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CONTRIBUTION OF COVER CROP ROOTS TO SOIL FERTILITY AND CROP NUTRITION IN ORGANIC SPRING WHEAT IN QUEBEC, CANADA.

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Abstract: Assessing the contribution of cover crops (i.e. crops that are planted to improve soil health – not for harvest) to soil fertility is particularly complex. Little is known about how much N and how N from decomposing cover crop roots will become available to subsequent crops. The objective of the project was to determine the respective N contribution of shoots and roots of annual cover crop species to crop N uptake in organic spring wheat. A 2-year field experiment was conducted twice (2016-2017, 2017-2018) in Quebec, Canada. Cover crops were grown and terminated in Year 1, and a cash crop of spring wheat was grown the subsequent year (Year 2). Four annual cover crop species (common vetch, field pea, forage radish, and cereal rye) and four cover crop biomass input levels (shoot only, root only, and shoot plus root) were tested. Forage radishes and peas produced the highest total biomass (shoot and root) while radishes produced the highest root biomass. Common vetch had higher shoot N concentration than other species whereas its root N concentration was similar to radishes and peas. At spring wheat seeding, soil mineral N content (0-45 cm) was significantly higher in whole CC treatments (39 kg N ha^{-1}) compared to treatments of shoot or root only (33 and 29 kg N ha^{-1}, respectively). In 2017, spring wheat yields were higher following the whole CC than following the shoot or root parts only. Improving our understanding on soil N budget may help to reduce N losses from cover crop-based cropping systems such as organic farming systems. On a broader scale, this research aims to reduce the impact of organic farming on the environment by increasing its N use efficiency.

Introduction: Nitrogen budgeting is a complex task in organic cropping systems, because crop fertilization is based on organic fertilizers (animal manures, cover crops, compost, etc.) rather than readily available mineral fertilizers. Many unknowns remain on the contribution of these organic fertilizers to the nutrition of crops. In particular, assessing the contribution of cover crops (i.e. crops that are planted to improve soil health – not for harvest) to soil fertility is particularly complex. However, cover crops are a key component of most organic cropping systems, occupying up to half of the crop rotation in vegetable and grain cropping systems. Farmers rely on legume cover crops to decrease farm N needs though the biological fixation of atmospheric N. Generally, only the shoot biomass of cover crops is considered when estimating the contribution of cover crops to nitrogen budget and fertilization plan. The contribution of cover crop roots is not considered. On rare occasions, root N contribution was calculated based on estimates of the root-to-shoot ratio (Jobin and Douville, 2000). However, C:N ratios of shoot and root biomass differ greatly, and so is the environment they are in during the decomposition after their incorporation into the soil (soil-plant contact, prior colonization by microbial population, etc.). There is a need to advance our knowledge on cover crop root contribution to soil fertility. The long-term goal of our research program is to elucidate the mechanisms of contribution of cover crop roots to soil fertility and crop nutrition in organic cropping systems. The specific objectives of the research project were:

- To compare the shoot and root characteristics of four annual cover crop species.
- To elucidate the temporal dynamics of N derived from the decomposition of cover crop roots in the soil-plant continuum.
- To estimate the respective N contribution of shoots and roots of annual cover crop species to crop N uptake in organic spring wheat.

The main research hypothesis is that cover crop roots contribute more to soil N supply and less to crop nutrition than cover crop shoots, influencing the transfer of this cover crop N into various soil fractions.

Material and methods: A 2-year field experiment was conducted twice (2016-2017, 2017-2018) in Quebec, Canada. Cover crops were grown and terminated in Year 1, and a cash crop of spring wheat was grown the subsequent year (Year 2). The experimental design was a split-plot, with 4 blocks. Four annual cover crop species (common vetch, field pea, forage radish, and cereal rye) were tested (main plot factor). Four cover crop biomass input levels (shoot only, root only, and shoot plus root) were tested (sub-plot factor). A control treatment with no cover crop was also added. Cover crop roots were washed using a hydropneumatic elutriation system (Smucker et al., 1982) and dried to estimate root biomass, N, C, and ash concentration. Cover crop shoot parameters (biomass, C, and N concentration) were also assessed. Spring wheat N uptake and yield were measured at harvest. Weed biomass, weed count, and weed N uptake were also assessed. Soil inorganic N was estimated using soil nitrates extraction from soil sampling (0-10, 10-20, and 20-30 cm). Field-based indices of soil N supply (crop yield, relative yield, and plant N uptake) were assessed.

Results: Forage radishes and peas produced the highest total biomass (shoot and root) while radishes produced the highest root biomass. Common vetch had higher shoot N concentration than other species whereas its root N concentration was similar to radishes and peas. In the fall of Year 1 (cover crop destruction), soil mineral N content was higher under peas and vetch than radishes and rye. At spring wheat seeding, soil mineral N content in the top 45 cm of soil was significantly higher in whole CC treatments (39 kg N ha^{-1}) compared to treatments of shoot or root (33 and 29 kg N ha^{-1}, respectively). In 2017, spring wheat yields were higher following the whole CC than following the shoot or root parts only.

Discussion: Results from this study allows to quantify and differentiate the contribution of cover crop shoots and roots to soil N dynamics, thus providing a fundamental understanding of cover crop root decomposition and associated soil N supply to plants and to the replenishment of the soil reserve and to plants. This allows for better estimation of the soil N supply to subsequent crops and, therefore, for better forecasting of the need for other N organic amendments. Knowledge of the actual contribution of cover crop roots will be integrated in farm N budgets, therefore conceptually advancing the cover cropping and nutrient budgeting in organic cropping systems. Moreover, increase in crop yield due to better N management and timing would represent important gains in revenues to farmers. On a broader scale, improving our understanding on soil N budget may help to reduce N losses from cover crop-based cropping systems such as organic farming systems. Indeed, this research program aims to reduce the impact of organic farming on the environment by increasing its N use efficiency.

References: Jobin, P., and Y. Douville. 2000. *Engrais verts et cultures intercalaires*. Guide des pratiques de conservation en grandes cultures, Feuillet 6-A, Conseil des productions végétales du Québec. 23pp.
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