MICROPROPAGATION AND UAV AS ADVANCED METHODOLOGIES FOR THE RENATURATION OF DEGRADED AREAS

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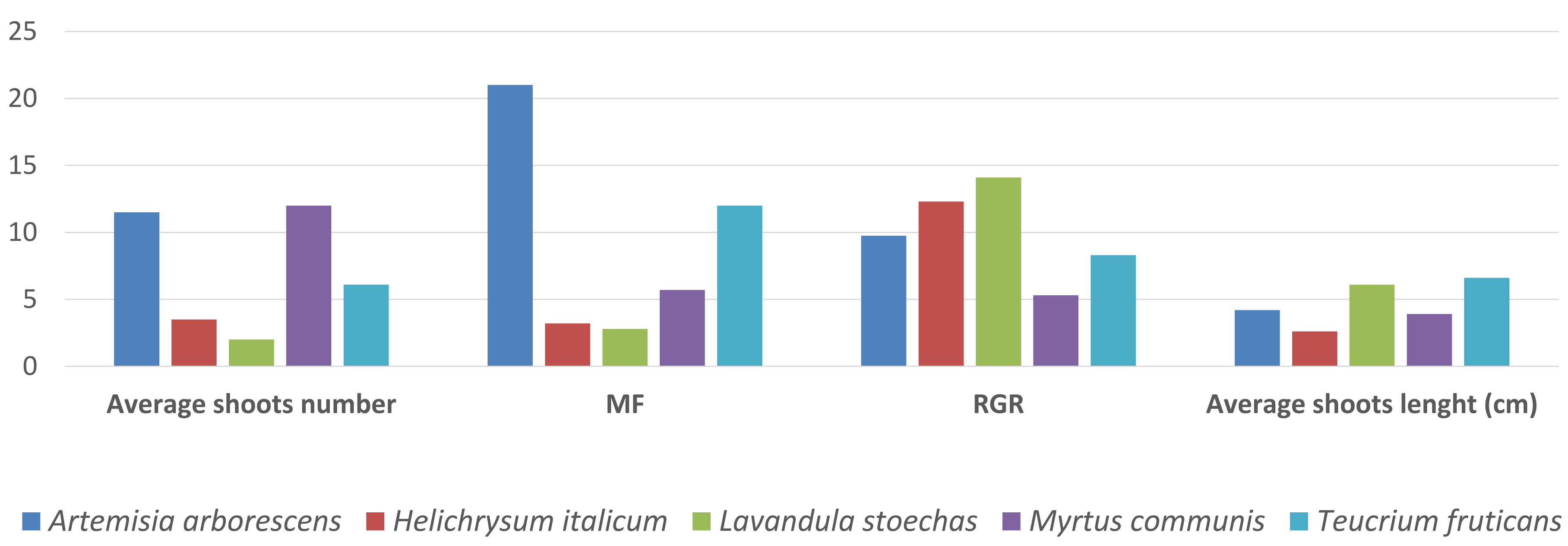
ABSTRACT

Anthropic activity is seriously compromising the environment by causing habitat loss, impoverishment of biodiversity and pollution of several matrices. Currently, the renaturation of degraded areas is essential for ecosystem health and human well-being. The aim of the present work was to develop a restoration methodology that included: the use of micropropagation for the standardized and high-yield production of plant species belonging to the Mediterranean shrub; the study of *ex vitro* rooting on substrates made from Process By-Products; open field monitoring of health status using RGB and multispectral cameras installed on Unmanned Aerial Vehicles (UAV). The species used (*Artemisia arborescens, Helichrysum italicum, Lavandula stoechas, Myrtus communis* and *Teucrium fruticans*) were selected from those originally present in the test area, already adapted to the pedological and environmental conditions of the site. *Ex vitro* rooting and the use of substrates starting from Process By-Product has made it possible to lighten the production phases and the associated costs. *In situ* acquisitions generated digital terrain models, orthophotos and vegetation index maps (NDVI). The analysis of Relative Growth Rate (RGR), rooting and survival percentages, along with the biometric data collected, highlighted the applicability of tissue culture in open field revegetation processes. Test area icluded a portion of the final coverage of the Ecoserdiana SpA landfill. This experimentation has allowed the development of an effective method for restoring the previous natural conditions of the site, proving to be in line with the objectives of the Agenda 2030 for Sustainable Development (Goal 15 – Protect and restore forests, soil and biodiversity).

