STEWARDING SOIL CARBON WITH THE CARBON SPONGE HUB

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INTRODUCTION

This is the final report for the 2024 Sustainable Agriculture Research and Education (SARE) Farmer Grant titled "Sorghum and Soil Health: Evaluating a Climate-Smart Crop and a Field Monitoring Tool Kit by a Small Farm Network in the Hudson Valley," led by Brooke Singer, founder of Carbon Sponge with five participating farms (Foxtrot Farm and Flowers, Home Farm, Nimble Roots Farm, Sweet Freedom Farm, and White Feather Farm), Dr. Sara Perl Egendorf of Pace University, the Cary Institute of Ecosystem Studies (Millbrook, NY), and our Technical Advisor, Nate Kleinman of the Experimental Farm Network. We could not have completed this work without the dedication and labor of Carbon Sponge's two field assistants, Nathan Pollack and Anne-Laure White.

The Carbon Sponge Hub is a network of small farmers who have been trialing and evaluating white-seeded annual grain-sorghum as a cash crop within an agroecological framework in the Hudson Valley and Catskills regions of New York since 2021 (see Appendix A). The Hub is designed as a peer-to-peer farm network for learning about soil carbon stewardship, regenerative practices, and climate-smart farming. Using a suite of off-the-shelf field monitoring tools, which we refer to as the Carbon Sponge Kit, and regular laboratory testing, Hub members collect data and review it with the assistance of soil scientists (see Appendix B). The data allows us to track changes over time, compare results between farms and improve cultivation techniques for the benefit of soil and plant health. There have been over a dozen participating farms in the Hub since 2021. In 2024, the Carbon Sponge Hub was supported by this Farmer Grant from SARE, with additional support provided by White Feather Farm and The Spark of Hudson.

Growing annual sorghum has been the focus of the Carbon Sponge Hub since 2021. Sorghum is an underutilized crop with great potential as both human food and a climate-smart crop capable of helping store carbon in soil. First cultivated in Northeast Africa approximately 6,000 years ago (if not earlier), sorghum is not widely grown in the Hudson Valley, and farmers can take advantage of the plant's ability to adapt to a wide range of conditions and provide ecosystem services on farms — like increasing soil organic carbon — while also generating revenue. Sorghum can be harvested for its grain as well as its stalk sap or juice (which can be evaporated into a molasses-like syrup), making it a valuable dual-purpose crop. Carbon Sponge has been growing several varieties of sorghum in the Hudson Valley and Catskills regions for the past five years without irrigation or chemicals, and few soil amendments.

Jalal Sabur of Sweet Freedom Farm with members of the Carbon Sponge Team (Anne-Laure White and Nkwi Flores), April 2023

We have been saving seed from year to year, adapting the plant to our bioregion while harvesting enough grain and juice to conduct experiments in the kitchen and begin to share the plant through culinary workshops and local markets with our communities.

The purpose of this report is two-fold. We are providing case studies from the 2024 Carbon Sponge Hub — five small farms in the Hudson Valley, each dedicating varying amounts of field space for annual sorghum production. In the case studies, we share details of each farm's experiences along with documentation of the sorghum production over the year, concluding with some shared challenges in the field and possible solutions. We met with an agronomist, Bryant Mason, mid-season and have included a summary of this conversation. Lastly, Dr. Egendorf of Pace University, led an analysis of the total data from across the farms to evaluate the Kit in relation to professional laboratory testing. There is a discussion of her analysis along with recommendations for farmers interested in tracking soil carbon stewardship.

While we have several years of experience growing sorghum in the Hudson Valley region and eight years of experience with soil testing as part of Carbon Sponge, this report is only a snapshot, covering 13 months starting in April 2024, and the overall project remains a work in progress. We have documented our process to encourage others to adopt climate-smart crops, such as sorghum, in our region along with simple testing protocols and evidence-based decision-making to benefit local food security, the soil and climate.

Jar of freshly squeezed sorghum juice at Nimble Roots Farm, October 2024

2024

March 21, 2024	**Initial Kick-off Meeting:** All participants met virtually to discuss grant, activities, timeline, expectations and procedures for the work. This was an opportunity for everyone to meet (although many knew each other from prior collaborations) and ask any questions or voice concerns.
April 11 & 13, 2024	The Carbon Sponge Team **visited all five participating farms**, met with the farmers to determine the site and size of the sorghum field for each farm.
May 2, 2024	White Feather Farm **seeded the flats** in the greenhouse.
May 9 & 11, 2024	**Round One Testing and Sampling:** The Carbon Sponge Team visited all five farms across two days to run testing in the field with the Kit and sampled soil for lab testing at both Cary Institute and Logan Labs (See Appendix B).
May 31, 2024	The Carbon Sponge Team **transplanted sorghum** at Foxtrot and direct seeded at Home Farm.
June 7, 2024	The Carbon Sponge Team helped **transplant sorghum** at Sweet Freedom Farm during their Community Farm Day.
June 13, 2024	The Carbon Sponge Team returned to Sweet Freedom Farm to **continue transplanting sorghum**.
June 29-30, 2024	Nimble Roots Farm with The Carbon Sponge Team **planted sorghum seed with tractor and seeder attachment.**
July 15-16, 2024	**Midseason check-in:** The Carbon Sponge Team and Nate Kleinman (technical advisor) visited all five farms, inspected sorghum fields, and discussed progress with farmers.
July 24, 2024	**Tissue sampling:** The Carbon Sponge Team sampled sorghum leaves for tissue testing at Logan Labs.
July 27, 2024	**Soil Fest at White Feather Farm:** Brooke Singer of Carbon Sponge ran a workshop sharing the project and demonstrated testing with the Kit.
August 14, 2024	**Midseason Consult with Agronomist:** Reviewed existing data with agronomist Bryant Mason with emphasis on Logan Labs standard soil analysis in comparison to plant tissue results.
September 27 & 28, 2024	**Round Two Testing and Sampling:** The Carbon Sponge Team conducted round two of testing with the Kit and tested the sorghum juice's degree Brix level. We sampled soil for the Cary Institute.
October 5, 2024	**Harvest:** The Carbon Sponge Team worked with Sweet Freedom Farm and volunteers as part of their Community Farm Day on October 5 and demonstrated the Carbon Sponge Kit's testing tools and sugar cane juicers for pressing sorghum.
October 10, 2024	**Round Two Testing and Sampling:** The Carbon Sponge Team conducted round two of testing with the Kit and tested the sorghum juice's degree Brix level. We sampled soil for the Cary Institute.
October 11, 2024	**Harvest:** The Carbon Sponge Team at Foxtrot Farm and continue harvest at Sweet Freedom Farm.
October 11-19, 2024	**Harvest:** The Carbon Sponge Team at Nimble Roots Farm with farmers and volunteers collected both grain and juice. The first frost was on October 17.
October 30, 2024	**Winter bed prep:** The Carbon Sponge Team at White Feather Farm, including flail mowing the plot and broadcasting a winter cover crop.
November 2024	**Winter bed prep:** Farmers at Nimble Roots Farm used a brush hog on the field with both chopped and standing sorghum.

2025

January 9-10, 2025	**Round Three Testing and Sampling:** The Carbon Sponge Team conducted round three of testing with the Kit and sampled soil for the Cary Institute.
May 8, 2025	**Round Three Testing and Sampling:** The Carbon Sponge Team conducted round three of testing with the Kit and sampled soil for the Cary Institute.
May 21, 2025	**Resampled four farms:** A box of soil was lost in shipping, and The Carbon Sponge Team had to resample soil at four farms for Logan testing.
July 2025	**Data Analysis** by Dr. Egendorf with input from the Carbon Sponge Team, participating farmers and our technical advisor, Nate Kleinman.

SECTION:1 CASE STUDIES

Nimble Roots Farm, August 2024

FOXTROT FARM AND FLOWERS

Foxtrot Farm and Flowers is a one-acre flower, herb, and fruit farm with an adjacent floral design studio and event space in Stanfordville, NY, established in 2021 by owner-operator Kate Farrar. Foxtrot participated in the Carbon Sponge Hub in 2022 and 2023, making 2024 its third consecutive year. Kate practices no-till and regenerative farming on land nestled within the rolling hills of Attlebury and next to an Audubon Society bird sanctuary. Kate sells her products through Community Supported Agriculture (CSA), wholesale, and farmers markets. In addition, she hosts pick-your-own flowers and fruit days and has private landscaping and wedding clients. Increasingly, Kate has been able to offer summer-time programming for the community, such as art exhibitions, yoga workshops, film screenings, and on-farm dinners. Kate's interest in Carbon Sponge was to learn and share information about regenerative agriculture with a network of local farmers. Sorghum grain heads are beautiful and come in a range of colors, which are sometimes used in floral arrangements and dried holiday wreaths, and could be potentially incorporated into her design work.

Kate Farrar of Foxtrot Farm and Flowers

Sorghum can be tall-growing, and the plant grew over 20 feet on Kate's farm in 2023. This means that when placing the crop in a compact and mixed-use farm, one must take into consideration the shade it will cast and the potential for lodging (or falling over). Part of the reason the sorghum grew so tall at Foxtrot in 2023 was because of the varieties we chose: a white-grain variety called Kassaby and Coral, a purple-grain variety. Both are from South Sudan and typically average at least 10 feet tall. Other reasons the sorghum could have been so robust in 2023 were due to the high soil organic matter (nearly 8%) and its location in full sun.

In 2024, Kate expressed interest in growing the plant along the fence to keep it away from her other crops in production and to provide a buffer between her property and the road. This area had never been farmed before by Kate, and the soil texture was a silt loam, like in 2023. The biggest differences were that the 2024 plot was in partial sun, the organic matter was quite a bit lower (between 3.4 and 4.8%), and the sorghum we planted was the variety, Korjaj.Originally from Darfur, Sudan, Korjaj is a white-seeded grain that grows on the shorter side (4-6 feet in some years), has a relatively sweet stalk, and a full grain head. All these factors resulted in a shorter and less vigorous sorghum stand at Foxtrot in 2024.

On May 31, 2024, the Carbon Sponge Team transplanted 360 Korjaj sorghum seedlings into a 70-foot by 9-foot bed (making it one of the three smaller plots in the 2024 Hub), spacing the plants 12 inches apart in five rows. We soaked the seedinglings in a bucket of water with lactic acid bacteria (see Appendix C) for about twenty minutes before hand planting using a plastic trellis as a guide. The plot had been tarped for two months by Kate to kill the pre-existing sod. When we uncovered the plot, the grass was dead, and we planted directly into the remains. The following week, Kate expressed concern that the grass might rebound and requested clover seed, which we delivered on June 8. During our kickoff meeting we had discussed co-planting the sorghum with clover to help reduce weed pressure and add the benefits of a nitrogen-fixing legume.

