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Valorization of agro-industrial residues and sheep manure through composting and agronomic application on beet (Beta vulgaris L.) in Arenosol

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Abstract

The valorization of organic waste by composting reflects a sustainable substitute for the management of agro-industrial residues in Morocco, particularly in the Gharb region. This study investigates the production of compost from residues originating from two industrial units: essential oil hydrodistillation and red fruit processing, combined with sheep manure incorporated at the beginning of the composting process. The process was evaluated over 90 days using an integrated approach combining physicochemical analyses. Temperature monitoring revealed a robust thermophilic phase, with temperatures reaching 65°C, ensuring effective hygienization of the compost. The final compost exhibited physicochemical properties favorable for agronomic use, including a stable C/N ratio of 16.63, a near-neutral pH (7.30), and a non-limiting electrical conductivity (3.64 mS/cm). Agronomic evaluation was carried out on beetroot (*Beta vulgaris* L.) cultivated in experimental plots at the Faculty of Sciences of Kenitra, on a soil classified as an Arenosol according to the World Reference Base (WRB) classification. The compost was applied at a rate of 25% (v/v), previously identified as optimal, and compared with a non-amended control soil. The results revealed a significant increase in tuberous root weight and leaf number in the compost-amended treatment, confirming the agronomic potential of the compost and its beneficial effect on the fertility of Arenosols.

Introduction

The rapid expansion of agro-industrial activities worldwide has led to a growing production of organic wastes, which currently represents a major environmental challenge. Inadequate management of these wastes significantly increases greenhouse gas emissions, soil degradation, and pollutes water resources. This threatens the sustainability of ecosystems and agricultural systems [1, 2]. Globally, the organic fraction makes up a large part of the solid waste generated each year, showing the urgent need for sustainable ways to use biodegradable materials [3]. In this context, composting offers a practical solution for managing organic waste in a sustainable way. This method reduces the amount of waste sent to landfills, recycles nutrients, and creates organic amendments that can improve soil fertility, structure, and biological activity in farming systems [1, 4]. Composting supports the goals of the circular economy by encouraging local reuse of organic materials and cutting down the need for synthetic mineral fertilizers [5].

Despite its well-documented benefits, large-scale adoption of composting remains constrained by several technical limitations, particularly the relatively long duration required to obtain a stable and mature compost. Depending on substrate composition and process management conditions, compost maturation may take several months, reducing the attractiveness of this technology for agro-industrial operators and farmers [6, 7]. Thus, improving composting conditions such as the initial C/N ratio, nutrient supply, and aeration plays a crucial role in accelerating organic matter breakdown without negatively affecting the quality of the final compost [5, 8]. In Morocco, agro-industrial wastes generated by aromatic and medicinal plant industries and fruit processing units represent an abundant but still underutilized organic resource. Their incorporation into composting processes represents an effective

way to reduce environmental impacts while producing organic amendments that meet the specific needs of Moroccan agriculture [2]. The use of sheep manure in composting substrates represents a promising approach, given its high nitrogen content and its role in stimulating microbial activity. This contributes to more efficient organic matter decomposition and improved compost quality [3, 5]. Moreover, previous research indicates that properly matured manure-based composts exhibit enhanced stability and superior agronomic performance [7].

In a previous study, Belkacemi et al. [9] demonstrated that composting agro-industrial wastes enriched with sheep manure resulted, after 150 days of composting followed by a maturation phase, in a stable compost with favorable physicochemical characteristics. Application of this compost significantly improved growth and physiological performance of red beetroot under greenhouse conditions, confirming its agronomic effectiveness [9]. However, the length of the composting process highlighted the need to optimize the protocol to improve its operational efficiency.

In this continuity, the present study addresses a clearly identified scientific challenge by aiming to reduce the total composting duration from 150 days to 90 days, while maintaining compost stability and agronomic performance. To achieve this objective, sheep manure was incorporated at the very beginning of the composting process, in combination with agro-industrial wastes from two processing units, including raspberry residues, in order to stimulate early microbial activity and accelerate organic matter mineralization [5, 8]. The agronomic evaluation of the compost was carried out on an Arenosol soil (World Reference Base, WRB, classification), characterized by low nutrient retention capacity and reduced organic matter content. This soil type shows a high responsiveness to organic amendments, which are essential for improving soil fertility, structure, and agricultural productivity [10, 11]. In line with the results of Belkacemi et al. [9], the compost was applied at a rate of 25%, corresponding to the optimal dose previously determined.

