Assessment of quality and maturity of green waste compost in Algeria.

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Abstract

Currently, Algeria's environment and economic policies prioritise the implementation of circular economy ideas. The execution of these programmes mostly relies on the advancement of trash recycling and composting. This article aims to examine the sustainable management of green waste by means of composting. The objective is to evaluate the calibre and level of development of compost derived from green waste and to demonstrate that composting may serve as a sustainable substitute for incinerating green waste in Algeria. The approach relies on empirical investigation. A pilot initiative has been established at the El Khroub commune nursery to collect waste from pruning and weeding activities in green spaces. The purpose of this project is to make compost, which is a completely natural fertiliser. The physico-chemical investigations validate that the compost possesses favourable characteristics and is abundant in organic matter, rendering it appropriate for agricultural use. Furthermore, a germination test conducted with radishes yielded a germination rate of 97%, indicating that the compost is fully mature and poses no phytotoxicity or harm to plants. The research findings indicate that the effectiveness of composting is directly correlated with the rate at which the raw materials decompose and, most importantly, with the quality of the final output. The maturity of compost is a crucial criterion to consider and monitor to assess the quality of compost as a soil amendment.

Keywords: green waste; compost; quality, maturity; heavy metals

Introduction:

The majority of developing countries face serious environmental, social, and economic challenges when it comes to managing different types of solid waste (Haniyeh et al.,2020, cited by Bouadam, 2022a). The management of urban solid waste has made significant progress in recent years through the development and implementation of regulatory measures. Disposal, landfilling, and burning have been the most common methods in Algeria due to their low cost. Before 2002, the collected waste was sent to unauthorised and public dumps. Since 2002, to reduce the nuisance linked to waste and contribute to the development of new processing and recovery channels, an ambitious infrastructure development programmeme has been launched within the framework of the implementation of the integrated household waste management programmeme (Bouadam et al., 2022). According to the report of the Ministry of the Environment and Renewable Energy (MEER, 2017), waste production is estimated at more than 12 million metric tonnes per year. However, recycling is estimated at between 5% and 7%. To date, the method used for their disposal remains landfill, due to its low cost compared to other sectors such as incineration and composting (GIZ, 2014). On the other hand, the quantities intended for recovery are too low, of which only 1% by composting. In terms of green waste, the annual production is estimated at around 130,000 tonnes and market waste of 96,000 tonnes (GIZ, 2014). The source of this waste is agriculture […]. They are characterized by a high organic matter

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content and high humidity which makes their incineration difficult. This waste is collected and landfilled. Faced with this situation, the Algerian state insists on the need to reduce their landfill.

In the context of environmental protection, Algeria is involved in projects with several foreign cooperations aimed at developing sectors to recover waste and thus achieve and strengthen the circular economy. The wilaya of Constantine generates approximately 50,000 m^3 of green waste each year and does not have a composting unit (EPIC EPWG-CET, 2019).

As an indication, the municipality of El Khroub with its large area of green spaces which is estimated by (approximately 6520 m^2) produced each year approximately 18000 m^3 of green waste including 51 m^3 / day, all its quantities are collected and put into discharge without any valuation.
The process of recovering green waste through composting is a very useful process that has many environmental, economic and social benefits. Composting is one way to achieve sustainable development. It is in this context that the pilot project envisaged, the objective of which is the recovery of green waste by means of composting, to produce an organic fertilizer and the evaluation of its quality and maturity

Research methodology

As part of the preservation of the environment and to reduce the quantities of waste put in landfills through the biological treatment of composting, our contribution consists of launching an experimental study of the valuation of green waste by means of windrow composting and the evaluation of its quality and maturity. In this context, a pilot project for the recovery of waste from pruning and weeding operations in green spaces is being set up at the nursery of the municipality of El Khroub to produce 100% natural fertilising compost. This is already being done successfully in other countries, for example.

In order to achieve our goal, we relied on the experimental method and other means to collect information, such as specialised books and interviews with stakeholders in this field.

The experiment contributes to the recovery of green waste rejected by the pruning and weeding operations of green spaces in the municipality of El Khroub by composting to form a stable product called "compost." This study consists of evaluating the production of green waste and its recovery through composting. To do this, a mini-pilot in the open air was installed at the nursery of El Khroub. The windrow composting method was carried out in order to verify its performance.
The experiment lasted three months (from March to June 2019). During this practice, physico-chemical parameters will be determined.

