Nutrient use efficiency in different harvesting strategies of silage swards based on timothy and two fescue species

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Introduction Mineral nutrient composition of grasses is usually used to evaluate the effect of mineral intake in feeding. The concentration of nitrogen (N) is integrally related to the protein concentration of the dry matter (DM). Along with calcium, phosphorus (P) has an important role in the mineral needs of any animal. It is known that grass swards can uptake so great amounts of potassium (K), that it addresses some problems concerning the balance of mineral intake of the cattle, since a surplus of K can affect the balance between the univalent and bivalent minerals.

In addition to implications on feeding, the composition of mineral nutrients in forage also reflects the removal of nutrients from the soil and thus the nutrient use efficiency (NUE) of the crop. By changing the cutting time of silage swards, both DM yield and the content of mineral nutrients of the yield change, which may have evident implications for NUE. The choice of harvesting strategy of silage, i.e. the combination of different cutting times and the number of cuts, can be a farm-specific solution. At the moment, there is no advisory framework for the timing of the cuttings in regard to NUE or environmental effects of forage production. For environmental and economical reasons, the aspect of NUE of different harvesting strategies should be recognized along with the effects to animal performance.

Materials and methods The DM yield accumulation and composition of mineral nutrients in different harvesting strategies of grass silage swards were studied in Maaninka and Ruukki, Finland, in three different field experiments with 6–12 m^2 plots in randomized block designs. During 2009-2011, Experiment I (Maaninka) had three replicates of mixture with timothy (TIM) and meadow fescue (MF) and Experiment II (Ruukki) four replicates of pure TIM, both with four harvesting strategies: one three-cut strategy with the first cut at booting stage and consecutive cuts after approximately 6 weeks and again after 10 weeks, and three two-cut strategies with differing cutting times in the first cut (flag-leaf stage, booting stage and full flowering) with the regrowth being cut on average 7-8 weeks after the first cut, usually in mid-August. Experiment III consisted of TIM and tall fescue (TF) in pure stands with three replicates in Maaninka, which were cut at booting during the first cut and after 4, 6 and 8 weeks for the regrowth in 2006–2007.

The amount of applied mineral nutrients N, P and K (kg ha^{-1}) were recorded. Inside each experiment, the number of applications and nutrient levels were the same with the exception of plots for three-cut strategy in Experiments I and II, which were given a third application for the second regrowth. Nutrient levels were different between experiments, as they were based on soil type and the availability of nutrients according to soil samples. No chemical plant protection or irrigation was used. During each cut, the DM yields (kg DM ha^{-1}) were analyzed by harvesting the plots with Haldrup 1500 plot harvester and by determining for fresh matter yield, DM content and consequently DM yields. Concentration of N was analyzed with Kjeldahl method and mineral nutrients P and K (g kg^{-1} DM) were analyzed with ICP at MTT Laboratories, Jokioinen. Using these data, the annual NUE (nutrient yield divided by nutrients applied) for N, P and K were calculated. The effect of harvesting strategy (along with effects of species and year and their interactions) on DM yield, NUE_N, NUE_P and NUE_K were analyzed by SAS 9.2 Mixed procedure.

Results and discussion The effect of timing of the cut in first cut to annual DM yield and NUE_N, NUE_P and NUE_K was studied with Experiments I and II, while the timing of regrowth cut was examined with Experiment III (Table 1).

Over the three years, the delay in the timing of the first cut clearly increased the average annual DM accumulation in the two-cut harvesting strategies with the TIM-MF mixture (Experiment I) and the pure TIM (Experiment II) (Table 1). In TIM-MF there were no differences in annual NUE_N, NUE_P or NUE_K between two-cut harvesting strategies, which shows that the annual efficiency of N, P or K uptake into the sward is not increased even if the grass is let to mature until flowering stages. In Maaninka, were no K fertilization was given for the regrowth, the efficiency of K use in TIM-MF sward was high: the herbage was able to uptake over 8 times of K compared to the amount of K given in fertilizers. This demonstrates well the potential of grass swards in mobilization of nutrients from the soil.