Materials and methods

Plant material and compliance with guidelines

Red beetroot (*Beta vulgaris* L.), cultivar “Plat d’Égypte”, was the only crop grown in the agronomic experiment. It is a cultivated commercial cultivar: untreated standard seeds were purchased from a commercial supplier (SOGEMAG, Berchid, Morocco; lot no. 880102), and no plants or plant parts were collected from the wild. Tomato (*Solanum lycopersicum*) and lettuce (*Lactuca sativa*) seeds were used only for the germination bioassay of the phytotoxicity test (same bioassay as in our previous study [9]). The aromatic and medicinal plant residues used for composting were solid by-products of the essential oil hydrodistillation process of the company EDEPAM (mainly rosemary, *Rosmarinus officinalis*, as in the previous study [9], where the same type of hydrodistillation residues and the same beetroot cultivar and seed lot were used), and the raspberry residues were by-products of a fruit processing unit. These residues were obtained as industrial waste from the two companies, and no plant material was collected from the wild by the authors. The cultivation and handling of all plant material complied with relevant

institutional, national and international guidelines and legislation, and no specific permissions or licences were required.

Composting materials and process

The materials used for composting were collected from an aromatic and medicinal plant hydrodistillation company (EDEPAM), operating on an area of approximately 7 200 m² and generating approximately 5–6 tons of solid organic waste each day. The compost was prepared using a blend of industrial and agro-industrial residues, mainly sourced from the essential oil hydrodistillation process and by-products of a red fruit processing unit, represented in this study by raspberry residues. This choice follows previous work demonstrating the agronomic valorization potential of hydrodistillation wastes combined with agro-food residues under controlled composting conditions [9].

In contrast to the previous study, sheep manure was incorporated at the beginning of the composting process in order to optimize the initial carbon-to-nitrogen (C/N) ratio and stimulate microbial activity at an early stage. The initial compost formulation consisted of 40% sheep manure, 30% raspberry residues, and 30% hydrodistillation wastes (fresh weight basis). These proportions were selected based on the physicochemical complementarity of the substrates: hydrodistillation wastes, rich in carbon and lignocellulosic compounds, ensured adequate structure and aeration of the mixture; raspberry residues, which are readily biodegradable, supplied sugars and easily assimilable nitrogenous compounds; sheep manure, rich in nitrogen and microorganisms, contributed to balancing the C/N ratio and accelerating organic matter degradation. Previous studies have shown that combining lignocellulosic residues with agro-food wastes and animal manures, particularly at relatively high manure proportions (30–40%), promotes intense microbial activity, improves composting kinetics, and significantly reduces compost maturation time [3, 5, 12, 13].

Composting was carried out in windrows with approximate dimensions of 6 m in length, 3 m in width, and 1.5 m in height. Moisture content was adjusted and maintained at approximately 60% through regular water addition to ensure favorable conditions for microbial activity. Aeration was ensured by weekly manual turning throughout the composting period. Compost temperature was monitored twice per week using a digital thermometer (Ludwig Schneider 12200, Germany) to follow the biological process.

The total duration of composting was intentionally reduced to 90 days. Representative samples of approximately 1 kg were collected from multiple locations within the windrow (center, core, surface, and sides) at the beginning of the composting process, immediately after preparation of the initial mixture, and at the end of composting in order to assess the evolution of compost characteristics over time. No additional maturation phase or secondary amendment was applied. Samples were air-dried, ground, and sieved to 2 mm before subsequent physicochemical analyses.

Physicochemical analyses of substrates and compost

Organic matter (OM) content was determined by the loss-on-ignition method, based on the difference between dry mass and mass after calcination [16]. Chemical oxygen demand (COD) was estimated using a colorimetric method following the protocol described by Knechtel [14]. Total organic carbon (TOC) was determined by wet chemical oxidation using the Walkley and Black [15] method. Total Kjeldahl nitrogen (TKN) was measured using the standard Kjeldahl method, involving acid digestion followed by distillation and titration of ammoniacal nitrogen [17]. The C/N ratio was calculated from TOC and TKN values.

