SMART - A Tool Kit for Sustainable Method of Agriculture Using Root Transition

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Method Article

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Abstract

The rapid increase in global population along with urbanization will continue to increase the challenge of food security and environmental sustainability. Agriculture is essential for food security, however, is an expensive process both financially and environmentally. Estimation of crop performance before investing in field would substantially benefit agricultural output and environmental sustainability. A simple, easy to use, portable, and inexpensive prototype of a device is described that can be successfully used to estimate plant performance and help tailor fertilizer formulations and microbial consortium for optimal agronomic output. The device can also be used for agriculture by farmers and for plant research by students and scientists.

Introduction

The global human population is estimated to reach 10 billion by the year 2050 (Ezeh et al. 2012). It is predicted that there will be a simultaneous increase in urbanization with nearly 70 percent of the entire population living in urban areas. Such shift in demography along with increasing demand for food will add to the existing challenges of deforestation, food security and climate change (van Dij et al. 2021). We depend on agriculture for our food supply; however, it is an expensive exercise both in terms of human labor, economy, and environment. Thus, the environmental costs and agricultural inputs such as water, fertilizer and seeds factored with the yield of a crops, fruits, vegetable, and edible plant products should be in equilibrium for environmental sustainability and agricultural success (Bongiovanni et al. 2004; Özerol et al. 2012). The performance of a plant is directly related to the success of agriculture. Since roots are the organs that absorbs minerals and water from belowground to nourish the aboveground parts of a plant, the performance of roots can be used to predict the performance of a plant in a certain environment (Marin et al. 2021). Here I have described a simple, reliable, cost-effective prototype to estimate seedling root performance and thus predict plant performance in a defined environment and in the field.

Design And Principle

The device (SMART - A tool kit for Sustainable Method of Agriculture using Root Transition) will consist of a transparent polypropylene box with agar or polyacrylamide-based media serving as matrix for seedling root growth. The central region of the media surface will serve as a germinating point of a seed where seedling root will start penetrating downward through the media. Four narrow and transparent tubes with perforated walls will be placed at equal depth each in the four corners of the box in such a way that they intersect the media halfway from the media surface to the base of the box and create a capillary. These capillaries will be used for three different purposes. First, they can be used as port of entry for polyacrylamide based and chemically defined beads serving as fertilizers. Four different formulations of fertilizers can be tested at a time. Upon addition through the capillary, these fertilizer beads will get lodged halfway through the media and adjacent to the walls in four spatially defined regions of the box. Once in contact with the media, they will slowly diffuse through the media to create a

chemical gradient. The rate and direction of the movement along with the developmental characteristics of the seedling root can be used as a signal of their propensity for the test fertilizers. Secondly these capillaries can serve as an entry point for four different microbial consortia made from sporulated microbes. Such microbial consortium will be activated once in direct contact of the media and start multiplying creating four different microenvironments within the box. The health and affinity of the seedling root towards these microenvironments can help predict the optimal combination of microbes that can augment root growth. Finally, the perforated walls of the tubes would serve as channels for aeration of the media supporting root growth and development. The inner wall of the tubes can also be coated with chemical receptors that can trap ligands such as specific volatiles including root leachates and exudates that are indicator of root health and physiology. Chemical modification of the receptors can be done such that the ligand-receptor reaction can result in a specific color in the visible range. The qualitative and quantitative estimation of the color can predict the root physiology. Such a modification will complement the morphological data (rate and direction of root growth along with developmental characteristics) with physiological perspectives to reaffirm the choice of optimal test fertilizer and test consortia of microbes.

The SMART device can be enhanced by several other modification to precisely predict the factors that decides performance of a specific plant variety in the field. A bead of a certain diameter made from silica gel or hydrophilic polymers can be placed in the center of the media. The change in diameter of the bead with time can be used to extrapolate the change in water content of the growing media. Similarly, a strip of pH paper can be placed vertically along the length of the media on all four walls of the box and the base to estimate the change in pH at different lengths of root growth and in different physiochemical and biological environment. A volume of soil from agricultural field that is equal the volume of the media can be repeatedly sieved, soaked, washed, and the extract can be concentrated and added to the agar or polyacrylamide to mimic the nutrient level of the natural soil. Such a media can be used as control along with the defined media as described above to compare the seedling root growth. Such comparative data can be used to tailor fertilizer and microbial consortium for a specific plant variety in a particular environment or growth conditions.

Finally, a smart phone can be used to image the progression of root growth (rate, length, thickness, branches) along with the changes of other factors such as color change of tubes, intensity of the color, pH stripes and diameter of the hydrophilic bead at different time points. Such data can be easily analyzed by using computer algorithms and can yield a score to predict the ideal physical, chemical and biological conditions for the performance of a plant variety in the field. Comparing the scores of seedling roots grown in defined and undefined media (derived from soil extracts) the algorithm can suggest remedial measures and predict combination of fertilizers and microbial consortium for optimal output from the field in an environmentally sustainable way.

Significance

Though the plan and design of the device is relatively simple, it can be very effective and versatile in applications concerning diverse crops and environmental conditions. The inexpensive material of the SMART device can make it easily affordable to farmers from developing countries and to teaching/research laboratories that have budget constraints. The device is relatively small, thus portable from field and, greenhouse to lab. Such a movable test system can be of great advantage in experiments that requires manipulation of temperature, humidity, and light. Plant scientists can use the SMART device for a quick preliminary investigation before committing to expensive and laborious biochemical and molecular tests. Farmers can use the device with little to no training to estimate seed performance and apply tailored fertilizer and biological supplements factoring the field conditions and seed performance. Finally, the small size and versatility of this device can be useful for astronauts to carry it in space for microgravity experiments concerning plants. It can be ascertained that such a device can predict plant performance by estimating seedling root growth following a simple and inexpensive protocol and can contribute towards food security and environmental sustainability.

Declarations

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CONFLICT OF INTEREST

The author declares no conflict of interest

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