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Monitoring of N-uptake by green manures and of the influence of N-release on N-availability, production and quality of sugar beet

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Abstract

To study N-cycling in a crop system with green manures, on two field trials, a monitoring programme was set up to evaluate the N-uptake and the N-release capacity of several types of green manure. The studied green manures vary not only with the efficiency with which they take up nitrate but also with which they release it again when ploughed-in. The N-release depends on the time of dying of the green manure (frost, chemical damage or mechanical cut), the time of ploughing-in, and, the type of green manure (easily decomposable or not). Important is whether this N is made available quickly enough to the following commercial sugar beet crop and if there is no reduction in yield and quality of the sugar beet. Monitoring of nitrate content in soil during the experiments, allows to classify green manures into several classes. One class are the winter-hardy green manures, like ryegrass and reply of winter barley. Notwithstanding their N-uptake capacity, there is seldom N available for the following sugar beet crop. Yield and sugar beet quality are not significantly influenced. A second class are green manures with a good developed aerial plant part like phacelia and mustard. A clear net mineralization of these green manures is determined but crop technical and climatic factors determine whether this mineralization results in a higher N-availability for the following crop. A third class are the legumes like vetch. In the two field trials the N-uptake by vetch is the highest and N is made available during a longer period in comparison with phacelia and mustard. The root and sugar yield were higher, but not significantly. No significant difference in technological quality of the beets is measured.

Introduction

Because of their N-uptake capacity, green manures are used as a catch-crop for nitrate-N (Addiscott et al., 1991). In that way, the use of green manures can be considered as an important technical measure to prevent nitrate from leaching during the winter period. Besides, the N released as a result of the mineralization of the green manure is available for the following sugar beet crop. This N, released before or during the growing period of the sugar beet crop, has to be taken into account by calculating the N fertilization. Soil samples of sugar beet parcels from practice, which are taken in February-May, show that the use of green manures influences the distribution of mineral N in the soil profile : on average, the parcels with green manures in the crop rotation have a higher mineral N content in the top layers (0–30 cm and 30–60 cm), which has an impact on the N recommendations for sugar beets (Geypens et al., 1994).

The N-uptake capacity of several types of green manures and the influence of N-release on N-availability, production and quality of the following crop (sugar beet) is studied in two field trials. Determining the N-uptake of the green manure and monitoring the nitrate content of the soil profile (0–90 cm) allows to study N-cycling in a crop system with green manures.

Materials and methods

Regarding this research, two field trials on a loamy soil were set up in the period 1991–1993. On each trial the green manures were sown after winter barley and ploughed-in in winter. Thereafter, sugar beets are sown in spring.

Table 1. General information about both field trials

	1991–1992	1992–1993
Sowing of green manures	09.08.91	03.08.93
Nitrate content of soil profile at sowing (kg N ha^{-1})	100.9	70.3
N-fertilization green manures (kg N ha^{-1})	–	40
Cutting of mustard	23.10.91	06.11.92
Ploughing-in of green manures	18.12.91	30.01.93
Sowing of sugar beets	10.04.92	28.03.93
N-fertilization sugar beets	09.04.92	22.03.93
Harvest of sugar beets	21.09.92	20.10.93

On both trials, ryegrass, mustard, phacelia and vetch were sown. In addition, an object with reply of winter barley and a fallow object were provided. Every treatment (12 × 15 m plots, randomly dispersed) was set up in four replications. Two times during the growing period of the green manures, the yield and the N-uptake of their aerial parts were measured.

After the ploughing-in of green manures, the sugar beets were sown on every object, one part without any N-fertilization, another part with N-fertilization following the N-recommendation according to the N-index of the parcel (Vandendriessche et al., 1992). During the growing period, soil samples are taken regularly until 90 cm of depth by layers of 30 cm to analyse for mineral N. At harvest, yield and quality parameters (such as sugar content, content of α-amino-N, potassium and sodium) were determined. General information about the field trials is given in Table 1.

