تراب SOILS
للتربية البيئية لبنان
PERMACULTURE ASSOCIATION LEBANON

A GUIDE TO THERMAL COMPOSTING IN LEBANON

CASE STUDY: AL SAFIR FARMS

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Foreword

The road to sustainable food systems is a long one but we believe that perseverance is the key. The landscape of international aid to small-scale farmers is still largely dominated by conventional agriculture that is heavily fuel-dependent and relies on subsidized chemical inputs, causing damage to agricultural land, communities, the environment, and human health. Since 2019, a series of crises in Lebanon and globally, including the failure of previous food security programs like AGRA Africa, have exposed the failure of conventional agricultural models and the food systems built around them, creating an urgent need for sustainable alternative approaches.

Over the past decade, local grassroots organizations like SOILS Permaculture Association – Lebanon and other organizations have been intensifying their efforts to steer international donors toward agroecology as a more sustainable alternative that favors local inputs in order to improve food sovereignty and environmental stewardship.

One such project consisted of a demo compost production facility which we assisted the Al Safir Farms in South Lebanon establish in 2022. The facility was funded with the support of Terre et Humanisme through their agroecology and food sovereignty in the southern Mediterranean (AMED) project. We helped build the capacities of Nour Nahouli, the farm's operations manager, empowering her to become an ambassador for local and high-quality natural compost on her way to achieving the full agroecological transformation of her farm. We coached her on conducting awareness visits and practical training sessions on compost, as well as creating engaging educational content. Within one short year, the facility grew into the Al Safir Compost Production Unit and Learning Center, hosting several trainings by SOILS Permaculture Association – Lebanon and becoming one of our major partners in the country. Through the center, we hope to amplify farmer-to-farmer exchanges and the dissemination of agroecological knowledge and practices.

The agroecological transformation of an agricultural operation as big as Al Safir Farms in Lebanon could set an example for how agroecology can function beyond smallholder farming – maybe the first such documented example – and could inspire other orchards to follow suit. The case study detailing the establishment of the Al Safir Compost Production Unit and Learning Center, supported by experimentation and observation in the field, is therefore an important milestone in gathering a necessary and compelling body of evidence to support that assertion.

With that, we invite you to discover how a successful composting unit became the first step in Al Safir Farms' transformative journey.

SOILS Permaculture Association – Lebanon

1. THERMAL COMPOSTING

1.1 Composting in the Lebanese Context

Lebanese growers rely mostly on conventional methods, an approach increasingly demonstrated as being environmentally, socially, and economically unsustainable. Large farms that supply the national market adopt high mechanization and are dependent on fossil fuels and chemical inputs.

Natural compost would be one the first elements for growers to integrate if any significant agricultural shift is to take place. Awareness of the detrimental effects of conventional agriculture on the environment, soil fertility, health, and nutritional value, has grown among both consumers and growers. However, in the absence of sufficient and affordable alternatives, the switch to a more natural approach is difficult.

1.1.1. Insufficient Supply and Demand

The large-scale production and use of agricultural compost is still not well-established in Lebanon.

In terms of demand, there is still insufficient awareness of the benefits of natural compost among Lebanese growers. Most large growers still adopt a conventional approach that relies on chemical inputs rather than natural compost, while small-holders (with very few exceptions) prefer to use animal manure – which they find more affordable – rather than natural compost.

Lebanon imported 55,045 tons of organic compost between 2016 and 2019 (prior to the economic crisis) totaling around USD 13.6 million at USD 247 per ton (average). However, this figure represents only a fraction of the imports of chemical inputs that total in the hundreds of millions
Source: Lebanese Waste Management Coalition

When awareness does exist among Lebanese growers, sufficient supply is inadequate. Local producers of natural compost for agricultural use are few in number and scale (private or community initiatives). Additionally, most of the compost produced is “environmental compost.” While it certainly has its uses (waste reduction, carbon sequestration), it is not recommended for growing crops.

There are significant opportunities for producers, however. According to the Lebanese Waste Management Coalition, 3,500 to 4,000 tons of organic waste are produced in Lebanon daily (from a total of 5,000 to 7,500 tons/day). If treated correctly, this could produce around 2,000 tons of natural compost and could eliminate the need for imports (Shoofy, 2020). Additionally, until recently, the goal of – and funding for – the quasi-totality of current Lebanese compost producers was mainly to reduce organic waste rather than produce agricultural compost.

1.1.2. Absence of Standards and Regulations

Environmental compost has clear benefits in terms of waste reduction and carbon sequestration, however there is insufficient research and documentation about its use in agriculture to make it a viable input.

This issue of compost safety in agriculture is exacerbated by the absence of adequate scientific standards regulating the quality of agricultural compost in Lebanon. The Lebanese Ministry of Agriculture (MOA) has no mechanisms to approve and register local compost products, thereby perpetuating a dependence on imported products. Even when it comes to using animal manure as fertilizers, no safety standards exist.

The Lebanese Ministry of Industry and Ministry of Economy are the only two regulating bodies that recognize compost quality assurance standards in Lebanon. These standards are based on the European Compost Network Quality Assurance Scheme (ECN-QAS) as part of a European Union (EU) project to establish 12 composting and recycling plants in Lebanon (European Compost Network, 2019). These standards rely on food safety microbiology tests to determine the presence of harmful substances, yet they do not measure the compost's safety or efficiency for agricultural use – much less its effects on soil health.

Additionally, achieving these high standards in EU-funded Lebanese composting plants is not evident for a number of reasons. An investigative report in 2019 found that none of the compost produced in any of the 12 plants was of a grade which could be sold to farmers – and some of it was not even safe for landfilling as it was quite capable of polluting the water table (Jay, 2019). On the other hand, the United States Department of Agriculture (USDA) and Environmental Protection Agency (EPA) compost quality standards are based on biological assessment and thermography technology. Both these practices are not recognized or implemented in Lebanon.

Such an environment promotes the importation of compost products not subject to oversight by the MOA. The ongoing Lebanese economic crisis and high cost of imports means an increase in lower quality products entering the local market.

Unsifted organic materials decomposing in the foreground, with finished compost in bags in the background
(Photo credits: Matt Hintsa via Flicker https://www.flickr.com/photos/matt_hintsa/2857640644)

1.2. Thermal Composting

1.2.1. Thermal Compost Definition

Compost is the result of the biodegradation of organic materials. Different types of compost exist depending on the types of materials and production methods used in their preparation.

