

High School Students for Agricultural Science Research

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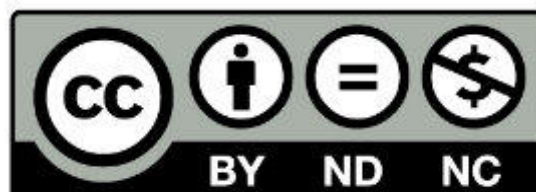
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Quince años de investigaciones con adolescentes. CAOS se mueve al plano Internacional

A lo largo de estas páginas podréis disfrutar de una nueva serie de investigaciones llevadas a cabo en centros de secundaria y dirigidas por investigadores de nuestro centro: la Estación Experimental del Zaidín. Como novedad importante, este año se han incorporado investigaciones de un nuevo centro de Investigación, el Instituto de Hortofruticultura Subtropical y Mediterránea La Mayora de Málaga. A su vez, tres nuevos Institutos de Secundaria se estrenan en este tipo de proyectos: IES Hermenegildo Lanz, IES Albaycín (ambos de Granada) y IES Torre del Prado (en la provincia de Málaga). Los alumnos, de la mano de sus profesores se embarcan en miniproyectos estrechamente relacionados (o no??) con proyectos de Investigadores de la casa. Como ejemplos destacados: (i) "usar la escuela como prueba de concepto en experimentos sobre percepción social y evaluaciones sobre la elaboración de bio-compost" (en las pgs 1-16). (ii) Claramente consolidado y cada vez más excepcional por el número de alumnos que participan (>120) procedentes de 5 centros de secundaria distintos es "el estudio fenológico de árboles como indicadores de cambio climático" al que este año se ha incorporado tb el análisis de aves (pgs 90-111). O (iii) iniciativas originales en las que alumnos de conservatorio de música se adentran en el terreno de la biología para determinar si "la música afecta a la fisiología de bacterias" (pgs 64-79). En general hasta 9 investigaciones presentadas en el VI congreso CAOS de la pasada primavera y que han terminado en manuscritos recogidos en este volumen. Os animo también a que os adentréis en el apartado de "*my own ideas*" de cada trabajo donde los alumnos participantes reflejan el impacto de lo aprendido y que va mucho más allá que los meros resultados obtenidos en la investigación.

Sin ninguna duda este volumen refleja un ilusionante punto de partida del proyecto que comienza y busca extender esta metodología más allá de nuestras fronteras en un contexto Europeo. Nace CAOS+ (Consolidating and Advancing Outreach Synergies). Un proyecto internacional seleccionado en la convocatoria ERASMUS+ KA20-2026 que busca extender este método a centros de secundaria en Europa. Coordinado desde la Estación Experimental del Zaidín, el consorcio lo forman cuatro instituciones de España, Portugal (Instituto de Tecnología Química e Biológica de Universidade NOVA de Lisboa) e Italia (Università degli Studi di Torino, UNITO) apoyadas por la empresa TKV (*TeKieroVerde*) que coordinará la implementación de los recursos didácticos que permitan de una manera ágil extender esta experiencia consolidada durante 15 años. El proyecto contará a su vez con el Museo Nacional de Ciencias Naturales de Madrid, que tendrá un especial protagonismo como sede de los eventos finales programados.

Francisco Martínez-Abarca

Investigador Responsable

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Preliminary results of the HUÉTORCOMPOST project: Integrating soil biological quality and social perception to evaluate school bio-waste composting

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Summary

Soil organic matter is essential for maintaining soil fertility, biodiversity, and ecosystem functioning. Composting of bio-waste is a sustainable circular economy strategy that recycles organic residues into valuable amendments capable of improving soil quality. This study evaluated the biological effects of school-produced compost in soils and the social perception of bio-waste composting through the citizen science project HUÉTORCOMPOST at IES Los Neveros (Granada, Spain). Three environments with contrasting organic matter contents, a school bio-waste composting bin (BC), a garden soil (GS), and a degraded playground soil (DPS), were compared by analysing moisture, pH, electrical conductivity, microbial respiration, seed germination, cultivable bacteria and fungi, and soil invertebrate biodiversity. Additionally, an online survey involving 286 members of the educational community assessed knowledge, attitudes, and perceptions regarding composting and bio-waste recycling. BC showed the highest moisture content, microbial respiration, microbial abundance, and invertebrate diversity, highlighting the positive influence of organic matter on soil biological activity. Although its relatively low germination index indicated incomplete maturity, the compost exhibited advanced biological stabilization. Survey participants demonstrated a high level of awareness and a positive perception of composting as an environmental and educational tool, despite persistent concerns about odours and management complexity. Despite being preliminary results, HUÉTORCOMPOST project demonstrated that school composting effectively enhances soil biological quality while promoting environmental education, citizen participation, and sustainable bio-waste management.

Keywords: Bio-waste composting, Soil biological activity, Citizen science, Environmental education, Circular economy, Soil biodiversity

INTRODUCTION

Soil organic matter (SOM) is a key determinant of soil fertility, ecosystem functioning, and agricultural sustainability [1]. It improves soil physical, chemical, and biological properties by enhancing aggregate stability, water retention, nutrient availability, and microbial activity, while contributing to carbon sequestration and climate change mitigation. However, intensive agriculture, land degradation, erosion, and increasing aridity have led to a continuous decline in SOM worldwide, particularly in Mediterranean regions that are highly vulnerable to desertification. Consequently, restoring soil organic matter has become a major environmental priority, as reflected in European initiatives such as the EU Soil Strategy for 2030 [2] and the Circular Economy Action Plan [3].

Bio-waste, mainly composed of food and green residues, represents an abundant source of organic matter that can be recycled through composting [4,5]. This aerobic biological process transforms unstable organic residues into a stable amendment suitable for agricultural use through the activity of diverse microbial communities [6]. Besides diverting biodegradable waste from landfills, compost improves soil fertility, stimulates microbial activity, enhances biodiversity, and increases agroecosystem resilience, making decentralized composting an attractive solution for municipalities, schools, and other public institutions [7].

