RAHMANN G & AKSOY U (Eds.) (2014) Proceedings of the 4th ISOFAR Scientific Conference.
'Building Organic Bridges', at the Organic World Congress 2014, 13-15 Oct., Istanbul, Turkey (eprint ID 23522)

High variability of symbiotic nitrogen fixation in farming conditions

PAUL RIESINGER[1], IRINA HERZON[1]

Key words: On-farm research, organic farming, SNF, spatial heterogeneity, *Trifolium pratense* L.

Abstract

Symbiotic nitrogen fixation (SNF) in perennial legume-grass leys is the primary source of N to organic farming systems in northern countries. This work aimed to quantify SNF in organically managed red clover (Trifolium pratense L.)-grass leys and to relate SNF to explanatory variables. The study was carried out on 27 farms located in the coastal regions of Finland and included 117 ley crops subjected to regular organic farming practices. In the accumulated first and second cuts of one- and two-year-old red clover-grass leys, SNF averaged 185.4 kg N ha^{-1} yr^{-1} (SD ± 90.0 kg N ha^{-1} yr^{-1}); fixation in the aftermath added 62.1 kg N ha^{-1} yr^{-1} (SD ± 49.8 kg N ha^{-1} yr^{-1}). Due to the poor persistence of red clover, SNF declined with ley age. Between- and within-field coefficients of variation of SNF in one- and two-year-old leys averaged 51.1 and 51.8%, respectively. SNF was positively related to soil fertility parameters, mainly to soil structure. It is concluded that the preceding crop value of legume-grass leys needs to be assessed individually. The spatial heterogeneity of soil properties can be reduced through site-specific amelioration and regular applications of animal manure.

Introduction

Correct assessment of symbiotic nitrogen fixation (SNF) is crucial for the design of crop rotations and the N-supply of single crops. Legume growth, and thereby SNF, depend on species, stand age, weather conditions, soil properties, and management (Mela 2003). The spatial heterogeneity of soil properties is high not only between but also within single fields (Geypens et al. 1999). Legume growth is likely to reflect this variability. In northern countries, perennial red clover (*Trifolium pratense* L.)-grass leys are of paramount importance for the N-supply of organic farming systems. The objectives of this work were (i) to quantify SNF in organically cropped red clover-grass leys, (ii) to explore between- and within-field variations of SNF, and (iii) to relate SNF to stand age and environmental conditions. On farm-research was expected to high-light issues unresolved at farm level for further experimental research.

Material and methods

SNF was assessed in 117 organically managed perennial red clover-grass leys. These ley crops were integrated in the crop rotation cycles of 27 different farms and subjected to regular agricultural practices. The location of the farms in two distinctly different regions, the southern and the north-western coastal zones of Finland (= south and northwest, respectively), was expected to elucidate possible impacts of different climate and soil conditions on SNF.
The rotations of all farms included ley and grain crops. The leys were undersown in cereal nurse crops, except in one of the farms. The seed mixtures included mainly red clover (27 farms), timothy (*Phleum pratense* L.; 25 farms), and meadow fescue (*Festuca pratensis* L.; 18 farms). In some cases white clover (*Trifolium repens* L.) or alsike clover (*Trifolium hybridum* L.), or both, were added in small proportions. The average clover content (by weight) of the seed mixtures was 31.7% (SD ± 16.9%). The harvest regimes were limited to two cuts per season, which is the generally recommended strategy for perennial mixed leys in Finland (Mela 2003).

Herbage samples were collected during two growing seasons, 2001 and 2002. Newly established leys were sampled at the end of each growing season (n = 38). Samples from one-, two-, and three-year-old leys (= three production years) were taken prior to the first and to the second cuts (n = 79). Here, the average interval between samplings and cuts was 6 days in the south, and 5 days in the northwest. Samples from the aftermath were obtained at the end of the growing periods (n = 52). In each site and at each occasion samples were always taken from four 0.25 m^2 plots situated at equal distances along the longest diagonal across the field. The herbage was cut with shears at 20 to 30 mm above the soil surface and separated by hand into a clover and a grass fraction (the latter also including dicotyledonous herbs others than clovers), which were then dried with air-flow dryers at 25-30ºC to a constant weight. All biomass weights were corrected to dry matter weight (DM).