For our purposes, we will differentiate between some kinds of compost, namely static, cold and hot compost. "Static compost" is produced anaerobically (without oxygen) and requires around 6 months to produce a soil amendment that is rich in bacteria with minimum effort. "Cold compost" relies on insects to decompose materials and requires up to 4 months. By contrast, "hot compost" or "thermal compost" is produced aerobically (with oxygen) and is much faster (within 6 weeks), resulting in a biologically rich product, but it requires more effort and constant monitoring.

1.2.2. Thermal Compost Production Process

There is no one-size-fits-all recipe for a good thermal compost, as many variables could affect the production process (climate conditions, types of materials available, available time and resources, etc.).

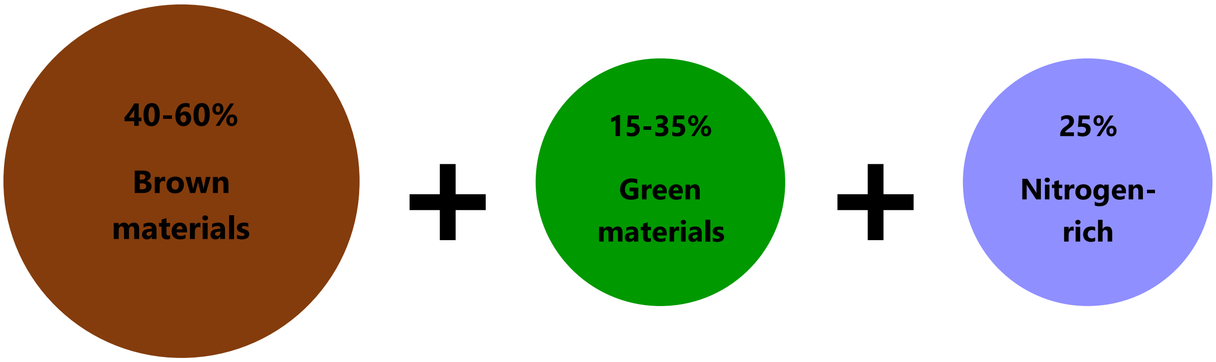
Generally speaking, however, the raw materials used in thermal composting are always the same, although their ratios might differ based on the desired compost quality. They consist mostly of:

- Brown materials (dry sticks, twigs, small branches, wood chips, wood shavings, sawdust, newspapers, cardboard, dry leaves and straw)

- Green materials (grass hay, weeds, vegetable waste, flowers, herbs cuttings, coffee grounds)

- Nitrogen-rich materials (animal manures, seeds)

Figure 1: Basic Formula for Ratios of Materials Used in Thermal Composting



The production process itself is fairly the same in all settings, although it may take longer to complete depending on conditions (setup, materials, weather, etc.). In all cases, it involves building piles (around

$1m^3$ in volume) or windrows of organic materials, and making sure they remain aerated, heated, and at the right levels of humidity.

The basic steps in producing thermal compost are as follows:

1. Prepare enough materials for a $1m^3$ pile
2. Start a pile by measuring out the materials in the proportions you need
3. Build a first layer of the materials in the right proportions, around 1m x 1m in area and 20cm tall
4. Press down heavily on the layer (by walking over it)
5. Water enough so that you have around 50% water content
6. Repeat with the next layer until you reach a height of 1m for a pile measuring $1m^3$ in volume
7. Water again and make sure the pile is not at risk of drying out
8. After 24 hours, measure the temperature in several places up the center of the pile.
9. When the temperature reaches around 55°C-75°C, break the pile and turn the outside to the inside to make a new pile.
10. Repeat the process around 5 times in 15 days - except if the pile temperature drops below 55°C

Note: The pile must remain aerobic (exposed to oxygen) at all times, and moisture levels should stay between 40% and 60% at all times.

Figure 2: General Comparison of Agricultural and Environmental Compost

Agricultural Compost	Environmental Compost
Free of contaminants (pathogens, weed seeds)	May contain contaminants
Made with agricultural waste	Made with municipal and household waste
Heat decomposes materials	Fermentation decomposes materials
Free of impurities (glass, plastic, metals, etc.)	May contain impurities
Pleasant earthy smell	May contain foul odors
Safe for agricultural use	Environmental end-use (landfill layering, carbon sequestration)
Ready in 1.5 months (minimum)	Ready in 4 months (minimum)
High maintenance (requires effort and monitoring)	Low-maintenance (requires little-to-no effort)
Requires a minimum volume of $1m^3$ for effective results	No limit to size or volume

