Analysis of N, P and K interactions in long-term experiments

A.G.T. Schut[1] and W. Reymann[1]

[1]Plant Production Systems Group, Wageningen University, Wageningen, the Netherlands

Keywords: nutrient use efficiency, recovery, rotations

Nitrogen and phosphorus use efficiency in intensified systems is low due to excess applications of artificial and organic inputs. Better balancing supply with demand is key to improve nutrient use efficiency but requires detailed understanding of short- and long-term responses to organic and synthetic fertilizer applications. At present, there are no models available that can give reliable predictions of soil P and K supply and crop uptake, especially for situations where P and K are suboptimal or deficient. A better understanding of short- and long term responses to fertilizer applications can help to optimize fertilizations of crops in a rotation.

Here, we present a new model that includes labile and stable pools for P and K and a K pool to account for fixation, losses and interactions between supplied N, P and K. This model was used to analyse crop nutrient uptakes in long-term experiments from Siaya, Kenya and Hanninghof, Germany. The on-farm trial in Siaya was a standard nutrient omission trial with replicates on 23 farms that ran for 11 seasons, starting at the long rainy season in 2013 up to and including the long rainy season in 2018. It had two phases and five plots per field. Treatments in phase one included a control, PK, NK, NP and NPK. In phase two, 16 farms remained. On 4 farms, plots were subdivided and PK, NP, NK and NPK were superimposed on phase one treatments, on the other farms NPK was applied to all plots. This experiment allowed to study depletion and build-up phases of soil nutrient pools.

The Hanninghof experiment started in 1958 and included 14 treatments, including the same treatments as in Siaya with an additional N and NPKMg treatment, a pig manure only treatment and combinations of all treatments with pig manure. We used only data from 1961-2009, when the rotation included potatoes, winter rye and oats. Pig manure was applied to potatoes only. Linear regression models were used to differentiate the effects of fertilizer supply and treatment from annual variability on nutrient uptakes.

The model was initialized using uptakes from NK and NP treatments. N supply from soil and deposition was estimated using yields in the control or PK treatments. Actual uptakes were computed using concepts from the QUEFTS model. Relative transfer rates between pools and crop-specific uptake coefficients for placed and broadcast P and K were calibrated. Predicted uptakes were compared to measured uptakes and root mean squared error (RMSE) values determined.

The results showed that the model could describe measured uptakes well with RMSE of 1.5-3.1 kg ha^{-1} for P and 15-25 kg ha^{-1} for K. Relative transfer rates for the stable K pool differed between the two sites, reflecting large differences in soil K retention characteristics. When placed, a fraction of applied P was directly taken up and bypassed the labile pool. Initial soil P and K pools strongly differed between farms and explained the observed differences in yield responses to applied fertilizer. Estimated uptake coefficients differed strongly between crops and between treatments with and without pig manure. We conclude that this relatively simple model provided valuable insights in (1) differences in crop responses to fertilizer applications due to soil fertility; (2) differences between crops types and (3) the influence of organic manures on the response to applied mineral fertilizer in crop rotations.