Sheep Wool: Eco-Friendly Sustainable Growing Medium for Microgreens

I. Introduction

Microgreens are vegetables and herbs grown from seeds and harvested at the seedling or cotyledon stage. Although small, microgreens are packed with flavor and nutrients. These superfoods can be grown easily in small, crowded spaces and have the potential to produce nutrient-dense food locally in space-constrained environments, especially in urban settings.

Peat moss is a very popular medium to grow microgreens because it absorbs and retains moisture and supports root growth. Peat is also preferred because it is sterile as microgreens are harvested close to the growing medium. However, harvesting peat moss from peat bogs harms the environment in many ways. Healthy peat bogs act as “carbon sinks” storing huge amounts of carbon. Harvesting peat also destroys unique ecosystems that the bogs host. Peat bogs act as sponges to absorb rainfall and prevent downstream flooding. Finally, peat bogs cannot be restored quickly, and hence, peat moss is not a renewable resource. Due to these environmental hazards, it is important to find other viable, sustainable alternatives to peat.

Upon reading about the recent use of sheep wool in gardening and farming, we wanted to explore whether sheep wool can be a viable alternative to peat moss to cultivate microgreens. Sheep wool is a 100% natural, renewable, biodegradable fiber. Wool from sheep’s belly is discolored, thin and is not valuable, and can be repurposed to grow microgreens. Discarded wool decomposes quickly, within 6-12 months, and returns nutrients to the soil.

II. Statistical Question

Is the mean biomass of broccoli microgreens grown in sheep wool greater than the mean biomass of the broccoli microgreens grown in peat moss? Our hypothesis is as follows:

H0: $\mu_w - \mu_p = 0$

Ha: $\mu_w - \mu_p > 0$

μ_w: true mean biomass of broccoli microgreens grown in sheep wool substrate.

μ_p: true mean biomass of broccoli microgreens grown in peat moss substrate.

III. Data collection

In this experiment, we tested only one species of broccoli microgreens (*Brassica oleracea* var. *italica*) to avoid confounding effects due to differences in germination, biomass production, and growth characteristics across species. Seeds produced by different commercial suppliers may also vary in seed quality and germination rates due to differences in cultivation practices, harvesting methods, packaging, storage and transportation. Therefore, to reduce supplier-specific bias, we obtained one package of broccoli microgreen seeds from two independent commercial sources: Amazon and True Leaf Market. Because each package contained a large quantity, it was considered a bulk source of seeds. We thoroughly mixed the contents of both packages in a large container to ensure uniformity across brands, minimize potential supplier-specific bias and produce a randomized composite seed sample.

We tested two groups, control and treatment. The control Group P used peat moss (source: Amazon) as the conventional growing substrate. The treatment Group W used sheep wool pads (source: Gardeners.com) as the experimental growing substrate. We used 64 2” x 3” punnet trays with drainage holes, each tray designated as one experimental unit (EU). The 64 EUs were allocated to the two groups randomly, by first assigning them a number (01-64), and then generating 32 unique two-digit numbers between 01 to 64 without replacement. EUs that matched the generated numbers were allocated to Group W and the remaining to Group P. This randomization ensured that any differences in the biomass of broccoli could be attributed to the growing medium rather than any systematic bias.

Microgreens are very sensitive to seed density because they lean on each other during the growth phase. Too many seeds cause overcrowding, while too few seeds are spread too thin; and in either scenario they do not grow well. Therefore, the volume of seeds for each EU was determined based on seed density. It is suggested to use about 0.2 g of broccoli seeds per square inch. The area of an EU is 6 in^2, so 1.2 g of seeds are needed per EU. A teaspoon of seeds weighs about 5 g, so one-fourth teaspoon will weigh about 1.2 g. Each EU was thus seeded with one-fourth teaspoon of broccoli seeds.