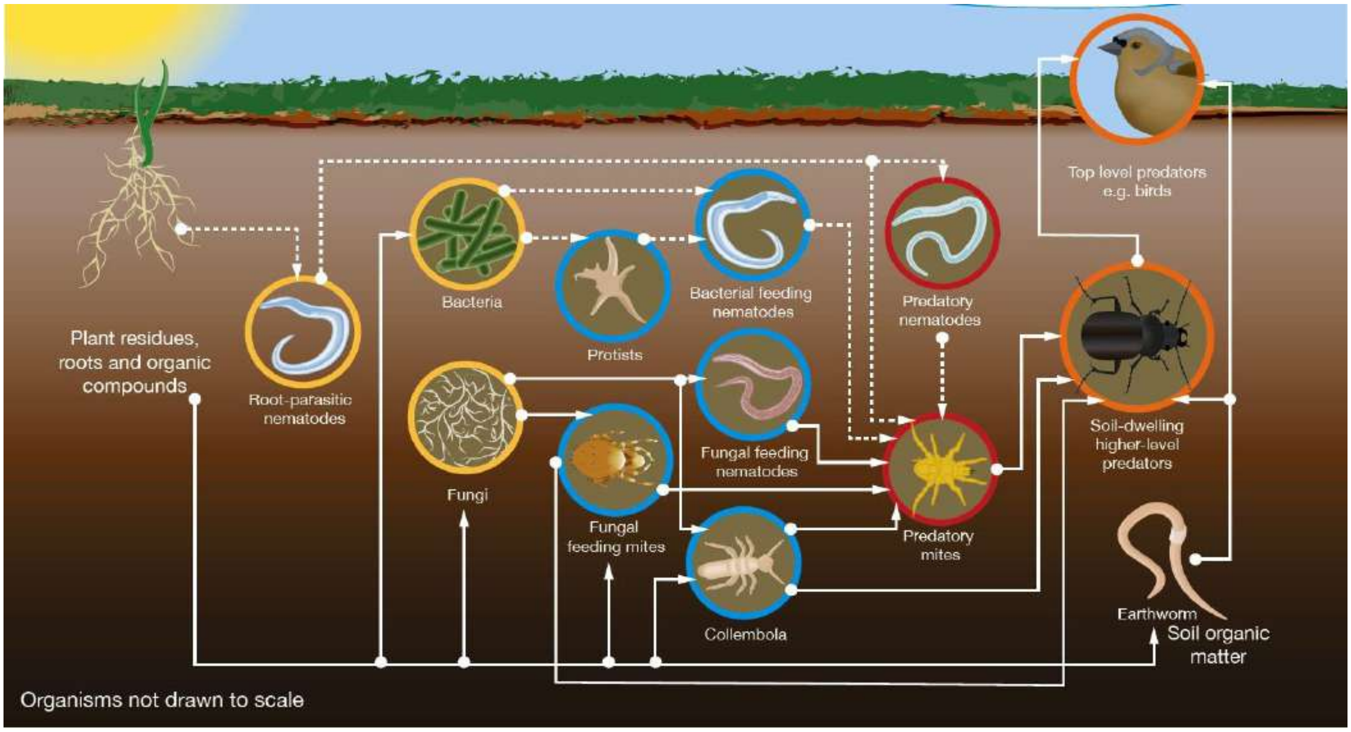
1.2.3. Thermal Compost Benefits

Thermal compost is ideal for agricultural use for the reasons mentioned in Figure 2 above. Most importantly, thermal compost contains a wider variety of beneficial components: a nutrient bank (bacteria and fungi) and nutrient cyclers (nematodes and protozoa) that facilitate nutrient absorption by crops.

These components are essential to the "soil food web", a network of microscopic biodiversity beneath the soil, closely linked to soil fertility. Dr. Elaine Ingham, a world-renowned soil microbiologist, has researched and developed this concept (Land Stewardship Project, 2019). The soil food web is present in soils around the globe and the correct balance of its different components and the interaction between them is key to effective soil regeneration, guaranteeing continued and sustainable fertility. In environmental compost, the soil food web components are not present in the correct quantities or ratios and therefore do not confer the full array of benefits to both soils and crops.

Figure 3: Soil Food Web Components

(Source: Agriculture and Horticulture Development Board www.ahdb.org.uk)



> *"Since the Industrial Revolution the processes of growth have been speeded up to produce the food and raw materials needed by the population and the factory. Nothing effective has been done to replace the loss of fertility involved in this vast increase in crop and animal production. The consequences have been disastrous. Agriculture has become unbalanced: the land is in revolt: diseases of all kinds are on the increase: in many parts of the world Nature is removing the worn-out soil by means of erosion."*
>
> **Sir Albert Hoard – An Agricultural Testament (1943)**

Benefits of a balanced soil food web for agriculture:

- Plants get a constant flow of nutrients that they control
- Plants are protected against pests and diseases
- Weed growth is inhibited
- Farmers no longer need to apply chemicals as ecosystem functions are restored
- The need for irrigation and plowing is decreased, resulting in cost savings

Over the years, Dr. Ingham has perfected a method of thermal composting that ensures optimal results based on needs. The compost recipe of brown, green and nitrogen-rich materials (*See Figure 1, Page 6*) remains constant, but different ratios of brown and green materials produce different results:

> -Using close quantities of brown and green (e.g. 40% brown – 35% green) produces a compost with a fungi to bacteria (F:B) ratio of 1:1 that is suited for row crops (it provides the minimum requirements for plant growth and soil health).
>
> -A higher percentage of brown to green materials (e.g. 60% brown – 15% green) produces a fungi-dominant compost with an F:B ratio between 2:1 (minimum) and 100:1 (maximum) that is suited for deciduous trees and perennials.

Perennial plants prefer fungal dominant environment while annual plants prefer a balanced ratio and weeds prefer a bacteria dominant environment.

Nematodes and protozoa are crucial for nutrient cycling, these microorganisms will release the nutrient from the fungi and bacteria and make them in available water-soluble form for plant to absorb.

2. CASE STUDY: AL SAFIR FARMS COMPOST PRODUCTION UNIT AND LEARNING CENTER

The case study herein aims to document and analyze all steps in the establishment of the Al Safir Thermal Compost Production Unit and Learning Center. The objective is to assess the economic feasibility of such a facility through a cost analysis and quantify its impact on soil fertility and health.

2.1. Al Safir Farms Presentation

Established in 1996, Al Safir Farms covers a site of 7.3 hectares in the region of Ghaziyeh in southern Lebanon. The farm is dedicated to the cultivation of a diverse range of fruit-bearing trees, mostly tropical and citrus trees, as well as some vegetables.

Initially, Al Safir Farms practiced conventional agriculture, until 2022 when the current operations manager, Nour Nahouli, committed to making the transition to a more sustainable and environmentally responsible type of agriculture, by phasing out pesticides, synthetic fertilizers, and other harmful practices.

Aerial view of Al Safir Farms (Image via Google Earth)

As part of this transformation, a compost production unit was established with the help of SOILS Permaculture Association - Lebanon, with funding from the Terre et Humanisme agroecology and food sovereignty in the southern Mediterranean (AMED) project.

The unit is intended for a dual purpose:

1) To produce enough high-grade thermal compost to cover the soil health needs of Al Safir Farms. In early years where experimentation with the compost produced on site is still ongoing, surplus quantities could be sold to neighboring farmers.

2) To serve as a practical demonstration site for the agroecological principles of closed-loop resource management, sustainability, and ecological harmony within orchard ecosystems, offering educational and training services to agricultural and compost practitioners.

2.2. Al Safir Thermal Compost Production Unit and Learning Center Setup

The thermal compost facility is tailored to the size and resources of Al Safir Farms, guaranteeing effective handling of the organic waste produced there.

2.2.1. Site Preparation

A suitable location for 10 compost piles within the farm was chosen in an existing concrete-covered area of 30 m^2near the farm's perimeter. The site offered convenient access for transporting materials to and from without disturbing the main orchard area. The area was extended to 70m^2 to meet the needs of the Al Safir Thermal Compost Production Unit and Learning Center. The area was covered to protect the compost piles from rainwater during winter and high temperatures from sun exposure during summer. This also helps big groups to focus better during practical training sessions.

Several conditions made the site an ideal location for thermal composting operations:

- Good wind circulation to disperse composting odors, thereby minimizing potential issues
- Partial sunlight exposure necessary to warm compost piles without drying them up
- Ready access to water for maintaining adequate moisture levels in compost piles
- Good water drainage to prevent waterlogging

Compost production unit at Al Safir Farms (Photo courtesy of Nour Nahouli)

2.2.2. Compost Production Unit Structure

The choice of structure for the compost production unit was influenced by the principles and teachings of Dr. Ingham to ensure optimal conditions for microbial activity.

The structure consisted of 10 managed thermal compost piles with real dimensions of 1m^{3}with ready access to water and sufficient wind exposure.

