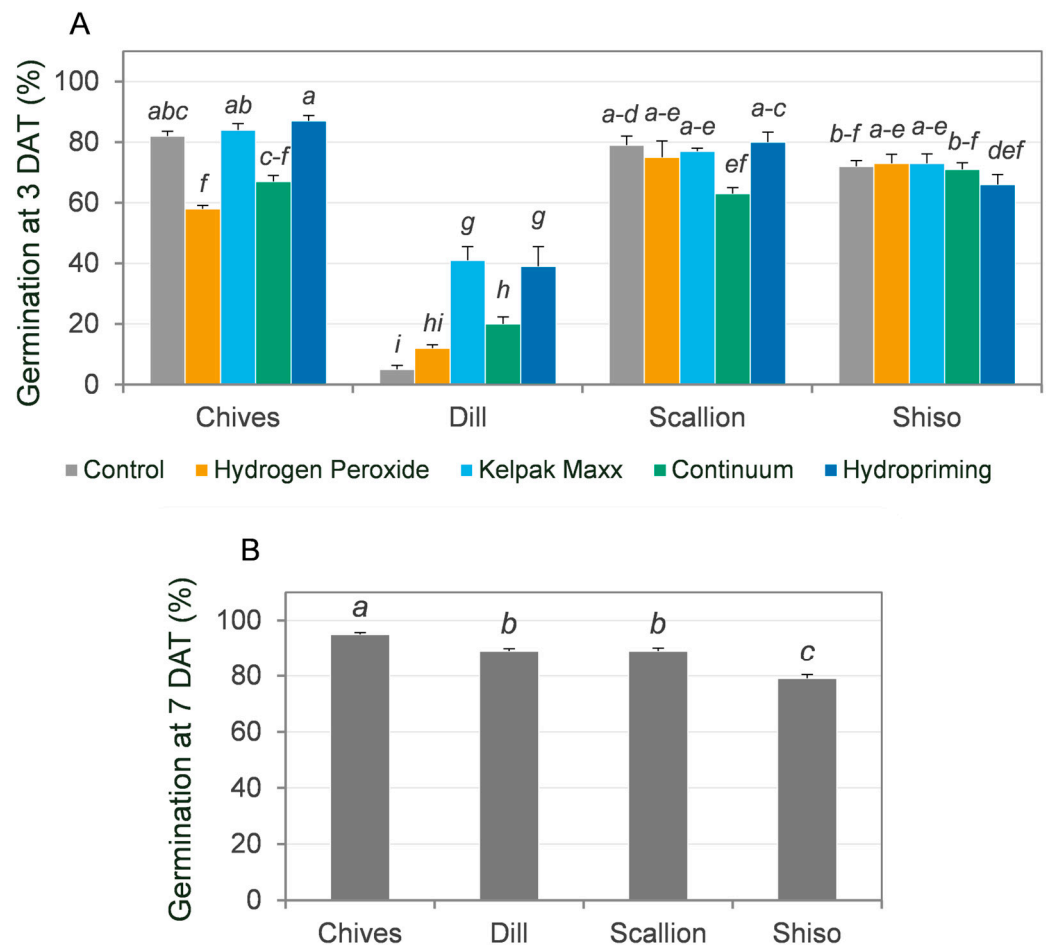


Figure 2. Germination percentages at 3 DAT (A) were affected by the interaction between microgreen species and priming treatment and varied among species, but were not affected by priming at 7 DAT (B) in the 2025 experiment. Different lower-case letters on top of a bar suggest significant differences among all means, as indicated by Tukey's HSD at $p < 0.05$.

3.2. Fresh and Dry Shoot Weights

Microgreens were harvested 18 to 19 days after planting (DAP) in the 2024 experiment (Figure S1) and at 16 to 18 DAP in the 2025 experiment (Figure S2). Fresh and dry shoot weights (FSWs and DSWs) of microgreens were affected by the interaction between microgreen species and priming treatment in both experiments (Figures 3 and 4).

In 2024, the four priming treatments resulted in similar FSWs compared to the control for chives (FSW ranging from 158.4 to 222.8 $\text{g}\cdot\text{m}^{-2}$), scallion (FSW ranging from 629.7 to 848.3 $\text{g}\cdot\text{m}^{-2}$), and shiso (FSW ranging from 500.0 to 927.5 $\text{g}\cdot\text{m}^{-2}$). In dill, the control resulted in a higher FSW of 1302.0 $\text{g}\cdot\text{m}^{-2}$ compared to Kelpak Maxx, Continuum, and hydropriming, which produced FSWs of 737.0, 740.7, and 345.8 $\text{g}\cdot\text{m}^{-2}$, respectively (Figure 3A).

