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AUTOMATED SOIL WATER TENSION-BASED DRIP IRRIGATION FOR PRECISE IRRIGATION SCHEDULING

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Introduction I

Main question: When and how much to irrigate?
Irrigation scheduling can be based on:

1. soil water balance calculations (SWB)
    - f.i. FAO-56 crop coefficient approach [1]
    - estimation of daily crop water use: $ET_c=ET_0*K_c-P$
    - empiric approach with limitations in the achievable accuracy and transferability
2. soil water measurements (whether in terms of water tension or water content)
    - irrigation if a certain threshold is reached
    - irrigation can be automated but difficulties arise from where exactly to probe
3. plant stress sensing (e.g. leaf water status, stomatal conductance, growth rate) [2]
4. crop growth modeling [3]

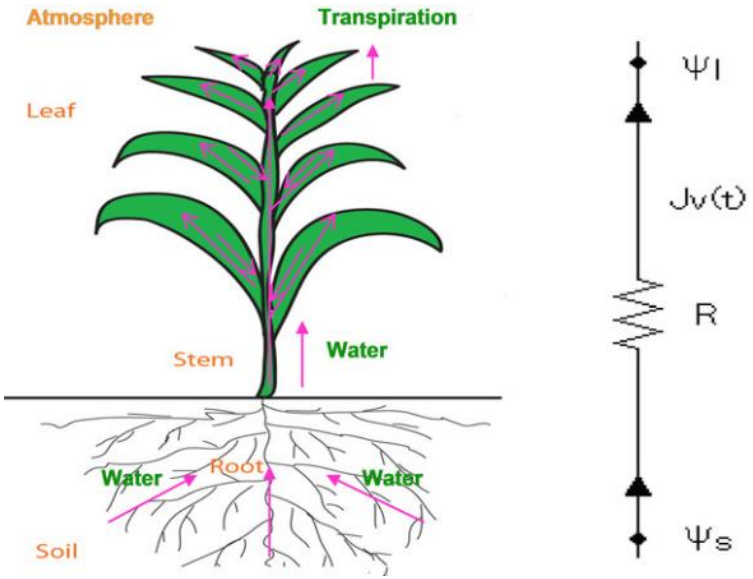
The present study addresses the question:
How does automated soil water tension-based irrigation perform?

