Comparison of Split Nitrogen Application Strategies in Leek (*Allium porrum*) to Reduce N Fertilization on Sandy Soils in the Netherlands

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Abstract

High nitrogen (N) fertilization to maximize production of leek (*Allium porrum* L.) combined with low N recovery can lead to considerable nitrogen pollution of the environment. A field trial was conducted in 2002 and 2003 on a sandy soil in the Netherlands. To synchronize N supply and N demand, two strategies of sequential split nitrogen application (SNA) were compared: 1) SNA-soil: in which the split N applications are the difference between standardized crop demand and the available amount of mineral N in the soil for each period; 2) Crop Scan method: in which the split N applications are derived from comparing the actual crop nitrogen status to the desired nitrogen status, using crop reflectance measurements and a crop growth model. Total fertilizer application according to Crop Scan method in 2002 saved 65 kg N ha^{-1} compared to recommendation of SNA-soil, maintaining maximal production. In 2003 the total N application of SNA-soil and Crop Scan were respectively 95 and 113 kg N ha^{-1}, whereas a N application of 45 kg N ha^{-1} was sufficient. The Crop Scan method overestimated the N application needed in 2003 because it did not account for the high mineral N content in the soil. SNA-soil overestimated the N application needed in autumn in both years. Combination of Crop Scan measurements, to assess plant N need, and soil N analysis may cover the flaws, which each method separately showed.

INTRODUCTION

Most vegetables need a high nitrogen fertilization to maximize production, which often leads to considerable nitrate leaching to groundwater (Goulding, 2000; Ramos et al., 2002). This can lead to high nitrate concentrations in drinking water and concomitant health problems. Leek (*Allium porrum* L.) is a vegetable, which despite its long growing season is particularly susceptible to N leaching due to its relatively weak root system (Thorup-Kristensen and Sørensen, 1999). In the Netherlands leek is largely grown on sandy soils. The common practice of high N fertilization (up to 400 kg N ha^{-1}) to maximize production of leek, grown in the period July-December, together with its relatively weak root system and the sandy soils, results in a high potential for nitrate leaching to groundwater. Several strategies were developed to synchronize N supply to N demand in order to maintain maximum production but minimize N leaching potential. Gröninger and Soorsma (1991) proposed to derive the level of split N applications from the difference between the available soil mineral N content (N_{min}) and an N uptake curve standardized for each crop (SNA-soil) in the Netherlands. The strategy is similar to the German "Kulturbegleitenden N_{min}-Sollwerte (KNS)-system" (Lorenz et al., 1989). Recently a new method has been developed in which supplementary N applications in leek are based on the crop nitrogen status, determined by light reflectance measured using the Crop Scan (Booij and Meurs, 2002). The aim of this experiment was to compare SNA-soil with the Crop Scan method and to determine their strengths and weaknesses.

MATERIALS AND METHODS

A field trial was conducted in 2002 and 2003 in the South East of the Netherlands. The experiment was carried out on a fertile, slightly loamy sand with 2.6-2.9% organic matter. In both years, leek (cultivar: 'Apollo' F1) was grown from the end of June until

the end of November. Biomass and N uptake were determined at 1.5, 2.5 and 3.5 months after transplanting and at harvest. Marketable yield and quality were determined as well. The irrigation water at the location contained approximately 200 mg l^{-1} of nitrate.

SNA-soil and the Crop Scan method were compared and related to a range of fixed N rates included in the trial to assess the response to N fertilization. N rates were: 0, 60, 120, 180, 240 and 300 kg N ha^{-1}, split into 3 equal applications of 33% each. N application in SNA-soil and the range of fixed N rates were at transplanting and 1.5 and 3 months after transplanting. For the Crop Scan method the crop N status was determined 8, 12, and 16 weeks after transplanting.

In SNA-soil the three split N applications were calculated by:

$$\text{N application} = \text{N uptake (period ahead)} + \text{safety margin} - \text{soil-}N_{min}$$

N uptake was estimated from a standardized N uptake curve (35 kg N ha^{-1} first 1.5 months, 55 kg N ha^{-1} 1.5-3.0 months, 70 kg N ha^{-1} between 3 months and harvest). The safety margin in the Dutch SNA-soil was 50 kg N ha^{-1} until 3 months after transplanting and 30 kg N ha^{-1} thereafter. Before and at 1.5 month after transplanting N_{min} was analyzed in the soil layer 0-0.3 m. At 3 months after transplanting N_{min} was analyzed in the layer 0-0.45 m in 2002 and in the layer 0-0.35 m in 2003, dependent on rooting depth. The trial contained six SNA-soil treatments with lower and higher N application rates (Table 1).

