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Rhizobacterial Application for Sustainable Water Management on the Areas of Limited Water Resources

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Editorial

The world population is predicted to increase beyond 8 billion by 2030, implying major challenges for the agricultural sector to secure food availability [1]. A key challenge for plant growth is global water shortage which limits crop yields already today. As the drought limitations gain in importance in the near future the agricultural activities must expand to less fertile areas to satisfy growing demands for food [2]. During the next years, many countries will experience water problems, shortages, poor water quality, or floods that will increase regional tensions. By 2030, available fresh water will not keep up with the demand and without more efficient management of our water resources; the problems we now encounter will hinder food production in key countries. This is a global problem for food markets and the associated economic growth. Due to developing economic pressures, North Africa, the Middle East and South Asia will face dramatic challenges in dealing with water problems [3]. Because of depleted and contaminated surface water supplies, many of these countries have resulted in over pumping the groundwater to satisfy growing food demands, which has resulted in a serious threat to food security, thereby risking social turmoil i.e. loss in agricultural jobs, significantly stressing the economy. A strong correlation exists between water supplies for agriculture and GDP. Approximately 70% of the global fresh water supply is used in agriculture, creating a great opportunity and potential for technology to provide solutions in order to effectively use the available water [3].

Several breeding and genetic engineering strategies have been proposed to increase the ability of plants to tolerate stress in order to find practical solutions. Past efforts to improve plant tolerance have has been slower than expected owing to the genetic complexity of stress responses. At the same time the resources already present in natural, complex self-regulating systems i.e. the underground resources of the plant rhizosphere offer new opportunities for agricultural biotechnology [4].

The very first report on plant drought tolerance enhancement by Plant Growth Promoting Rhizobacteria (PGPR) was published in Uppsala, Sweden (Figure 1) [5]. It was shown that *Arabidopsis thaliana* inoculated with PGPR *Paenibacillus polymyxa* B2 could survive drought stress remarkably longer compared to the untreated control plant. The report was followed by Prof. Glick group in Canada [6]. Research is being conducted for the mechanisms behind the observed plant drought stress tolerance enhancement in order to find possibilities for economically efficient rhizobacterial applications for plant drought tolerance enhancement. It has been shown that certain PGPR enhance plant stress tolerance through 1-aminocyclopropane-1-carboxylate deaminase (ACCd) and provide significant protection to a wide range of plant species from the damage caused by various abiotic stress conditions [7]. ACC breakdown and ethylene synthesis inhibition by ACCd decreases the damage of various stress situations by enhancing homeostasis in and around the plant root, especially at early stages of stress exposure. Hence ACCd can be considered one of the signaling compounds mediating plant basic stress tolerance. The ACCd containing and biofilm producing bacteria which show the best drought tolerance enhancing ability excrete the 'matrix' to provide a buffer against the environment (Figure 2)[4, 8]. The dense biofilm matrix, limits diffusion of compounds secreted by root bacteria and are therefore concentrated at the root surface where they are most likely to affect plant growth [4]. Our experiments show that bacteria can engineer their own microenvironment in a form of porous extracellular matrix mixed soil particles. The environment immediately interacts with plant root providing buffered and predictable hydration and transport properties (Timmusk manuscript in preparation). The extracellular matrix producing *Paenibacillus* sp. strains significantly increased soil aggregation in comparison to the null mutants of the strains (Timmusk manuscript in preparation). The matrix may also contribute to mechanical stability of the biofilm and interact with other macromolecules and low molecular mass solutes, providing a multitude of microenvironments within the biofilm. Currently many of these effects can only be speculated. We keep highlighting themes regarding the nature and diversity of the bacterial isolate biofilms and elucidate their potential protecting plants against drought stress.

The underground resources of plant rhizosphere could provide insights associated with global water shortage and climate change. So far, these resources have been neglected to a large extent, but hopefully with the help of new technologies we will be able to understand and employ the natural potential of biofilms for our agro-ecosystems.

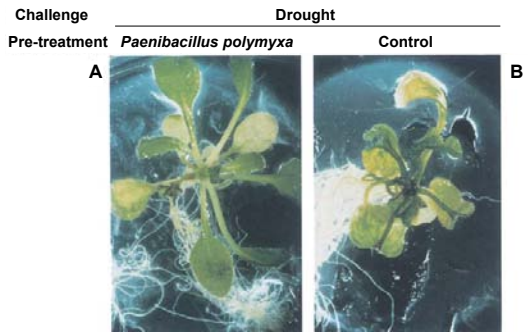

Figure 1: Enhancement of plant drought tolerance by *Paenibacillus polymyxa*. *P. polymyxaB2* inoculated plants (A) survived drought stress two weeks longer than untreated control plants (B). Image after three day drought exposure is shown. Plants were grown and inoculated and subsequently exposed to drought stress as described by Timmusk [5].

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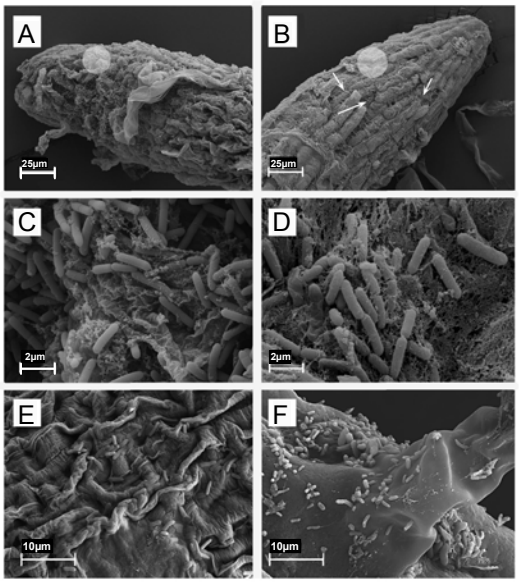

Figure 2: Typical pattern of *P. polymyxa* B1 colonization and biofilm formation on plant roots. Scanning electron microscopy micrographs of colonized roots. Studies in the controlled system after two hours of colonization (A, C, E) and in non-sterile soil assays after one week of colonization (B, D, F). Plants were grown and inoculated as described by Timmusk (8) Images were taken from the root tips (A, B, C and D) and from tip-distal regions (E and F) (8).

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