High School Students for Agricultural Science Research

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Project "CAOS" 2

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PREFACE

Ninguna especie viva practica tantas actividades distintas como la nuestra. Muchas son universales, y entre ellas, las esenciales para la supervivencia de los organismos y de la especie, "mantenencia" y "juntamiento", como decía el Arcipreste; su fuerte determinación genética deja pocas decisiones al sistema nervioso, cuando lo hay. Los genes determinan las bases del conocimiento, la producción de objetos y la comunicación sonora, actividades prominentes, pero no exclusivas, de *Homo sapiens*; para alcanzar niveles altos tenemos que aprender, sea por imitación o por enseñanza activa, modificando nuestro cerebro a largo plazo. El método científico es una adquisición única de nuestra especie, tan reciente que la evolución biológica no ha podido afectarla específicamente y tan improbable que ha requerido la acumulación de pasos sucesivos; es difícil de aprender y debemos preguntarnos si todos deberíamos intentarlo y a qué edad convendría empezar.

La Estación Experimental del Zaidín ha abierto una experiencia modélica para iniciar en el método científico a jóvenes adolescentes. Aprovecha la presencia en las enseñanzas preuniversitarias de muchos docentes experimentados, competentes y entusiastas, sin tiempo ni medios para practicar habitualmente la investigación científica.

Ocho grupos de jóvenes expusieron en el "Congreso Caos" y colgaron en la Red los resultados de sus trabajos dirigidos al alimón por científicos y profesores. Han sido actividades muy variadas, tanto por sus fines, producir conocimiento (Ciencia) o mejorar el mundo (Técnica), como por sus métodos, que incluían el acopio de información preexistente y la aplicación de protocolos biológicos, físicos, químicos e informáticos. Me han sorprendido las nuevas habilidades, la capacidad de comunicación y el entusiasmo demostrados por muchos jóvenes. Sugiero que también se aplique a esta experiencia al método científico siguiendo el rastro dejado en ellos.

Me quedan dudas sobre si siempre se intentó aplicar el método científico, cuyo rigor puede inducir sequedad ascética, o se cayó en los juegos de la ciencia recreativa. Las imperfecciones del inglés usado por varios participantes dificultó la comunicación sin mejorar el nivel lingüístico de los oyentes.

Sospecho por de pronto que se lo han pasado muy bien y certifico que yo me lo he pasado muy bien en su Congreso.

Enrique Cerdá Olmedo

Sevilla, 2022-05-17

No living species carries out so many different activities as ours. Many of them are universal, and among them, those essential for survival of the organisms and the species, "sustenance" and "adjoining", as the Arcipreste said; their strong genetic determinism leaves few decisions to the nervous system, when there is one. Genes determine the basis for learning, the production of objects and sound communication, prominent activities –though not exclusive– of Homo sapiens*. To reach high levels we must learn, be it by imitation or by active teaching, modifying our brain in the long term. The scientific method is a unique acquisition of our species, so recent that biological evolution has not been able to influence it specifically yet, and so unlikely that it has needed an accumulation of sequential steps. It is difficult to learn and we must ponder if all of us should try, and at what age it would be best to start.*

The Estación Experimental del Zaidín has started a model experience to acquaint teenagers with the scientific method. It takes advantage of the presence in pre-university studies of experienced, able, and enthusiastic teachers, without the time or means to carry out scientific research on a routine basis.

Eight groups of students presented at the "CAOS Meeting", and published on the web, the results of their projects, supervised jointly by scientists and teachers. The activities have been very varied, both in their goals –producing knowledge (Science) or improving the world (Technology)- and in their methods, which included collecting preexisting information and applying biology, physics, chemistry and informatics protocols. I have been surprised by the new abilities, the communication capacity and the enthusiasm shown by many youngsters. I suggest to apply the scientific method also to this experience, following up the imprint left in them.

I still have some doubts as to whether the scientific method –whose rigour may lead to ascetic harshness– was always sought, or if there were instances of recreational science games. Imperfections in the English used by some participants made communication difficult without improving the language level of listeners.

I suspect in any case they had a lot of fun, and I certify I had a lot of fun in their Meeting.

Enrique Cerdá Olmedo (*Translation: M. Espinosa*)

Seville, 2022-05-17

Plants can be used as electrical batteries

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Summary

In the rhizosphere, lots of chemical reactions occur while root plants are transforming the soil organic matter and assimilating nutrients. These redox conversions produce an electrons flux similar to a battery, which can be captured by an electrode device; it's the so-called biophotovoltaic energy. In this project, we have evaluated onions growth to produce it and the electric potential difference (or voltage) was measured every week during 89 days. According to our results, the voltage of pots with plants was notable higher than in pots with soil but without plants, which meant that roots stimulated organic matter degradation and the electrical flow. During this trial, the voltage became higher when plants start growing properly and then, onion roots were able to produce similar voltage as a zinc-carbon battery.

