Maize root-derived C in soil and role of physical protection in its relative stability over shoot-derived C

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Introduction

Efficient and sustainable utilization of biomass resources is getting more important as they are not infinite. Currently, an increasing attention has been paid to non-harvested aboveground crop residues and the key role of underground residues within soil organic carbon (SOC) balance. Some meta-analyses of field experiments reported that the removal of aboveground biomass from the field often has little influence on SOC levels in the long term. Therefore, several studies have been done to compare the relative stability of above- and underground biomass derived SOC, most cases considering maize as model crop. Rasse et al. (2005) indicated that root-derived C remains about two times longer in the soil as stabilized SOC than shoot-derived C. Nevertheless, the mechanisms responsible for the stabilization of root-derived C and the interactions with agricultural management are still not well understood.

Objectives

In this study, we focus on the importance of physical stabilisation of root derived C in micro-aggregates. We hypothesize that compared to shoot-derived C, root-derived C is more likely to accumulate in micro-aggregates due to the intimate contact of maize root promoting physical occlusion and stabilization during growth. Furthermore, we look at the impact of soil texture and maize cultivar on the total root biomass.

Materials and methods

Three long term European experimental fields with maize-based crop rotation were selected, namely the 12-year-trial Bottelare (North Belgium), the 22-year-platform Tetto Frati (Northwest Italy) and the 32-year-field Puch (South Germany). A comparison of the plough layer SOC from silage and grain maize rotations was made in these fields to investigate the stability of root- and shoot-derived C. Each site involved non-manured objects to exclude other ^{13}C input than maize biomass. The physically stabilized SOC was isolated according to a physical fractionation scheme based on Virto et al. (2008). C content and its stable isotope ratio of bulk soil and fractions were analysed with an elemental analyser coupled to an IRMS. Moreover, an experiment of 8 commercial maize cultivars was carried out in three Belgian field trials with different soil texture (sandy, sandy loam and clay). Roots were taken at harvest time, while their dry matter and C content were measured.

Results

Long term grain maize cultivation had a significantly higher SOC content and more maize derived C than silage cultivation mainly due to more crop residue in the field. Root-derived C contributed more than twice as much to the total SOC compared to shoot-derived C. The relative contribution factor of root vs shoot was calculated based on a method developed by Rasse et al. (2005). According to this factor, the root-derived C also showed 2-3 times more relatively stable than shoot-derived C in the plough layer. Most of maize root-derived C was distributed in the fractions of free sand-sized C and mineral-bound C. No preferential accumulation of root-derived C in silt-sized micro-aggregate particulate organic matter was observed. Both the soil texture and cultivars showed significant effect on aboveground dry matter yield. The impact of soil texture on maize root biomass (C/plant) was significant, however, no difference could be seen between cultivars, although the involved cultivars originated from three different vendors. It is also noticed that root biomass of different cultivars had various sensitivity to soil texture.

Conclusion

Our results show that root-derived C is more relatively stabilized than shoot-derived C, however, root-derived C does not preferentially accumulate in silt-sized micro-aggregates. Soil texture plays a key role on both above- and underground biomass, while cultivars only affects the aboveground biomass. At this moment, root architecture systems of maize have been successfully visualized by X-ray CT scanning. The architectural traits will be quantified in 3D model to further elucidate the effect of cultivars and soil texture on root architecture systems.

References

Rasse, D., Rumpel, C., Dignac, M.-F., 2005. Is soil carbon mostly root carbon? Mechanisms for a specific stabilization. Plant and Soil 269, 341-356.

Virto, I., Barre, P., Chenu, C., 2008. Microaggregation and organic matter storage at the silt-sized scale. Geoderma 146, 326-335.