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ORIGINAL ARTICLE

Effect of Growing Media and Foliar Applications on Growth, Yield, and Shelf Life of Mustard (*Brassica nigra* L.) Microgreens

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Abstract

Microgreens are young vegetable greens picked after 7-21 days of seed sowing. The popularity of microgreens has increased in recent years due to short production cycles and the requirement of minimal space. Mustard (*Brassica nigra*) microgreens are popular but empirical evidence on the effect of growing media and foliar sprays on their growth, yield, and sensory attributes is low. The effects of growing media (coir dust, tissue papers, coir dust 1: compost 1) and foliar sprays (water, Albert's solution 100 ppm, or Ca $(NO_3)_2$ 100 ppm) on growth, yield, shelf life, and sensory properties of mustard microgreens were tested in a completely randomized design. Shoot fresh weight (4.21±0.04 g), shoot dry weight (0.73±0.03 g), and shoot height (7.3±0.05 cm), each for 100 shoots, was significantly greater in coir dust medium+Albert's foliar spray treatment than the other treatments. The shelf life of refrigerator-stored samples (5°C ±1 for 4 days) was significantly greater than those stored at room temperature (27°C±1 for 2 days). The highest weight loss (83.86±1.12%) was obtained in tissue papers+foliar spray of water, stored under room temperature, and the lowest (31.96±1.66%) was reported in coir dust+Albert's foliar spray under refrigerated conditions. The sensory evaluation indicated the highest preference for taste, odour, color, and overall acceptability of mustard microgreens cultivated in coir dust medium + Albert's foliar spray. Thus, the mustard microgreens grown in a coir dust medium+Albert's solution spray and preserved under refrigerated conditions lead to better production and consumer preference.

Keywords: *Albert's solution, coir dust, keeping quality, refrigerated conditions, sensory properties*

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1. Introduction

Microgreens are immature and tender seedlings harvested between 7-21 days after seed germination (Treadwell et al. 2020). Recently they have gained popularity due to the high content of micronutrients, health-promoting bioactive compounds (Xiao et al. 2012), and organoleptic properties such as attractive colours, delicate textures, and unique flavours. Microgreens are consumed commonly fresh in salads, soups, and sandwiches (Xiao et al. 2012), and produced using various species of vegetables, herbaceous plants, aromatic herbs, and wild edible plants. Mostly, the cultivated microgreens species belong to the families, Brassicaceae, Asteraceae, Chenopodiaceae, Lamiaceae, Apiaceae, Amarillydaceae, Amaranthaceae, and Cucurbitaceae (Xiao et al. 2016).

Brassicaceae microgreens, including mustard (*B. nigra)*, are rich in protein, fiber, carbohydrates, energy, calcium, iron, and vitamins A, C, and E. In addition, the hydrolyzed products of glucosinolates present in brassica vegetables have antimicrobial properties (Herr et al. 2020). Mustard microgreens are tender and juicy while offering a gentle spicy nature for the salads. Mustard microgreens can combat diabetes, clear out sinuses, and help relieve congestion of body fluids (Naik et al. 2022).

Microgreens are suitable for indoor production and move with the global movements toward controlled environmental agriculture (Riggio et al. 2019). The high market price, the better appeal, and the short production cycle of microgreens have attracted greenhouse growers, and urban and peri-urban farmers to invest in microgreen production (Kyriacou et al. 2016). The attention is given to enhancing the quality and shelf-life of microgreens. The supply of adequate essential nutrients can significantly improve the growth, quality, and nutritional values of plants. The pre-harvest foliar spraying has a significant benefit on the enhancement of the quality of microgreen production. Especially, preharvest Calcium treatments delay the decline of quality and extend the shelf life of microgreens (Kou et al. 2014).

Usually, microgreens are grown on peat-based mixes which are quite costly and non-renewable. This leads to a higher market price of microgreens. Besides, rapid quality and shelf-life deterioration are of high concern in microgreen production due to the high surface area/volume ratio, high respiration rate, and delicacy of leaves that easily wilt. These conditions cause rapid postharvest decaying of microgreens (Turner et al. 2020). In Sri Lanka, there are several low-cost and renewable materials available abundantly for microgreen production. These local materials could be substituted for imported peat-based mixtures; hence, they may serve as the most affordable growing media for small-scale and large-scale microgreen producers. Therefore, the objective of this research was to assess how using coir dust, tissue paper towel, or a combination of coir duct and compost as the growing medium, along with the application of Albert's solution, Calcium nitrate, or water as a foliar treatment, impacts the germination rate, shoot height, shoot length, leaf length, and consumer preference during the storage of mustard microgreens.

