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Evaluation of electrical signals in pine trees in a Mediterranean forest ecosystem

Rodolfo Zapata, Jose-Vicente Oliver-Villanueva, Lenin-Guillermo Lemus-Zúñiga, Jorge E. Luzuriaga, Miguel A. Mateo Pla and Javier F. Urchueguía

Universitat Politècnica de València, ITACA - Institute of Information and Communication Technologies, Research Group ICT against Climate Change, València ,Spain

* Corresponding author:
Rodolfo Zapata
Universitat Politècnica de València
ITACA - Institute of Information and Communication Technologies
Research Group ICT against Climate Change (ictvscc.webs.upv.es/en/)
Camí de Vera s/n
46022 València (Spain)
email: rozaza@upv.es

ABSTRACT

Evaluation of electrical signals in pine trees in a Mediterranean forest ecosystem

Electric potential differences in living plants are explained by theories based on sap flow. In order to acquire more advanced knowledge about the spatial distribution of this electric potential measures in trees, this research aims to analyse electrical signals in a population of Aleppo pines (*Pinus halepensis* Mill.) in a representative Mediterranean forest ecosystem.

The specific research objective is to assess some of the most significant factors that influence the distribution pattern of those electric signals: tree age, measurement type and electrode placement.

The research has been conducted in representative forest stands, obtaining measurements of different representative trees. After a statistical evaluation of the obtained results, the main conclusions of our research are:

A. Tree maturity influences directly on electric potential.
B. Maximum electrical signals can be measured in young pines showing values of 0.6 V and 0.6 µA for voltage and current, respectively.
C. The distribution patterns of both voltage and short-circuit current depending on electrode placement are uniform.

Keywords: natural electric signs; plant electrical potential; natural electrical power; Mediterranean pines; tree age influence; electrode placement influence; adaptive forest management.

1. INTRODUCTION

Plants have electrical activity; this fact was first revealed by Burdon-Sanderson [1] and Darwin [2] by observing insectivorous plants. Bose [3] and then Pickard [4] evidenced the existence of action potentials in some plants regardless of the presence of rapid leaf movements. Regarding trees, Wright and Fisher [5] detected the existence of a difference in continuous electrical potential between the electrodes inserted in the tree's phloem and the surrounding soil.

There are both, physical and biological hypothesis to explain the origin of the electrical signals measured in plants that have been scientifically documented.

On the one hand, the biological hypothesis establishes that different parts of the plants develop in their evolution an internal system [11]. Following this, the transmission of electrical signals at the cellular level activates physiological responses to external environmental stimuli [11]. In this context, different studies have reported the effect of different stimuli, such as light conditions [12,13], temperature variations [14-18], and mechanical wounds [19, 11].

According to some authors [7,11,20-22] the variation of the electrical signals depends on the intensity of the stimulation that could be associated with changes in water tension or ion concentrations, creating a transient electrochemical imbalance. These electrical signals would be transmitted through living cells of plants. Understanding mechanisms of electrical responses, changes in physiological processes and predicting responses to stress factors requires mathematical modelling of electrical activity in plant organisms, a review of such models can be found in Sukhova[23].

On the other hand, the physical hypothesis is based on the fact that trees continuously suck water, nutrients and charged particles into the xylem by transpiration [6,7], In this process a pH imbalance is created between the tree and the soil, which causes an electric current that circulates between different parts of the trees [6]. Several experiments to support this hypothesis are available in different studies, e.g., the phloem [7], the xylem and the leaves [6], as well as other elements of the living tree and the adjacent soil [8].

Another physical theory is based on the fact that the electric current is the result of electrokinetic phenomenon, which is caused by the movement of liquids in a porous medium [9,10]. In order to model the physical models behind this potential, it is necessary to perform the experiments under the controlled conditions of a laboratory. Additionally, several works have been done with agricultural species under laboratory conditions [11,31-33]. We also have to take into account that some of these studies are limited only to analysing just the voltage data [10, 27].