Each compost pile was mounted on a wooden pallet to facilitate aeration and drainage and prevent ground contamination. One extra pallet was used as a way station when turning the compost piles.

The piles were surrounded with galvanized steel mesh cylinders with a diameter of 1mto contain the materials, allow proper airflow, maintain the piles' shape, and provide structural support.

The area was partially covered to protect the piles from rainwater and provide shade for workers and visitors.

For a list of all materials used in setting up the thermal compost structure, see Figure 13: Al Safir Compost Production Unit Installation Costs and Capital Investment (Page 21).

Compost pile structure construction (Photo courtesy of Nour Nahouli)

2.3. Thermal Compost Production

2.3.1. Preparation of Raw Materials

In the interest of reducing costs and promoting self-sufficiency, it was important to source raw materials (green, brown, and nitrogen-rich materials) at Al Safir Farms or as close as possible to location. The correct storage of these materials was also crucial in ensuring that they were in optimal condition to support microbial activity and produce high-quality compost.

Figure 4: Description of Raw Materials used in Al Safir Farms Compost Production

Brown Materials	Description	Tree prunings
	Preparation	Cut and chopped into small pieces (a wood chipper was used at Al Safir Farms)
	Storage	Outdoors exposed to rain and sunlight. This guarantees that the material turns "brown" (showing optimal carbon content) and accelerates its decomposition.
	Source	Al Safir Farms + one neighboring school

Green Materials	Description	-Weeds* -Crop waste (e.g. stems, skins, damaged fruits and vegetables)**
	Preparation	Cut and chopped into small pieces (manually)
	Storage	None (used directly) Some weeds can be stored outside under the sun and still be used as green materials, but if they are exposed to water, then they are left to become brown materials
	Source	Al Safir Farms

**Less than 10% of total weeds removed from Al Safir Farms were used, the remaining weeds were chopped and dropped on-site to provide soil cover and organic matter*

***Approximately 80% of the crop waste was generated on the farm*

Nitrogen-rich Materials	Description	Goat manure*
	Preparation	None
	Storage	Outdoors, away from living/working spaces to prevent bad odors and allow the manure to dry out and decompose, further enhancing its nutrient value
	Source	Neighboring goat farm

**Initially, horse manure from stables in Saida was used because it was less expensive and more accessible. However, when it was discovered that the horse manure contained brown materials and other impurities, including antibiotics that prevented microorganism growth, the switch was made to goat manure.*

2.3.2. Mixing and Layering

The compost piles were constructed with precise ratios of carbon-rich to nitrogen-rich materials to yield the correct particle size, structure, and carbon to nitrogen ratio (C:N). The materials were measured using a 20L bucket then mixed and layered based on 2 recipes to produce different types of compost intended for a) trees and b) vegetables.

Figure 5: Comparison of Raw Material Composition in Thermal Compost for Different Uses

Intended Use	Brown Materials	Green Materials	Nitrogen-rich Materials
Trees	60%	15%	25%
Vegetables	40%	35%	25%

The materials were placed inside the steel cylinders in layers following the "lasagna" method. Each layer consisted of brown materials, followed by a layer of green materials, then a layer of nitrogen-rich materials to a height of about 20 cm. The layer was then sufficiently watered then compressed before the next layer was constructed.

The same layering process was repeated until the desired volume of $1m^3$ was reached.

Compost pile layering (Photos courtesy of Nour Nahouli)

2.3.3. Turning and Watering

The piles underwent regular temperature-sensitive turning cycles (35 turns per cycle on average) to sustain aerobic conditions and ensure uniform decomposition throughout the compost mass.

The piles were closely monitored and maintained at specific temperature and moisture levels. Pile temperatures were checked daily using a compost thermometer at a depth of 0.5m. Moisture levels were checked regularly through hand inspection (squeeze test) to prevent the compost from becoming too dry or too wet during the composting phases:

Thermophilic Phase

The thermophilic phase is characterized by elevated temperatures in compost piles, ranging between 55°C and 75°C due to the intense activity of microorganisms engaged in decomposing raw materials inside the piles.

During this phase piles are watered and turned regularly, with a minimum frequency of once every 2-3 days (daily if temperatures remained at 75°C) and for a period of at least 15 days or more, depending on the material mix used.

Mesophilic Phase (maturation)

The mesophilic phase sees the composting process slowing down. Temperatures inside compost piles start to drop gradually, reaching and stabilizing at atmospheric level (*See 4.1. Sample Thermograph of 1 Compost Pile, Page 26*). This signals compost maturity and readiness for use.

During this phase, watering and turning frequency can be adjusted based on the ongoing decomposition, with attention paid to maintaining the necessary moisture levels.

Under optimal conditions, this system can produce high-quality compost per cycle (approximately 2 months), with a yield equal to around 40%-50% of the input material (contingent on its composition).

Compost pile temperature monitoring

Compost pile turning

(Photos courtesy of Nour Nahouli)

2.3.4. Packaging and Storage

Upon successful completion of the composting process, the final product is ready for use or storage. The compost is measured and packaged in 100L or 25L sacks commonly referred to as grain sacs. The bags are sealed and stored away from direct sunlight, wind, and water.

Carefully preparing the raw materials and closely monitoring the composting process eliminated the need to screen the finished compost in order to remove large chunks or unwanted impurities. This streamlined approach not only saves time and effort but also guarantees the consistent quality of the compost.

In its first year of operation, the Al Safir Compost Production Unit and Learning Center only used a small portion of the compost produced on site. To date, 3variations of vegetable composts and 2variations of tree composts have been produced. Experimentation is ongoing to determine ideal compost compositions for vegetables and trees before expanding compost applications to larger sections of the farm (*See 2.4.1. Experimentation*).

2.4. Thermal Compost Grading

2.4.1. Experimentation

The Al Safir Compost Production Unit and Learning Center adopted 2 recipes in varying ratios of brown and green materials to produce 2 main types of compost intended for vegetable and tree applications (*See Figure 5 page 14*).

