



Research Article

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Growth Performance of Microgreens of Minor Millet

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Abstract

Minor millets are climate-resilient, nutrient-dense cereals gaining attention for their potential use as microgreens. Seed soaking is a simple cost effective, pre-sowing technique that regulates water imbibition and activates metabolic enzymes can influence germination efficiency and early growth of cereals. However, comparative data on optimal soaking durations across multiple minor millet species remain limited. This is among the first comparative studies across six minor millet microgreens under household conditions. The six minor millets such as Foxtail, Kodo, Little, Barnyard, Proso, and Brown Top Millet were selected for the study. The millet seeds were soaked for different time durations (control (no soaking), 6h, 12h, 24h). The soaked seeds were grown in cocopeat under ambient household conditions. Shoot length and root length were recorded and microgreens were harvested on the 11th day. Data were analyzed using two-way ANOVA followed by Tukey's HSD test using JMP version 18 Software. The results depicted that soaking duration significantly ($p < 0.001$) influenced microgreen growth in all millet species. Seeds soaked for 24h consistently exhibited maximum shoot and root elongation, followed by 12h and 6h soaking, while control seeds showed the least growth. Among different minor millets kodo millet demonstrated the highest shoot elongation, whereas, barnyard millet showed highest root development. A 24-hour soaking duration was identified as the most effective pre-sowing treatment for enhancing minor millet microgreen growth. The findings highlight that pre-soaking of minor millet seeds offers a low-cost, scalable strategy for improving microgreen productivity under household conditions.

Keywords: Minor millets, Microgreens, Seed soaking, Germination, Optimization, Nutri cereals

Abbreviations: C4: C4 Photosynthetic Cycle; cm: Centimetre; h: Hours; gm: Gram; SE: Standard Error; CRD: Completely Randomized Design; ANOVA: Analysis of Variance; HSD: Honestly Significant Difference; °C: Degree Celsius

Introduction

Millets are small seeded cereal grains belonging to the botanical family Poaceae cultivated for centuries in the Indian subcontinent and other parts of Asia and Africa. They have been classified in two categories such as major millets (Pearl Millet (*Pennisetum glaucum*), Finger Millet (*Eleusine coracana*), Sorghum (*Sorghum bicolor*)) and minor millets (Foxtail Millet (*Setaria italica*), Barnyard Millet (*Echinochloa frumentacea*), Little Millet (*Panicum sumatrense*), Kodo Millet (*Paspalum scrobiculatum*), Proso Millet (*Panicum miliaceum*), Brown Top Millet (*Urochloa ramosa*)) [4]. These minor millets are known to be drought resistant crops grown (highly resilient to moisture stress) in various arid and semi-arid regions. They follow C4 photosynthetic cycle, enabling efficient carbon fixation and rapid growth in hot and dry climates and possess natural tillering ability, recover effectively after moisture stress, exhibit natural resistance to pests during cultivation and storage, and thereby requiring minimal pesticide use, benefiting both agriculture and industry [9]. They play a vital role in enhancing agricultural sustainability and strengthening food security, as millets have been traditionally an integral part of the indigenous

staple diets in India [23].

In addition to their agronomic advantage, millets have been recognized as functional grains due to their rich nutrient profile and diverse health-promoting properties. Minor millets are high in dietary fiber, resistant starch, essential amino acids, antioxidants, and minerals such as iron, calcium, magnesium, and zinc, making them beneficial for both preventive and therapeutic nutrition. Their low glycemic index supports better blood glucose regulation, enhances insulin sensitivity and helping manage and prevent type-2 diabetes [23]. Regular millet consumption has been associated with improvement in weight management by improving satiety. Furthermore, they are reported to be gluten-free, making them suitable for individuals with celiac disease or gluten intolerance, thereby provide scope for enhancing micronutrient security and dietary diversity in both rural and urban populations [9].