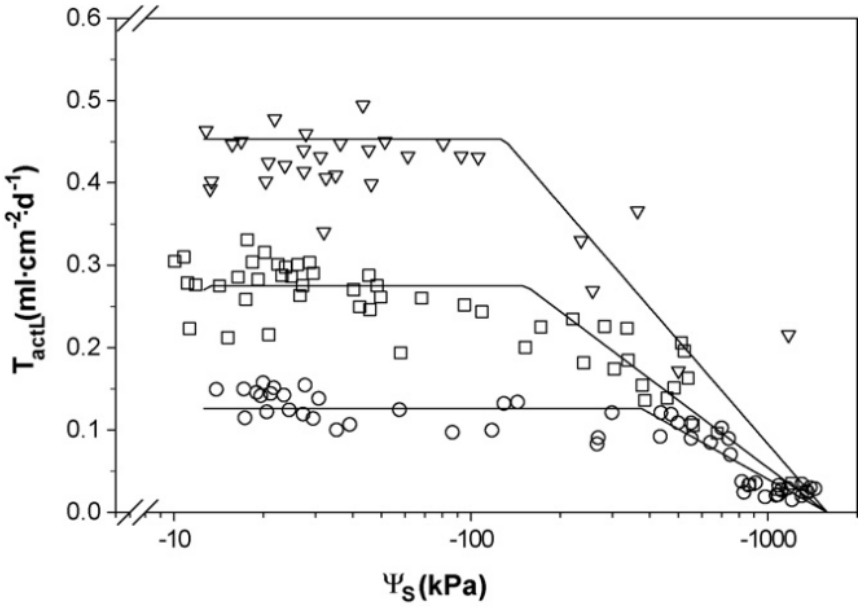
Introduction II

The **soil-root-shoot-atmosphere continuum**

The water flow in the plant is driven by potential differences

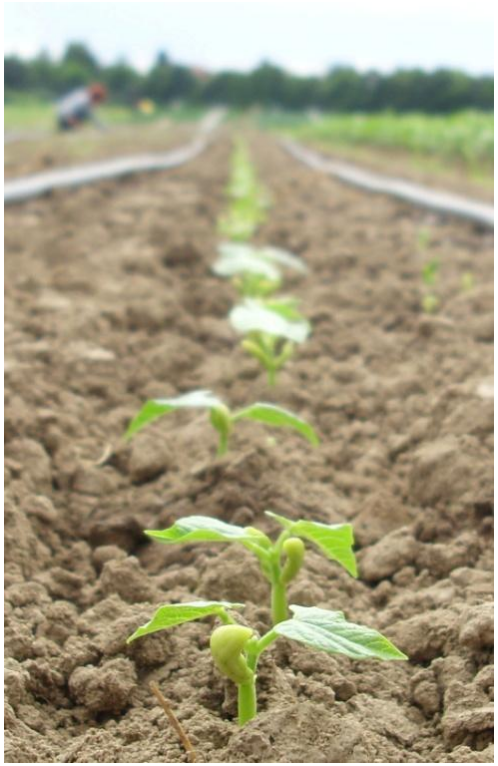
The soil water tension is closely related to transpiration and plant stress





Left: Water flow in the plant [4]. Right: Actual transpiration, T_{act}, of cauliflower dependent on the mean soil water tension, ψ_s, for three classes of specific potential transpiration [5].

Experimental focus crop



Common bean (*Phaseolus vulgaris* L.):

- a very important food legume [6]
- characterized by a rather limited and shallow root system [7]
- drought stress results in significant seed yield reductions in 60% of global bean production areas [6]
- particularly susceptible to drought stress during flowering [7]

Experimental site & design

Experimental site:

- located near Dresden in Germany
- average annual P= 650mm and T=10.4°C
- loamy sandy soil with a deep groundwater table

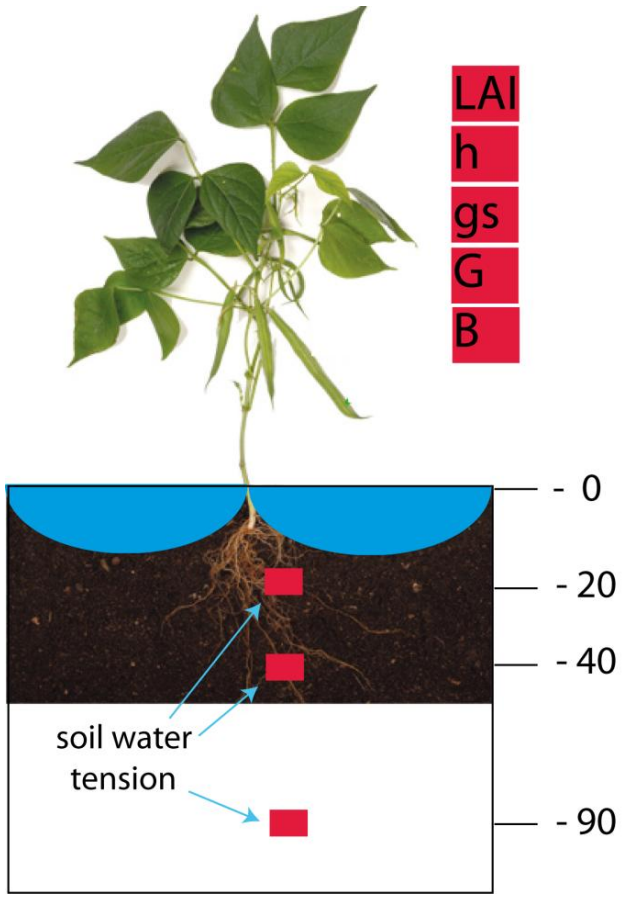
Experimental design and setup:

- one-year field trial with bean (cultivar Stanley)
- row spacing: 50cm, between-plant spacing: 6cm
- sowing date: 5/13/2014, harvest: 7/29/2014

Four irrigation treatments:

- rain-fed treatment (treatment RF)
- SWB based sprinkler irrigation (treatment SWB)
- two treatments with automated soil water tension-based drip irrigation (treatments $T_{-200hPa,}$ $T_{-350hPa}$)

