Improved potassium fertiliser recommendation for grasslands in the Netherlands

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Abstract

Optimal potassium (K) fertilisation stimulates grassland production. In 2011 and 2012 fertiliser trials on grassland were executed to update the 40-year-old recommendations. Farm field trials were executed on 24 locations on sand, clay and peat soils with varying K-availability and buffering capacity. There were three treatments on each site: with or without cattle slurry application, two nitrogen (N) levels (60 and 120 kg N ha^{-1}) and two K fertiliser levels (0 and 60 kg K_2O ha^{-1}). Uptake of K in the first and second cut (to account for any residual effect) was determined to derive the optimal K-application rate. In parallel there was a seasonal trial with different N and K levels to test the interaction of K with N. Fertilisation with 60 kg K_2O ha^{-1} resulted in extra yield of the first cut of 200 to 650 kg DM ha^{-1}. The fertiliser increased the yield in the seasonal trials up to 2 tons DM ha^{-1} $year^{-1}$. The experimental data were used to develop a new recommendation system based on the soil parameters of cation exchange capacity and available K determined in 0.01 M $CaCl_2$. The new recommendation results, on average, in a lower K application rate than the previous recommendation.

Keywords: potassium, fertilization, soil fertility, CEC, herbage yield, recommendation

Introduction

Optimal grass growth requires an adequate supply of potassium (K) at the right time. The Dutch K fertiliser recommendation system is to a large extent based on trials from 60-80 years ago (Van der Paauw, 1943) at a time when heavy first cuts (5-7 Mg DM ha^{-1}) were common. In later years these results were extrapolated to the actual grassland management system with first cuts taken at a much earlier growth stage (3-4 Mg DM ha^{-1}). The soil K status in the current recommendation system is provided as a K-index (derived from a soil extraction with 0.1 M HCl and corrected for the amount of soil organic matter) though it is known that this is not the best method to predict the K supply by the soil. Measuring available K via an extraction with 0.01 M $CaCl_2$ in combination with the cation exchange capacity (CEC) seems a promising method as was shown by Van Rotterdam (2010). Therefore, in 2011 a two-year K-fertiliser trial on multiple locations was performed to implement the findings of Van Rotterdam. This paper summarises some of the results leading to a new recommendation system, which was introduced in autumn 2014.

Materials and methods

The trial consisted of two sub-tests: farm field trials on 24 locations (11 in 2011 and 13 in 2012) during the first and second cut, and a detailed seasonal trial at three locations (see also Holshof and Van Middelkoop, 2014). Farm field trials were executed on different soil types with 2 sites per location varying in K-availability and buffering capacity. There were three treatments on each site: without and with cattle slurry application (30 m^3 ha^{-1} on average), two nitrogen (N) fertiliser levels (60 and 120 kg ha^{-1}) and two K fertiliser levels (0 and 60 kg K_2O ha^{-1}). This setup resulted in K-levels of: 0, 60, 90 and 150 kg K_2O ha^{-1}. On every plot superphosphate was applied to ensure an adequate supply of phosphorus and sulphur. In total there were respectively 20, 14 and 14 sites on sand, clay and peat grassland with a large variation in soil characteristics (Table 1). The second cut was used to measure the residual K effect and received only N-fertiliser at a rate of 30 kg N ha^{-1}. Herbage dry matter (DM) yield and K uptake of both cuts were determined to derive the optimum K-application rate. The seasonal trials were conducted

Table 1. The soil analysis results of the 54 sites used in the trials: the minimum, mean and maximum value.

	clay g kg^{-1}	OM[1] g kg^{-1}	CEC[1] mmol+ kg^{-1}	NLV[1] kg N ha^{-1}	SLV[1] kg ha^{-1}	pH[2]	K[2] mg kg^{-1}	Mg[2] mg kg^{-1}	Na[2] mg kg^{-1}	P[2] mg kg^{-1}	PAL[1,2] mg 100 g^{-1}
min	10	11	46	61	6	4.6	32	23	5	0.3	17
mean	148	116	205	181	16	5.9	114	272	35	2.1	45
max	490	257	442	250	32	7.3	317	510	90	9.3	116

[1] OM denotes organic matter; CEC the cation exchange capacity; NLV the N supply of the soil; SLV the sulphur supply of the soil; and PAL the amount of P extracted with ammonium lactate.

[2] Measurement based on extraction 0.01 M $CaCl_2$.

on sand, clay and peat grassland with a relatively low K-status and with different sites in 2012 than in 2011. In total, five cuts were harvested annually. Fertilisation took place with only mineral fertiliser. The setup was a randomized block trial (in duplicate) with three N levels: 0, 180 and 360 kg ha^{-1} yr^{-1} and four K levels for the first cut: 0, 60, 120 and 180 kg K_2O ha^{-1}. The 60 and 180 K-treatments were setup in triplicate. After the first cut these treatments received respectively 0, 40 and 80 kg K_2O ha^{-1} per cut. The 120 K_2O ha^{-1} treatment received the same amount in every cut. This resulted in a total annual application of between 0 and 600 kg K_2O ha^{-1}. The grass yield data were statistically analysed with GenStat® Release 16 (Payne *et al.*, 2010) using Restricted Maximum Likelihood with as random factor location×year. The derived model contained 18 soil and fertiliser application parameters and relevant two-way interactions. Data were log transformed before the analysis for homogeneity.

