The effect of potassium on dry matter production and nutritive value of grass on three different soil types

Kykkänen S.[1], Virkajärvi P.[1], Hyrkäs M.[1], Järvenranta K.[1], Kurki P.[2] and Suomela R.[3]
[1]*Green technology, Natural Resources Institute Finland (Luke), Halolantie 31 A, 71750 Maaninka, Finland;* [2]*Natural resources and bioproduction, Natural Resources Institute Finland (Luke), Lönnrotinkatu 5, 50100 Mikkeli, Finland;* [3]*Green technology, Natural Resources Institute Finland (Luke), Tutkimusasemantie 15, 92400 Ruukki, Finland*

Abstract

In Finland, grass yield response to potassium (K) fertilization varies with soil acid-extractable potassium (K_{HCl}) availability, rather than the traditionally used measure of soil acid ammonium acetate-extractable potassium (K_{AAc}). However, in previous experiments, no animal manure was used and grass nutritive value was only partially taken into account. The objective of this experiment was to measure the effects of cattle slurry, mineral K-fertilization (0, 50, 100, 150, 200 kg ha^{-1} year^{-1}) and their interaction on grass (*Phleum pratense – Festuca pratensis*) dry matter (DM) production and nutritional value (organic matter digestibility, K concentration, Diet Cation Anion Difference = DCAD, grass tetany index) under three different levels of soil K_{HCl}. Three-year field experiments were established at three locations: site 1, 2 and 3. The study was carried out as a split plot experiment. K_{HCl} concentration of soil did not entirely explain the utilization of potassium by grass. Mineral K fertilization, given as KCl, decreased nutritional value of forage except for DCAD, on which Cl has a strong positive effect. K uptake was more effective without slurry application especially on soils with low and medium levels of K_{HCl}.

Keywords: grass, potassium fertilization, extractable potassium, non-extractable potassium, cattle slurry, nutritive value of grass

Introduction

In Finland, the recommendation of K fertilization for cultivated short-term grasslands has been based on concentration of easily extractable potassium (mg K_{AAc} l^{-1} soil; Vuorinen and Mäkitie, 1955). However, in many Nordic studies the concentration of K_{HCl} (often referred to as 'potentially' or 'reserve K', 'mineral K', or 'acid-extractable K') seems to explain availability and utilization of potassium better than K_{AAc} (e.g. Virkajärvi *et al.*, 2014).

High concentrations of K, high diet cation anion difference (DCAD) and grass tetany index (GT, ratio of K × (Ca+Mg)$^{-1}$) in forage can increase the risk of milk fever and grass tetany (e.g. Pelletier *et al.*, 2008). Previous studies have concentrated mostly on DM production responses to mineral K-fertilization. Effects of mineral fertilization, and especially slurry application, in terms of their effects on K-related nutritional values of grass remain poorly understood.

In this study our main aims were to clarify how soil type and different K_{HCl} concentrations of soil affect the grass yield response to K fertilization, how cattle slurry application affects the grass yield production and how K fertilization (mineral or slurry) affects the nutritive value of the grass.

Materials and methods

The study was carried out as a split plot experiment at site 1 (63°08' N, 27°19' E, silt loam), site 2 (61°40' N, 27°13' E, sandy loam) and site 3 (64°41' N, 25°9' E, sandy loam), Finland, during the growing seasons of 2011-2014. The average concentrations of K_{HCl} in topsoil and subsoil were high/high (2,700/2,600 mg l^{-1}) medium/high (1,200/2,000 mg l^{-1}) and low/medium (4,50/8,00 mg l^{-1}), respectively. Sown plots of a mixture of timothy (*Phleum pratense* L.) and meadow fescue (*Festuca pratensis* Huds.) were established in 2011 in four replicates using barley (*Hordeum vulgare*) as a cover crop. The plots were harvested two or three times per year. The effect of cattle slurry, compared with mineral N and P, was investigated as a main plot. Slurry at 30 Mg ha^{-1} was injected for the second cut and complemented with mineral N to correspond to the amount of soluble N on the main plot without slurry application. Mineral K-fertilization (0, 25, 50, 75 and 100 kg ha^{-1} for both the first and the second cut) was the subplot.

Dry matter yields (DM yield, kg DM ha^{-1}) were measured from each cut. Mineral concentrations of grass were determined by standard methods in the laboratory of the MTT Agrifood Research Finland. DCAD and GT were calculated using equations $[(Na^+ + K^+) - (Cl^- + S^{2-})] \times 1000$ and $K^+ \times (Ca^{2-} + Mg^{2-})^{-1}$, respectively (Ender *et al.*, 1962; Kemp and Hart, 1957). DCAD value 250 mmol$_c$ kg^{-1} DM and GT value 2.2 are used as maximum recommended values (Host *et al.*, 1997; Kemp and Hart, 1957). The digestibility values (D value; g kg^{-1} DM) were determined by near-infrared spectrometry (Valio Ltd). Statistical analyses were performed using ANOVA (Mixed procedure of SAS 9.3). Experimental sites were analysed separately.