Experimental data collection



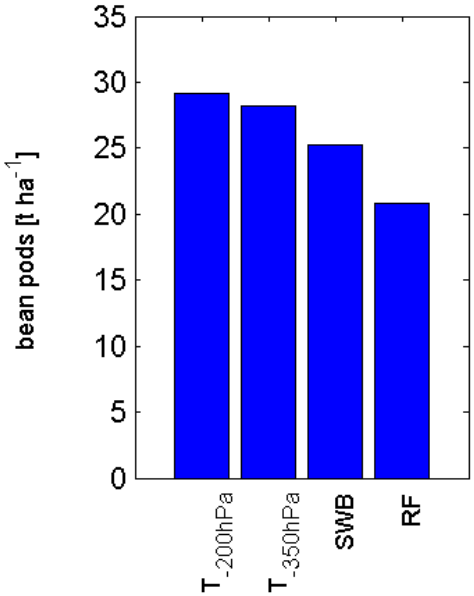
Continuous measurement of:

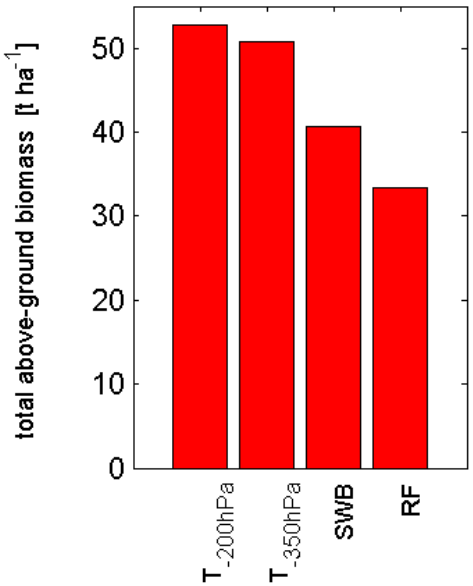
- leaf area index (LAI)
- plant height (h)
- stomatal conductance (gs)
- foliar greenness (G)
- total above-ground biomass (B) partitioned into leaves, stems and pods
- soil water tension in 20, 40 and 90cm soil depth
- weather data

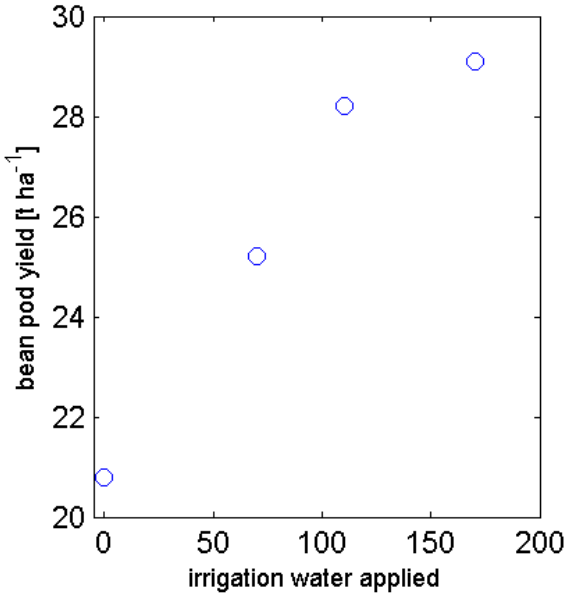
Experimental results I

Irrigation clearly influenced bean growth and bean fresh matter yield:

- with 29.1 ($T_{-200hPa}$, 170mm) and 28.2 t ha^{-1} ($T_{-350hPa}$, 110mm), the drip irrigated treatments achieved the highest pod yield
- the SWB treatment gained 25.2 t ha^{-1} with 70mm
- the rain-fed treatment reached 20.8 t ha^{-1}