When we returned for the midseason check-in on July 15, the sorghum was 3.5 to 4.5 feet tall, and some were already in the bloom stage. The sorghum plants on the shadier side of the plot to the east were shorter than those on the sunnier side. Not much of the clover took, and the grass was growing back. Although the grasses did not smother the sorghum, it was likely competing for nutrients. We also detected some aphids on about 20% of the sorghum. Nate suggested applying clove oil if the aphids spread, which was not ultimately needed. When we returned on September 27 for our second round of testing, there was evidence of bird pressure. Some of the sorghum panicles (or seed heads) were partially eaten. We used the refractometer to determine the Brix values of the sorghum juice, a reading for sugar content, and the results were the highest at Foxtrot (19-20) in comparison to the average across the Hub farms, which was 14.5. When we returned on harvest day on October 10, there was very little grain left to harvest due to the birds. We took the few sorghum heads that were remaining and chopped and dropped the stalks in place for winter.

Transplants in the soil at Foxtrot, May 2024

Sorghum varieties Coral and Kassaby at Foxtrot, October 2023

Anne-Laure White of the Carbon Sponge Team conducts the Microbiometer test at Foxtrot, April 2024

Mid-season check-in at Foxtrot, July 2024

Presence of aphids on sorghum crop at Foxtrot, July 2024

HOME FARM

In 2024, Home Farm, located in Clermont, NY, in Columbia County, consisted of nine acres of leased land. It was the second year the farm was in operation, and its first-year collaboration with Carbon Sponge. The farm is run by Jon Marcklinger, the founder, and in 2024, he had assistance from two part-time workers. The farm grows grain and vegetables for a limited CSA, food access programs, and a handful of restaurants. Embedded in the farm is Coming Home Seeds, a population breeding and selection program for adapting crops to Northeast for the purpose of expanding staple foods and reducing crop loss, an urgent need in the extreme conditions produced by climate change. Since 2016, Coming Home Seeds has worked with over 2000 ancient and modern grain varieties.

Jon Marckingler of Home Farm

Home Farm was one of two farms, the other being Sweet Freedom Farm, in our group of five that had prior experience growing sorghum before participating in the Hub. Jon had a selection of saved sorghum seeds that he wanted to plant, and, therefore, we did not use the Carbon Sponge seed stock like we did on the other farms. The varieties we planted were Dorado, Korjaj, and a mix Jon had labelled "promiscuous," which were off-type seeds. Dorado is an annual grain sorghum developed for Central America that is known for its shorter stature (roughly 4 feet), large and dense panicle, and light yellow grain color. Jon saved Korjaj seed from the previous year from his plants with the highest Brix value, indicating the sweetest juice, selecting for this attribute.

The space on the farm designated for sorghum was 30 feet by 100 feet. It was fallow the previous year, and for many prior years, and Jon knew it was a high moisture area that did not drain well. While sorghum is known to do well in drought and does not need much water, relying on its deep roots to extract water well below the surface, sorghum can also withstand wet, and even water-logged, conditions for periods of time. The soil texture, defined by initial testing at Logan Labs, was silt loam, and the organic matter was low (>2%). Jon prepared the land by discing (May 15) and adding compost (May 30). On May 31, Jon and his crew with the Carbon Sponge Team seeded by hand a little less than a pound of sorghum. Jon used a dibbler to mark the soil with 12-inch spacing, which was hard to see in the roughly plowed soil.

When we returned for the mid-season check-in on July 16, the sorghum had grown to 1.5 and 2.5 feet tall. Jon had originally planned to cultivate with hand hoes twice, but the busy season prevented it, and there were many weeds (mostly grasses and wild carrot) in the plot with th sorghum. Jon was interested in seeing which plants could outcompete the weeds, survive in these conditions, and from those, he would save seed. However, on September 27, for the second round of testing, we observed that the weeds had completely outcompeted the sorghum, and only a few sorghum plants survived. Those that did survive did not bloom, and there was nothing to harvest come October.

Carbon Sponge returned twice more for testing on January 10 and May 8, 2025. In January, the ground was frozen, making it hard to use the probes and collect soil samples. The weeds were still standing, as there was no winter bed preparation. In early May, for our last visit, most of the plot had been plowed for the new 2025 season, with a small portion of the plot along the western edge untouched.

Korjaj sorghum seeds

John Marcklinger of Home Farm and Nathan Pollack of the Carbon Sponge Team discuss seed planting, May 2024

Nathan Pollack (CST) and Robin Ellis of Home Farm use the dibbler to mark the soil for planting, May 2024

Home Farm sorghum plot overtaken by weeds, September 2024

Few sorghum plants survived at Home Farm, September 2024

Soil sampling at Home Farm, May 2025

NIMBLE ROOTS FARM

Fabio and Christine Ritmo of Nimble Roots Farm

Nimble Roots Farm, owned and managed by Christine and Fabio Ritmo, moved to a new location in Catskill, NY, in 2024, only a mile down the road from where they had been farming since 2022. The move was significant because it was a first-time land purchase, and yielded the farmers larger acreage (14.7) with more promising soil conditions. Nimble Roots has been participating in the Carbon Sponge Hub since 2022. They are Certified Naturally Grown vegetable farmers and raise goats and fowl. They farm as a way to combine their passions for environmental action and community-building. Christine is the co-director of the Catskill Farmers Market, where Fabio is known as Egg Man, occasionally serving breakfast sandwiches or "flippin' yolks for decent folks."

Carbon Sponge Hub field meeting at Nimble Roots Farm with Rutabaga, April 2024

Nimble Roots closed on the sale of their land in December 2023, and there was no infrastructure on the property, including water and electricity. The land had been a hay field for approximately 40 years. The plan was to open two acres for growing sorghum and postpone other crop production for a year while they built out the farm, including a greenhouse, animal shelters, and a covered workspace. This was by far the biggest planting of sorghum we had collectively undertaken, allowing us to experiment with scaling up from a market garden bed size, necessitating the use of machinery for planting, harvesting, and post-harvesting processing. We had success growing sorghum at the former Nimble Roots location both in 2022 and 2023, and we were ready to increase production. The only major challenge for us had been predators, both birds and deer. The new parcel of land was flat, and the texture was a silt loam with an average of 3.5% soil organic matter. We were all excited to grow more sorghum.

In early June, a friend and neighboring farmer came over with his tractor and disc plowed two acres. After a second round of discs plowing on June 21, there were still a lot of clumps of grass and debris on the field, and the surface was quite rough. We considered other implements to use besides the discs to better prepare the field, like a Prefecta and moldboard, but due to time restraints and not wanting to disturb the soil too badly, we opted against these methods. After disc plowing twice, however, the field was too rough to hand push a seeder, like a Jang, and we began to reach out to local farms to rent a seed drill for use with Nimble Roots' tractor. By June 29, we had a drill and over two days were able to plant the two acres with a mix of Kassaby and Korjaj sorghum that were saved from the 2023 harvest.

The seeder we rented was designed for a much bigger area than two acres. To make it work, we had to pour all our saved seed into the bucket even though it was much more than we were going to drill. This meant mixing the Kassaby and Korjaj varieties rather than planting them separately, which would have been better for harvesting since the varieties grow to different heights and bloom at different points. The planting we achieved with the seeder was roughly 14" apart across the entire field, leaving no empty pathways. Since the sorghum seed was small for the seeder, we added agricultural lime to try to slow the seed rate and prevent more than one from dropping at a time.

Two weeks later, on July 16, we visited Nimble Roots Farm for the mid-season check-in with Nate Kleinman. The sorghum was growing in patches, along with grasses and other volunteers, but was healthy at about four to six inches in height. Nate identified what was growing in the field besides the sorghum, which included flea bane, narrow leaf plantain, birds-foot trefoil, cleavers (or bedstraw), sedges, milkweed, dock, dandelion, chicory, moss, red clover, yarrow, and rudbeckia. Due to the compact nature of the planting, we would not be able to use a cultivator to kill the weeds and hoped the sorghum would outcompete them. Early in the season, we discussed undersowing with a companion plant, but there were enough roots in the ground to cover the soil. In the future, Nate suggested co-planting cowpeas with the sorghum, since they are slow to grow, climb up the sorghum without strangling the plant, and provide a source of nitrogen.

Because the seed was drilled so late, about three to four weeks later than we desired, we discussed the possibility that the grain would not fully ripen before the first frost. The ideal window for planting sorghum in the Hudson Valley, we believe, is late May or early June to allow approximately 100-110 days for maturation. In the case the grain does not fully ripen before frost, we would still be able to harvest the juice, which is typically ready before the grain fully matures or is in dough stage. The peak Brix value, a representation of juice sweetness and readiness to harvest for juice, would be something we would track this year once the plant began to fill in grain.

Nate shared with us that sorghum is sensitive to water, and if the fall months are wet, then the plant will focus on growing more roots and leaves rather than reproduction (grain development). A warm fall with later frost and not much rain would help the field fully mature in time. Also, many sorghum varieties are naturally photoperiod-sensitive, meaning the plants initiate flowering as the days shorten, another factor to consider.

Tractor with seed drill at Nimble Roots Farm, June 2024

Sorghum grows at Nimble Roots Farm, July 2024

Nearly ripe Korjaj sorghum panicle, October 2024

Carbon Sponge returned to Nimble Roots on September 27 for the second round of testing. Grain heads were developing on about 10% of the stand, and the average height was about 5 feet and it still looked healthy. There had been some signs of deer eating the leaves earlier in the season, but it appeared that the plants were not harmed and continued to grow. The Brix values we were seeing at this stage were already averaging 15 degrees, which is sweet enough for pressing and turning into syrup.

By early October, we could see a difference between the taller Kassaby variety mixed with the Korjaj. The Korjaj was about 5 feet tall, and by mid-October, many of the grain heads were hard enough to harvest. The Kassaby was a foot taller, sometimes more, and the grain heads were still wispy and immature. The Fall was warm, and there was not much rain, which was favorable. We had not seen any bird pressure, but wanted to get the grain out as soon as possible to avoid losing the Nimble Roots harvest to birds like we had in 2022.

