TR32DB - B5

General information

From 2011 to 2013 we conducted the following measurements in winter wheat, winter barley, and sugar beet:

1. Biomass (organ specific), height, phenology, SPAD
2. Carbon and nitrogen contents of different plant organs
3. Leaf area index (LAI)
4. AC_i curves
5. Crop gas exchange (photosynthesis, transpiration) on leaf and canopy level
6. Soil respiration

Accordingly, we determined the soil N_{min}, the root length density, the soil texture, and the soil water content.

All time codes are in UTC (Universal Time Coordinated) to avoid misunderstandings with summer and winter time and to ensure comparability of the data.

All measurements were carried out at Selhausen and Merzenhausen. In Selhausen samples were taken in four different fields (P3, P5, P6, P7). Since our main aim is to understand within-field crop growth heterogeneity, measurements were conducted at seven to twelve sampling points within each field (Tab. 1).

Tab. 1: Sampling points and the according coordinates.

field name	coordinates
P31	50.868806,6.451444
P32	50.868750,6.450806
P33	50.868722,6.450306
P34	50.868694,6.449750
P35	50.868556,6.449250
P36	50.868694,6.449111
P37	50.868833,6.450306
P38	50.868917,6.450944
P51	50.866806,6.448611
P52	50.883278,6.447028
P53	50.883028,6.445083
P54	50.881444,6.445917
P55	50.881694,6.447667
P56	50.882417,6.447472
P57	50.882194,6.449389
P61	50.863753,6.450973
P62	50.864038,6.452145
P63	50.864283,6.452232
P64	50.864122,6.452599
P65	50.864147,6.453146
P66	50.864530,6.452849
P67	50.864308,6.451458
P68	50.864109,6.451082
P69	50.864106,6.451800
P71	50.862682,6.451370
P72	50.862881,6.452129
P73	50.862996,6.452706
P74	50.863042,6.453328

P75	50.863256,6.453476
P76	50.863281,6.452865
P77	50.863130,6.452307
P78	50.863069,6.451690
P41	50.930694,6.295806
P42	50.929678,6.297515
P43	50.929275,6.298369
P44	50.928585,6.297317
P45	50.929204,6.296808
P46	50.929834,6.296111
P47	50.930062,6.294932
PK43	50.930164,6.295380
PK46	50.929958,6.297149
PK47	50.929407,6.296443
PK411	50.930889,6.295519
PK412	50.930298,6.294500

In 2012 a rhizotron facility was built in the upper part of P3 (Selhausen); in 2014 a second one in the lower part of this field was constructed. The sampling points on these facilities are only about two meter apart from each other. Therefore, we could not differentiate the sampling points from each other with an commercial GPS (eTrex). Figure 1 shows the arrangement of the sampling on the rhizotron facilities.