The European Union has strengthened legislation promoting separate bio-waste collection and recycling through Directive (EU) 2018/851, which established mandatory separate collection by the end of 2023. In Spain, these requirements were incorporated into Law 7/2022 on Waste and Contaminated Soils for a Circular Economy, promoting local treatment of organic waste and nutrient recycling. However, the long-term success of composting programmes depends not only on technical implementation but also on public participation, environmental awareness, and social acceptance [7].

Educational centers provide ideal settings for decentralized composting because they generate bio-waste while offering opportunities for experiential learning and environmental education [8,9]. School composting projects enable students to participate in authentic scientific research, developing knowledge of soil ecology, microbiology, waste management, circular economy, and climate change. Within this context, citizen science has become an effective approach for promoting scientific literacy, critical thinking, and environmental responsibility through collaboration between researchers, teachers, and local communities. Although compost has been extensively studied as an organic amendment, relatively few studies have simultaneously evaluated its effects on soil biological quality and public perception within educational environments. Integrating ecological and sociological assessments provides a more comprehensive understanding of school composting programmes and their environmental and educational impacts.

MATERIAL AND METHODS

1. Citizen science framework

The HUÉTORCOMPOST project was conducted during the 2025–2026 academic year at IES Los Neveros (Huétor Vega, Granada, Spain) as part of the Andalucía + Ciencia Ciudadana programme [10–12]. The project was developed through a citizen science approach involving secondary school students, teachers, researchers from the Estación Experimental del Zaidín

(EEZ-CSIC), and environmental educators from Ariadna Estrategia Ambiental. Students actively participated in all stages of the research, including sampling, laboratory analyses, data interpretation, and dissemination of the results, under the supervision of researchers and teachers.

The research aimed to evaluate the influence of organic matter derived from composted bio-waste on soil biological quality while simultaneously assessing the social perception of composting within the educational community. To achieve this objective, both environmental and sociological approaches were combined into a single experimental design.

The present study reports the preliminary results of the ongoing HUÉTORCOMPOST project, corresponding to its mid-term evaluation.

2. Sampling sites

Three locations with contrasting organic matter contents were selected within the school facilities (Figure 1):

- School bio-waste composting bin (BC): Mature and partially matured compost produced from food waste and pruning residues generated at the school.
- School garden soil (GS): Cultivated soil receiving regular agronomic management and organic inputs.
- Degraded playground soil (DPS): Compacted ornamental soil with very low organic matter content and limited biological activity. This was form mainly by "albero" soil.

These three environments represented a gradient of soil organic matter availability and biological activity, allowing the influence of compost on soil quality to be evaluated. Composite samples were collected from each site, homogenized, transported to the laboratory, and analysed immediately after sampling.



Figure 1. An overview of the three sampling sites studied in this research: BC (bio-waste composting bin), GS (garden soil) and DPS (degraded playground soil). All locations were at IES Los Neveros (Huétor Vega, Granada, Spain)

3. Physicochemical analyses

The following physicochemical properties were determined for each sample, according to previous studies:

- Moisture content [13]. Moisture content was determined gravimetrically by drying fresh samples at 105 °C in an oven until constant weight. Results were expressed as percentage of fresh weight.
- Soil pH [13]. The pH was measured using a portable pH meter after aqueous extraction of the samples following a 1:10 (w:v) sample-to-water ratio.
- Electrical conductivity (EC) [13]. Electrical conductivity was measured in the same aqueous extracts used for pH determination using a portable conductivity meter. EC was expressed as mS cm^{-1} and was used as an indicator of soluble salt concentration.
- Soil biological activity [13]. Microbial respiration was estimated through CO_2 emission measurements, which were used as an indirect indicator of microbial activity. Approximately equal amounts of each sample were incubated in airtight containers connected to a portable gas analyser. Carbon dioxide accumulation inside the containers was monitored until stable emission rates were obtained. Results were expressed as $\text{ppm CO}_2 \text{ kg}^{-1} \text{ s}^{-1}$. Higher respiration rates were interpreted as reflecting greater microbial metabolic activity and therefore higher biological quality of the evaluated substrate.
- Seed germination bioassay [14]. Compost maturity and potential phytotoxicity were evaluated using a seed germination test. Water extracts were prepared from each sample and used to germinate *Lepidium sativum* seeds under controlled laboratory conditions. The Germination Index (GI) was calculated by combining seed germination percentage and root elongation relative to the distilled water control. GI values below 70% were considered indicative of phytotoxic effects associated with insufficient compost stabilization, whereas values higher than 70% indicated mature and non-phytotoxic materials.
- Enumeration of cultivable microorganisms [14]. The abundance of cultivable bacteria and fungi was assessed using conventional microbiological techniques. Serial dilutions of each sample were prepared in sterile saline solution and plated onto selective culture media suitable for bacterial and fungal growth. Plates were incubated under laboratory conditions until visible colonies developed. Because the educational purpose of the project focused on comparing relative microbial abundance among substrates rather than obtaining absolute microbial counts, colony development was evaluated qualitatively according to the density of colonies observed in the culture plates.
- Invertebrate biodiversity [15]. Macro- and mesofauna associated with each substrate were evaluated using the Berlese funnel extraction method. Fresh samples were placed inside Berlese funnels equipped with a light source (40 w) that gradually forced soil invertebrates to migrate downward into collection containers containing preservative solution (ethanol 70% v/v). Recovered organisms were counted and classified into the main taxonomic groups observable by secondary school students, including: insect larvae, collembola, mites, woodlice, beetles, ants, pseudoscorpions and spiders. The abundance of each group was used as an indicator of biological diversity associated with the different organic matter contents.