We hand-harvested the Korjaj grain heads that were ready, starting on October 11, and continued throughout the next week. This work was done by the Carbon Sponge Team of three to four people, with additional help from the Nimble Roots farmers and volunteers. We used a sickle to cut 12" below the grain head, leaving the rest of the stalk in the ground. We placed the grain heads to dry on long tables with metal mesh tops, allowing for air flow, which we had set up in a covered hut. We positioned fans around the hut to keep the air circulating. After a week's worth of drying or longer, we threshed the grain heads with a Japanese stand-alone, electric thresher designed for soybeans powered by a generator, since the farm still did not have electricity. We then used a grain dryer we custom-built to reduce the moisture to 13% or lower before we did a final cleaning with a Winnow Wizard and stored it in food-grade buckets in a walk-in cooler.

The Kassaby grain heads never fully developed and were not harvestable. We saw the same issue with the Kassaby seed at the other Hub farms, confirming the issue was not the late planting at Nimble Roots Farm. Because the majority of the field was Kassaby and did not develop viable grain, harvesting by hand was not an issue and we had sufficient time to press stalks for juice too. Even though the Kassaby sorghum did not yield good grain, its juice was sweet, as was the Korjaj's. The Brix values in early October held steady at 15 degrees and began to dip around October 19 into the low teens. We cut the stalks an inch above the ground, moved them to a "pressing station" where we had set up several commercial-type, electric sugar cane presses, and filled 5-gallon food-grade buckets with the juice. Afterwards, we returned the bagasse, or residue of sorghum stalks, to the field. We did not have time or the resources to transform the juice into syrup, and since sorghum juice quickly perishes, we stored the buckets in a freezer.

On October 17, there was a light frost, followed by another on October 19, when we finally shut down operations, even though the daytime weather was still unseasonably warm.

By late October, the smell of fermenting sorghum juice emanated from the field. Fabio used the brush hog to cut down the rest of the sorghum stalks and chop them in place along with the stalks already lying on the ground, creating a good soil cover for winter. With more time, we would have better mulched the stalks with a flail mower, lightly tilled them into the topsoil and planted a winter cover crop.

In total, we harvested, cleaned, and stored about 40 pounds of Korjaj grain and squeezed nearly 100 gallons of juice from the Nimble Roots field.

Sorghum stand at Nimble Roots Farm, August 2024

Tony Van Glad of Wood Homestead Farm with Christine and Nathan checking the Brix value of the sorghum stalk juice at Nimble Roots Farm, October 2024

The electric thresher at Nimble Roots Farm, October 2024

Bryana Shevlin of the Carbon Sponge Team laying out harvested sorghum grain to dry, October 2024

Pressing sorghum stalks for juice at Nimble Roots Farm, October 2024

Kate Ray, chef and recipe developer based in Kingston, NY, visiting Nimble Roots Farm, October 2024

SWEET FREEDOM FARM

In 2013, Jalal Sabur founded Sweet Freedom Farm in Germantown, NY, to grow and distribute vegetables, grains, and maple syrup primarily to serve people adversely affected by the carceral system. Today, Sweet Freedom continues this work as well as providing food for mutual aid programs, traditional food banks, and other institutions in support of working families. Sweet Freedom is also a training site for young BIPOC–Black, Indigenous and People of Color–farmers, and the farm practices no-till, cover cropping, and minimal-spray. The core group of organizers totals nine, with additional support from volunteers through regular community days. Sweet Freedom connects to the communities it supports by growing crops of cultural relevance, including sorghum, an African diaspora plant. Sorghum, an ancient grain first cultivated around 6,000 years ago in East Africa, likely arrived in North America from West Africa via the transatlantic slave trade. In the 1800s, abolitionists encouraged the production of sorghum syrup in the North as an alternative to sugar cane sweeteners and as a means to undermine plantation economies ("Abolition Sugars"). Sweet Freedom begins its sorghum planting and harvesting days with a discussion of the plant's history and a dedication to African ancestors whose knowledge of and care for sorghum lives on through the farm.

Jalal Sabur of Sweet Freedom Farm

Sweet Freedom, in addition to its space in Germantown, operates a field in Millerton, NY, that is part of the Wildseed Community Farm, a partner organization with an aligned mission. The field in Millerton is roughly an acre in size. The soil texture is sandy loam, transitioning to silt loam towards the southernmost end. Sweet Freedom participated in the 2023 Carbon Sponge Hub, and we planted Korjaj sorghum in a third of the field at the North. The sorghum in 2023 was not harvestable due to weed pressure, primarily foxtail millet. In 2024, Sweet Freedom planted corn where the sorghum had grown in 2023, and we planted a mix of sorghum varieties in the southern half of the field that had been fallow the previous year. The plan was to cultivate with a walk-behind tractor twice during the season to combat the weeds. This half-acre plot was the second largest in the 2024 Hub after Nimble Roots.

Before planting on June 8, the field was prepared through a multi-step process of plowing, discing, fertilizing, tilling, and shaping. The fertilization consisted of a combination of compost and chicken manure. On June 8, Sweet Freedom organized a Community Farm Day, and volunteers met at Millerton with the Carbon Sponge team and Sweet Freedom farmers to plant sorghum. The group of approximately 20 people transplanted mostly Korjaj and some Rox Orange starts that had been grown in greenhouses by Carbon Sponge and Sweet Freedom, spacing them 12 inches apart in the beds. The beds had 4-foot rows between them to allow space for the tractor wheels when weeding. The seedlings were soaked in water with fish emulsion and lactic acid bacteria before hand-planting. We used a dibbler to mark the soil for placement. On June 13, the Carbon Sponge Team returned to continue planting, adding a few more varieties like Kassaby, Black African, Dorado, and Allu Jola. By the end of that day, there were approximately 4,000 sorghum plants in the soil (2700 Korjaj, 750 Rox Orange, and 550 of the other varieties).

Carbon Sponge Team returned with Nate Kleinman for the midseason check-in on July 15. The sorghum looked healthy despite weeds (mostly Lamb's Quarters) growing; the Sweet Freedom walk-behind tractor was broken, and weeding was not possible. At this point, it was too late to cultivate, but it seemed as if the sorghum would outcompete the other plants, unlike last year, and was receiving enough nutrients. The Korjaj was between 1.5 feet and 3.5 feet tall. The other varieties looked similarly healthy, except the Black African was prematurely blooming. We found one caterpillar on a plant in the field, but there was no significant pest pressure.

On September 27, during the second round of testing, we ran Brix tests on the different varieties. The Korjaj was the highest, averaging 15 degrees, while the Rox Orange averaged 10.5, and the Black African 6. There were more weeds, including Foxtail grasses, all around, but the sorghum had outgrown them and was looking strong overall.

The Carbon Sponge Team returned for the Community Farm Day on October 5. There were approximately 100 people in attendance, including volunteers, a documentary crew, African musicians, and members of Sweet Freedom, Carbon Sponge, and Wildseed. This was a public event to learn about Sweet Freedom's work with sorghum, connect with the heritage of the plant, and assist with the harvest. Jalal greeted everyone, spoke about the importance of sorghum for Sweet Freedom, and led a ceremonial offering, or libation, honoring ancestors. Jon Marcklinger of Coming Home Seeds set up a table to share his breeding and seed selection work, and Brooke Singer of Carbon Sponge had a table to present the work of the Hub, including the Kit.

Over October 5 and 6, about half of the sorghum was harvested for grain with community volunteers. The volunteers were instructed to harvest only the ripe grain heads. People chopped the stalk at the base, an inch above the ground, and another group came through to remove the grain head with 12" of stalk and bag them. Yet another group stripped the canes of leaves in preparation for pressing. We transported the grain heads to tables in the greenhouse at Rock Steady Farm (a nearby farm and partner) to dry down. Anything that was not fully developed was left uncut in the field. Carbon Sponge brought two commercial cane presses, and demonstrated the pressing of the stalk for juice, as well.

On October 11, Carbon Sponge Team and Sweet Freedom returned to the Millerton field to harvest what was remaining. Carbon Sponge brought back a truckload of sorghum heads to Nimble Roots to continue drying, making room for the newly harvested heads to dry at Rock Steady. We left one cane press for Sweet Freedom to continue pressing for juice, which they boiled down into syrup (about 20 gallons total). Back at Nimble Roots, Carbon Sponge Team threshed and winnowed the grain. In the end, Carbon Sponge cleaned and stored 40 pounds of Korjaj, 37 pounds of Rox Orange, 3 pounds of a mix of Allu Goja and Dorado (the two grains look similar and were erroneously combined), and 2 pounds of Black African. The Kassaby did not ripen as seen at the other farms. Sweet Freedom Farm brought the remaining harvested Korjaj to Nimble Roots to clean with the Carbon Sponge thresher and Winnow Wizard. This total weighed 40 pounds. More Rox Orange and some of the other varieties were left on drying tables at Rock Steady, contributing another 35 pounds to the total grain harvest, which was 75 pounds.

Over winter, the field was left with a mix of leaves and stalks on the ground. The stalks that were not harvested were left standing until field preparation in May 2025.

Quentin Stallworth of the Carbon Sponge Team at Sweet Freedom Farm's Community Farm Day with sorghum starts, June 2024

Community Farm Day volunteer soaking the sorghum starts prior to planting, June 2024

Sorghum growing among weeds, July 2024

Midseason check-in at Sweet Freedom Farm with Nate Kleinman (Technical Advisor) and Anne-Laure White, July 2024

Nathan in the sorghum field at Sweet Freedom Farm, September 2024

Community Farm Day harvesting the sorghum at Sweet Freedom Farm, October 2024

Sorghum laying to dry in Rock Steady Farm's greenhouse, October 2024

Sorghum stand at harvest time at Sweet Freedom Farm, October 2024

A mixed variety of harvested sorghum panicles, October 2024

The sorghum field over winter, January 2025

The sorghum field in spring, May 2025

WHITE FEATHER FARM

White Feather Farm is in Saugerties, NY, and was founded in 2020. It is a 66-acre certified organic, small-scale farm and educational nonprofit. The mission is to cultivate connections with the local community through sustainable organic farming, experiential education, and innovative research. White Feather cultivates over 1.5 acres, providing a wide variety of organic produce, eggs, maple syrup, and flowers. They sell produce through an on-site farm stand and to local restaurants and food outlets. The farm has two administrators, three operations staff, two educators, a farm manager (Celia Fay Brubaker), a greenhouse manager (Jonathan Friedmann), and a part-time farm crew during the growing season. White Feather hosted Carbon Sponge starting in 2021. In 2022, the Farm supported the first year of the Carbon Sponge Hub, which included five farms in the Hudson Valley and Catskills, and in 2023, the participating farms grew to 10. By 2024, Carbon Sponge had been growing sorghum in the same small plot, 16 by 50 feet, already for three seasons. Celia and Jonathan were the point people and support team for the Hub.

