

Optimizing Rooftop Yield: Performance of Naturcycle Media in Raised-Bed Systems: A Three-Year Study

Introduction

Urban and rooftop farming has emerged as a sustainable strategy to meet the growing demand for local, fresh produce in densely populated areas. Green roof media play a critical role in these systems, influencing crop performance, water retention, energy use, and the overall sustainability of urban agriculture.

This report presents a collaborative research study between **Naturcycle, LLC** and the **Boston Medical Center (BMC) Rooftop Farm**. Established in 2017 by Somerville-based Recover Green Roofs, the BMC Rooftop Farm spans 2,658 square feet and produces more than 30 crop varieties. In addition to supplying fresh produce to patients, cafeterias, the Demonstration Kitchen, and the Preventive Food Pantry, the farm advances BMC's sustainability goals by reducing stormwater runoff, expanding green space, and lowering energy use, including transportation-related costs.

Naturcycle, LLC specializes in compost, engineered soils, and green roof media, with a mission to provide high-quality, sustainable materials that enhance landscapes and green infrastructure projects.

The objective of this research project was to evaluate how different green roof media influence crop cultivation and overall system efficiency. By comparing crop yields, soil compaction, soil chemistry, and moisture dynamics across three consecutive trial years, **this report provides clear, data-driven insights that underscore the importance of selecting an appropriate growth medium for optimal plant growth** in a real-world rooftop farm setting.

Methods

Media Types

Four raised bed media types were evaluated over three consecutive growing seasons:

1. **Potting Soil (Standard):** A high-organic potting soil used as the baseline control.
2. **BMC Blend:** The urban agriculture mix historically used at the BMC Rooftop Farm.
3. **Naturcycle Blend:** A soilless medium provided by Naturcycle, LLC.
4. **Third-Party Blend:** An additional soilless medium currently in use in select areas of the farm.

Experimental Setup

The experiment was conducted in two raised beds (Beds 5 and 7) on the BMC rooftop farm. Each bed was divided into four rows: Bed 5 contained 12 boxes per row, and Bed 7 contained

29 boxes per row. Media assignments were balanced, with 12 boxes per media type in Bed 5 and 29 boxes per media type in Bed 7.

In Year 1, each box was filled with its designated medium and fitted with a central irrigation emitter. Spray emitters were positioned between rows; irrigating four boxes each. Irrigation practices were consistent within each bed but differed between Beds 5 and 7.

All media received equal treatment with fertilizers, additives, and pest control, applied at the discretion of the farm manager. Fish fertilizer was incorporated prior to direct seeding or transplanting. Flowering crops (tomatoes and peppers) received bone meal before transplant. All seedlings were greenhouse-grown in standard media before transfer to soilless boxes. Insect damage, when observed, was treated uniformly across affected boxes with four applications of *Bacillus thuringiensis* (BT) and neem oil.

Soil Compaction

To quantify seasonal soil compaction, we measured the distance from the container rim to the soil surface at the start of the season and again at the end of the season in November in year 1. All boxes were initially filled to a 12-inch depth, establishing a common baseline. End-of-season “inches from the top” measurements were averaged by media type within each experimental bed. Percent compaction was calculated as the change from the 12-inch baseline divided by 12 inches and expressed as a percentage; these values were then compared across media types.

Relative Moisture Measurements

In Years 1 and 2, soil moisture was measured weekly using a Reotemp garden and compost moisture meter. The same boxes selected for temperature measurements were used for moisture readings. The probe reported relative moisture on a scale of 1–10; values were standardized by measuring the potting soil standard and calibrating the device to an “ideal” soil moisture value of 5. All measurements in other soil types were taken in relation to this value. In Year 3, soil moisture was measured using an Ecowitt WH0291 Soil Moisture Tester, which reports values as a % on a scale from 1–100. Measurements in year 3 were not calibrated to the potting soil standard. The third-party soilless medium was excluded from moisture measurements.