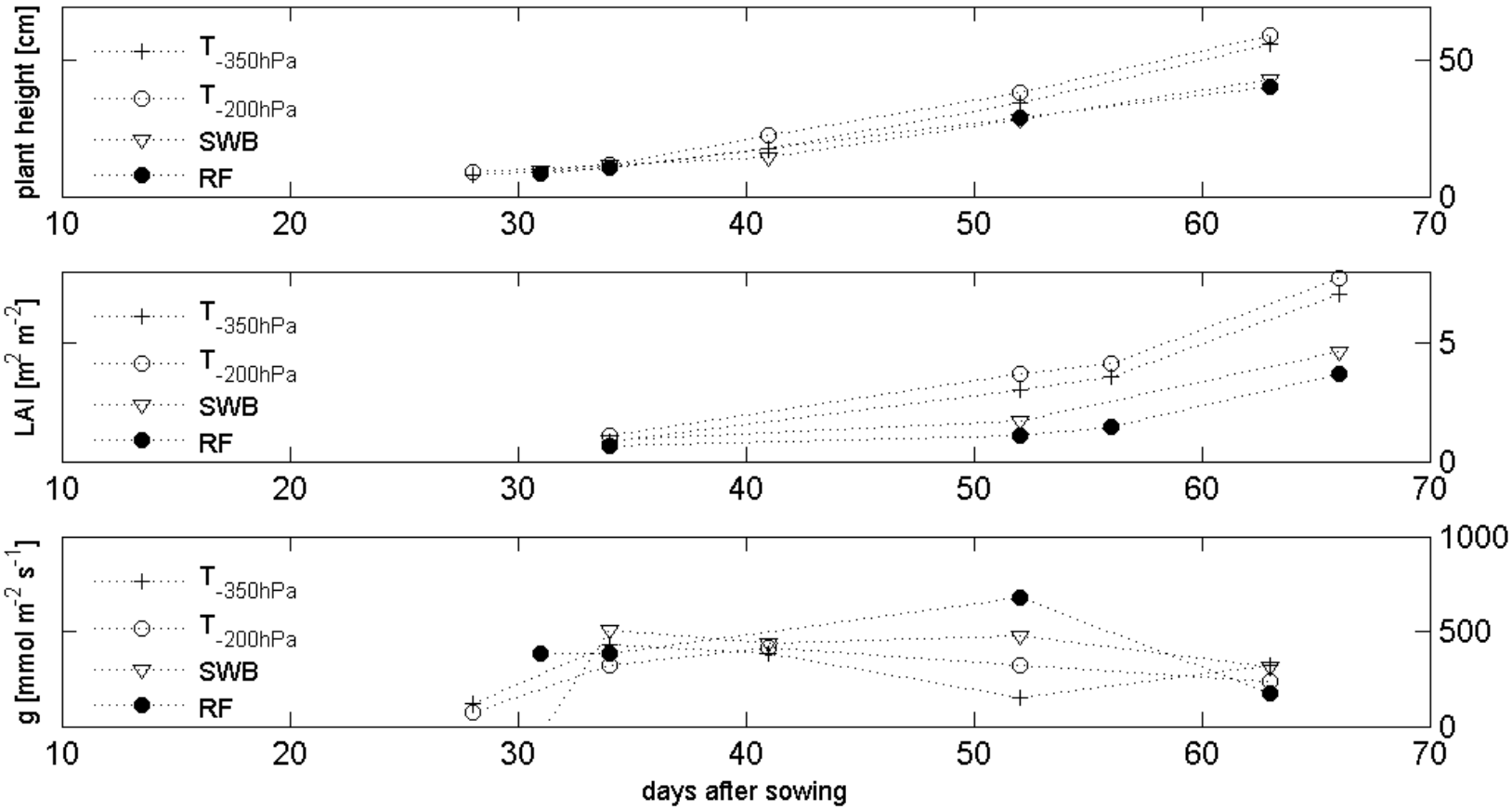




Observed bean pod yield, total above-ground biomass and pod yield vs. irrigation water applied.