The Crop Scan method was used as described by Booij et al. (2001) and Booij and Meurs (2002). This method calculates the N application from the actual N uptake of the crop (derived from relations between measured radiation reflectance, LAI and consequent light interception of the crop), the N uptake in the period ahead (as predicted with a crop growth model) and the difference between calculated and desired uptake.

RESULTS AND DISCUSSION

In 2002 N supply of the SNA-soil treatment "standard/0" and of the Crop Scan method were sufficient for an optimal yield (Table 2) and quality. Thus 65 kg N ha^{-1} could be saved compared to the "standard" SNA-soil (Table 2), due to reduced N applications in autumn.

The relatively dry spring and summer of 2003 resulted in a high mineral N content of the soil at transplanting. Yield response to N fertilization was low in 2003 (Fig. 1). An N application of 45 kg N ha^{-1}, 3 months after transplanting, was sufficient to achieve an optimal yield (Table 2) and quality. "Standard" SNA-soil recommended 95 kg N ha^{-1}, thus 50 kg N ha^{-1} could be saved, again due to a lower N application in autumn (Table 2). The Crop Scan method advised an N application of 113 kg N ha^{-1}, which was too high. This overestimation was likely caused by the high mineral N content in the soil in the first 3 months of the growing season. Such a high soil N supply was not accounted for by the calculation of N applications in the Crop Scan method.

"Standard" SNA-soil overestimated the N application needed for the autumn period again. The higher N applications in 2002 and 2003 (65 and 50 kg N ha^{-1}, respectively) resulted in higher N contents (46 and 23 kg N ha^{-1}, respectively) in the crop (Table 2), but did not affect yield or quality. Even if N_{min} in the soil layer 0-0.6 m was taken into account, the recommended N application still would have been too high in both years. This was partly due to overestimation of the crop N demand and probably also due to N supply from mineralization and deposition, which were not counted, or to a too high safety margin.

Fig. 2 shows that N uptake in the first three months of the growing period was higher than the standard N uptake curve for the Dutch SNA-soil indicates. However, in these first three months irrigation contributed ± 50 kg N ha^{-1} in 2002 and ± 65 kg N ha^{-1} in 2003. Without this N contribution by irrigation water, the N supply to "standard" SNA-soil might have been too low. The N uptake pattern of leek in the trial corresponded better to the N uptake curve of Fink et al. (2001) as given in Fig. 2 as well.

CONCLUSIONS

The Crop Scan method recommended proper N applications in 2002. However in 2003 it recommended too high N applications as it does not account for a high soil mineral N content.

The standard SNA-soil recommended too high N applications in autumn in both years, likely due to overestimation of crop N demand, N supply from mineralization and deposition (which were not counted) or a too high safety margin.

The standard N uptake curve of the Dutch SNA-soil showed to low N uptake in the first three months and somewhat too high N uptake in the last months compared to the measured N uptake and should therefore be revised.

Combination of Crop Scan measurements, to assess plant nitrogen need, and soil analysis to asses available soil mineral N, may cover the flaws, which each method separately showed.

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Tables

Table 1. SNA-soil treatments.

Treatment	Target values (kg N ha^{-1})		
	At transplanting	After 1.5 month	After 3 months
standard[1]	$85 - N_{min}$	$105 - N_{min}$	$100 - N_{min}$
standard/½	$85 - N_{min}$	$105 - N_{min}$	$0.5 * (100 - N_{min})$
standard/0	$85 - N_{min}$	$105 - N_{min}$	0
raised/2	$125 - N_{min}$	$145 - N_{min}$	$2 * (100 - N_{min})$
raised/1	$125 - N_{min}$	$145 - N_{min}$	$100 - N_{min}$
raised/0	$125 - N_{min}$	$145 - N_{min}$	0

[1] The official Dutch recommendation for SNA-soil.

Table 2. N applications, marketable yield and total N uptake at harvest in 2002 and 2003.