All these requirements make it difficult the researches about trees in forests, which could explain the reduced number of publications found. For example, the studies in [6,8,24,25] observed electrical signals in individual trees, which do not allow analysing the variability between individuals in an ecosystem. Furthermore, the few investigations that we have been able to document have been carried out mainly in Continental and central European climatic areas, e.g. *Aesculus hippocastanum* [26] and *Populus nigra* [10] both in France, *Eucalyptus globulus* in Portugal [26], *Salix alba* in Austria [28], *Quercus spp*. and *Fagus sylvatica* [29,30].

Consequently, rigorous analysis of electrical signals has not been found related to, neither coniferous species nor Mediterranean ecosystems. For these reasons, the present study aims to fill this lack of knowledge. Focusing on the characterization and analysis of the electric signals under natural conditions (outside laboratories) exploring the behaviour of the two components of electrical signals (voltage and short-circuit current (ISC)) in a representative population of Aleppo pines (*Pinus halepensis* Mill.) in the Mediterranean area.

A suitable application of these electrical signals measures is the idea of using plants as biosensors. This idea has been studied by other authors in research laboratories under controlled conditions [31-34]. In order to use trees in the wild forest as biosensors we have to face the problem of the lack of information on electrical signals in natural uncontrolled conditions. Thus, we consider it necessary to create a good research base on the behaviour of those electrical signals of trees, both statically and dynamically.

In the present work, we have evaluated the most significant static factors that influence on the distribution of voltage and ISC electrical signals, specifically: i) the influence of tree age, ii) the electrode placement (height and orientation of the assignment) and iii) the measurement settings (bipolar or referenced to ground setups).

2. MATERIAL AND METHODS

Next, we describe the principal material and methods used in this study, which was carried out outside laboratory in representative pine trees belonging to a Mediterranean forest.

2.1 Sample stands

Conifer species are very representative of the Mediterranean area, and one of the most important of them is the Aleppo pine (*Pinus halepensis Mill.*) [35-39]. We surveyed a series of potential forests for this study using the layers for the Geographical Information System (GIS) of the Spanish National Forest Inventory [40]. We look for pole and pure mature stands of *Pinus halepensis* in Eastern Spain. Because of the different physiological behaviour of the trees according to the age [7,41], we include the tree age as a critical variable in the research design and in the sample stands selection. Thus, to capture a representative tree population in these forests, we considered the following forest characteristics:

A. An arboreal population of the same species (pure stands),
B. Enough specimens for each age group,
C. A not affected area (at least in the last years) by substantial environmental disturbances (forest fires, pests or snow damages).

Crossing all GIS layers with these considerations a representative sample forest was found in the *Sierra Calderona Natural Park* located in the region of Valencia, Spain. The chosen area, of approximately 20 hectares, contains pure stands of Aleppo pine trees. The trees clearly show that they belong to two different age classes, located very close to each other. These trees maintain the same edaphological conditions as well as insolation regime, orientation, and water availability. The two age classes are:

A. Young trees: about 26-year-old naturally regenerated stands originated after a forest fire in 1994 [42].
B. Mature trees: even-aged pure stands, which were afforested around 50 years ago and survived forest fire of 1994.

The selected sample stand has an approximate size of 0.25 hectares and is located at latitude 39º 45' 28.80" N and longitude 0º 30' 36.36" W. Figure 1 shows the nature of the study area.

Figure 1: Study area location: (A) Panoramic view of the sample stand, (B) tree distancing in the sample stand.

2.2 Selection of representative trees

In the selected sample stand, a total of 121 trees were inventoried. The main dendrometric parameters, i.e. diameter at breast height (DBH at 1.3 m) [43] and total tree height (h_t) have been measured. The results of this inventory are summarised in Table 1.

	Breast-height diameter DBH [cm]	**Total tree height h_t [m]**
Mean	**12.10**	**5.16**
Median	11.10	5.13
Maximum	25.10	9.69
Minimum	6.4	2.77
Standard deviation	3.95	1.30
Variance	15.59	1.68
Number of samples	121	

Table 1: Dendometric parameters of the tree population: breast-height diameter (DBH) and total tree height (ht).

Following the recommendations of Fernández-Puratich [44], Oliver-Villanueva [45] and Hapla [46], we disregarded form the study those trees that: i) are located at the edge of the plot, ii) have grown with excessively braided shafts or iii) show affections of fungi or insects.