Mineral elements, including potassium (K), phosphorus (P), calcium (Ca), and zinc (Zn), were quantified by inductively coupled plasma optical emission spectrometry (ICP-OES) after sample dissolution [18]. pH and electrical conductivity (EC) were measured in a suspension prepared by diluting 1 g of sample in 10 mL of distilled water, in accordance with the French standard AFNOR NFT 90 – 015 [19].

Phytotoxicity test

The potential phytotoxicity of the compost was evaluated using a seed germination test with tomato (*Solanum lycopersicum*) and lettuce (*Lactuca sativa*), commonly utilized as bioindicators. An aqueous compost extract was prepared using a 1:10 (w/v) ratio, by mixing 10 g of air-dried and sieved compost with 100 mL of distilled water. The suspension was shaken for 1 hour at room temperature, allowed to settle for 30 minutes, and filtered through Whatman No. 1 filter paper.

Sterile Petri dishes were prepared with filter paper moistened with 5 mL of compost extract, while distilled water served as the control treatment. Each dish received 20 seeds, evenly arranged, and was subsequently sealed and incubated under controlled conditions at 25°C in darkness for 72 hours. The germination index (GI) was computed according to the following equation:

$$GI = \left(\frac{GC}{GT}\right) \times \left(\frac{LC}{LT}\right) \times 100$$

1

where GC corresponds to the number of seeds germinated in the compost extract, GT in the control, LC the root length in the extract, and LT in the control.

Agronomic test design and soil analysis

The agronomic experiment was conducted at the Faculty of Sciences, Ibn Tofail University (Kenitra, Gharb region, Morocco). Seedling production of red beetroot (*Beta vulgaris* L.), cultivar “Plat d’Égypte”, was initiated on 23 September 2024 in plug trays placed in a greenhouse, using two substrates: a

substrate amended with 25% (v/v) compost (C25 treatment) and a control substrate without compost (T0).

Seedlings were transplanted on 10 October 2024 outdoors in experimental plots established on a sandy soil classified as an Arenosol according to the WRB classification. Each plot was arranged in three planting rows, with seven plants per row, and a spacing of 20 cm between plants, ensuring uniform plant density (21 plants per treatment) (Fig. 1). Irrigation was applied regularly according to crop requirements. No mineral fertilizers were applied. Leaf chlorophyll content was measured non-destructively using a FieldScout CM 1000 chlorophyll meter (Spectrum Technologies Inc., USA).

Prior to the establishment of the experiment, soil mineral nitrogen was determined by extraction with potassium chloride (KCl). Steam distillation was used to analyze the extracts. To determine ammonium ($N–NH_4^+$), 50 mL of the extract was transferred to a digestion tube with 1 g of magnesium oxide (MgO). The released ammonia (NH_3) was distilled and captured in a boric acid (H_3BO_3) solution. Then, 0.5 g of Devarda's alloy was introduced to the same extract to reduce nitrate ($N–NO_3^-$) to NH_3, followed by distillation and titration with 0.02N sulfuric acid (H_2SO_4) [20].

Statistical analysis

All statistical analyses were performed using Python software. Differences between treatments (T0 and C25) were assessed using Student's t-test when data followed a normal distribution and when variances between groups were equal. When the assumption of homogeneity of variances was violated, Welch's t-test was applied. If normality assumptions were not met, the non-parametric Mann–Whitney U test was used. Differences were considered statistically significant at $P < 0.05$. Results are presented using boxplots showing the median, interquartile range, and minimum–maximum values.

Results and discussion

Evolution of temperature during the composting process

Continuous monitoring of temperature during the composting process revealed the occurrence of three distinct thermal phases (Fig. 2), reflecting the successive stages of microbial succession and biochemical transformation of organic substrates [3, 21, 22].