2. Materials and Methods

This experiment was conducted at a site located in the Kalutara South of Sri Lanka (6°35′ N, 79°57′ E) as a home-based study during the COVID-19 pandemic in 2021. The elevation from the mean sea level, mean annual rainfall, mean annual temperature and average relative humidity were 147 m, 2998 mm, 27°C, and 78%, respectively.

Three experiments were conducted. Experiment 01: Two-factor factorial, completely randomized design (CRD) with three replicates was used to assess the impact of growing media (coir dust, tissue paper towels, or coir dust: compost as 1:1 by weight) and foliar sprays (spraying of water, 100 ppm Albert foliar spray, or 100 ppm Ca $(NO_3)_2$ on the growth and yield of mustard microgreens. Coir dust and compost were steam-sterilized under 75°C for 45 minutes using a barrel. Coir dust alone and coir dust: compost (1:1) media were filled to a depth of 2.5 cm in plastic trays (30×24×7 cm). Four layers of moistened tissue paper were laid at the bottom of the plastic trays for the tissue paper-based medium. The mustard seeds were uniformly broadcast on the surface of each growing medium as 4 seeds/cm^2 (120 g m^{-2}) (Palmitessa et al. 2020). A wooden grid with 1 cm^2 was used for broadcasting seeds evenly. All twenty-seven trays were randomly placed under shade (indoor) conditions (27°C±1 and 70% RH). The trays were covered using a black polyethylene film for three days to facilitate seed germination (Palmitessa et al. 2020). After seed germination, each seedling tray was watered daily (300 mL per day) during the experimental period (Kopsell et al. 2012). Foliar spraying was done at 2-day intervals. According to the treatments, 10 mL from the Albert's solution, Ca $(NO_3)_2$ solution (Palmitessa et al. 2020) or 10 mL of water was sprayed.

The seed germination percentage was recorded in each treatment after 3 days of sowing. Growth and yield parameters of mustard microgreens were measured after 14 days of seed sowing. Harvesting was done using a pair of sharp and sterilized scissors by cutting the hypocotyl just above the growing media leaving the radicle. Shoot height, shoot fresh weight of 100 shoots, shoot dry weight of 100 shoots), and leaf length were measured. The shoot height and leaf length were obtained for 10 randomly selected fresh mustard seedlings from each tray, using a scaled ruler. An electrical balance was used to measure the shoot fresh yield (and shoot dry matter yield. During the drying process, fresh microgreens were placed inside an oven set at 60°C and maintained there to dry until a constant weight was obtained (Palmitessa et al. 2020).

Experiment 02: Shoots (n=100) of fresh seedlings were packed in polypropylene bags (15 cm×20 cm) and stored at room temperature (27°C±1) or refrigerated conditions (5°C±1) with 3 replicates per treatment (Paradiso et al. 2018) to assess the impact of storage conditions on harvested microgreens. The visual colour of mustard microgreen leaves in each condition was evaluated by a digital version of the Munsell colour chart. Finally, the percentage weight loss of each sample was calculated as

Percentage weight loss = Weight loss/Initial weight x 100.

Table 1: Visual quality rating of microgreens.

Score	Description	Visual quality
5	Essentially free from defects.	like extremely
4	Minor defects are not objectionable.	like moderately
3	Moderately objectionable defects, marketability threshold. Slight chlorosis (yellowing). Areas of dry and wilted microgreens	neither like nor dislike
2	Excessive defects, not saleable – discolour hypocotyls	dislike moderately
1	Unusable, degraded product. 100% chlorotic. Mold present, foul odor. Physical degradation apparent (liquid present)	dislike extremely

Experiment 03: A sensory evaluation was conducted to find out the impact of growing media and foliar sprays on the sensory properties of harvested raw microgreens using a five-point hedonic scale (Table 1) according to Kou et al., 2014 (1=dislike extremely and 5=like extremely) performed by using an untrained panel of 30 members. The samples were assigned three-digit random numbers and presented to panelists in a random sequence for assessment of their appearance, colour, odour, taste, and overall acceptability (Ranasinghe et al. 2013).