Experimental results II

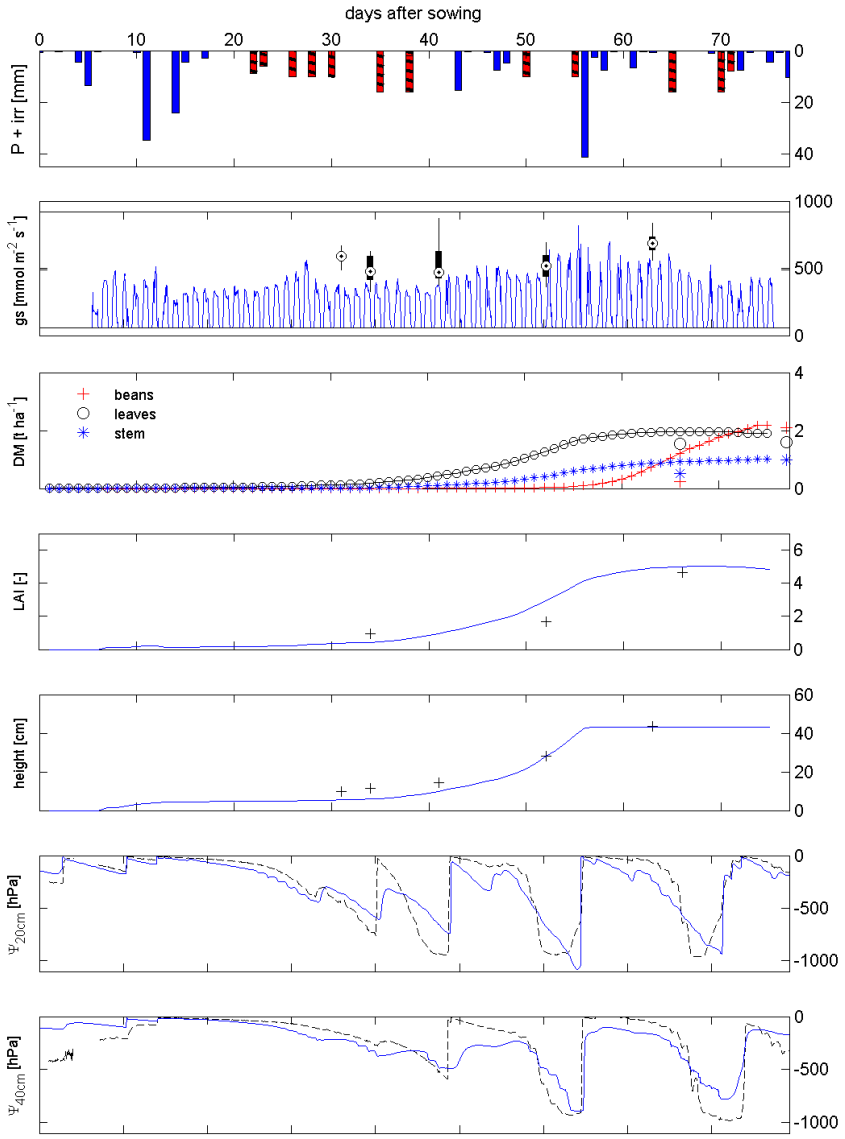
- the drip irrigated treatments achieved the highest plant heights and LAIs
- drought stress occurred in the rain-fed treatment



Experimental results III

How to gain an appropriate cultivar-specific soil tension threshold?

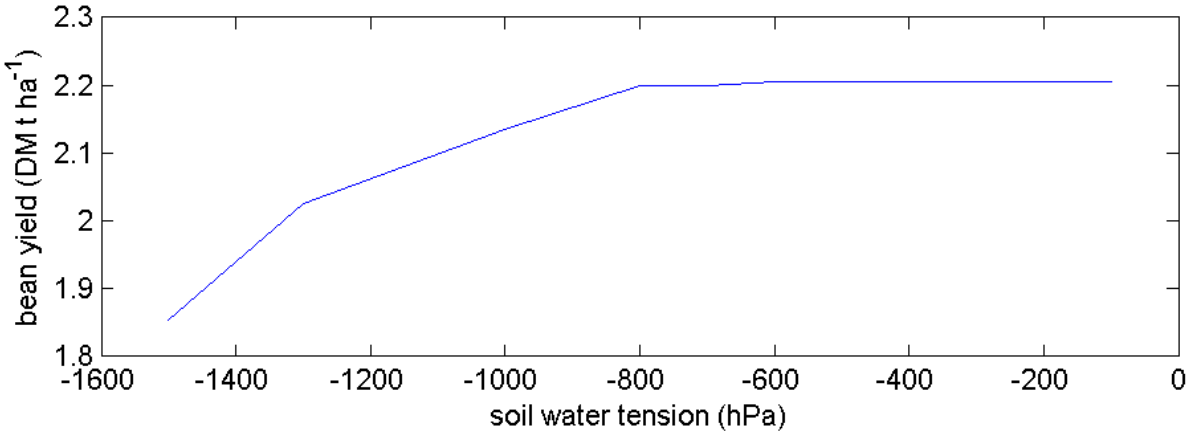
1. application of literature values
2. measurements of T_{act} and ψ_s
3. estimation using crop growth models
   - calibration of crop model Daisy [8] using the collected field data [9]