From the composite sample of seeds, we created 64 portions of one-fourth teaspoon each using a standard measure. Each portion was placed in a cup labeled from 01 to 64. To reduce sampling bias, seeds were scooped from different areas and depths of the container. The contents were remixed after scooping every four times to keep the distribution uniform throughout the sample. This ensured that each portion represented a randomized subset of the mixed seed sample. This allowed us to compare between treatment groups, and accurately evaluate the effect of the experimental treatment on broccoli microgreen growth and biomass production.

To prepare EUs in Group W, 32 pieces of wool pads, each of size 2” x 3” were cut to match the interior base dimensions of the punnet trays. To minimize variability in the dimensions, one correctly sized wool piece was used as a template to cut the remaining pieces. After cutting, each piece was checked against the tray base and uneven edges (if any) were trimmed so that all wool substrates fit snugly. Standardizing the cutting process helped ensure that all the substrates in Group W had similar surface area, volume, moisture retention capacity, and space to grow the roots. Each wool strip was soaked in water, and excess water was removed by squeezing it four times before placing it in the tray. Squeezing each strip the same number of times potentially reduced the variation in the level of moisture across the 32 wool strips.

To prepare the EUs for Group P peat was first moistened. Water was added gradually and mixed evenly to hydrate consistently taking care that there was no water standing or oversaturation. Peat was moistened in bulk rather than for individual trays to reduce variations in the initial moisture levels across the EUs. Through trial-and-error we determined how much peat was necessary to build a substrate whose thickness is nearly the same as the thickness of the wool strips. This approach settled on a standard volume of 3 tablespoons of peat per EU. Each EU in Group P was filled with exactly 3 tablespoons of moistened peat. Both the peat and wool substrates were pressed down firmly so the seedbed is uniform and stable across all EUs. This resulted in a substrate thickness of approximately 1 inch across both peat and wool EUs. This minimized variation in root support and moisture retention between the two groups.

Each EU was seeded with one-fourth teaspoon of broccoli microgreen seeds by matching the number of the cup with the number of the EU. These seeds were spread evenly across the surface, with each EU receiving four strokes by a teaspoon. All the 64 EUs were seeded at once, and were then randomly distributed among four larger growing trays. Each large tray contained 16 EUs, mixed from both groups, organized into a 8 x 2 layout. Placing the 64 EUs randomly into 4 trays minimizes the confounding effects arising from specific locations within the trays such as differences in airflow, humidity, or temperature. The four large trays were placed in separate drawers under blackout conditions for the initial germination phase which lasted 4 days. Every 12 hours, the large trays were rotated among these drawers to reduce the effects of potential environmental differences between drawer locations. During the blackout, EUs were watered using top watering. Every 12 hours, each EU was given four puffs of water from a spray bottle, taking care to distribute evenly across the surface. This maintained sufficient moisture for germination but prevented oversaturation. All 64 EUs were watered simultaneously and maintained under identical environmental conditions to ensure consistency across treatments.

After the initial blackout, the microgreens were moved to normal light. Watering was changed from top to bottom watering, as the latter is more efficient and effective at holding moisture levels consistent and it also prevents disturbing the delicate microgreen leaves. For bottom watering, each larger tray holding the EUs is filled with 2 cups of water. Roots of the microgreens absorb water as needed through the drainage holes. The larger trays were checked every 12 hours and each large tray was replenished with 2 cups of water whenever it was dry. Microgreens in both groups were grown side-by-side under identical environmental conditions to control for confounding variables such as temperature, humidity, and light exposure. EUs were rotated every 12 hours between larger trays to avoid any effects of environmental conditions.

Figure 1: Snapshot of EUs from Peat & Wool Groups at Harvest

The experiment was run for 10 days as the time to harvest for broccoli microgreens is 8-12 days and the leaves were fully open by that time. The microgreens were harvested, cutting as close to the substrate as possible, and placing them on a paper towel for 5 minutes to dry. Microgreens from each EU were weighed separately. Figure 1 shows a snapshot of EUs from both peat and wool groups and the variability in growth among the two groups is visible. Due to space and lighting constraints all 64 EUs could not be photographed simultaneously.