Seed germination is a process by which a dormant seed resumes growth and develops into a seedling. It involves a complex series of physiological, biochemical, and structural changes triggered



by water uptake (imbibition) which leads to the reactivation of enzymatic activity and resulting in emerging of the radicle (the first root of the plant) through the seed coat (the outer covering of the seed). Various suitable environmental conditions such as optimum temperature, humidity, air, pH etc. are required to initiate seed germination process [2]. Seed pre-soaking duration is a crucial factor influencing germination efficiency and early seedling vigor. It is a simple, low-cost method that facilitates water imbibition, activates hydrolytic enzymes, and accelerates metabolic processes essential for the germination of seeds [24]. The duration of seed soaking plays a decisive role in determining the rate of germination, uniformity, and subsequent shoot and root development impacting overall microgreen quality. After germination, the seed develops into a sprout within 2-5 days, showing a small root and shoot but no true leaves. If growth continues, the plant develops into a microgreen which is characterized by showing set of true leaves within 7-12 days [6].

Microgreens can be easily grown indoor (hydroponically) or outdoor (in soil). They have been popularized over the past decade due to their fresh taste, high phytochemical, antioxidants, and micronutrient nutrient content as compared to their mature counterparts and reported as better substitute for sprouts, contributes to better health outcomes [27]. They have a great potential to combat "hidden hunger" by serving as functional foods [5]. However, Millet microgreens are emerging as nutrient-dense functional foods that offer concentrated health benefits compared to their mature grain counterparts. Various studies have reported that they contain higher content of vitamins (A, C, E), essential amino acids, minerals (iron, calcium, zinc, magnesium), chlorophyll, and bioactive phytochemicals, they exhibit strong antioxidant, anti-inflammatory, and metabolic-protective properties [18]. Their rapid growth, low resource requirement, and adaptability to household production systems further enhance their potential for improving food and nutrition security [17].

Despite increasing interest in millet microgreens, there remains a significant research gap in understanding the effect of pre-sowing treatments, particularly soaking duration, across multiple minor millet species under low-input conditions. Most existing studies have focused on single species or nutritional profiling, with limited emphasis on comparative growth performance and species-specific responses. Furthermore, there is a lack of systematic evaluation of soaking durations in relation to early growth parameters such as shoot and root elongation under practical household cultivation conditions. Therefore, this study was undertaken to address this gap by evaluating the effect of different soaking durations on the germination performance and growth characteristics of selected minor millet microgreens. The findings are expected to contribute toward optimizing low-cost, techniques for household-level microgreen production and improving their practical applicability at household level.

Materials and Methods

Selection and Preparation of Seeds

Six minor millets such as Foxtail millet, Kodo millet, little millet, Proso millet, Barnyard millet, and Brown Top millet were selected for the study. The seeds were procured from a local certified source and were manually sorted to remove broken, damaged, and diseased grains. A random sample from each millet type was selected to ensure unbiased representation in the experiment [7].

Seed Soaking

The minor millets were weighed using a weighing machine. Five grams of seeds were used per block. The seeds of minor millets were soaked for different durations (6h, 12h and 24h) in potable water at ambient room temperature (Figure 1). After soaking, excess water was drained using a sterile sieve, and the seeds were surface-dried using blotting paper prior to sowing [19].

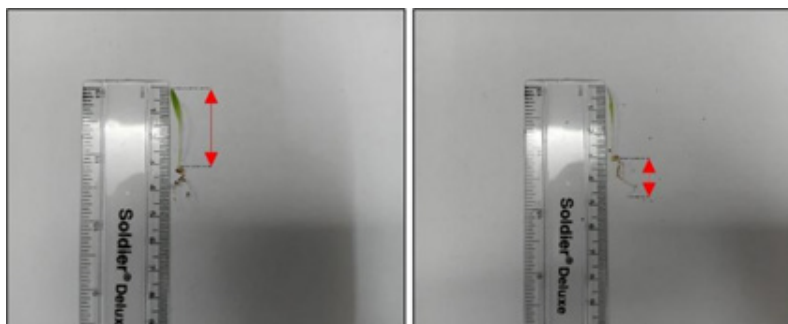


Figure 1: Shoot & Root Length Measurement (in cm)..