4. Social perception survey

To evaluate public awareness and acceptance of composting, an anonymous online questionnaire was designed using Google Forms. The survey was distributed through the institutional mailing lists of IES Los Neveros and remained open during the experimental period. The form is accessible at the following link: <https://forms.gle/bjub8iuiVwHf48dX6>. Responses were collected from students enrolled in secondary education (ESO), high school students (Bachillerato), and teachers.

The questionnaire included questions regarding:

- current household waste disposal habits;
- previous knowledge of composting;
- perceived functions and environmental benefits of compost;
- educational value of composting within schools;
- perceived barriers that may discourage composting among the general population.

By the end of the survey period (21 April 2026), 286 valid responses had been collected, providing a representative overview of the educational community participating in the project.

5. Data analysis

Experimental data obtained from physicochemical and biological analyses were expressed as mean values with their corresponding variability (standard deviation). Due to the educational nature of the project and the preliminary character of the study, the results were primarily interpreted through descriptive comparisons among the three sampling sites. Survey data were analysed by calculating response frequencies and percentages for each question.

6. Use of Artificial Intelligence

Artificial intelligence (ChatGPT, OpenAI, GPT-5.5) was used exclusively to support language editing and improve the clarity and readability of the manuscript. The study design, data collection, analyses, interpretation of the results, and all scientific conclusions were carried out by the authors, who take full responsibility for the content of this article.

RESULTS AND DISCUSSION

The preliminary results of the HUÉTORCOMPOST project have demonstrated that school composting constitutes an effective strategy not only for recycling bio-waste but also for improving soil biological quality and promoting environmental education through citizen science. By integrating laboratory analyses with a sociological survey, the project provided a comprehensive evaluation of the environmental and educational benefits associated with decentralized composting or vermicomposting in secondary schools [13].

Physicochemical properties

Clear differences in the physicochemical characteristics of the three studied environments were observed, reflecting their contrasting organic matter contents. The BC sample exhibited the highest moisture content, reaching values close to 55%, whereas the GS contained approximately 20% moisture and the DPS less than 10% (Figure 2A). This result reflects the

high water-holding capacity of composted organic matter and the limited moisture retention of the degraded playground soil. The pH also differed among the substrates. BC presented a slightly acidic to neutral pH (approximately 7.6), while both soils (GS and DPS) were moderately alkaline, with values close to 7.9 (Figure 2B). Although these differences were relatively small, they indicate that the composting process generated a substrate with chemical properties distinct from the surrounding mineral soils. Electrical conductivity (EC) showed a marked increase in the compost compared with both soils (Figure 3A). EC values in BC sample were almost one order of magnitude higher than those measured in the GS and DPS samples, reflecting the greater concentration of soluble nutrients released during organic matter decomposition. Despite this higher salinity, EC values remained within the range commonly observed in immature or partially stabilized bio-waste composts.

Compost maturity was evaluated through the seed germination bioassay (Figure 3B). The GI of BC was approximately 22%, considerably lower than the values measured in the GS ($\approx 98\%$) and the DPS ($\approx 82\%$). These results indicate that the compost had not yet reached complete biological maturity and still contained phytotoxic compounds derived from the ongoing degradation of organic matter. Nevertheless, the GI values suggest that the compost was undergoing the final stabilization stage rather than representing a completely unstable material.

Soil biological activity

Microbial respiration clearly reflected the influence of organic matter availability on biological activity (Figure 4). BC exhibited by far the highest CO_2 emission rate, exceeding $300 \text{ ppm CO}_2 \text{ kg}^{-1} \text{ s}^{-1}$, whereas respiration in GS sample was approximately seven times lower and DPS soil showed only minimal microbial activity. The progressive decrease in respiration from compost to garden soil and finally to playground soil demonstrates the close relationship between organic matter availability and microbial metabolism. It is well known that the biologically active compost provided abundant organic substrates for microbial communities [14], while the degraded playground soil contained insufficient organic resources to sustain comparable levels of microbial activity.

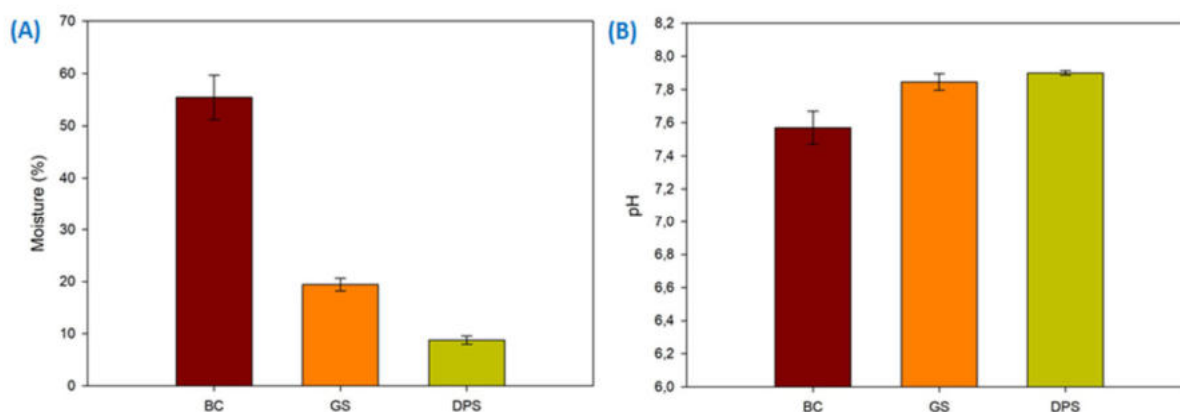


Figure 2. Moisture (A) and pH (B) in the three sampling sites studied in this research: BC (bio-waste composting bin), GS (garden soil) and DPS (degraded playground soil).

