þÿLong-term P fertilisation experiment on grass and soil

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Long-term P fertilisation experiment on grass – effects on plant and soil

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Abstract

The effects of P fertilisation on grass yield, grass P concentration (GPC) and soil P status (ammonium acetate extraction; P_{AAC}) were monitored in long-term field experiments. The experiments were carried out in sandy loam soils on intensively managed ley during 2003–2020 on two sites in Central Finland. The study included P0 plots, and P fertilisation (average 16 kg P ha^{-1} y^{-1}), based on soil test recommendations. Dry matter yield (DMY) and GPC were measured on each cut. P_{AAC} was analyzed initially and after each growing season. Despite the decline of the average P_{AAC} (16–20 mg l^{-1}→ 8–13 mg l^{-1}) between 2003 and 2020, no consistent yield response to P fertilisation was observed even when the soil P status decreased to a level where yield response has occurred previously. The average GPC of the P treatment in the last ley rotation was lower than in the first rotation at one site, but not at the other. Yield responses to P fertilisation were rare, but the decrease of GPC indicates a gradual decrease of P supply. P fertilisation of ley can be lowered, but the impact on soil P status has to be monitored. Availability of slowly soluble P reserves in soil needs further research.

Keywords: grass, phosphorus, silage, yield, soil P

Introduction

Grass production is the most important factor behind sustainable cattle farming. Appropriate use of phosphorus (P) plays a large role in improving the profitability and reducing the environmental impacts of farming. In the last 25 years, P fertilisation has been reduced and the concentration of easily soluble P has declined in many regions in Finland, being currently 11 mg P_{AAC} l^{-1} in cattle production areas (Ylivainio *et al.* 2014). At the same time, concern about depletion of available soil P and the sufficiency of P content in silage for animal health has increased. Recent results of P fertilisation experiments on ley have shown no constant yield response (Kykkänen *et al*. 2018), even when the soil P status has decreased to the level where a response was expected based on earlier experiments (Valkama *et al*. 2009). The aim of this study is to compare the long-term effects of recommended and P0 fertilisation on grass yield and soil P status and identify needs for future studies.

Material and methods

The experiment with four replicates and seven P fertilisation treatments as a randomized complete block design was established in 2003 on Site 1 (Maaninka, 63°08’ N, 27°19’ E, sandy loam) and Site 2 (Ruukki, 64°44’N, 25°15’E, sandy loam) in Finland. This paper includes two treatments: a mineral P application according to the Agri-environmental Scheme limits (PF) and a control with no added P (P0) covering four ley rotations from year 2003 to 2020. At four- or five-year intervals, the ley was established with whole crop barley (*Hordeum vulgare* L.; years 2003, 2007, 2012 and 2017) as a cover crop for a mixture of timothy (*Phleum pratense* L.) and meadow fescue (*Festuca pratensis* Huds.). The PF applied in the beginning of each growing season averaged at 16 (8–28) kg P ha^{-1}. Other nutrients were provided as recommended for both treatments. Soil P status (P_{AAC}, mg l^{-1}) in the 0–20 cm layer was measured in the beginning of the study and at the end of each growing season by ammonium acetate extraction, pH 4.65 (Vuorinen and Mäkitie, 1955). The leys were harvested two or three times annually, except the year of establishment. Dry matter yield (DMY; kg DM ha^{-1}) was measured and the grass P concentration (GPC; g kg^{-1} DM) was determined. The cumulative DMY (Mg DM ha^{-1}), P yield (kg ha^{-1}) and P balance (kg ha^{-1}) from 2003–2020 were calculated, including the whole crop years (cut height 6 cm). The GPC is presented as the average of the first grass cut of a year for each ley rotation. Statistical analyses were calculated using ANOVA (SAS 9.4., *Mixed*-procedure).

