Nitrogen dynamics following fertilizer application in tropical maize-based agriculture highlands with contrasting soil texture

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Introduction and objectives Maize provides 60% of dietary calories to Tanzanian population, and impressively, nearly half of the maize are produced in highlands due to its high potential of crop yield and unique climatic conditions (e.g. lower temperature, higher precipitation, etc.). Tanzania and most Sub Saharan African (SSA) countries have, however, long been suffering from low crop productivity due to the declined soil fertility. Most soil resources are nutrient poor in SSA, and sandy and clayey soils are widely spread across the whole African continent. Soils with contrasting texture can differ significantly in water holding capacity and nutrient retention (especially nutrient leaching), which could result in different behaviors of nitrogen (N) dynamics after treated with fertilizer. To improve crop productivity, a better understand of N dynamics is essential. Studies on N dynamics with contrasting soil texture in highlands are, however, still quite limited, and site-specific recommendations for N fertilization are urgently required. Therefore, the study tries to investigate the soil inorganic N dynamics and availability to maize under different N fertilizer treatments and contrasting soil texture.

Materials and methods To monitor soil inorganic N (NO_3-N and NH_4-N) dynamics, soil sampling was conducted throughout the cropping season in two depths, 0-15 cm and 15-30 cm, from maize field under different N fertilization regimes (0, 50, 100, and 150 kg N ha^{-1} as urea; noted as N0, N50, N100, and N150) using randomized block design with three replicates in sandy site (TZs, 4.7% clay, in Iringa) and clayey site (TZc, 28.4% clay, in Mbeya), Southern Highland of Tanzania. Plant samples were also collected at three growth stages (six leaves, V6; tasselling, VT; and physiological maturity, PM) for estimating crop N uptake. Environmental factors including soil moisture at different depths (5, 20, and 40 cm), precipitation, etc. were monitored.

Result and Discussion **(1) Environmental factor**; The precipitation during the cropping season was 882 and 548 mm, for TZc and TZs, respectively. Maize was not stressed by water supply at 0-40 cm of both sites, considering the matric potential. Interestingly, behavior of soil moisture at 20 cm depth for two sites showed distinct difference. At TZc, it was similar to the variation and content at subsoil (40 cm depth), while it was much closer to topsoil (5 cm depth) at TZs, indicating the fast movement of water and consequently solute transport at TZs surface soil under sufficient rainfall. **(2) Soil inorganic N dynamics**; TZc has much higher content of inorganic N compared with TZs. Both the concentration of NO_3-N and NH_4-N responded to N fertilization predictably at TZs, while only NO_3-N responded significantly at TZc (the response of NO_3-N to first N fertilization could be affected by previous experiment). Longer lasting effect at TZc (ca. two months) of N fertilization – significant difference of N level between treatments was remained after N fertilization – was found compared with fast N depletion at TZs (the effect disappeared after ca. two weeks), indicating much higher N retention capacity at TZc soils, due to high content of clay. At TZs, short lasting effect could mainly be caused by fast leaching (supported by the 20 cm soil moisture behavior mentioned above). **(3)Above-ground plant biomass and N uptake**; Both N fertilization and soil texture affected maize yield, as we observed the significant response of maize yield to N fertilization and also the significant difference of yield between plots with same treatment at each site. TZc had much higher yields compared with those of TZs. The lowest yield of 2.9 Mg ha^{-1} at TZc N0 plot was already comparable with the highest yield of 2.5 Mg ha^{-1} at TZs N150 plot. At TZc, maize growth showed no difference between treatments until the VT stage started. At TZs, on the other hand, significant difference of N uptake was found between treatments at early time before VT stage, although above-ground biomass accumulation did not show significant difference. Luxurious N consumption was occurred, at least at TZc, as higher N uptake was found along with non-significant difference of grain yield or above-ground plant biomass between treatments. Also, this indicates N might no longer be the limiting factor for yield at TZc when applied with more than 50 kg N ha^{-1}. For TZs, however, yield could still be limited by N supply. Significant difference of yields between N100 and N150 plots was not observed could largely be due to fast depletion of soil N after fertilization (short lasting effect discussed above), indicating similar and limited N availability to maize from different N fertilization rates at relatively higher level (e.g. N100 and N150). **(4) N Recommendations**; For TZs, sole application of fast-release chemical N fertilizer does not seem to be a cost-effective way for further improving crop productivity. As influenced by the coarse soil texture, N depleting can be very fast, therefore the combination of chemical fertilizer (N100 treatment) with organic residue may be recommended to improve N synchrony between soil N pool and crop N uptake (i.e. through microbial activity; Sugihara et al., 2012). For TZc, due to its high retention capacity of N, a single application of N fertilizer at VT stage (50 kg N ha^{-1}) could be enough to achieve a relatively good result (3.9 Mg ha^{-1}), however, effect of previous experiment (i.e. high initial inorganic N content in soils) need to be considered, and further research at TZc may focus on the co-limiting nutrients on yields since N is no longer the limiting factor with increasing N fertilization rate while the yield gap is still large compared with the variety yield potential and the global averaged level.