Keywords: *Allium cepa,* bio-waste, compost, electricity, onions, organic matter, substrate, voltage.

INTRODUCTION

Soil is essential for the development of life on our planet, especially for plants. Organic matter is one of its basic components, which can be defined as a group of carbon-based compounds and molecules. It is well known that the organic matter can improve the physical, chemical and biological properties of soils [1]. Therefore, the addition of organic matter to soil is beneficial for the biological process of nutrient conversion and its assimilation by the root system. For that reason, soil organic matter brings important ecological and production benefits for agriculture and environment.

When the organic matter is added to a soil, several chemical compounds oxidations and reductions occur and a flow of electrons similar to a battery is created. This electrical energy can be used to generate electricity; it's the so-called Biophotovoltaic energy [2]. This technology is based on installing anodes and cathodes in the soil rhizosphere (where biological activity and redox reactions occur) to generate an electric potential difference (or voltage) that can produce electrical energy [3, 4 and 5].

According to that, the objective of this project was to demonstrate if plants can be used as a common battery.

MATERIAL AND METHODS

1. Growing substrates

In this experiment, 1 kg of a pre-sieved soil was collected from an agricultural location of La Vega de Granada (Churriana de la Vega, Spain). Also, bio-waste compost was used as an organic matter amendment. Briefly, compost was made by mixing chopped tree pruning, fresh cut grass and food waste from Estación Experimental del Zaidín (EEZ-CSIC). The composting procedure and characteristics can be consulted in [6].

2. Plant experiment.

At the beginning of the assay, several 0.1 l pots were filled with growing substrates according to these treatments (Figure 1):

- Agricultural soil (S): 150 g.
- Bio-waste compost (C): 150 g.
- Mixture 1:1 (v/v) of soil and compost (SC): 75 g of S and 75 g of C.

Then, pots were watered with 50 ml of tap water every week, and after 19 days, pre-germinated onions (*Allium cepa*) were transplanted in each pot (four pots per treatment). A set of pots with only soil were used as a Control treatment.

Plants were grown at the I.E.S. Padre Suárez facilities under environmental conditions. After 89 days, onions were harvested and plant heights were registered. Also, soil pHs were measured by using a portable pH-meter (pH PCE-PHD 1-PH) after 1:20 (w:v, weight to volume) aqueous extraction at both, the beginning and the end of the experiment.

2. Electrical device and voltage measurement.

Copper tubes (120 and 15 mm of length and diameter) and galvanized screws (60 mm of length) were used as cathodes and anodes, respectively (Figure 1). Both electrodes were inserted in each pots substrate (40 mm under soil surface) at the beginning of the experiment and the electric potential difference (or voltage) was recorded by using a professional digital multitester (AoKoZo 21D Polimetro Digital 6000 Cuentas, TRUE RMS). Every week and just after watering, the voltage was both measured individual and collectively, the later by connecting pots as a series circuit (with cable connectors), as it is shown in Figure 2.

Figure 1. Pots used in this experiment: S (soil), C (compost) and SC (soil and compost at 50%). In each pot, a copper tube and galvanized screws were used as a cathode and anode, respectively.