Results and discussion

The annual average DMY of grass at Site 1 for P0 were 9,000 and for PF 9,110 kg ha^{-1} while at Site 2 yields were P0 9,590 kg ha^{-1} and PF 9,680 kg ha^{-1}. There was no significant difference between the cumulative DMY of P0 and PF (Fig. 1a). At Site 1, the DMY of PF was significantly higher (10–18%) only in the whole crop (barley) years 2007, 2012 and 2017. At Site 2, grass yield of PF was 5% higher in 2009 and 7% in 2018, but no difference in yield of barley was observed in the whole crop years. In contrast to Valkama *et al*. (2009), a stronger yield response of cereals compared to grasses was not consistently detected.
A GPC ≤ 1.0 g DM kg^{-1} indicates a severe P shortage for grass. In this study, the critical P concentration was not reached indicated by the absence of difference in DMY between P0 and PF. In the P0 treatment, the average GPC of the first cut decreased from the 1st rotation (2004‒2006) to the last one (2018‒2020) in both sites: From 3.1 to 2.1 g kg^{-1} in Site 1 (P < 0.001) and from 2.7 to 2.4 g kg^{-1} in Site 2 (P = 0.001). In the PF treatment, the decrease was observed only in Site 1 (from 3.3 to 2.3 g kg^{-1}, P < 0.001) indicating in the beginning of experiment, higher capacity of soil to provide P for grass need at Site 1 than at Site 2. At Site 2, GPC of PF was 2.8 g kg^{-1} in both first and last rotations. A difference in GPC between the treatments is likely caused by P fertilisation and decrease of soil P_{AAC}. Like in an earlier experiment (Kykkänen *et al*. 2018), the GPC was higher when P fertilisation was used, but the effect varied by site. Soil properties (structure, organic matter content and the size and composition of slowly released P pool etc.) may affect GPC. It is important to clarify the role of soil organic matter content and nitrogen supply on GPC and yield when determining the critical P concentration of grass (Belanger *et al*. 2017).
Due to decreased GPC, the cumulative P yield of P0 was significantly lower compared to PF (Fig. 1b). The average P yield of grass per year was 21 and 25 kg ha^{-1} in P0 and 23 and 27 kg ha^{-1} in PF at Site 1 and Site 2, respectively. The cumulative P balance of P0 treatment was highly negative at both sites (Fig. 1c). The P fertilisation increased the balance of PF, but it was still negative at both sites. Highly negative P balances of P0 treatment indicate that perennial grasses can utilise soil P reserves more efficiently that was expected based on previous results (Valkama *et al.* 2009, Belanger *et al.* 2017).
The negative P balances caused a decrease of soil P_{AAC} at both sites and both treatments. In the spring 2003, P_{AAC} was 19.5 and 14.8 mg l^{-1} at Site 1 and 2, respectively. At Site 1, P_{AAC} declined to 9.3 in P0 and to 13.0 mg l^{-1} in PF in 2020. At Site 2, the decline was from 14.8 to 8.4 in P0 and to 10.4 mg l^{-1} in PF in 2020. In both sites, the P_{AAC} of P0 declined below 10 mg l^{-1}, where the yield response has occurred in earlier studies (Valkama *et al.* 2009). However, P_{AAC} indicates the P intensity in soil solution rather than the amount of available P reserves (Valkama *et al*. 2016). According Belanger *et al*. (2017), the lack of response to P fertilisation in low P concentrations may indicate a need to revise the interpretation of soil P test method for forage grasses.