Furthermore, following the recommendations of Ríos-Rojas [33], for a first phase of the study, we selected randomly different standard samples: two mature trees, two young trees and a standing dead tree. This phase was focussed on voltage and current measurements as a function of tree age.

In the second phase of the study, we conducted a statistical study to determine the population size following the methodology described by Hapla and Saborowski [47]. These authors made several measurements at different heights of the trees demonstrating that if the height and diameter of the trees do not differ more than a confidence interval the increasing number of samples does not improve the results significantly. For this phase, our tree population was reduced to 15 representative trees, to reach 95% confidence interval, considering the selection criteria used in different studies related to wood characteristics and physical properties of several tree species [45, 46, 48-52]. The selected trees accomplish the following characteristics:

1. Height and diameter do not differ more than a standard deviation of the mean values.
2. Belong to KRAFT sociological class I (dominant trees) or class II (co-dominant trees).
3. Without significant or appreciable damage or disease present on the trunk
4. Homogeneously distributed throughout the entire plot surface, to achieve a greater diversity of results.
5. Belong to the same age group and with enough level of electrical activity (measured in phase 1 of the study)

2.3 Measurement equipment

The electrical parameters were measured with a UT71D UNI-T multimeter with an input impedance of 2.5 GΩ, and accuracy of 0.1% ± 2 millivolts (mV), as it is used in other studies [53, 54].

We used extracellular stainless-steel electrodes as in previous works [10]. To eliminate as far as possible the measurement overpotentials induced by the galvanic effect in bipolar measurements, we made sure that all our electrodes were manufactured with the same material.

We chose screws as the electrodes because they can easily be inserted into and extracted from trees, causing a small injury. Besides, because of their thread, screws have a larger contact surface area than smooth electrodes.

For the measurements, as a ground connection to the circuit, we used a titanium nitride-coated platinum-iridium alloy electrode (1999/5/EC) [55]. Non-polarisation electrodes were used as earth to minimise false results induced by the charges freely crossing over between the electrode-electrolyte interface following the experiences of Prutchi [56]. Each electrode was connected with the measuring equipment through an electrical connector and a 0.5 mm copper conductor cable insulated with a flexible plastic coating (CE 0123). Figure 2 shows the materials and equipment used.

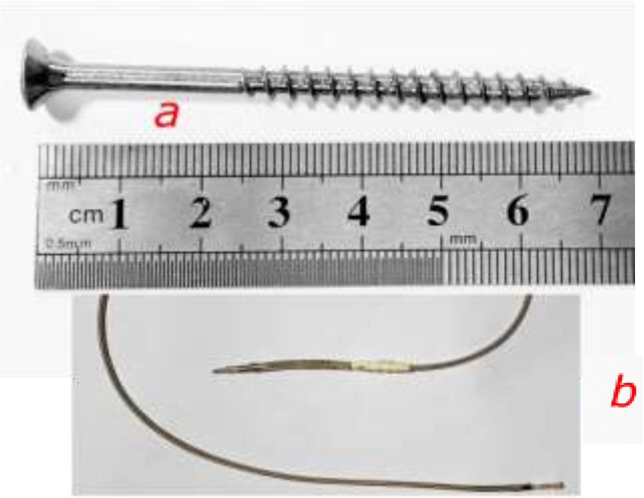


Figure 2: Equipment used for the measurement of the electrical signals (a) a 70 mm screw as an electrode, (b) an earth electrode.

2.4 Electrode placement and measurement

To record the voltage and short-circuit current (ISC) of the sample tree, electrodes were inserted directly into the trunk in contact with the phloematic tissue. This was ensured by inserting the electrodes using a torque wrench that allowed us to detect the change in hardness. According to other authors, phloem [11] play an active role in the electrical response of the trees. Oyarce [11] demonstrated that the living cells that compose these areas offer lower resistance to the current flow in comparison with the rest of the tissues of the plant.

We placed the electrodes in a circular and longitudinal distribution to determine the distribution of the potential difference along the trunk of each tree. In the circular ring cuff configuration, the electrodes were placed at 1.5 m above the ground at the four cardinal compass points (north, east, south and west). Using the compass to select the orientation of the faces of the trees where the electrodes were inserted, as is shown in Figure 3 (left and middle). In the longitudinal configuration, the electrodes were longitudinally inserted into the trees every 50 cm, following a longitudinal line at the trunk's north face. Figure 3 (right) shows this setup. The low-polarisation electrode was buried 15 cm into the ground, a minimum of 3 m away from the tree to use as ground or reference electrode.