Results

In 1991 the mineral N residues in the soil profile (0–90 cm) at sowing time of green manures are clearly higher than in 1992 (101 kg N ha^{-1} vs. 70 kg N ha^{-1}). Therefore, only in the second trial a limited N-fertilization (40 kg N ha^{-1}) is applied to the green manures. In that way, the growth of green manures in both trials was moderate, but sufficient. The N-uptake of the aerial parts at the end of the growing season varies from 28 to 98 kg N ha^{-1}.

Figure 1 illustrates the N-uptake capacity of the different green manures : in October the mineral N reserve in the soil is clearly lower on the parcels with green manure (especially in the layers 0–30 cm and 30–60 cm). The same conclusions can be drawn from the 1992-trial, despite the fertilizer application of 40 kg N ha^{-1}. In both trials, vetch and mustard are characterized by a high N-uptake.

Comparatively to the fallow object, the parcels with ryegrass show no net N-mineralization during the growing season of the sugar beet (Fig. 2). Only at the end of the season some N-mineralization can be remarked. The green manures mustard and phacelia, on the other hand, are characterized by a net mineralization in spring. The mineralization of vetch is totally different from the other green manures. In both trials a clear net mineralization of vetch can be distinguished during the growing season of the following crop. This net mineralization starts early and persists for a longer period. The mineralization on the winter barley parcel is comparable with that on the ryegrass parcel. The net mineralization of the winter barley during the growing season of the sugar beets is negligible.

The sugar beet yield reflects the N-availability during the growing season. Considering the unfertilized sugar beets, only the vetch parcels got the highest beet and sugar yields on both trials. Of all green manures, vetch had the most important net mineralization during several months. The total N-uptake of the unfertilized sugar beets (roots and crowns) was 192 kg N ha^{-1} on the vetch parcel, clearly higher than on the other objects : 148, 149, 160 and 161 kg N ha^{-1} for the ryegrass, mustard, phacelia and winter barley object respectively. The fertilized sugar beets got on average higher yields than the unfertilized ones. The use of a green manure in the crop rotation had a small positive effect on the fertilized sugar beet yield, except for ryegrass and for reply of winter barley (Table 2). The technological quality of the sugar beets is reflected by the extractability index of Van Geijn (Van Geijn et al., 1983), taking into account the α-amino-N, potassium and sodium content of the beets. No significant difference in technological quality is measured (Table 2).

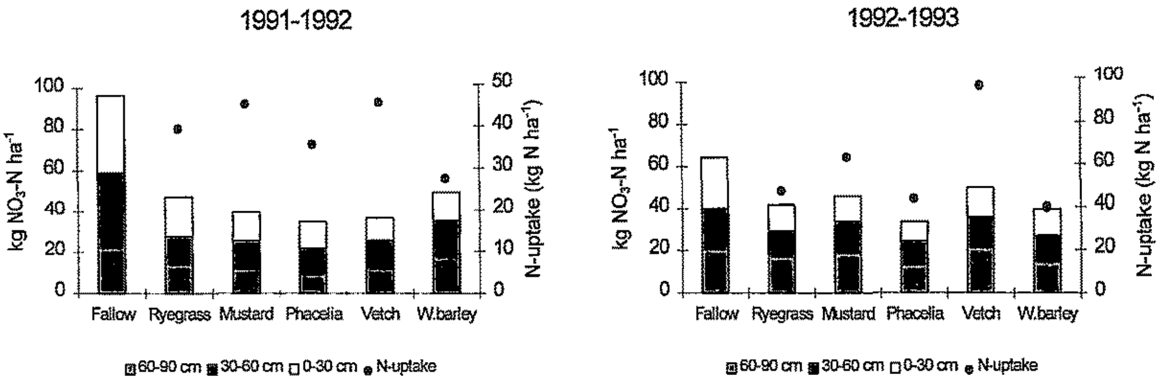

Figure 1. Nitrate reserve (kg NO_3-N ha^{-1}) of the soil profile on 23.10.91 and on 04.11.92 (before ploughing-in) and N-uptake (kg N ha^{-1}) of the green manures.

