Changes of metabolizable energy content of functional group in permanent grassland after N fertilization levels

Rini Dwi Wahyuni[1], Erich M. Pötsch[2], Martin Gierus[1]

[1]Institute of Animal Nutrition, Livestock Product and Nutrition Physiology, University of Natural Resources and Live Sciences, Vienna, 1190 Wien, AT
[2]Grassland Management and Cultural Landscape, Institute for Plant Production and Cultural Landscape, Agricultural Research and Education Center Raumberg-Gumpenstein, Irdning/AT

Abstract

Intensive management of permanent grassland implements increasing N-fertilization which influences the proportion of functional groups in plant community. An experiment was established at AREC Raumberg-Gumpenstein (Austria) almost 50 years ago, and for the present study the period of 2014-2016 was evaluated. The field experiment is based on a randomized block design, with four replications. There were five different N-fertilization levels: treatment 1 - no fertilizer at all (control), treatment 2 - PK dynamic, treatment 3 - PK dynamic + 80 N, treatment 4 - PK dynamic + 120 N and treatment 5 - PK dynamic + 180 N. The plots were cut and harvested three times per year and beside bulk samples, additional separated sample of grass, legumes and herbs were taken. Fresh forage was dried at 58°C and milled to pass a 1 mm sieve. Metabolizable energy (ME) was calculated according the equation generated by GfE (2008). The results showed highly significant difference ($P<0.01$) among the treatments concerning the proportion of grass and legumes, ME concentration of grass, and total yearly ME production of grass and legume. The results of this experiment suggest that keeping a 3-cut harvest regime for highly fertilized treatments is not suitable to obtain higher ME content as MJ ME/kg DM, although higher DM yield is achievable. Increasing cutting frequency at higher fertilization level is therefore recommended for this long-term experiment.

Introduction

Grassland-based production systems play an important role in ruminant nutrition with low production costs in mountainous areas (Ferris, 2007; O'Donovan *et al.*, 2011). In those regions, permanent grassland is supposed to supply sufficient feedstuff for year-round feeding, particularly during summer season, and conserved forage (hay or silage) in the winter time. In order to maintain and increase productivity, intensively management is needed. Management (cutting regime and N-fertilizer application) clearly influence the grassland productivity and quality as well (Nevens & Rehuel 2003). Applying N fertilizer to grass swards increases the proportion of grass and dry matter (DM) yield but it may inhibit legume growth. However, changing the botanical composition contributes to transform nutritive value of grassland. There are several indicators regarding nutritive value such as crude protein (CP), ME, ADF and neutral detergent fibre (NDF) (Van Soest, 1994; Loyra-Tzab *et al*, 2011; Ball *et al*, 2001). Obviously legumes provide higher nutritive value than grass, due to differences in fibre composition and protein content. Kolver & Muller (1998) reported that milk production correlates with ME intake and with protein which reaches the small intestine. The ME content of forages may be the limiting factor for higher production efficiency of grassland-based dairy cow diets. Therefore it is necessary to investigate the changes in ME content, which is provided by grassland to assist appropriate management strategies.

Material and Methods

The experiment was established at AREC Raumberg-Gumpenstein, Austria in 1967 and the samples for the present study originate from the period of 2014 to 2016. The field experiment is following a block design with four replications. This long term experiment includes five different fertilization levels which are: T1 - no fertilizer at all; T2 - P (phosphorous) and K (potassium) dynamic (dynamic means that PK was applied according to the removal of the previous year), no N; T3 - PK dynamic + 80 kg N fertilizer/year; T4 - PK dynamic + 120 kg N fertilizer/year; and T5 - PK dynamic + 180 kg N fertilizer/year.

A 3-cut system was fixed for all treatments independent on the intensity of fertilization since 1993 (Table 1). Forage was cut 5-6 cm above ground and dry matter content (DM) of the bulk sample was determined after drying at 58°C for yield determination. In addition forage was separated manually into aliquot samples of functional groups (legume, grass and herbs). Approx. 200 g fresh samples were taken, dried, and milled in a Cyclotech mill to pass 1mm sieve for further analysis. All samples were scanned using Perkin Elmer FT-IR/ NIR spectrometer. ADF was determined using ANKOM 200 Fiber Analyzer apparatus. The method used to analyse ELOS adopting the technique by De Boever *et al.* (1988). The ME content was estimated according to the equation of GfE (2008).

$$ME = 5.51 + 0.00828\ ELOS - 0.00511\ CA + 0.02507\ CL - 0.00392\ ADF_{org}$$

where,
ELOS = soluble organic matter
CA = crude ash
CL = crude fat
ADF_{org} = organic acid detergent fibre

Table 1. Harvest date

Year	Harvest date		
	1	2	3
2014	26 May	22 July	30 September
2015	1 June	23 July	5 October
2016	25 May	21 July	28 September

All the data was subjected to analysis of variance using the general linear model (GLM) procedure of SAS (2008). Differences were tested using the Tukey-Kramer test and were declared significant at $P<0.05$.

