Parameterisation and Evaluation of Light Use Efficiency and Photosynthesis/Respiration Based Model Modules for Calculation of Dry Matter Production

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Objectives

Empirical evidence indicates the possibility of a constant light use efficiency (LUE) over a wider range of radiation intensities. This is also theoretically supported if certain adaptations of the nitrogen distribution and the associated photosynthetic capacity to the light profile within the canopy are assumed (Haxeltine & Prentice, 1996).
Here, the hypothesis is evaluated that the assumption of a constant LUE is sufficient for prediction of dry matter production of cauliflower. Alternatively, more complex modules were tested, which either assume a linear relationship between LUE and radiation intensity or are based on the photosynthesis/respiration approach. All dry matter production modules were coupled with existing modules for development and dry matter partitioning (Kage & Stützel, 1999b) using the *HUME* modeling environment (Kage & Stützel, 1999a). Data from 10 field experiments were used for parameterisation and data from 10 further independent experiments were taken for evaluation purposes. Especially within the evaluation data set the average radiation intensity varied substantially from about 5 to 9 MJ PAR $m^{-2}d^{-1}$.

Results

Model modules

Module	Short description
LUE I	Constant LUE, radiation interception according to Monsi & Saeki
LUE II	As LUE I, but assuming a linear decrease of LUE with increasing radiation intensity $LUE=LUE_0 + a_{LUE} \cdot PAR$
ACOCK I	Analytical integration of the rectangular hyperbola describing single leaf photosynthesis over the canopy, numerical 3-point Gauss integration over the day, respiration calculation according to the SUCROS-assumptions
ACOCK II	As ACOCK I, but assuming a decrease of the photosynthetic capacity P_{max} proportional to the light intensity within the canopy

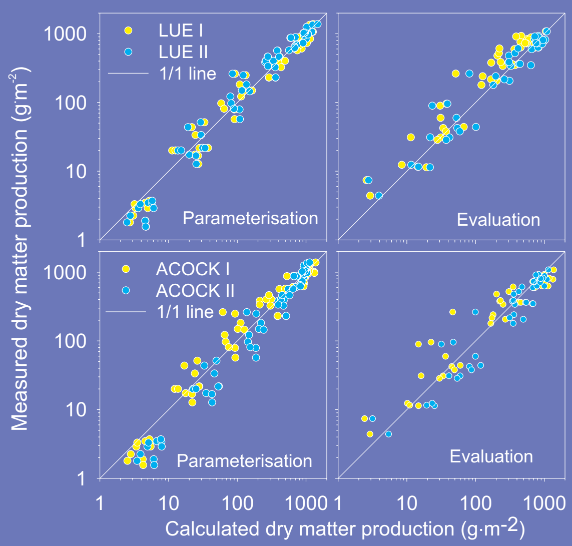
Estimates, standard deviations (SD) and least significant differences of the model parameters

Module	Parameter	Estimate	SD	LSD
LUE I	LUE	3.15	0.04	0.09
LUE II	LUE_0	6.66	0.80	1.83
	a_{LUE}	-0.36	0.08	0.19
ACOCK I	P_{max}	1013	14	33
ACOCK II	P_{max0}	1438	29	66

LUE = Light use efficiency (g DM · MJ PAR^{-1}), LUE_0=Intercept of the LUE-radiation intensity function (g DM · MJ^{-1}), a_{LUE}= Decrease of LUE per MJ PAR (MJ PAR^{-1}), P_{max}=Photosynthetic capacity of a single leaf (µg $CO_2 \cdot m^{-2} \cdot s^{-1}$), P_{max0}= As P_{max}, but assumption of a declining P_{max} within the canopy

Parameters of linear regressions between measured and calculated dry matter production

Data set	Module	Slope	Intercept	r^2	n
Param.	LUE II	0.98 (±0.03)	27.99 (±17.20)	0.94	60
Param.	ACOCK II	1.04 (±0.04)	-35.78 (±22.56)	0.92	60
Param.	LUE I	0.95 (±0.04)	23.22 (±20.26)	0.92	60
Param.	ACOCK I	0.89 (±0.04)	47.80 (±22.81)	0.90	60
Evalua.	LUE II	0.88 (±0.05)	39.39 (±25.16)	0.90	43
Evalua.	ACOCK II	0.86 (±0.05)	11.56 (±28.78)	0.88	43
Evalua.	LUE I	1.07 (±0.11)	108.79 (±42.15)	0.78	43
Evalua.	ACOCK I	0.70 (±0.05)	93.54 (±28.53)	0.85	43



Comparison of calculated and measured dry matter production

Conclusions

The differences between the modules were more pronounced using the evaluation data set with a high variability of average radiation intensity between the experiments. Here, the constant LUE approach was only poorly able to predict dry matter production (r^2=0.78). The 'LUE II'-aproach, calculating a higher productivity under low radiation conditions, however, allowed a much better prediction of dry matter production (r^2=0.90). The predictive value of the photosynthesis / respiration based model module 'ACOCK II', was similar to the LUE II approach. This module assumes a decline of the photosynthetic capacity within the canopy, which is in good accordance with direct measurements of the N distribution within the canopy (Alt *et al*. 2000).

References
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