Tagungsbeitrag zu: Jahrestagung der DBG Kommission IV
Titel der Tagung: Böden verstehen - Böden nutzen - Böden fit machen
Veranstalter: DBG, September 2011, Berlin
Berichte der DBG (nicht begutachtete online Publikation),http://www.dbges.de

How much water is used by a black locust (*Robinia pseudoacacia L.*) short-rotation plantation on degraded soil?

Dario Mantovani[1,2], Maik Veste[3] , Dirk Freese[2]

Introduction

Robinia pseudoacacia L. is an autochthonous North American tree species, where its distribution ranges from a humid to sub-humid climate. As an early successional and nitrogen-fixing species, black locust grows rapidly as a pioneer tree species under a wide range of site condition and it is considered a drought tolerant tree species (VESTE and KRIEBITZSCH, 2010). In southern Brandenburg these trees have been successfully used in short-rotation plantations for land reclamation and biomass production in recultivated open-cast lignite mining areas, where nutrients and water resources are limited (BÖHM et al., 2009). Short-rotation plantations for bioenergy production are raising interest, particularly for those areas where conventional crop systems are economically not profitable. Furthermore woody crops have a high benefit for landscape restoration (QUICKENSTEIN et al., 2009, DILLY et al., 2010, VESTE et al., 2010).

Since the availability of water and nutrition is limiting the primary production (Sinclair et al. 2005), a key open question is the water use of the trees under different soil water contents. Additionally, the ecophysiological response of the plants to different water availability is investigated by using a portable gas exchange system, which allows the measurement of transpiration rate and net photosynthesis. In ours experiment water use at whole plant level is linked to the biomass production and ecophysiological performance.

Key words: Bioenergy production, short-rotation plantation, water use, ecophysiological response, yield-transpiration relation.

Material and methods

Two years old black locust trees have been selected from the recultivated post-mining area in Welzow, near Cottbus, Brandenburg, where *R. pseudoacacia L.* are established as a short-rotation plantation for bioenergy production. The experiment is carried out by using wicked lysimeters with three replicate for each treatment. The three treatments have different irrigation regimes, which are related to the soil water content at 20 cm depth (7%, 10% and14%) (Fig. 1).

Fig.1 Black locust established in wicked lysimeters at soil water content mean 14%

[1] Brandenburg University of Technology, International Graduate School, Cottbus;
[2] BTU, Chair of Soil Protection and Recultivation,Cottbus;
[3] CEBra – Centre for Energy Technology Brandenburg e.V. Cottbus; Germany

A critical problem with zero tension lysimeters is that saturation at the bottom layer can occur, (BEN-GAL and SHANI, 2002). In those conditions the roots are exposed to oxygen restraint and anaerobic processes may take place. A cost efficient solution is provided by wick lysimeters (BEN-GAL and SHANI, 2002), in which a constant suction at the bottom layer is exerted by a high conductive drainage extension. Our lysimeters (MANTOVANI et al., 2011) consist of 70x50 cm polyethylene drums filled with sandy soil at bulk density 1.3 (Fig. 1). To avoid saturation at the bottom layer, a polyethylene extension pipe filled with rockwool has been installed at bottom of the lysimeter. Roots are prevented from growing into the drainage extension by fitting in a roots stop geotextile. Flax continuity at the interlayer rockwool-geotextile is guaranteed by an interposed 5 cm tick soil layer. The water amounts are controlled by an automatic drip irrigation system and supplied in relation to the volumetric soil water content. The lysimeters are installed under a light transmissive roof to avoid uncontrolled water input. The soil water content and soil matrix potential variations are determined at two depths 20 and 40cm deep respectively by a TDR (Time Domain Reflectometry) device (SM 200, Soil Moisture Sensor, Delta-T Devices, Cambridge) and a gypsum tensiometer (SIS, UMS, München). Soil water content along all the profile (every 10 cm) has been recorded weekly by a profile probe (PR2/4w-02, Delta-T). Soil temperature has been recorded at 20 cm depth by a thermistor (SKTS 200, Skye Instruments Ltd, Powys). A schematic diagram of the system is shown in figure 2. The transpiration is calculated from the experimental water balance daily, and the plant growth rate is evaluated monthly by allometric measurements. The trunk diameter increase of the trees are measured daily by dendrometers (DD-S, Ecomatik, Dachau).