Analysis of Variance (ANOVA) was conducted on the data from experiments 1 and 2 using the R Statistical Software package. Mean separation was done using least-square means. The probability level for significance was 0.05. Data from experiment 3 was analyzed by the Friedman test using MINITAB software.

3. Results and Discussion

Seed germination

Seed germination of mustard significantly differed ($P<0.05$) due to the growing medium and the foliar sprays (Fig. 1). The highest seed germination percentage (78%) was recorded in the coir dust medium with Albert's spraying. The seed germination percentage was minimum in the tissue paper towel medium in all three solutions as well as in the coir dust+compost medium when using either water or Albert's solution as the foliar spraying. In different treatments, the seed germination varied from 40.3 - 78%, Water intake is a prerequisite for germination (Haj Sghaier et al. 2022) and coir is an ideal low-cost and renewable organic material having high water holding capacity along with facilitating good drainage for accelerating the growth and development of roots (Olle et al. 2012). Although growing microgreens on tissue papers are one the simplest methods for growing microgreens without soil (Alam 2020), the minimum water potential required to induce seed imbibition (Ramírez-Tobías et al. 2014; Campos et al. 2020) could not be achieved with water application in this study.

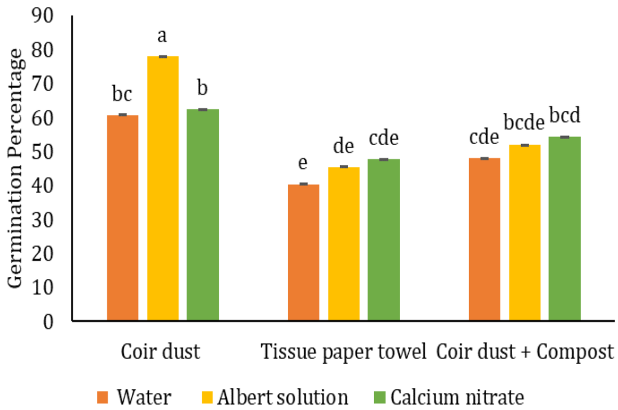

Figure 1: The germination percentage as affected by the growing medium.

Growth and yield

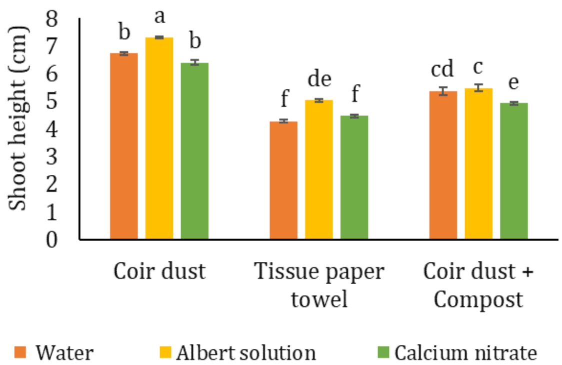

Figure 2: The shoot height (cm) of mustard microgreens obtained following different treatments.

The interaction of the growing medium and the foliar sprays was significant (P<0.05) on shoot height (Fig. 2), fresh weight (Fig. 3), and dry weight (Fig.3). The maximum shoot height (7.3±0.05 cm) (Fig. 2), fresh weight (4.21±0.04 g) (Fig. 3) and dry weight (0.73±0.03 g) (Fig. 3) were shown in the coir dust medium with Albert's foliar spray (0.01%) as the coir dust provides a favorable balance between the air and water for better growth (Francisca et al. 2003). Further, Albert's solution provides a balanced combination of macro- and micro-nutrients essential for better growth and development of plants (Marschner 2012). The coir dust and compost used as 1:1 medium showed lower growth performance than the coir dust medium and it could be due to the increased compaction in the coir dust+compost medium. The lowest seedling shoot height was shown in the tissue paper medium with the water (4.27±0.05 cm) and Ca $(NO_3)_2$ (4.47±0.05 cm) foliar sprays (Fig. 2). The lowest fresh weight and dry weight of 100-shoots of seedlings were reported with the tissue paper medium with three foliar applications with non-significant (P>0.05) differences (Fig. 3). The rapid desiccation of the tissue paper medium (Liu et al. 2016) could be the reason for the low growth of seedlings. Although the interaction effect between the growing medium and the foliar sprays was not significant (P>0.05) on the leaf length (Fig. 4), the effect of the growing medium was significant (P<0.05) on the leaf length of mustard

microgreens. Microgreens grown on the coir dust medium showed the highest mean leaf length (3.51±0.14 cm) due to favourable conditions of the medium for the supply of water and air to roots (Francisca et al. 2003).