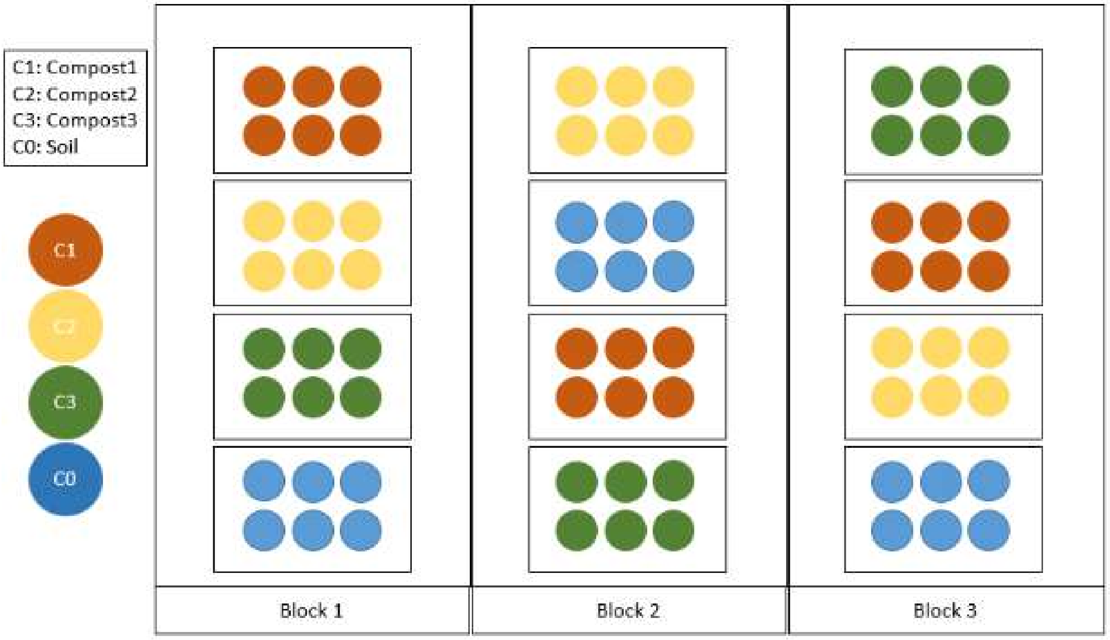
It was then necessary to measure the efficiency of the produced compost. A set of experiments was conducted to observe how different crops responded to specific compost types and determine the ideal mix for optimal plant growth. Observing compost applications in vegetable crops required less time than in trees. The experiments and results presented below are mainly for vegetable applications. The results of other applications are expected by April 2024.

Experiment 1: Examining the effects of vegetable composts on radish seed germination and growth

The protocol aimed to assess the impact of the 3 vegetable composts (C1, C2, C3) produced at the Al Safir Compost Production Unit and Learning Center on the germination and growth of radish seeds (F1 hybrid) over 30 days.

The experiment employed a randomized complete block design with a total of 72 pots divided into 4 treatment groups of 18 pots each: 1 group for each compost type (3 types) and a fourth control group that would not receive any compost (C0). The control group was grown in black gray soil poor in organic matter, sourced on-site. A total of 360 seeds were divided into the pots (5 seeds per pot). Pots from each treatment group were placed in randomized blocks to reduce the effects of any variation between blocks, e.g. sunlight exposure. Parameters such as seed germination rate, plant height, and weed incidence were set to quantify the results. The statistical analysis of the results was performed using statistical software (SPSS and Excel), to assess the significance of observed differences ($p<0.05$).

Figure 6: Experimental Design for Effects of 3 Types of Compost on Radish Seed Germination



Compared with the control group, the 3 types of compost showed significantly improved results across all established parameters:

Figure 7: Mean Values of Estimated Germination Rate, Leaf Length, and Weed Incidence

Compost Type	Germinated Seeds (#)	Germination Rate (%)	Leaf Length (cm)	Weed Incidence (#)
C0	1.22^{b}	24.44^{b}	15.67^{a}	37.83^{a}
C1	3.94^{a}	78.89^{a}	21^{b}	3.83^{b}
C2	4.11^{a}	82.22^{a}	21.67^{b}	3.05^{b}
C3	4.16^{a}	83.33^{a}	23.5^{b}	2.5^{b}

Figure 8: Mean Values of Germination Rate (%) of Radish Seeds in 3 Compost Types and in Soil

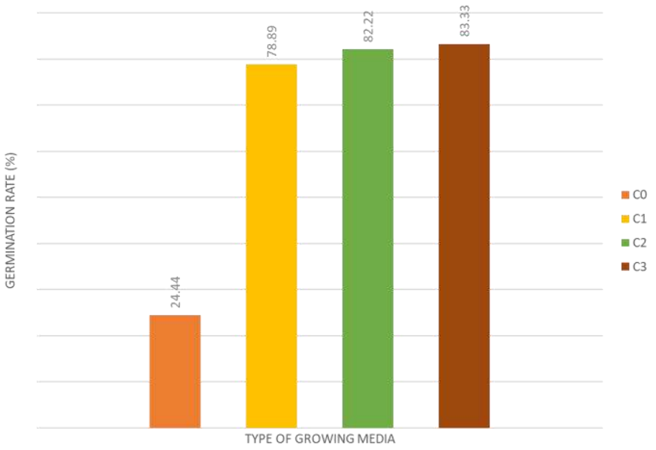


Figure 9: Mean Value of Leaf Length (cm) of Radish Plants in 3 Compost Types and in Soil

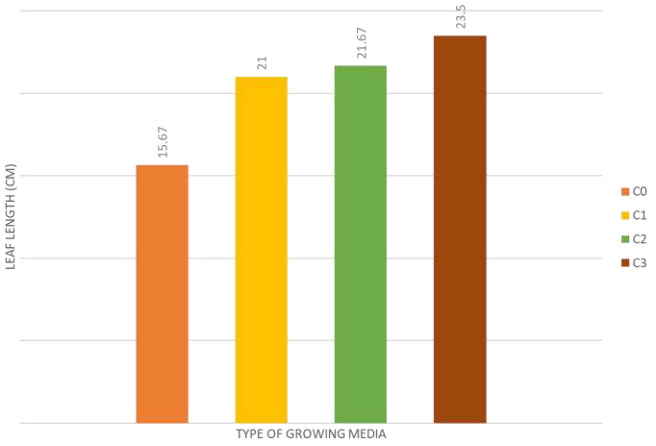
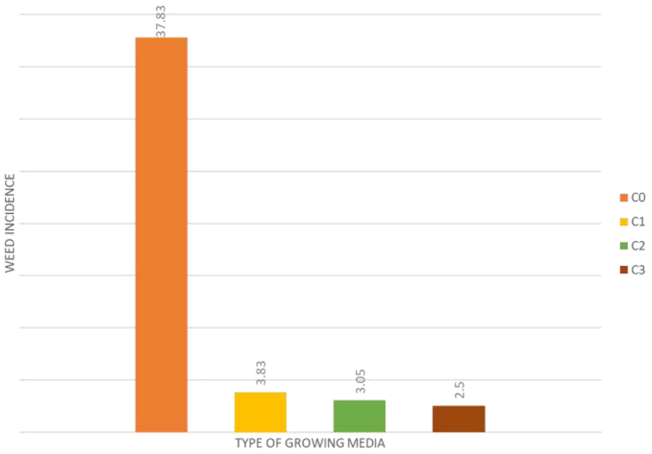


Figure 10: Mean Values of Weed Incidence (#) in 3 Compost Types and in Soil



Weed incidence in control group (left) and in compost (right)

(Photos courtesy of Nour Nahouli)

Experiment 2: Examining the effects of tree composts on carob seed germination and growth

The protocol aims to assess the impact of two types of tree compost (TC1, TC2) generated at the Al Safir Compost Production Unit and Learning Center on the germination and growth of carob seeds over 30 days.