Results and discussion

K-fertilization increased significantly the total DM yield only twice: site 1 in 2013 and site 2 in 2014, even though concentrations of soil K_{HCl} on these sites were high or medium, both in subsoil and topsoil. At low level of soil K_{HCl} concentration (site 3) no responses to K-fertilization were observed. Over the experimental years the fertilization effect was not significant at any site (Table 1). These results were not as expected. Potassium deficiency in grass (K concentration of <17 g kg^{-1} DM) was observed only at site 2 in 2014, treatment without K-fertilization (slurry or mineral-K). Previous findings have indicated that environmental factors, like exceptional dryness and moisture, can affect the exchangeable-K uptake from soil (Kuchenbuch *et al.,*1986; Saarela *et al.*, 1998). In these circumstances 50 kg K ha^{-1} was enough

Table 1. Slurry (MP) and K-fertilization (SP) effect on total DM yield (kg ha^{-1} y^{-1}) and K concentrations (g kg^{-1} DM), DCAD value, GT value and D-value (digestibility organic matter, g kg^{-1} DM) in the second cut over the experimental years 2012-2014 (Y).[1]

	Site	Slurry (Mg ha^{-1} y^{-1})		SEM	K-fertilization (kg ha^{-1} y^{-1})					SEM	Significance[2]			
		0	30		0	50	100	150	200		MP	SP	MP*SP	Y
Total yield	1	10.7	10.6	1.26	10.5	10.7	10.7	10.6	10.6	1.40	ns	ns	ns	***
	2	10.0	9.9	1.43	9.9	9.9	10.0	10.0	10.0	1.42	ns	ns	ns	***
	3	13.3	12.8	2.27	12.9	13.2	13.0	13.0	13.1	1.80	ns	ns	ns	**
K	1	30.0	30.1	0.38	27.3	29.0	30.4	31.4	32.1	0.33	ns	***	***	***
	2	23.5	28.8	0.61	20.5	24.5	26.6	29.4	29.8	0.59	**	***	***	***
	3	31.7	34.3	0.62	27.4	30.7	33.5	36.0	37.4	0.62	**	***	***	ns
DCAD	1	355	303	10.6	478	384	318	239	228	9.5	**	***	**	***
	2	160	248	15.6	249	204	184	189	192	14.2	**	***	**	***
	3	272	247	11.5	384	302	233	198	183	12.6	ns	***	ns	ns
GT	1	2.3	2.4	0.05	2.1	2.3	2.3	2.4	2.5	0.04	ns	***	ns	***
	2	2.1	3.0	0.10	1.8	2.3	2.6	3.0	3.2	0.10	**	***	***	**
	3	2.0	2.6	0.05	1.8	2.1	2.3	2.6	2.8	0.06	***	***	***	**
D-value	1	677	678	1.7	693	684	675	668	667	1.7	ns	***	ns	***
	2	663	667	2.5	677	668	663	657	659	2.6	ns	***	**	**
	3	679	675	3.0	692	681	674	669	671	2.9	ns	***	**	***

[1] Values are averaged over the experimental years.

[2] *, **, and *** indicate the treatment effect is significant at $P<0.05$, $P<0.01$ and $P<0.001$, respectively. Non-significant effect is denoted by ns ($P>0.05$). Y×MP, Y×SP and Y×MP×SP were included in the model but not be presented.

to satisfy grass K-requirement in these soil types. According to the present recommendations (based on K_{AAc}), the fertilization rate in this case would have been 130-170 kg ha^{-1} $year^{-1}$.

Mineral K-fertilization (as KCl) significantly decreased (P<0.001) grass nutritional quality (more K and GT, lower D-value) except for a positive effect (P<0.001) of mineral Cl on DCAD. Cl-uptake of grass was relatively more effective than K-uptake, which decreased DCAD-value of the grass. Nutrient imbalances can be partly corrected by using fertilizers containing balancing nutrients. When the concentration of K_{HCl} in soil was high the K-related quality values of grass were also high despite the fertilization rate. K-fertilization decreased D-value (P<0.001). Cattle manure was equally effective as mineral K as a source of K-fertilizer. Slurry increased the K-concentration of grass significantly on soils that had low/medium concentrations of K_{HCl}. The interaction between slurry application and mineral K-fertilization was almost always significant in the second cut, when K uptake was more effective without slurry application especially on soils with low/medium level of K_{HCl}. The opposite effect occurred in the first and third cuts.

Conclusions

Soil K_{HCl} concentration does not entirely explain the plant availability and utilization of potassium. The results of this study support the theory that the concentration of soil K_{HCl} would be a better basis for grass K-fertilization recommendations in Finland. In addition to soil analysis it is advisable to analyse K-related nutritional values (K-concentration, DCAD, GT) of the herbage yields. As a source of K fertilizer, cattle slurry is as effective as mineral K.

References

Ender F., Dishington I.W. and Helgebostad A. (1962) Parturient paresis and related forms of hypocalcaemic disorders induced experimentally in dairy cows. *Acta Veterinaria Scandinavica* 3, 5-52.

Horst R.L., Goff J.P., Reinhardt T.A. and Buxton D.R. (1997) Strategies for preventing milk fever in dairy cattle *Journal of Dairy Science* 80, 1269-1280.

Kemp A. and Hart M.L. (1957) Grass tetany in grazing milking cows. *Netherlands Journal of Agricultural Sciences* 5, 4-17.

Kuchenbuch R., Claassen N. and Jungk A. (1986) Potassium availability in relation to soil moisture. *Plant and Soil* 95, 221-243.

Pelletier S., Bélanger G., Tremblay G.F., Virkajärvi P. and Allard G. (2008) Timothy mineral concentration and derived indices related to cattle metabolic disorders: A review. *Canadian Journal of Plant Science* 88, 1043-1055.

Saarela I., Huhta H., Salo Y., Sippola J. and Vuorinen M. (1998) Kaliumlannoituksen porraskokeet 1977-1994. *Maatalouden tutkimuskeskuksen julkaisuja*. Sarja A 42, pp.41.

Virkajärvi P., Kykkänen S., Räty M., Hyrkäs M., Järvenranta K., Isolahti M. and Kauppila R. (2014) Potassium fertilization of grass in Finland. Use of acid-soluble potassium as a basis for potassium fertilization. *MTT Report* 165.

Vuorinen J. and Mäkitie O. (1955) The method of soil testing in use in Finland. *Agrogeological Publications* 63, 1-44.