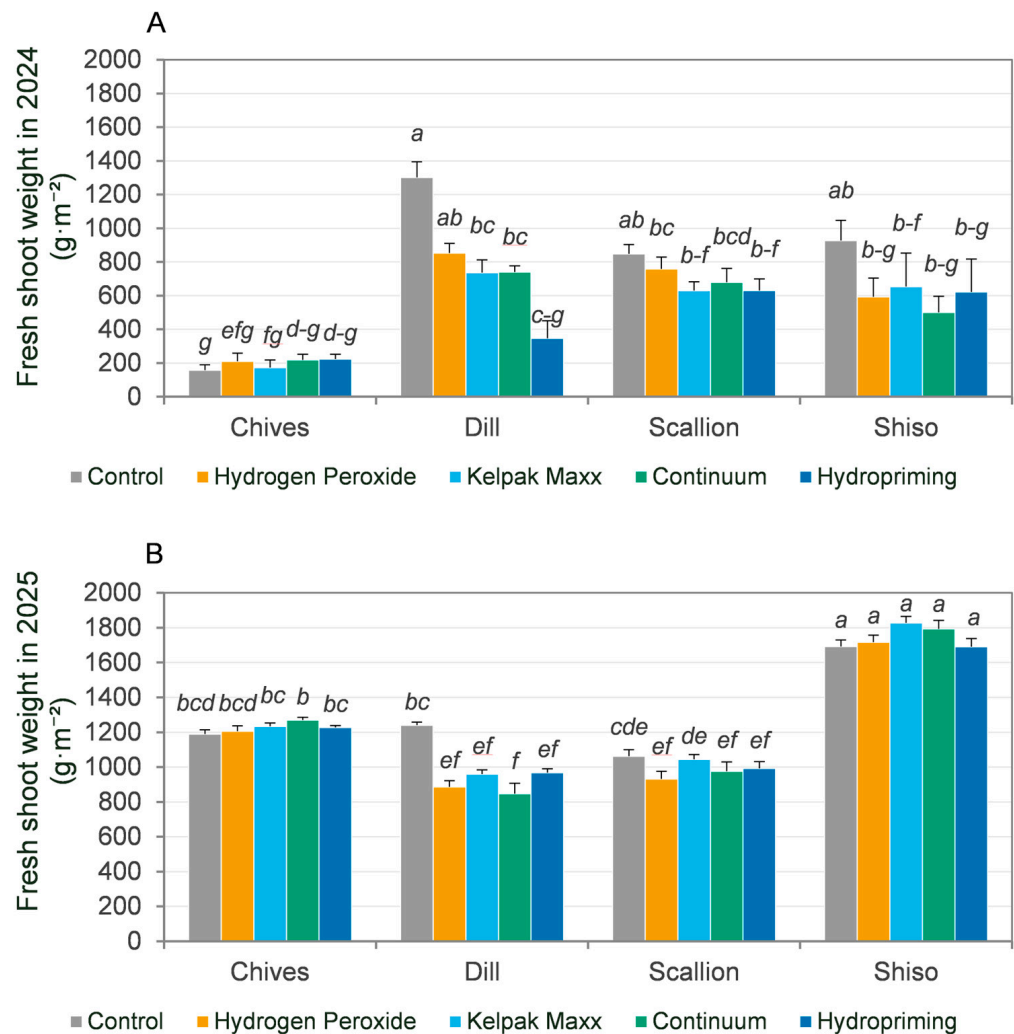


Figure 3. Fresh shoot weights in the 2024 (A) and 2025 (B) experiments were affected by the interaction between microgreen species and priming treatment. Different lower-case letters on top of a bar suggest significant differences among all means, as indicated by Tukey's HSD at $p < 0.05$.

Dry shoot weights followed a similar trend to FSW in 2024. Chives, scallion and shiso had similar DSWs within a species among all treatments, ranging from 34.9 to 49.4 $\text{g}\cdot\text{m}^{-2}$, from 81.8 to 86 $\text{g}\cdot\text{m}^{-2}$, and from 42.5 to 63.9 $\text{g}\cdot\text{m}^{-2}$, respectively. In dill, the control resulted in a significantly higher DSW of 86.3 $\text{g}\cdot\text{m}^{-2}$ compared to hydropriming with a DSW of 41.0 $\text{g}\cdot\text{m}^{-2}$ (Figure 4A).

In the 2025 experiment, shiso microgreens produced higher FSWs, ranging from 1690.0 to 1827 $\text{g}\cdot\text{m}^{-2}$, compared to any other species under each treatment (Figure 3B). The four priming treatments resulted in similar FSWs to the control within the species of chives, scallion, and shiso. In dill, the control resulted in a higher FSW (1240 $\text{g}\cdot\text{m}^{-2}$) than any of the four priming treatments, with FSWs ranging from 846.8 to 966.8 $\text{g}\cdot\text{m}^{-2}$. All treatments resulted in similar DSWs within each species in 2025. Among species, DSWs were similar among chives, scallion, and shiso, regardless of priming treatment, ranging from 120.3 to 136.9 $\text{g}\cdot\text{m}^{-2}$ (Figure 4B). Dill produced the lowest DSWs, ranging from 85.0 $\text{g}\cdot\text{m}^{-2}$ to 94.6 $\text{g}\cdot\text{m}^{-2}$, compared to any other species for any treatment.