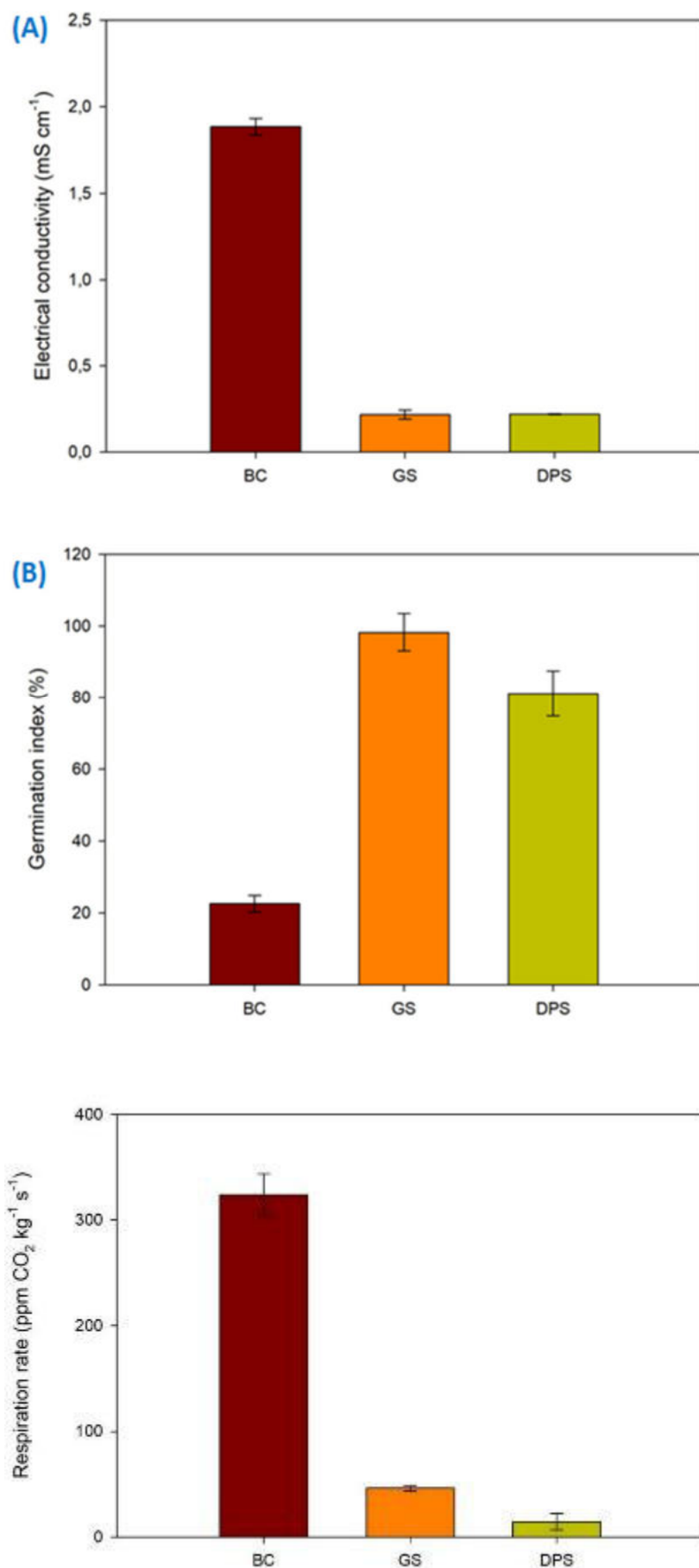


Figure 3. Electrical conductivity (EC) (A) and germination index (B) in the three sampling sites studied in this research: BC (bio-waste composting bin), GS (garden soil) and DPS (degraded playground soil).

Figure 4. Respiration rate of CO₂ in the three sampling sites studied in this research: BC (bio-waste composting bin), GS (garden soil) and DPS (degraded playground soil).

Cultivable microorganisms

The abundance of cultivable microorganisms followed the same pattern observed for microbial respiration. Culture plates inoculated with BC extracts showed abundant bacterial colony development, whereas considerably fewer colonies appeared in samples from the GS sample, and only isolated colonies were detected in DPS (Figure 5A). This qualitative comparison indicates that cultivable bacterial populations increased with increasing organic matter availability. A similar trend was observed for cultivable fungi (Figure 5B). Compost samples exhibited numerous fungal colonies with different morphologies, while fungal abundance progressively decreased in the garden soil and was almost absent in the playground soil. Overall, both bacterial and fungal populations followed the sequence: BC >> GS > DPS, indicating that compost provides a highly favorable habitat for microbial growth due to its elevated organic carbon content and nutrient availability [14].