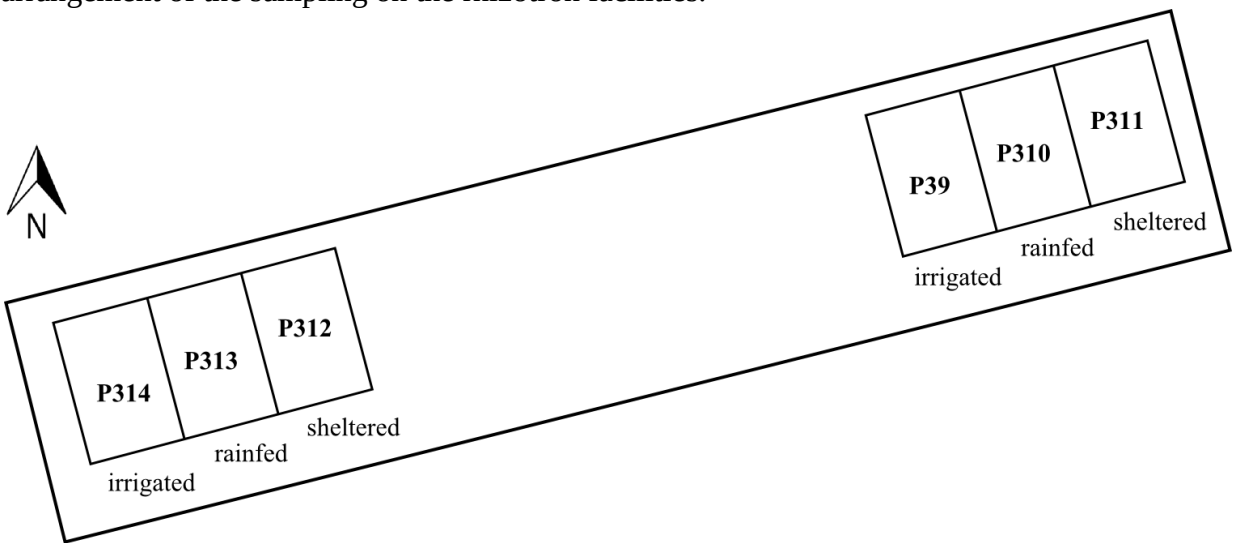

Fig. 1: Arrangement of the sampling points on the rhizotron facilities at P3 (rhizotron facilities are enlarged) (source: A. Stadler).

1. Biomass (organ specific), height, phenology, SPAD

Biomass samples were taken at each within-field sampling point. For cereals one running meter was cut within a three meter radius from the gas exchange measuring chamber (location coordinates). For sugar beet samples two to four plants were taken.

The samples were first weighed in total for each sampling point, then separated into the different plant organs and weighed. Afterwards, subsamples were extracted from these samples, which were weighed, then dried at 105 °C for at least 24 hours, and weighed again for dry matter calculation. Square meter values of biomass and dry matter were calculated from the data for one meter. At harvest one square meter was collected for dry matter and LAI determination.

Crop height was measured at stretched plants, i.e. the plants were stretched to their full height when e.g. ears were bending down.

Phenology was determines according to the BBCH scale.

The soil plant analytical development (SPAD) is a dimensionless measure of the greenness of the plant from which the chlorophyll content can be estimated.

2. Carbon and nitrogen contents of different plant organs

Plant material taken for biomass sampling was analyzed concerning nitrogen and carbon content. The samples were oven dried at 60 °C for at least 24 hours, then milled and weighed. Repeat determinations were conducted for each plant organ, i.e. green leaves, senescent leaves, stems, and ears or grains (cereals), if available, and tubers (sugar beet) with an Euro Elemental Analyzer (HekaTech).

3. Leaf area index (LAI)

The LAI was measured destructively and non-destructively. For the destructive LAI determination we used the LI-3100C (LI-COR Biosciences) (Fig. 4). Two transparent plastic transport belts are running around a fluorescence lamp and the plant material is put between these belts. A camera is measuring the shadowing created by the plant material with a 0.1 mm resolution so that the exact size of the plant material can be detected.

For the non-destructive LAI determination we used the SunScan Canopy Analysis System with an external light sensor (Delta-T Devices). The external light sensor measures the incoming radiation, while the probe is used to estimate the transmitted fraction of the radiation below the canopy. Considering latitude, solar angle, and leaf angle the LAI is immediately calculated by the device.

Fig. 4: Leaf area meter LI-3100C and the SunScan Canopy Analysis System with an external light sensor (source: A. Stadler, http://www.delta-t.co.uk/imagesMCL/mcl-02-02-2011-10-24-55.jpg)

4. AC_i curves

AC_i curves were measured with the LI-6400XT (LI-COR Biosciences) (Fig. 5) along with the leaf chamber fluorometer. This device is an open system measuring the differences in CO_2 and H_2O concentrations between in-chamber and pre-chamber conditions to derive photosynthesis and transpiration. An air flow is moved through a cuvette containing a controlled atmosphere where an infrared gas analyzer (IRGA) measures the CO_2 and H_2O concentrations (Fig. 6).

