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ENGINEERING TECHNOLOGY FOR PLANT PHYSIOLOGY AND PLANT STRESS RESEARCH

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Plant physiology and plant stress: Plant physiology will be much more important for human mankind because of yield and cultivation limits of crops determined by their resistance to stress. To assess and counteract various stress factors it is necessary to conduct plant research to gain information and results on plant physiology. Especially for agriculture this is of great significance, because stress is very harmful to plants resulting in reduction of biomass production of crops. Stress is defined as a tension state, describing the effect of a load of the organism caused by external factors which impair the metabolism or growth. Not only humans but also plants and animals are exposed to a so-called stress. There are many different types of plant stress. Major abiotic stress factors in plants are:

- mechanical stress
- water stress
- aridity stress
- salt stress
- heat stress
- frost stress
- oxygen stress
- light stress
- UV radiation stress

C3-Plants: The C3-photosynthesis is the best known and most common type of photosynthesis in nature. It is the most effective process for the synthesis of biomass. In hot climates, the stomata of plants close to keep the water-loss due to transpiration as low as possible. It follows a reduction in CO_2-uptake necessary for photosynthesis. Examples of C3-plants are: Wheat, rice, sugar-beet and potatoes.

C4-Plants: During evolution these plants, developed from the C3-plant-type, pursue a special kind of photosynthesis. These botanical species are able to pursue photosynthesis with low CO_2-concentrations and they also lose very little water under strong solar irradiation. Thus these plants are adapted well to hot climates. Examples of C4-plants are: Millet, maize, sugarcane, china-reed and tumbleweed.

Aim of the study: Climate change and growing population lead to food shortages in the near future. A major objective in plant research is to combine the characteristics of C4 plants to the species of C3 plants in order to protect them against climate change and the increased use of agricultural areas for C3 plants in hot areas of the world too. Therefore it is important to exactly quantify the biomass production of individual plants at regular conditions as well as at defined plant stress. The determination process has to be quick and accurate. Therefore we combined our skills in technical engineering with knowledge in plant biology to built an automated system for analyzing the shape and cross section of individual plant leaves at high accuracy.

Experiments: To reinforce the idea of a mobile plant-scanner, there were two experiments conducted with a stationary test-stand-construction. A plant leaf of a potted plant was fixed between two laser sensors, one coming from below and one from above the leaf (Figure 1).

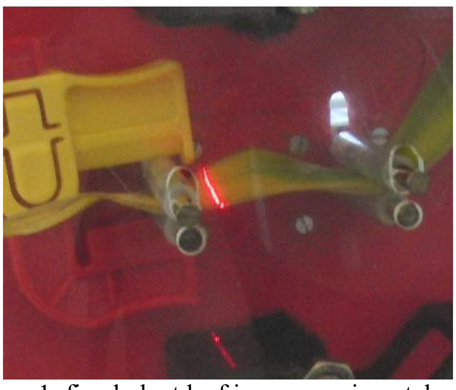
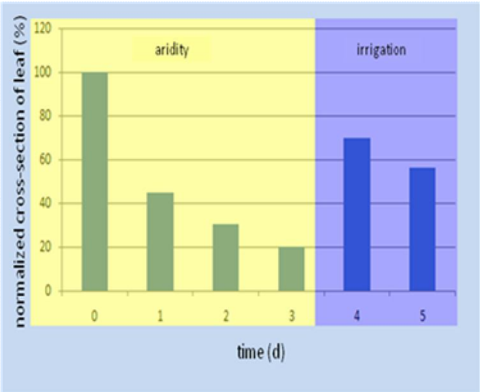


Figure 1: fixed plant leaf in an experimental setup

1. aridity stress: Cross-sectional area changes during slow drying of the plant and subsequent one-time irrigation were detected (Figure 2). The graphic shows a fast decrease of the normalized cross-section of the leaf to 20 % at day three. After the irrigation the cross-section recovers and increases. However, never completely but up to only about 75% of the value before irrigation.



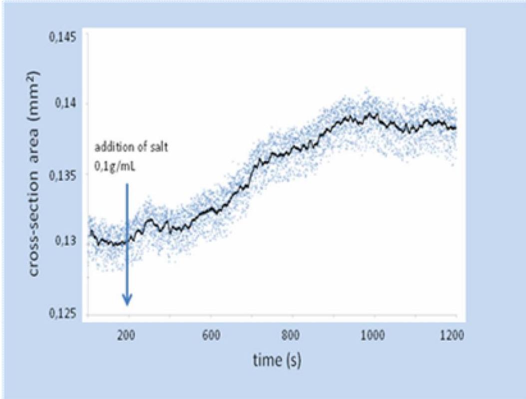


Figure 2: aridity stress

Figure 3: salt stress

2. salt stress: It was also possible to detect very fast cross-sectional area changes of the leaf caused by salt stress. Similarly to the first experiment, a plant leaf of a second potted plant was fixed to the test-stand. After 200 seconds a salt solution (0.1g/ml) was added to the pot (Figure 3). Contrary to the expected decrease of the cross-section the volume of the leaf increased. In literature this is described as direct admission of nutrients of the cells.

PhytoScan Alpha 70: After successful preliminary experiments the plant-scanner PhytoScan Alpha 70 (Phytos: greek plant, Alpha: first Version, 70 mm scan width,

Figure 6) was developed. It is a mobile device to be used in greenhouses and plant research institutes to analyze the shape and cross-section in real time (Figure 4 and Figure 5). It is possible to create a 3D-model of the plant leaves.

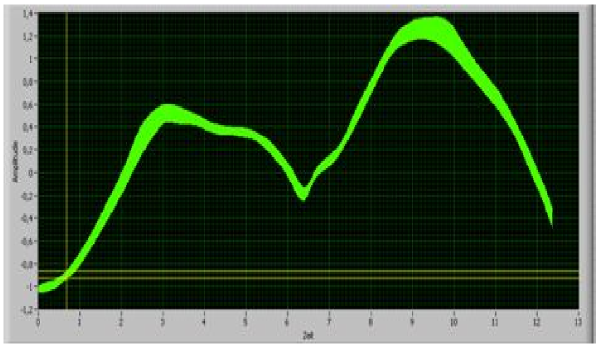


Figure 4: analyzed plant leaf

Figure 5: computer computation of a cross-section of a leaf

Figure 6: PhytoScan Alpha 70