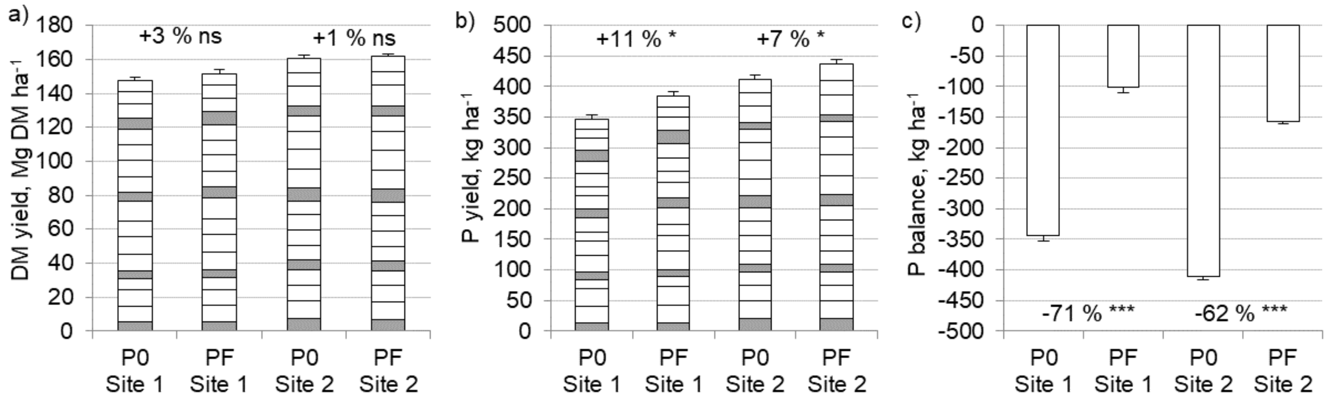

Figure 1. a) Cumulative dry matter yield (Mg DM ha^{-1}), b) P yield (kg ha^{-1}) and c) P balance (kg ha^{-1}) of P0 and PF treatments at Site 1 (Maaninka) and Site 2 (Ruukki) in 2003–2020. Cumulative P fertilisation 2003–2020 was 0 kg P for P0 and 285 kg P for PF. Establishment years (whole crop barley; 2003, 2007, 2012 and 2017) are highlighted in grey. Percentages above the bars are differences between P0 and PF. Statistical significances: *** $P < 0.001$, * $P < 0.05$, ns = non-significant. Error bars show the standard error of means (SEM).

Conclusion

According to the results of this study, it seems possible to lower P fertilisation recommendations for perennial grasses without yield losses even down to soil P_{AAC} of 8 mg l^{-1}, which is currently considered suboptimal for ley. However, the availability of slowly soluble soil P reserves to grasses requires further study. In the future, revision of the soil P test classification in Finland may also be necessary.

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References

Belanger, G., Ziadia, N., Lajeunesse, J., Jouany, C., Virkajarvi, P., Sinaj, S. and Nyiraneza, J. (2017) Shoot growth and phosphorus-nitrogen relationship of grassland swards in response to mineral phosphorus fertilization. Field Crops Research 204, 31-41.
Kykkänen, S., Hartikainen, M., Hyrkäs, M., Virkajärvi, P., Toivakka, M. and Kauppila Raimo (2018) Forage grasses effectively use soil P-pools in low-PAAC soils in Finland. Grassland Science in Europe 23, p. 271-273.
Valkama, E., Uusitalo, R., Ylivainio, K., Virkajärvi, P. and Turtola, E. (2009) Phosphorus fertilization: A meta-analysis of 80 years of research in Finland. Agriculture, Ecosystems & Environment 130, 3–4
Valkama, E., Virkajärvi, P., Uusitalo, R., Ylivainio, K. and Turtola, E. (2016) Meta-analysis of grass ley response to phosphorus fertilization in Finland. Grass and Forage Science 71, 36-53.
Vuorinen, J. and Mäkitie, O. (1955). The method of soil testing in use in Finland. Agrogeological Publications 63, 1-44.
Ylivainio, K., Sarvi, M., Lemola, R., Uusitalo, R. and Turtola, E. (2014) Regional P stocks in soil and in animal manure as compared to P requirement of plants in Finland: Baltic Forum for Innovative Technologies for Sustainable Manure Management. WP4 Standardisation of manure types with focus on phosphorus. MTT report 124.