Impacts of forb abundance on plant nutrition indexes along the growing season in intensively managed permanent grasslands

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Abstract

Plant nutrition indexes are important tools to estimate forage nutritional status and adjust fertilisation to plants requirements. However, these indexes have initially been developed for grasses and may be ill-suited to grasslands with relatively high abundance of forbs. To test the validity of nutrition indexes (NI) for forb-rich grasslands, we set up an experiment involving nine intensively managed permanent grasslands across Switzerland with contrasted plant composition and soil fertility. The three first harvests of the year 2018 were sorted into grasses, forbs and legumes. Forb abundance in plots ranged from 2 to 74% while legumes represented less than 5% on average. We measured nitrogen (N), phosphorus (P) and potassium (K) content of bulk forage and grasses, and calculated the respective nutrition indexes (NNI, PNI, KNI) separately for both. The PNI and KNI calculated for bulk forage and grasses were slightly different and differences varied among harvests. In addition, we found a strong discrepancy between grasses and forage NNI (up to 70% difference), which was independent of the harvest but influenced by forb abundance. Overall, our findings suggest an increasing underestimation of N fertiliser needs of grasses with an increasing abundance of forbs when using bulk NNI.

Keywords: botanical composition, fertilisation, plant nutrition indexes, permanent grasslands, herbs, forbs

Introduction

Plant nutrition indexes are helpful tools to estimate forage nutritional status and adjust fertilisation to plants requirements. Nitrogen (N), phosphorus (P) and potassium (K) nutrition indexes (NI), respectively NNI, PNI and KNI, have initially been developed for grasses (Duru and Thélier-Huché, 1997; Lemaire and Salette, 1984; Salette and Huché, 1991) but are now widely used for different types of grasslands. While a correction of these indexes has been developed to account for the abundance of legumes within the sward (Jouany *et al.,* 2005; Cruz *et al.,* 2006), the abundance of forbs has not been taken into consideration up to now. As a consequence, these indexes may not be adapted to grasslands with relatively high abundance of forbs. To test the validity of the nutrition indexes for forb-rich grasslands, we set up an experiment using nine intensively managed permanent grasslands across Switzerland with contrasted plant composition, forb abundance and soil fertility.

Materials and methods

Dominant grass species were *Alopecurus pratensis*, *Agrostis capillaris, Lolium* × *hybridum* and *Lolium perenne*, while *Taraxacum officinale* and *Achillea millefolium* were the dominant forbs. Three replicated plots (1.05 m × 5 m) were established at each site and managed according to intensive cutting practices (i.e. forage harvest approximatively every 6 weeks). We considered the first three harvests of 2018, which together yielded more than 75% of annual yield. Forage harvests were split in two subsamples: one representing forage bulk and one separated into grass, forb and legume biomasses. We measured N, P and K content separately for bulk forage and for the grass biomass only, and calculated the nutrition indexes (NNI, PNI, KNI) of the grasslands based on the N, P and K content and dry matter (DM) of either the bulk forage or the grass biomass according to Lemaire *et al.* (1989) and Duru and Thélier-Huché (1997):

$NNI = 100 \times \%N / (4.8\ DM^{-0.32})$
$PNI = 100 \times \%P / (0.15 + 0.065 \times \%N)$
$KNI = 100 \times \%K / (1.6 + 0.525 \times \%N)$

Indexes calculated for bulk forage were corrected for legume abundance (Cruz *et al.,* 2006; Jouany *et al.,* 2005) following the equations:

$NNI_c = NNI - (0.7 \times \%legume)$
$PNI_c = PNI + (0.5 \times \%legume)$
$KNI_c = KNI + (0.5 \times \%legume)$

Nutrient contents in plant biomass are expressed in percentage, DM in Mg ha^{-1} and legume abundance in percentage of the total community biomass. In order to determine the percentage error between nutrition indexes calculated on bulk forage compared to grasses only, we calculated the response ratio (RR) as follows:

$RR_{index} = (Index_{Bulk} - Index_{Grass}) / Index_{Grass}$

We ran regressions between nutrition indexes, calculated for the bulk and grass fractions across different sites, and harvests to highlight any discrepancy between both measurements. The effect of harvest (1^{st}, 2^{nd}, 3^{rd}) on RR_{index} across sites was tested using linear mixed effect models specifying 'plot' nested into 'site' to take into account of repeated measures (harvest) within the same plot and in different sites. To investigate the importance of forbs on the discrepancy between indexes measured for bulk forage and grasses, we ran regressions between RR_{index} and abundance of forbs in plots.