Temperature and pH measurements are taken regularly. During this stage, the taking is carried out every week on Sunday, Tuesday, and Thursday at the same time. If the temperature drops, the swath is inverted to allow it to aerate and restart microbial activity. Each turnaround is followed by controlled watering. Turning allows the complete mixing of the compost and its homogeneous development. After about 3 months, the compost reaches maturity.

The source of green waste

Green waste refers to plant-derived leftovers that are produced as a result of gardening operations and the upkeep of green spaces. We differentiate:

Green waste is generated by humans.

The technical services of the communities generate municipal green waste. To be more exact, green waste refers to organic waste that is generated from the upkeep of green spaces, private gardens, greenhouses, sports grounds, and similar areas. Green waste refers to organic materials such as dead leaves, grass clippings, hedge trimmings, shrubs, pruning residues, flower bed maintenance trash, and private garden waste that are collected independently or through waste receiving centres (Ascher et al., 2005).

The principle of composting

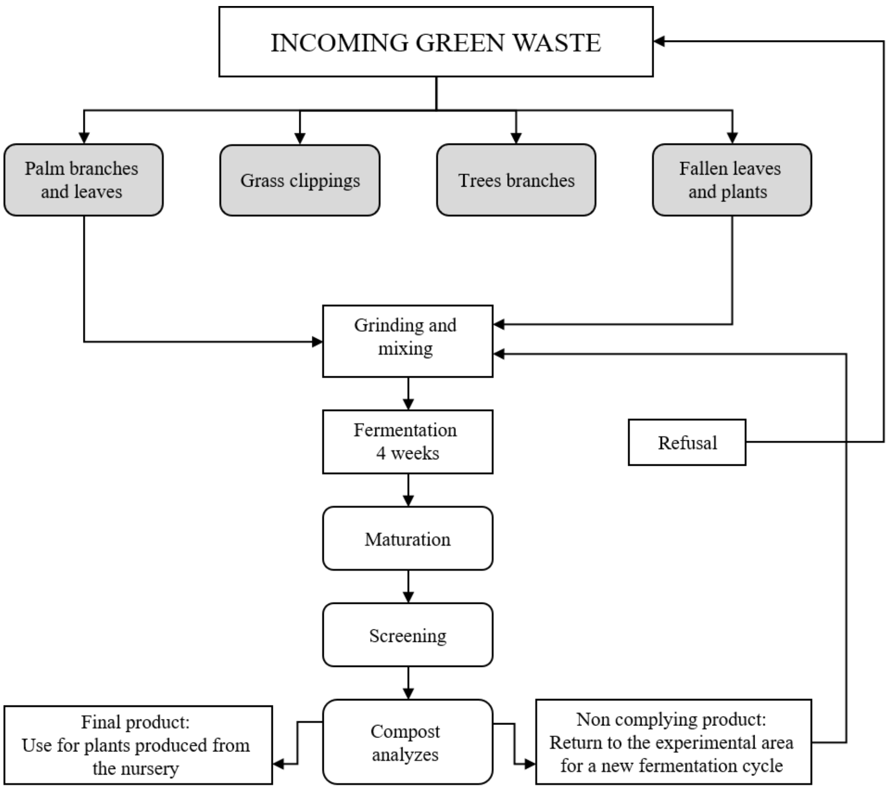
Composting is the process of breaking down organic materials in the presence of oxygen. Organic molecules undergo a series of sequential transformations, leading to the formation of compounds with progressively smaller molecular weights. This process ultimately yields carbon dioxide (CO_2) and water (Maustier P., 2004).

The impact of compost on soil

Compost enhances the fertility of the soil, according to Jenkins, Joseph (2005).

1. incorporates biological material.
2. Enhances reproductive capacity and efficiency.
3. It inhibits the occurrence of plant diseases.
4. enhances the capacity to retain water.
5. introduces beneficial microbes into the soil through inoculation.
6. Minimises the requirement for fertilisers.
7. The phases of composting

Fig. 1 Schematic of green waste compost



Source: Authors, 2023

Instructions for the composting experiment

Management and categorization of contaminants

To prevent contamination, it is essential to carefully separate the green trash, ensuring that no inert materials (such as soil combined with the waste) or undesired objects (such as plastic bags or leftover meals) are included.