Preparation of Growing Medium and Trays

Shallow plastic trays of dimensions 13.4 × 9.84 × 4.72 inches were used for developing microgreens. Each tray was divided into four equal blocks. Cocopeat was used as the growing medium and

prepared prior to seed sowing. Cocopeat (500gm) was soaked water (1 litre) for 15 minutes, after which excess water was manually squeezed out. The hydrated cocopeat was evenly spread in the trays to form a uniform growing bed of approximately 1 inch depth.

Seed Sowing and Development of Microgreens

The soaked seeds were uniformly spread over the prepared cocopeat medium. The trays were covered with paper for 2–3 days to facilitate seed germination. After the emergence of shoots, the covers were removed, and the trays were placed in a well-ventilated indoor. Microgreens were exposed to indirect natural sunlight for 2–3 hours daily and maintained at ambient room temperature.

Moisture content of the tray was maintained by occasionally spraying water to avoid waterlogging. The growth parameters (shoot length and root length) were recorded manually using scale in centimeters as depicted in the Figure 1 (measured in triplicates) at regular daily intervals [21]. The microgreens were harvested on the 11th day after sowing. The process of development of microgreens has been shown in (Figure 2,3,4,5,6,7,8,9).

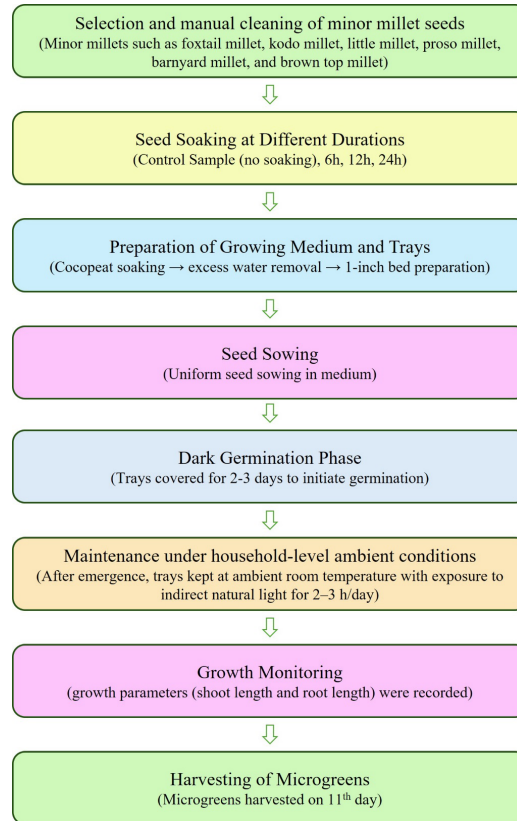


Figure 2: Flow Chart of Methodology.

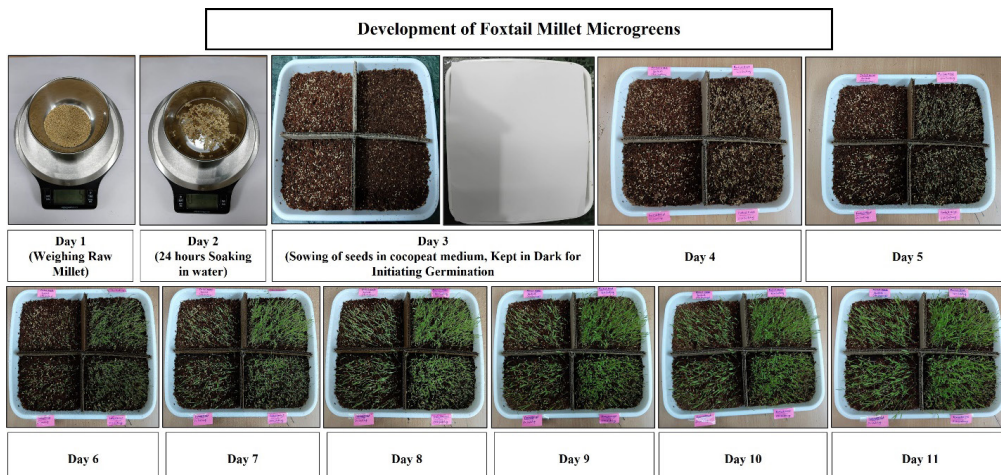


Figure 3: Represents process of development of foxtail millet microgreens..