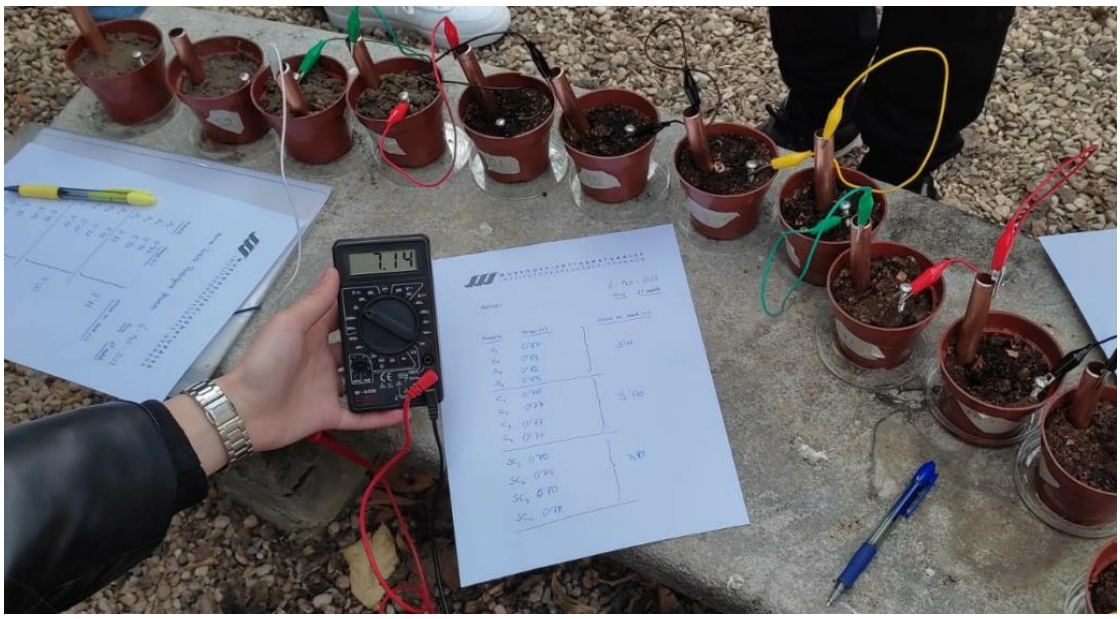

Figure 2. Electric potential difference (or voltage) measurement done by using a digital multitester.

RESULTS AND DISCUSSION

The evolution of voltage during the experimentation is shown in Figure 3. According to these data, three periods were found:

The first phase was related to pots without plants and lasted 14 days. The voltages were ranged between 2.6 and 3.2 V, in which the voltage values were S>SC>>C.

The second one (from 14 to 69 days) lasted 55 days. This period began when the onions were transplanted. During this period, voltage values and their behavior were similar that those obtained in the first period (S>SC>>C).

Finally, the third phase (from 69 to 89 days) was characterized by an increase in the voltage values in all treatment assayed compare to pots with only soil (Control treatment). This behavior could be explained due to plants start to grow significantly. This fact was confirmed with onion tallness results: SC showed the highest onion height recorded (45 cm) compare to S (37 cm) and C (31 cm) treatments, respectively (Figure 5). According to that, compost promoted onions growth only when it was mixed with soil at 50%.

Just before transplanting, substrate pHs were measured and pH values (7.9, 8.5 and 8.1 for S, C and S+C treatments) showed an inverse tendency compare to voltage (Figure 4). As much higher the pH was, the lower voltage was registered. However, this behavior was not found at the end of experimentation, with alkaline pH values ranged between 8.5 an 9.0 for all treatments.

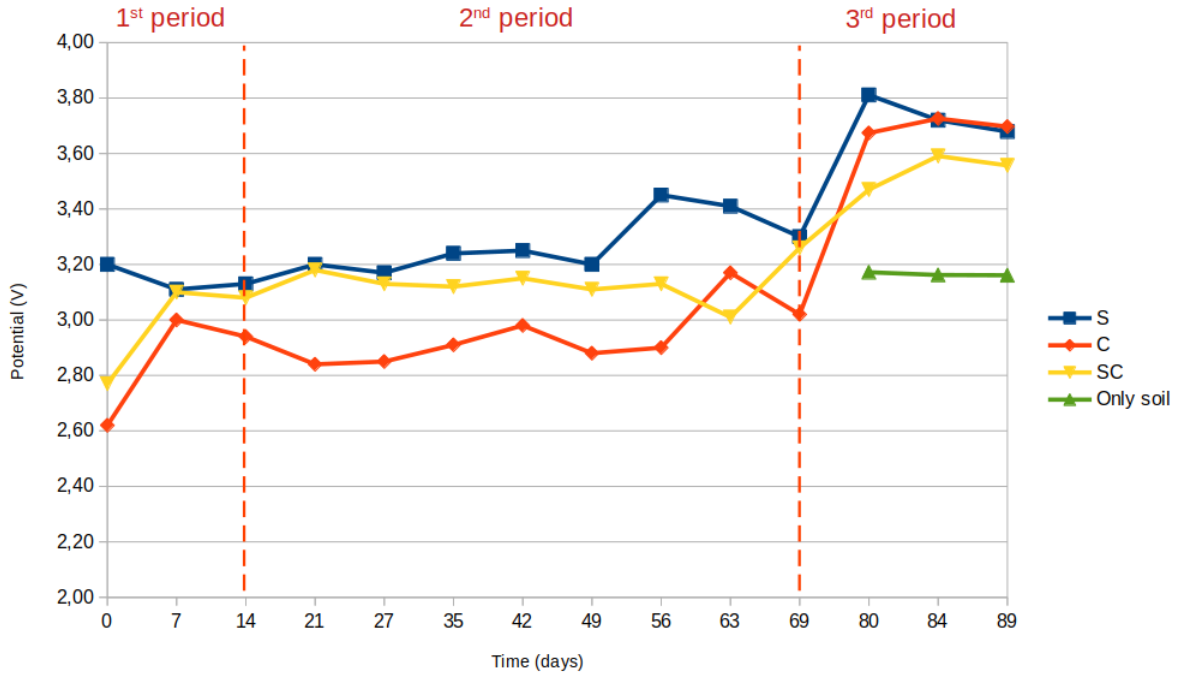

Figure 3. Evolution of electric potential difference (V) during the experimentation: S (soil), C (compost) and SC (soil and compost at 50%).