Celia Fay Brubaker and Jonathan Friedmann of White Feather Farm

The plot was originally selected for Carbon Sponge because of its poor conditions. It has compacted silt soil and bad drainage. The idea was to see how much improvement we could achieve with only plants and minimal cultivation. The west side of the plot is higher in organic matter, possibly due to runoff from the adjacent field, a main production area of the farm. The Carbon Sponge plot had no amendments since the addition of compost in 2021. In the fall of 2023, the sorghum grain was harvested, and the stalks were dropped in place, flail-mowed, and gently incorporated with a power harrow into the topsoil before a winter cover crop (field peas, oats, and tillage radish) was seeded. By the spring of 2024, the winter cover crop had mostly died.

Before the June 7 planting, the plot was tilled with a walk-behind tractor to incorporate the winter cover and remove weeds that were emerging. The field was additionally smoothed with a tilther. We planted 15 rows of sorghum of the varieties Dorado, Allu Jolla, Rox Orange, Kassaby, and Black African. It was the only plot in the Hub that we did not plant Korjaj. We soaked the seedlings in water with lactic acid bacteria before putting them into the ground. The plants were spaced 1 foot apart in all directions, and there were a total of 690.

By the midseason check-in on July 15, the plants looked healthy and were on average 1 to 1.5 feet tall. The sorghum closest to the farm's production field was noticeably darker and slightly taller. This could have been from the nutrient and/or irrigation runoff. There was no competition with other plants since the plot was regularly weeded, and no pest pressure was visible.

On October 10, we decided to harvest everything but the Allu Jola, which was the least mature, but was removed a week later. All the plants could have benefited from being in the ground for longer since there was no bird pressure, and the first frost was in late October. All the varieties ultimately did well except for the Kassaby, which had stopped maturing like the other farms.

For winter bed prep, we flail-mowed the sorghum stalks like the year before. We realized it would have been better to cut the grain heads only, leaving the stalks in the ground; the mower works best when it cuts down the stalks and mulches at once, rather than when the stalks are already on the ground. We were not able to power harrow afterwards to incorporate the mulch in the top soil like the previous year, but we did still broadcast the winter cover mix of winter rye, field peas, and oats. The seeds had little soil contact with so much sorghum mulch on the surface, and therefore the germination was greatly reduced from the previous year.

Prepared field at White Feather Farm, May 2024

Sorghum at White Feather Farm, September 2024

Sorghum biomass after harvest at White Feather Farm, October 2024

Flail mowing the sorghum biomass with a walk-behind tractor at White Feather Farm, October 2024

Nate Kleinman and Celia Fay Brubaker during the mid-season check-in at White Feather Farm, July 2024

Sorghum stand after harvesting panicles at White Feather Farm, October 2024

FARM BY FARM QUICK COMPARISON

	FOXTROT	HOME	NIMBLE ROOTS	SWEET FREEDOM	WHITE FEATHER
LOCATION (NY)	Stanfordville	Clermont	Catskill	Millerton	Saugerties
PLOT SIZE (SQ FT)	630	3000	87120	21780	800
SOIL TEXTURE	Silt Loam	Silt Loam	Silt Loam	Sandy Loam	Silt Loam
% SOM SP2024	4.1	2	3.5	4.3	2.8
% SOM SP2025	4.5	1.8	5.3	4	2.5
% Difference	0.4	-0.2	1.8	-0.3	-0.3
PLANT #	360	400	63,000	4000	690
PLANT DATE	31-May-24	31-May-24	29-Jun-24	8-Jun-24	7-Jun-24
SEED/TRANSPLANT	Transplants	Seed	Seed	Transplants	Transplants
INPUTS (SOIL)	None	Compost	None	Compost, Manure	None
INPUTS (SEED/STARTS)	LAB*	None	Ag Lime	Fish Emulsion, LAB*	LAB*
IRRIGATION	No	No	No	No	No
PESTS	Aphids, Birds	No	Deer	No	No
WEED PRESSURE	Medium	High	Low	Medium	None
SEED YIELD	>10 lbs	0	40 lbs	75 lbs	10 lbs
WINTER PREP**	1	0	2	1	3
JUICE/SYRUP YIELD	NA	NA	100 gallons (juice)	20 gallons (syrup)	NA

*LAB= Lactic Acid Bacteria (See Appendix C)

** Winter Prep: Farmers had various approaches to winter bed preparation after harvest, which was primarily a factor of the amount of available time and resources. There was no action (0), chop the sorghum at harvest and drop leftover stalks in field for cover, leaving some stalks standing that were not harvested (1), chop the sorghum at harvest, drop leftover stalks in field, cut remaining stand and mulch in place with a brush hog (2) or all of the steps in #2 with the addition of winter cover crop seeding (3).

OUR TOP CHALLENGES

1. *Weeds were a challenge, more than insects or animals.*

Regular cultivation to control weeds until the sorghum reaches about a foot in height is often necessary. We have experienced pressure mostly from grasses and plants in the Asteraceae family (specifically ragweed and mugwort) that compete for light and nutrients. Co-planting with a legume like cowpeas, which is slower growing than sorghum, or broadcasting clover when sorghum reaches a couple of inches tall could temper weeds.

2. *Bird pressure was also a challenge and has been an issue in the past, especially when the grain is hardening and in the final phase of growth.*

For smaller plots, you can deter birds using scare tape. If birds become an issue later in the season when the grain heads are formed but not fully hard (known as the dough stage), you can harvest the heads early and let them harden as they dry down in a greenhouse with air circulation before threshing. Or, cover the "doughy" grain heads in the field with corn tassel bags for the last couple of weeks of growth, checking periodically to make sure mold is not forming. For larger plots, invest in a laser scarecrow or audio deterrent boxes.

3. *Kassaby sorghum plants did not mature.*

The Kassaby in 2024 was grown from our saved seed from plants that were healthy and abundant with seed in 2023. African varieties of sorghum are adapted for specific seasonal rainfall patterns, so the variable rain patterns of the Hudson Valley can result in plants that grow very tall but fail to ripen before frost. Planting seed from a common or commercial stock that is well tested is a probable solution to this problem. If you are interested in trialing non-standard seed varieties and adapting a sorghum variety with specific, desirable traits to your bioregion, crop failure like what we saw with the Kassaby in 2024 is a risk. Sorghum has incredibly rich diversity; in the USDA-ARS (Agricultural Research Service) National Plant Germplasm System (NPGS) alone, there are 45,000 accessions. There is a lot to gain from dipping into this gene pool and experimenting, but it's less dependable than standard, commercial seed.

4. *Mechanical equipment that is right sized for small farms is hard to acquire.*

The biggest hurdle to increasing sorghum production in the Hudson Valley from a market garden-size plot, that can be managed with hand tools, to a 2-acre size plot or bigger is securing the proper equipment. Even if financial barriers were not an issue for small farming operations, which of course they are, U.S. manufacturers are not making farm equipment tailored to this scale. Small farmers have to "hack" and/or fabricate unique solutions or buy imported equipment from Italian or Japanese companies, where small-scale farming is better supported but sorghum is not typically grown. In 2025, we improved our ability to seed with a tractor at Nimble Roots by opting for an Italian-made precision vacuum planter. This served us much better than the large ground seeder we used the year before. Finding the right solutions for cultivating, harvesting and processing sorghum grain and juice requires capital investment, research and development, and trial and error.

Brooke Singer and Dr. S. Perl Egendorf

SECTION:2 DATA ANALYSIS

Testing day in the field with the Carbon Sponge Kit

AGRONOMY: NUTRIENT ANALYSIS

On August 14, the Hub farmers, Carbon Sponge Team and our Technical Advisor, Nate Kleinman, met with agronomist Byrant Mason, a Certified Crop Advisor and organic farmer. The purpose of the meeting was to compare the soil and plant tissue samples that had already been analyzed by Logan Labs to see if the sorghum was deprived of any basic nutrients that could negatively impact photosynthesis, and ultimately the crop's yield and quality. Photosynthesis is also an important pathway for carbon to enter the soil; excess plant food formed during photosynthesis is transferred out the roots and into the soil where it feeds microbes. If conditions are right, these exudates or liquid carbon can be stored over the long term and, therefore, photosynthesis is an essential process to track and boost as a soil carbon steward.

Bryant prioritizes plant tissue testing in his approach because it is an easy and inexpensive, even though crude, way to check plant nutrition. While a certain soil may have plenty of available nutrients, this does not guarantee that the plant can receive them. A tissue test will tell you what is limiting the plant nutritionally. Bryant typically reviews standard soil analysis and saturated paste analysis (an indication of soluble, plant-available nutrients in the soil) with the plant tissue results to make decisions like whether to apply soil amendments or foliar sprays during the season or change cultivation plans.

Erin Mulholland at the Cary Institute processing Carbon Sponge Hub soil samples, 2023

Nathan recording soil temperature, May 2025

Since we did not order saturated paste analyses (it is an additional charge of about $30 per sample at Logan Labs), we focused on plant tissue results. For Bryant, walking the field, or visual identification, is the most important way for a farmer to learn about plant needs, followed by looking at the data; something like chlorosis, or leaves turning yellow, can be the first sign there is a problem and, if it's a nutritional deficiency, the tissue data will reveal what it is. Bryant recommends doing an annual soil test (both the standard and paste) along with plant tissue test, and only adding more testing if issues develop.

Across the Hub, many of the farms' tissue tests looked great and there was no need for action. There was a pattern of elevated phosphorus and potassium in the results, but Bryant said if the crops look healthy, it's not an issue. He did point out the calcium to potassium (Ca:K) ratios were low at most of the farms and correcting that through application of gypsum would add calcium and improve overall crop yield and health. There was a slight nitrogen deficiency at Sweet Freedom Farm (but not as low as the year before) and a larger nitrogen deficiency at Home Farm. He pointed out the different soil texture at Sweet Freedom; it is mostly sandy loam versus silt loam at the other farms, making it harder to hold onto water and nutrients. Home Farm, along with its reduced nitrogen, also lacked sulfur and zinc. He recommended top dressing with feathermeal or bloodmeal for nitrogen and using gypsum for more sulfur. The zinc could be addressed by dissolving a small amount of zinc sulfate into water and spraying it on the soil to apply evenly. The Home Farm soil was hungry and amending it midseason might not result in immediate relief for the sorghum, but would improve the bed for the next growing season.

