Grain legume nitrogen fixation and balance model for use in practical (organic) agriculture

H. Kolbe
Saxony State Institute for Agriculture, Department for Plant Production,
G.-Kuehn-Str. 8, D-04159 Leipzig, Germany, Hartmut.Kolbe@leipzig.lfl.smul.sachsen.de

Introduction

Common calculation models for the nitrogen fixation of grain legumes are:

- inaccurate (see Fig. 3),
- require annually collected experimental N uptake data from non-fixing reference crops,
- or these methods are too complex.

Therefore, Central European grain legume investigations in the literature (see Schmidtke & Rauber, 2000) were collected and correlation analyses were then carried out for developing calculation models for use in agricultural practice.

Materials and methods

Investigations for field-grown *Vicia faba* L. (n = 44) and *Pisum sativum* L. (n = 41) grain legumes were collected for the following root- and shoot-derived variables: grain yield, N surplus, N output, N uptake, N harvest index (N_{hi}), N stubble and roots. Air-derived nitrogen (N_{dfa}) was calculated from ^{15}N-isotope dilution and difference methods (McAuliffe et al., 1958; Stülpnagel, 1982); soluble soil nitrogen (N_{min}) 0 - 90 cm soil depth was extracted with $CaCl_2$ (VDLUFA, 1991). Statistical analysis was carried out with SPSS (SPSS, Munich, Germany).

Results

Initial model constructions using literature mentioned variables of highly significant relations gave disappointing results when the results calculated were compared with experimental results as well as findings from previous methods (not shown). Further analysis indicated that substantially better relationships could only be achieved if the N_{hi} was included, but this variable is not detectable by the farmer. Detailed multiple regression analyses indicated that the grain yield and the N_{min} content needed to be significantly integrated into the equation to determine the N_{hi} indirectly. The correlation coefficient grew from single r = 0.421*** to multiple r = 0.777*** for *Vicia faba* and to r = 0.923*** for *Pisum sativum* (Fig. 1):

- *Vicia faba* N_{hi} = 30.261 + 1.621 x grain yield + 0.00526 x grain yield x N_{min} - 0.02077 x grain yield^2 - 0.001381 x N_{min}^2
- *Pisum sativum* N_{hi} = 15.257 + 2.34 x grain yield + 0.009296 x grain yield x N_{min} - 0.03173 x grain yield^2 - 0.002144 x N_{min}^2.

In the next step, relations were analysed between N_{hi} and other variables. The N surplus/N output ratio was closely correlated with the N_{hi} (r = -0.759***), and also with the N surplus (r = 0.878***). As these relations do not change with legume species (Fig. 2), this ratio was used in multiple regression analyses as a further equation (r = 0.864***) and the model was completed as follows:

- Ratio N surplus/N output = 3.264 - 0.008651 x N_{min} + 0.01053 x grain yield - 0.08141 x N_{hi} + 0.00003076 x N_{min}^2 + 0.000496 x N_{hi}^2.
- N output = grain yield x N content (derived from measured or table values for each legume species)
- N surplus = N output x N surplus/N output ratio
- N_{dfa} = N surplus + N output.

