Rapeseed-Faba bean intercrop in low input systems: nitrogen transfer and niche separation

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BACKGROUND

Agriculture is facing new challenges as optimal levels of production with less fertilisers and pesticides, the European directives and French environmental policies becoming more restrictive. The rape is a bigger consumer of inputs than other crops, particularly for insecticides and nitrogen. In such a context, yield potential may be limited. Yet, biological diversity and especially through intercropping, can be way of combining productivity with less chemical inputs. In intercrops, interspecific competition may lead to niche separation with more vigorous root systems and a more efficient exploration of the soil for nutrients and water, resulting in an increase of productivity (Hauggaard-Nielsen et al., 2001; Tilman et al., 2002). Most examples of intercropping combine a legume with another crop; in low input systems, legumes increase the soil N pool throughout their growth, through N symbiotic fixation and rhizodeposition (Fustec et al. 2010). After mineralisation, N can be transferred from the legume to the non-fixing companion crop. Most data are based on legume-cereal mixtures, and rape-legumes intercrops are poor documented, whereas nitrogen is a crucial factor: the whole crop accumulates approximately 6 kg N to produce 0.1 t of seeds, Morever winter oilseed rape accumulates 25–30% of the total N-uptake (40–80 kg N ha_1) from the soil during early growth stages (Cramer, 1993).
To determine whether intercropping a brassica with a legume might reduce fertiliser inputs, we scrutinised in a rape-faba bean intercrop, i) increase of intercropped rape dry weight and N transfer between faba bean and rape and ii) if there was niche separation .

METHODS

In march 2010, in a greenhouse, seeds were sown in rhizotrons. The substrate was N-deficient to enhance biological fixation. Three modalities were tested, with either one specie (monoculture): 1) rapeseed 2) faba bean or two species (intercropping). In five rhizothrons and for each modality, either the faba bean or the rape was labelled with 15N urea. Root development was drawn and recorded every three days during 8 weeks. At the end of the experiment, the above ground parts were harvested, dried (70°C), weighted and prepared for ^{15}N:^{14}N mass spectrometer measurements. N biological fixation was calculated using the natural abundance method. N transfer from the faba bean to the rape was calculated as described by Høgh-Jensen and Schjoerring (2000).

RESULTS

1) Dry weight

At the end of experiment, total Dry Weight of intercropped rape were significantly higher than in monocultures (8,8g and 7,2 g per plant respectively), this difference was induce by a higher dry matter accumulation in roots and above ground parts for intercropped rape compared to monocropped rape (30.2 and 21.4% respectively).

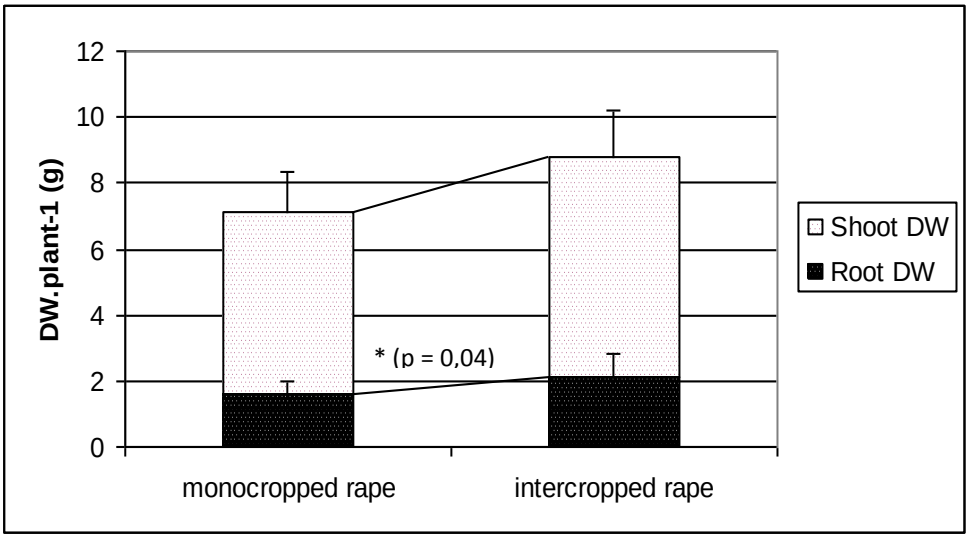


Fig 1: Shoot and root DW per plant in monocropped and intercropped rape (with faba bean). Error bars represent standard error.

2) N concentration (%) and N accumulated (mg per plant)

The shoot N content was different between monocropped and intercropped rape (fig. 2a) but not for roots. Indeed, the above ground N content for intercrops was significantly higher than for monospecific rhizotrons (diff= 6%) whereas root N content tend towards decreased (diff = 9% but p-value=0.12).

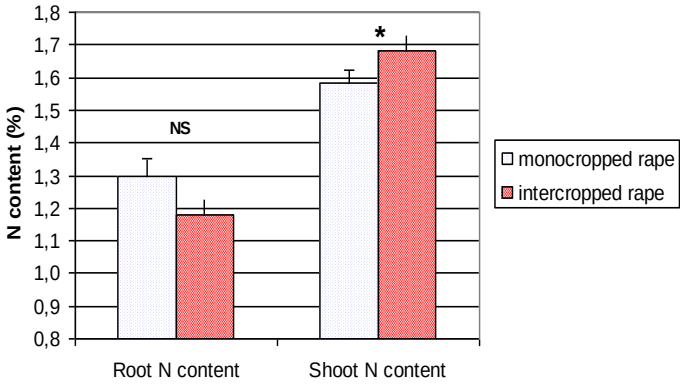


Fig 2a : Shoot and root N content in monocropped and intercropped rape. Error bars represent standard error.