Processing organic waste into smaller pieces
Shredding encourages the blending of waste materials from various categories and reduces the amount of space that waste takes up. The process enables the mixture to be restored to a carbon-to-nitrogen ratio of 30 to 35, which is crucial for optimal composting conditions. The shredder's primary objective is to optimise defibration, thereby enhancing the contact area available for microorganisms and promoting the decomposition of the woody component.

Windrowing
The swath should not be packed too tight, it will lack air. It should not be too ventilated; it will dry out very quickly. When windrowing, humidity must be controlled and if necessary, a water report must be made by sprinkling. This is done by sprinkling water with uncontaminated tap water.

Watering the compost batch
Watering the compost is one of the most important factors that increases the water content for the activity of microorganisms. We watered the lots to achieve humidity between 50% and 60%. Watering is from the top of the swath until the water runs off at the base.

The swath turning
Turnovers take place as soon as a significant drop in the temperature of the swath or in the oxygen content is observed. Their role is:
Aerate the mass of compost and promote the availability of oxygen necessary for the activity of microorganisms.
Facilitate degradation by improving the quality of the mixture of materials and by fragmenting woody materials.

Aerobic degradation
Refers to the process of breaking down organic compounds using oxygen. Heat is generated in the compost swath during the initial stage of composting. This phase is known as fermentation, which occurs as a consequence of the breakdown of organic matter. The process of fermentation, also known as decomposition, is particularly crucial in the central region of the compost heap. An emission of water vapour and other gases that were previously confined in the area is detected. Microorganisms decompose organic materials (waste) to generate carbon dioxide, thermal energy, and water vapour. his exercise exhibits a pronounced increase in temperature (reaching 65 °C or even higher), a decrease in humidity, and a substantial consumption of oxygen. Throughout the procedure, we monitor the emergence of macros and microbes, as well as the alteration in colour and grain size of the swath as time progresses. A 13-cm-long penetrating probe thermometer was used to measure the temperature of the swath three times per week throughout the entire composting process. The probe is fully entered from various sides of the windrow (core and peripheral) a total of six times to acquire the average temperature of the windrow. The probe is inserted into the compost, reaching the middle from the top of the swath. Due to the probe's limited length, a hole was manually excavated in the compost's centre. The pH of the compost was assessed three times each week using pH strips.

Examination
To achieve the necessary particle size, the raw compost undergoes a screening process with a mesh size of 0–20 mm. The resulting product is specifically designated for use in nurseries for plant cultivation.
Screening refusals measuring over 20 mm can be repurposed at the beginning of the process, utilised as a material for structure, or employed to safeguard plants from inclement weather.

The level of maturity of the compost
Fully decomposed compost is a uniformly dark brown substance that may appear black. The texture and aroma of the substance resemble those of potting soil, as experienced by the other animals. The compost must be safeguarded against adverse weather conditions such as excessive drying or

excessive moisture, potential nutrient loss through leaching, and the introduction of weed seeds by wind dispersal.

Assessment of compost ripeness

Laboratory analyses were conducted on the initial shredded green waste and compost at monthly intervals during the composting process.

The technique employed to conduct these analyses is the quartering sampling method.

Successive samples are collected from the swath at the beginning of the shredded material at intervals of 1 month, 2 months, and 3 months.

Unfold the fabric to create many apertures.

Specify four coordinates within the swath. Extract samples evenly from all layers of the compost.
For each 10 kilogramme sample, place it in a container with a total weight of 40 kg (10 kg * 4).

We achieve perfect homogenization.

To form the final sample, a 5 kg portion must be extracted from this homogenised mixture.

Seed viability assessment

A germination test was conducted using redis grains to assess the compost's quality and maturity. In order to conduct these studies, we have selected a species with a remarkably high germination capacity. A variety of combinations, consisting of compost, dirt, and potting soil, are placed in a tray containing 72 tiny cells.