Crop Types and Harvesting

Daikon radish was grown in Year 1. Turnips, collard greens, tomatoes, and hot peppers were grown in all three years of the experiment. Crops were harvested on a “ready-to-harvest” basis at the discretion of the farm manager. All crops from the same soil type were harvested and weighed collectively.

Analysis

Soil compaction data were analyzed using a two-factor ANOVA, with Soil Type treated as a fixed factor and Experimental Bed as a random factor. Soil moisture, chemical, and crop harvest data were analyzed using a two-factor ANOVA, with Soil Type treated as a fixed

factor and Sampling Date as a random factor. When treatment effects were significant ($p < 0.05$), differences among means were further evaluated using Tukey's post hoc pairwise comparison test.

Results

Soil Compaction

Soil compaction measurements in Year 1 were significantly different among media types: Potting Soil had the highest compaction (23%) followed by the third party media (17%), while BMC and Naturcycle media had the lowest compaction (13%) (Table 1).

Table 1. Year 1 average percent compaction of different media types over the growing season.

Average Compaction (%)				
P-Value	Potting Soil	BMC	Naturcycle	3rd Party
0.000	22.8 (a)	13.5 (c)	13.8 (c)	16.6 (b)

Soil Moisture

Relative moisture measurements in Year 1 showed that Naturcycle and potting soil were significantly wetter than BMC ($p = 0.000$). In Year 2, potting soil exhibited the highest moisture, followed by Naturcycle, with BMC being the driest ($p = 0.000$; Figure 2).

In Year 3, % moisture measurements indicated that potting soil and Naturcycle were significantly wetter than BMC ($p = 0.000$; Figure 3).

Figure 2. Relative soil moisture for years 1 and 2.