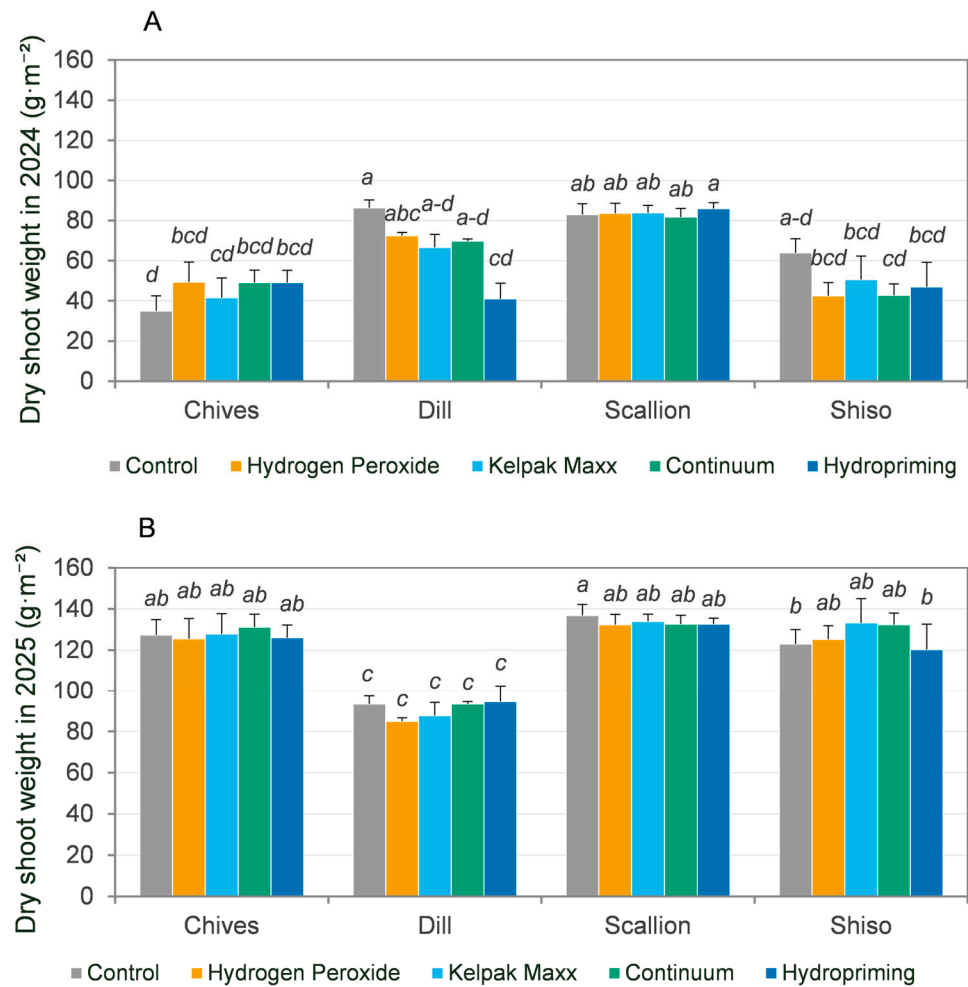


Figure 4. Dry shoot weights in the 2024 (A) and 2025 (B) experiments were affected by the interactions between microgreen species and priming treatment. Different lower-case letters on top of a bar suggest significant differences among all means, as indicated by Tukey’s HSD at $p < 0.05$.

3.3. Visual Rating

The visual rating scores varied among species and were not affected by priming in the 2024 experiment (Table 3). Scallion had the highest visual rating of 5.0 among the microgreen species. Chives produced the lowest visual rating of 2.3 compared to the other species, with poor shoot coverage of less than 40%. Dill and shiso microgreens had similar intermediate visual ratings of 4.8 and 4.0, respectively, with over 60% shoot coverage. In the 2025 experiment, all species showed satisfactory shoot growth with visual ratings of 5, regardless of priming treatment.

Table 3. Visual rating and shoot height varied among species in 2024 or were affected by the interaction between species and priming treatment in 2025.

Species	Priming Treatment	2024		2025	
		Visual Rating ^{1,2} (1–5)	Shoot Height (cm)	Visual Rating (1–5)	Shoot Height (cm)
Chives	Control	2.3 c	5.3 b	5	6.4 cd
	Hydrogen Peroxide			5	6.6 bcd
	Kelpak Maxx			5	6.6 bcd
	Continuum			5	6.6 bcd
	Hydropriming			5	6.8 a–d

Table 3. Cont.

Species	Priming Treatment	2024		2025	
		Visual Rating ^{1,2} (1–5)	Shoot Height (cm)	Visual Rating (1–5)	Shoot Height (cm)
Dill	Control			5	7.5 a
	Hydrogen Peroxide			5	6.5 cd
	Kelpak Maxx	4.8 b	6.9 a	5	6.9 a–d
	Continuum			5	6.3 d
	Hydropriming			5	6.5 cd
Scallion	Control			5	7.5 a
	Hydrogen Peroxide			5	6.9 a–d
	Kelpak Maxx	5.0 a	7.0 a	5	7.5 a
	Continuum			5	7.2 abc
	Hydropriming			5	7.4 ab
Shiso	Control			5	6.3 d
	Hydrogen Peroxide			5	6.5 cd
	Kelpak Maxx	4.0 b	6.8 a	5	6.4 d
	Continuum			5	6.3 d
	Hydropriming			5	6.2 d
<i>p</i> -value	Species	<0.0001	<0.0001	1.00	<0.0001
	Priming	0.17	0.0025	1.00	0.020
	Interaction	0.28	0.42	1.00	0.0006

¹ Different lower-case letters within a column suggest significant differences among means, as indicated by Tukey's HSD at $p < 0.05$. ² Means for visual rating and shoot height in 2024 were averaged across all priming treatments from a total of 25 data points and when the interaction between species and priming treatment was significant in 2025, each mean was sourced from a total of 5 data points.

3.4. Shoot Height

In 2024, microgreen shoot height varied among species and priming treatments separately without interaction (Tables 3 and 4). Dill, scallion, and shiso produced similar shoot heights of 6.9, 7.0, and 6.8 cm, respectively, higher than chives, which produced the shortest shoot height of 5.3 cm (Table 3). When affected by priming, Kelpak Maxx and hydropriming resulted in shoot heights of 6.3 and 6.2 cm, respectively, which were similar to those of hydrogen peroxide or Continuum, but lower than the control's shoot height of 6.9 cm (Table 4).

Table 4. Shoot coloration, shoot height, and Mg concentration, as affected by priming in two experiments in 2024 and 2025.