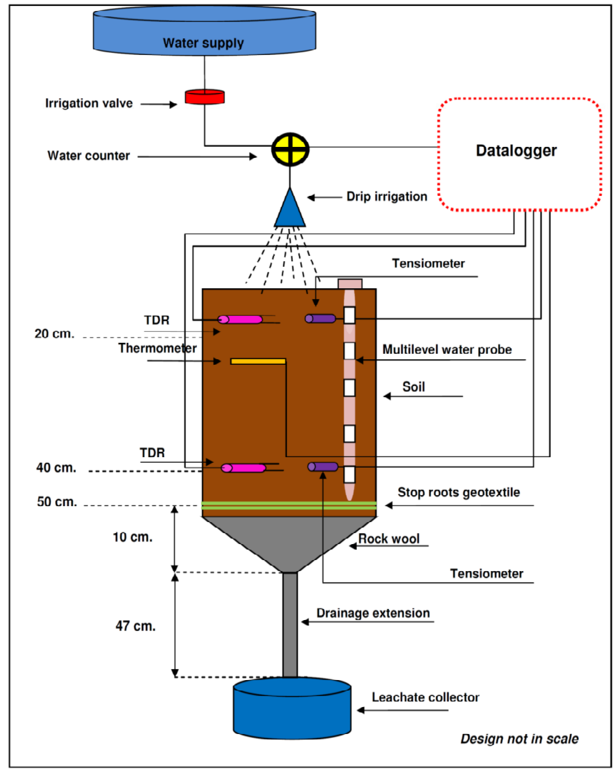

Fig. 2 Schematic diagram of the lysimeter and irrigation system

Photosynthesis is the essential process for biomass productivity. CO_2 uptake and water loss are controlled by the stomata on the leaf level. In order to evaluate ecophysiological performance of Robinia we measured the net photosynthesis and transpiration of fully expended leaves with a minicuvette system (CMS 400, Heinz Walz Effeltrich, Germany) under constant light conditions (approx. 1200 mmol m-2 s-1) and temperature (20°, 25℃, 32℃). The air humidity was similar to ambient conditions. CO_2 and H_2O fluxes were determined with an infra-red gas analyzer (BINOS 100-4P, Rosemount, Hanau, Germany) and expressed on the projected leaf area.

Results and Discussion

The amount of water used by the plants grown under different irrigation regimes with the SWC mean at 7%, 10% and 14%, from the June 1st to August 30 estimated from the experimental water balance is shown in figure 3.

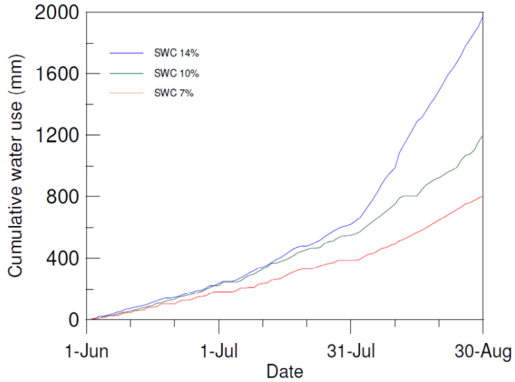

Fig. 3 Cumulative water use of individual tree at different soil water conditions from 1June to 30 August 2011.

At the whole plant level, differences in terms of mean relative length increments between the treatments are significant only during the last period of growth (Fig. 4A). The relative diameter increase is shown in figure 4B.