For every combination, we utilised a total of 12 compartments, with each compartment containing 3 seeds. Following a 15-day period of daily irrigation, the germination rate was determined, and the lengths of the roots and shoots were compared.

Results and discussion

The tangible component of the compost

The composting process of green waste lasted for 92 days, during which regular watering and stirring were carried out as necessary. As a consequence, a compost with defined boundaries was formed, exhibiting the following characteristics:

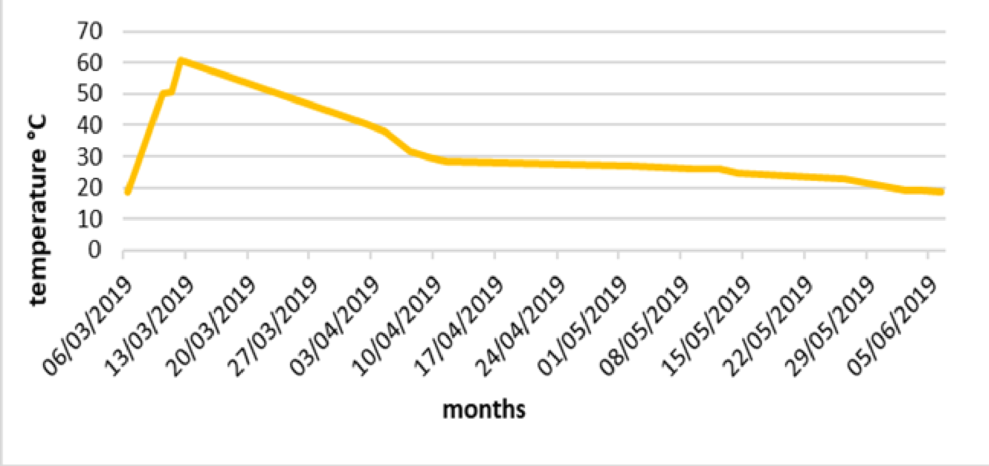
It is devoid of any ammonia scent.

The temperature of the compost is equivalent to the surrounding temperature. The texture is coarse, the colour is deep, and the aroma is pleasant. The original chemicals cannot be separated due to the high level of decomposition in the compost. Uniform.

The progression of temperature

Graph 1 displays the temperature (T °C) changes in the compost throughout a 3-month experiment on green waste composting, namely in the months of March, April, and May.
The temperature exhibits a quick and distinct increase over time, culminating on the 7th day of composting (during the initial stages of decomposition) at a maximum value of 60 °C.

Graph. 1 Evolution of temperature averages (° C)



Source: Authors, 2023

This is a result of microbial activity. The temperature increase is sought after during the hot fermentation phase for two specific reasons. Biodegradation speeds exhibit a substantial rise in correlation with temperature. Conversely, the increase in temperature fulfils the goal of sterilising the waste by eliminating any unwanted organisms that may be present initially, such as pathogens (Bayard et al., 2007).

The decline in temperature over time can be attributed to the deceleration of microbial activity. The deceleration is associated with the stabilisation of the organic materials in the compost. During fermentation, microorganisms undergo fast multiplication and transformation, leading to a rise in heat output. This is the initial stage of self-propelled acceleration. The fermentation phase typically commences during a span of 4 to 5 days.

Inckel et al. (2005) show that fermentation reaches its peak when the temperature of the compost heap is between 60 and 70 °C. This is due to the fact that the elevated temperature effectively eliminates a significant number of harmful microorganisms present in the organic material.

Pepin asserts that there are uncomplicated assessments to ascertain the age of composts. The attainment of a stable temperature in the compost signifies the conclusion of the phase characterised by intense deterioration (Pepin D., 2008).

Humidity

Throughout the process of composting, the increase in temperature causes a significant amount of water in the compost pile to undergo evaporation. It may decrease as a result of the drying process caused by the attained temperatures (Amir, S., 2005). Humidity decreases during the initial stages of composting as a result of water evaporation. PEPIN (2008) states that the magnitude of water losses fluctuates depending on the properties of the decomposed materials and the composting circumstances (Pepin D., 2008). According to Uri, one possible explanation is that the moisture content of the product should be below 50% (Uri M., 1994). The experiment yielded a moisture content measurement of 40% in the compost after a three-month period, satisfying the requirement. Insufficient water content hinders the growth of microorganisms, whereas excessive humidity saturates the gaps and suffocates microorganisms in the compost mixture pile (Belaib, 2012). The oxidation reactions of organic matter can lead to the formation of water, which in turn can cause a rise in humidity:

$$\text{Organic matter} + O_2 \text{ ---> } CO_2 + H_2O$$

The evolution of pH

The pH measurements were taken every three days a week during the composting process in the swath during the three months of the experiment. The results are shown in graph 2.

