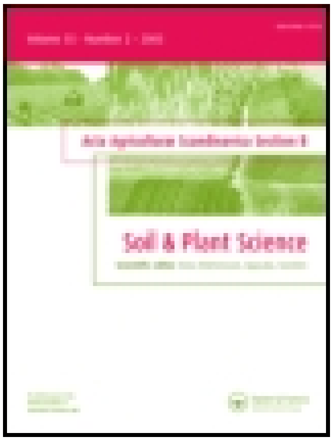

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SHORT COMMUNICATION

Effects of a weak DC electric field on root growth in *Arundo donax* (Poaceae)

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Abstract

Electric fields can determine changes at the morphological and the physiological level in plants. Plants of *Arundo donax* L. (giant reed), obtained by set, grown on organic substrate were exposed to a DC electric field. A significant increase in growth rate was observed in the shoots and roots of treated plants. Treated roots also showed a modification in their morphology as compared to untreated ones. Our results point to a possibility of applying electric fields in plant propagation and reproduction.

Keywords: Arundo donax*, DC electric field, root morphology, growth rate.*

Introduction

The application of an electric field is a type of stress, which can affect directly or indirectly the organisms exposed to it. Plant species vary in their tolerance and in their response to environmental stresses because they have various capabilities for stress perception, signaling, and response. In fact, electric fields may directly affect root meristem architecture (Wawrecki & Zagórska-Marek, 2007), as well as have a role in the development of lateral roots (Hamada et al., 1992). Electric fields have been tested in several instances, with contradictory results, having a stimulatory action (Stenz et al., 1998) or an inhibitory effect (Rabold et al., 1990) on root growth, the actual outcome depending on the strength applied, and on the presence of at least two distinct response regions in roots (Wolverton et al., 2000).

Another element to be considered is the substrate in which roots grow. Several experiments have been carried out in liquid media (Wolverton et al., 2000) as well as in hydroponics or in artificial soil (Nechitailo & Gordeev, 2004), less often in organic substrates.

Electric fields can be an important factor in plant propagation and reproduction, as well as in the control of phytopathogenic zoospores (Van West et al., 2002). A fertilizer effect in soils by electric fields has been reported (Wang & Wang, 2004).

Arundo donax L. (giant reed) is a robust perennial grass originally distributed in the Mediterranean and Middle East areas but also as far east as India, presently naturalized in temperate and sub-tropical regions. This plant can endure a large diversity of ecological conditions, reproducing mainly vegetatively by underground rhizomes and propagating through the sprouting of rhizome and stem fragments (Decruyenaere & Holt, 2001). Stems (and rhizomes) shorter than 5 cm in length and with a single node have been reported to readily sprout (Boose & Holt, 1999). Regeneration from stem fragments, however, is highly seasonal, varying (in greenhouse experiments) from 0–20% in winter to 90–100% in summer (Wijte et al., 2005). It has been often cultivated for several uses, such as making flutes (in the past) and reeds for woodwinds (Perdue, 1958). It is a source of high quality fiber, and a

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Table I. Physico-chemical characteristics of the substrate.

Moisture content (wt.%)	60.0%
pH	6.58
Total carbon (wt.%)	34.0%
Total nitrogen org (wt.%)	2.14%
C/N	14.17

potential source of chips and pellets, as well as an ideal biofuel (Raghu et al., 2006). *Arundo* also plays a relevant role in bioremediation for its ability to grow in soils contaminated by heavy metals (Papazoglou, 2007).

The aim of this work is to estimate the effect of a DC electric field on the ability of *A. donax* in developing roots from stem fragments in a controlled environment, in consideration of possible applicative outcomes, and to evaluate potential modifications in root growth rates and morphology.

Materials and methods

Plant material

Sixty *A. donax* sets showing only root-primordia were used. The sets were split into two groups (30 sets each), one treated and the other utilized as a control. The sets were collected from *A. donax* stalks growing in the wild on the banks of the Basento river (Potenza, Basilicata – Southern Italy) with the same section as measured at the 5–6th internode.

Experimental design

The experiment was realized in plastic pots and under controlled climatic conditions (Tm = 22 ± 1 C; UR = ca. 70%). The two groups of plants (treated and control) were managed in the same way. The substrate was an organic compost with the addition of an inorganic mineral base of perlite. Substrate properties are reported in Table I.