In the early mesophilic phase (0–10 days), temperatures rose quickly from about 25°C to over 45°C, indicating vigorous microbial degradation of readily biodegradable compounds [23]. During the thermophilic phase (days 15–20), temperatures reached approximately 60–65°C. Maintaining temperatures above 55°C for several days is essential to ensure effective pathogen reduction and compost sanitization [24, 25]. After the thermophilic peak, a gradual decrease in temperature was observed from day 30 onward, marking the cooling phase, where mesophilic microorganisms progressively recolonized the substrate [23]. Finally, during the maturation phase (days 50–90), the

temperature stabilized close to ambient values (25–30°C), indicating that the compost had reached biologically stable conditions suitable for agricultural use [26].

The temperature changes recorded during the composting process (Fig. 2) reflect the typical progression of aerobic composting driven by microbial activity. In the early mesophilic phase (0–10 days), temperatures rose quickly from about 25°C to over 45°C, indicating vigorous microbial degradation of readily biodegradable compounds such as simple sugars and proteins. This initial temperature spike is a common feature of aerobic composting and serves as a clear sign that the process has been activated [21, 23].

During the thermophilic phase, observed around days 15–20, temperatures reached approximately 60–65°C. This stage is dominated by thermophilic microbes capable of decomposing more complex organic materials, including cellulose, hemicellulose, lipids, and proteins. Maintaining temperatures above 55°C for several days is essential to enhance decomposition and ensure effective pathogen reduction. This thermophilic period is widely recognized as critical for both compost sanitization and overall process efficiency [24, 25].

After the thermophilic peak, a gradual decrease in temperature was observed from approximately day 30 onward, marking the cooling phase. This decline reflects a reduction in microbial activity due to the depletion of easily degradable substrates. During this stage, mesophilic microorganisms progressively recolonize the compost and continue the transformation of the remaining organic matter, contributing to the stabilization of the material and the onset of humification processes [21, 23].

Finally, during the maturation phase (approximately days 50–90), the temperature stabilized close to ambient values (25–30°C). This stabilization indicates that the compost had reached biologically stable conditions. At this stage, the degradation of more resistant compounds such as lignin proceeds slowly, leading to the formation of humified organic matter and a mature compost suitable for agricultural use. Temperature stabilization near ambient conditions is therefore widely regarded as a reliable indicator of compost maturity and stability [23, 26].

Overall, the temperature profile observed in this study aligns with the classical three-phase model of aerobic composting. The distinct thermophilic phase, followed by gradual cooling and stabilization, indicates that the composting process occurred under optimal conditions. These findings highlight the value of temperature monitoring as a simple yet effective indicator of microbial activity, organic matter transformation, and the quality of the final compost.

Physicochemical properties of the substrate and compost

The changes in physico-chemical parameters between the initial substrate and the final compost, as shown in Table 1, demonstrate the efficiency of the aerobic composting process and underscore the strong interplay between microbial activity, temperature dynamics, and organic matter transformation.

Table 1
Initial and final physico-chemical characteristics of the composted substrate

Parameter	Initial State	Final State
Moisture Content (%)	9.49	50.42
Dry Matter (%)	90.51	49.58
pH	8.01	7.30
Electrical Conductivity (mS/cm)	3.21	3.64
Organic Matter (OM) (%)	39.08	19.93
Organic Carbon (OC) (%)	46.69	18.95
Mineral Matter (%)	51.43	29.65
Total Nitrogen (N) (%)	1.81	1.14
C/N Ratio	25.80	16.63
Phosphorus (as P_2O_5) (%)	0.79	0.52
Potassium (as K_2O) (%)	1.08	0.66

The substantial increase in moisture content from 9.49% to 50.42% (Table 1) played a decisive role in enhancing microbial metabolism, as moisture availability is widely recognized as a key factor controlling oxygen diffusion, enzymatic activity, and microbial respiration during composting. Similar moisture ranges have been reported as optimal for active composting and compost stabilization in recent studies [27, 28].

The progressive shift in pH from slightly alkaline to near-neutral values (8.01 to 7.30; Table 1) further confirms the occurrence of effective compost stabilization. During the early stages of composting, the production of organic acids induces temporary pH fluctuations; however, the subsequent degradation of these acids and the gradual formation of humic substances lead to pH buffering and stabilization. Near-neutral pH values are consistently described in recent literature as reliable indicators of compost maturity and suitability for agricultural application [27, 29].