The experiment employs a randomized complete block design with a total of 36 pots divided into 3 treatments groups and a fourth control group that would not receive any compost (C0). Parameters such as seed germination rate, plant height, root weight, and weed incidence will serve to quantify the results.

Results expected by end of 2024.

Experiment 3: Examining the effects of tree composts on strawberry seedling growth

The protocol aims to assess the impact of two types of tree compost (TC1, TC2) generated at the Al Safir Compost Production Unit and Learning Center on the growth and development of strawberry seedlings.

The experiment involves five treatments, including compost and soil mixtures, compost extracts, and a soil-only control, with a randomized complete block design and three replications. Key parameters such as plant height, leaf count, root development, flowering, fruit development, and taste will serve to quantify the results.

Results expected by end of 2024.

Experiment 4: Examining the effects of tree composts on young olive trees

The protocol aims to conduct a comparative study on the effects of two types of tree compost (TC1, TC2) generated at the Al Safir Compost Production Unit and Learning Center on the performance of a young olive orchard.

The experiment involves five treatments, including compost mulch and incorporation, with a randomized complete block design and three replications. Key parameters, such as tree growth, fruit yield, weed growth, pest and disease incidence, and environmental factors, will serve to quantify the results.

Results expected by October 2026 at the earliest.

2.4.2. Biological Assessment

Testing the biology in compost is crucial in providing valuable information about the health and functionality of the composting process. The biological aspect of compost is assessed through microbiological testing to observe the presence and activity of soil food web components.

This microbiological approach is based on the science of Dr. Elaine Ingham and is more suited to the purposes of Al Safir Farms and SOILS Permaculture Association - Lebanon. Other approaches in grading compost quality involve cultivating cultures in petri dishes, for example, but this is only effective in observing selective anaerobic bacteria growth to determine the possible presence of diseases and pathogens – most crucially, it does not determine the presence and activity of nutrient cyclers.

Figure 11: The Importance of Biological Assessment in Compost Grading

Microbial Activity	Decomposition: Microorganisms, such as bacteria, fungi, and actinomycetes, play a key role in breaking down organic matter into nutrient-rich compost. Testing the biology allows us to gauge the level of microbial activity, ensuring that the composting process is effectively breaking down organic materials.
Nutrient Cycling	Release of Nutrients: Microorganisms break down complex organic compounds into simpler forms, releasing essential nutrients for plant growth. Assessing microbial activity helps in understanding the efficiency of nutrient cycling in the compost, which is important for soil enrichment.
Pathogens and Weed Seeds	Pathogen and Weed Seed Reduction: Proper composting with the right microbial activity can help suppress harmful pathogens and weed seeds. Testing allows us to confirm that the composting process has reached temperatures sufficient to eliminate potential plant diseases and weed seeds.
Aerobic vs. Anaerobic Conditions	Aeration Levels: Microbial activity is often aerobic (requires oxygen), and proper aeration is necessary for optimal composting. Testing helps ensure that the compost pile is well-aerated, preventing the development of anaerobic conditions that can produce unpleasant odors and harmful by-products.
Compost Stability and Maturity	Testing can indicate the level of compost stability and maturity. Compost that is fully matured is less likely to cause nitrogen tie-up issues in the soil and is more beneficial for plant growth.
Optimizing Composting Conditions	If microbial activity is not at the desired level, testing can guide adjustments in the composting process, such as turning the pile, adjusting moisture levels, or balancing carbon-to-nitrogen ratios.

Several factors can significantly influence the biology in a compost system. Understanding and managing these factors is essential to achieve optimal composting conditions and produce high-quality compost:

•Carbon-to-Nitrogen Ratio: Microorganisms require an appropriate balance of carbon and nitrogen for efficient decomposition. The C:N ratio will affect the fungal to bacterial (F:B) ratio. (*See Page 9*).

•Moisture Content: Microorganisms need moisture to thrive. Compost piles that are too wet can become anaerobic, leading to unpleasant odors and reduced microbial activity. Conversely, overly dry conditions can kill or deactivate microorganisms.

•Aeration and Oxygen Levels: Adequate aeration is essential for aerobic decomposition. Turning or aerating the compost pile helps maintain oxygen levels, preventing the development of anaerobic conditions that can lead to foul-smelling compost and incomplete decomposition.

•Feedstock Selection: The types of materials used as feedstock influence the microbial community in the compost. Diverse feedstocks contribute to a broader range of nutrients and microbial species. Ammonium will increase the level of fungi while nitrates will increase the level of bacteria.

•Turnover Frequency: Regular turning or mixing of the compost pile introduces fresh oxygen, helps distribute moisture evenly, and promotes microbial activity. Turning also prevents the formation of anaerobic pockets within the compost. Excessive turning also can affect microorganism numbers, fungi, nematode and protozoa do not like excessive disturbance

Figure 12 records the populations of microorganisms found in different compost samples. These populations are influenced by moisture, heat, and organic matter. These numbers help evaluate the compost process and indicate compost quality. The absence of nematodes reflects the need to improve the diversity of inputs, as nematodes are essential for nutrient cycling and availability. Nematodes play this role by decomposing organic matter and feeding on bacteria, fungi and other microorganisms, as such they are essential in the soil food web. Moreover, low nematodes rates in soil indicate poor soil health, low organic matter content, or unfavorable environmental conditions. (For more details on F:B ratio refer to section 1.2.3. Thermal Compost Benefits).

Figure 12: Biological Assessment of Compost Samples from 8 Piles at Al Safir Farms

	Pile 17	Pile 18	Pile 19	Pile 20	Pile 21	Pile 22	Pile 23	Pile 24
F:B ratio	1.044429032	0.96244369	0.283578832	1.083174941	1.709262074	1.063949845	0.99356634	2.464863751
Bacteria (#)	547,920,000	579,577,600	667,244,800	773,176,000	508,956,800	607,060,571	1,098,275,200	686,726,400
Fungi (length)	4,452	4,657	913	6,849	5,394	2,808	5,068	5,251
Flagellate	608,800	913,200	1,522,000	913,200	608,800	913,200	1,522,000	304,400
Cilliate	0	304,400	304,400	608,800	304,400	608,800	1,826,400	0

Amoeba	1,217,600	0	0	0	1,217,600	2,435,200	304,400	304,400
Nematode F	0	0	0	0	0	0	0	0
Nematode B	0	0	0	0	0	0	100	0
Nematode R	0	0	0	0	0	0	0	0
Nematode P	0	0	0	0	0	0	0	0

2.5. Thermal Compost Facility Setup Costs

2.5.1. Capital Investment

The main investments associated with hot composting operations concern setting up the composting site and buying the necessary equipment.

