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The European Union Renewable Energy Directive, which sets a binding target of a final energy consumption of 20% from renewable sources by 2020, has markedly promoted the increase of biogas plants, particularly in Germany. As a consequence, a large amount of biogas residue remains as a by-product of the fermentative process. These residues are now widely used instead of mineral fertilizers or animal slurries to maintain soil fertility and productivity. However, to date, the effect of the application of biogas residue on greenhouse gas (GHG) emission, compared to that of other organic fertilizers, is contradictory in literature, not having been completely understood. It is often stated that GHG fluxes are closely related to the quality of the raw material, particularly the type of soil to which the digestates are applied. This study addresses the questions (a) to what extent are the applications of biogas digestate and cattle slurry different in terms of their GHG emission (CO_2, CH4 and N2O) potential, and (b) how do different soil organic carbon contents (SOCs) influence the rate of GHG exchange. We hypothesize that, i) cattle slurry application enhances the CO_2 and N2O fluxes compared to the biogas digestate due to the overall higher C and N input, and ii) that with increasing SOC and N content, higher emissions of CO_2 and N2O can be expected. The study was conducted as a pot experiment. Biogas digestate and cattle slurry were applied to and incorporated into three different soil types with varying SOC contents (Cambisol, termed Clow; Mollic Gleysol, termed Cmedium and Sapric Histosol, termed Chigh). The application rate was equivalent to 150 kg NH4+-N ha^{-1}. GHG exchange (CO_2, CH4 and N2O) was measured on five replicates over a period of 22 days using the closed chamber technique to simulate the high-risk situation of enhanced GHG emissions following organic fertilizer application in energy maize cultivation. Generally, it was found that the application of cattle slurry resulted in significantly higher CO_2 and N2O fluxes compared to the application of biogas digestate. The total cumulative CO_2 exchange rates after 22 days ranged from 137 $\pm$ 4.6 kg C ha^{-1} $22d^{-1}$ (Clow, control) to 885 $\pm$ 32.5 kg C ha^{-1} 22 d^{-1} (Chigh, CS). However, the total cumulative N2O exchange rates ranged from 7.7 $\pm$ 6.1 g N ha^{-1} 22 d^{-1} (Clow, control) up to 2000 $\pm$ 226 g N ha^{-1} 22 d^{-1} (Cmedium, CS). No differences were found regarding the CH4 exchange, which was close to zero for all treatments. Total cumulative CH4 exchange rates ranged between -31 ± 32 g C ha^{-1} $22d^{-1}$ (Cmedium, control) and $^{-1}67 \pm 34$ g C ha^{-1} $22d^{-1}$ (Chigh, CS). Calculated cumulative emissions revealed that 4% to 15% of the C derived from the organic fertilizer was emitted as CO_2, and 0.06% to 0.67% of the applied N as N2O. Significantly higher CO_2 emissions were observed at the Chigh treatments compared to the other two soil types investigated, whereas the significantly highest N2O emissions were found at the Cmedium treatments. The results clearly demonstrate the importance of soil type-adapted fertilization with respect to changing soil physical and environmental conditions.
Considering the distinctly higher global warming potential (GWP) of N2O compared to CO_2 (298:1; IPCC 2014), the present results revealed that soil type-specific 22-day cumulative N2O emissions contributed to 8% of the total GWP balance at Clow, 25% at Cmedium and 4% at Chigh, respectively. Overall, it seems that soils rich in SOM have a higher sensitivity regarding changing physical soil conditions than soils with low SOM contents.