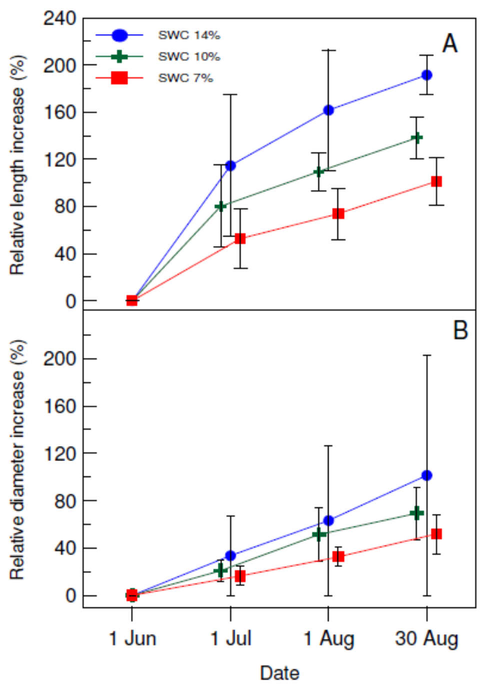

Fig. 4 Mean relative plant increase A) length B) diameter, from 1June to 30 August 2011.

At the leaf level, transpiration and net CO_2 exchange is reduced in trees with a soil water content of 7% due to stomata closure (Fig. 5). This response of the stomata was more pronounced during days with high temperature and high water vapour pressure deficit (vpd) to minimise water loss. However, during hot days (32°) transpiration of the well-watered trees are not controlled by stomata and increased with increasing vpd (Fig. 5A). Furthermore, the net photosynthesis rate is lower in the SWC 7% treatment compared with the other two treatments as a result of lower leaf conductance (Fig. 5B).

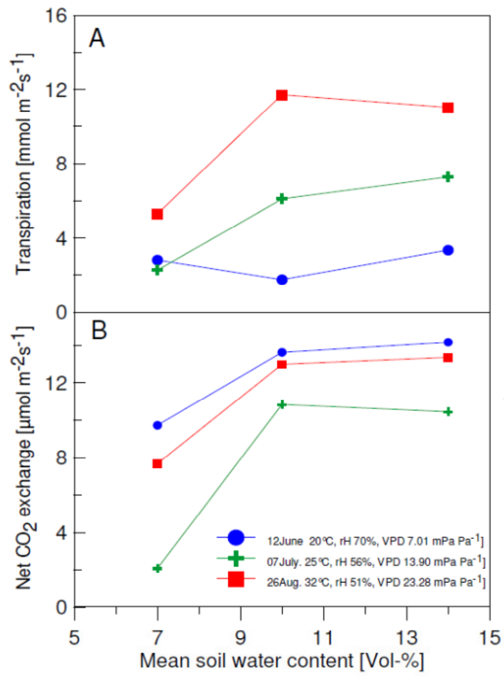

Fig. 5 Transpiration (A) and net CO_2 exchange (B) of *R. pseudoacacia L.* under different soil water and climatic conditions.VPD = Water vapour deficit.

Conclusion

The growth of the trees with the volumetric soil water content mean of 7%, 10% and 14% used 132, 187 and 311 liters of water, respectively. At the whole plant level, the well-watered plants (14%) produced a significant length increase only during the last period of growth (from August 1st to 30) by using approximately three times the water used by the trees grown at lower irrigation amount. Furthermore at the leaf level the increase of transpiration is not followed by an increasing of photosynthesis. As a result *Robinia pseudoacacia L.* cannot be considered a water saving tree.

