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Canceling effect: a natural mechanism to reduce the effects of global warming

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The temperature sensitivity of enzymes responsible for organic matter decomposition in soil is crucial for predicting the effects of global warming on the carbon cycle and sequestration. We tested the hypothesis that differences in temperature sensitivity of enzyme kinetic parameters Vmax and Km will lead to a canceling effect: strong reduction of temperature response of catalytic reactions. Short-term temperature response of Vmax and Km of three hydrolytic enzymes responsible for decomposition of cellulose (β-glucosidase, cellobiohydrolase) and hemicelluloses (xylanase) were analyzed in situ from 0 to 40 °C. The apparent activation energy varied between enzymes from 20.7 to 35.2 kJ mol-1 corresponding to the Q10 values of the enzyme activities of 1.4–1.9 (with Vmax-Q10 1.0–2.5 and Km-Q10 0.94–2.3). Temperature response of all tested enzymes fitted well to the Arrhenius equation. Despite that,the fitting of Arrhenius model revealed the non-linear increase of two cellulolytic enzymes activities with two distinct thresholds at 10–15 °C and 25–30 °C, which were less pronounced for xylanase. The nonlinearity between 10 and 15 °C was explained by 30–80% increase in Vmax. At 25–30 °C, however, the abrupt decrease of enzyme-substrate affinity was responsible for non-linear increase of enzyme activities. Our study is the first demonstrating nonlinear response of Vmax and Km to temperature causing canceling effect, which was most strongly pronounced at low substrate concentrations and at temperatures above 15 °C. Under cold climate, however, the regulation of hydrolytic activity by canceling in response to warming is negligible because canceling was never observed below 10 °C. The canceling, therefore, can be considered as natural mechanism reducing the effects of global warming on decomposition of soil organics at moderate temperatures. The non-linearity of enzyme responses to warming and the respective thresholds should therefore be investigated for other enzymes, and incorporated into Earth system models to improve the predictions at regional and global levels.

Key words: carbon cycle, Michaelis-Menten kinetics, Arrhenius function, soil enzymes, temperature sensitivity, canceling effect, activation energy.