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Nitrogen use efficiency of plant species matters: CO_2 emission from soil inorganic carbon and its temperature dependence in a calcareous soil

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Terrestrial ecosystems play a significant role in global warming by regulating CO_2 concentration in the atmosphere. A comprehensive understanding of carbon (C) sources and stocks in soils, as well as the driving mechanisms, are critical to reducing CO_2 emission from soil and thus mitigating climate change. To date, most studies have solely focused on processes involving soil organic C (SOC), but few studies have addressed the potential contribution of soil inorganic C (SIC) mostly $CaCO_3$ pool to ecosystem C fluxes. SIC can potentially be a regulator of atmospheric CO_2. However, so far the effects of plant species (i.e. variations in nitrogen (N) demand and N use efficiency (NUE)) as well as soil temperature on SIC-derived CO_2 are unclear. We hypothesized that 1) relatively less SIC-derived CO_2 is expected from soils covered under plant species with lower N demand and higher NUE. We conducted a 4-month field experiment from June to October 2021 at the research station of the University of Göttingen in Deppoldshausen (51.58^{o}N, 9.97^{o}E) with ca. 6% $CaCO_3$ equivalent in the topsoil. We analyzed the effects of two plant species 1) wheat (high N demand and low NUE), 2) legume (low N demand and high NUE) and two N fertilization (urea) levels, 1) low (50 kg N ha^{-1}), 2) high (200 kg N ha^{-1}) on CO_2 emission out of SIC. Each treatment had four replicate plots (1×1 m^2), and at least a 0.5 m gap was established between plots. We measured CO_2 fluxes weekly by using the static chamber method. The $\delta^{13}C$ natural abundance was used to determine the contribution of SIC and SOC in the emitted CO_2. The total CO_2 emission and its $\delta^{13}C$ signature increased with soil temperature, indicating that the portion (%) of SIC-derived CO_2 was stimulated by temperature (^{o}C) (slope = 0.33). The portion of SIC-derived CO_2 stimulated by temperature increased faster under wheat than under legume (slope = 0.36 vs. 0.26), especially under high N treatment (slope = 0.65 vs. 0.54). The portion of SIC-derived CO_2 under wheat (13.0%) was higher than that under legume (11.3%). Moreover, the portion of SIC-derived CO_2 was 1.2% higher under wheat than under legume at high N fertilization level, whereas it was increased to 2.2% under low N fertilization. This indicates a significant role of plant species with different N demand and NUE on dynamics of SIC pool and its contribution in CO_2 emission from soil. The rate of SIC-derived CO_2 was comparable between wheat and legume under high N fertilization, but it

was 1.6 times higher under wheat than that under legume at low N fertilization. The contribution of SIC-derived C to the atmosphere was ~63.7 g C m^{-2} yr^{-1} under legume with low N demand vs. ~82.1 g C m^{-2} yr^{-1} under wheat with high N demand. In this regard, the impacts of plant species and their N demand and NUE are important controlling factors determining the dynamics of the SIC pool in agroecosystems.