Figure 3 Electrode placement using a compass (left), identification of trees and radially location of the electrodes (centre), electrodes separated longitudinally (right).

The electrode placement used was the same in bipolar mode or referenced to the ground, changing only the electrodes connection. So, measurements referenced to the ground were carried out between each electrode concerning to the ground. On the other hand, bipolar measurements were made between two nearby electrodes, with a fixed separation of 0.5 m between them. The first level was from the electrode located at zero meters to 0.5 m, the next level was from 0.5 m to 1 m, continuing thus, up to three meters in height on the tree. Figure 4 shows a diagram of this configuration.

Figure 4: Electrode placement setup modes (left) measurements referenced to the ground, (right) bipolar setup.

The setup used for the electrodes to measure the potential difference was the same for the total population of trees. Between 18th and 19th November 2017, continuous measurements were carried out during 24h, sampling data every hour. In this measurement session, we did not intend to observe a difference in behaviour, it was only to obtain voltage values between the two age groups.

After obtaining the results of the preliminary phase of the study, the trees that formed the population for the second phase were selected, based on the observed results. The voltage and intensity began to be measured in the 15 selected trees that made up this representative population, analysing the distribution of the electrical potential in the trees.

2.5 Experimental conditions

Data collection was performed through measurements by inserting electrodes into the trees. With the intention that our collected data were not affected by external variables, the following two premises were followed.

First, given that we caused a small injury in the trunks by inserting the electrodes, the trees responded by forming border areas and compartmentalisation barriers to prevent infection and to resist the spread of wood decay [57]. Generally, within 24 days' post of the wound creation, an impervious boundary appears approximately 1 mm inside the wound surface [57, 58]. In conifer trees, the impermeability arises between 28 and 30 days after injury in these trees [57]. Following this, we carried out our study after leaving enough time for the generation of the boundary zone (necrofilactic periderm) of the tree bark.

Second, we have to address the fact that environmental conditions affect the behaviour of the plant and generate changes in the electrical potential [25, 33, 60, 61]. To avoid that uncontrollable external factors that may influence our observations, we made the measurements of the fieldwork in days with similar air humidity and temperature, mainly in bright days without clouds. All measurements were made in the hour of zenith in the work area (between 1:30 pm and 2:00 pm CET). The decision to carry out the measurements at this time was based on the highest solar incidence, the lowest cloud presence and stable conditions.

2.6 Statistical Analyses

Each collected data of voltages and ISC were analysed. We carried out normal distribution, homoscedasticity of variance and ANOVA tests. In our case, to check if the data follows a normal distribution t-Student parametric test was applied. This allows evaluating the comparison between the two tree ages as well as between bipolar and referenced to the ground electrode configuration data (for two samples).

The concept of data homoscedasticity implies constancy in the variance of the errors, and it is used to guarantee a variable prediction by calculating the average value of its set [60].

An analysis of the variance (ANOVA) was performed with north, east, south, and west (N, E, S, W) orientation data (for three or more samples). Besides, the Kruskal-Wallis test and Mann-Whitney U test were applied to check the heterogeneity of data for two and three samples, respectively.

3. RESULTS

3.1 Influence of tree age

Table 2 shows the obtained results for young and mature trees. Furthermore, this table also shows a significant influence of the tree age in the referenced to the ground measurements. Hence, there is a significant difference between the age groups (*p*-value <0.0001) with an average voltage of 0.929 V in young trees and 0.238 V in mature trees. On the other hand, the bipolar measurements show an average voltage of 0.010 V and 0.014 V for young and mature trees, respectively. In bipolar measurements, the age difference does not show significant differences between groups (*p*-value = 0.45).

Measurement	Group	Max	Min	Mean	Std. Dev.
Referenced to the ground measurements	Young	-0.887	-1.016	-0.929	0.024
	Mature	-0.222	-0.261	-0.238	0.013
Bipolar	Young	0.033	0	0.010	0.008
	Mature	0.148	0	0.014	0.027
Mean of referenced to the ground measurements 24h	Young	-0.223	-0.626	-0.383	0.100
	Mature	-0.012	-0.295	-0.150	0.073

Table 2: Observations summary using different configurations over mature and young tree groups, volts as unit of measurement.