Result and Discussion

The botanical composition clearly responded to the N-fertilization level (Figure 1-3). Grass is highly responsive to N-fertilizer, higher level of N-fertilizer consequently increases substantially the proportion grass in permanent grassland ($P<0.01$). It can be seen from the Figure 1 that in treatment 4 and 5 the proportion of grass was more than 80%. In contrast, legume proportion was reduced significantly due to the higher proportion of grass. This result is in line with McDonagh *et al.* (2017), who observed lower white clover proportion with increasing amounts of N-fertilizer. Despite this, the proportion of legumes was highest at T2, with P and K application only (Figure 2). In regards to Andrade *et al.* (2010) P and K fertilization tend to increase the percentage of legume.

The highest level of N-fertilizer resulted in the highest total DM yield (Figure 4). Table 2 provides data on DM yield, ME content and total ME yield of grass and legume functional groups. Grass contributes to DM yield performance more than legume. However, ME content of grass significantly declines by increasing N-fertilizer level ($P<0.01$), as the cutting frequency was kept constant among treatments.

The lowest ME content of grass was observed in treatment 5. There was no statistical difference on the ME content of legumes.

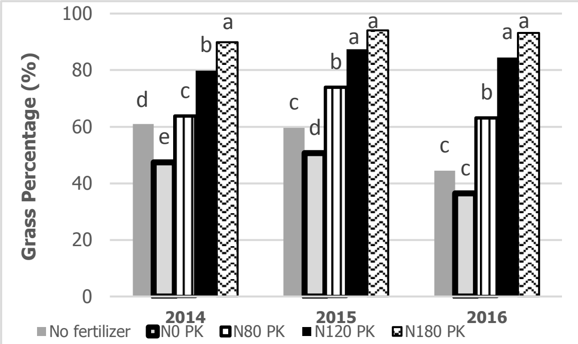

Figure 1. Grass proportion per year

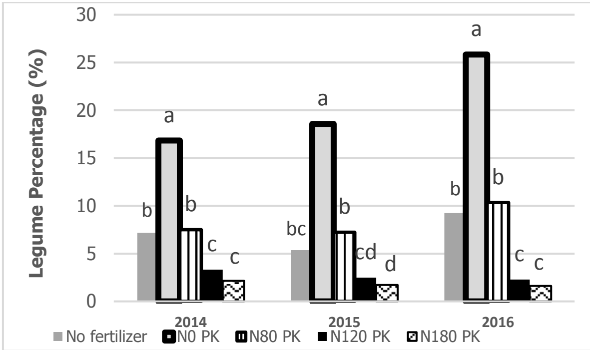

Figure 2. Legume proportion per year

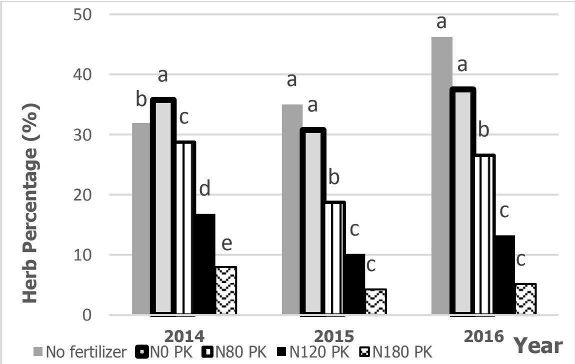

Figure 3. Herbs proportion per year

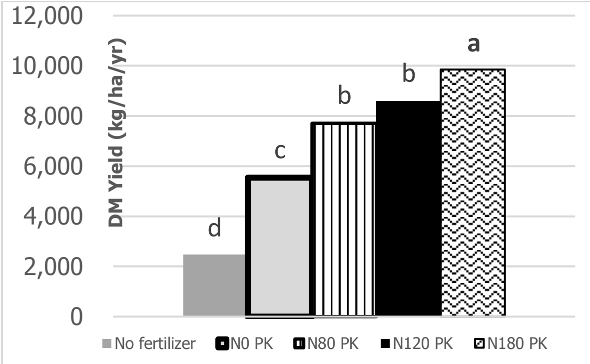

Figure 4. Average DM yield (2014-2016)

Grass responded to N-fertilization and showed higher and faster growth rates than legumes and herbs, contributing to higher DM yields (Figure 4). However, at the same cutting date grasses were at different maturity stages in the observed treatments. We assume that lignin increases as part of the process of cell maturation, causing negative impact on organic matter digestibility, which again is affecting the ME content negatively (Table 2).