Priming Treatment	2024			2025	
	a* ^{1,2}	b*	Shoot Height (cm)	a*	Magnesium (mg·g ^{−1})
Control	−11.59 ab	20.74 ab	6.9 a	−11.28 b	3.69 a
Hydrogen Peroxide	−10.63 a	20.47 b	6.5 ab	−11.27 b	3.52 ab
Kelpak Maxx	−11.67 b	21.69 a	6.3 b	−10.74 ab	3.42 b
Continuum	−11.22 ab	20.81 ab	6.5 ab	−9.70 a	3.36 b
Hydropriming	−11.45 ab	20.99 ab	6.2 b	−10.29 ab	3.40 b
<i>p</i> -value	Species	<0.0001	<0.0001	<0.0001	<0.0001
	Priming	0.035	0.025	0.0004	0.0012
	Interaction	0.48	0.22	0.15	0.084

¹ Different lower-case letters within a column suggest significant differences among means, as indicated by Tukey's HSD at $p < 0.05$. ² Means were sourced from a total of 20 data points averaged across all four microgreen species.

In the 2025 experiment, shoot height was affected by the interaction between species and priming treatment (Table 3). All priming treatments resulted in similar shoot heights within the species of chives, scallion and shiso. Dill microgreens produced significantly taller shoots of 7.5 cm under the control compared with those treated with hydrogen peroxide (6.5 cm), Continuum (6.3 cm), or hydropriming (6.5 cm).

3.5. Shoot Coloration

3.5.1. Lightness (L*)

Shoot lightness readings were affected by the interaction between species and priming treatment in both experiments.

In 2024, all priming treatments resulted in similar L* readings within a species in chives, scallion, and shiso (Table 5). In dill, Kelpak Maxx resulted in a higher L* reading of 33.14 compared to a hydrogen peroxide value of 27.55. Among species, shiso shoots had the highest L* readings, ranging from 41.68 to 44.08, higher than any other species, regardless of priming treatment.

Table 5. Shoot coloration varied among species or was affected by the interaction between species and priming treatment in two experiments.

Species	Priming Treatment	2024			2025		
		L* 1,2	a*	b*	L*	a*	b*
Chives	Control	26.60 d			26.16 fg		
	Hydrogen Peroxide	27.18 cd			25.57 fg		
	Kelpak Maxx	28.20 cd	−9.30 a	18.78 b	26.47 fg	−11.02 bc	19.61 b
	Continuum	26.42 d			23.58 g		
	Hydropriming	27.62 cd			25.94 fg		
Dill	Control	31.17 bc			31.78 cde		
	Hydrogen Peroxide	27.55 cd			35.98 abc		
	Kelpak Maxx	33.14 b	−11.40 b	22.53 a	32.24 b–e	−10.36 ab	24.22 a
	Continuum	31.45 bc			34.5 bcd		
	Hydropriming	29.44 bcd			33.48 bcd		
Scallion	Control	27.47 cd			27.3 efg		
	Hydrogen Peroxide	28.45 cd			29.39 def		
	Kelpak Maxx	29.46 bcd	−9.85 a	19.45 b	27.98 efg	−9.61 a	17.47 c
	Continuum	28.72 cd			27.83 efg		
	Hydropriming	30.03 bcd			29.13 def		
Shiso	Control	44.08 a			39.96 a		
	Hydrogen Peroxide	41.68 a			37.47 ab		
	Kelpak Maxx	42.79 a	−14.70 c	22.95 a	34.77 abc	−11.63 c	18.95 b
	Continuum	42.38 a			37.5 ab		
	Hydropriming	42.29 a			37.49 ab		
p-value	Species	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	Priming	0.024	0.035	0.025	0.18	0.0004	0.064
	Interaction	0.049	0.48	0.22	0.023	0.15	0.070

¹ Different lower-case letters within a column suggest significant differences among means, as indicated by Tukey's HSD at $p < 0.05$. ² Means for a* and b* values in both experiments were averaged across all priming treatments from a total of 25 data points, and when the interaction between species and priming treatment was significant each mean was sourced from a total of 5 data points.

In 2025, shoot lightness readings showed a similar trend to those in 2024, where priming treatments or the control resulted in similar L* readings within each species (Table 5). Among species, shiso microgreens produced higher lightness readings, ranging from 34.47 to 39.96, significantly higher than chives or scallion, regardless of priming treatment, and similar to dill under each priming treatment but not the control.

3.5.2. Green/Red Coloration (a*)

Green/red coloration (a*) varied among species and priming treatment separately, with no interaction in either experiment (Tables 4 and 5). All microgreens showed negative a* values, suggesting green coloration.

Among species, chives and scallion had the highest a* readings of −9.30 and −9.85, respectively in 2024 (Table 5). Dill had an intermediate a* reading of −11.40, while shiso had the lowest a* reading of −14.70, suggesting the greenest hue. In 2025, scallion produced higher a* readings of −9.61 compared to chives (−11.02) or shiso (−11.63), but similar to dill (−10.36).

The four priming treatments and the control resulted in generally similar a* readings in 2024, except that hydrogen peroxide produced a significantly higher a* reading of −10.63 compared to Kelpak Maxx, with an a* reading of −11.67 (Table 4). In 2025, Continuum resulted in a higher a* reading of −9.70 compared to the control or hydrogen peroxide, but similar to Kelpak Maxx or hydropriming.

3.5.3. Yellow/Blue Coloration (b*)

In both experiments yellow/blue coloration (b*) varied among species (Table 5) and was also affected by priming in 2024 (Table 4), with all positive readings suggesting a yellow hue.