Figure 4: Represents process of development of kodo millet microgreens.



Figure 5: Represents process of development of little millet microgreens.

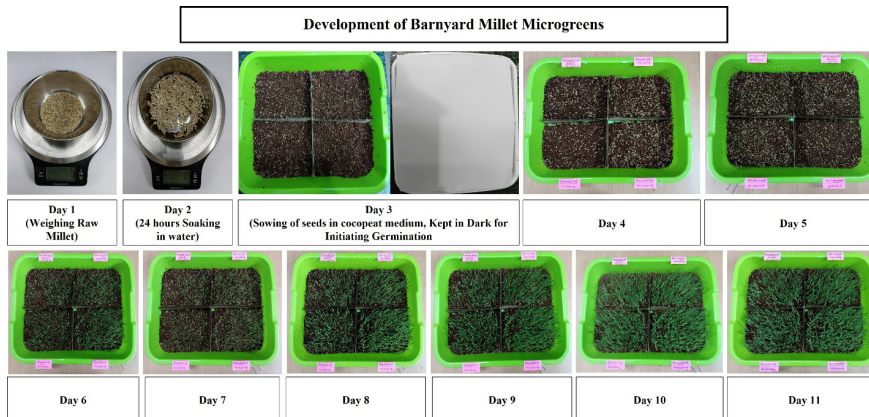


Figure 6: Represents process of development of barnyard millet microgreens.



Figure 7: Represents process of development of proso millet microgreens.



Figure 8: Represents process of development of brown top millet microgreens.



Figure 9: Represents summary of development of six minor millet microgreens.

The present study used a factorial Completely Randomized Design (CRD) with two factors (millet species and soaking duration) was conducted under household-level experimental conditions to simulate realistic microgreen development practices suitable for domestic settings. All experiments were carried out at ambient room temperature ($25\pm 2^\circ\text{C}$) in well-ventilated room. The development of microgreens was maintained without the use of artificial lighting, controlled humidity or temperature, to reflect low-cost and sustainable household practices. The effects of soaking duration, millet species, and their interaction (soaking duration \times millet species) on growth parameters (shoot length and root length) were evaluated using two-way analysis of variance (ANOVA). Mean comparisons were carried out using Tukey's HSD post hoc test at a significance level of $p \leq 0.05$. Statistical analyses were performed using JMP version 18 Software.

Results and Discussion

Effect Of Soaking Duration on Shoot and Root Length of Millet Microgreens

The results demonstrated that soaking duration significantly

affected the growth of minor millet microgreens. Two-way ANOVA indicated that soaking duration ($p < 0.001$), millet species ($p < 0.001$), and their interaction ($p < 0.001$) had a significant effect on shoot and root length. As presented in Table 1, an increase in the growth was observed with the increase in the soaking duration from control to 24h. The highest shoot length (5.87 ± 0.08 cm) and root length (4.76 ± 0.08 cm) were recorded in seeds soaked for 24 h, which were significantly higher ($p \leq 0.05$) than all other treatments. This was followed by 12 h soaking (5.39 ± 0.07 cm shoot; 3.98 ± 0.07 cm root) and 6 h soaking (4.91 ± 0.07 cm shoot; 3.52 ± 0.07 cm root), while the control exhibited the lowest values (4.63 ± 0.07 cm shoot; 2.86 ± 0.07 cm root). This improvement may be attributed to improved seed hydration (imbibition), which facilitates the activation of metabolic enzymes required for the germination of seed, and mobilization of stored nutrients during germination [24]. Adequate soaking in water (24h) facilitates faster cell division and elongation, resulting in increased shoot development in microgreens. The significant differences among all soaking treatments, as indicated by distinct Tukey groupings, suggest that soaking duration is a critical pre-sowing factor influencing early seedling vigor.

Table 1. Effect of soaking duration on shoot and root length of minor millet microgreens.