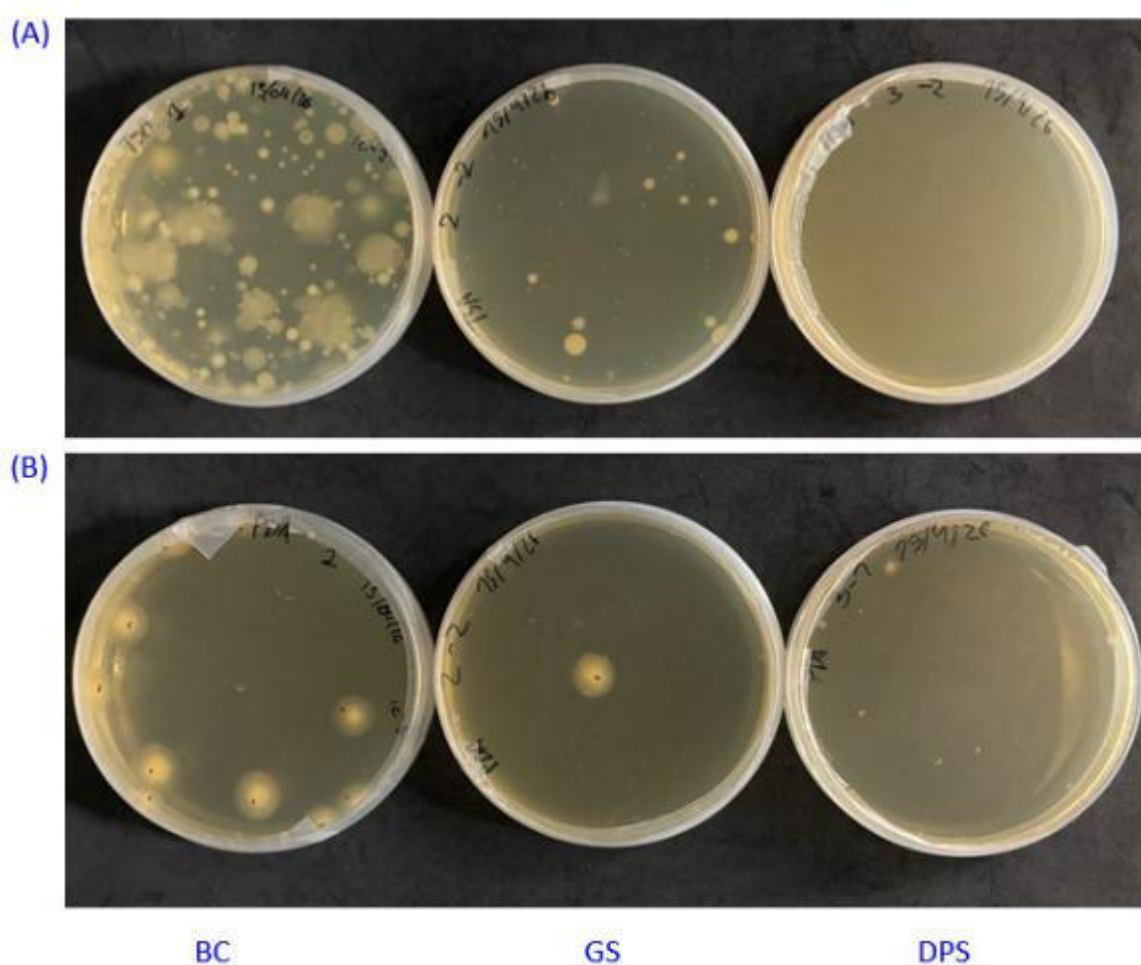


Figure 5. Cultivable bacteria (A) and fungi (B) in the three sampling sites studied in this research: BC (bio-waste composting bin), GS (garden soil) and DPS (degraded playground soil).

Invertebrate biodiversity

Marked differences were also found in soil fauna diversity. Macro- and mesofauna were detected exclusively in the BC samples, whereas no invertebrates were recovered from either GS or DPS using the Berlese extraction system (Figure 6). The compost community was dominated by insect larvae, followed by collembola, mites, woodlice, and pseudoscorpions.

Smaller numbers of ants, beetles, and spiders were also recorded. The exclusive presence of these organisms in the compost confirms that decomposing organic matter provides suitable habitat and food resources for a diverse decomposer community, whereas mineral soils with low organic matter content support much lower faunal diversity under the studied conditions [15].

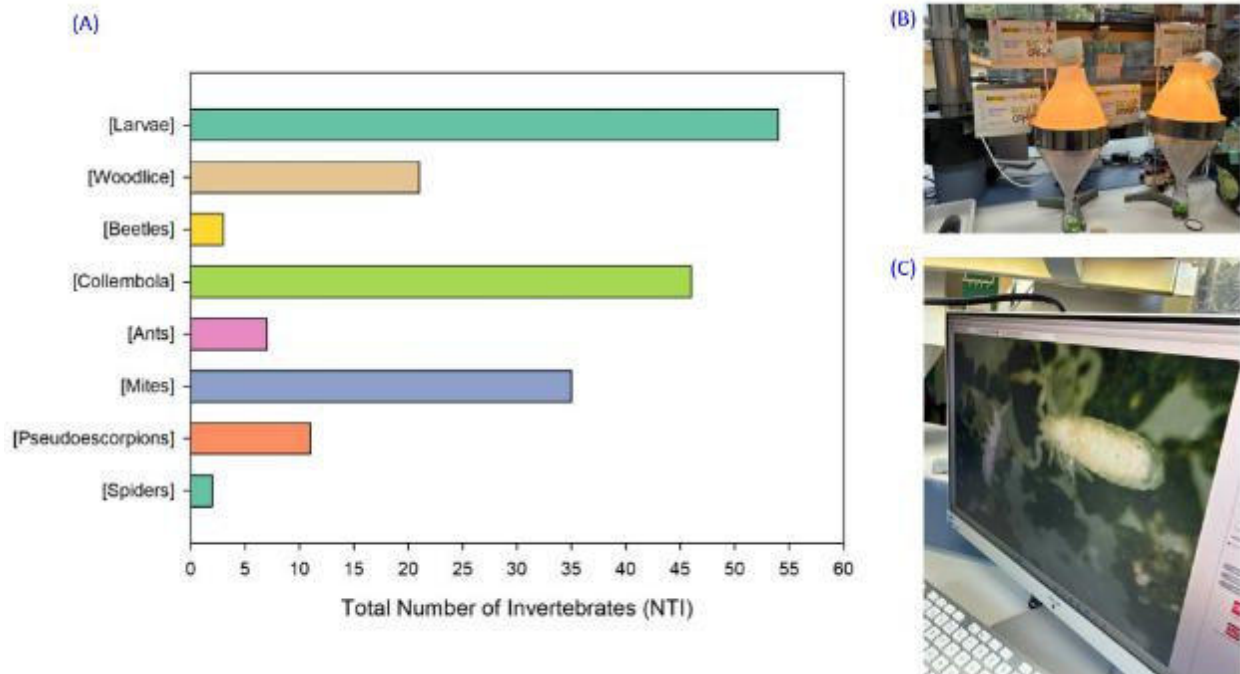


Figure 6. Total Number of invertebrates (A) detected in BC (bio-waste composting bin) samples. An overview of the Berlese funnel system (B) and the digital microscope (x10) used to identified invertebrates (C) are also shown.