The meeting continued with instruction on how to evaluate standard soil and saturated paste results with the tissue test as well as reviewing results of two fermented plant juices we had made and how to best apply them. We ended with an overview of sap analysis, a higher precision method of testing plant nutrition than leaf tissue analysis, but also more expensive and labor intensive.

Brooke Singer and Dr. S. Perl Egendorf

TEST COMPARISONS

Meeting with an agronomist to review inorganic elements or mineral nutrients is a chemical approach to soil and plant health that has been foundational to farming since the late 1950s. Today, farmers are also looking to understand the biology of soil, testing for biological markers (like microbial biomass or respiration) and addressing agricultural problems with biology (like using compost teas or biochar) to improve agricultural soils and food systems. The Carbon Sponge Kit and the panel of tests at the Cary Institute are both biological frameworks. We do not believe there is a reason to endorse one over the other, since biology and chemistry are intertwined and are always both part of the farming story, but it's best to understand the differences and pick and choose the right tool for the job. Because Carbon Sponge emphasis is validating soil carbon stewardship, we foreground soil biology. Microbes are the engine of carbon storage, essential for carbon transformation, carbon cycling and carbon stabilization.

In this next section, led by Dr. Perl Egendorf, we compare The Carbon Sponge Kit results to the laboratory tests from the Cary Institute of Ecosystem Studies, a research-oriented analysis of soil microbial community activities pertaining to carbon and nitrogen cycling, and Logan Labs, a general agronomic test. The Kit includes two commercial tests, the Microbiometer and Solvita, along with an inexpensive moisture and pH probe, thermometer, penetrometer and refractometer (see Appendix B). We set out to see how closely the tests at the professional lab correlate to the Kit tests, which are less expensive, less time consuming and can be conducted by farmers in the field.

1) Microbiometer

Microbiometer provides an accessible field test for microbial biomass carbon (MBC) along with fungi:bacteria ratios. Cary Institute provides a lab-based test (the "gold standard") for MBC. In this study, as well as in several previous studies (with unpublished data), we have not found strong correlations between these tests. We expected that higher Microbiometer readings would be correlated with higher Cary Institute MBC readings, but our data did not support this hypothesis (Figure 1).

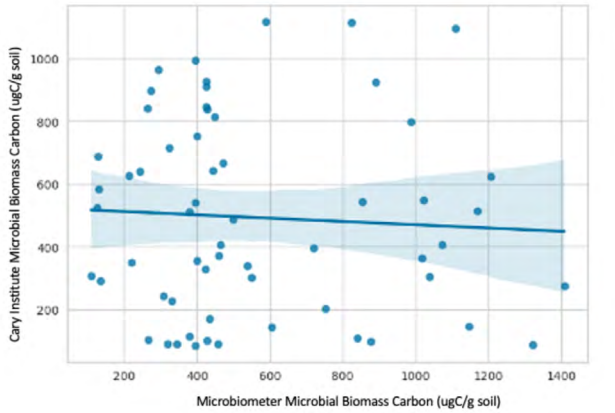


Figure 1: Microbiometer Microbial Biomass Carbon (ugC/g soil) vs. Cary Institute Microbial Biomass Carbon (ugC/g soil). The scatter around the plot shows that the samples analyzed by these two methods are not strongly correlated.

However, when we compared Microbiometer tests to organic matter (OM) tests from Logan Labs (conducted at the beginning and end of study, instead of over 4 sampling points), we have much better correlation (Fig 2). Our data suggests that Microbiometer can be used as a proxy for OM levels. Prior data (unpublished) are also aligned with this finding.

The Microbiometer also had a negative correlation with the % clay content of soils. Our data suggest that sites with increasing clay had reduced microbial biomass, according to Microbiometer. As such, Microbiometer could be used to estimate clay content.

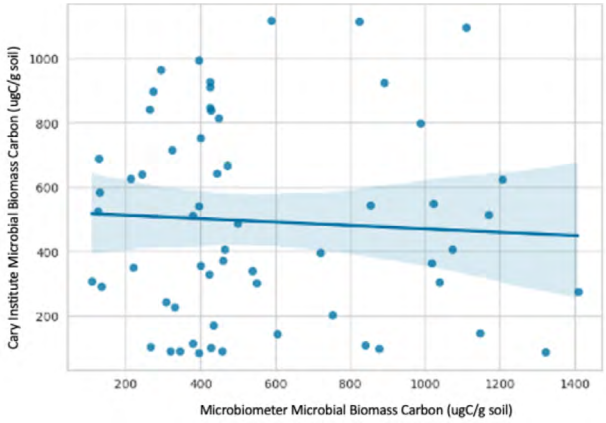


Figure 2: Microbiometer (Microbial Biomass Carbon; MBC) vs. Organic Matter (OM%) from Logan Labs. We see that as MBC increases, OM% also increases. Fungi count from the Microbiometer kit follows a similar trend (tightly correlated with Microbiometer MBC).

2) Solvita

We used the Solvita "Basic CO2 Burst" test available in 2024 which measures microbial respiration (microbes breathing and exhaling CO2). We did not purchase the digital color reader which promises more precise results than using the color charts with the basic test because of the expense; ease of use and costs are important factors when we consider implementing on the farm testing. An upgraded Basic CO2 Burst test, not available in 2024 when we started our study, has an additional "wetting" step using a specific volumetric protocol. We compared our Solvita results to Cary Institute's microbial respiration test (which requires a 10-day lab incubation). These two tests did not show strong alignment with our samples (Figure 3). The Pearson's r correlation between Solvita and respiration is -0.25 (Figure 4). In general, an absolute value of r equal to or greater than 0.5 is considered a meaningful correlation. While other research suggests that Solvita is a reliable indicator of this type of lab test, our data did not support this. More research on this topic would be beneficial, especially considering the recent changes made to the basic test.

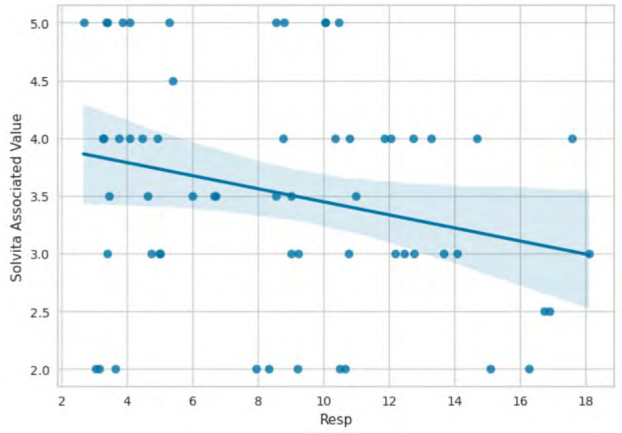


Figure 4: Cary Institute lab-based respiration test vs. Solvita tests. The scatter around the plot shows that the tests for each sample analyzed by these two methods are not strongly correlated.

While Solvita was found to have a weak correlation with respiration, it had slightly stronger correlations with ammonium (NH4) and microbial biomass nitrogen (MBN) from the Cary Institute (Pearson's r of 0.37 and 0.31, respectively) (Figure 5). Microbes can only live and breathe (respire) when there is sufficient nitrogen for them. The correlations between Solvita respiration and nitrogen are pointing to the presence of N as essential for microbial activity.

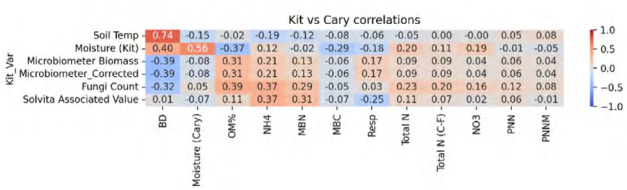


Figure 5: Pearson's r correlations for Carbon Sponge Test Kit vs. Cary Institute tests

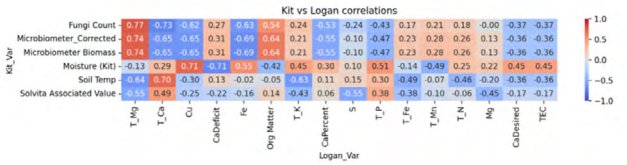


Figure 6: Pearson's r correlations for Carbon Sponge Test Kit vs. Logan Labs tests

3)Other Kit tests: pH, temperature and moisture

One of the most important tests for soils is pH. Unfortunately, the combined pH and moisture meter we used was not working during the winter testing due to the frozen soil, and the replacement meter that we purchased for the final round of testing in Spring 2025 did not work either (the pH needle never moved from the 7 point on the scale). Midrange digital pH meters that cost around $100 may be worth the investment over the cheaper combination pH and moisture meters that we used and cost as little as $10. Unfortunately, we don't have meaningful pH data from our field Kit.

We did have good correlations between field moisture readings and measurements at Cary Institute; the moisture feedback in the probe was reliable. The Kit's soil moisture results were strongly correlated with Logan lab's copper (Cu; r = 0.7) and iron (Fe; r = 0.55). This is likely a result of clay minerals and OM that have capacity to cling to water (moisture) as well as cations like Cu and Fe.

As for temperature, we found a strong correlation (r = 0.74) with bulk density (BD) from Cary (Figure 5). This suggests that the soils with higher bulk densities retained more heat. This makes sense because denser soils contain fewer macropores filled with air, and the solid particles can retain heat.

In the first and last testing rounds, we used a penetrometer in the field, which measures the resistance the soil has to penetration. This value (in pressure, PSI) can be used to assess compaction and consistency of soils. As seen below (Figure 7), all sites underwent a reduction in resistance (except FT), a sign of decreased compaction. A penetrometer is a helpful and easy to use tool that can assess soil physical properties and the impacts of planting and management.

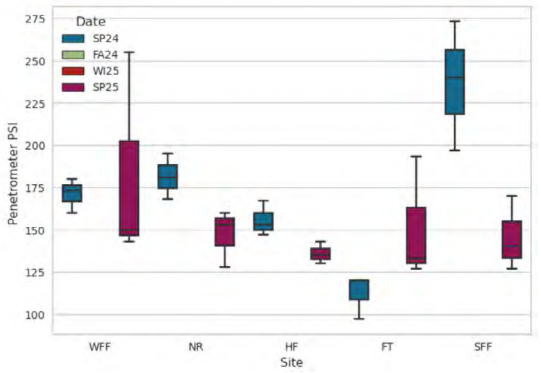


Figure 7: Penetrometer (resistance; PSI) for each site at the beginning and end of the project.