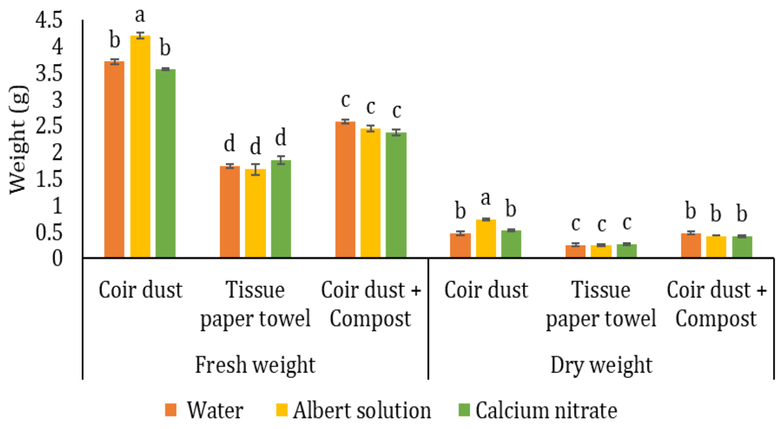

Figure 3: The fresh and dry weight of mustard microgreens as affected by treatments (Mean separation for fresh weight and dry weight was conducted separately).

Similar to other growth parameters, tissue paper medium was reported to have the lowest leaf length compared to other growing media (Fig. 4).

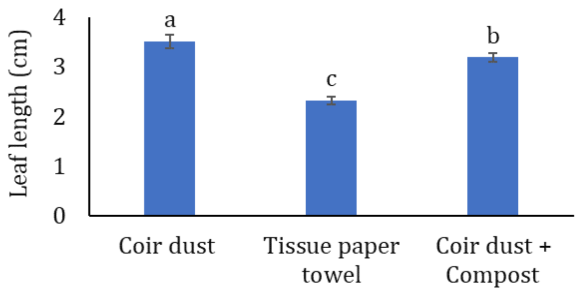

Figure 4: The leaf length of mustard microgreens obtained following different treatments.

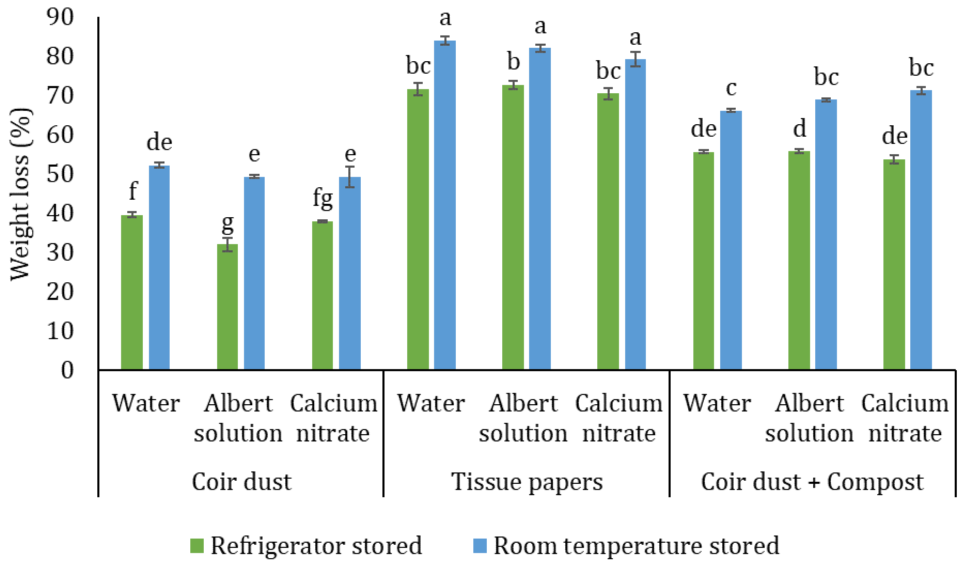

Figure 5: The percentage weight loss percentage of stored microgreens under room and refrigerated conditions.