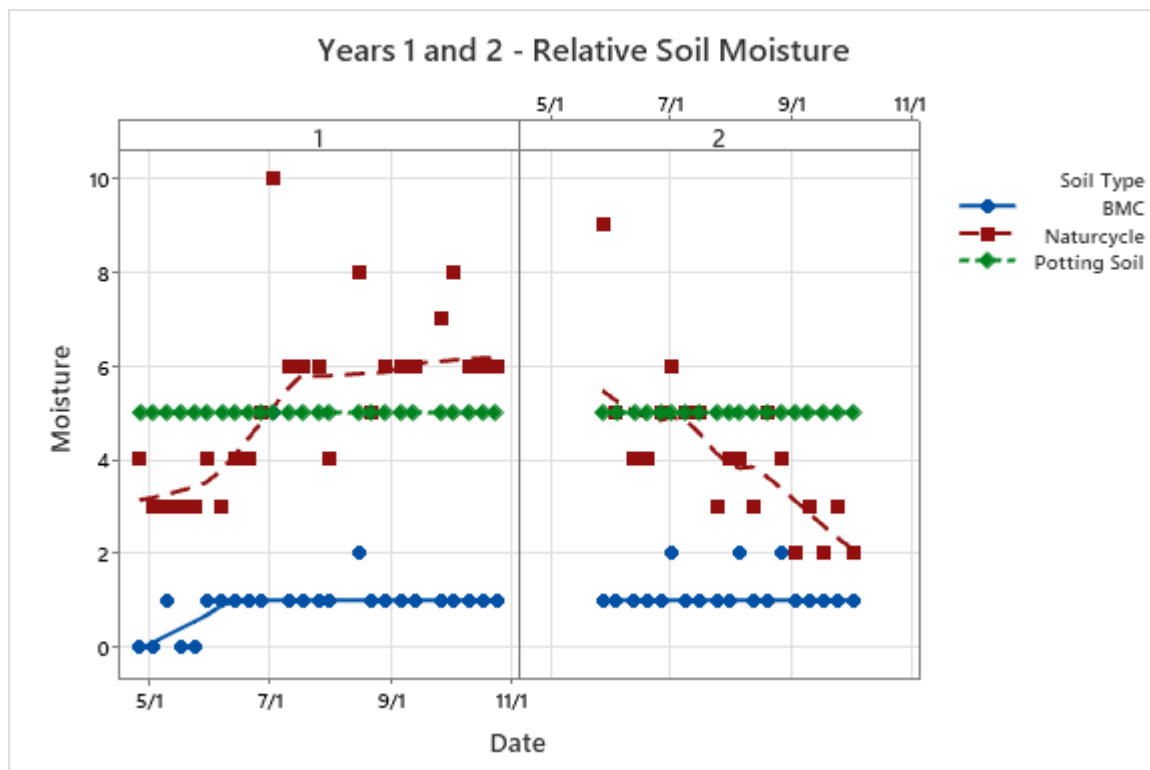
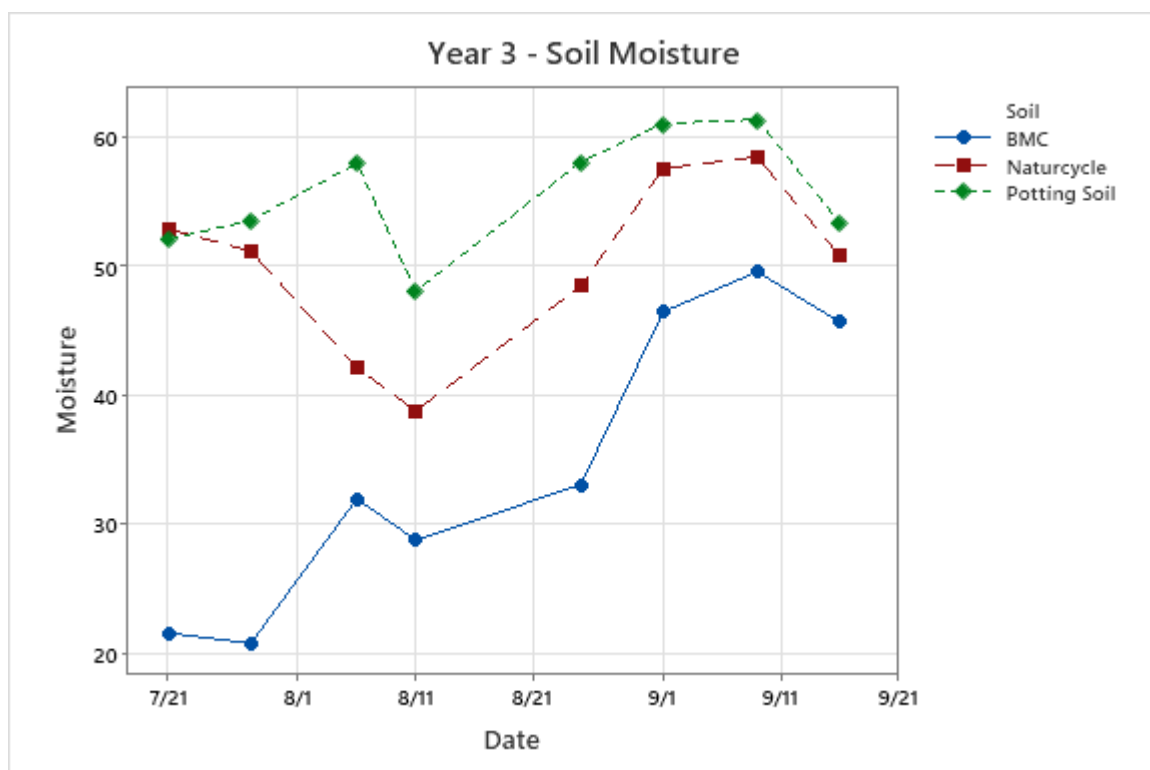


Figure 3. Soil Moisture in year 3.