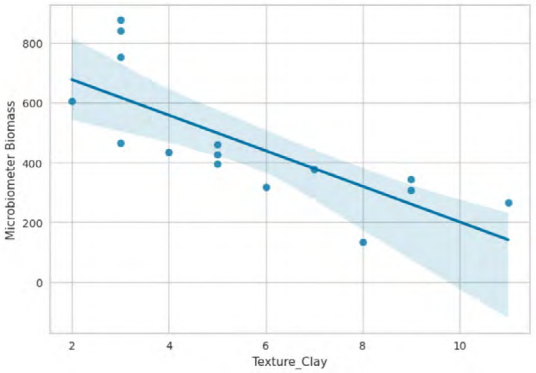


Figure 3: Soil clay content (%) vs. Microbiometer (Microbial Biomass Carbon; MBC). We see that as clay content increases, Microbiometer values decrease.

TEST RECOMMENDATIONS

1) Organic matter from Logan Labs

This is a relatively affordable gold standard test that can be a good proxy for soil carbon, health, and fertility. We recommend taking samples for this every year, in order to get into a routine and track changes over time. If it's not feasible to test for OM every year, this is fine. Implement a schedule that is manageable. Also, if declines in OM are found, this is part of carbon cycling. Soil organic matter (OM) takes time to build up, and can reach a threshold. We recommend embracing a long-term view; assessing the impacts of practices visually, for soils and plants, and doing what works for each unique group of farmers and each unique site. Organic Matter data can help make assessments, but should not be used in isolation.

We recommend developing a plan. We like to sample before planting in the spring to see a baseline for the year and avoid disturbing root systems. Some people recommend sampling in August. If farmers are going to couple soil analysis with tissue sampling, as Bryant suggests, we recommend sampling in mid-season when there is enough plant tissue and sufficient time to add amendments, if needed. Again, we recommend doing what works for each site while attempting to be consistent.

As seen in Figure 8, we found some clear changes in OM over time. Notice Nimble Roots' large increase in one year. This is rare, but we believe this happened as a result of opening up the pasture for the first time in decades and mulching the sorghum biomass in place after harvest. In contrast, at Home Farm, where fallow land was also opened up for the first time in 2024, there was no sorghum biomass incorporated and no gains in OM (rather there was a dip). At White Feather Farm's plot, which we have been cultivating for four years, the biomass of the sorghum was incorporated into the topsoil in the Fall along with minimal winter cover cropping but there was also a drop in OM. The soils there are more clayey, more compacted (Figure 7), and more alkaline (Figure 10) which may be preventing gains in OM.

Moving forward, we will track the OM added to the soils at Nimble Roots to see if it is consumed by microbes and becomes incorporated into microbial biomass maintaining organic matter levels or if microbial consumption and respiration produce losses in OM in the soil. This is the nature of carbon cycling and stewardship. Carbon doesn't build in soils in a linear fashion. We aim for net accumulation over many years, not just from one season to the next. As such, future work is necessary, including studying the development of different carbon pools (labile vs. stable; or particulate vs. mineral-associated) over time.

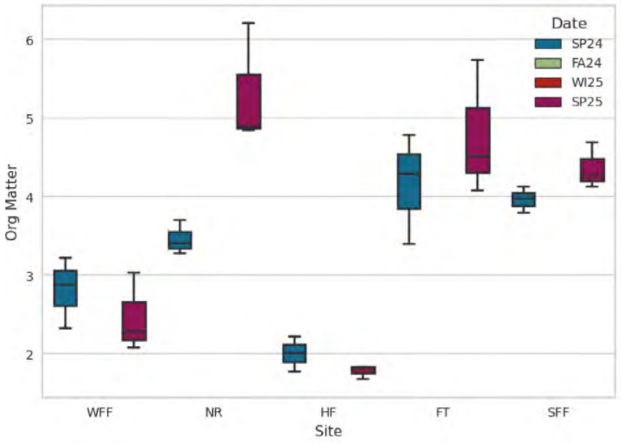


Figure 8: Organic Matter (%; Logan Labs) at each site at the beginning and end of the study.

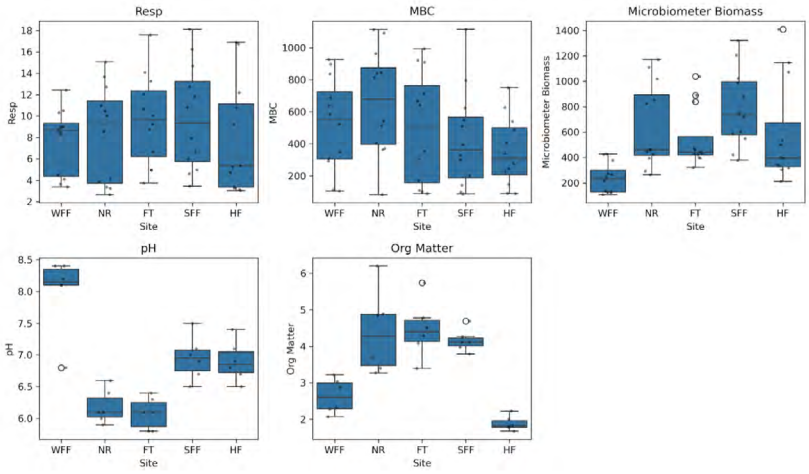


Figure 10: Boxplots of data across parameters and all time points from all sites: Respiration and MBC (Cary); Microbiometer Biomass (Kit); and pH and Organic Matter (Logan). Boxes extend from the 25th percentile to 75th percentile, with mid-lines showing the median values. Lines extend to minimum and maximum values. Sites did not differ significantly in Respiration and MBC (boxes all overlap), but clear differences are seen between sites for other parameters (boxes do not overlap).

Testing with the penetrometer

2) Microbiometer

This can be used as a proxy for OM from agronomic labs like Logan. As with other OM tests, this can be done annually, or more frequently if farmers are interested in tracking seasonal changes or impacts of different management approaches on seasonal shifts. We recommend making a plan for sampling locations and time of year, and keeping it consistent to effectively track changes.

3) Penetrometer, moisture, texture

The penetrometer can tell us about compaction, which is linked to other physical properties like pore space, soil structure, and water retention, all of which are all important for soil health and carbon stewardship. We recommend using the penetrometer at least once per year, along with OM tests.

Soil moisture probes are generally reliable, and can be useful to assess water retention directly, along with irrigation needs. Moist soils enable active microbial life and carbon stewardship. While saturated soils support anaerobic microbes that can end up storing more carbon, these conditions may not be ideal for many plants, and are not necessarily optimal for cycling nutrients like carbon. Moisture tests can be conducted quickly and as frequently as desired.

We recommend analyzing soil texture to understand how the size particles of minerals in your soil impact the soil's health. While texture isn't an automatic proxy for carbon cycling, it's important to know your soils' textures, in order to optimally support your plants and soil microbes in doing their work. For example, sandy soils may need to be watered more frequently than clayey soils, and clayey soils might need specialized equipment for cultivation. A texture test can be done once and repeated after major inputs or tilling has occurred.

Tools for sampling for bulk density

LESSONS LEARNED AT EACH FARM

1. *Nimble Roots Farm: Organic Matter Increases*

Nimble Roots has a clear story emerging: they experienced a very large gain in OM gain (nearly 2%!). This is the clearest sign that practices there are building soil carbon. The practices used there were highly effective: residue retention, mulching in place and reduced soil disturbance.

But why did we see this gain at Nimble Roots and not the other sites? Nimble Roots was a pasture prior to the sorghum planting. They had a lot of biomass from grasses along with the sorghum. So the question is, what does this look like in year 2 and beyond? Is this boost sustained? Sorghum wasn't grown in year 2, but will be grown next year in year 3. All of the "labile" organic matter that was added to the soil may be consumed by microbes in the near future. Looking into particulate vs. mineral-associated carbon fractions in the future will help gauge impacts of planting, crop rotations and changes over time.

The changes we are seeing at Nimble Roots are likely due to many factors: the addition of grass biomass from opening up the pasture, lots of sorghum with so many roots pumping exudates during the season, biomass added in fall that was mulched to jumpstart decomposition, along with the soil texture and pH that were conducive to microbes thriving.

2. *Sweet Freedom Farm: Sandy Soils and Organic Amendments*

Sweet Freedom Farm had the highest Microbiometer and OM content. This was likely due to the fact that it's the only farm that spent resources on compost and manure amendments in Spring 2024. The data show that this investment was worthwhile, especially given that it had the only sandy soil in the group, and demonstrated such productive yields.

3. *Foxtrot Farm and Flowers: Elevated Nitrogen*

Foxtrot had relatively high OM at the start of the study (around 4.5%) which increased slightly over the course of the study. They also had elevated microbial biomass nitrogen and nitrate (Figure 11 and 12). The data show benefits of cumulative effects of inputs. It would be good for Foxtrot to keep monitoring MBN/nitrate to avoid leaching.

4. *White Feather Farm: Cultivating Clay-rich Soils*

White Feather Farm had the highest calcium (Figure 13) which is likely linked to its elevated pH. This can be a result of the underlying geology or possibly from runoff from the surrounding farm. However, White Feather also had the lowest potassium (Figure 14) and may benefit from amending with this nutrient. Because the soils have such high clay content and do not drain well, adding compost and using a broadfork or tilling will also be of benefit. While clay-rich soils tend to accumulate more organic matter than other soil types, management is necessary to correct for issues like poor drainage and reduced aeration. Emphasizing N-fixing and deep rooting cover crops are also recommended here.

5. *Home Farm: Low Biological Indicators*

Home Farm had the highest phosphorus of all the sites (Figure 15). We observed a small decline in OM decline (−0.22 %) and generally lower biological indicators. This may be due to the weeds outcompeting the sorghum. We recommend emphasizing N-fixing cover crops as well as adding organic amendments and crop residues.

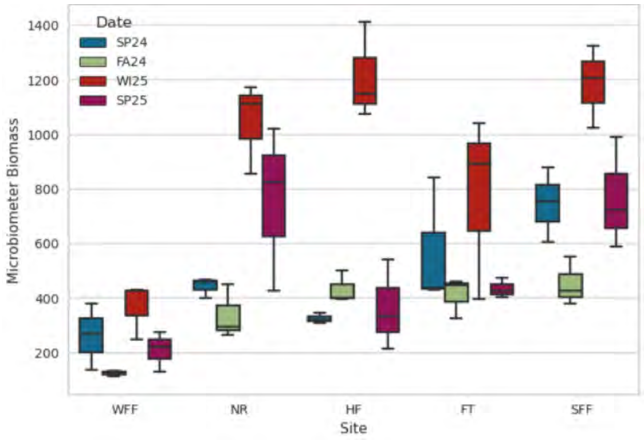


Figure 11: Microbiometer (MBC; Microbial Biomass Carbon (ugC/g soil)) at each site at 4 time points throughout the study.