After six weeks four plants were randomly collected. The root system, from each plant was washed and treated for analysis. Samples of the substrate were air dried at room temperature, and ground to pass a 2.0 mm mesh for the determination of physical parameters.

The electric conductivities (EC) of the substrate were measured using a conductivity meter (Hanna pH 213 – Hanna Instruments Inc., Woonsocket, Rhode Island, USA) and pH values using a pH meter (Jenway 4310 – Barloworld Scientific T/As Jenway, Dunmow, Essex, England) on the substrate extract obtained by shaking the soil with double distilled water at 1:2.5 (w/v) substrate:water ratio.

Electric field

Treated plants were exposed to a DC electric field of 12.0 V m^{-1} with a current intensity of 10 mA by the insertion of two parallel stainless steel plates (60 × 15 × 0.2 cm) placed in the organic substrate. The electric field was applied continuously for the whole length of the experiment. The electric field was obtained directly by a 50 Hz voltage set-up transformer (BIO-RAD Power-Pac 3000 – Hercules, California, USA) and monitored by a digital multimeter.

Morphological analysis

At the end of the 6 week treatment for each group of plants (treated and control) the roots were cleaned and measured.

Two representative root samples from each group were fixed in FAA (10:5:50), then dehydrated in a graded ethanol series and critical point dried in liquid CO_2. The samples were coated to ca. 30 nm

Figure 1. (A) Shoot – left: treated plant, right: control; (B) Root – left: control, right: treated plant.

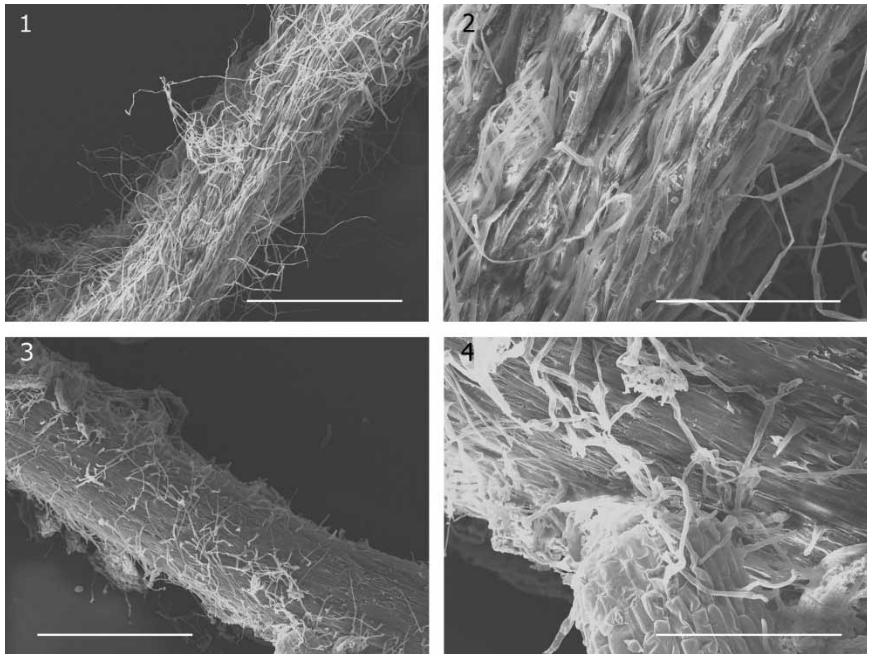

Figure 2. *Treated sample*. (1) Root hairs concealing the epidermis; scale bar = 1 mm. (2) Soil particles and hyphae visible on the root hair surface; scale bar = 300 μm. *Untreated sample*. (3) Rare hairs visible on the root epidermis; scale bar = 1 mm. (4) Scarce soil particles and hyphae present on the root hair and epidermis surface; scale bar = 300 μm.

with gold. Specimens were observed by FEI Quanta 200 ESEM – Hillsboro, Oregon, USA (CISME Università di Napoli).