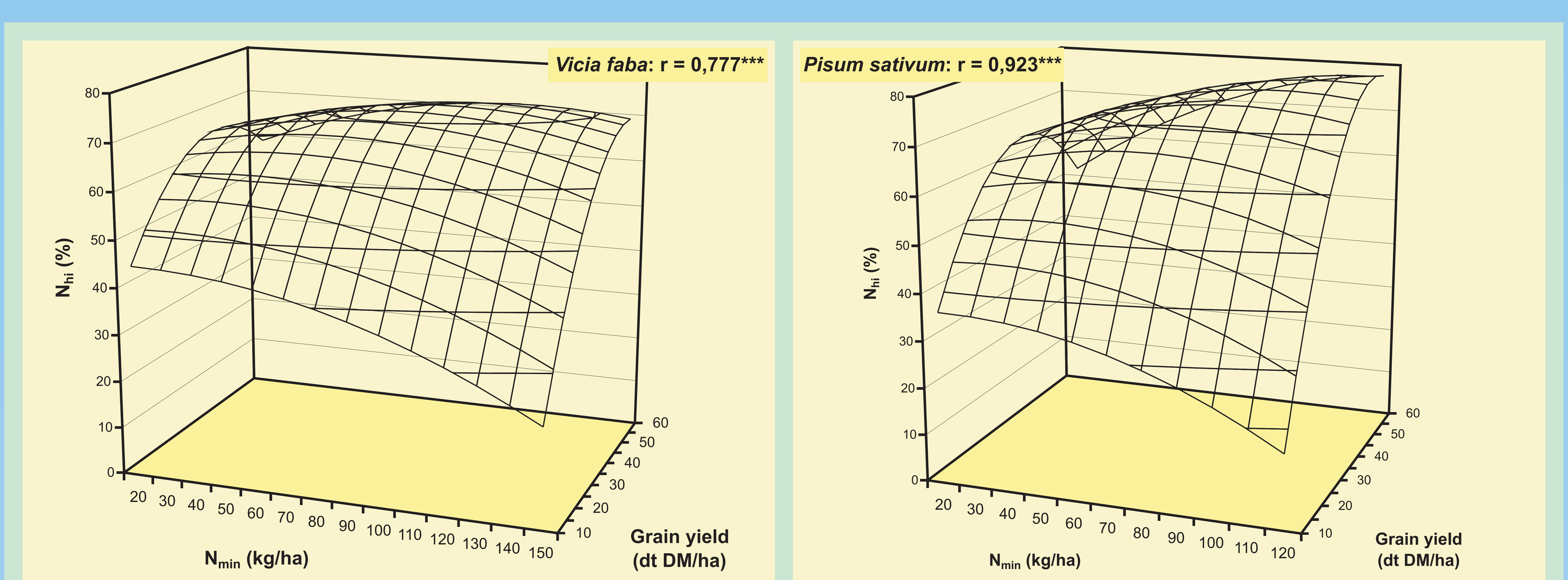

Figure 1. **Calculated effects of the N_{min} content (0 - 90 cm soil depth) and the grain yield on *Vicia faba* (left) and *Pisium sativum* (right) N harvest index**

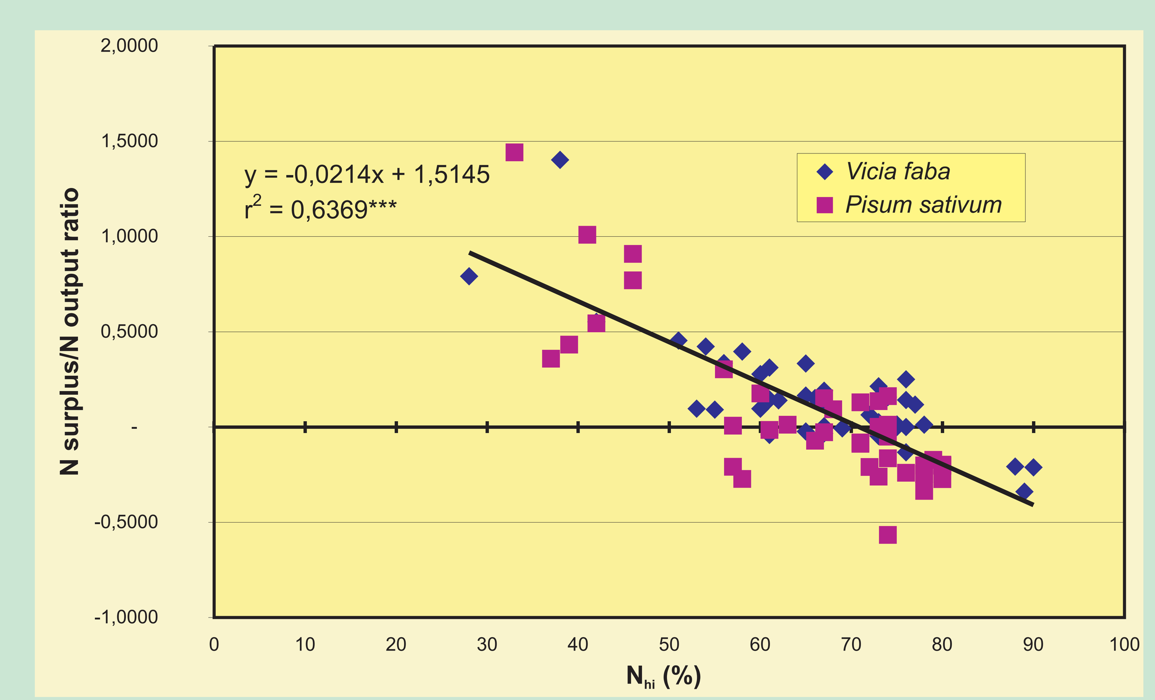

Figure 2. **Relationship between N_{hi} and the N surplus/N output ratio**

Conclusion

Data calculated by the new model show correspondence which, although not ideal, is still much better with the 1:1 ratio axis in Figure 3. Therefore the relatively simple model obtained can be used with a much higher degree of accuracy in broad agricultural practical. Only two input variables (grain yield and N_{min} content before sowing) are needed to drive the model, and they are available from farmers' familiar plot-card indices.