Figure 5 shows the main results obtained in 24 hours of referenced to the ground measurements. The average voltage in young trees is 0.383V with a maximum value of 0.626V. Mature trees show significantly lower values versus young trees (*p*-value < 0.0001) with an average voltage of 0.150 V and a maximum value of 0.295 V. The control dead tree shows values of 0 V, as expected.

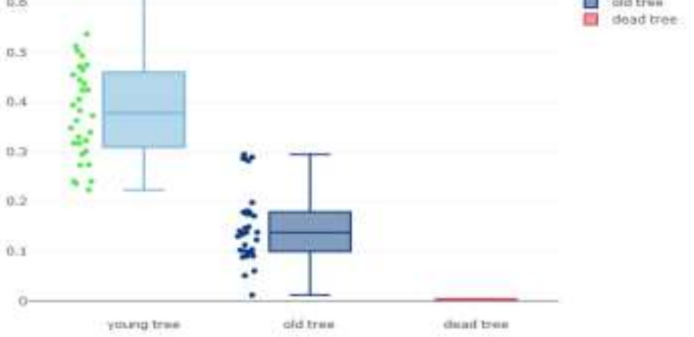


Figure 5: Boxplots presenting the data dispersion for young, old, and dead tree 24h measurements. The median voltages measured significantly differed according to the tree age, young trees showing much higher values than older individuals.

3.2 Influence of height

For the analysis of the longitudinal variation of the electric signals, only the young trees have been selected, since they show significantly higher values in the voltage measurements as the older trees.

3.2.1 Referenced to the ground measurements

Figure 6 and Table 3 show values very constant at every height level. With a maximum voltage value of 0.626 V measured at ground level and a minimum value of 0.597 V at 2.5 m. The ISC show values even closer to each other than the voltage, with a maximum ISC value of 0.568 µA at 0 m and a minimum value of 0.519 µA measured at 2.5 m.

Analysing the data obtained, we found significant differences neither in voltage (*p*-value = 0.86) nor in ISC (*p*-value = 0.91) among the different height levels. Therefore, the measurement height shows no influence on the voltage or ISC referenced to the ground measurements.

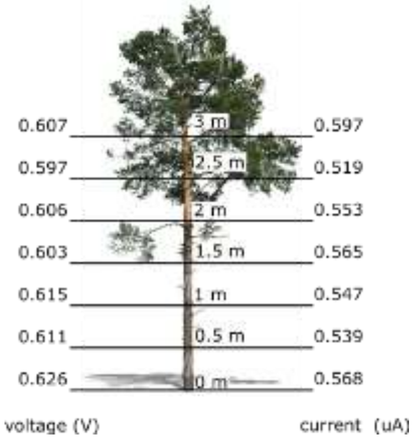


Figure 6: Monopolar referenced to the ground measurements for voltage and current considering the height at the tree

	Voltage (V)		ISC (µA)	
Height (m)	Mean	Variance	Mean	Variance
0.0	-0.626	0.011	-0.568	0.027
0.5	-0.611	0.008	-0.539	0.038
1.0	-0.615	0.005	-0.547	0.023
1.5	-0.603	0.006	-0.565	0.023
2.0	-0.606	0.003	-0.553	0.027
2.5	-0.597	0.005	-0.519	0.022
3.0	-0.607	0.004	-0.597	0.021

Table 3: Statistical mean and variance of referenced to the ground measurements for voltage and current considering the height at the tree

3.2.2 Bipolar measurements

Both the voltage and the ISC show very close values between each height level for bipolar measurements. The highest values for voltage mean have been obtained between 1 m to 1.5 m above the ground (0.036 V) and the minimum values at 2.5-3.0 m (0.025 V). On the other hand, the maximum values for ISC were measured between 0.0 m to 0.5 m (0.471 µA) and the minimum values at 2.0-2.5 m (0.218 µA).