In 2024, dill and shiso had similarly higher b* readings of 22.53 and 22.95, respectively, than chives (18.78) or scallion (19.45). A similar trend was found in 2025 with yellow/blue coloration. Dill and shiso also had higher b* readings of 24.22 and 18.95 compared to chives or scallion microgreens with b* readings of 19.61 and 17.47, respectively. When affected by priming in 2024, each priming treatment resulted in similar b* reading to the control. However, Kelpak Maxx resulted in a significantly higher b* reading of 21.69 compared to hydrogen peroxide with a b* reading of 20.47.

3.6. Macronutrients

3.6.1. Nitrogen

Nitrogen concentration was affected by the interaction between microgreen species and priming treatment (Table 6). The four priming treatments and the control resulted in similar N concentrations within each species. Shiso generally had the highest N concentrations among species, ranging from 43.62 mg·g^{−1} to 47.07 mg·g^{−1}, higher than chives or dill for each priming treatment.

Table 6. Macronutrient concentration variation among species, or as affected by the interaction between species and priming treatment in 2025.

Species	Priming Treatment	2025					
		Nitrogen ^{1,2} (mg·g ^{−1})	Phosphorous (mg·g ^{−1})	Potassium (mg·g ^{−1})	Calcium (mg·g ^{−1})	Magnesium (mg·g ^{−1})	Sulfur (mg·g ^{−1})
Chives	Control	39.15 def		9.35 b			2.21 b
	Hydrogen Peroxide	40.09 c–e	4.96 c	6.72 cd	9.37 b	2.46 d	2.09 b–e
	Kelpak Maxx	39.56 def		6.54 cd			2.20 bcd
	Continuum	39.71 c–f		6.91 cd			2.31 b
	Hydropriming	39.91 b–e		6.68 cd			2.20 bcd

Table 6. Cont.

Species	Priming Treatment	2025					
		Nitrogen ^{1,2} (mg·g ⁻¹)	Phosphorous (mg·g ⁻¹)	Potassium (mg·g ⁻¹)	Calcium (mg·g ⁻¹)	Magnesium (mg·g ⁻¹)	Sulfur (mg·g ⁻¹)
Dill	Control	33.44 g		18.76 a			2.60 a
	Hydrogen Peroxide	36.39 efg	5.29 b	7.02 cd	12.06 a	4.51 a	1.22 f
	Kelpak Maxx	34.97 g		7.14 cd			1.17 f
	Continuum	35.85 fg		7.12 cd			1.23 f
	Hydropriming	32.71 g		6.73 cd			1.19 f
Scallion	Control	39.34 def		7.79 bc			1.99 cde
	Hydrogen Peroxide	41.3 bcd	5.10 bc	6.36 cd	6.59 d	3.82 b	1.96 cde
	Kelpak Maxx	39.76 c–f		6.05 d			1.85 e
	Continuum	39.87 cde		6.63 cd			1.98 cde
	Hydropriming	39.76 c–f		6.43 cd			1.92 de
Shiso	Control	47.07 a		6.52 cd			1.16 f
	Hydrogen Peroxide	46.23 a	7.78 a	5.93 d	7.24 c	3.13 c	1.17 f
	Kelpak Maxx	43.62 abc		5.85 d			1.13 f
	Continuum	43.88 ab		5.74 d			1.13 f
	Hydropriming	46.94 a		5.72 d			1.05 f
<i>p</i> -value	Species	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	Priming	0.059	0.47	<0.0001	0.26	0.0012	<0.0001
	Interaction	0.0063	0.96	<0.0001	0.085	0.084	<0.0001

¹ Different lower-case letters within a column suggest significant differences among means, as indicated by Tukey's HSD at $p < 0.05$. ² As affected by the main effect of species, means for P, Ca, Mg were averaged across all priming treatments from a total of 25 data points, and when the interaction between species and priming was significant, each mean was sourced from a total of 5 data points.

3.6.2. Phosphorous

Phosphorous concentration varied among species and was not affected by priming (Table 6). Shiso microgreens had the highest P concentration of 7.78 mg·g⁻¹ compared to the other three species. Chives and dill had similarly the lowest P concentrations of 4.96 mg·g⁻¹ and 5.29 mg·g⁻¹, respectively.

3.6.3. Potassium

Potassium concentration was affected by the interaction between species and priming treatment (Table 6), ranging from 5.72 mg·g⁻¹ in shiso treated with hydropriming to 18.76 mg·g⁻¹ in dill under the control. The control resulted in higher K concentrations in chives and dill than in any of the priming treatments, with the four priming treatments resulting in similar K concentrations within these two species. The control also produced higher K concentrations in scallion microgreens compared with Kelpak Maxx. The four priming treatments and the control resulted in similar K concentrations in shiso, ranging from 5.72 mg·g⁻¹ to 6.52 mg·g⁻¹.

3.6.4. Calcium

Calcium concentrations varied among species and were not affected by priming treatment (Table 6). Dill microgreens had the highest Ca concentration, while scallion produced the lowest Ca concentration among the four species. The ranking of Ca concentrations among species was as follows: dill (12.06 mg·g⁻¹) > chives (9.37 mg·g⁻¹) > shiso (7.24 mg·g⁻¹) > scallion (6.59 mg·g⁻¹).