For the AC_i curves, the light conditions in the cuvette were set to 1500 µmol, while air humidity and air temperature were adjusted to ambient conditions. Air CO_2 level inside the cuvette was modified stepwise: 400, 300, 200, 100, 50, 400, 400, 600, and 800 µmol/mol.

Fig. 5: LI-6400XT with the fluorescence chamber (source: A. Stadler).

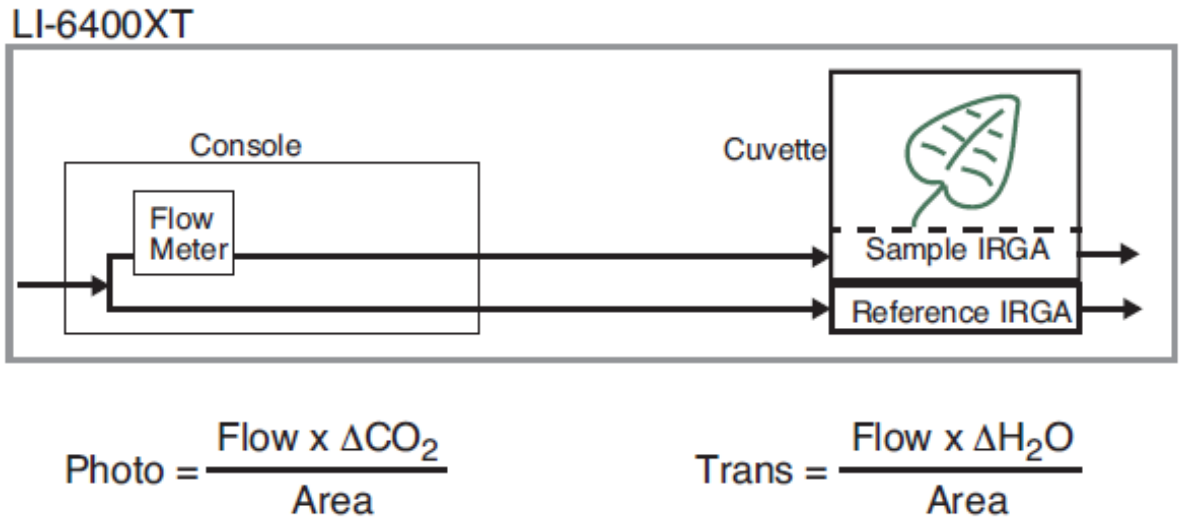

Fig. 6: General measuring principle of the LI-6400XT: From the differences in CO_2 and H_2O between in-chamber and pre-chamber conditions photosynthesis and transpiration are computed (source: LI-COR LI-6400XT user manual, p. 1-2).

5. Crop gas exchange on leaf and canopy level

Leaf and canopy level photosynthesis and transpiration rates were measured with the LI-6400XT (LI-COR Biosciences) (Fig. 6) under ambient conditions.

For the canopy gas exchange measurements the concentration change within a 1m x 1m plexiglass chamber (Fig. 7) is used for estimating the rates of photosynthesis and transpiration. Measurements last two minutes per sampling point under ambient conditions. For further details refer to Langensiepen et al. 2012.

The values of UTC, PAR, and temperature are always observed at the beginning (with four seconds offset) of the two minute interval measured to analyze the gas concentration change within the chamber.

Fig. 7: Measuring chamber for canopy fluxes in a winter wheat stand (source: M. Langensiepen).

6. Soil respiration

Soil respiration was measured with a LI-8100 (LI-COR Biosciences) (Fig. 8). It measures the CO_2 efflux from the soil produced by respiration from plant roots and microorganisms surrounding the roots, and from heterotrophic microorganisms that metabolize plant litter and soil organic matter. “The LI-8100 uses the rate of increase of CO2 in a measurement chamber to estimate the rate at which CO2 diffuses into free air outside the chamber” (LI-8100 instruction manual). The calculation of the fluxes is done with an exponential and with a linear fit as well as.

Fig. 8: The LI-8100 for measuring soil respiration (source: A. Stadler).