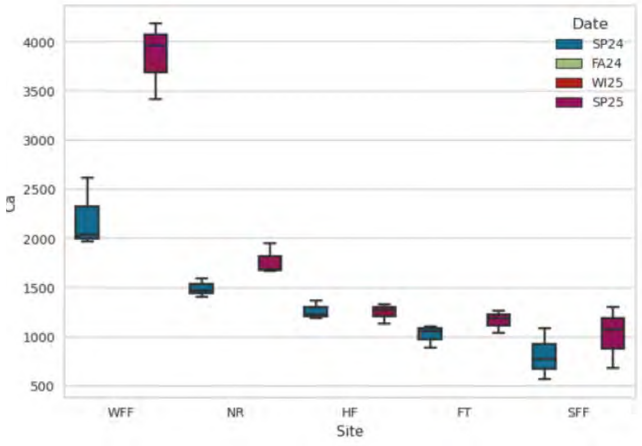


Figure 14 Calcium (Ca in ppm) across all sites and sampling times

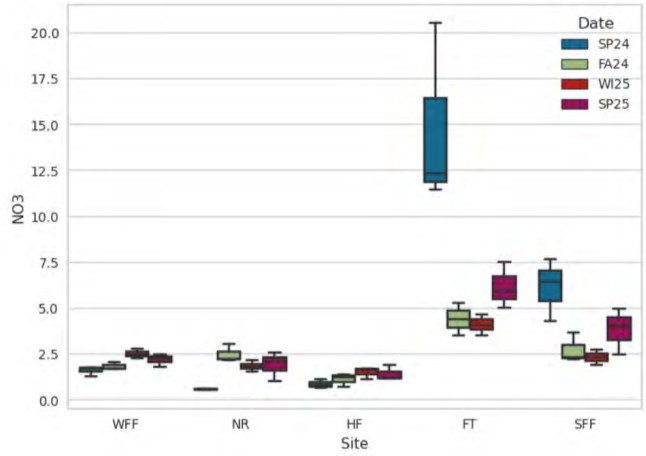


Figure 12: Nitrate (NO3 in ppm) across all sites and sampling times

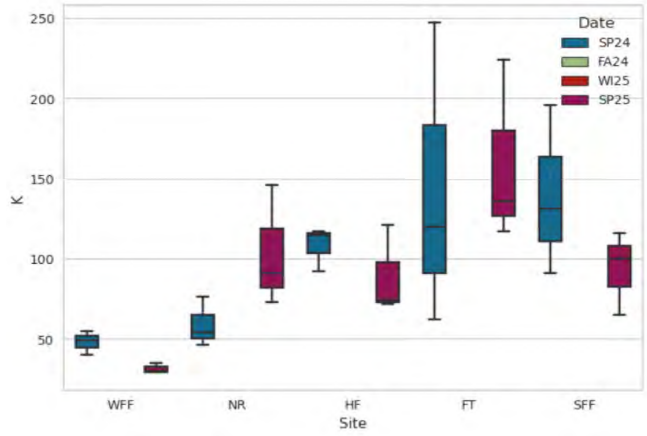


Figure 15: Potassium (K in ppm) across all sites and sampling times

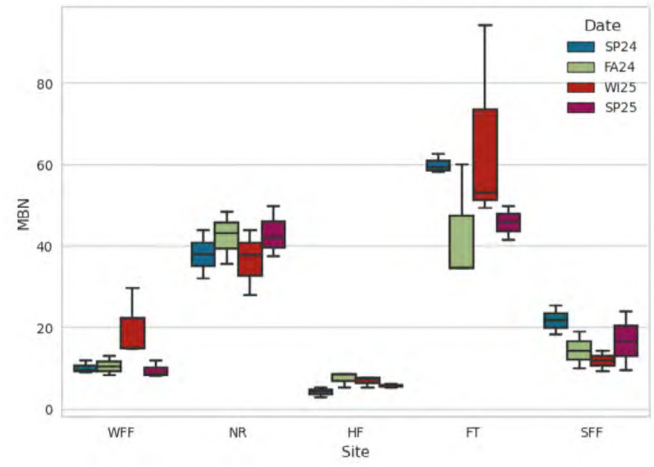


Figure 13 Microbial Biomass Nitrogen (MBN in ppm) across all sites and sampling times

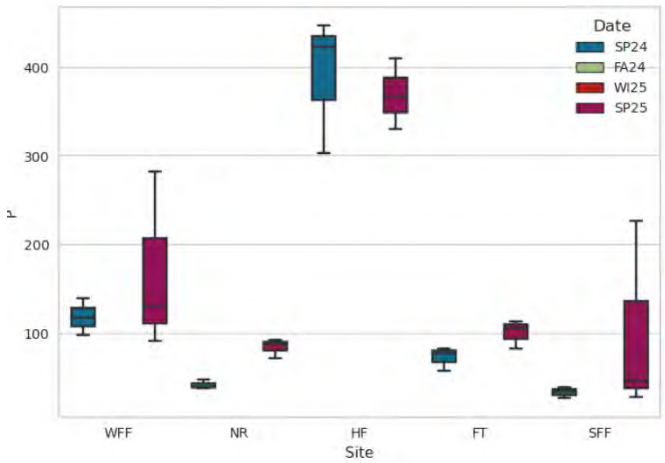


Figure 16: Phosphorus (P in ppm) across all sites and sampling times

SUMMARY & ACTIONABLE STEPS

Summary of Findings

Nutrient Status:

- Most farms had healthy plant tissue results. Common issues were low calcium-to-potassium ratios and site-specific nitrogen, sulfur, and zinc deficiencies.

Soil Health Monitoring:

- Annual soil and tissue tests are essential. The Carbon Sponge Kit provided useful, affordable field tools, though some (like Solvita and pH meters) showed weak reliability compared to lab tests.

Soil Organic Matter (OM):

- Organic matter gains varied widely. Nimble Roots saw a major short-term increase due to residue retention and high biomass inputs. Other farms saw slower changes, especially on clay-rich or compacted soils.

Actionable Steps for Farmers

Test Regularly

- Conduct annual soil organic matter (OM) tests (Logan Labs or equivalent).
- Pair with annual plant tissue tests mid-season to catch deficiencies early.
- Use affordable field tools (Microbiometer, penetrometer, moisture probes) to track trends.

Build Soil Organic Matter

- Retain residues, reduce soil disturbance, and apply compost/manure if starting off with very low OM or difficult texture like high clay or high sand.
- Use N-fixing cover crops (especially at White Feather and Home) to build fertility naturally.
- On sandy soils, prioritize organic inputs and moisture management.
- On clay soils, improve structure with broad forking or light tillage, plus compost amendment and drainage management.

Track Physical Properties

- Use a penetrometer once per year to monitor compaction.
- Measure soil moisture regularly to ensure microbial activity.
- Assess soil texture at least once (repeat only following major disturbance or addition of amendments).

Long-Term Carbon Stewardship

- Focus on building stable carbon pools (via cover crops, living roots in the ground all year, residues, and organic inputs).
- Expect slow visible changes; track trends over years, not just seasons.
- Future work should include testing of different carbon pools (particulate organic matter vs. mineral-associated organic matter).

APPENDIX A: AGROECOLOGY AND REGENERATIVE AGRICULTURE

There are numerous terms to describe holistic farming in use today. Terms like regenerative agriculture, sustainable farming, permaculture, organic and agroecology all have specific origins and histories but can sometimes seem indistinguishable due to factors like marketing, lack of precise meanings, or consensus. In this document, two are included, agroecology and regenerative agriculture, and below are fuller descriptions of their meaning along with why we use them.

Agroecology is the application of ecology in agriculture and was first used by a Russian agronomist in the 1930s. Its usage spread to Europe, and then the United States and Latin America, and Africa and Asia. The origins are much older than the term, however, with roots in Indigenous and peasant societies around the world (Pimbert). Agroecology is a form of systems thinking as it considers multiple components of agriculture (like the plants, animals, soil, and climate) and their interconnectedness, as well as the impacts of human management. Agroecology looks to nature as a model for agriculture and has been described as domesticated ecology. In the 1970s, with the rise of the Green Revolution, agroecology began to expand into a movement and set of practices, becoming more than strictly a scientific discipline. This included aligning with the nascent environmental movement and taking into consideration societal factors, which are typically considered externalities in industrial agriculture with its laser focus on economics and yield. In Central America, for instance, agroecology was a tool to help local farmers preserve and improve upon traditional, indigenous practices, seen as an alternative to corporate agriculture (Wezel et al). Agroecology has also become a recognized academic discipline offered by universities around the world.

Soil aggregates found at White Feather Farm, 2023

If agroecology is first a scientific field and then a movement and set of practices, regenerative agriculture is a set of practices that has also become a movement and one that includes science. Robert Rodale, founder of the Rodale Institute in the U.S., is cited as the first person to use the term and arguably its leader. He was not satisfied with the popular usage of sustainable agriculture in the 1980s, preferring instead a term that signaled a desire to improve conditions and not simply sustain them, thereby maintaining a dangerous status quo. His legacy continues at the Rodale Institute which has been committed to innovation for the betterment of agriculture by placing soil health and soil carbon storage at the center of the conversation along with animal welfare, workers' rights, and planetary health ("Regenerative Organic Agriculture"). The practices promoted by regenerative agriculture are reduced tillage, diversified crop rotation, planting cover crops, using natural sources of fertilizer, eliminating synthetic chemicals and managed grazing. There are about a dozen regenerative agriculture certifications currently, including Rodale's own Regenerative Organic Certified ("Regenerative Certifications & Verifications"). There has been criticism of the movement, especially over how to quantify and verify the benefits, how to put concepts into practice, the feasibility of widespread soil carbon capture, as well as issues concerning racial equity and land ownership (Fassler). There is understandable outrage when people refer to this movement as "new," considering traditional and indigenous peoples have been practicing many of these techniques for millennia.