3.6.5. Magnesium

Magnesium concentrations varied among microgreen species and were affected by priming treatment separately, with no interaction (Tables 4 and 6). Dill microgreens had the highest Mg concentration, while chives had the lowest Mg concentration. The ranking of Mg concentration among microgreen species was as follows: dill ($4.51 \text{ mg}\cdot\text{g}^{-1}$) > scallion ($3.82 \text{ mg}\cdot\text{g}^{-1}$) > shiso ($3.13 \text{ mg}\cdot\text{g}^{-1}$) > chives ($2.46 \text{ mg}\cdot\text{g}^{-1}$). When affected by the priming treatment, the control resulted in a higher Mg concentration ($3.69 \text{ mg}\cdot\text{g}^{-1}$) compared to Kelpak Maxx, Continuum, or hydropriming, but similar to hydrogen peroxide's Mg concentration of $3.52 \text{ mg}\cdot\text{g}^{-1}$ (Table 4).

3.6.6. Sulfur

Sulfur concentration was affected by the interaction between species and priming treatment (Table 6). The four priming treatments and the control resulted in similar S concentrations in chives, scallion, and shiso, whereas the control produced a higher S concentration ($2.60 \text{ mg}\cdot\text{g}^{-1}$) in dill than in any priming treatment. Among species, chives and scallion had higher S concentrations than shiso at each priming treatment or the control.

3.7. Micronutrients

3.7.1. Boron

Boron concentration was affected by the interaction between species and priming treatment (Table 7). The four priming treatments resulted in similar B concentrations compared with the control in three species, including chives, scallion, and shiso, whereas the control resulted in a higher B concentration in dill than in any of the priming treatments, with similar B concentrations. Among microgreen species, chives and dill had higher B concentrations than scallion or shiso, regardless of priming, while shiso had lower B concentrations than scallion at each treatment.

Table 7. Micronutrient concentration variation among species, or as affected by the interaction between species and priming treatment.

Species	Priming Treatment	2025				
		Boron ^{1,2} ($\mu\text{g}\cdot\text{g}^{-1}$)	Iron ($\mu\text{g}\cdot\text{g}^{-1}$)	Manganese ($\mu\text{g}\cdot\text{g}^{-1}$)	Zinc ($\mu\text{g}\cdot\text{g}^{-1}$)	Copper ($\mu\text{g}\cdot\text{g}^{-1}$)
Chives	Control	36.1 b	73.9 cde			1.8 fe
	Hydrogen Peroxide	36.0 b	73.5 cde			1.7 fe
	Kelpak Maxx	34.4 b	73.5 cde	53.7 b	50.8 b	3.1 fe
	Continuum	35.6 b	75.9 cd			3.6 e
	Hydropriming	33.9 b	73.8 cde			3.2 fe
Dill	Control	48.6 a	114.9 a			15.9 a
	Hydrogen Peroxide	34.5 b	81.9 bcd			11.6 b
	Kelpak Maxx	33.8 b	87.6 bcd	62.5 a	78.4 a	11.6 b
	Continuum	32.8 b	99.4 ab			12.7 b
	Hydropriming	34.8 b	91.2 bc			11.7 b
Scallion	Control	26.9 c	54.8 e–h			3.2 fe
	Hydrogen Peroxide	26.6 c	53.5 e–h			1.5 fe
	Kelpak Maxx	24.6 c	50.1 h	47.3 c	56.0 b	1.7 fe
	Continuum	24.2 c	52.3 fgh			0.8 f
	Hydropriming	24.8 c	51.7 gh			2.2 fe

Table 7. Cont.

Species	Priming Treatment	2025				
		Boron ^{1,2} ($\mu\text{g}\cdot\text{g}^{-1}$)	Iron ($\mu\text{g}\cdot\text{g}^{-1}$)	Manganese ($\mu\text{g}\cdot\text{g}^{-1}$)	Zinc ($\mu\text{g}\cdot\text{g}^{-1}$)	Copper ($\mu\text{g}\cdot\text{g}^{-1}$)
Shiso	Control	13.6 d	77.9 cd			10.8 bc
	Hydrogen Peroxide	12.8 d	71.9 c–g			8.7 cd
	Kelpak Maxx	12.9 d	73.3 cde	52.7 b	59.5 ab	8.5 cd
	Continuum	12.5 d	72.6 c–f			7.6 d
	Hydropriming	12.3 d	69.6 d–h			6.9 d
p-value	Species	<0.0001	<0.0001	<0.0001	0.0063	<0.0001
	Priming	<0.0001	0.0026	0.16	0.37	<0.0001
	Interaction	<0.0001	0.015	0.36	0.26	<0.0001

¹ Different lower-case letters within a column suggest significant differences among means, as indicated by Tukey's HSD at $p < 0.05$. ² As affected by the main effect of species, means for Mn and Zn were averaged across all priming treatments from a total of 25 data points, and when the interaction between species and priming treatment was significant, each mean was sourced from a total of 5 data points.

3.7.2. Iron

Iron concentration was affected by the interaction between species and priming treatment (Table 7). Chives, scallion and shiso had similar Fe concentrations among the four priming treatments and the control within a species. The control resulted in a higher Fe concentration of $114.9 \mu\text{g}\cdot\text{g}^{-1}$ in dill compared with hydrogen peroxide, Kelpak Maxx, or hydropriming, with Fe concentrations of $81.9 \mu\text{g}\cdot\text{g}^{-1}$, $87.6 \mu\text{g}\cdot\text{g}^{-1}$, and $91.2 \mu\text{g}\cdot\text{g}^{-1}$, respectively. Continuum produced a similar Fe concentration ($99.4 \mu\text{g}\cdot\text{g}^{-1}$) to the other three priming treatments in dill. Among species, dill microgreens had a higher Fe concentration than scallion than each priming treatment and the control.