Crop Yield

Collards: Highest yields per harvest date occurred in Naturcycle and potting soil in Year 1, Naturcycle in Year 2, with no differences among soil types in Year 3 (Table 2).

Peppers: Yields were greatest in Naturcycle and potting soil in Years 1 and 3, with no differences among soil types in Year 2 (Table 2).

Turnips: Highest yields were observed in Naturcycle and potting soil in Year 2, Naturcycle in Year 3, with no differences among soil types in Year 1 (Table 2).

Tomatoes: Yields were greatest in Naturcycle and potting soil in Year 1; Naturcycle, potting soil, and BMC in Year 2; and showed no differences among soil types in Year 3 (Table 2).

Daikon Radish: Highest yields per harvest date were recorded in Naturcycle and potting soil in Year 1 (Table 2).

Table 2. Average crop harvest (lbs) per sampling date across Years 1–3 for each media type. Letters following harvest values denote results of Tukey's post hoc pairwise comparisons: different letters indicate significant differences among media types, while shared letters indicate statistical similarity.

Year	Crop	Harvest Dates	P-Value	Potting Soil	BMC	Naturcycle	3rd Party Media
1	Collards	18	0.000	2.7 (a)	0.5 (b)	2.4 (a)	0.6 (b)
	Peppers	12	0.000	1.1 (a)	0.5 (b)	1.4 (a)	0.6 (b)
	Turnips	5	0.113	6.1	1.2	2.8	0.8
	Tomato	9	0.043	1.1 (ab)	0.7 (b)	1.3 (a)	0.8 (ab)
	Daikon	7	0.003	4.5 (a)	0.6 (b)	2.9 (ab)	0.9 (b)
2	Collards	7	0.000	2.1 (b)	1.2 (c)	3.0 (a)	1.9 (bc)
	Peppers	6	0.177	1.8	1.1	1.8	1.0
	Turnips	2	0.040	0.5 (ab)	0.0 (b)	1.9 (a)	0.0 (b)
	Tomato	2	0.500	1.8 (ab)	1.7 (ab)	2.5 (a)	1.3 (b)
3	Collards	10	0.379	0.9	0.7	1.0	0.9
	Peppers	9	0.036	1.2 (ab)	0.8 (ab)	1.4 (a)	0.6 (b)
	Turnips	2	0.004	0.4 (b)	0.6 (b)	3.2 (a)	0.9 (b)
	Tomato	4	0.600	0.5	0.5	0.4	0.2