Treatment	N-application (kg N ha^{-1})			Yield	N-uptake
	1st period[1]	2nd period[2]	Total	(t ha^{-1})	(kg N ha^{-1})
2002:					
SNA-soil:					
standard	145	65[3]	210	47.9	283
standard/½	145	30	175	46.4	260
standard/0	145	0	145	47.0	237
raised/2	210	40	250	47.3	283
raised/1	210	20	230	45.6	270
raised/0	210	0	210	46.3	267
Crop Scan method	128	20	148	46.8	258
LSD (P = 0.05)				2.5	19
2003:					
SNA-soil:					
standard	0	95[4]	95	46.2	278
standard/½	0	45	45	46.6	255
standard/0	0	0	0	44.5	215
raised/2	40	75	115	46.0	279
raised/1	40	40	80	47.4	263
raised/0	40	0	40	45.4	240
Crop Scan method	55	58	113	47.0	267
LSD (P = 0.05)				2.8	27

[1] Until 3 months after transplanting.
[2] 3 months after transplanting till harvest.
[3] 55 kg N ha^{-1} if N_{min} in the soil layer 0-0.60 m would have been taken into account.
[4] 70 kg N ha^{-1} if N_{min} in the soil layer 0-0.60 m would have been taken into account.

Figures

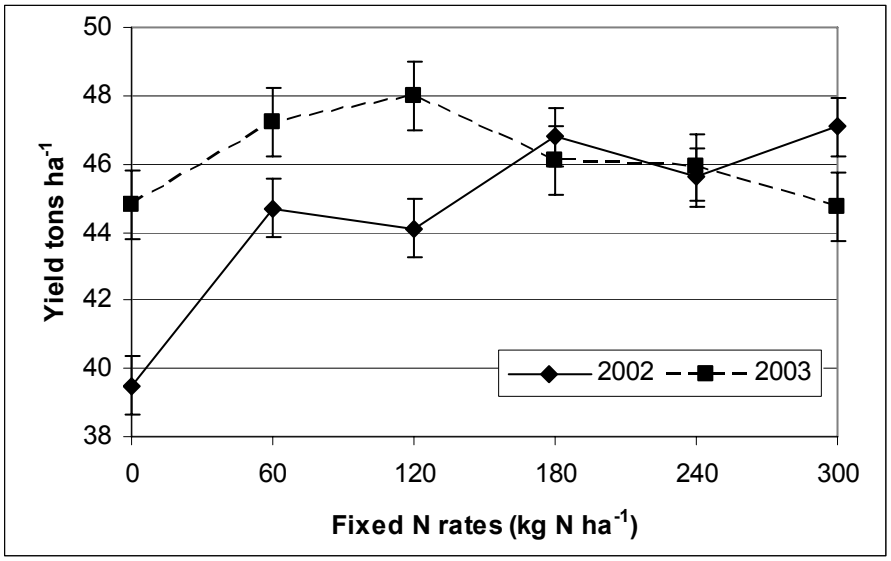

Fig. 1. Yield at the fixed, split N rates. Vertical bars represent SE.

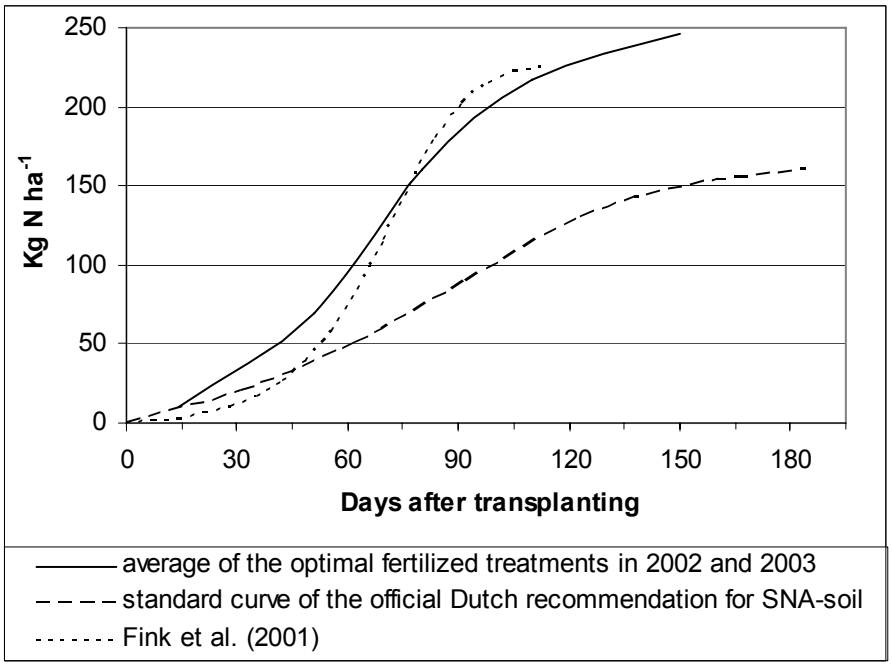

Fig. 2. Nitrogen uptake curves of leek.