3.7.3. Manganese

Manganese concentration varied among microgreen species and was not affected by priming (Table 7). Dill microgreens had the highest Mn concentration ($62.5 \mu\text{g}\cdot\text{g}^{-1}$) compared to any other species. Chives and shiso had similarly intermediate Mn concentrations of $53.7 \mu\text{g}\cdot\text{g}^{-1}$ and $52.7 \mu\text{g}\cdot\text{g}^{-1}$, respectively. Scallion microgreens had the lowest Mn concentration ($47.3 \mu\text{g}\cdot\text{g}^{-1}$) compared to any other species.

3.7.4. Zinc

Zinc concentration varied among microgreen species and was not affected by priming (Table 7). Dill microgreens had higher Zn concentrations ($78.4 \mu\text{g}\cdot\text{g}^{-1}$) than chives or scallion. The three species—chives, scallion and shiso—had similar Zn concentrations, ranging from 50.8 to $59.5 \mu\text{g}\cdot\text{g}^{-1}$.

3.7.5. Copper

Copper concentrations were affected by the interaction between species and priming (Table 7). The four priming treatments and the control resulted in similar Cu concentrations within chives and scallion. By comparison, dill microgreens had a significantly higher Cu concentration of $15.9 \mu\text{g}\cdot\text{g}^{-1}$ under the control compared to the four priming treatments, with similar Cu concentrations, ranging from 11.6 to $12.7 \mu\text{g}\cdot\text{g}^{-1}$. The control also resulted in a higher Cu concentration in shiso compared with Continuum or hydropriming. Among species, dill had the highest Cu concentration for each priming treatment and the control, higher than any other species. Chives and scallion produced the lowest Cu concentrations among species, regardless of priming.

4. Discussion

Seed germination reflected species-specific responses to priming treatments in both experiments. Early germination at 3 DAT of chives was significantly improved by priming treatments, including Kelpak Maxx and Continuum, compared to non-primed seeds in 2024. Similarly, for dill, all four priming treatments increased germination at 3 DAT in 2024. The three treatments—Kelpak Maxx, Continuum, and hydropriming—also improved early germination in dill at 3 DAT in 2025. These findings align with the common benefits of seed priming in improving germination rate, speed, and uniformity in numerous reports [34–36], where priming accelerates germination and promotes uniform seedling growth by activating biochemical changes including DNA repair, synthesis of RNA and metabolic enzymes involved in storage reserve mobilization [37,38]. In addition to these general metabolic processes, priming-induced “controlled hydration” activates pre-germinative redox-signaling pathways, including the accumulation of reactive oxygen species (ROS) such as hydrogen peroxide (H₂O₂) and superoxide radicals, which function as signaling molecules to regulate the transition from dormancy to germination within an optimal oxidative window [39,40]. To maintain redox homeostasis, antioxidant enzymes such as superoxide dismutase, catalase, and guaiacol peroxidase are upregulated during priming, preventing oxidative damage while enabling ROS-mediated signaling [41,42].

The benefits of priming were mainly limited to early germination in the current study, especially in relatively slow-germinating species like dill. When microgreen seeds are grown under favorable greenhouse conditions, the priming treatments either resulted in similar germination percentages in all species at 7 DAT in 2024 or did not affect germination percentage in 2025, except for Kelpak Maxx resulting in a higher germination percentage than the control in dill in 2024. While priming may have activated metabolic processes and accelerated early germination, unprimed seeds eventually reached a comparable germination percentage under optimal environmental conditions. Seed priming has often been applied to enhance germination quality under less than ideal open field conditions with various abiotic stresses. Priming has also been used in greenhouse plug production (e.g., lettuce and pansy) to promote establishment and synchronize seedling growth for species subject to secondary dormancy conditions induced by suboptimal environmental conditions like high temperature [37,43]. The absence of abiotic stress in protected environments may have contributed to the diminished benefits of priming treatments. Seed priming may potentially show significant benefits when used on species with particularly slow and non-uniform germination, e.g., parsley, or those that are sensitive to stressful environments, which merits further investigation.

When affected by the interaction between species and priming, the four priming treatments resulted in similar fresh and dry shoot weights to the control in chives, scallion and shiso, suggesting that these three species do not require seed priming to achieve satisfactory germination and shoot growth. Such results are consistent with a report from Ciriello et al. where three priming treatments including hydropriming, and chemical priming with two biostimulants (protein hydrolysates derived from legume and from peanut biomass) did not affect the fresh and dry shoot weights of two *Brassica rapa* microgreens [32]. Another report also observed that three priming treatments, including hydropriming and nutri-priming with two concentrations of sodium selenate, resulted in similar fresh and dry shoot weights of dill microgreens in both indoor farming and greenhouse production systems [44].

Shoot growth response to the priming treatments varied among species and reports. The three treatments—Kelpak Maxx, Continuum, and hydropriming—reduced the fresh shoot weight of dill compared with the control in both experiments, but resulted in similar dry shoot weights to the control, which suggests higher moisture levels in dill microgreens under the control. The priming treatments, including hydrogen peroxide, Continuum, and

hydropriming also decreased the shoot height of dill compared with the control in 2025. A previous study showed that hydropriming or seed soaking consistently decreased the fresh and dry shoot weights of ten microgreen species, which was attributed to the fact that cellular membranes in dehydrated seeds can be dysfunctional, leading to the leakage of nutrients including inorganic ions, amino acids, carbohydrates, and phenolics [37,45]. This can occur during rapid hydration, when membrane integrity is temporarily compromised, allowing the efflux of essential solutes into the priming solution [45]. Without external fertilizer application, early seedling growth of microgreens relies almost exclusively on seed nutrient reserves [46]. Therefore, the observed reductions in fresh shoot weight and mineral nutrients (e.g., K, Mg, S, Fe, and Cu) in dill suggest that priming-induced leaching depleted internal nutrient pools required for early growth, which can subsequently lead to reduced shoot growth or biomass accumulation.