Soaking duration	Shoot length (cm)	Root length (cm)
24 h	5.87 ± 0.08a	4.76 ± 0.08a
12 h	5.39 ± 0.07b	3.98 ± 0.07b
6 h	4.91 ± 0.07c	3.52 ± 0.07c
Control	4.63 ± 0.07d	2.86 ± 0.07d

Values represent mean ± SE (n = 3) of all minor millet microgreens. Means followed by different letters within a column differ significantly according to Tukey's HSD test at p ≤ 0.05

These findings are consistent with previous studies reporting that priming or soaking treatments improve germination performance and seedling growth in various species. Similar improvements in millet growth performance have been reported in previous studies, demonstrating increased shoot and root length along with enhanced seed metabolic efficiency following seed priming with *Pseudomonas fluorescens* [16,25]. It has been reported that soaking fenugreek seeds for 12 h enhanced microgreen height, while a 24 h soaking duration resulted in maximum root development; however, excessive soaking beyond this period adversely affected growth [3]. Similarly, a 12 h soaking duration in bitter melon resulted in superior germination and growth performance compared to shorter or prolonged soaking treatments [20]. Furthermore, germination of foxtail millet is strongly influenced by seed pre-soaking and germination conditions, leading to improved nutritional quality and reduction of antinutritional factors [10,22]. Enhanced water uptake through high-pressure soaking has also been shown to improve the nutritional quality of foxtail millet grains while reducing phytic acid and tannins [22]. Additionally, a 24 h soaking period followed by germination has been identified as an effective approach for producing nutritionally enriched millet products [28]. Studies have also reported that soaking pearl millet seeds for six hours promotes earlier shoot emergence compared to untreated controls, highlighting the role of pre-soaking in accelerating early growth [15,28]. Similarly, soaking finger millet seeds has been observed to enhance growth, with increases in both shoot (from 1.87 cm to 2.07 cm) and root length (from 5.90 cm to 6.27 cm) compared to unsoaked seeds [25]. Collectively, these findings indicate that the controlled soaking durations enhance early seedling development, while excessive soaking may lead to metabolic imbalance or reduced growth. Therefore, optimizing soaking duration emerges as a critical pre-sowing strategy for maximizing growth performance and biomass yield of kodo millet microgreens under household conditions (Table 1).

Effect Of Millet Species on Shoot and Root Length of Millet Microgreens

A significant variation in shoot and root length was also observed among the millet species (p < 0.001) (Table 2). Among the evaluated six minor millet species, kodo millet exhibited the highest shoot length (6.18 ± 0.09 cm), followed by barnyard millet (5.52 ± 0.08 cm) and little millet (5.24 ± 0.08 cm). In contrast, proso millet (4.58 ± 0.08 cm) and foxtail millet (4.67 ± 0.08 cm) recorded comparatively lower shoot lengths. For root length, barnyard millet showed the highest value (4.74 ± 0.08 cm), followed closely by

kodo millet (4.58 ± 0.08 cm), indicating superior root development potential in these species. Foxtail millet exhibited the lowest root length (2.33 ± 0.08 cm), suggesting relatively slower root growth under the same conditions. The variation in growth performance among millet species may be attributed to inherent genetic differences, seed size, reserve composition, and physiological efficiency during germination. Millets such as kodo and barnyard are known for their robust growth characteristics and efficient nutrient utilization, which likely contributed to enhanced shoot and root elongation in the present study. In contrast, species like foxtail and proso millet may exhibit relatively slower early growth due to differences in seed structure and metabolic activity. Various studies have also reported significant interspecific variation in seedling growth parameters of different plant species. [14] reported that seed soaking and priming for 6h and 9h showed enhancement in the seedling growth (shoot length and root length) of brinjal seeds. Microgreens have also shown that certain species exhibit rapid elongation while others show comparatively slower growth due to differences in physiological processes and nutrient utilization efficiency [21,10] reported that seed pre-soaking and optimized germination conditions enhance nutritional quality while reducing antinutritional factors in millet.