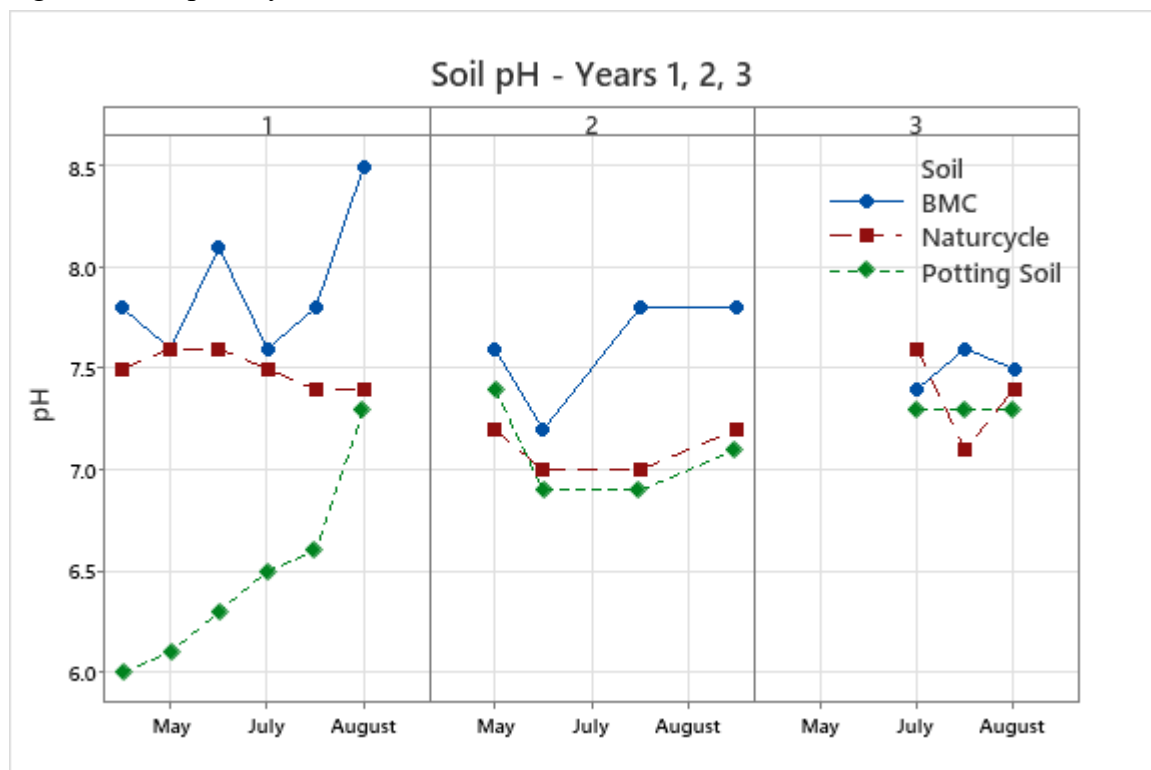
Soil Chemical Properties

Naturcycle and BMC began with average pH values of 7.5 and 7.9, respectively, in Year 1. By Year 2, only BMC remained elevated, and by Year 3, all three soils had converged to a pH range of 7.3–7.5 (Table 3, Figure 4). Electrical conductivity (EC) was higher in Naturcycle and BMC in Year 2, but all soils were statistically similar in Years 1 and 3 (Table 3). Organic matter and cation exchange capacity (CEC) were consistently greater in potting soil compared to the other media across all years (Table 3).

Table 3. Soil chemical properties comparison across Years 1–3 for each media type. Letters following harvest values denote results of Tukey’s post hoc pairwise comparisons: different letters indicate significant differences among media types, while shared letters indicate statistical similarity.

Variable	Year	P-Value	Potting Soil	BMC	Naturcycle
pH	1	0.000	6.5 (b)	7.9 (a)	7.5 (a)
	2	0.011	7.1 (b)	7.6 (a)	7.1 (b)
	3	0.460	7.3	7.5	7.4
EC	1	0.060	2.5	1.2	2.3
	2	0.028	0.8 (b)	1.1 (ab)	1.8 (a)
	3	0.101	0.7	1.0	1.4
Organic Matter	1	0.000	52.7 (a)	4.2 (c)	11.5 (b)
	2	0.000	50.4 (a)	5.0 (c)	11.1 (b)
	3	0.000	47.9 (a)	4.7 (c)	11.2 (b)
CEC	1	0.000	42.8 (a)	7.5 (c)	16.4 (b)
	2	0.000	39.5 (a)	7.5 (c)	15.8 (b)
	3	0.034	52.8 (a)	11.0 (c)	25.2 (ab)

Figure 4. Soil pH in years 1-3



Discussion

Balancing Organic Matter, Moisture, and Compaction for Rooftop Production

In outdoor production, plants are particularly vulnerable to drought stress because high evapotranspiration rates increase water loss. Under water deficit, stomatal closure reduces transpiration but also limits CO₂ uptake, lowering photosynthetic rates and slowing metabolic activity; the net effect is reduced growth and smaller plants.