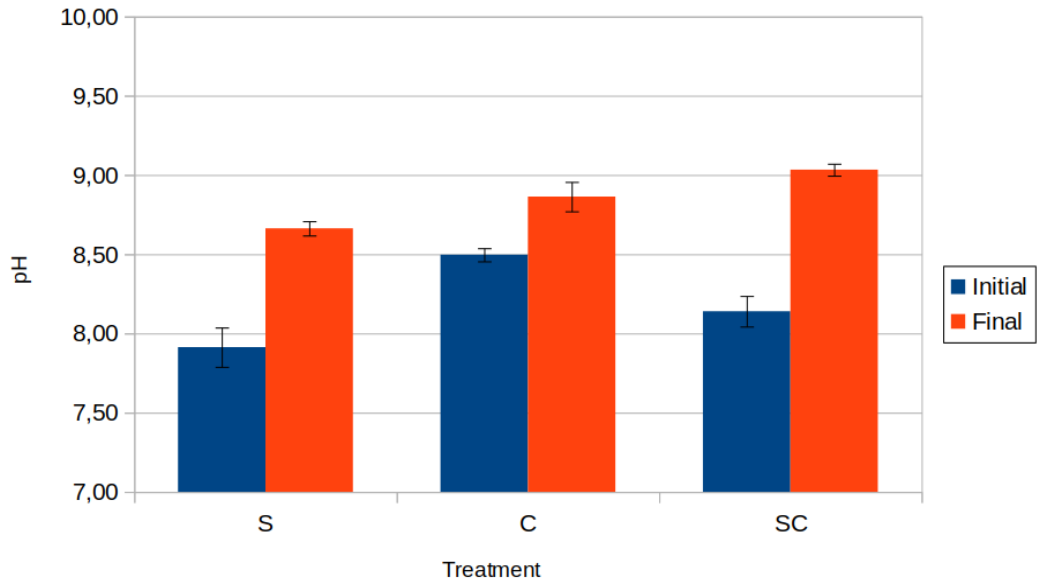

Figure 4. Soil pH of pots measured at initial and final stages of the experiment. Treatments: S (soil), C (compost) and SC (soil and compost at 50%).

According to these data, it can be concluded that the voltage with onion pots was higher compare to control pots without plants, and voltages became higher when plant starts growing. On the other hand, it was confirmed that compost promoted plant growth with apparently no influence on biophotovoltaic energy production. This could be explained due to volume pots were so small (only 0.1 L) or even electrodes sizes and configuration were not optimal. Further research needs to be done in order to address these issues and to obtain electrical energy flow from this system.

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We are very grateful to Loli Riesco Conde for her kindly and useful help with the watering while we cannot do it.

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MY OWN IDEAS

Luis José Fernández Cirre

It has been an unforgettable experience since we have learned things that we normally do not study in our institute. It has been very interesting to know how an investigation should be carried out. We have used instruments that we had not used before.
Going to a congress and presenting in front of scientists is something incredible and makes me want to participate in new research projects more.

Jorge Plaza De Bruijin

I really enjoyed participating in this project with my colleagues. I've learned things I didn't know about plants, like how you can get electricity from them. That has surprised me.
During these last months we have worked very well and I hope that this project will support other new ones and that this method of obtaining electrical energy will be used more often in the future. I think it would be better for everyone.

Jaime Ortega Martín

This research project has been very interesting. I have learned many things about plants and about the scientific method.
Participating in a project like this, attending the final congress at the Estación Experimental del Zaidín (EEZ-CSIC) in Granada and presenting our results in front of such a large audience, are experiences that have been worthwhile and I recommend other colleagues to participate in the future.

Lucía Rodríguez Moreno

I really liked the experience. Learning science by doing research is very interesting. I have learned to face a large audience, larger than normal to what I am used to. I have increased my creativity, working in a group with my colleagues and doing a process that is not easy, but in the end every effort has its reward.

Daniel Illescas Vílchez

I really liked participating in this project, since we have promoted learning outside the classroom. I have learned how to do scientific research, learning new concepts and handling new instruments.