It is worth noting that Al Safir Farms already possessed some of the necessary installation materials and access to water. The operators were also able to obtain some of the raw materials for free (green materials generated at the farm) or at a reduced cost (goat manure).

Moreover, some of the investment costs at Al Safir Farms covered items such as the concrete base extension, the wood chipper, and the TOT shelter, that may not be necessary when duplicating the model in other locations.

Figure 13: Al Safir Compost Production Unit Installation Costs and Capital Investment

Item	Qty.	Unit Price	Total Cost	Amortization Years	Annual Depreciation
Concrete Base Extension	1	USD 200	USD 200	30	USD 6.67
Metal sheets (TOT) in m^2	70	USD 3.8	USD 266	15	USD 17.733
Installation of Shelter (Labor)	1	USD 14	USD 14	15	USD 0.93
Galvanized mesh (3.5 m x 1 m)	10	USD 8.5	USD 85	3	USD 28.3
Wood Chipper*	1	USD 1,500	----	10	0
Wooden Pallet	11	USD 12	USD 132	10	USD 13.2
Watering Can (15L)	1	USD 5.6	USD 5.6	3	USD 1.86
Water Barrel (200L)**	1	USD 14	USD 14	30	USD 0.46
Pruning shears	1	USD 40	USD 40	10	USD 4
Compost thermometer	1	USD 10	USD 10	10	USD 1

Net (1 m x 1m)	11	USD 1	USD 11	2	USD 5.5
Hay fork head	1	USD 10	USD 10	15	USD 0.67
Fork stick	1	USD 3	USD 3	3	USD 1
Total			**USD 790.6**	**Annual Total**	**USD 81.33**

*Funded via SOILS Permaculture Association - Lebanon grant

**Purchased used at a reduced price

2.5.2. Cash Inflow and Operational Costs

Since most of the raw materials are already provided by Al Safir Farms, operational costs mainly consist of labor and fuel expenses.

In evaluating the feasibility of setting up and operating a thermal compost unit, we examined the viability of the project's three major components: a) raw material supplies, b) machinery maintenance, and c) fuel consumption, labor, and other operational costs needed to keep the business afloat.

Figure 14: Al Safir Compost Production Unit Annual Operational Costs (10 Piles x 4 Cycles)

Item	Qty.	Unit Price	Total Cost
Labor (average monthly cost based on varying hours)	12	USD 98	USD 1,177
Manure Shipment (50 bags, ~90L per bag)	4	USD 50	USD 200
Fuel Consumption	250L	~USD 1	~USD 250
Gloves	12	USD 2	USD 24
Bucket*	1	USD 2	USD 2
Broom	1	USD 3.5	USD 3.5
Broomstick	3	USD 0.5	USD 1.5
Electricity (negligible)	----	----	----
Water (negligible)	----	----	----
Total			**USD 1,656**

Additional Costs

Item	Qty.	Unit Price	Total Cost
Machinery Maintenance**	1	~USD 50	**~USD 50**

*Received for free

**In reality, maintenance costs will increase with time but in the interest of simplification, the figure was considered as fixed and roughly estimated at USD 50.

2.5.3. Yield

Each tree compost pile produced an average of 500 liters, and each pile of vegetable compost produced an average of 430 liters.

Based on these figures, the annual production of 20 tree compost piles and 20 vegetable compost piles (10 piles over 4 cycles for a total of 40 piles annually) amounted to around 10,000 liters of tree compost and 8,600 liters of vegetable compost as shown in Figure 15.

Figure 15: Compost Piles Yield per Year (4 Cycles)

Compost type	Average yield per pile	Number of piles	Average total annual yield
Tree compost	500L	20	10,000L
Vegetable compost	430L	20	8,600L
Total annual yield			**18,600L**

2.5.4. Cash Flow

In the first year of operation, the Al Safir Compost Production Unit and Learning Center produced 18,600L of compost. At an average price of USD 0.28/liter, the total production is valued at USD 5,208 (for a total production cost of USD 1,706).

In practice, as this was the first year of production and experimentation, only some of the compost produced was used on-site for vegetable crops and trees. Another part of the production was sold to local farmers in bags of 25L or 100L at an average price of USD 0.28/liter.

Figure 16: Al Safir Compost Production Unit Cash Flow Statement (Year 1)

<table>
<tr><th>Compost Produced</th><th>Production Cost</th><th>Compost Used</th><th>Savings</th><th>Compost Sold</th><th>Sales Revenue</th><th>Remaining Compost</th></tr>
<tr><td>18,600L</td><td>USD 1,706</td><td>1,900L</td><td>USD 532</td><td>2,035L</td><td>USD 569.8</td><td>14,665L</td></tr>
<tr><th colspan="2">Total Expenses</th><th colspan="4">Total Income</th><th>Value</th></tr>
<tr><td colspan="2">USD 1,706</td><td colspan="4">USD 1,101.8</td><td>USD 4,106.2</td></tr>
</table>

3. RECOMMENDATIONS

A lot of time and effort went into planning and implementing the Al Safir Compost Production Unit and Learning Center as a dual-function facility and space.

Based on the learnings from this experience, we can share the following set of recommendations for any individual or enterprise looking to replicate the format:

- Conduct ample research and seek guidance. For first-time composters, consulting a specialist is crucial for drafting an optimal composting plan.
- Start with small-scale composting projects to allow for a reasonable learning curve and resource adaptation, then work your way up to larger operations.
- Select the most appropriate composting structure suited for your conditions (climate, access to labor, raw materials, and resources).
- Perform diligent and consistent monitoring and evaluation of compost piles (temperature, moisture levels, and aeration) to ensure optimal outputs.
- Experiment, observe, and adapt. Composting is a trial-and-error process. The recipe for a great compost will need to be modified depending on local conditions.
- Arm yourself with patience. Composting is a natural process that requires sufficient time to ensure optimum compost quality and effectiveness.

