MODULATION OF MEMBRANE PROPERTIES BY OPTICAL TWEEZER, AS POSSIBLE TOOL TO GUIDE THE FORMATION OF ROOTS IN ORDER TO PREVENT LANDSLIDES

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ABSTRACT: Growth of plants as a method to prevent landslides is widely used. Modulating the roots growth direction could increase the effectiveness of stabilizing land through the use of calculated growth models. They can be guided by interactions between bacteria and plants, which in turn can be guided by modulating cell membrane functions using localized mechanical forces. Using optical tweezer could simplify the application of mechanical forces likely to influence ion channels with a degree of mechanical sensitivity involved in this signaling.

KEY WORDS: optical tweezer, root, plant-bacteria interaction, landslide, ion channels

1. INTRODUCTION

The root growth-promoting bacteria interact with plant roots in a way that influences their feeding and development [1]. Signaling pathways of root-rhizobium symbiosis are relatively known [2], but no efforts have been made to guide directions of development of roots and their branches. Theoretical models have been developed to predict the optimal distribution of the roots in order to prevent landslides [3].

Mechanical forces ability to influence ion channels with a degree of mechanical sensitivity through optical tweezer [4] opens new opportunities in guiding root's growth directions and branching.

2. THEORETICAL MODEL

Guiding the position that certain bacteria get to the root may modulate the direction in which it develops. This can be achieved by targeted transport of bacteria using a multi-point optical tweezer that can transport them individually in the desired direction [5]. The transport of these bacteria can be achieved using mechanical forces applied with a holographic optical tweezer in order to be able to transport a large number of targets in the same time [6]. Since it is necessary to identify easily the bacteria over long distances, fluorescent labels may be used such as those from GFP family [7]. In this way, it may be simultaneously identified different types of bacteria labeled with different fluorescent proteins, with reposition the bacteria escaped from the optical tweezer due to large distances. Reduced amounts of the fluorophore from a bacterium and large distances of optical paths require the use of a multi photon microscopy [8] system and the use of optical scientific camera with high quantum efficiency [9] (Figure 1).

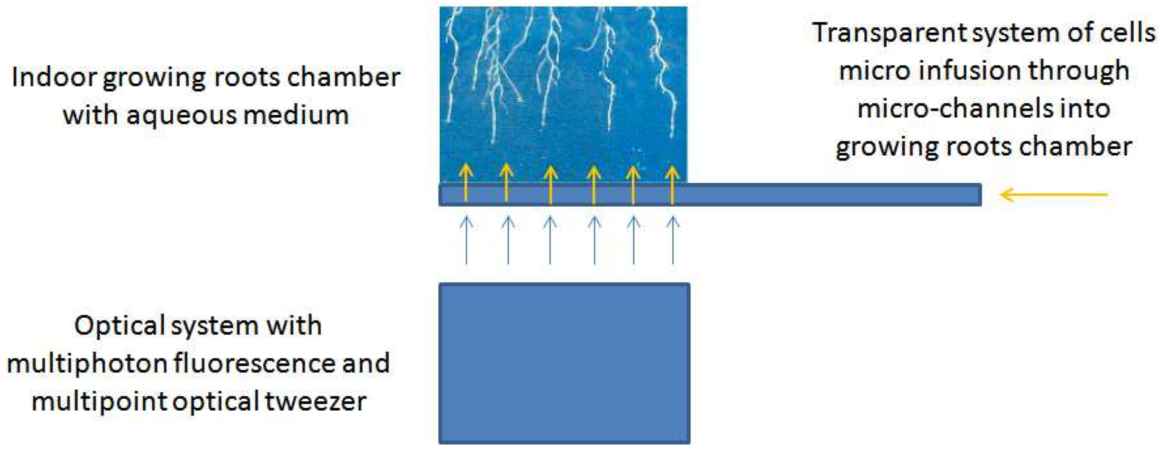

Figure 1. Optical guidance system of root's growth and branching directions

Cells co-localization may be achieved using FRET [10] and consequently can be evaluated bacterial associations or bacteria proximity in certain fluorescent areas of the roots. In this respect, it is necessary that fluorescent proteins to be expressed at membrane level and in case of the roots to be present in the native or genetic modified extracellular structures. This method of investigation allows the identification of interactions between bacteria and roots and between associations of different bacteria and roots.

3. METHODS OF SYSTEM DEVELOPMENT

Identifying critical points in the functioning of the proposed system highlights an optimal method of its development.

Using an optical tweezer with a large working distance and a large number of traps is a problem relatively easily achievable. However, described construction details raise many problems.

Transparent system of micro-channels is an optical element difficult to develop in order to not introduce optical aberrations that cannot be corrected by softwares. It can be done with such precision using Two-Photon Photo polymerization 3D Laser Lithography. There's a commercial device of the Nanoscribe company, but the desired dimensions are performed only with a non-commercial device from TETRA Ilmenau company.

