Designing and evaluating arable cropping systems with cash and cover crop legumes in sole crop and intercrop to improve nitrogen use

Laurent Bedoussac, Hélène Tribouillois, Daniel Plaza Bonilla, Etienne-Pascal Journet, Eric Justes

DESIGNING AND EVALUATING ARABLE CROPPING SYSTEMS WITH CASH AND COVER CROP LEGUMES IN SOLE CROP AND INTERCROP TO IMPROVE NITROGEN USE

L. BEDOUSSAC[1,2] – H. TRIBOUILLOIS[2] – D. PLAZA-BONILLA[2] – E.-P. JOURNET[2,3] – E.JUSTES[2]*

[1] ENFA, F-31320 Castanet-Tolosan, France, *laurent.bedoussac@toulouse.inra.fr
[2] INRA, UMR1248 AGIR, F-31320 Castanet-Tolosan, France
[3] CNRS, UMR2594 LIPM, F-31320 Castanet-Tolosan, France

Introduction

Increasing concern about climate change and environmental impacts requires transformation of cropping systems. Introducing more legumes (grain or cover crop forage) grown alone or in intercropping (IC) is an interesting option to benefit from N_2 fixation and also for break crop effects. Rotational position of legumes needs to be carefully analyzed to maximize their benefit. From field experiments and crop modelling the objective of our work was to design and evaluate prototypes of arable systems analyzing: 1) impact of grain legume at the rotation level, 2) potential of IC with legumes for improving yield and cereal protein content and 3) effect of cover crops with forage legume to achieve nitrate capture and green manuring services.

Materials and Methods

Two 6-year field experiments were initiated in 2003-04 at INRA Toulouse (SW France). Six rotations of three-years differentiated by the frequency of legumes in the rotation and the presence or not of cover crop were compared. Crop management was based on decision rules to adjust technical acts, in particular N application, to the soil and crop status. Simulations at the rotation time scale were carried out using the STICS soil-crop model for water and N dynamical budgets (Plaza-Bonilla et al., 2015).
Complementary experiments with IC were carried since 2005-06 with a large range of IC combinations (durum wheat, bread wheat or barley intercropped with pea or faba bean) with various cultivars, sowing densities and N treatments. Grain yield and cereal grain protein content were used to evaluate the efficiency of the IC over the sole crops (SC). The percentage of N derived from N_2 fixation of legumes was estimated with ^{15}N dilution method with also nitrogen content in plant and soil (Bedoussac et al., 2015).
In addition others experiments were conducted to analyze ten cover crop species (five legumes and five non-legumes) selected according to their rapid growth rate and contrasted shoot/root architectures. Species were evaluated in three French experimental sites with contrasted climate conditions and soil characteristics both in SC and in IC and compared to a bare soil as control. Biomass, N acquisition, C:N ratio and soil mineral N were measured and ecosystem services of N management were assessed using both experimental and modelling data (Tribouillois et al., 2015).

Results and Discussion

Winter and spring legumes preceding crops show positive effects on durum wheat, notably due to higher soil mineral-N availability at wheat sowing. However, higher soil mineral-N levels after legume crops at harvest and in November increased the potential risk of nitrate leaching which was efficiently reduced by the introduction of cover crops. Cover crop mixtures and non-legume SC reduced similarly nitrate leached during the whole drainage period compared to the bare soil. Legume SC only slightly reduced N leaching in comparison to bare soil. Cover crops were particularly efficient during wet winters because the more the drainage volume, the more the reduction of nitrate leaching and nitrate concentration in leached water. N release from cover crop residues could be sufficient to compensate in a great part the pre-emptive competition for soil mineral-N when destroyed before winter. Prediction of mineralized N from cover crop residues was significantly higher for mixtures than for non-legume crops.

IC experiments showed that the total IC grain yield was almost always higher than the mean SC (3.3 vs. 2.7 Mg ha^{-1}) and similar result was found with accumulated N (121 vs 101 Kg N ha^{-1}). IC was more efficient than SC for low N availabilities due to dynamic complementarity for light and N acquisition. Cereal grain protein concentration was significantly improved in IC compared to the respective SC (11.1% vs. 9.8%) and the lower the SC value the higher the increase in the IC due to: i) a lower cereal grain yield in IC and ii) a quite similar (ca. 90%) amount of available soil N for the cereal in both systems because of a higher legume N_2 fixation rate in IC than in SC (75% vs. 62%).

Conclusions

Legume sole crops, intercropping a legume and a non-legume are of particular interest both for grain production and cover crops ecosystem services to design innovative cropping systems. This is due to the complementarity between legumes and non-legumes in improving use of N resources especially in low N systems. Bispecific cover crop with a legume can simultaneously provide good compromises between nitrate capture and green manuring ecosystem services by recycling the soil mineral-N in good synchrony with the succeeding cash crop. Intercropping for grain production provided compromises between grain yield, cereal grain protein content and species proportion.

A number of factors still needs to be optimized in order to propose optimized future cropping systems including intercrops like: i) species and cultivars, ii) correct rotational position to not increase pests and diseases and also iii) sowing practice (e.g. alternate row or mixture within each row, density of each component, width between rows,…). These choices depend on specific goals like for grain production the maximum total yield, the global protein production or the highest wheat grain protein content while for cover crops the choice of a mixture must be adapted according to site's soil and climate conditions, priorities of fallow-period management and services desired.

References

Plaza-Bonilla, D. et al. 2015. Agriculture, Ecosystem and Environnement, http://dx.doi.org/10.1016/j.agee.2015.06.014

Bedoussac, L. et al. 2015. Agronomy for Sustainable Development, http://dx.doi.org/10.1007/s13593-014-0277-7

Tribouillois, H. et al. 2015. Plant and Soil, http://dx.doi.org/10.1007/s11104-015-2734-8