IV. Data and Analysis

The biomass (in g) for EUs from each group are in Table 1. The summary statistics and the distributions are shown in Table 2 and Figure 2 respectively. All data analysis is conducted in R. We conducted a one-sided, two-sample, pooled-variance t-test to determine whether the broccoli microgreens grown in wool produce significantly more biomass than those grown in peat. The conditions for inference are satisfied as follows:

1. **Random Assignment:** 64 EUs were randomly assigned to either Group W (wool) or Group P (peat). EUs were also randomly distributed among the four larger trays to minimize positional bias. This two-level randomization satisfies the random condition.
2. **Independence:** EUs were physically separated so that the growth of microgreens in one EU does not directly affect the growth in another EU. The total amount of seeds used is less than 10% of the total supply. Therefore the independence condition is satisfied.
3. **Normal/Large Sample Condition:** According to the Central Limit Theorem, if the sample size is 30 or more per group, the sampling distribution of the mean can be considered approximately normal, even if the underlying population distribution is not perfectly normal. Since each group included 32 EUs this condition is satisfied.

Table 1: Biomass (g) for Microgreens in Peat and Wool

Group W (Wool)		Group P (Control – Peat)	
EU 01	9.95	EU 03	2.62
EU 02	10.03	EU 04	3.39
EU 05	10.28	EU 06	7.37
EU 07	10.46	EU 10	2.63
EU 08	9.07	EU 12	3.28
EU 09	8.90	EU 15	4.78
EU 11	11.45	EU 17	7.65
EU 13	12.33	EU 20	3.76
EU 14	14.20	EU 21	2.59
EU 16	9.24	EU 23	5.12
EU 18	7.11	EU 26	6.62
EU 19	10.60	EU 28	2.69
EU 22	10.27	EU 30	3.68
EU 24	8.58	EU 32	3.06
EU 25	9.55	EU 33	3.29
EU 27	11.64	EU 35	2.83
EU 29	9.39	EU 37	3.86
EU 31	7.82	EU 38	5.92
EU 34	7.91	EU 39	4.64
EU 36	8.95	EU 41	3.24
EU 40	11.49	EU 43	2.82
EU 42	9.63	EU 44	3.04
EU 45	10.32	EU 46	3.52
EU 47	7.36	EU 48	3.66
EU 50	6.79	EU 49	4.44
EU 53	9.63	EU 51	4.14
EU 55	10.35	EU 52	3.81
EU 58	8.79	EU 54	2.78
EU 60	9.47	EU 56	5.24
EU 61	7.35	EU 57	3.54
EU 63	11.80	EU 59	7.87
EU 64	10.36	EU 62	4.45

4. **Equal Variance Condition:** For pooled-variance t-test the population variances must be equal across treatment and control groups. The sample standard deviation of the biomass of microgreens grown in wool is s_W = 1.627 and for those grown in peat moss is s_P = 1.504, so this assumption appears reasonable. The pooled standard deviation is 1.5667.

Table 2: Summary Statistics of Broccoli Microgreen Biomass for Wool and Peat Substrates

Group	Mean	Std. Dev	Min	Q1	Med	Q3	Max
Wool (n = 32)	9.7209	1.627	6.79	8.8725	9.59	10.385	14.2
Peat (n = 32)	4.135	1.504	2.59	3.055	3.67	4.675	7.87