Table 2. Root yields, sugar content and quality of sugar beets after different green manures

	1992			1993		
	Root yield (ton ha^{-1})	Sugar (%)	EI[a] (%)	Root yield (ton ha^{-1})	Sugar (%)	EI[a] (%)
Unfertilized sugar beets						
Fallow	67.3	15.4	83.1	70.5	17.8	91.6
Ryegrass	57.2	16.5	85.4	64.6	17.9	91.2
Mustard	56.8	16.0	84.5	64.8	17.7	91.3
Phacelia	60.8	16.2	84.8	66.3	18.0	91.3
Vetch	69.8	16.3	84.5	74.9	17.6	91.2
W. barley	62.4	16.2	85.1	68.0	17.9	91.1
Fertilized sugar beets						
Fallow	60.0	15.2	83.8	76.9	17.7	90.9
Ryegrass	60.4	16.1	85.0	75.8	17.7	91.1
Mustard	70.5	16.1	85.2	79.2	17.7	90.9
Phacelia	67.2	16.1	84.9	77.0	17.8	91.1
Vetch	64.4	15.9	83.8	77.0	17.4	90.5
W. barley	63.1	16.1	84.7	76.7	17.9	90.5

[a] extractability index of Van Geijn (Van Geijn et al., 1983)

Discussion

The situation in the two field trials was certainly not identical (rainfall, temperature, N- content of the soil at sowing, date of ploughing-in, N-fertilization...). Nevertheless, both trials confirm the N-uptake capacity of the green manures and show their capacity to function as a catch-crop for nitrate-N, however the development of the green manure was moderate. A higher N-uptake by the green manures would have been possible by applying more mineral or organic N-fertilizer, but that was not the aim of the experiment (to avoid higher mineral N residues in the soil profile during winter period).

The amount of N-release and the moment of net N-mineralization are influenced by several factors : time of ploughing-in, time of cutting or dying of the green manure, climatic factors and type of green manure. This means that too early mineralization can be prevented by the use of crop technical measures.

The results of the soil profile analysis on the green manure parcels, compared with the fallow object, suggest that the green manures can be classified into three groups, considering their rate and time of mineralization.