[1]Agroecology Group, Department of Agricultural Sciences, University of Helsinki, Finland, eMail: paul.riesinger@novia.fi

Simulation with a grassland growth model (Riesinger et al. 2008) showed that when the farmers cut the leys the herbage production on average was 13.0% higher than at the time of sampling. Since the final statistical models for observed and simulated data were the same, only observed data and results of analyses based on these are reported here. SNF was calculated from clover herbage dry-matter yield with an empirical model that estimates total SNF in cut one- and two-year-old red clover-grass leys in temperate climate under low external input conditions (Høgh-Jensen et al. 2004). SNF was related to sampling year, ley age, geographical location, interaction between ley age and geographical location, and soil properties by general linear modelling (GLM) in SPSS 15.0 (SPSS Inc. 2006). Soil properties included cation-exchange capacity (CEC), soil organic matter content (SOM), pH-value, and concentrations of phosphorus (P), potassium (K) and magnesium (Mg). Within-field variation of SNF was assessed as the coefficient of variation of SNF in the four sub-samples from each field.

Results

The autumn growth of newly established leys on average fixed 38.6 kg N ha^{-1} yr^{-1} (SD ± 25.2 kg N ha^{-1} yr^{-1}). SNF in the accumulated annual growth of one- and two-year-old leys averaged 247.5 kg N ha^{-1} yr^{-1} (SD ± 114.4 kg N ha^{-1} yr^{-1}); of that the contribution of the aftermath was 62.1 kg N ha^{-1} yr^{-1} (SD ± 49.8 kg N ha^{-1} yr^{-1}) (Table 1).

In the statistical model, sampling year was retained as a significant explanatory variable only in the model for the aftermath, in which SNF was lower 2002 than 2001. Being a function of clover herbage biomass, SNF in the first cut was significantly lower than that in the second cut. Clover herbage biomass and SNF were consistently negatively related to ley age. During the production years, percentages of clover and SNF were significantly higher in the south than in the northwest.
However, once soil properties were included into the analysis, region lost its previous significance as an explanatory variable for SNF. SNF was significantly positively correlated with soil-CEC and with concentrations of soil-K and -Mg (not shown).

Table 1: Symbiotic nitrogen fixation (SNF) in organically cropped red clover-grass leys in the coastal regions of Finland (n = 52; means averaged over two growing seasons, standard deviations in parenthesis)

	Accumulated cuts (kg N ha^{-1} yr^{-1})[a]		Aftermath (kg N ha^{-1} yr^{-1})		Accumulated growth (kg N ha^{-1} yr^{-1})[b]	
	South[c]	Northwest[c]	South[c]	Northwest[c]	South[c]	Northwest[c]
One-year-old leys	287.3 (108.2)	145.5 (81.3)	78.6 (70.1)	61.9 (47.2)	365.8 (113.6)	207.4 (121.0)
Two-year-old leys	194.9 (86.6)	113.8 (83.8)	77.4 (54.4)	30.6 (27.6)	272.2 (115.1)	144.4 (109.0)
Three-year-old leys	NA[d]	67.8 (77.6)	NA[d]	18.2 (20.2)	NA[d]	86.0 (94.9)

[a] First and second cuts
[b] Accumulated first and second cuts plus aftermath
[c] South = southern coastal region, northwest = north-western coastal region
[d] Not assessed due to termination subsequent to the second cut

Calculated over the three annual growth cycles of one- and two-year-old leys, the coefficients of between- and within-field variation of SNF averaged 51.1 and 51.8%, respectively, being about twice as high as those of herbage production (not shown). The between- and within-field coefficients of variation of SNF decreased from the first to the second cut but increased with ley age. Whereas the variability of herbage production did not differ between the regions, the between- and within-field variations of clover percentages (not shown) and SNF were considerably higher in the northwest than in the south (for SNF: Tables 1 and 2). The lower was SNF on a field level, the higher was its within-field variation (not shown).