The comparison of three environments with contrasting organic matter contents clearly showed that compost harboured substantially greater biological activity than either the garden soil or the degraded playground soil. The higher moisture content, increased microbial respiration, greater abundance of cultivable bacteria and fungi, and the exclusive presence of diverse invertebrate communities in the compost all indicate that organic matter is the principal driver of biological activity within these substrates. These findings reinforce the widely recognised role of compost as a key resource for restoring soil biological functioning and enhancing ecosystem services [16].

Social perception of composting

A total of 286 members of the educational community completed the online questionnaire, including students from secondary education (ESO), high school students, and teachers. The survey therefore provided a broad representation of the school community involved in the project. Regarding previous knowledge, 90.9% of respondents had heard about composting, with 61.9% indicating that they clearly understood what composting is, whereas only 9.1% had never heard of it. This result indicates a relatively high level of environmental awareness within the school community.

Participants also demonstrated a good understanding of the main purpose of composting. Approximately 85.0% correctly identified composting as a process that simultaneously reduces

organic waste, produces natural fertiliser, and contributes to environmental protection. Only a small proportion of respondents considered composting useless or reported not knowing its function.

When asked about the environmental benefits of compost, 78.7% recognised its capacity to improve soil fertility by supplying nutrients, improving soil structure, and increasing water retention. In addition, 49.7% associated compost use with carbon sequestration and greenhouse gas mitigation. Very few respondents believed that compost served merely decorative purposes.

The educational value of composting was also widely recognised. Nearly two-thirds of respondents (63.6%) considered composting an effective tool for promoting environmental awareness and sustainability within schools, while approximately half believed that it contributes to improving waste management practices (54.2%) and teaching concepts related to the circular economy (40.9%).

Despite this generally positive perception, respondents also identified several barriers that may limit composting adoption by people unfamiliar with the practice. The most frequently cited concerns were the generation of unpleasant odours (52.8%) and the perception that composting is inconvenient or requires excessive effort (52.8%). Other common misconceptions included the belief that composting is useless (44.8%) or difficult to maintain (30.4%). Addressing these barriers through evidence-based environmental education and practical demonstrations should therefore constitute a priority for future outreach activities [7].

Overall, the survey demonstrates that the educational community of IES Los Neveros shows a favourable perception of composting, recognises its environmental and educational benefits, and identifies the main misconceptions that should be addressed through future environmental education activities.

CONCLUSIONS

The principal conclusions of this study can be summarised as follows:

- Bio-waste compost exhibited substantially greater biological activity than both the garden soil and the degraded playground soil, demonstrating the strong influence of organic matter on microbial and faunal communities.
- Compost contained the highest abundance of cultivable bacteria, fungi, and soil invertebrates, confirming its role as a biodiversity hotspot compared with mineral soils poor in organic matter.
- The compost analysed had not yet reached complete biological maturity, indicating that additional stabilization time would be required before its optimal agricultural use.
- The educational community showed a high level of awareness and acceptance of composting, recognising both its environmental and educational benefits.
- Citizen science proved to be an effective framework for environmental education, enabling students to participate in authentic scientific research while generating useful information for sustainable bio-waste management.

Future perspectives

The encouraging results obtained in this preliminary study open several avenues for future research and educational development. Future investigations should include long-term monitoring of compost maturation to determine when biological stability and phytotoxicity reach optimal levels for agricultural application. Incorporating additional soil quality indicators, such as soil enzyme activities, microbial biomass, DNA-based microbial community analyses, or functional biodiversity assessments, would provide a more comprehensive understanding of the ecological effects of compost application.

From an agronomic perspective, field experiments evaluating the impact of school-produced compost on crop growth, soil fertility, carbon sequestration, and water retention would allow the practical benefits of decentralized composting to be quantified under real cultivation conditions.

The citizen science component could also be expanded by increasing the number of participating schools, comparing educational centres located in different environmental and socioeconomic contexts, and evaluating changes in environmental attitudes before and after participation in composting programmes. Such studies would help quantify the long-term educational impact of hands-on scientific research.

Finally, the HUÉTORCOMPOST project demonstrates that school composting can serve as a valuable model for integrating environmental research, waste management, and science education. Replication of this approach in other educational institutions could contribute to strengthening circular economy strategies while simultaneously promoting scientific literacy, environmental responsibility, and public engagement in sustainable resource management.

Acknowledgements

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References

- [1] The importance of soil organic matter. Key to drought-resistant soil and sustained food production. Alexandra Bot and José Benites. FAO Soils Bulletin, N.º 80, ISBN 92-5-105366-9. Available in: <http://www.fao.org/3/a0100e/a0100e.pdf>
- [2] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS EU Soil Strategy for 2030 Reaping the benefits of healthy soils for people, food, nature and climate. Available in: <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0699>
- [3] European Commission: Directorate-General for Communication, Circular economy action plan – For a cleaner and more competitive Europe, Publications Office of the European Union, 2020. Available in: <https://data.europa.eu/doi/10.2779/05068>
- [4] Definition of Biodegradable Waste. European Commission. Available in: <https://ec.europa.eu/environment/waste/compost/index.htm>