Nevertheless, the slight differences observed are not significant among levels of height, neither for voltage (*p*-value = 0.517) nor for ISC (*p*-value = 0.248).

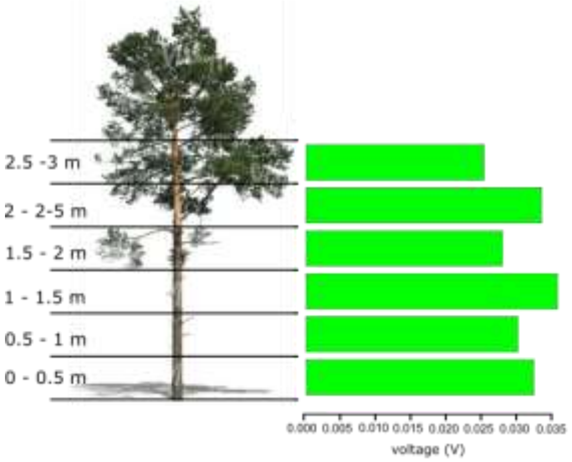


Figure 7: Bipolar voltage measurements considering the height at the tree.

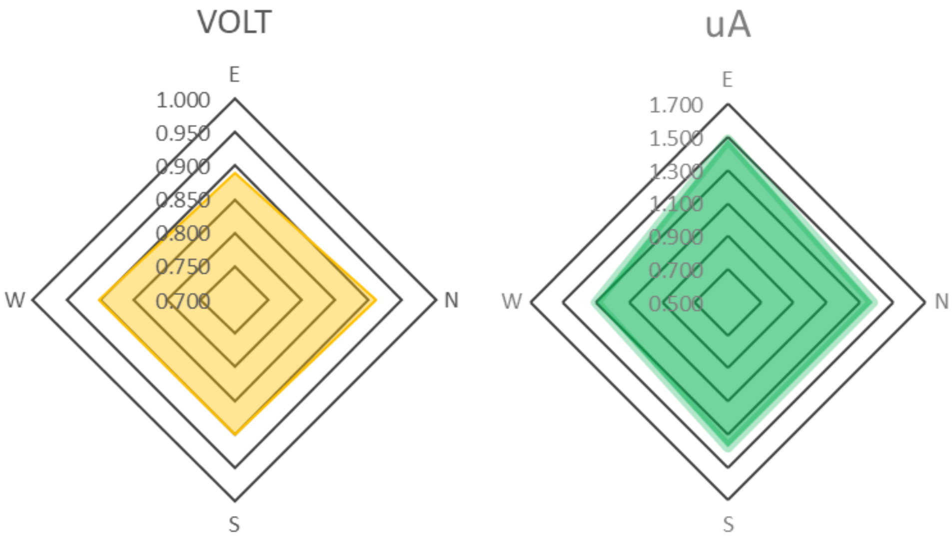
	Voltage (V)		ISC (µA)	
Height (m)	mean	Variance	mean	Variance
0.0-0.5	0.032	0.001	0.471	0.164
0.5-1.0	0.030	0.001	0.427	0.062
1.0-1.5	0.036	0.001	0.441	0.068
1.5-2.0	0.028	0.000	0.263	0.091
2.0-2.5	0.033	0.001	0.218	0.060
2.5-3.0	0.025	0.001	0.332	0.269

Table 4: Statistical mean and variance of bipolar voltage measurements considering height at the tree.

3.3 Influence of orientation

Very similar values and no significant differences can be found among the cardinal point placement of the electrodes (*p*-value = 0.871), as can be observed in figure 8. However, it is necessary to point out that a tiny significant difference was detected only for ISC between the east and the other cardinal points (*p*-value = 0.048). It was decided to continue to obtain data in order to analyse more in detail the possible influence of orientation on ISC. Thus, three other measurements were carried out on

21st April 5th and 12th May 2018. None of them showed statistically significant differences, neither for voltage nor for ISC, as can be seen in table 5. Consequently, these additional measurements ruled out a possible influence of orientation on voltage and ISC.



Voltage (V)

Current (µA)

Figure 8: Average values for voltage and electrical current in function on the cardinal orientation.