Table 2: Coefficients of within-field variation of symbiotic nitrogen fixation (SNF) in organically cropped red clover-grass leys in the coastal regions of Finland (averaged over two growing seasons)

	First cut (%)[a]		Second cut (%)[a]		Aftermath (%)[b]	
	South[c]	Northwest[c]	South[c]	Northwest[c]	South[c]	Northwest[c]
One-year-old leys	40.8	87.2	32.2	52.7	33.4	58.2
Two-year-old leys	63.8	68.5	38.2	56.5	45.8	81.4
Three-year-old leys	102.4	101.0	63.6	106.1	NA[d]	117.6

[a] n = 79
[b] n = 52
[c] South = southern coastal region, northwest = north-western coastal region
[d] Not assessed due to termination subsequent to the second cut

Discussion

Between-field variation of SNF did not exceed its within-field variation, indicating that the variability of clover growth was caused by soil properties rather than by management (including fertilization practices). The positive correlation between SNF and soil-CEC emphasized the importance of soil structure for red clover growth. CEC increases with clay and humus contents, i.e., factors that define porosity, and therefore water and gas transport in the soil, storage of plant-available soil water, mineralization of SOM by the decomposer population, chemical reactions, and penetrability of the soil by roots. To avoid soil compaction, the load of machinery, the number of passes, and the intensity of tillage ought to be reduced (Reintam et al. 2009).

Soil structure is enhanced especially by certain perennial crops and animal manure. Under green manuring where organic matter (OM) and plant nutrients are cycled within a narrow area, within-field variation will increase. In contrast, the re-cycling of OM and nutrients through harvest of forage and application of animal manure to the field decreases the heterogeneity of soil properties between and within fields. Application of animal manure also allows for a higher share of non-leguminous crops in the crop rotation, which helps breaking legume disease cycles.

Conclusions, as well as suggestions to tackle with the future challenges of organic animal husbandry

The spatial variability of SNF between and within fields was high. Consequently, the preceding crop value of single ley crops needs to be assessed from case to case. Soil properties, especially soil structure, appeared to be decisive for the productivity of organic crop husbandry. Site-specific soil amelioration obviously offers a huge potential to increase crop yields on a field level. Within-field variation of soil properties can be reduced through an integration of crop and animal husbandry.

References

Geypens M, Vanongeval L, Vogels N & Meykens J (1999): Spatial variability of agricultural soil fertility parameters in a gleyic podzol of Belgium. Precision Agriculture 1, 319-326.
Høgh-Jensen H, Loges R, Jørgensen FV, Vinther FP & Jensen ES (2004): An empirical model for quantification of symbiotic nitrogen fixation in grass-clover mixtures. Agricultural Systems 82, 181-194.
Mela T (2003): Red clover grown in a mixture with grasses: yield, persistence and dynamics of quality characteristics. Agriculture and Food Science in Finland 12, 195-212.
Reintam E, Trükmann K, Kuht J, Nugis E, Edesi L, Astover A, Noormets M, Kauer K, Krebstein K & Rannik K (2009): Soil compaction effects on soil bulk density and penetration resistance and growth of spring barley (*Hordeum vulgare* L.). Acta Agriculturae Scandinavica Section B-Soil and Plant Science 59, 265-272.
Riesinger P, Eckersten H, Torssell B & Forkman J (2009): Radiation-use efficiency in leys: influences of growth period and clover proportion. Acta Agriculturae Scandinavica, Section B, Soil and Plant Science 59, 465-474.
SPSS (2006): Statistical Package for the Social Sciences, Version 15.0. SPSS Inc. Chicago, Illinois.