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Improving nutrient and water use efficiency of IGNISCUM® – a new bioenergy crop

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Introduction

The new cultivars IGNISCUM Candy® and IGNISCUM Basic® of the Sakhalin Knotweed (*Fallopia sachalinensis*, Fam. Polygonaceae) are new bioenergy crops, which are characterized by a high annual biomass production. It can be harvested 2-3 times during the growing season and the crop can be used for biogas production or combustion (CONPOWER, 2011). Information on the crop production of this species is rare. Therefore, understanding plant response to the combinations of water and nutrients availability is crucial for the development of sustainable plant production. Consequently, the introduction of new bioenergy crops requires new physiological and ecological details about their nutrients and water use efficiency. Proper development of crop production systems based on specific crop and environmental quality information can lead to maximum economic returns and reduction of environmental consequences. The objectives of our study are to investigate (i) the water consumption; (ii) the interrelations between nutrient supply, biomass production, and transpiration; and (iii) the optimization of the biomass production.

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Methods

A chlorophyll fluorescence PAM-system (PAM-2100, Heinz Walz GmbH, Effeltrich, Germany, Fig. 1) is used to determined the quantum yield of linear electron transport of

Fig.1: Gas exchange (left) and chlorophyll fluorescence (right) measurements of IGNISCUM in the greenhouse.

photosystem II ($\Phi PSII$) (VESTE et al, 2001). Electron transport rates (ETR) of the leaves are calculated according to SCHREIBER et al. (1986) as ETR= $\Phi PSII$ * 0.5 * 0.84 * PPFD (PPFD = photosynthetic photon flux density). Measurements are carried out only under high light conditions (PPFD ≥1000

µmol m^{-2} s^{-1}) in full sunshine. Under greenhouse conditions an external halogen lamp is used to illuminate the leaf sample with PPFD ≥1100 µmol m^{-2} s^{-1} for 2 minutes prior PAM measurements. Net CO_2 exchange and transpiration of fully expanded leaves are measured with a minicuvette system (CMS 400, Walz GmbH, Effeltrich, Germany) under constant light (PPFD ≥1100 µmol m^{-2} s^{-1}), temperature (T_{cuv}= 25°C) and air humidity conditions.
The plant specific chlorophyll content is *in situ* determined with a Yara-N-Tester (Yara, Oslo, Norway) at the different field sites. The Yara-N-Tester is commonly used for the evaluation of the N-status of various crops under field conditions (e.g. GOFFART et al, 2011). The Yara-N-Tester averages the measurements of 30 leaves, and therefore, 10 measurements are repeated in each plot.

Field experiments

Field experiments are arranged under different climatic and soil conditions across Germany from Schleswig-Holstein to southern Germany to investigate the plant growth on the field scale. Ecophysiological parameters are determined for the relations between growth stages, chlorophyll content, photosynthesis and plant nutrients status.

Fig.2: IGNISCUM Candy field in Schleswig-Holstein.

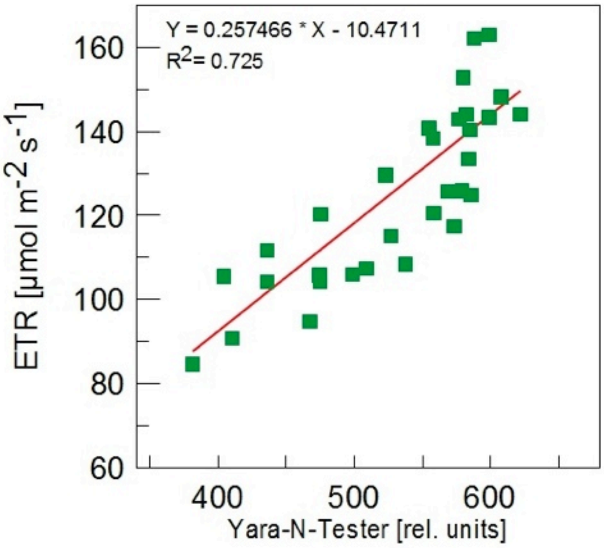

Fig.3: Relation between the mean chlorophyll content measured with the Yara-N-Tester and the mean electron transport rate (ETR) in IGNISCUM leaves at various growth stages and different field sites in Germany (Satrup (SH) Haus Düsse (NRW), Langenau (BW)) in summer 2011.

The investigation shows clearly the correlation between the *in situ* measured Yara-N-Tester values and the electron transport rates in the different field trials (Fig. 3). From this experiment we can conclude, that the Yara-N-Tester is a suitable tool for the determination of the ecophysiological status of IGNISCUM plants under field conditions.Thus fertilization amounts can be calculated based on the Yara-N-Tester.