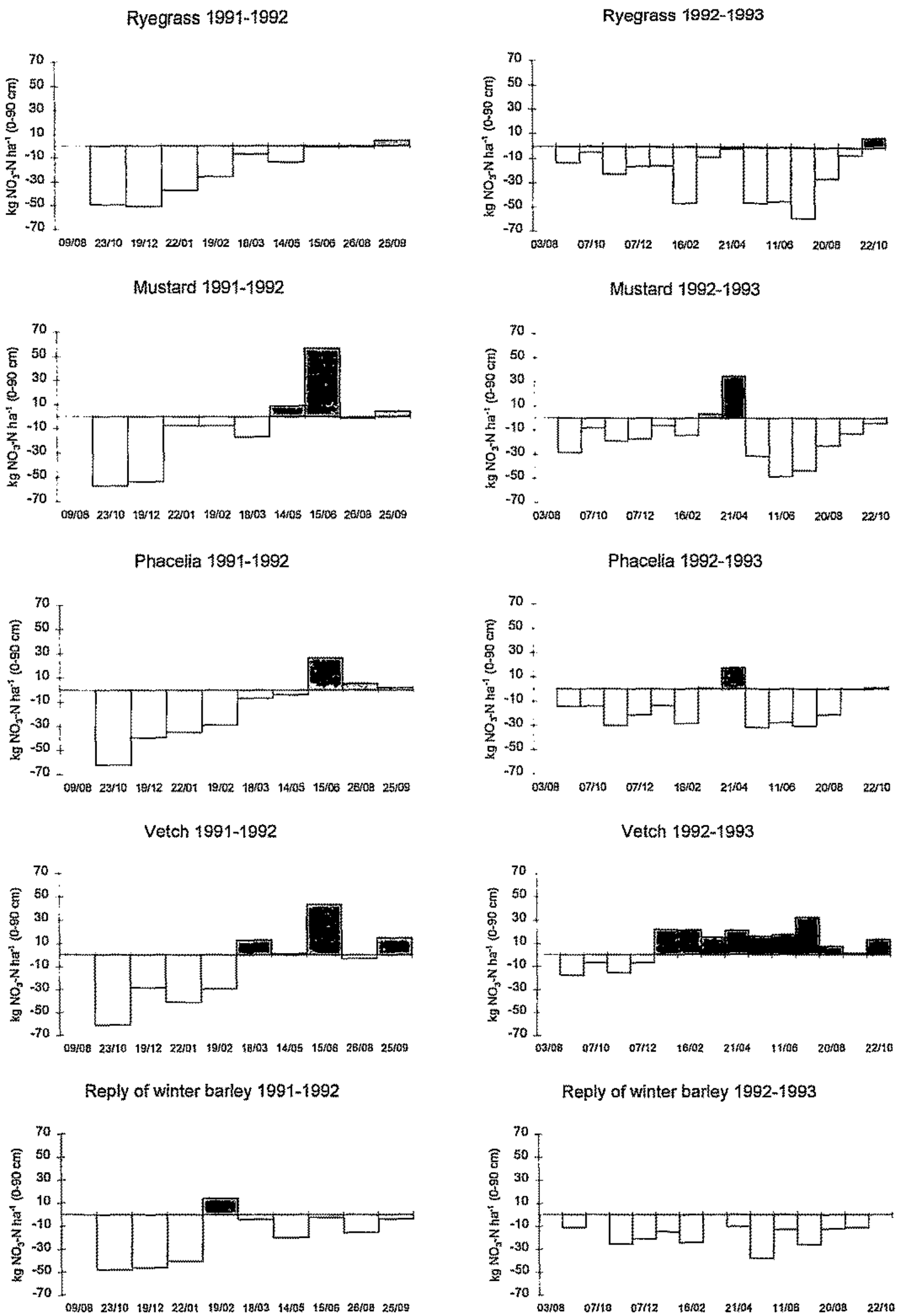

Figure 2. Evolution of the mineral N reserve of the soil profile (0–90 cm) comparatively to the fallow object.

Ryegrass and reply of winter barley

The mineral N reserve of the soil profile after ploughing-in of these green manures is continuously lower than on the fallow object. Ryegrass and winter barley are winter-hardy green manures with moderate N-uptake in their aerial parts, but with a relatively good developed root system. Possibly, because of the relatively high C/N-ratio of the root system, a part of the mineralised N from the soil organic matter is used for further decomposition of the green manure. As a result, less N is available for the following crop (sugar beets). However, the sugar beet yield and quality was hardly influenced.

Mustard and phacelia

These green manures have (compared with the first group) a good developed aerial plant part. After ploughing-in, a weak net mineralization was determined. The rate and time of mineralization may be influenced by climatic factors and crop technical measures (such as time of sowing and ploughing-in). The N-availability for the following sugar beet crop depends on the time of net mineralization. For these green manures, it will be important to prevent too early mineralization by the use of crop technical measures.

Vetch

Vetch is the only legume in the experiment. This green manure provides a net mineralization during a relatively long period. So, the released N can be used by the following crop. The results of the sugar beet trials show a higher N-uptake by the sugar beet crop and also a higher root and sugar yield.

As a result, the use of green manures as a catch-crop for N is only significant when too early mineralization of the green manure is prevented by the use of crop technical measures (choice of the green manure, ploughing date,...). Because N releases before or during the growing period of the following crop, this N has to be taken into account by the calculation of the N-fertilization of the following crop. If not, the use of green manure is only a delay of N-leaching in time.

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References

Addiscott T M, Whitmore A P and Powlson D S 1991 Farming, fertilizers and the nitrate problem. C A B International, Wallingford, Oxon, UK. 170 p.

Geypens M, Vandendriessche H, Bries J and Hendrickx G 1994 Experience with the N-index expert system : a powerful tool in N recommendation. Commun. Soil Sci. Plant Anal. 25, 1223–1238.

Vandendriessche H, Geypens M and Bries J 1992 N-index : an expert system for N fertilization of arable crops. *In* Nitrogen Cycling and Leaching in Cool and Wet Regions of Europe. Proceedings of the COST Workshop, October 22-23, 1992, Gembloux, Belgium. Eds. E François, K Pihan and N Bartiaux-Thill. pp 55–57.

Van Geijn N J, Giljam L C and De Nie L H 1983 Alfa-amino-N in sugar processing. Proceedings of the I.I.R.B. Symposium 'Nitrogen and Sugar-beet', February 16-17, 1983, Brussels, Belgium. pp 13–24.