It should be noted that the pH in the swath varies from March to June. In March, it is slightly acidic (pH= 5). This phase is called the acidogenic phase, which results from the production of gas (CO_2) and acid. So the compost went through an acid phase due to microbial activity. Then it gradually increased towards neutrality in June (pH = 7.5). Due to the presence of microorganisms responsible for the degradation of organic matter, the decomposition of green waste can explain this pH variation.

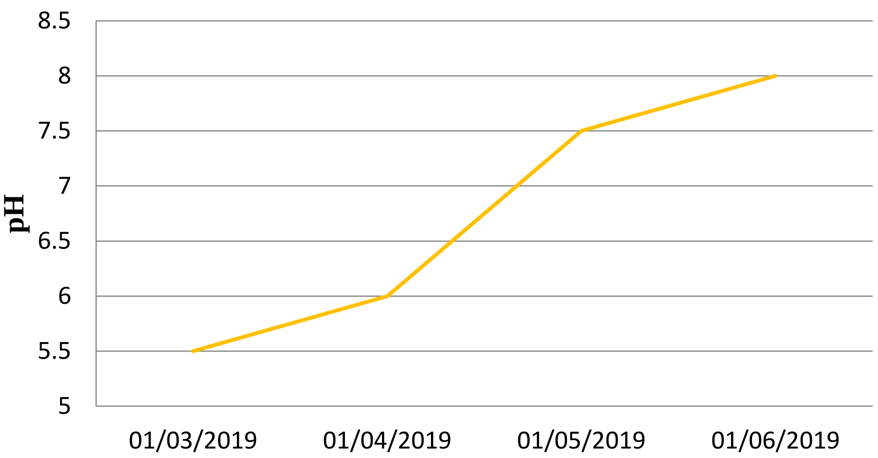
The compost then goes through a phase of alkalization, where the acidity decreases (the pH rises) thanks to the transformation of nitrogenous materials of plant and animal origin into ammonia.

The gradual release of the mineral elements contained in plant waste and their concentration in the compost confirm and maintain a basic atmosphere, which results in a final pH between 7.5 and 8.5.

This increase in pH can be explained either by the production of ammonium from the degradation of amines or by the release of bases previously integrated into organic matter. This is the thermophilic phase. After the thermophilic phase, the pH values should decrease a little and stabilise until they approach neutrality.

Under optimal conditions, acidic compost is too young and has not yet reached maturity. An acidic pH indicates poor stabilisation of the organic matter, which can lead to negative agronomic impacts after spreading the compost. So, the ripe composts are characterised by a pH between 6 and 9.

Graph. 2 Evolution of the pH



Source: Authors, 2023

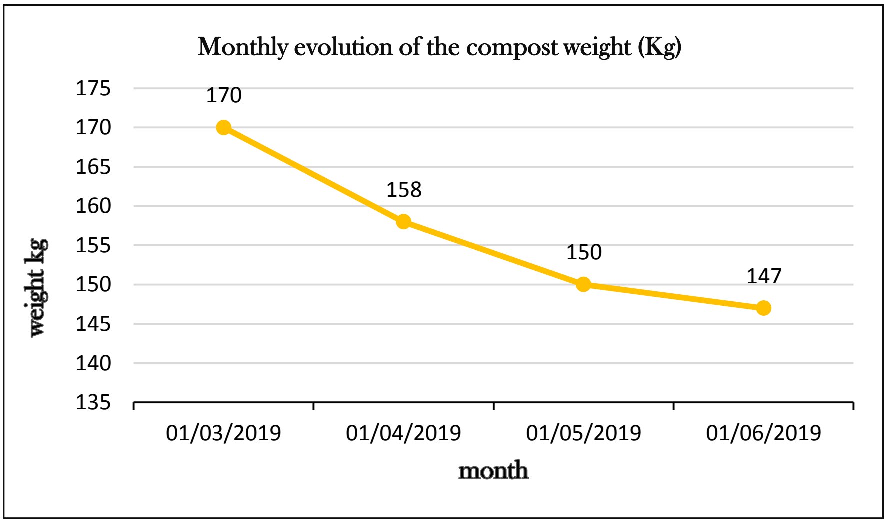
Monthly weight change (Kg)