Greenhouse experiment

A controlled greenhouse experiment is carried out to investigate the influence of nitrogen and phosphate fertilization on plant growth. The applied nitrogen amounts are 0, 50, 150 and 300 kg N ha^{-1} and for phosphate 20, 40, 80 kg P ha^{-1}, respectively. Photosynthesis is the essential process for biomass productivity. CO_2 uptake and water loss is controlled by the stomata at leaf level and environmental stresses affect this physiological process.

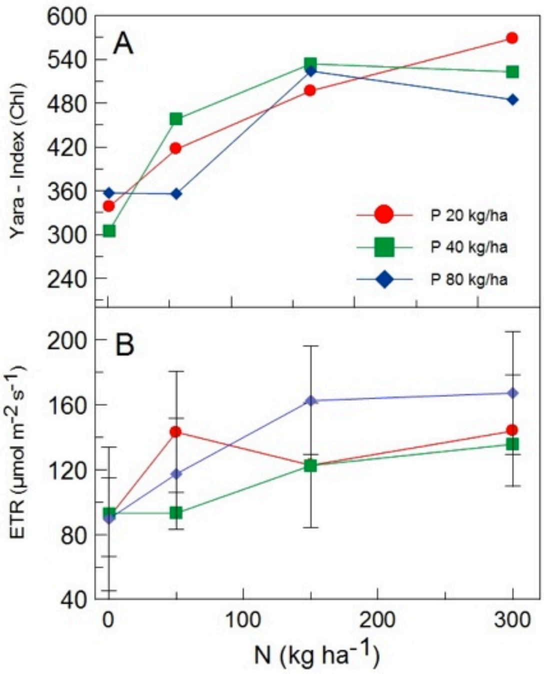

Fig.4: (A) Chlorophyll content measured with the Yara-N-Tester and (B) the electron transport rate (ETR) in leaves of IGNISCUM Candy under different N- and P- applications in a greenhouse experiment.

Therefore, the ecophysiological response of the plants to different N and P supplies are investigated under controlled environmental conditions in a greenhouse. Yara-N-Tester values and photosynthesis (ETR) increases until 150 kg N ha^{-1}, while no significant differences are observed between the different P-levels (Fig. 4).

Lysimeter experiment

For the determination of yield-transpiration relations at whole plant level we developed a wick lysimeter system (BEN-GAL and SHANI, 2002; MANTOVANI et al., 2011), which allows us to study plant growth under controlled water regimes. The irrigation is supplied by an automatic drip irrigation system in relation to the volumetric soil water content (SWC). The four different treatments associated to the SWC range from well-watered (14%), moderate (10%)

Fig. 5: IGNISCUM Candy growing in lysimeters.

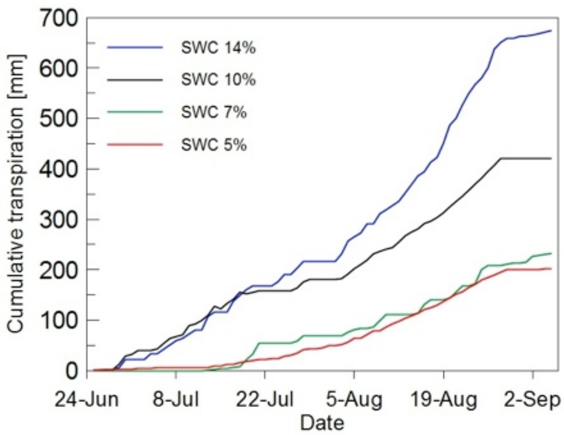

Fig. 6: Cumulative transpiration of IGNISCUM Candy plants under different soil water contents (SWC) in the lysimeter experiment.

to low water content (7%, 5%). Water consumption is calculated on the basis of water input, storage and drainage in daily intervals (Fig. 4A). The cumulative transpiration of the plants during the summer of 2011 is 122, 76, 42 and 37 liters of water per plant, respectively. Additionally fertilization management and yield relation is investigated in well-watered plants (14%). The fertilizer applied is calcium ammonium nitrate (N) and the rates for the four treatments are 0, 50, 100, 150 kg N ha^{-1} at the beginning of the growing season. An accurate database is generated with

reference to the relations water consumption-yield and fertilization-yield.
The soil-plant-atmosphere processes as well as the ecophysiological plant performance obtained from the experimental water balance and the gas-exchange measurements will be integrated into a yield-transpiration model (e.g. JANSSON, and KARLBERG, 2001, SHANI et al., 2007).

Conclusions

IGNISCUM® is a new bioenergy crop highly suitable for the climatic conditions in Central Europe. The experiments show that those plants are even able to grow in soils poor in nutrients. The application of a low amount of nitrogen shows improvement of the growth conditions and increase of the yield also in those depleted soils. Furthermore, that key characteristic is extremely important for further land planning in marginal lands where conventional crop systems are economically not profitable.

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