For an easy software correction, it may be useful to use material with refractive index as close as possible to the aqueous medium. Due to the fact that the materials used are limited in diversity, an attempt to match their refractive indices with the aqueous medium can be achieved by modulating the refractive index of the aqueous medium by addition of non-harmful substances. This equalization of refraction indices would be useful to be valid for as many as possible of used wavelengths.

Identifying the root surface position can be achieved using extracellular fluorescent natural substrate, due to the large amount and its relative uniformity. Using multi photon microscopy enables precise identification of these proteins. In case the fluorescent signal is below the sensitivity of the camera with high quantum efficiency, it will be necessary to use a fluorescent signal amplification system. It is recommended in this case the use of genetically modified plants that have a stronger fluorescence component. This approach would have the main drawback the cost of development, testing and validation for commercial use. Another possible approach would be to use the fluorescent labeled antibodies. Due to technical impossibility to perform washing for the removal of antibodies unattached to the substrate, a possible approach in this case is the use of antibodies labeled with fluorophores on the FRET pair. This approach has as main negative issues the cost of reagents, complicated optical system and interface between the micro-channels and aqueous medium.

The use of FRET allows identifying when the bacteria were fixed to the roots by identifying the existence of a reduced distance between the root extracellular matrix proteins and a large proportion of fluorescent proteins from bacteria's membrane. Intensifying FRET signal allows preservation of fluorescence in case of partial photo bleaching due to laser long stimulation. In this respect, weak signals can be detected from bacteria out of control due to technological limitations or due to bacterial growth.

Due to the exposed complexity of the system and the multiple interdependent elements between constructive and financial decision, an inter- and trans-disciplinary team project is needed. Moreover, it is necessary to involve some companies with significant market potential, to take over the research results and insert into the economic circuit. Potential applications of this approach are not limited to increasing the efficiency of land stabilization and preventing landslides, but also it may be achieved more efficient use of agricultural resources. This could be useful for lowering the amount of chemicals used in agriculture with secondary decreased food induced health problems, and development of new agricultural devices used for intercropping. This new paradigm in guiding economical use of root formation can develop a new business ecosystem that could be supported and funded in order to develop new SME by university graduates, with the absorption of local labor forces and decrease in unemployment (Figure 2).

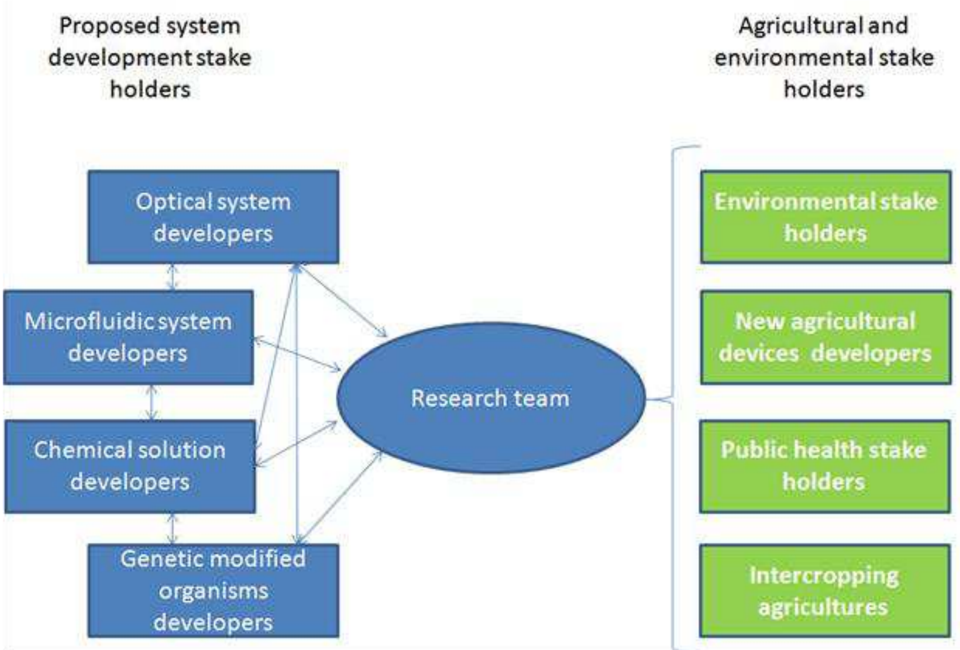

Figure 2. The new economical paradigm in guiding root formation, with stake holders and most impotant interdependencies

4. CONCLUSIONS

- ✓ The proposed technology is feasible using existing technologies;
- ✓ The proposed technological development requires attracting significant financial resources through research projects, preferably in partnership with industry;
- ✓ Potential results of such a project would change the crops culture, having an impact on different levels from enviromental to agricultural devices industry.

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