Graph 3 shows that the fresh weight varies monthly and very significantly. During the months of experimentation, we notice a great loss of weight. The possible losses during composting mainly concern nitrogen and potash.

Composting results in a mass reduction of around 50% due to the release of CO_2 (mainly coming from the mineralization of cellulose) and water vapor. Thus, the mineral elements contained in the original raw material tend to concentrate during composting. During composting, the total volume and mass only decrease. The decrease in the total mass at constant humidity is caused by a decrease in the mass of organic matter during the degradation phase (degradation accompanied by losses of carbon by the departure of carbon dioxide), mineralization of the organic matter in CO_2, and losses of important water by evaporation.

The weight varies during the months of composting and gradually decreases up to 147 kg of the initial weight (see table 1). The organic matter has significantly decreased due to microorganisms. Organic matter + O_2+ H_2O + CO_2 + Heat + NH_3

Graph. 3 Monthly evolution of the weight (Kg) of compost



Source: Authors

Table 1 Quantitative assessment of compost production and rejects

WEIGHT		**Processing efficiency in % (W1/W0) x100**	**WEIGHT**		**Production yield in % (W2/W1) x 100**
Green waste W0	**Raw compost W1**		**Refusal**	**Refined compost W2**	
170 Kg	147 Kg	(147/170)x100	42.428 Kg	101.724 Kg	(101.724/147)x100
		86.47 %			69.2 %

Source: Authors, 2023

After the operation of screening the final product, the raw compost is estimated at 71% (the production yield) compared to the refusal, which represents only 29%, which is generally represented by the branches and leaves of palm trees, which are not completely decomposed because they were not well crushed and they take a long time to decompose. However, the presence of palm fronds was positive for the composting process; they helped considerably in the aeration of compost, especially at the bottom of the heap.

The chemical aspect of compost

Knowledge of the physico-chemical composition of waste is essential in the management and treatment of discharges and in predicting potential pollution risks for the environment. It therefore makes it possible to set up procedures for the control and reduction of polluting emissions in the receiving environment. Table 2 below shows all the results of the analyses carried out in the "technical centre" laboratory of the University of Rostock in Germany.

Table 2 The results of analyzes of green waste compost

		Sampling date10/06/2019	Standards
parameters	Units	Phase de maturation	
Organic carbon total	gN/Kg MS	14.4	-
Total nitrogen	g/Kg MS	1.2	0.5 – 1.8
The C / N ratio	g/Kg MS	12	10 - 20
Humidity	%	45	40 – 65
Organic matter or volatile solids (SV)	%	45,2 %	20 - 50
Matières sèche	%	50,7 %	50 - 60
pH	-	7,84	7 - 8
Potassium	g/Kg MS	1.4	0.6 – 1.8
Phosphor	g/Kg MS	0.6	0.4 - 1
Electrical conductivity	µS/cm	1587,00	-

Source: Authors

The C / N ratio

Different parameters can be used to determine the maturity and quality of the compost. The C/N ratio, the recommended value of which is in the interval (10–15), constantly decreases during composting to stabilise in a finished compost around 10: This is explained by the fact that microorganisms consume more carbon than nitrogen. According to Mustin, the increase in the percentage of total nitrogen during the composting process comes from the degradation of the proteins of the starting materials under the effect of heat. And the action of microorganisms. We can also assume that part of the increase in nitrogen comes from the residues of microbes and bacteria that have multiplied, especially during the first phase of composting (Mustin, 1987). The leaching of nitrogen following repeated waterings and rains may account for the decline in its percentage.