The moderate increase in electrical conductivity observed during composting (from 3.21 to 3.64 mS cm^{-1}) is mainly associated with organic matter mineralization and the release of soluble inorganic ions. Recent investigations indicate that such increases in EC generally reflect enhanced nutrient availability rather than salinity risk, provided that values remain within agronomically acceptable thresholds, as observed in the present study [28]. This suggests that the final compost does not impose constraints for soil application.

The pronounced reduction in organic matter and organic carbon contents (39.08% to 19.93% and 46.69% to 18.95%, respectively) highlights the intensity of microbial degradation processes, particularly during the thermophilic phase, when carbon losses occur predominantly through CO_2 emissions. These trends are consistent with recent findings demonstrating that organic carbon depletion is a robust indicator of compost stabilization and microbial respiration efficiency [27]. Although total nitrogen content slightly decreased, the marked reduction in the C/N ratio from 25.80 to 16.63 (Table 1) confirms advanced compost maturity and indicates a low risk of nitrogen immobilization following soil application, as reported by several recent studies [28, 29].

The slight reductions observed in phosphorus and potassium contents (Table 1) can be attributed to dilution effects resulting from increased moisture content and organic matter loss, as well as possible mineral transformations during composting. Nevertheless, the retention of these essential nutrients in the final compost supports its agronomic value as a nutrient source and soil amendment. Overall, the combined evolution of moisture content, pH, electrical conductivity, organic matter, and C/N ratio reported in Table 1 confirms the production of a stable, mature, and agronomically valuable compost, in agreement with recent studies emphasizing the reliability of physico-chemical indicators for compost quality assessment [27, 29].

Soil analysis

The physico-chemical properties of the soil used in this study are presented in Table 2. According to the World Reference Base for Soil Resources (WRB), the soil was classified as an Arenosol, based on its sandy texture (100% sand), very low organic matter content, and lack of pedogenic horizon development, which are diagnostic features of Arenosols worldwide [30].

The soil exhibited a neutral to slightly alkaline pH (7.89), which is generally favorable for plant growth and nutrient availability. Similar pH ranges have been reported for Arenosols under agricultural use and are considered suitable for crop development, although nutrient retention remains limited [27]. The electrical conductivity was very low (0.09 dS m^{-1}), indicating that the soil is non-saline and does not present salinity constraints for agricultural use. The absence of calcium carbonate ($CaCO_3$ = 0.00%) confirms the non-calcareous nature of the Arenosol, a characteristic frequently observed in highly weathered sandy soils [31].

Organic matter content was extremely low (0.34%), reflecting poor biological activity and limited nutrient reserves, which are typical characteristics of Arenosols. Recent studies have highlighted that such low organic matter levels strongly limit microbial activity, nutrient cycling, and soil structural stability in sandy soils [32]. This low organic matter content is directly associated with the very low total nitrogen content (0.01%), indicating a high risk of nitrogen deficiency and leaching losses under conventional cropping systems [28].

Table 2
Physico-chemical characterization of the Arenosol

Parameters	Arenosol
pH	7.89
EC (dS m^{-1})	0.09
$CaCO_3$ (%)	0.00
OM (%)	0.34
N (%)	0.01
$N–NH_4^+$ (mg kg^{-1})	61.65
$N–NO_3^-$ (mg kg^{-1})	14.32
Available P (mg kg^{-1})	176.9
Exchangeable K (mg kg^{-1})	397
Sand fraction	100

Agronomic test and physiological response of beetroot

The agronomic and physiological performance of beetroot (*Beta vulgaris* L.) cultivated on Arenosol was strongly affected by compost amendment. Plant mortality occurred in the non-amended treatment, resulting in only 16 beetroot plants surviving until harvest, whereas all plants were maintained in the compost-amended treatment. Clear differences between compost-amended (C25) and non-amended (T0) treatments were observed at both vegetative and harvest stages, as illustrated in Figs. 3–5, reflecting contrasting soil fertility and nutrient availability conditions.