Results

The values of soil conductivity (EC) and pH, measured on soil samples taken in the central area of plots were 345 and 237 mS m^{-1} for treated samples and control, respectively, while no variation was observed for the respective values of pH (6.58). A significant increase in growth rate was observed in the shoots and roots of treated plants, as compared to untreated ones (Figure 1). The roots length of the treated plants was variable from 50–60 cm, while the control showed a length variable from 4–7 cm.

At the macroscopic level, the treated sample we observed showed a marked increase in root diameter (about 4 mm), length (57 cm) and branching (Figure 2) in comparison to the control (diameter about 1.4 mm, length 4.9 cm).

Both in the proximal and the distal parts of the root, the treated sample shows the epidermis heavily covered with root hairs about 7–15 μm thick, frequently as long as 1.3 mm. The correspondent parts from the control show the epidermis with rare hairs, about 7–15 μm thick, generally 100–500 μm in length (Figure 3).

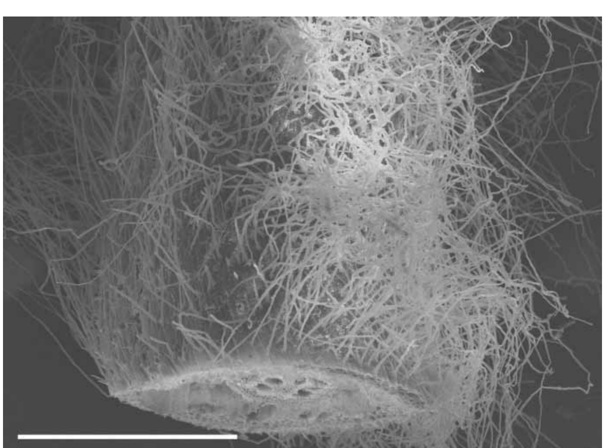

Figure 3. Treated sample, long root hairs enveloping the root; scale bar = 1 mm.

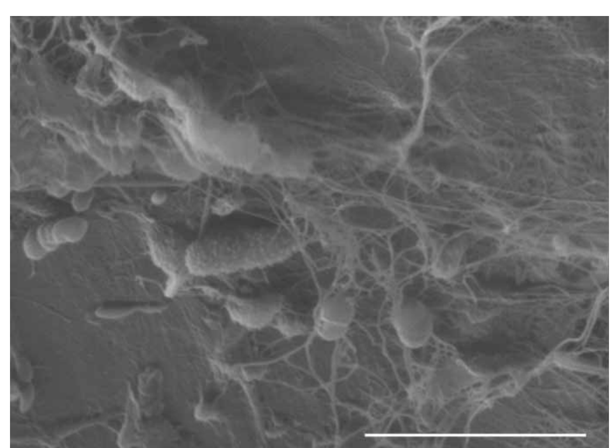

Figure 4. Detail of treated sample showing hyphae actively growing on root hair surface; scale bar = 5 μm.

Discussion

Root hairs are usually long up to 1 mm and thick up to 15 μm (Mauseth, 1988). The treated sample has a root hair length a little oversized; while the control is clearly undersized compared to normal dimensions (Figure 2).

The presence of root hairs alters the environment close to the root by means of carbon dioxide released during respiration so promoting the cation exchange from the soil particles, as well as the nutrient uptake. Also, the mucigel secreted increases the growth of microbes active on both soil properties and mineral availability (Rovira, 1979) (Figure 4). The observed variation in soil conductivity values could probably be linked to the observed differential in root growth development. Even though no variation was observed on the values of pH, a local variation of acidification at the root surface cannot be excluded. It has been observed in several instances that plants roots have stable electric patterns which are related to growth, and that elongation can be controlled by the application of an external electric field (see, e.g. Hamada et al., 1992). Most of those experiments, however, were carried out in aqueous solutions. In conclusion, our preliminary results, by the use of a substrate closer to natural soil, seem to confirm those results, opening the possibility, perhaps, for future practical uses of electric fields in plant propagation and reproduction. In this we are encouraged by the confirmation of our results, at least at the macroscopic level, by other ongoing experiments on different plant systems (*Fragaria vesca* L., and *Jatropha curcas* L.), again by the use of organic substrates, where comparable differentials in root growth rates have been observed (unpublished data).

Consequently, the next step we plan is the application of electric fields, varying in current intensity and voltage, to better assess their possible practical use in plant propagation and cultivation.

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