Priming efficacy is affected by numerous factors, including species, cultivar, priming agent/method, and environmental conditions [38]. Hydropriming is one of the simplest, low-cost, and environmentally friendly methods found to effectively increase seed vigor and germination uniformity, with the disadvantage being uncontrolled water uptake highly dependent on the affinity of seed tissues for hydration [43]. Hydrogen peroxide is also widely used as a seed priming agent to enhance germination and increase the abiotic stress tolerance of various agronomic and horticultural species [47,48]. Hydrogen peroxide (50 mmol·L⁻¹) soaking increased the germination rate and percentage of three legume seeds—mung beans, cowpeas, and red beans—by influencing antioxidant enzyme activity, the breakdown of storage substances, and the regulation of germination-related substances, where the activity of α -amylase, protease, and the antioxidant enzymes (peroxidase, superoxide dismutase, and catalase) were enhanced and the soluble sugar and protein were increased as a result of H₂O₂ soaking [49]. Hydrogen peroxide was also applied as a priming cue to trigger protective mechanisms associated with stress adjustment [50]. When used in microgreen production, it also serves as a sanitizer to reduce seed-borne pathogens [51].

Priming with the seaweed extract Kelpak was observed to increase the germination percentage of an indigenous African leafy vegetable (*Ceratotheca triloba*) at low osmotic potential. However, continuous application of this priming agent inhibited seedling growth [52]. In addition, a fungal inoculant of *Trichoderma asperellum* was found to increase the stem length and fresh weight of hydroponically grown tendrill pea (*Pisum sativum*) microgreens when directly sprayed on the roots [53]. There is a lack of information regarding applying plant-growth-promoting rhizobacteria as a biopriming treatment in microgreen production. Biopriming introduces beneficial microorganisms (e.g., *Bacillus* and *Pseudomonas* spp.) to enhance plant growth through mechanisms such as phytohormone production, nutrient solubilization, and pathogen suppression [54–56]. However, the short production cycle of microgreens (16–19 days in this current study) and the hydroponic production conditions without natural soil may have limited microbial colonization in the rhizosphere, which was not directly assessed within this study. Therefore, successful establishment of PGPR cannot be confirmed. Future studies incorporating microscopic or molecular analysis would provide helpful insight into the mechanisms underlying biopriming effects.

Even though fast and uniform germination is valued, microgreen production often prioritizes fresh shoot yield and high mineral nutrient concentrations. When applying seed priming treatments in microgreen production, the benefits of accelerating germination should be weighed against possible negative effects in decreasing shoot yield and/or mineral nutrient concentrations [45]. Besides reducing the fresh shoot weight of dill microgreens in our current study, the four priming treatments decreased macronutrients including overall Mg, K in chives and dill, and S in dill. Decreases in micronutrients including Fe and Cu were also observed in dill. These reductions are consistent with

nutrient-leaching mechanisms during priming and highlight a critical trade-off between germination enhancement and nutrient retention. Other than the results mentioned above, the four priming treatments had little effect on the mineral nutrient compositions of tested microgreen species. It should be noted that the macro- and micro-mineral nutrient profile in microgreens does not necessarily align with human nutritional needs and N and B are not essential mineral nutrients for humans.

The four microgreen species varied in all measured variables in this study, including germination percentage, shoot height and yield, shoot coloration, and mineral nutrient concentrations. This agrees with previous reports that genetic variation is considered the primary factor in determining the fresh shoot yield of microgreens [14,20,57]. The contrasting responses among species further indicate that priming-induced metabolic reprogramming is genotype dependent. Different species may prioritize distinct metabolic pathways, including reserve mobilization versus secondary metabolite biosynthesis (e.g., polyphenols or glucosinolates), resulting in variable outcomes in growth and nutrient uptake [22,58]. This present study focused on shoot growth and mineral nutrient composition, as affected by priming, and did not evaluate bioactive compounds. Considering that phytochemicals are primarily responsible for many of the health-promoting properties of microgreens, their accumulation in response to pre-sowing seed priming requires further investigation in order to assist in the targeted nutritional enhancement of microgreens for human health.

5. Conclusions

Seed priming improved early germination percentage at 3 DAT in chives and dill, but did not alter germination percentage in chives, scallion, or shiso at 7 DAT. The four tested priming treatments resulted in similar FSWs and DSWs in chives, scallion, and shiso in both experiments, but decreased FSWs in dill compared with the control. The four herbal microgreen species varied in their mineral nutrient concentrations. The priming treatments reduced concentrations of K, S, Fe and Cu in dill and/or chives, reduced overall Mg concentrations, and otherwise did not alter mineral compositions in tested microgreens. Our findings for mineral compositions in the four microgreens as affected by priming were limited to one single trial, and should be validated through subsequent experimental replications. These results emphasize that species differ in their response to priming. When applying priming treatments in microgreen production, the trade-off between accelerated germination and possible reduction in yield and mineral nutrient content warrants careful consideration. Under optimal greenhouse conditions, using untreated raw seeds may be equally or more effective for microgreen production of selected herbal species.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/horticulturae12070795/s1>, Figure S1: Appearance of microgreen growth of four herbal species including chives (A), dill (B), scallion (C), and shiso (D) on the day of harvest (18–19 days after planting) in the 2024 experiment; Figure S2: Appearance of microgreen growth of four herbal species including chives (A), dill (B), scallion (C), and shiso (D) on the day of harvest (16–18 days after planting) in the 2025 experiment.

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