Table 2. The average of yearly DM yield, ME content and ME yield of grass and legume (2014-2016)

	Functional Group	Fertilization level					SEM	P-value
		1	2	3	4	5		
DM yield (kg/ha)	Grasses	1,266^{e}	2,487^{d}	5,247^{c}	7,238^{b}	9,098^{a}	403	<0.0001
ME (MJ/kg DM)		9.56^{a}	9.31^{b}	9.07^{bc}	9.02^{c}	8.88^{c}	0.04	<0.0001
ME (MJ/ha)		12,070^{e}	22,926^{d}	47,480^{c}	65,202^{b}	80,772^{a}	3544	<0.0001
DM yield (kg/ha)	Legumes	221^{c}	1,236^{a}	684^{b}	250^{c}	188^{c}	63.8	<0.0001
ME (MJ/kg DM)		10.78	10.67	10.79	10.79	10.62	0.65	NS
ME (MJ/ha)		2,363^{c}	13,181^{a}	7,433^{b}	2,665^{c}	2,115^{c}	718	<0.0001

SEM: standard error of the mean
NS: not significant
Different superscripts (a-e) in a row show significance

Grasses are the dominant functional group, and they substantially influence yield and the nutritive value of permanent grassland as well.

Conclusion

The increasing level of N-fertilization decreased the ME content of grass, whereas the ME content of legume remained at a constant level. The application of 180 kg N/ha and year in combination with PK dynamic fertilization resulted in highest total ME yield. The results of this experiment suggest that keeping the 3-cut harvest regime for highly fertilized grassland is not suitable for higher ME content as MJ ME/kg DM, although high DM yield is achievable. Therefore higher N-fertilization level should absolutely be combined with increasing cutting frequency.

References

Andrade, C. M. S., Valentim, J. F., Pereira, J. B. M., & Ferreira, A. S. (2010). Yield and botanical composition of a mixed grass-legume pasture in response to maintenance fertilization. *Revista Brasileira de Zootecnia*, *39*(8), 1633–1640. http://doi.org/10.1590/S1516-35982010000800003

Ball, D., Collins, M., Lacefield, G., Martin, N., Mertens, D., Olson, K., Putnam, D., Undersander, D. & Wolf, M. (2001). *Understanding forage quality*. Park Ridge, Illinois: American Farm Bureau Federation Publication 1-01.

De Boever, J. L., Cottyn, B. G., Andries, J. I., Buysse, F. X., & Vanacker, J. M. (1988). The use of a cellulase technique to predict digestibility, metabolizable and net energy of forages. *Animal Feed Science and Technology*, *19*(3), 247–260. http://doi.org/10.1016/0377-8401(88)90088-0

Ferris, C. P. (2007). Sustainable pasture-based dairy systems – meeting the challenges. *Canadian Journal of Plant Science*, *87*, 723–738.

GfE. (2008). New equations for predicting metabolisable energy of grass and maize products for ruminants. In *Proc. Soc. Nutr. Physiol. 17* (pp. 191–197).

Kolver, E. S. & Muller, L. D. (1998). Performance and Nutrient Intake of High Producing Holstein Cows Consuming Pasture or a Total Mixed Ration. *Journal of Dairy Science*, *81*(5), 1403–1411. http://doi.org/10.3168/jds.S0022-0302(98)75704-2

Loyra-Tzab, E., Sarmiento-Franco, L. A., Sandoval-Castro, C. A., & Santos-Ricalde, R. H. (2011). Nutrient digestibility and metabolizable energy content of *Mucuna pruriens* beans fed to growing Pelibuey lambs. *Animal Feed Science and Technology*, *169*(1-2), 140–145. http://doi.org/10.1016/j.anifeedsci.2011.06.003

McDonagh, J., Gilliland, T. J., McEvoy, M., Delaby, L., & O'Donovan, M. (2017). Nitrogen and white clover impacts on the management of perennial ryegrass–clover swards for grazing cattle. *The Journal of Agricultural Science*, *155*(09), 1381–1393. http://doi.org/10.1017/S002185961700051X

Nevens, F., & Rehuel, D. (2003). Eeffects of cutting,grazing grass swards on herbage yield, N uptake and residual soil N at different levels of N fertilization. *Grass and Forage Science*, *58*, 431–449. http://doi.org/10.1111/j.1365-2494.2003.00396.x

O'Donovan, M., Lewis, E., & O'Kiely, P. (2011). Requirements of future grass-based ruminant production systems in Ireland. *Irish Journal of Agricultural and Food Research*, *50*(1), 1–21.

Van Soest, P. (1994). *Nutritional ecology of the ruminant*. Ithaca: Cornell University.

Corresponding author

Univ.Prof. Dr. agr. Martin Gierus
martin.gierus(at)boku.ac.at
Institute of Animal Nutrition, Livestock Products, and Nutrition Physiology (TTE)
Muthgasse 11
1190 Wien