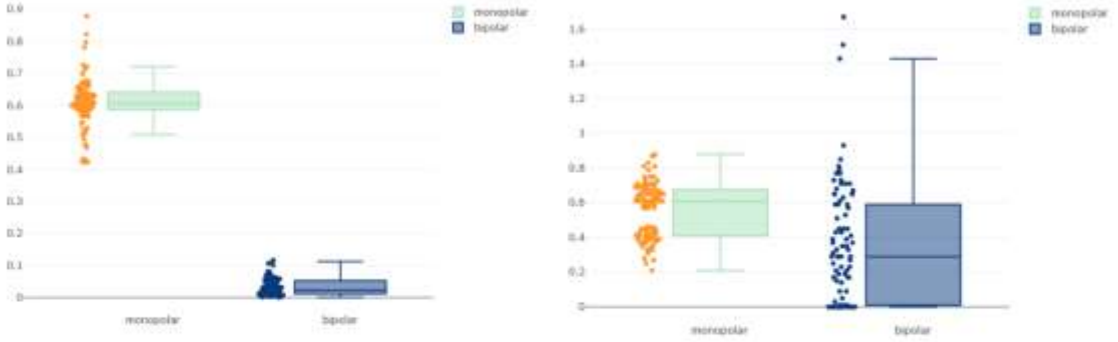
	Voltage (V)				ISC (µA)			
	E	N	S	W	E	N	S	W
21/04/2018								
Min	-0,828	-0,864	-0,864	-0,833	-1,830	-1,540	-1,670	-1,430
Max	-1,109	-1,125	-1,109	-1,114	-5,100	-4,760	-4,660	-4,660
Mean	-1,014	-1,033	-1,026	-1,025	-3,411	-3,126	-3,173	-2,860
Variance	-0,007	-0,008	-0,007	-0,006	-0,008	-1,001	-0,874	-1,033
05/05/2018								
Min	-0,713	-0,715	-0,706	-0,703	-0,350	-0,370	-0,030	-0,370
Max	-1,017	-1,032	-0,998	-1,015	-1,470	-1,610	-1,530	-1,610
Mean	-0,876	-0,900	-0,877	-0,886	-0,871	-0,876	-0,817	-0,880
Variance	-0,001	-0,001	-0,001	-0,001	-0,012	-0,011	-0,011	-0,012
12/05/2018								
Min	-0,742	-0,756	-0,747	-0,741	-0,010	0,000	-0,010	-0,010
Max	-0,841	-0,852	-0,852	-0,838	-0,310	-0,310	-0,290	-0,310
Mean	-0,780	-0,802	-0,791	-0,793	-0,167	-0,141	-0,154	-0,152
Variance	-0,012	-0,015	-0,012	-0,012	-0,132	-0,137	-0,173	-0,154

Table 5: Statistical mean and variance of voltage measurements referenced to the ground considering orientation at the tree.

3.4 Optimal electrode configuration

The results confirm significant differences (*p*-value < 0.001) in the data obtained according to electrode configuration, either referenced to the ground or bipolar. Figure 9 shows this result graphically.

The obtained results demonstrate that the measured voltage values show a clear and significant difference between the electrode configurations, with an average value of 0.626 V for the referenced to the ground measurement and a value of 0.036 V for the bipolar measurement. On the other hand, the observed values for ISC show smaller differences than for the voltage (see figure 9). Thus, the difference between the means is much smaller with an average of 0.597 µA for the referenced to the ground measurement and 0.471 µA for the bipolar measurement. However, these small differences are statically significant (p <0.001).



Voltage (V) Current (µA)

Figure 9: Significant differences between the bipolar and referenced to the ground configurations in terms of voltage (left) and ISC (right) (p-value < 0.0001).

4. DISCUSSION

The first result to consider is the observation of a negative electric potential difference of the tree with respect to the ground. This observation is consistent with the different authors who have studied the voltage in several tree species [8,10,11,30]. Regarding the direction of ISC, Le Mouël[25] concludes on the presence of positively charged islands that produce a reversal of current flow. During the fieldwork for this research, we have not been able to observe any reversal of the current direction. However, as mentioned in the materials and methods section, the different sets of measurements were made under meteorological conditions that were as similar as possible.