From an agronomic standpoint, compost application significantly enhanced vegetative growth, as evidenced by the higher number of leaves per plant in the C25 treatment compared with the control (Fig. 3). Increased leaf production in compost-amended soils has been widely reported and is attributed to improved nitrogen availability, better water retention, and enhanced microbial activity, particularly in nutrient-poor sandy soils [31, 33]. In contrast, plants cultivated on the non-amended Arenosol exhibited limited leaf development, highlighting the restrictive nature of sandy soils with low organic matter content.

Physiological responses further confirmed the beneficial effect of compost amendment. As shown in Fig. 4, chlorophyll content was markedly higher in beetroot leaves from the compost-amended treatment. Chlorophyll concentration is closely related to plant nitrogen status and photosynthetic efficiency, and its increase indicates improved nutrient assimilation and enhanced physiological functioning [34, 35]. Lower chlorophyll values observed in the non-amended treatment reflect nutrient

limitations typical of Arenosols, which negatively affect chlorophyll synthesis and photosynthetic performance [36].

The combined improvement in vegetative growth and physiological performance translated directly into enhanced root development. Beetroot roots harvested from compost-amended plots exhibited substantially higher fresh weight compared with those grown in non-amended soil (Fig. 5). Similar responses have been reported in studies showing that organic amendments promote root biomass accumulation by improving soil physical structure, nutrient availability, and carbon allocation toward belowground organs [31, 32]. In contrast, reduced canopy development and limited photosynthetic capacity in the control treatment resulted in smaller and less developed roots.

The higher plant mortality observed in the non-amended treatment further emphasizes the inability of Arenosols to sustain optimal beetroot growth in the absence of organic inputs. Previous studies have also reported poor plant establishment and increased mortality rates in sandy soils lacking organic amendments [37]. Compost application mitigated these limitations by improving soil structure, water-holding capacity, and nutrient retention, thereby creating more favorable conditions for plant establishment and growth.

Overall, the results presented in Figs. 3–5 clearly demonstrate that compost amendment significantly improves both agronomic traits and physiological responses of beetroot cultivated on Arenosol. The strong relationship observed between leaf development (Fig. 3), chlorophyll content (Fig. 4), and root biomass accumulation (Fig. 5) confirms that organic amendments enhance crop productivity through integrated improvements in soil fertility and plant physiological functioning.

Conclusion

In this study, a compost was prepared from a mixture of raspberry residues, sheep manure, and hydrodistillation by-products, allowing the valorization of agricultural and agro-industrial wastes. The composting process resulted in a compost suitable for agricultural use after 90 days, showing that a relatively short composting period can be sufficient to produce an organic amendment intended for soil improvement.

The application of this compost contributed to improving the conditions of an initially poor Arenosol, characterized by low organic matter content and limited capacity to retain water and nutrients. Organic amendment helped create a more favorable soil environment for crop growth.

As a result of these improvements, beetroot (*Beta vulgaris* L.) grown on compost-amended soil exhibited more vigorous vegetative growth, higher chlorophyll content, and greater root biomass accumulation. In contrast, plants cultivated on non-amended soil showed limited growth and higher plant mortality, confirming the constraints imposed by Arenosols in the absence of organic inputs.

Overall, this study demonstrates that the use of compost derived from local organic residues represents an effective and sustainable approach to improve sandy soil fertility and enhance beetroot agronomic performance, while contributing to more sustainable management of organic wastes.

Declarations

Ethics and consent to participate

Not applicable. This study did not involve human participants, animals or their data or biological materials. The plant material used in this study complied with local, national and international guidelines. The red beetroot (Beta vulgaris L.) cultivar “Plat d’Égypte” was a cultivated commercial cultivar grown from commercially purchased seeds (SOGEMAG, Berchid, Morocco; untreated standard seeds, lot no. 880102); no wild plants or plant parts were collected. Tomato (Solanum lycopersicum) and lettuce (Lactuca sativa) seeds were used only for germination bioassays. The aromatic and medicinal plant residues (rosemary) and the raspberry residues used for composting were industrial by-products supplied by EDEPAM and a fruit processing unit, respectively, and no plant material was collected from the wild by the authors. The cultivation and handling of all plant material complied with relevant institutional, national and international guidelines and legislation, and no specific permissions or licences were required. Details are given in the Materials and methods section (Plant material and compliance with guidelines).