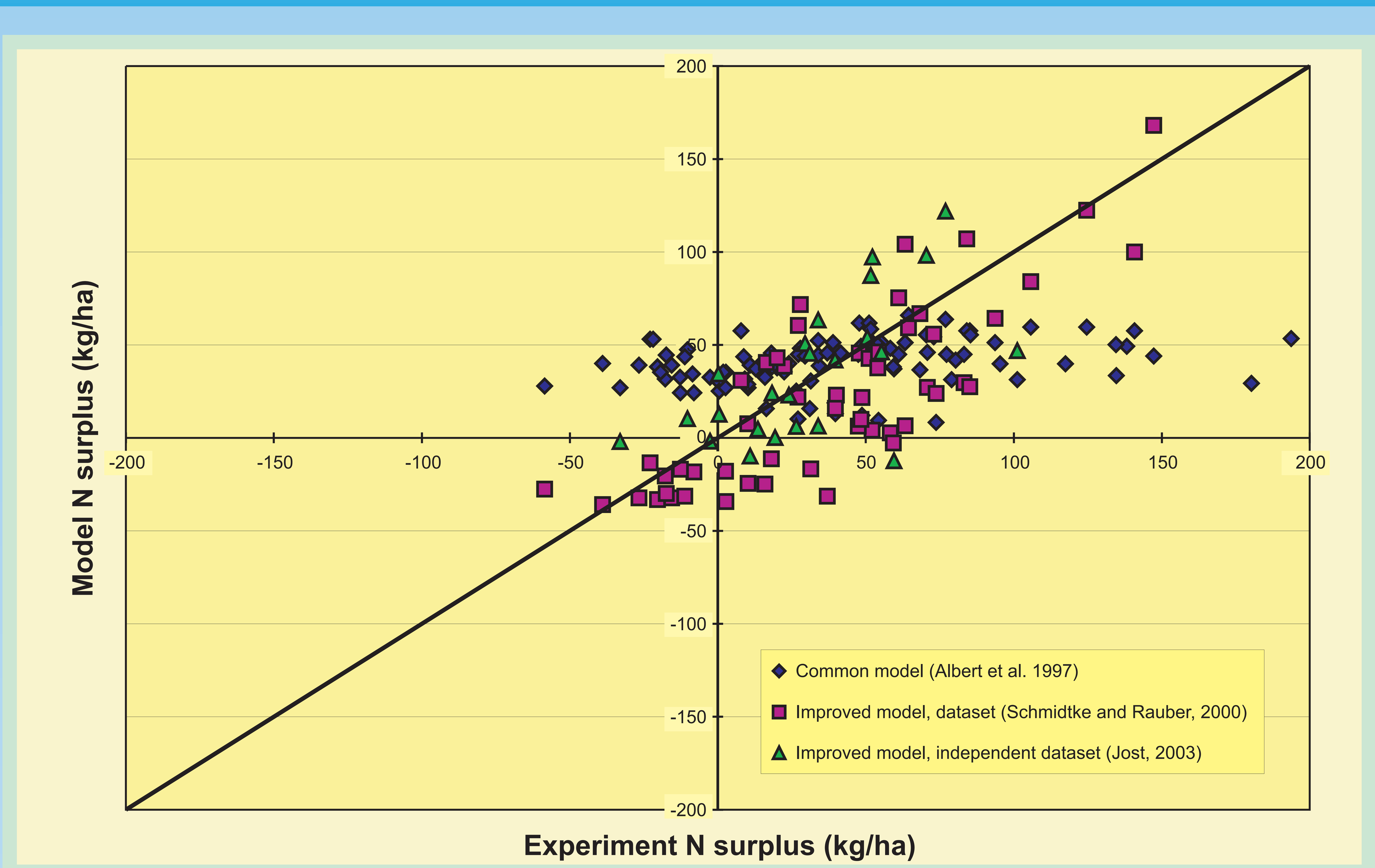

Figure 3. **Comparison of experimentally derived N surplus with values calculated with the commonly used and the improved balance models for grain legumes**

References

Albert E Ernst H Biermann S Michel D 1997 Stickstoffbindung durch Leguminosen sowie Möglichkeiten zu ihrer Abschätzung. Sächs. Landesanst. f. Landwirtschaft, Dresden, Infodienst Sächs. Agrarverw. No 5, 67-71

Jost B 2003 Untersuchungen und Kalkulationstabellen zur Schätzung der N_2-Fixierleistung und der N-Flächenbilanz beim Anbau von *Lupinus albus* und *Lupinus luteus* in Reinsaat und von *Vicia faba* und *Pisum sativum* in Reinsaat und im Gemenge mit Avena sativa. Dissertation, University of Göttingen, Germany

McAuliffe C Chamblee DS Uribe-Arango H Woodhouse WW 1958 Influence of inorganic nitrogen on nitrogen fixation of legumes as revealed by ^{15}N. Agron. J. 50, 334-337

Schmidtke K and Rauber R 2000 Stickstoffeffizienz von Leguminosen im Ackerbau. Initiativen zum Umweltschutz 21, 48-69, Erich Schmidt Verlag, Berlin, Germany

Stülpnagel, R 1982 Schätzung der von Ackerbohnen symbiontisch fixierten Stickstoffmenge im Feldversuch mit der erweiterten Differenzmethode. Z. Acker- u. Pflanzenbau 151, 446-458

VDLUFA 1991 VDLUFA Methodenbuch Band I. Die Untersuchung von Böden. VDLUFA-Verlag, Darmstadt, Germany