Results and discussion

Forb abundance in plots ranged from 2 to 74%, while legumes represented less than 5% on average. The nine grasslands and the three harvests used in this study yielded a wide range of values for all three nutrition indexes. Our results showed that indexes calculated from the forage bulk and grass biomasses were relatively similar for the phosphorus (PNI) and potassium (KNI) nutrition indexes (Figure 1B,C) with an average percentage error (RR) of 3 and 10%, respectively. Higher percentage error was found during the first and second harvests for KNI (about 10% error) and during the third harvest for PNI (about 8% error), but were not related to forb abundance. By contrast, we found strong discrepancy between nitrogen nutrition index (NNI) calculated from bulk and grass biomass (Figure 1A) with an average percentage error of 20%. Contrarily to PNI and KNI, the percentage error of NNI was

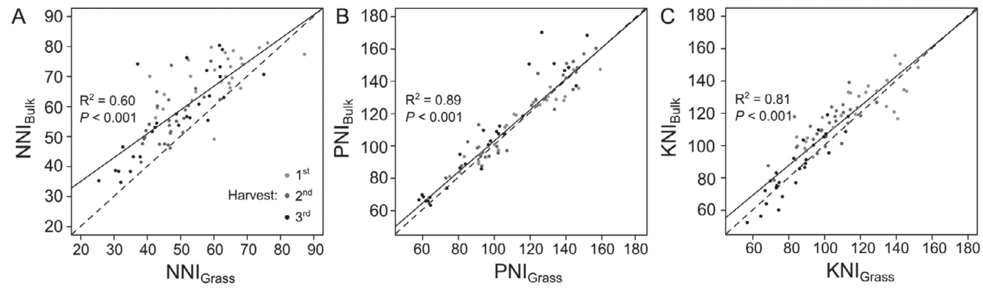

Figure 1. Relationships between plant nutrition indexes calculated on the bulk and grass fractions, (A) Nitrogen nutrition index [NNI], (B) Phosphorus nutrition index [PNI], (C) Potassium nutrition index [KNI] across sites and harvests. Dashed lines indicate cases where bulk and grasses indexes have the same value.

independent on the harvest along the vegetation growing season. This important difference between NNI_{Bulk} and NNI_{Grass} was strongly associated with forb abundance (Figure 2). Indeed, our results showed that discrepancy between NNI_{Bulk} and NNI_{Grass} remained relatively low (10%) up to 20% forb abundance within the community and then quickly increased to reach 70% discrepancy in plots with forb abundance above 60%. These results suggest that forbs may have very different N needs compared to grasses, which strongly impact NNI calculated on bulk forage. It is important to note that vegetation of the nine grasslands included in the study was rarely limited by P and K (i.e. mean PNI and KNI >80; Soil P [Olsen] varying between 14 and 85 mg kg^{-1} across sites), but according to recommendations was insufficiently supplied with N (i.e. mean NNI <80). Limitations in N, but not in P and K, might have affected the observed results and percentage error in PNI_{Bulk} and KNI_{Bulk} might be higher in P- and K-limited grasslands.

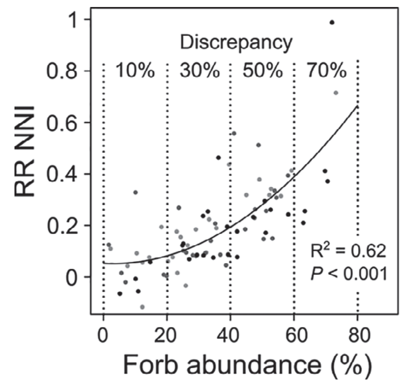

Figure 2. Relationship between the response ratio (RR) of nitrogen nutrition index (NNI) and forb abundance in plots. Discrepancy corresponds to average RR NNI calculated for each class of forb abundance (0-20, 20-40, 40-60, 60-80%).

Conclusions

Overall, our findings show that using plant nutrition indexes calculated on bulk forage might induce important bias in determining vegetation needs for nitrogen, above all in grasslands with forb abundance higher than 20%. Further research is thus needed to better understand nutrient needs in forb-rich permanent grasslands and adapt nutrient supply accordingly.

Acknowledgements

We are grateful to David Frund, Luc Stévenin, Cornel J. Stutz and Rafael Gago for their valuable management of the experimental sites, as well as for the forage sampling and sorting.

References

Cruz P., Jouany C., Theau J.P., Petibon P., Lecloux E. and Duru M (2006) L'utilisation de l'indice de nutrition azotée en prairies naturelles avec présence de légumineuses. *Fourrages* 187, 369-376.

Duru M. and Thélier-Huché L. (1997) N and P-K status of herbage: use for diagnostic on grasslands. In: Diagnostic procedures for crop N management. *Les colloques de l'INRA* 82, 125-138.

Jouany C., Cruz P., Theau J.P., Petibon P., Foucras J. and Duru M. (2005). Diagnostic du statut de nutrition phosphatée et potassique des prairies naturelles en présence de légumineuses. *Fourrages* 184, 547-555.

Lemaire G. and Salette J. (1984) Relation entre dynamique de croissance et dynamique de prélèvement d'azote pour un peuplement de graminées fourragères. I. Etude de l'effet du milieu, II. Etude de la variabilité entre génotypes. *Agronomie* 4, 423-430.

Salette J. and Huché L. (1991) Diagnostic de l'état de nutrition minérale d'une prairie par analyse de végétal: principes, mise en œuvre, exemples. *Fourrages* 125, 3-18.