Consent to participate

Not applicable.

Consent to publish

Not applicable.

Clinical trial number

Not applicable.

Competing interests

The authors declare no competing interests.

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Author Contribution

S.B. conceived the study, conducted the composting experiment and the laboratory analyses, and wrote the original draft of the manuscript. F.E. designed and supervised the agronomic experiment, performed the statistical analysis, prepared the figures and tables, and revised the manuscript. Y.A.M. carried out the soil analyses and contributed to data interpretation. R.H. and M.L. contributed to data collection and to the interpretation of the physicochemical results. M.O. supervised the work and reviewed and edited the manuscript. All authors reviewed and approved the final manuscript.

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Data Availability

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

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Figures

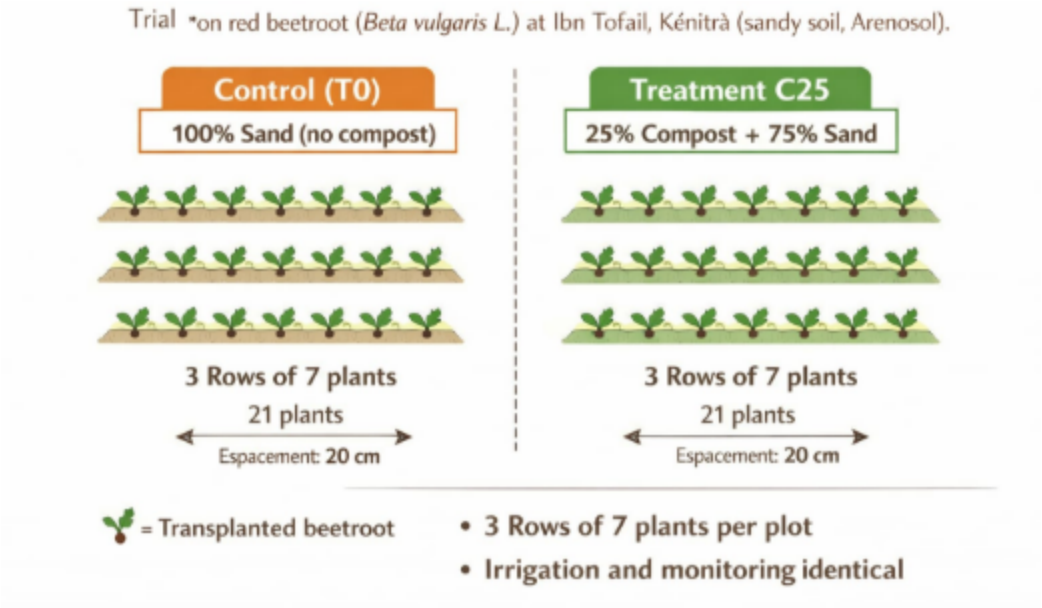


Figure 1

Experimental design of treatments

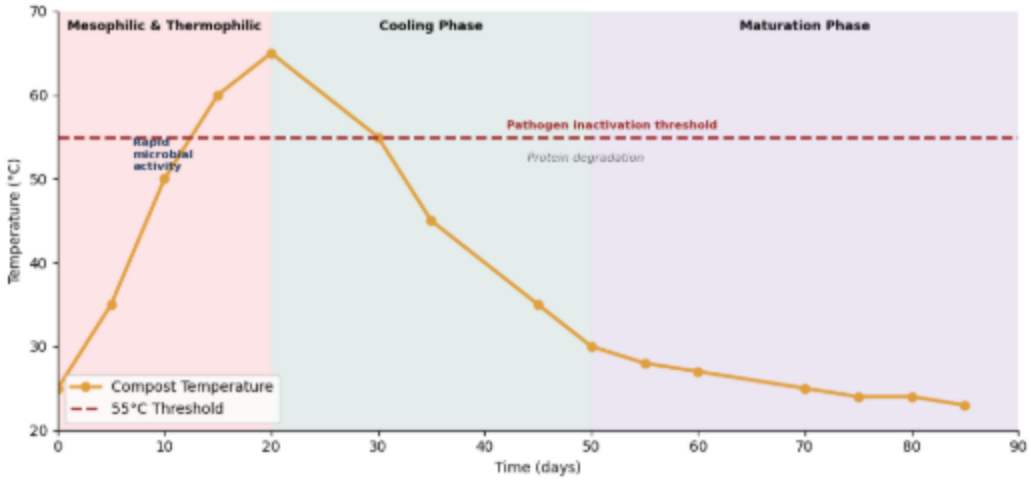


Figure 2

Evolution of composting temperature during 90 days

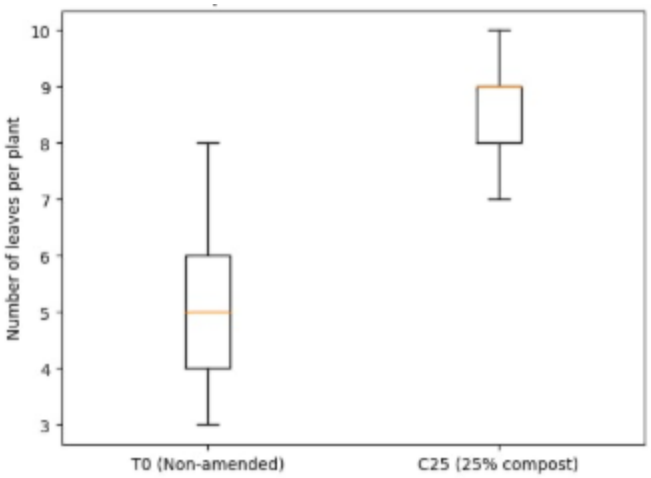


Figure 3

Effect of compost amendment on beetroot leaf number

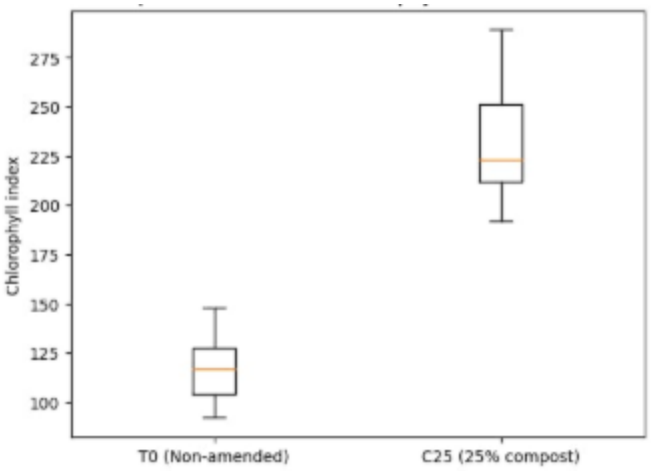


Figure 4

Effect of compost amendment on chlorophyll content in beetroot leaves

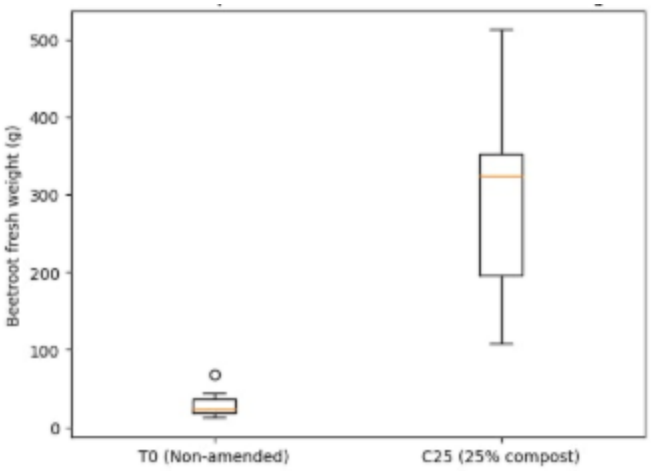


Figure 5

Effect of compost amendment on beetroot fresh weight