At Carbon Sponge, we have been learning about these terms, movements, and theories over the last eight years when we first asked the question "what would it mean to be an urban carbon farmer." The field practices we have been trialing thus far on small farms in the Hudson Valley via the Hub include: low till, dry farming, keeping living roots in the ground all year, low amendments and no chemicals. For this reason, and because we are actively pursuing the question of how we can best steward soil carbon on small farms or plots of managed land, there is considerable overlap with the regenerative agriculture movement. We also strongly identify with agroecology in its embrace of systems thinking and because it is transdisciplinary with practical applications and empowering forms of participation.

APPENDIX B: TESTING

During the grant period, we conducted a series of in-field tests and sampling for further laboratory tests. Following is a comprehensive description of the tests conducted and the schedule of testing.

Carbon Sponge Kit

Since the beginning of Carbon Sponge in 2018, we have been using several commercial tests and popular tools to monitor soil and plant health over time. The Kit, as it was originally conceived, is described in Carbon Sponge: A Guide to Grow Carbon in Urban Soils (and Beyond) from 2019.

For the duration of this study, we tested in the field with the Kit every three months for a total of four times (May 2024, September 2024, January 2024, and May 2025). We divided each farm's sorghum field into three equal-sized sections, took three samples at 3-6" depth in each section, and combined the three samples from each section into a bucket to make a composite sample. We ran two tests on each composite sample: the Microbiometer (standard) and Solvita Basic CO2 Burst. The Microbiometer and Solvita tests are competing commercial tests on the market for evaluating soil health. The Microbiometer is a low cost and quick field test for microbial biomass and fungal to bacterial ratio that uses an extraction power to separate microbes from soil particles and detects microbial pigmentation on a membrane. The Solvita Basic CO2 Burst test is also a low-cost test that calculates microbial biomass by measuring carbon dioxide respiration.

We also used an inexpensive Sonkir pH and moisture probe and Taylor soil thermometer to gather data for each section. pH is also recorded in a professional lab. We took readings at three random locations per section and recorded an average. On the first and last testing days, we used an Agratronix penetrometer to measure soil compaction and measured Degrees Brix with an Aichose refractometer on the juice from several sorghum stalks per section on the third testing day (September 2024) and again at harvest time. As part of the Kit testing, we also recorded site conditions like weather, irrigation, and percent soil coverage. We document with photographs as well. Here is the worksheet we used on testing days.

Carbon Sponge Kit and sorghum starts at Mossy Stone Farms on planting day, 2023

Cary Institute Lab Testing

The testing at the Cary Institute of Ecosystem Studies, conducted in Dr. Peter Groffman's lab, included carbon and nitrogen pools, microbial biomass carbon and nitrogen, potential net mineralization, potential net nitrification, and soil respiration. These lab analyses use professional "gold standards," like the chloroform fumigation and incubation method to measure microbial biomass carbon. These tests were run from the same composite mix as the Microbiometer and Solvita tests in May 2024, September 2024, January 2024, and May 2025. Additionally, we ran a bulk density test on each section of each site on the four testing days that were processed at the Cary Institute.

Logan Lab Testing

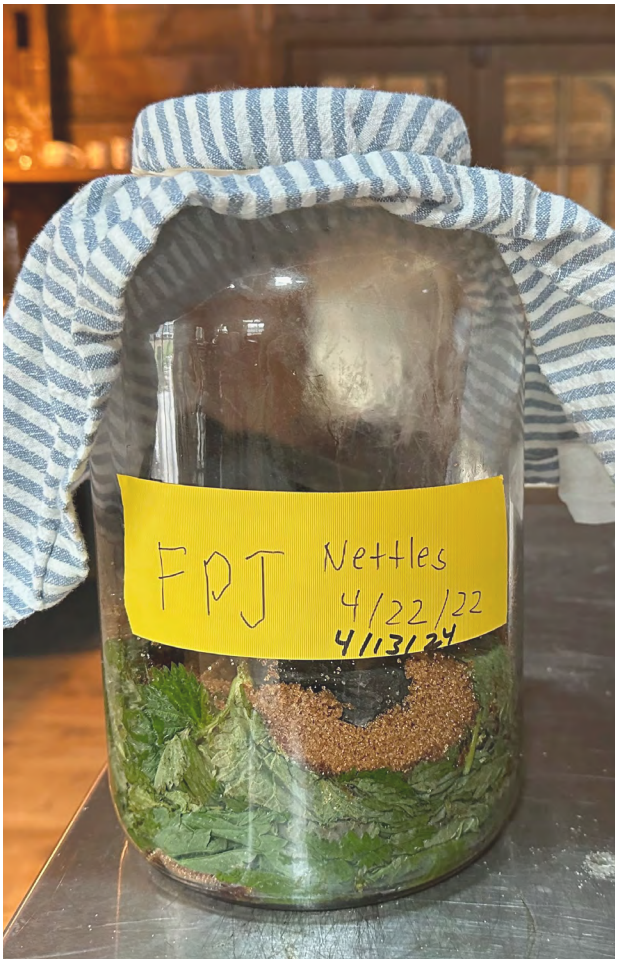
We sent soil samples to Logan Labs in Ohio on the first and last testing days in May 2024 and 2025 to provide a standard soil analysis. The samples were taken from the composite sample bucket at each of the three sections at each farm. This analysis includes the following information: pH, total exchange capacity, organic matter percent, what nutrients are available for the plant (macro and micro), and estimated nitrogen release.

We also sampled the sorghum leaves and ran a plant tissue test at the end of July when the plant had not yet reached bloom stage. Link to all data.

APPENDIX C : LACTIC ACID BACTERIA

Carbon Sponge has been experimenting with making amendments from materials that are in abundance on the farm, like weeds, or byproducts of our practices. This is an aspect of holistic farming or the circular economy meant to break our dependence on petroleum-based products and materials that have to be packaged and transported. The most common example of this is composting. In addition to compost, we have tried several Korean Natural Farming techniques, including fermented plant juice (FPJ) for fertilizer and lactic acid bacteria (LAB) as a biostimulant. There are numerous resources online from scientists to gardeners studying the effects of natural amendments and providing recipes.

In 2024, we made LAB following instructions in Nigel Palmer's book "The Regenerative Grower's Guide to Garden Amendments: Using Locally Source Materials to Make Mineral and Biological Extracts and Ferments." We used the LAB on planting days with the seedlings only; we did not treat the seeds we directly sowed. The general recommendation is to dilute the LAB with water at a ratio of 1:100. In the field, we filled a 5 gallon bucket with water and added 6 ounces of LAB. This was then used to soak the roots of the seedlings for approximately 10-20 minutes before planting.



Fermented Plant Juice made from nettles, 2024

Sorghum starts soaking in diluted lactic acid bacteria before planting, June 2023

CITATIONS

"Abolition Sugars." Sweet Freedom Farm, www.sweetfreedomfarm.org/abolition. Accessed 23 Aug. 2025.

Fassler, Joe. "Regenerative Agriculture Needs a Reckoning." The Counter, 10 June 2021, thecounter.org/regenerative-agriculture-racial-equity-climate-change-carbon-farming-environmental-issues/.

Pimbert, M.P., N.I. Moeller, J. Singh, and C.R. Anderson. "Agroecology." Oxford Research Encyclopedia of Anthropology. August 31, 2021. Oxford University Press. Date of access 23 Aug. 2025.

"Regenerative Certifications & Verifications." Kiss the Ground, kisstheground.com/education/resources/regenerative-certifications/. Accessed 23 Aug. 2025.

"Regenerative Organic Agriculture." Rodale Institute, 29 Oct. 2020, rodaleinstitute.org/why-organic/organic-basics/regenerative-organic-agriculture/.

Wezel, A., et al. "Agroecology as a science, a movement and a practice. A Review." Agronomy for Sustainable Development, vol. 29, no. 4, Dec. 2009, pp. 503–515, https://doi.org/10.1051/agro/2009004.

Sorghum drying after harvest at Nimble Roots Farm, October 2024

AUTHORS BIOS

Brooke Singer

Photo by Jess Giacobbe

Brooke Singer has over a decade of experience in agriculture, first in New York City and, more recently, in the Hudson Valley and Catskills regions of New York. Her background is in the visual arts and education. She is Professor of New Media at SUNY Purchase where she has taught at the intersection of art and technology for over 20 years. As an artist, she began to work with soil and food in 2011 when she joined a collaboration to build a system diverting edible food from the garbage, commissioned by Matadero Contemporary Art Center in Madrid. The following year, she co-founded a community garden and living lab in Brooklyn, called La Casita Verde, to address food waste and soil health, establishing a place for creative, land-based interventions. In 2018, she initiated Carbon Sponge at the New York Hall of Science as a Designer in Residence in collaboration with soil scientists from CUNY Graduate Center's Advanced Science Research Center, with whom she still works. The goal was to develop methods for urban carbon farming through a hybrid museum exhibition and professional scientific study. In 2021, she relocated Carbon Sponge to White Feather Farm in Saugerties, NY, establishing the Carbon Sponge Hub to assist small farmers in improving soil health and food security while increasing soil carbon storage. In 2025, Carbon Sponge moved its headquarters to Wally Farms in Ancram, NY.

Dr. Perl Egendorf

S. Perl Egendorf, PhD, is an Earth and Environmental Scientist who studies urban soil dynamics and their intersections with food-, environmental- and climate-justice. Perl uses a range of methods from biogeochemistry and critical participatory action research to engage students and collaborators towards better understanding of systems processes and experimenting with systems change. Perl has an MS from Brooklyn College (2016) and a PhD from the CUNY Graduate Center (2020), where their research focused on limiting exposure to contaminants like lead (Pb) in soil, particularly through conducting pilot studies of the NYC Mayor's Office of Environmental Remediation's Clean Soil Bank. This program is now the only free clean soil distribution system in the US. From 2020-2022, Perl was a postdoctoral researcher with the Cornell Atkinson Center for Sustainability, studying urban soil microbial communities. From 2021-2023, Perl was a researcher with the NYC Compost Project Hosted by Earth Matter, co-creating research with urban growers city-wide on the use of small-scale composts for growing crops. Since September 2023, Perl has been an Assistant Professor in the Department of Environmental Studies and Science at Pace University, NYC, where they have been assembling a Mobile Soil Lab, co-creating and tending to the Pace Land and Labor Acknowledgement Farm, and continuing to work with students and community collaborators to leverage the tools and resources of science, technology, engineering, art, and math (STEAM) to contribute to various scales of environmental justice.

Design by Lili Bisits

Front cover photo by Jess Giacobbe. All photos without credit by Brooke Singer.

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