7. N_{min}

Soil samples were taken using a Pürckhauer soil sampler. The sampled soil material of two to four drillings was mixed to receive a representative sample. Afterwards, these samples were stored in a freezer to prevent ammonia volatilization until lab analyses could be conducted.

In the laboratory process 50 g of the soil sample and 200 ml of a 1% potassium-sulphate solution were mixed and shaken for one hour to dissolve all nitrate and ammonium. Afterwards, the solution was filtrated. The extracted N_{min} samples were prepared with indicator chemicals. The analyses of the soil's nitrate and ammonium contents were conducted by photometric determination in a liquid flow using the Continuous Flow Analyzer (Skalar Breda).

For soil dry matter determination 25 g soil were dried for at least 24 hours at 105 °C and afterwards weighed again.

8. Root length density

The root length density was determined once on August 6, 2012 at P3. At each sampling point a hole with the size 1.5 m * 1.5 m * 2 m was dug. Soil monoliths (10 cm * 10 cm * 12.5 cm) were then taken up to 70 cm soil depth in 10 cm steps (Fig. 9). Three monoliths were taken at each soil depth to get a representative sample. The samples were stored in a fridge.

Fig. 9: Soil monolith sampling for the determination of the root length density. (source: A. Stadler)

The roots were washed out of the soil monoliths by soaking them in a bucket full of water and then sieving them out of the soil. The pure roots were then scanned with a commercial scanner prepared with a glass container (Fig. 10). The glass container was filled with water to spread the roots widely so that the scanner image comprises as many roots as possible. This is crucial for the next analysis step: the root length measurement. This was done with the software WinRhizo Pro, which measures the length and the diameter of the roots' scan images. Afterwards, the root length density was calculated from this data by dividing the root length by the soil monolith volume (1250 cm^3). All data from one soil depth were averaged for the sampling point, respectively.

