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RESEARCH ARTICLE

Provision of contrasted nitrogen-related ecosystem services among grain legumes

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Abstract

Legumes deliver unique functions that are complementary to those of other groups of species (cereals and oil-rich crops), providing many ecosystem services related to nitrogen. However, the choice of grain legumes according to their ability to provide these ecosystem services remains difficult due to a lack of references for a variety of species. During two legume – wheat successions established between 2014 and 2017, five nitrogen pools were measured, and considered as proxies of nitrogen functions supporting ecosystem services and dis-services. Nitrogen pools were analyzed together with several of their explanatory shoot and root characteristics (i.e. plant traits and properties). For the first time, a wide range of grain legumes could be characterized by their contrasted functional profiles relative to nitrogen. For each species, synergies and trade-offs between the different nitrogen functions were highlighted and related to the explanatory plant characteristics. Shoot and root characteristics explained 76.1% of the variability of nitrogen functions among legumes species. Chickpea, common bean, and soybean had high capacity to take up soil nitrogen during their growth cycles, reducing the risk of nitrogen losses after their harvest. These species were characterized by a high root lateral expansion rate and their capacity to invest a large proportion of belowground biomass in nodules. Conversely, common vetch, faba bean, lentil, pea and Narbonne vetch, were less able to take up soil nitrogen, with higher risks of nitrogen losses, but these species induced high amounts of nitrogen in the following wheat crop and were characterized by high crop residue nitrogen concentration. Larger amounts of nitrogen fixed and exported in seeds were measured for species characterized by high shoot dry matter, high nitrogen harvest index, high seed nitrogen concentration, and large seeds. Hence, this study should facilitate the selection of legume species according to the expected objectives.

Keywords Functional profile · Plant traits · Multifunctionality index · Symbiotic nitrogen fixation · Seed nitrogen · Iorganic nitrogen uptake · Nitrogen leaching · Pre-crop nitrogen benefits

1 Introduction

To overcome environmental issues (water soil and air pollution, biodiversity loss, etc.) and resource scarcity in the context of climate change, cropping systems must enable the production of agricultural goods through a better resource use efficiency while minimizing negative impacts on the environments (Tilman et al. 2002).

In the context of agroecological transition, ecosystem services should be maximized to ensure agricultural production while reducing farm inputs (MEA 2005; Power 2010; Tibi and Therond 2017). The provision of ecosystem services relies in particular on the reintroduction of spatial and temporal biodiversity (Isbell et al. 2011) in farming landscapes and in cropping fields. Indeed, species diversity in agricultural ecosystem ensures a variety of ecological functions, resulting from ecological processes, and providing ecosystem services. Synergy between ecological functions induced by different species allows: i) more efficient resource use, ii) the simultaneous provision of a wider range of ecosystem services, and iii) better adaptation to environmental disruptions.

Although legumes deliver unique and complementary ecological functions to those of other groups of species (Peoples et al. 2019) grain and forage legumes only represent 3% of the French agricultural land (Voisin et al. 2014). Consequently, legumes should play a leading role in the provision of ecosystem services relative to nitrogen (N) when reintroduced in

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