Quality characteristics during storage

Coir dust medium with Albert's solution and Ca (NO3)2) foliar sprays showed a 2.5GY 6/6 value of Munsell colour. Regardless of the treatment applied, samples left at room temperature deteriorated within 2 days whereas those stored at 5°C reached the same condition only after 4 days. The Munsell colour notation 10Y 9/8 was recorded for all treatments when the samples were stored under refrigerated conditions at 5°C, while 10Y 9/12 was reported for those stored at room temperature. Yellowing is caused by the breakdown of chlorophyll (Shewfelt 1993) indicating that the product is undergoing oxidative degradation. This breakdown can produce off-flavours and odours as well as the growth of bacteria and other microorganisms. In such cases, increased intensity of yellowing may be an indication of a shorter shelf life (Chaijan and Panpipat 2020). Therefore, storing mustard microgreen under refrigerated conditions following all the treatments tested in this study is a better choice for extending the duration for consumption than at room temperature.

The percentage weight loss of microgreens significantly differed ($P<0.05$) among growing media, foliar application, and storage conditions (Fig. 5). The highest weight loss was recorded with tissue paper medium with all three foliar applications stored under room temperature.

Consumer preference

Coir dust medium with Albert foliar application recorded the highest rank relevant to the appearance, colour, odour, and taste of raw mustard microgreen (Fig. 6). Grown on coir dust: compost (1:1) medium with foliar spraying of water had the highest rank for texture. The highest rank for overall acceptability was obtained with the coir dust medium alone with Albert's (0.01%) foliar application.

4. Conclusion

Cultivation of mustard microgreens on the coir dust medium with foliar spraying of Albert's solution at 100 ppm is the best way to increase their growth and yield. In addition, the harvested microgreen can be kept under refrigerated conditions (5°C±1) to extend the shelf life by 2 more days than stored under ambient temperatures. Consumer preference was also enhanced when mastered microgreens were grown in the coir dust medium by foliar spraying of Albert's solution.

Future studies are proposed to compare the nutrient composition of mustard microgreens grown in different media that receive different foliar spray combinations.

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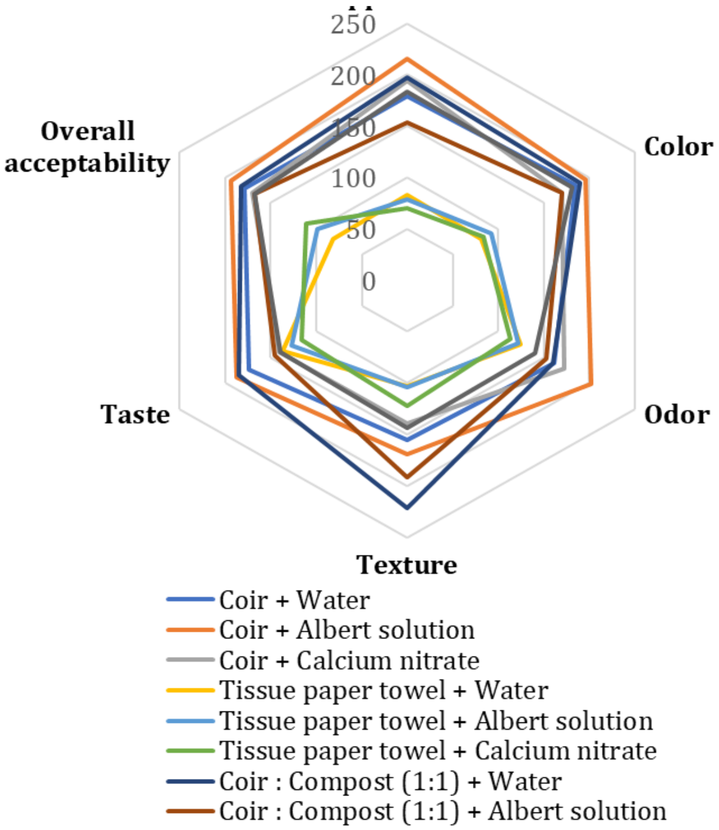
Conflicts of Interest: The authors declare that there are no conflicts of interest regarding the publication of this paper.

Figure 6: Sum of ranks of Freidman test for sensory properties of mustard microgreens.



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