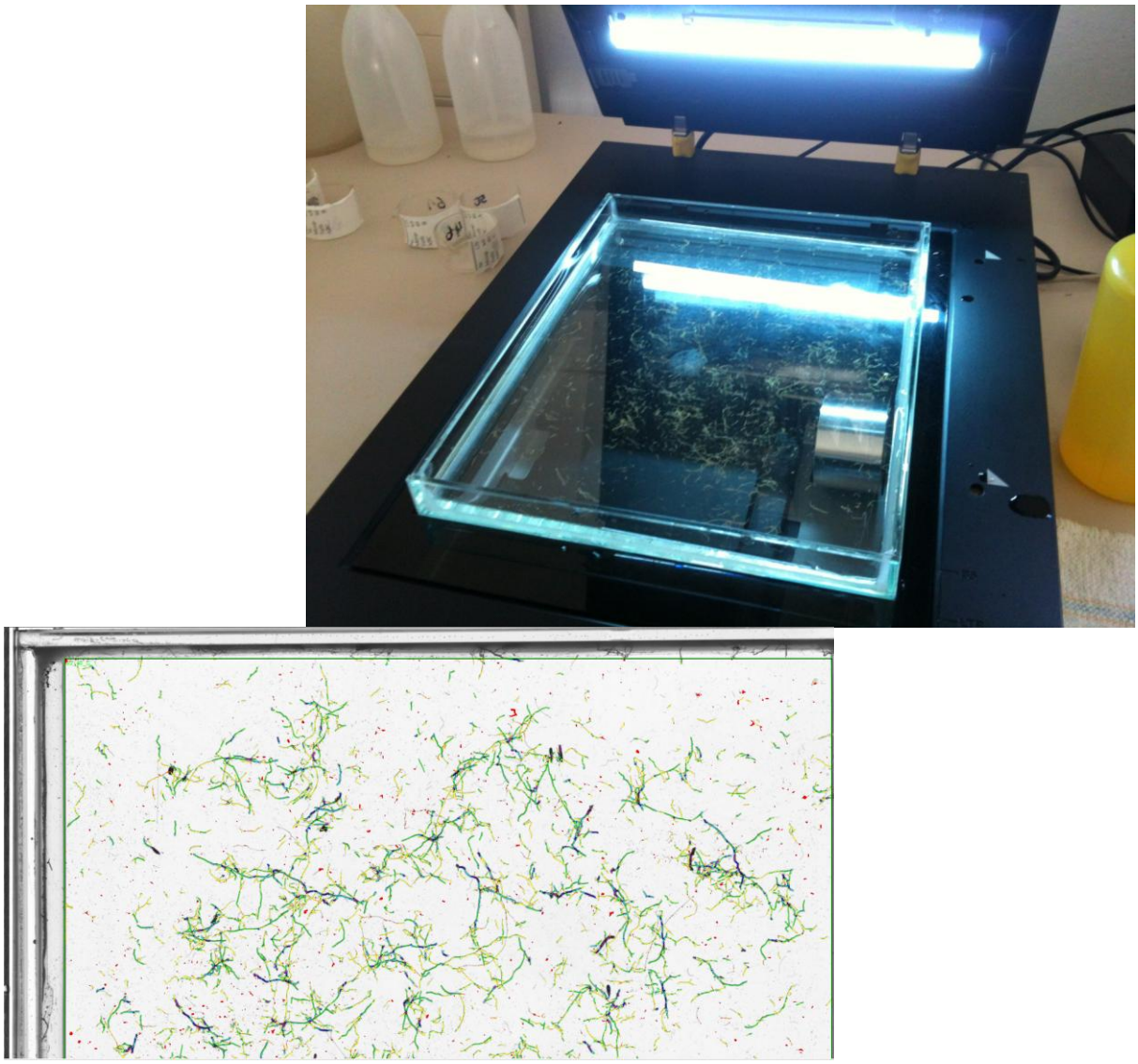

Fig. 10: The scanner prepared with the glass container filled with water to get images of the roots and the analyzed root scan image (source: A. Stadler).

9. Soil texture

Soil samples were taken with a Pürckhauer soil sampler. The sampled soil material of two to four drillings was mixed to receive a representative sample. The samples were dried at 105 °C for at least 24 hours and then sieved. Only material smaller than 2 mm (Feinboden) was used for the texture analyses, which were made at the institute for soil sciences, University of Bonn.

10. Soil water content

The volumetric water content was measured at P3 at all sampling points in the soil depths 15, 45, and 75 cm with TDR probes (Fig. 11) in 2011 and ECH_2O 5TE soil moisture sensors (Decagon Devices Inc., USA) in 2012 and 2013.

The TDR data was read out once per sampling day, i.e. no continuously logged data is available.

The ECH_2O 5TE data was continuously logged in a 10 minute time step during the vegetation period (March - July).

Fig. 11: TDR probes installed in the soil depths 15, 45, and 75 cm (source: M. Kupisch).

References

Ad-hoc-Arbeitsgruppe Boden (2005): Bodenkundliche Kartieranleitung. Ed.: Bundesanstalt für Geowissenschaften und Rohstoffe in Zusammenarbeit mit den Staatlichen Geologischen Diensten, 5. Edition., Hannover.

Dimitrov, M., Vanderborght, J., Kostov, K.G., Jadoon, K.Z., Weihermüller, L, Jackson, T.J., Bindlish, R., Pachepsky, Y., Schwank, M., Vereecken, H., 2014. Soil Hydraulic Parameters and Surface Moisture of a Tilled Bare Soil Plot Inversely Derived from L-Band Brightness Temperatures, Vadose Zone J. 13 (1).

Langensiepen, M.; Kupisch, M.; van Wijk, M. T.; Ewert, F. (2012): Analyzing transient closed chamber effects on canopy gas exchange for optimizing flux calculation timing. Agricultural and Forest Meteorology 164, 61-70.

LI-COR (2008): Using the LI-6400/LI-6400XT Portable Photosynthesis System. 9. Edition, Lincoln, Nebraska.

LI-COR (2006): LI-8100 Automated Soil CO_2 Flux System & LI-8150 Multiplexer instruction manual. 3. Edition, Lincoln, Nebraska.