Beyond its agricultural applications, composting can support the creation of community-led initiatives dealing with improved sustainability, food safety and nutrition, biodiversity conservation, and responsible resource management to ensure the health of future generations and the planet. Achieving this requires engaging the surrounding community through:

- Building awareness about environmentally friendly approaches to handling organic waste through outreach and educational content and activities.
- Demonstrating the efficiency and benefits of compost through site visits to agricultural plots and sharing data about costs, yields, crop quality soil health, etc.
- Promoting transformative agroecological food systems by reaching out to conventional farmers with training, guidance, and support.

> *"The transition of Al Safir Farms to agroecological practices with composting has been a rewarding journey that has transformed the orchard into a model of sustainability. We fervently encourage fellow growers to embrace this transformative approach and actively contribute to a more environmentally conscious and sustainable agricultural future."*
> **Nour Nahouli, Al Safir Farms Operations Manager**

4. ANNEXES, REFERENCES AND FURTHER READINGS

4.1. Annexes

Appendix A: Compost Production Unit Minimum Annual Costs

Equipment

Item	Qty.	Unit Price	Total Cost
Galvanized mesh (3.5 m x 1 m)	10	USD 8.5	USD 85
Wooden Pallet	11	USD 12	USD 132
Watering Can (15L)	1	USD 5.6	USD 5.6
Compost thermometer	1	USD 10	USD 10
Hay fork head	1	USD 10	USD 10
Fork stick	1	USD 3	USD 3
Gloves	12	USD 2	USD 24
Total			**USD 790.6**

Raw Materials

Item	Qty.	Unit Price	Total Cost
Manure Shipment (50 bags, ~90L per bag)	4	USD 50	USD 200
Total			**USD 200**

Additional Costs (Optional)

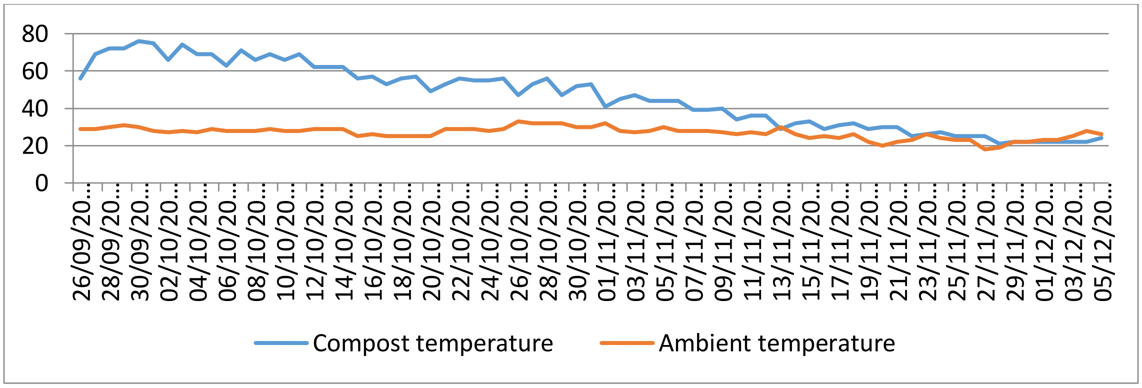
Item	Qty.	Unit Price~	Total Cost~
Labor (average monthly cost based on varying hours)	12	USD 100	USD 1,200
Wood Chipper	1	USD 1,500	USD 1,500
Machinery Maintenance	1	USD 50	USD 50

•Prices may vary depending on origin/quality
•Prices are contingent on availability of raw materials (green and brown materials) on-site. Additional materials and transportation costs may need to be included.

Appendix B: Sample Thermograph of 1 Compost Pile

Date	Pile Temperature (°C)	Ambient Temperature (°C)	Remarks
9/25/2023	--	--	--
9/26/2023	56	29	no turn
9/27/2023	69	29	no turn
9/28/2023	72	30	1st turn + water
9/29/2023	72	31	no turn
9/30/2023	76	30	2nd turn + water
10/1/2023	75	28	3rd turn + water
10/2/2023	66	27	no turn
10/3/2023	74	28	4th turn + water
10/4/2023	69	27	no turn
10/5/2023	69	29	5th turn + water
10/6/2023	63	28	no turn
10/7/2023	71	28	6th turn + water
10/8/2023	66	28	no turn
10/9/2023	69	29	7th turn + water
10/10/2023	66	28	no turn
10/11/2023	69	28	8th turn + water
10/12/2023	62	29	no turn
10/13/2023	62	29	no turn
10/14/2023	62	29	9th turn + water
10/15/2023	56	25	no turn
10/16/2023	57	26	10th turn + water
10/17/2023	53	25	no turn
10/18/2023	56	25	no turn
10/19/2023	57	25	11th turn + water
10/20/2023	49	25	no turn
10/21/2023	53	29	no turn
10/22/2023	56	29	12th turn + water
10/23/2023	55	29	no turn
10/24/2023	55	28	no turn
10/25/2023	56	29	13th turn + water
10/26/2023	47	33	no turn
10/27/2023	53	32	no turn
10/28/2023	56	32	14th turn + water
10/29/2023	47	32	no turn
10/30/2023	52	30	no turn
10/31/2023	53	30	15th turn + water
11/1/2023	41	32	no turn
11/2/2023	45	28	no turn
11/3/2023	47	27	16th turn + water
11/4/2023	44	28	no turn
11/5/2023	44	30	no turn
11/6/2023	44	28	17th turn + water
11/7/2023	39	28	no turn
11/8/2023	39	28	no turn
11/9/2023	40	27	18th turn + water
11/10/2023	34	26	no turn
11/11/2023	36	27	no turn
11/12/2023	36	26	19th turn + water

11/13/2023	29	30	no turn
11/14/2023	32	26	no turn
11/15/2023	33	24	20th turn + water
11/16/2023	29	25	no turn
11/17/2023	31	24	no turn
11/18/2023	32	26	21st turn + water
11/19/2023	29	22	no turn
11/20/2023	30	20	no turn
11/21/2023	30	22	22nd turn + water
11/22/2023	25	23	no turn
11/23/2023	26	26	no turn
11/24/2023	27	24	23rd turn + water
11/25/2023	25	23	no turn
11/26/2023	25	23	no turn
11/27/2023	25	18	24th turn + water
11/28/2023	21	19	no turn
11/29/2023	22	22	no turn
11/30/2023	22	22	25th turn + water
12/1/2023	22	23	no turn
12/2/2023	22	23	no turn
12/3/2023	22	25	26th turn + water
12/4/2023	22	28	no turn
12/5/2023	24	26	no turn



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4.3. Further Readings

To read more about the Soil Food Web and the role and benefits of each of its elements, check out:

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Composting unit execution and operation: Nour Nahouli
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Editing and communications consultancy: Alexis Baghdadi
Project coordination: Roula Khawand
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