Organic matter or volatile solid (SV)

The results of the analysis of the sample of the reconstituted green waste compost show that the volatile solids represent, on average, 45.2%. This rate is comparable to the European standard, which varies from 20 to 50% depending on the waste. According to Inckel, the end product is well-decomposed organic material containing humus and nutrients. Organic matter improves the physical properties of the soil. This promotes root development, biological development, and tillage. Organic matter in the soil reduces the risk of erosion phenomena (Inckel et al., 2005).

Heavy metals

For compost, the most often used quality criterion is the heavy metal content, which can come from different sources. Evaluating the quantities of heavy metals is important and allows us to assess their polluting potential. The presence of heavy metals in waste has various adverse effects on human and animal health and the environment more generally. The results of the analysis of the sample of the reconstituted green waste compost showed that the product is poor in heavy metals (Table 3).

Table 3 Limits for heavy metals in the European regulations on compost (mg.Kg-1)

Heavy metals	Green waste compost	Regulation values
Cadmium (Cd)	1.5	1.2 - 4
Chrome (Cr)	100	50 - 750
Copper	100	60 - 1200
Lead	150	120 - 1200
Mercury	1	0.3 - 25
Nickel (Ni)	50	20 - 400
Zinc (Zn)	400	200 – 4000

Source: Peter et al, 2001

The germination test

Adding immature compost to the soil has negative effects on the germination, growth, and development of plants. The phytotoxic effect of immature compost is due, among other causes, to the excessive presence of toxic and harmful compounds (excess ammonia and organic acids, pathogens, heavy metals, excess salinity, etc.). Thus, the maturity and degree of stability of a compost are the most important characteristics to consider when testing its quality (Compaore et al., 2010). During the experiment, a germination test is carried out to test the quality as well as the degree of maturity of the green waste compost. Figure 2 shows the first germinations in the substrates used after one week. At the end of the test, the total number of seedlings obtained makes it possible to calculate the germination rate. The germination test results are reported in Table 4 below.

$$Germination\ rate\ in\ \% = \frac{Number\ of\ germinated\ seeds}{Number\ of\ seeds\ tested}/100$$

Table 4 The germination rate of different substrates

	substrate	Number of germinated seeds	Number of germinated seeds	Germination rate
1	50% Compost 50% Soil	35	35*100/36	97 %
2	50 % Potting soil 50 % Soil	20	20*100/36	55 %
3	100 % Soil	14	14*100/36	39 %
4	100% Compost	33	33*100/36	91 %

Source: Authors, 2023

Figure 2: radish germination results

Source: Authors, 2023

Substrate 50% potting soil with 50% soil gave a germination rate of 55%; in contrast, cultivation on 100% soil gave a very high germination rate. Low at 39%. The last 100% compost substrate has a germination rate of 91%.

The significantly highest germination rates were therefore obtained with the addition of substrate n° 1 (50% soil, 50% compost) and substrate n° 4 (100% compost); this shows that the compost is mature and does not represent phytotoxicity or danger to plants, and the analyses already carried out confirm that it is a quality compost.

After a few days, and to calculate the growth of the plants on the different substrates used, we see that substrate n° 1 (50% soil, 50% compost) presents a good growth of leaves, stems, and roots compared to two other substrates.

Conclusion

Composting as a sustainable method of managing green refuse is the subject of this article. The objective of this study is to evaluate the compost's development and quality as it is derived from green waste. Composting represents a significant ecological dilemma despite its potential as a highly viable economic instrument that provides intriguing avenues for resource conversion from refuse.

The outcomes of laboratory examinations conducted on the organic product conformed to established criteria: by the conclusion of the decomposition phase, the relative humidity hovered above 50% and the pH tended towards neutrality (pH = 7.84). Weight reduction occurs as a result of decomposition. Additionally, this fertiliser is abundant in minerals necessary for plant growth and organic matter, which are the fundamental components of carbon and nitrogen.

The germination test conducted using radishes yields a germination rate of 97%, which indicates that the compost has reached maturity and no longer poses a threat to plants in terms of phytotoxicity.

Green waste composts continue to be a valuable organic matter resource for agricultural purposes, contributing to the enhancement of soil fertility. A multitude of studies have provided evidence of both qualitative and quantitative benefits associated with crops. This enhancement appears to be attributable more to the organic amendment's impact on the soil than to nutrient supply.

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