Reference

BEN-GAL, A. and U. SHANI, 2002 A highly conductive drainage extension to control the lower boundary condition of lysimeters, Plant and Soil, Vol. 239, 9 – 17

BEN-GAL, A., U. YERMIYAHU, U. SHANI and M. VESTE, 2008 Irrigating table grapes in arid regions with low quality water: effects of salinity and excess boron. Acta Horticulturae, Vol. 792, 107 – 114

BEN-GAL, A., D. KOOLB, N. AGAM, G:E: VAN HALSEMA, U. YERMIYAHU, A. YAFE, E. PRESNOV, R. EREL, A. MAJDOP, I. ZIPORI, W. SEGAL, S. RÜGER, U. ULRICH ZIMMERMANN, Y. COHEN, V. ALCHANATISE and A. DAG, 2010 Whole-tree water balance and indicators for short-term drought stress in non-bearing 'Barnea' olives. Agric. Water Manage, doi:10.1016/j.agwat.2010. 08.008

BÖHM, C., A. QUINKENSTEIN, D. FREESE, and R.F. HÜTTL, 2009 Wachstumsverlauf von vierjährigen Robinien. AFZ-DerWald 10, 532-533

DILLY, O., S. NII-ANNANG, J. SCHRAUTZER, V. BREUER, E. M. PFEIFFER, W. GERWIN, W. SCHAAF, D. FREESE, M. VESTE and R.F. HÜTTL, 2010 Ecosystem manipulation and restoration on the basis of long-term conceptions. In: Müller, F.; Baessler, C.; Schubert, H.; Klotz, S. (eds.), Long-Term Ecological Research Between Theory and Application, Springer Science+Business Media, Amsterdam, pp. 411-428.

DELTA-T DEVICES LTD, 130 Low Road, Burwell Cambridge CB25 0EJ,UK, (Accessed 03/06/2010), www.delta-t.co.uk

ECOMATIK Münchner Str. 22 D-85221 Dachau/Munich, Germany (accessed 10/10/2011), http://www.ecomatik.de

MANTOVANI, D., FREESE, D., VESTE, M., HÜTTL, R.F. 2011, Modified wick lysimeters for critical water use efficiency evaluation and yield crop modelling. – In: LFZ Raumberg-Gumpenstein, (ed..) Conference proceedings 14th Lysimeter Conference „Lysimeters in Climate Change Research and Water Ressources Management", 3.-4. May 2011, Gumpenstein, Austria, 245-248.

QUINKENSTEIN, A., J. WÖLLECKE, C. BÖHM, H. GRÜNEWALD, D. FREESE, B.U. SCHNEIDER and R.F. Hüttl 2009 Ecological benefits of the alley cropping agroforestry system in sensitive regions of Europe, Environmental Science & Policy, Vol. 12, 1112 – 1121

SKYE INSTRUMENTS LTD, 21, Ddole Enterprise Park, Llandrindod Wells, Powys LD1 6DF UK, (Accessed 05/06/2010) http://www.skyeinstruments.com/

SINCLAIR, T.R., N.M. HOLDBROOK and M.A. ZWIENIECKI, 2005 Daily transpiration rates of woody species on drying soil, Tree Physiology, Vol. 25, 1469 – 1472

UMS GmbH, Gmunder Str. 37, D-81379 München Germany, (Accessed 03/06/2010) http://www.ums-muc.de

VESTE, M., C. BÖHM, A. QUINCKENSTEIN, and D. FREESE, 2010 Biological fixation of atmospheric nitrogen by *Robinia pseudoacacia* L. in short-rotation plantations on post-mining sites in Lower Lusatia (Brandenburg, NE Germany). *Verh. Ges. Ökol.* 40, 313

VESTE, M., KRIEBITZSCH, W.-U, 2010 Response of chlorophyll fluorescence, photosynthesis and transpiration in *Robinia pseudoacacia L.* to drought stress. Verh. Ges. Ökol.40, 26

WEIHERMÜLLER, L., J. SIEMENS, M. DEURER, S, KNOBLAUCH, H. RUPP, A. GÖTTLEIN, AND T. PÜTZ, 2007 In Situ Soil Water Extraction: A Review, Journal of . Environmental Quality, Vol. 36, 1735 – 1748