Associating wheat crop and undersown forage legumes in organic agriculture: Incidence of forage legumes species

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One of the key issues of organic arable systems is to increase use of N_2 fixation from legume plants while enhancing autonomy by the limitation of off-farm inputs. Wheat yield in organic agriculture is generally low and variable. Grain yield and protein content are strongly affected by N deficiency and weed competition (*Casagrande et al*., *2009*). Previous research had clearly demonstrated the benefits of forage legumes to improve N balance and preserve weed infestation (*den Hollander et al., 2007*). Several authors highlighted the interest of crop mixtures combining cereal and legumes to provide higher overall productivity, enhance ecological services and improve economical profitability (*Malezieux et al., 2008*). Nevertheless, previous research also highlights how important it is to manage whether above- and belowground interactions between species to optimise benefits and limit competition. We propose here to analyse how the insertion of legumes species influences the performance of organic wheat (yield, grain protein content) but also the weeds population during and after crop cycle.

Methodology

Three field experiments have been carried out in 2009 in South-eastern France. These locations differed by soil and climate conditions (*Table 1*). Winter wheat was sown (200 $kg.ha^{-1}$) at the end of November in sites A and B; beginning of November in site C. Three different species of legumes (*Trifolium pratense*-*Tpra*, *T. repens*-*Trep* and *Medicago lupulina*-*Mlup*) were sown (800 $grains.m^{-2}$) at the end of March in the different sites. An additional control treatment with wheat grown as sole crop was added (T0). Each treatment was repeated in three randomised blocks. Additional irrigation was applied in site B (30 in April, 40 mm at the end of May and 40 mm in August). On each treatment, weeds (density, biomass & diversity), legumes (density & biomass) and wheat crop (biomass, yield components & protein content) were monitored on 0.25m² plots (3 replicates per block) every 4-6 weeks.

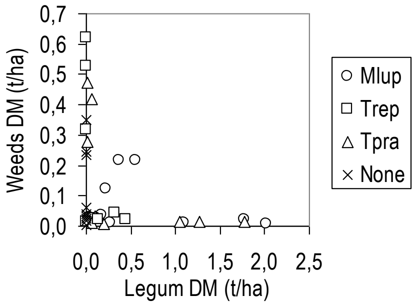
Table 1. Description of the three experimental sites and climate

Sites	Soil type	Climate	Leg. sowing – wheat harvest	Wheat harvest – end of October.
A	Loamy	Degraded oceanic and continental climate	ET0* = 413mm Rain = 162mm	ET0 = 507mm Rain = 229mm
B	Sandy	Degraded continental and Mediterranean climate	ET0 = 420mm Rain = 173mm	ET0 = 557mm Rain = 151mm
C	Clay Loam	Degraded continental and mountain climate	ET0 = 376mm Rain = 216mm	ET0 = 378mm Rain = 187mm

* Potential evapotranspiration

Results and discussions

Wheat yields and grain protein contents were significantly different from one site to another. Mean wheat yield varied between 2.2 $t.ha^{-1}$ in site C, 2.6 $t.ha^{-1}$ in site B to 4.1 $t.ha^{-1}$ in site A according to the soil N fertility and the climatic conditions ($p<0.01$). The insertion of legume did not affect significantly grain yield on all sites. Grain protein contents varied between 10% in site A to 12% in site C (10.5% in B) ($p<0.01$) with no significant incidence of forage legumes. Nevertheless, in favourable water conditions (Site B) an important growth of some legume covers (Mlup mainly, Tpra in site B) enabled to a low decrease of proteins ($p\sim0.10$).



Legumes presented a significant growth (more than 0.5t.ha^{-1}) during crop association in situations with low pressure of weeds (*Figure 1*). On the contrary, no significant control of weeds infestation by the cover of legumes was observed except for treatments with a high biomass of legumes at wheat harvest (Mlup in sites B and C, Tpra in site B) (*den Hollander et al., 2007*).

Figure 1: Weeds dry matter in relation with legume dry matter (tons/ha) at wheat harvest time in the three experimental sites (SA, SB and SC) and for the three studied legumes.

Legumes growth was highly variable from one site to another but also between species (*Figure 2*). During crop association, Mlup presented the higher growth ($p<0.05$) in all sites even the growth had been limited by the competition for light and nutrient resources from wheat (*Malezieux et al., 2008*). Tpra generally presented similar development and growth to the Mlup. Trep appeared to be the most sensitive to the lack of radiation during crop association due to its development and form (*Frame, 2005*). Trep was also extremely sensitive to intensive drought as observed on sites A. In sites B and C where legumes covers were well implanted, it resisted to drought during summer and reinitiated growth after autumn rainfalls. However, in Site C, clover species did not grow significantly, even after rainfalls, maybe because of a basic pH (*Frame, 2005*).

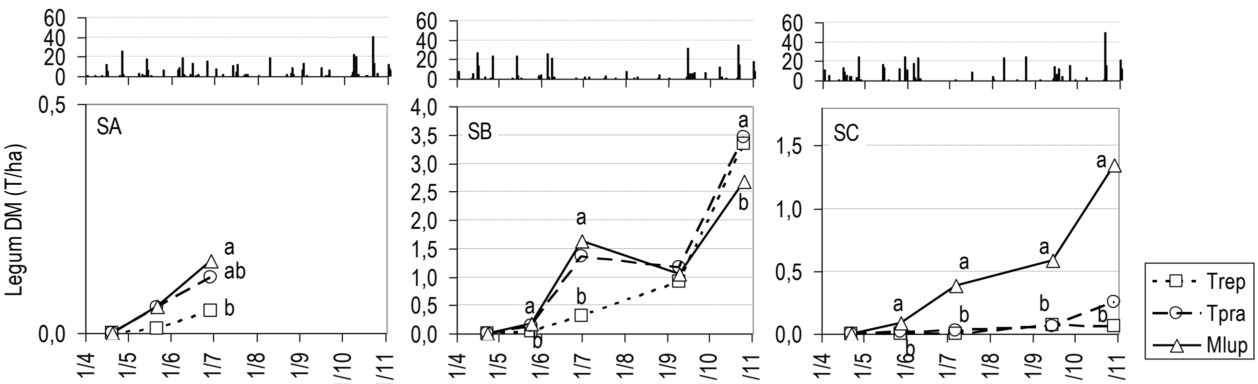


Figure 2: Time course of legume dry matter (tons/ha) in the three experimental sites (SA, SB and SC) and for the three studied legumes. Top frame of the figure represents daily rainfall. Letters represent significant differences between treatments (Newman-Keuls test with α=5%).

Den Hollander et al. (2007) gave evidence that the short form and the high density of Trep permit to mitigate weeds infestation without impairing wheat crop performances. However, when Trep is associated with wheat crop by undersowing, it appeared to strongly suffer from competition for radiation and then with weeds after wheat harvest. On the contrary, Tpra and Mlup presented significant growth during crop association (when water nutrition was not limited) and controlled weeds infestation after wheat harvest. However, attention has to be paid to the development of this legume cover during association as it could significantly impair the wheat crop performances if competition for resources is too intense (*den Hollander et al, 2007*; *Malezieux et al, 2009*). Such a cropping system should also be evaluated on its impact on the crop rotation (N nutrition for subsequent crops and mitigation of the weeds infestation).

References

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