MICROPROPAGATION

The micropropagation of the species under study was carried out using Murashige & Skoog, Quoirin & Lepoivre and McCown Woody Plant media, supplemented with cytokinin (BAP) in combination with various auxins (IAA, IBA and NAA). In all experiments plant cultures were grown under a 16/8h (day/night) photoperiod at 23 ± 2°C. *Artemisia arborescens* and *Myrtus communis* stood out for the high average number of shoots but a different Multiplication Factor was applied during subcultures. On the other hand, in *Teucrium fruticans* and *Lavandula stoechas*, a marked increase in height and clear nodal division were observed.



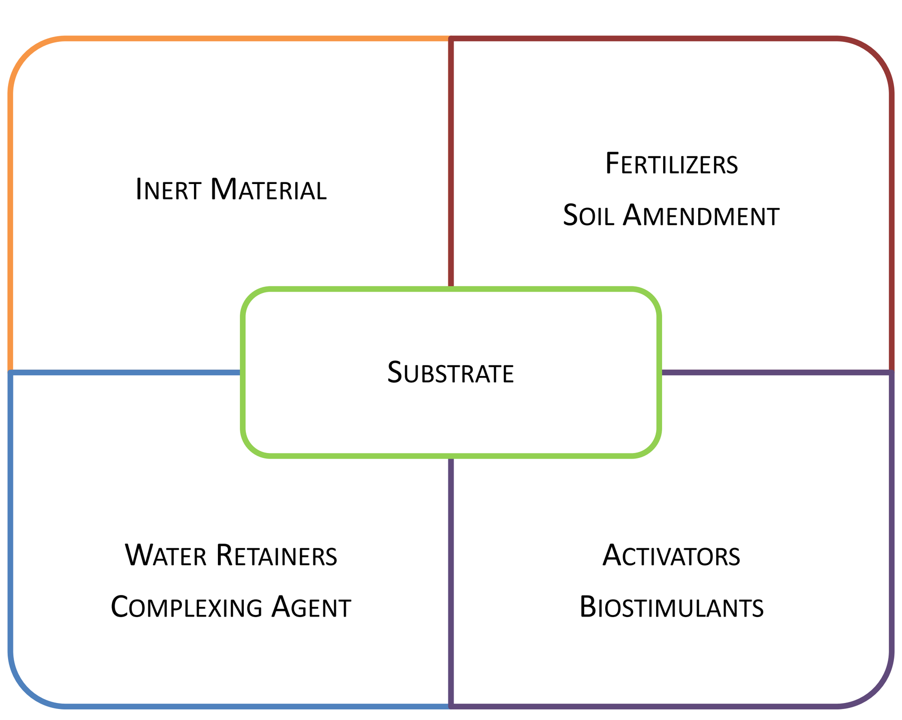
EX VITRO ROOTING

Shoots obtained from the multiplication stage were transplanted into 84 holes trays filled with rooting substrate, and cultivated in a greenhouse with a temperature of 25 ± 2°C and humidity of ≃90%. Rooting rate and survival rate were recorded after 15, 30 and 60 days for all species. Among all the species, *Artemisia arborescens* and *Teucrium fruticans* stood out for their faster rooting (15 days) and a simultaneous remarkable increase in height. *Helichrysum italicum* and *Lavandula stoechas* rooted at 30 days while *Myrtus communis* rooted at 60 days, showing stress during the phase. All surviving plantlets successfully rooted, resulting in a 100% rooting rate.

SPECIES	SURVIVAL RATE (%)	ROOTING RATE (%)
Artemisia arborescens	>95	100
Helichrysum italicum	>90	100
Lavandulastoechas	>80	100
Myrtus communis	>85	100
Teucrium fruticans	>95	100