- [5] Definición de los biorresiduos domésticos. Ministerio para la Transición Ecológica y el Reto Demográfico. Available in: <https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/prevencion-y-gestion-residuos/flujos/domesticos/fracciones/biorresiduos.html>
- [6] Definición de compostaje. Compostando Ciencia Lab. Available in: <http://www.compostandociencia.com/2008/09/definicion-de-compostaje-html/>
- [7] Brambilla V., Confalonieri A., Krutova I., Lopez E., Giavini M. & Ricci M. (2024). LIFE BIOBEST Deliverable 3.1 Guidelines on the separate collection of bio-waste. 3.1 prepared by CIC for the project LIFE BIOBEST - Guiding the mainstreaming of best bio-waste. DOI: 10.13140/RG.2.2.25880.92165. Available in: https://zerowasteurope.eu/wp-content/uploads/2024/06/Jun24_240618_LIFE-BIOBEST_WP3_D3.1_Guideline_Bio-waste_SeparateCollection_Annex1-BP_Submitted.pdf
- [8] Trautmann NM, Krasny ME. 1998. Composting in the Classroom: Scientific Inquiry for High School Students. Editorial Kendall/Hunt Publishing Company. ISBN 0-7872-4433-3. Available in: <https://ecommons.cornell.edu/handle/1813/3338>
- [9] Vázquez M.M., Moreno Noguera P., Tortosa G., Rodríguez R. 2024. Composta con ciencia: del huerto a la mesa y viceversa. En: Cocinando a fuego lento. Situaciones de aprendizaje en torno al compostaje. Red Estatal de Entidades Locales por el Compostaje Doméstico y Comunitario (Composta en Red), pp: 98-109. ISBN: 978-84-09-62818-6.
- [10] HUÉTORCOMPOST: Ciencia ciudadana para mejorar el suelo y reciclar biorresiduos mediante compostaje escolar. Available in: <https://www.compostandociencia.com/huetorcompost/>
- [11] HUÉTOCOMPOST. Available in: <https://andaluciacienciaciudadana.es/proyectos/huetorcompost/>
- [12] Andalucía más ciencia ciudadana. Available in: <https://andaluciacienciaciudadana.es/proyectos/huetorcompost/>
- [13] Amador Ruiz F., Caballero González A., del Castillo López M., Fernández Mérida H., Fuentes Góngora H., Galindo García A.I., González Girela F.J., Jiménez Arquelladas L., López Rodríguez L., Moreno López A., Navarro García A.B., Tribak Pérez I., Vázquez M., Rodríguez Ramírez R., Palma Toro A.I., Pérez González S., Gómez-Muñoz B., Nogales Vargas-Machuca R., Tortosa G. 2025. Vermicomposting is socially accepted and technically feasible for managing the bio-waste generated at the Estación Experimental del Zaidín (EEZ-CSIC). High School Students for Agricultural Science Research. 14, 1-15. ISSN: 2340-9746
- [14] Díaz J.M., Moro C., Coletti Y., de la Torre A., de la Torre J., Rolland A., Ledesma D., Bedmar E.J., Tortosa G. 2020. Biological insights of Estación Experimental del Zaidín (EEZ) bio-waste composting. High School Students for Agricultural Science Research, 9, 14-26. ISSN: 2340-9746.
- [15] Barros Wilkinson C., Fernández Fernández E., García Romero E., Gómez Álvarez C., Mota Salceanu N., Vallberg Fernández E., Vázquez Vázquez M.M., Rodríguez Ramírez R., Pérez González S., Juárez-Martos R.A., Tortosa G. 2024. Moisture and mixture recipe strongly influence the abundance and biodiversity of invertebrates of bio-waste composting. High School Students for Agricultural Science Research. 13, 77-87. ISSN: 2340-9746.
- [16] Tortosa G., Bedmar E.J. 2019. El compost como fuente de materia orgánica y de microorganismos beneficiosos para la agricultura. MOL, 19, 80-92. ISSN: 1133-3669.

MY OWN IDEAS

Natalia Amador Ruiz

I really enjoyed participating in this project and learned a lot. I would like to participate again next year because I felt very comfortable with the treatment I received from both the organizing and participating staff. I had never had any contact with composting before; it disgusted me, especially because of the bugs I might find. But the truth is, as soon as I started working on the project, I became more and more interested in the topic, and my disgust turned into curiosity and a desire to learn. I've even come to enjoy it. I also had a great time when we visited the EEZ laboratories, where we carried out some tests for the experimental part of the project. I found everything we did very interesting and learned a lot. In conclusion, if I had the opportunity, I would participate in this type of initiative again and encourage other students to do so as well.

Jesús Arquelladas Olmos

My experience with HUETORCOMPOST project has been very fun and interesting. During this project, we learned the importance of recycling organic waste and how it can be turned into compost to improve the soil. We worked as a team with our classmates and carried out different activities related to science and the environment. We observed how microorganisms help decompose food scraps and plant matter. We also conducted experiments to learn more about the soil and the biodiversity it contains. Thanks to this project, we understood that small actions can make a big difference in caring for our planet. What I enjoyed most was participating in the investigations and discovering new things every day. I also learned how to collect data, analyze it, and draw conclusions, just like scientists do. I also improved my ability to work in a group and share ideas with my classmates. I think HUÉTORCOMPOST is a very important project because it teaches us to be more responsible towards the environment. Thanks to this experience, I have a better understanding of the importance of recycling and composting. It has been an educational, entertaining, and very useful activity for our future.

Alejandro Avivar del Río

Participating in this edition of the CAOS program has been a very enriching experience, unlike any other work I've done at school. Thanks to this project, I've been able to see firsthand how scientists work and better understand the research process, from formulating a hypothesis to obtaining and analyzing results. During the HUETORCOMPOST project, I learned the importance of composting and the sustainable management of organic waste. I also had the opportunity to work with samples, make observations, collect data, and collaborate with my classmates to draw well-founded conclusions. All of this helped me develop skills such as teamwork, organization, and critical thinking. One of the aspects I enjoyed most was the opportunity to collaborate with researchers and receive guidance from professionals dedicated to science. Preparing the presentation of our results and presenting our work was also very interesting, as it allowed me to improve my ability to communicate ideas clearly and confidently. Overall, participating in the CAOS program has been a very positive experience, both academically and personally. I've learned a lot about science and the environment, but also about responsibility, effort, and cooperation. Without a doubt, it is an activity that I will remember with satisfaction and that has allowed me to value research work and its importance to society even more.