In TIM sward with two-cut strategy, annual NUE_N and NUE_K were consistently but mildly increased by delaying the first cut (Table 1). This might be a result of a high content of available organic N in the soil in Ruukki and the potential of ample N reserves to maintain the uptake of K into the herbage (Alfaro et al. 2003). The effect of organic N in soil can be seen also in the constantly high levels of annual NUE_N in Ruukki (typically over 1.30) when compared to annual NUE_N from sandy soil in Maaninka (below 1.00 in all harvesting strategies). With TIM in Ruukki, the rate of uptaking additional P was reduced after booting, as the level of annual NUE_P did not increase along with NUE_N and NUE_K.

In the three-cut strategy, the average annual DM yield over three years was intermediate in pure TIM, but the lowest in TIM-MF mixture when compared to all strategies (Table 1). In pure TIM annual NUE_N and NUE_K were the lowest of all harvesting strategies, while in TIM-MF the levels of annual NUE_N or NUE_K were no different from the two-cut strategies. With both sward types, annual NUE_P was the highest when taking three cuts.

When prolonging the time for regrowth, annual NUE_N showed no significant differences between harvesting strategies, even though DM yields increased as the cutting time of regrowth was delayed (Table 1). This points out that the uptake of N for regrowth takes place early after first cut, and the total amount of N is simply diluted into the accumulating DM (Eckersten et al. 2007). Annual NUE_K and NUE_P increased only until the regrowth week 6 and remained at the same level later on, which reveals that no new P and K was uptaken after 6 weeks of regrowth time.

When considering the effects of altered timings of harvest for the whole growing season, the two experiments in Maaninka can be used as a template. During both of the cuts, the NUE_N was not affected by the timing of harvest. Since the levels of NUE_N were the same in Experiments I and III but different from Experiment II in Ruukki, the availability of N in the soil might have been the restricting factor in N uptake. The differences in NUE_P between harvesting strategies were statistically significant, but minor in practice. Majority of the difference in the levels of NUE_K between experiments in Maaninka was due to different fertilization practices and availability of K in the soil.

Table 1. Annual dry matter (DM) yields and nutrient use efficiencies (NUE) of nitrogen (N), phosphorus (P) and potassium (K) in three different harvesting strategies for grass silage (timothy, TIM; meadow fescue, MF; tall fescue, TF). Differences between harvesting strategies inside each experiment are statistically significant (p <0.05) when marked with different letters (a, b, c, d).

			Maaninka				Ruukki			
Harvest strategy	First cut timing	Regrowth weeks	Annual DM yield	NUE_N	NUE_P	NUE_K	DM yield	NUE_N	NUE_P	NUE_K
			Experiment I: TIM + MF, 2009-2011				*Experiment II: pure TIM, 2009-2011*			
3 cuts	Flag leaf	+6; +10	8708 a	0.87	1.67 b	8.55	11239 b	1.30 a	3.52 c	2.04 a
2 cuts	Flag leaf	+8	8901 a	0.85	1.55 a	8.18	8919 a	1.29 a	2.69 a	2.08 a
2 cuts	Booting	+7	9513 b	0.86	1.57 a	8.45	10904 b	1.35 b	2.90 b	2.24 b
2 cuts	Flowering	+7	10216 c	0.85	1.55 a	8.38	12268 c	1.42 c	2.97 b	2.37 c
			Experiment III: pure TIM, pure TF, 2006-2007							
2 cuts	Booting	+4	7119 a	0.90	1.34 a	1.97 a	.	.	.	.
2 cuts	Booting	+6	8426 b	0.92	1.46 b	2.16 b	.	.	.	.
2 cuts	Booting	+8	9380 c	0.89	1.47 b	2.28 b	.	.	.	.

Conclusions Grass swards with timothy and fescue species show great capacity of nutrient uptake, since the efficiencies for P and K use are easily positive and in organic soils this is possible for N, too. Although the choice of harvesting strategy of silage did affect the nutrient use efficiency of the sward in some cases, the differences were not dramatic or remarkable in practice. Majority of N, P and K may be uptaken into the herbage well before the range of reasonable cutting times. Greater changes on NUE might be expected on different soil types and when the fertilization level of the sward is adjusted.

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