Moreover, the results indicate that the age of Mediterranean pines has a direct influence on the electrical potential, since young pines present a significantly higher voltage than mature trees (0.92 V and 0.24 V respectively). Beside from laboratory or nursery research [11, 31-33], there are research activities that were carried out with trees in the natural environment, but those activities were performed with a single tree. Thus, e.g., Cardoso [27] analyse the electrical signals of a eucalyptus tree (*Eucaliptus globulus*) with a height of 15 m and a diameter at breast height of 45 cm. Although the age of the tree was omitted, we concluded that they were done on mature trees considering the specified tree dimensions. The same happens in other works [10, 26, 28-30].

Additionally, when comparing the voltage values obtained by these authors with ours, they are close to those obtained with our sample of mature trees. Furthermore, the results obtained in our research on the electric signal difference between young and mature trees could be compared with other research related to physiological changes and age in trees. Thus, for example, Sellin[63] observes that the sapwood thickness, in which the physiological activity is concentrated, decreases its relative proportion when the trees' age. Also, Rosenvald [64] demonstrate that the main functional parameters for the tree's mineral nutrition decrease as the age of the trees increases, reverting a behaviour similar to the *Pinus halepensis* volumetric increase functions developed and published by Montero[65].

Furthermore, the results indicate that both voltage and ISC measurements show uniform distribution patterns in the trunks. Consequently, the measurement does not vary depending on the height or orientation positioning of the electrode in the trunk. Le Mouel [25] shows a slight tendency to increase the voltage values with increasing electrode positioning height at the trunk. However, it should be borne in mind that this research was only carried out on a single tree. Our research cannot verify this presumed increase either in bipolar or referenced to the ground measurements. Thus, in the same way that we have been able to demonstrate with the results obtained in our research, Gibert [10] and Love [6] do not observe significant differences between the measurement of voltage at different heights of the electrode's position in the trunk xylem respecting to the ground. Furthermore, our mean voltage values obtained are in the same order of magnitude as those of the literature consulted [6, 10], despite the fact that these authors carried out their work outside and under laboratory conditions, respectively. Thus, in accordance to Gibert [10], we can discard the assumption of the electrokinetic theory as a generator of the difference in electrical power in trees. According to the electrokinetic theory, the electric field would be proportional to the pressure gradient [67], which transferred to a plant, would be the flow of sap per unit area. Therefore, this theory would imply a linear increase in the amplitude of the electrical potential with the height in the trunk, at least on average.

In the case of the electrode placement depending on the orientation, our voltage results also coincide with those obtained by other authors [6,30], which were obtained in measurements on individual trees. The values of current in short-circuit ISC is presented in only one work [6, instantaneous current in short-circuit ISC values shown there are quite similar to our registered values. However, the distribution of the ISC is not mentioned. Since the voltage distribution is homogeneous, we expected the same with ISC, so we have not arguments against the hypothesis that the distribution of the ISC should behave differently.

In conclusion, the electrical current and voltage do not vary depending on the measurement height or the orientation of the electrode, which reduces the difficulty of fieldwork to collect data, expanding the possibilities of installation of measurement equipment. Furthermore, the use of young trees in ground-referenced measurements gives the possibility of working with higher value electrical signals. All this will allow us to optimize the placement of the measurement electrodes in the trees depending on the circumstances. And it also allows us to consolidate the knowledge of how static factors influence the measurement of electrical signals.

Consequently, this allows us the opportunity to continue researching the dynamic behaviour of electrical signals on a population of *Pinus halepensis* in a Mediterranean ecosystem. We plan to evaluate the influence of other factors such as the trees' cycle variations (daily, monthly and annual) or even the different characteristic meteorological variables of the Mediterranean climate. The present and future works will be the basis for the use of measurable electrical signals in trees as a means of indicating the state of individual trees and forest mass.

We work with long term objective of developing low-cost and easy-to-use devices that could be integrated with other sensing technologies and would allow more accurate and correct decision-making in forest planning and management through constant monitoring of trees. .

GEOLOCATION INFORMATION

Datum:	ETRS89N
Latitud:	39º 45' 28.80" N
Longitud:	0º 30' 36.36" W
Huso UTM:	30
Coord. X:	713.297,97
Coord. Y:	4.403.863,10

DISCLOSURE OF INTEREST

The authors report no conflict of interest

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