Results and discussion

In the farm field trials yield levels varied largely between locations. The average yield for the first cut in 2011 and 2012 was 4.9 and 5.2 Mg DM ha^{-1}, respectively. The second cut had an average yield of 2.3 Mg DM ha^{-1}. The yield of the first cut was mainly controlled by the first application of 60 kg K_2O ha^{-1} (Table 2). The variation in K content and herbage uptake was high but on average at an adequate level; 80% was above the critical level of 20 g K kg^{-1} DM (Whitehead, 2000). The farm field trials clearly demonstrated yield responses to the level of N and K fertilisation, which were dependent on soil conditions. The effects of the first cut were also measured in the second cut, but treatment effects were less than in the first cut. As in the farm-field trials, the seasonal trials also showed that with 60 kg K_2O ha^{-1} in the first cut a yield increase was obtained of about 650, 350 and 200 kg DM ha^{-1} on sand, peat and clay grassland, respectively. A higher K-level yielded almost no additional response. On an annual basis the yield increase was, respectively, 2, 1.5 and 0.3 Mg DM ha^{-1} when 500 kg K_2O ha^{-1} was applied. Higher N-levels gave a higher dry matter yield at all locations. The treatments that received K fertiliser in the first cut and no K during the rest of the year, gave also a higher DM yield in all cuts compared to the treatments without any K fertiliser.

Table 2. Grass yield (kg DM ha^{-1}) in the first and second cuts for the treatments with and without mineral K_2O fertiliser and cattle slurry for two N fertiliser levels (in parenthesis the relative compared to the maximum yield).

K_2O fertiliser	Cattle slurry	First cut		Second cut[1]	
		60 kg ha^{-1}	120 kg ha^{-1}	60 kg ha^{-1}	120 kg ha^{-1}
0	no	4,586 (83)	5,118 (93)	2,128 (85)	2,282 (91)
0	yes	4,947 (90)	5,453 (99)	2,346 (94)	2,449 (98)
60	no	4,799 (87)	5,249 (95)	2,205 (88)	2,284 (91)
60	yes	5,213 (95)	5,507 (100)	2,279 (91)	2,501 (100)

[1] The applied amount for the 2nd cut was 30 kg N ha^{-1}.

Crop yield was satisfactorily explained by the included soil and fertilizer parameters (R^2_{adj}=87%). The effective amount of applied N from fertiliser and cattle slurry (N_{eff}) and K_2O (K_2O_{eff}) were used as explanatory variables. The applied amounts of N_{eff} and K_2O_{eff} were highly significant (P<0.001) as well CEC and the potassium content of the soil (K). The interaction between K_2O_{eff} and CEC, and between K_2O_{eff} and K were also significant (P<0.05). Organic matter and clay content were not significant. There was no interaction between K_2O_{eff} and N_{eff}. This pattern was observed also for K-uptake. The derived statistical relationship for yield was used to develop a new K-recommendation. The relationship was simplified to:

$$\ln(\text{Yield}) = C + \ln(K_2O_{eff}) + \ln CEC + \ln K + \ln(K_2O_{eff}).\ln CEC + \ln(K_2O_{eff}) \times \ln K \quad (1)$$

Without any K_2O fertilisation, this relationship reduced to:

$$\ln(\text{Yield}_0) = C + \ln CEC + \ln K \quad (2)$$

For different combinations of CEC and K, the constant c was calculated for target yields of 1,700, 3,500 and 5,000 kg DM ha^{-1}. Combining Equation 1 and Equation 2 under the assumption that the amount of K_2O_{eff} should result in 4 kg extra DM ha^{-1} per kg K_2O_{eff} resulted in the relationship:

$$K_{crit} = 4 = \text{EXP}(\ln(\text{Yield}) - \ln(\text{Yield}_0))/K_2O_{eff} \quad (3)$$

which was iteratively solved for the same combinations as Equation 2, including the corresponding C. This resulted in a dataset of optimum K_2O_{eff} rates for different target yields, CEC and K. To compare the previous recommendation with the improved recommendation, analysis of a large dataset of 2,800 soil samples showed that for a normal (3,500 kg DM ha^{-1}) and a heavy (>4,500 kg DM ha^{-1}) first cut, applications of 42 and 66 kg K_2O ha^{-1} fertilizer were needed to obtain the desired crop yield. These fertiliser rates are much lower than those recommended in the previous system.

Conclusions

An improved K fertiliser recommendation for grasslands in the Netherlands has been developed based on two-year trials on multiple grassland locations. It is based on the soil parameters CEC and $CaCl_2$ extractable soil K. The recommended amounts of K_2O for the first cut are much lower than in the previously recommended system.

References

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