Mireya Bautista Sánchez

It all started when Germán and Rubén came to a lab class to present a composting project. At first, I wasn't very interested, as I thought it would be a quick assignment just to improve my grade, but I was wrong. In the second session, I realized how mistaken I'd been. The session was very entertaining. We took soil and compost samples and observed the invertebrates they contained. It was a lot of fun. After a while, we were told that our project had been selected in the "Andalucía, más ciencia ciudadana" call for proposals from the Fundación Descubre. Knowing that we were one of the eight projects selected this year made me even more interested. But when the teacher told us we had to present our work at a conference, I got a little nervous, as I'm embarrassed to speak in front of so many people. However, being with my friends encouraged me to volunteer to give the presentation. Furthermore, this project offered me a great opportunity to work in a real laboratory, outside of school. I found it very interesting and had a great time. Besides the field trips and the experiments for the conference, we conducted surveys about the students' perceptions of composting. This was also a lot of fun. I found it to be a very positive experience that helped me face situations I wasn't used to and allowed me to improve.

Fernando Castillo Pedrajas

The CAOS project began with a talk where Germán and Rubén explained us what the project was about and how we would have the opportunity to be one of the schools lucky enough to participate in this year's CAOS call for proposals. From there, we worked with them for several weeks to analyze different parameters of various soil samples taken from different points around our school (compost bin, garden, and playground). We analyzed both physicochemical and microbiological parameters. We also included a study on the social perception of composting within our school community. During the project, we visited the EEZ-CSIC, where I was struck by the large number of people working in research and their approach, especially regarding environmental aspects. Finally, this year's project concluded with the presentation of our work at a conference, where we were quite nervous as it was our first time at this type of event. But everything went very well. We will continue working along these lines next year.

Álvaro Delgado Cuesta

My personal experience at CAOS has been something very special! I was also able to participate in the project HUETORCOMPOST studying how composting impacts soil biology and people's perceptions of organic waste recycling. While doing this project, there were many new things I learned about composting and the environment as well as the importance of reducing waste. I found it very interesting to see how organic waste is converted into compost and is used to improve soil. The most rewarding part of the project was the collaboration with my classmates. I gained experience collecting data, analyzing data and brainstorming ideas which improved my skills in teamwork and communication abilities. Another fact I really enjoyed about this project is that it was different from the usual classes because I was able to experience a real life scientific investigation which demonstrated how we can use science on a day to day basis. CAOS has helped make me aware of how important it is to recycle and respect nature. This project has helped me grow academically and personally. In closing, working on HUETORCOMPOST was an invaluable experience that I will always remember. I am so thankful for all that I learned from this project.

Arturo Marín Molina

When we started the project, I had some doubts about whether I would like it or if it had potential, but I was wrong. Over time, I've realized how wonderful the project is and how well it's developing. EEZ-CSIC is a great center where leading experts work, from whom I've learned a great deal, and my colleagues are excellent. I'm increasingly aware of how important this project is and how much you can learn from it.

Pablo Martínez Torres

The project began in class when two scientists from the CSIC (Spanish National Research Council) came to the school to talk about the compost bin, which we then started to reactivate. After several work and study sessions, part of the group went to the EEZ-CSIC where we had a day of experimentation to complete the first part of the study. Later, we presented our project, within the framework of "Andalucía, más ciencia ciudadana" to the educational community of our school, and finally, we presented our work at a scientific conference (CAOS, 2026), although our project will continue next year. In my opinion, it has been a very educational project and has opened many doors for the school in the scientific field.

África Murciano Cogolludo

The project began one day in class when we had a chat with Germán and Rubén. They explained what the project was and what it entailed. Ultimately, we had to present our results at a conference, where only a few schools participated. After a couple of weeks, we started working on our project. We began by examining the characteristics of our compost bin and its condition. We took samples from different areas of our schoolyard and began the analyses. While we were working, we learned that our project had been selected for the "Andalucía, más ciencia ciudadana" grant program, which motivated us even more. Later, we visited the EEZ-CSIC laboratories, where we continued determining some of the parameters we wanted to study. While the experimental phase was underway, we also conducted a survey-based study on the social perception of composting among the school community. Finally, we presented our project and shared our results at the CAOS conference. I felt a little overwhelmed during the presentation to the 7th grade students because they asked so many questions, but it also helped us prepare for the conference. It was a great experience!

Estela Padilla Fernández

One day, Germán and Rubén came to the school to present a very interesting project. They told us we would be investigating the different types of soil we have at the school. We would also be studying soil invertebrates and microorganisms. At first, it didn't seem as interesting as it turned out to be. During the project, we had the opportunity to visit the EEZ-CSIC, an agricultural research center, where we carried out part of the experimental phase. What I enjoyed most that day was working with soil fungi and bacteria. Overall, it's been a very interesting and fun project, which allows me to share many moments with my classmates outside of school.

Andrea Pancorbo Morenate

It all started when we were in class and the teacher told us we were going to do a project called "Huétorcompost" and I really enjoyed it. It was really cool because it wasn't just theory. We started by comparing the soil from three different places in our school: the compost bin, the garden, and the patio. We learned some very important things, like how compost retains

moisture better and has much more life than the other samples we studied. What impressed me most was seeing the number of invertebrates, and that some only appeared in the compost. We also conducted surveys at school and saw that almost everyone is in favor of recycling. I really enjoyed participating because I learned that by using compost, we help enrich the soil and take better care of the planet. I loved this experience; it was the best way to feel like scientists for a few days and see that what we do really helps the planet.

Iván Reyes Ruiz

Participating in the CAOS project has been a very interesting and educational experience. It all started when our Natural Environment and Laboratory teacher informed us that we would be participating in a project with the CSIC (Spanish National Research Council). The project consisted of analyzing how organic matter and the recycling of biowaste through composting influence soil health and biological activity. During the project, I learned the importance of recycling organic waste and how it can be transformed into a useful resource, compost, to improve soil properties. We also carried out practical activities in teams, which helped me learn in a more dynamic way. Overall, it has been a very positive experience because I acquired new knowledge and also a greater awareness of environmental care.