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Nutrient limitation of fine roots and fertilization effects on soil nutrients in a moist tropical forest

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Fine roots represent a small but important part of belowground plant biomass, however, field-based evidence of how nutrient availability control fine root production in species-rich tropical forests is scarce yet remain imperative to our understanding of ecosystem biogeochemistry.

To evaluate the responses of fine root production and plant-available soil nutrients to N, P and K fertilization thereby identifying which (if any) nutrients limit plant growth and microbial processes, we conducted a large-scale, full factorial nutrient manipulation experiment (8 treatments × 4 replicates: 32 plots of 40 × 40 m each) in a humid tropical forest in Uganda. We added nitrogen (N), phosphorus (P), potassium (K), their combinations (NP, NK, PK, and NPK) and control at the rates of 125 kg N ha^{-2} yr^{-1}, 50 kg P ha^{-2} yr^{-1} and 50 kg K ha^{-2} yr^{-1}, divided into four equal applications. We quantified fine root biomass (0–10 cm soil depth) at the end of the first and second years of the experiment by excavating soil monoliths (20 cm × 20 cm) at six random locations within each plot. Fine root production in the top 30 cm soil depth was estimated using the sequential coring technique in the second year of the experiment.

It was determined that the addition of N reduced fine root biomass (FRB) by 35% after the first year of the experiment and did not change in the second year whereas K addition was associated with reduced fine root production, suggestive of an alleviated ecosystem-scale N and K limitation. This rapid reduction in fine root biomass and production highlight that maintaining a large fine root network is an energy and resource-intensive process, therefore, trees will scale back their root network when they have adequate resources available. Next, a strong positive relationship was evident between FRB and NH_4:NO_3 ratio and highlights how FRB decreases dramatically when NO_3 concentrations surpass NH_4 concentrations (NH_4:NO_3 < 1). Additionally, nutrient additions resulted in a cascade of biochemical responses in soil nutrient availability. Specifically, (1) the interaction effects of all three nutrients (N, P and K) enhanced net N mineralization and nitrification rates. This highlights the complementary roles of these nutrients in regulating soil processes related to N-cycling in this ecosystem. (2) Microbial biomass C increased with P additions but was dependent on the season. Lastly, P additions increased plant-available P by 80%. This large increase could indicate that the demand for P was not very high. Our data show that N and K are particularly important in regulating fine root growth in this ecosystem.