Table 2. Effect of millet species on shoot and root length of microgreens at day 11.

Millet	Shoot length (cm)	Root length (cm)
Kodo millet	6.18 ± 0.09a	4.58 ± 0.08a
Barnyard millet	5.52 ± 0.08b	4.74 ± 0.08ab
Little millet	5.24 ± 0.08b	3.76 ± 0.08b
Brown top millet	4.89 ± 0.10b	4.12 ± 0.10c
Foxtail millet	4.67 ± 0.08c	2.33 ± 0.08d
Proso millet	4.58 ± 0.08c	3.13 ± 0.08e

Values represent mean ± SE (n = 3). Means followed by different superscript letters (a-c) within the column indicate significant differences among millet types at (p<0.05) according to Tukey's HSD test.

Effect Of Millet Species and Soaking Duration on Root and Shoot Length of Microgreens

The interaction between millet species and soaking duration plays a crucial role in determining the overall growth performance of microgreens. The combined effect observed in the present study suggests that optimal soaking duration enhances growth differently depending on the intrinsic characteristics of each millet species. Figures 10 and 11 depict the interaction effect of millet species and soaking duration on root length of microgreens. This interaction can be explained by the differential water absorption capacity, seed coat permeability, and metabolic response of each species to soaking. While soaking improves hydration and metabolic activation in all seeds, the extent of these effects depends on seed structure and composition. Some species may respond more efficiently to extended soaking by rapidly activating enzymatic systems, whereas others may experience adverse effects such as nutrient leaching or oxygen limitation under prolonged soaking [24]. Various studies have shown that the interaction between soaking duration and species significantly influences germination and seedling growth parameters. [12] reported, in sesame, the effect of pre-soaking on shoot and root length varied depending on

environmental conditions and treatment duration, indicating that seed response is species specific. Similarly, studies on microgreens have reported that soaking treatments can either enhance or

reduce growth depending on species, highlighting the importance of optimizing soaking conditions for each crop [13].

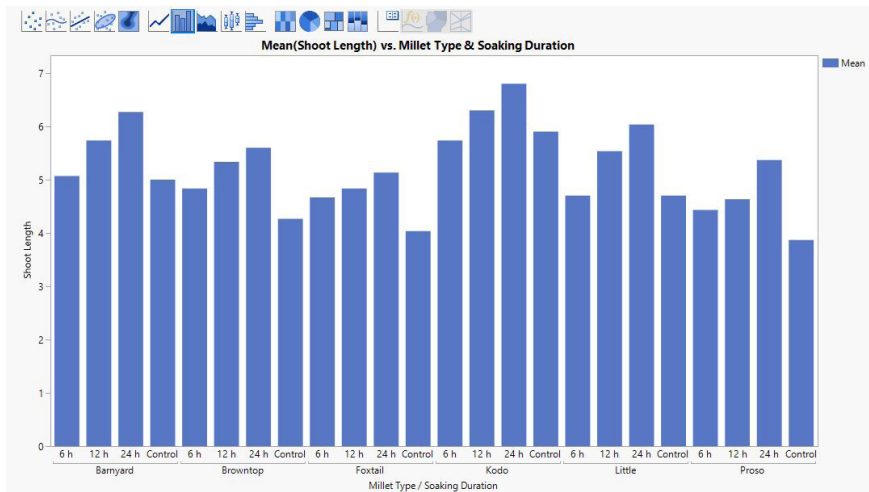


Figure 10: Represents interaction of millet type and soaking duration with root length.