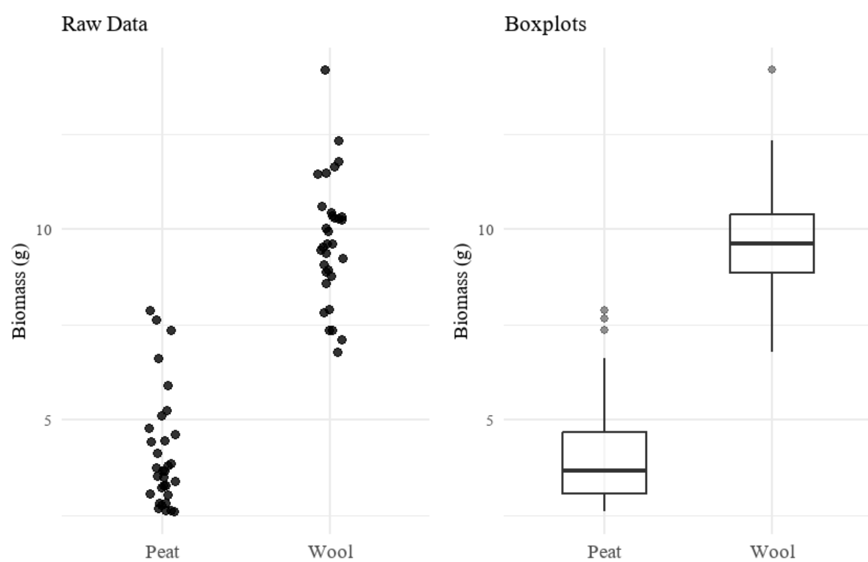

Figure 2: Side-by-side Distributions of Microgreen Biomass Grown in Peat & Wool

The value of the t-statistic is 14.261, degrees of freedom is 62, and p-value is less than 2.2×10^{-16}. Because the p-value is much lower than the significance level of 0.05, we reject the null hypothesis and conclude that broccoli microgreens grown in wool produced significantly higher biomass than those grown in peat for the conditions maintained in this experiment.

Moreover, the magnitude of the difference (5.59 g) between the two groups is substantial relative to the typical variation within each group. A 95% confidence interval for the difference in mean biomass is approximately (4.80 g, 6.37 g). This implies that we are 95% confident that under the conditions in this experiment broccoli microgreens grown in wool will produce between 4.80 g and 6.37 g more biomass on average than broccoli microgreens grown in peat. This suggests that the difference is also practically meaningful. One possible explanation is that wool may retain and distribute moisture more effectively and evenly than peat under the watering conditions used in this experiment. Although we used a pooled-variance t-test, the conclusions are not sensitive to the assumption of equal variances between two groups. We also conducted Welch's two-sample t-test, which does not require equal population variances. This test produced essentially the same result and led to the same conclusion, that microgreens grown in wool produced substantially more biomass than those grown in peat.

V. Reflections, Limitations, Future Research

Although the possibility of a Type I error exists, the extremely small p-value provides convincing evidence that microgreens grown on sheep wool produced substantially greater mean biomass than those grown on peat moss. The estimated mean difference is 5.59 g per tray and the 95% confidence interval is 4.80 g to 6.37 g for the conditions in this experiment. Because sheep wool is renewable and biodegradable, it can thus offer a sustainable, eco-friendly growth medium to cultivate microgreens. Highlights of the experiment were the randomization process, consistently better growth in wool substrate and strong separation between the two groups. It was satisfying to watch the microgreens grow at their own pace in different EUs, but eventually reach the same endpoint. The main challenge was to maintain consistent moisture despite variable temperature (in New England, temperatures can swing wildly in the spring). However, we were keen on growing under normal, ambient conditions without any specialized equipment such as grow lights to keep it accessible to ordinary households.

The experiment has many limitations. We grew only one type of microgreen and used only one wool pad. The experiment was conducted under one set of environmental conditions and only over one growth cycle. Therefore, the results cannot be generalized to other microgreen species, wool pads, or growing conditions. We are continuing this experiment to grow other microgreens such as radish and also investigate other substrates such as home-made paper pulp infused with spent coffee grounds. We also plan to compare the nutrient density and antioxidant content of microgreens grown in different substrates using chemical assays.

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VII. References

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