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Nitrogen benefits of ten legume pre-crops for wheat assessed by field measurements and modelling

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ABSTRACT

The positive effect of grain legume pre-crops on the yield of the subsequent crop has been studied widely, whereas less information is available on the nitrogen (N) processes related to this positive effect, especially for a wide range of grain legume species.

The objective was to quantify and understand the effect of grain legume compared to cereal pre-crops (sown in 2014 and 2016) on grain and shoot N yields and shoot N concentration of wheat (*Triticum aestivum*) grown the following year (2015 and 2017). Spring legumes (faba bean (*Vicia faba)*, fenugreek (*Trigolia foenum-graecum*), common vetch (*Vicia sativa)*, lentil (*Lens culinaris*), lupin (*Lupinus albus*), and pea (*Pisium sativum*)) were compared to barley (*Hordeum vulgare*). Summer legumes (chickpea (*Cicer arietinum),* common bean (*Phaseolus vulgaris*), soybean (*Glycine max*) and Narbonne vetch (*Vicia narbonensis*)) were compared to sorghum (*Sorghum bicolor)*. Inorganic N remaining in the soil at pre-crop harvest (N sparing) was measured. The STICS model which accurately predicted soil humidity and soil inorganic N in the pedoclimatic conditions of the field experiments was used to calculate N mineralisation from pre-crop residues and N leaching between pre-crop harvest and wheat harvest.

Grain and shoot N yields of unfertilised N wheat were respectively 27 and 25 % higher after faba bean and lentil compared to barley pre-crops, and 66 and 51 % higher after summer legumes compared to sorghum pre-crop. In the second experiment, N fertilisation reduced the positive effect of fenugreek, and lentil on wheat yield compared to barley while it did not modify the pre-crop effect of the other legumes. A positive relationship between N mineralisation from pre-crop residues and wheat shoot N yield was established, with higher amounts of N available for the subsequent wheat after legume pre-crops. In 2014, N sparing was higher after spring pre-crops compared to summer pre-crops inducing higher N leaching after spring legume pre-crops, especially in the first experiment which was characterised by heavy rain in summer and autumn. Estimating N availability by taking into account N sparing, N mineralisation from soil and pre-crop residues and N leaching explained 49 % of wheat shoot N yield variability. Unquantified N processes and non-N processes might also have contributed to the positive effects of legumes on the subsequent wheat.

1. Introduction

Cereal crops generally have higher yields when cultivated after unrelated species (Kirkegaard et al., 2008) and especially after legume crops (Angus et al., 2015; Preissel et al., 2015). Some studies also highlighted higher grain N concentrations in cereals grown after legumes compared to cereals grown after cereals (Biederbeck et al., 1996; Gan et al., 2003). Part of the positive effect of legumes on the following cereals are due to N benefits.

Indeed, a substantial amount of N can be left by legume crop residues. Moreover, during crop residue decomposition by soil microbes, organic N is converted into inorganic forms that can be taken up by the subsequent crop. Much of the inorganic N released is rapidly immobilised by soil microbial biomass. Inorganic N accumulation in the soil occurs when the amounts of N released exceeds the microbial N requirements (net N mineralisation). Conversely, when inorganic N released from the mineralisation of crop residues is not sufficient, micro-organisms will also assimilate soil inorganic N to meet their N requirements, which results in net N immobilisation (Nicolardot et al., 2001). Net N mineralisation or smaller amounts of net N immobilisation are expected for legume residues compared to cereal residues, since legume residues are generally characterised by higher N concentrations and lower C:N ratios.

Furthermore, part of the additional soil inorganic N after legume

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