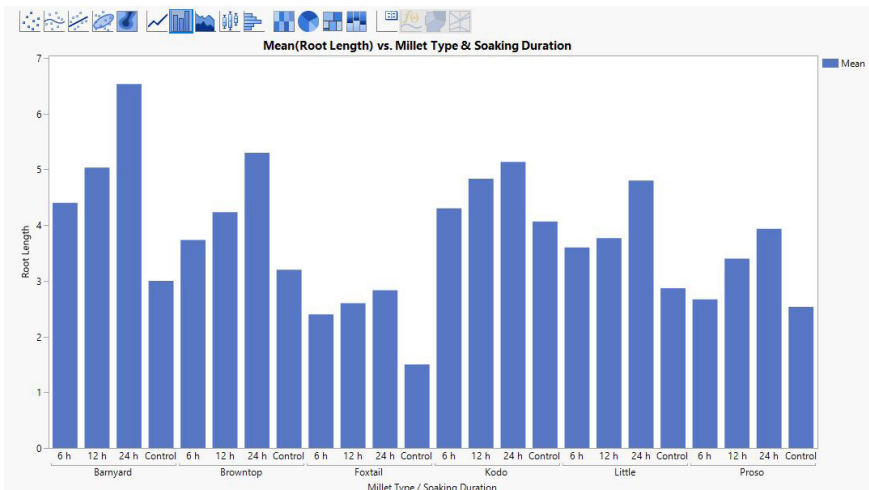


Figure 11: Represents interaction of millet type and soaking duration with root length.

Further evidence from microgreen research indicates that while moderate soaking durations enhance growth, excessive soaking may lead to reduced oxygen availability and impaired metabolic activity, thereby negatively affecting certain species more than others [3]. Similarly, [26] reported that seed priming significantly improved growth parameters in little millet, including increases in shoot length, root length, and seed metabolic efficiency compared to unprimed seeds. [20] reported that hydro-priming of barnyard millet seeds significantly enhanced plant height within 30 days of growth, highlighting the positive influence of controlled hydration on early plant development.

Collectively, these results emphasize that optimized soaking or hydro-priming treatments play a crucial role in improving growth performance and vigor of millets, both at the microgreen stage and during subsequent plant development. The enhanced growth performance observed in minor millet microgreens subjected to prolonged soaking durations can be attributed to improved water imbibition and activation of metabolic pathways

during germination. Soaking facilitates rapid seed hydration, triggering hydrolytic enzymes such as amylases and proteases, which mobilize stored reserves to support early seedling development [8]. Extended soaking, particularly for 24 h, was most effective, likely due to increased enzymatic activity and efficient utilization of seed reserves, resulting in greater cell elongation and biomass accumulation. Enhanced shoot length reflects improved development of photosynthetic tissues, while increased root length indicates higher water and nutrient absorption capacity [11]. Control seeds showed delayed and reduced growth, likely due to slower imbibition and limited metabolic activation. A 6 h soaking period moderately improved growth compared to control but was insufficient to fully activate the physiological processes required for optimal microgreen development. Seeds soaked for 12 h exhibited intermediate growth, indicating partial activation of germination mechanisms [1]. These findings are consistent with earlier reports demonstrating that appropriate pre-soaking treatments enhance germination uniformity, seedling vigor, and early growth in minor millets and other seeds. Therefore, the interaction effect

observed in the present study underscores the need for species-specific optimization of soaking duration to achieve maximum growth performance. The results suggest that while 24 h soaking is generally beneficial, its effectiveness may vary among millet species depending on their physiological and biochemical characteristics.

Conclusion

The present investigation highlights that the seed soaking duration influences the growth performance of minor millet microgreens. Across all six millet species studied, extended soaking significantly enhanced shoot and root development, with a 24-hour soaking duration consistently producing the most favourable growth outcomes. Improved growth under prolonged soaking can be attributed to enhanced water imbibition, activation of metabolic pathways, and efficient mobilization of seed reserves during early germination. Distinct species-specific responses were observed underscoring inherent physiological variability among minor millets. The study was conducted under household-level conditions, thereby providing practical and scalable insights for low-input microgreen development. The findings have important implications for community nutrition and food security, as millet microgreen development offers a cost-effective approach to producing nutrient-dense fresh foods. Future research should focus on assessing nutrient composition, bioactive potential, shelf life, and consumer acceptability of millet microgreens, as well as their integration into community-based nutrition interventions. Overall, the study supports the promotion of minor millet microgreens as sustainable functional foods with potential benefits for public health and resilient food systems.

Acknowledgement

Not Applicable.

Conflict of Interest

Not Applicable.

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