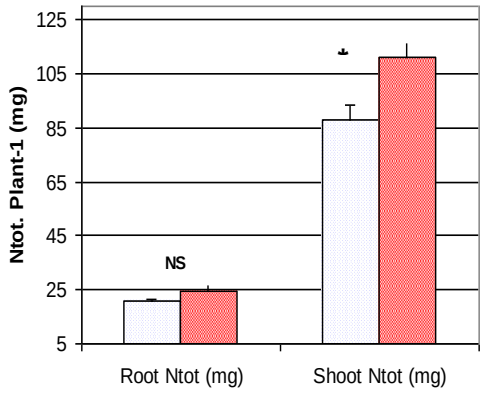


Fig 2b : Shoot and root N accumulated per plant in monocropped and intercropped rape. Error bars represent standard error.

When considering the total plant-N (fig. 2b), this difference for root N content was balanced by the DW: Ntot tended to be higher for intercropped than in monospecific rhizotrons, but not significantly different, whereas there was a marked difference for N accumulation in the case of above ground part (diff = 26%).

Two hypothesis can explain differences on nitrogen and dry matter accumulation: first, The N transfert between faba bean and rape; secondary a complementary use of N source.

3) Nitrogen transfer from Faba bean to Rape

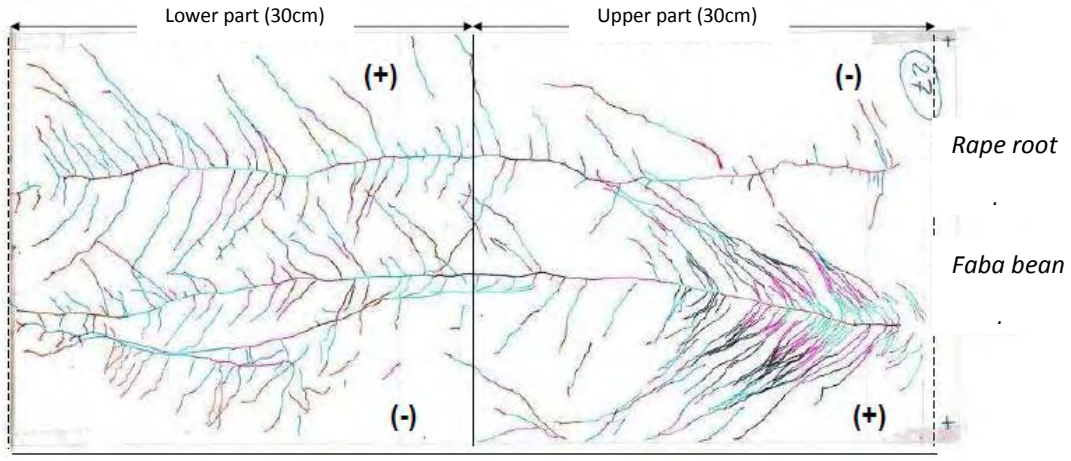
Table N°1: Nitrogen transfer rate (%) and N transferred (mg.plant$^{-1)}$ from fababean to rapeseed

	Faba bean -> Rapeseed
% Ntransfer	0.62 ± 0.08
N transferred (mg.plant^{-1})	0.66 ± 0.24

N Transferred from faba bean to rapeseed are very slight compared to Ntot in intercropped rape (135 mg N) and do not explain the difference between 2 modalities.

4) Complementary use of N sources

- Niche separation for root systems



Rape	44.8	32.6
Faba bean	48.0	59.5
P value	<0.05	<0.05

Fig 3: root systems drawing on 60cm depth rhizotron and Nb of branching in 2 rhizotron parts for both root systems (12 repetitions).

Niche separation between the roots of faba bean and the brassica was observed. The proportion of the root number located in the lowest part of the rhizotron was higher in rapeseed than in faba bean ($p<0.05$ at 970 degree-days).

- Contribution of N_2 fixation to Faba bean Nitrogen content.

Table N°2: Contribution of N2 fixation to faba bean Nitrogen content above ground part (% and N quantity)

	% N2 fix	N fix (mg.AG_plant^{-1})	Ntot (mg.AG_plant^{-1})
Monocropped faba bean	73	108.5	148.7
Intercropped faba bean	84.8	103.2	121.7
P value	<0.05	NS	NS

Contrary to results observed for rapeseed, the Ntot in faba bean above ground part is statistically similar between the 2 modalities. However, the contribution of N2 fixation to fababean Nitrogen accumulation was higher in intercropped condition than monocropped condition (84.5% vs 73%).

DISCUSSION

These results show a significant benefit effect of intercropping system (rape x faba bean) on dry matter and nitrogen accumulation of rape during the first part of growth cycle (56 days after sowing), in low inorganic soil nitrogen conditions.
It's in accordance with others intercropping studies: the yield of the non fixing companion crop of legume increases significantly compared to sole crop; as demonstrated in pea-barley mixture by Corre-Hellou et al. (2007).

Several mechanisms can explain these results:

i) if the direct nitrogen transfer from faba bean to rapeseed cannot explain the intercropped rape Nitrogen accumulation, Xiao et al. (2004) and Corre-Hellou and al. (2006) showed that the non-legume was found to be much more competitive than the legume for soil N, forcing the legume to rely mainly on N2 fixation for its N Nutrition. This mechanism seem to be confirmed by our results on rapeseed x faba bean intercropping (%Nfix intercropped FB > %Nfix monocropped FB).

ii) Spatial and time separation of root systems are keys factors in determining the intensity of below ground inter-specific competition. A previous study showed that the intercropped rapeseed have to speed up the growing root rates compared to sole crop during earlier growth stages; however, no statistical differences were observed for faba bean root system. (prendre public serbe). Moreover, rapeseed and faba bean are a different root distribution and thus a possible reduce of below ground competition.

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