SUBSTRATE FORMULATION

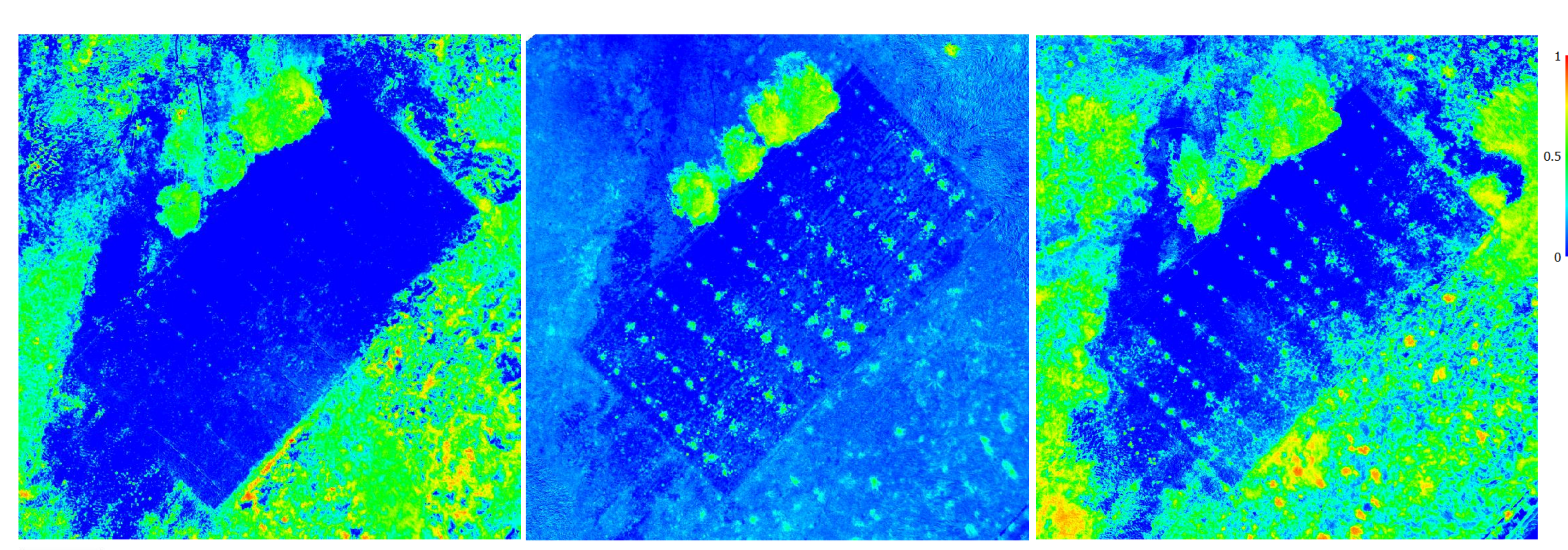
The use of process by-products and their valorization in the reuse market are central to the Circular Economy, aiming to maintain high-quality characteristics for specific applications. The proposed substrate is peat free and adheres to best practices that enhance the sustainability of the final product. Testing of dedicated substrates involves the use of Secondary Raw Materials (SRM) and process by-products including inert materials, fertilizers and soil amendments, activators and biostimulants, complexing agent and water retainers. The goal is to use these materials during the *in vivo* rooting and repotting phases, thereby reducing production costs and promoting sustainable reuse practices.



Revegetation areas: Fig. 1 - Miniera Monte Sinni (Gonnesa, CI); Fig. 2 - Ecoserdiana SpA landfill (Serdiana, SU)

UAV

The project uses drone-mounted sensors (UAVs) and ground-based measurements to monitor a landfill area undergoing revegetation. The use of drones enables for rapid and accurate data acquisition through multispectral sensors that detect the physical and chemical properties of vegetation and soil. NDVI is related to the photosyntetic potential of the crop and the concentration of chlorophyll and can vary between -1 and 1. Bare soil and rocks have values close to 0 while vegetation has always positive values. The NDVI detection three months after planting (T1) does not show values higher than 0,10 due to the very young plants and reduced plant biomass. The growth development is validated by a value close to 0,50 after nine (T2) and thirteen months (T3). This data is essential to optimize the post-planting phases, improving crop growth and making water and agrotechnical resources more efficient.



Multispectral analysis of revegetated landfill area: **N**ormalized **D**ifference **V**egetation **I**ndex (**NDVI**) in December-23 (T1), July-24 (T2) and October-24 (T3).

CONCLUSION

The experimentation led to the definition of effective micropropagation protocols for different plant species (*Artemisia arborescens, Helichrysum italicum, Lavandula stoechas, Myrtus communis and Teucrium fruticans*). Due to the high proliferation ratesa, it has been possible to mass-produce high-quality clones. The *ex vitro* rooting of the species resulted in favorable root development and shoot growth. Moreover, ex vitro rooted plantlets did not require any further acclimatization before being transplanted to the regular greenhouse conditions. Initially, ex vitro rooting phase on substrates made from process by-products was challenging and required careful optimization to ensure the success of the phase. Using micropropagated plants for the revegetation of a degraded area confirmed the effectiveness of the restoration methodology, highlighting a significant improvement in environmental conditions and expanding the biodiversity of the intervention site. The entire study was conducted during the early stages of planting, and significant developmental changes are expected to occur over time. These results demonstrate the potential of micropropagation as a tool for the conservation and ecological recovery of compromised areas.

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