Across the trial, the organic potting-soil standard and the Naturcycle blend maintained higher soil moisture than the BMC blend (Figures 2–3). This pattern is consistent with their higher organic matter content (potting soil: 48–53%; Naturcycle: ~11%; BMC: 4–5%), since organic matter increases water-holding capacity and nutrient retention. Excessive compaction, however, can negate those benefits by reducing pore space and aeration in the root zone, which impairs root growth, increases susceptibility to root diseases, and can inhibit nitrification (conversion of NH₄⁺ to plant-available NO₃⁻). In this trial, potting soil showed the greatest seasonal compaction while BMC and Naturcycle compacted less. These results suggest that the **Naturcycle formulation achieves a practical balance**—sufficient organic matter to improve moisture retention and nutrient supply while avoiding the high compaction observed in the high-organic potting mix—**making it well suited for rooftop raised-bed production** (Figure 5).

Figure 5. Graphical illustration showing how soil physical characteristics affect suitability for rooftop raised-bed production.

Media Type	Organic Matter	Soil Moisture	Percent Compaction
Potting Soil	↑	↑	↑
BMC	↓	↓	↓
Naturcycle	↔	↑	↓

Chemical performance: pH stability and cation exchange capacity

For rooftop raised-bed production, growers need media that strikes the right balance in cation exchange capacity (CEC). Media with too low CEC allow nutrients to leach quickly, leading to instability and frequent fertilizer inputs. On the other hand, media with excessively high CEC can hold nutrients so tightly that fertility management becomes sluggish, limiting flexibility and crop responsiveness. Excessively high CEC can also prevent growers from quickly correcting pH imbalances due to a high buffering capacity in the media. The optimal solution is a moderate CEC range, which buffers nutrients enough to reduce losses while still keeping them readily available for plant uptake. For growers, this balance translates into consistent moisture retention, reliable nutrient supply, and reduced risk of compaction; exactly the performance needed to maximize yields and efficiency in rooftop raised-bed systems.

In this trial, the organic potting soil had very high CEC (40–53 meq/100 g), Naturcycle was moderate (16–25 meq/100 g), and BMC was low (8–11 meq/100 g). The high CEC in potting soil likely contributed to slower pH adjustment during Year 1 (Figure 4). BMC recorded the highest pH in Years 1 and 2 (7.9 and 7.6), above the optimal 5.5–6.5 range for most growing media, where micronutrient availability (Fe, Mn, Cu, Zn) declines. By Year 3, all media converged to similar pH (7.3–7.5), likely reflecting the influence of applied fertilizers. **The Naturcycle blend’s moderate CEC supports responsive nutrient management and pH correction while still buffering against losses—an advantageous profile for rooftop production.**

Crop outcomes: Consistent yield advantage with Naturcycle

Among all media types tested, **Naturcycle consistently delivered the strongest performance**, achieving the highest statistical yields in nine crop comparisons, seven of which were also numerically superior. In Year 1, Naturcycle produced the highest yields for collards, peppers, tomatoes, and daikon radish. In Year 2, yields remained highest for collards, turnips, and tomatoes, while in Year 3 Naturcycle led in peppers and turnips.

The organic potting soil ranked second overall, with statistically highest yields in seven comparisons, (two numerically highest). In contrast, the BMC blend and the third-party medium showed limited performance, achieving statistically highest yields in just two and one instances, respectively.

Conclusion

For rooftop raised-bed farms, Naturcycle delivers the balanced physical and chemical profile growers want: high moisture retention without excessive compaction, moderate CEC for responsive fertility and pH management, and consistently superior yields across diverse crops. These results position Naturcycle as a reliable, market-ready media choice for suppliers seeking proven rooftop performance.

Authorship and Collaboration

This report was drafted in December 2025 by Dr. Tera Lewandowski of Nova Environmental Consulting. The research was conducted between 2023 and 2025 as a collaborative effort between Naturcycle, LLC and the Boston Medical Center Rooftop Farm, bringing together industry expertise and on-farm trials to evaluate media performance in rooftop raised-bed production