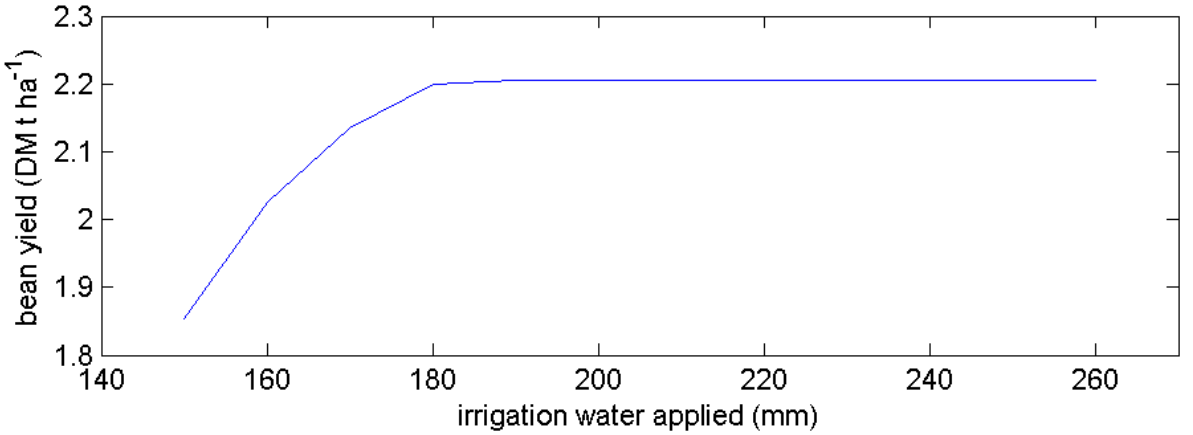


Experimental results IV

How to gain an appropriate threshold based on crop growth simulation models:

- calibration of crop model Daisy [8] on field data [9]
- testing of different irrigation thresholds
- irrigation of 10mm if a certain tension threshold is reached at 30cm soil depth





Summary and Conclusions

- evaluation of different irrigation scheduling approaches in order to promote better agronomic practices in irrigated horticulture
- the tension-based drip irrigation approach using tensiometers achieved the highest yields with the highest irrigation water input
- the measurements of the stomatal conductance in the tension-based treatments showed very low dynamics indicating no water limitation
- crop models can be applied to find appropriate soil tension thresholds
- irrigation scheduling based on SWB calculations led to under-irrigation due to underestimated crop coefficients

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References

[1] **Allen**, G., Pereira, L. S., Raes, D., Smith, M. 1998. Crop evapotranspiration: Guidelines for computing crop requirements. Irrigation and Drainage Paper No.56. FAO, Rome, Italy.

[2] **Jones**, H., 2004. Irrigation scheduling: advantages and pitfalls of plant-based methods. Journal of Experimental Botany 55(407), 2427-2436.

[3] **Seidel**, S. J., Schütze, N., Fahle, M., Mailhol, J.-C., Ruelle, P. 2015. Optimal irrigation scheduling, irrigation control and drip line layout to increase water productivity and profit in subsurface drip irrigated agriculture. Irrigation and Drainage 64, 501-518.

[4] **Zhuang**, J.,Yu, G.-R.,Nakayama, K., 2014. A Series RCL Circuit Theory for Analyzing Non-Steady-State Water Uptake of Maize Plants. Scientific Reports 4, Article number: 6720.

[5] **Kochler**, M., Kage, H., Stützel, H., 2007. Modelling the effects of soil water limitations on transpiration and stomatal regulation of cauliflower. European Journal of Agronomy 26, 375-383.

[6] **Porch**, T. G., Ramirez, V. H., Santana, D., Harmsen, E. W. 2009. Evaluation of common bean for drought tolerance in Juana Diaz, Puerto Rico. Journal of Agronomy and Crop Science 195(5), 328-334.

[7] **Graham**, P., Ranalli, P. 1997. Common bean (*Phaseolus vulgaris* L.). Field Crops Research 53(1-3), 131-146.

[8] **Abrahamsen**, P., Hansen, S. 2000. Daisy: an open soil-crop-atmosphere system model. Environmental Modelling and Software 15, 313-330.

[9] **Seidel**, S. J., Rachmilevitch, S., Schütze, N., Lazarovitch, N. Modelling the impact of drought and heat stress on common bean with two different photosynthesis model approaches. Submitted to Journal of Environmental Modelling & Software (2015).

Thank you for listening!