Supplementary Nitrogen Application in Leeks, Based on Determination of Crop Nitrogen Status

Remmie Booij and Bert Meurs
Plant Research International
P.O. Box 16
6700 AA Wageningen

Keywords: Leeks, nitrogen, fertilization, light interception, nitrogen uptake

Abstract

From a number of basic relationships between several crop ecological components (Booij et al., 1996a) a system was developed for giving supplementary nitrogen application in leeks, that was based on the measurement of light interception. A description of the approach is given and a comparison is made with existing systems for supplementary nitrogen application. A comparison was made for four aspects: nitrogen input, yield, quality and residual mineral soil nitrogen. The system based on the measurement of light interception performed in general as well as a system that was based on the determination of soil mineral nitrogen. However, the system based on the measurement of light interception is easier to use and provides a recommendation instantaneously. For both systems yield and quality were the same as for the standard recommendation but nitrogen input was less and residual mineral soil nitrogen was reduced.

INTRODUCTION

In most horticultural crops nitrogen fertilizer is applied to obtain optimum marketable yield and quality. For most crops recommendations of nitrogen fertilizer application rates are given (Smit and van der Werf, 1992). Although the optimum rate can be determined experimentally a large variation in optima can be observed due to the strong influence of environmental conditions (Van Keulen & Stol, 1991). In most field grown vegetables the range of optima is relatively broad, because the economic optimum is difficult to establish due to the low costs of fertilizer in relation to the financial yield (Uthe, 1990). Moreover, in many crops there is no clear yield optimum with dose response curves having a plateau. These two aspects allow the grower to apply high amounts of fertilizer, partly as insurance, and when applied at recommended rates, crops differ in their use of applied nitrogen fertilizer (Smit & Van der Werf, 1992). A poor utilization of N-fertilizer means that nitrogen is lost to the environment. In the last decade it became obvious, that current practice adversely affects the environment due to high losses of nitrogen (leaching, denitrification) to the environment (Greenwood, 1990; Neeteson et al, 1999; Rahn, 2000)).

To reduce environmental pollution, nitrogen application, the nitrogen supply during crop growth should be matched with the crop nitrogen demand during the period of crop growth, in order to maintain yield and quality to maximize economic returns. This means that crop growth should be monitored and nitrogen applied at certain set points according to the need.

The present paper describes an approach to achieve this goal and the first results of field experiments in which the approach was tested.

THE CONCEPT

The key issue in the concept of meeting supply and demand is controlling the nitrogen application based on the crop nitrogen status. The scheme in Figure 1 shows the outline of the concept. The present crop nitrogen status is determined and based on the targeted crop nitrogen status on a fixed date in the future (set-point), a certain amount of nitrogen is applied. The cycle can be repeated several times during crop cultivation.
Within the concept two components are essential, namely:

1. A method to monitor the crop nitrogen status
2. A series of decision rules based on set points for crop nitrogen status.

The concept developed for leeks is based on earlier results regarding the nitrogen husbandry in leeks (Booij et al., 1996a), and consists of the following components.

1. A relationship between nitrogen uptake and dry matter production. Total crop dry matter production increases with increasing nitrogen uptake and levels off at higher nitrogen uptake (Booij et al. 1996a, Fig. 3b). In this figure the relationship is presented at number of times during crop growth. From this curves the required nitrogen uptake at a certain time to achieve 95% of the maximum dry matter production can be calculated (Booij et al. 1996a, Fig. 4c). The slope of this line represents the nitrogen concentration and can be regarded, as the minimum nitrogen concentration needed to obtain maximum growth rate. This optimum nitrogen concentration during crop growth will be regarded as the set points for crop nitrogen status.
2. So to determine crop nitrogen status, total nitrogen uptake and total dry matter production need to be determined. Total dry matter production can be estimated from the accumulation of intercepted photosynthetically active radiation (Booij et al. 1996a, Fig. 9). So if the fraction of intercepted radiation is measured regularly (e.g weekly) and the total incoming radiation is measured continuously a determinant of one of the components of the crop nitrogen status, total dry matter production, can be determined.
3. The other component of the nitrogen status, namely total nitrogen uptake is linearly related to the leaf area index (Booij et al.1996a, Fig. 8b). On the other hand the leaf area is related to the fraction of intercepted light (Booij et al. 1996a, Fig. 7b). So by measuring the fraction of intercepted light, the leaf area index can be estimated and by that the total crop nitrogen uptake. Given total nitrogen uptake and dry matter yield, nitrogen concentration can be compared with the set point

From this analysis it becomes clear that the measurement of light interception can be used to estimate the two components of crop nitrogen status, as there are total nitrogen uptake and total dry matter production, which together represent the nitrogen concentration. So by measuring light interception, crop nitrogen status can be monitored.
From the same analysis the set point for the crop nitrogen status became evident, namely a constant total nitrogen concentration during the whole crop growing period (Booij et al., 1996a).

Based on this information a system was designed to decide on supplementary N application. The approach is given schematically in Figure 2.

TESTING THE CONCEPT

The performance of the recommendation system for supplementary nitrogen application as based on the measurement of light interception was tested in a number of field experiments and compared with other systems for supplementary nitrogen application in leeks such as the Dutch recommended split application rate and a supplementary N application system based on soil available mineral nitrogen (NBS or KNS Lorenz et al., 1989). Preliminary results will be presented in this paper.

DESCRIPTION OF THE TESTING CONDITIONS

The experiment was carried out in 1999 on a sandy soil (Booij et al., 1996a). The following systems of supplementary N application were compared.

1. Recommended split application (120- Nmin kg/ha at planting; 75 kg/ha 8 weeks after transplanting and 75 kg/ha at 12 weeks after transplanting. Nmin is the mineral nitrogen present in soil layer 0-30 cm) (Van Dijk, 1999).
2. NBS (85- Nmin at transplanting; 105- Nmin at 8 weeks after transplanting and 100- Nmin at 12 weeks after transplanting. Nmin is the mineral nitrogen present in soil layer 0-30 cm at 8 weeks after transplanting; for the N application 12 weeks

after transplanting Nmin is mineral nitrogen present in soil layer 0-60 cm) (Gröniger & Soorsma, 1991)

3. Light Interception concept. (no nitrogen fertilizer at transplanting and from 8 weeks after transplanting every four weeks light interception was determined and supplementary nitrogen was applied in accordance). As the system based on light interception is only at its start of development, while the others are already proven, two versions were of the system based on light interception were included. One "standard" (LI100) in which the nitrogen rate was supplied as calculated from the relationships as given in the concept description. In a second one (LI150), the supplied amount was 1.5 times higher than the "standard". This was done to validate the necessary set points.

The leek crop (cv Davina) was transplanted on June 9 at 75* 9 cm and the final harvest was on October 26. After supplementary N application the crop was irigated.

The three systems were compared for final yield (total plant fresh weight), quality (nitrogen concentration, being a characteristic that is very closely related to the green color (Booij et al, 1996b)) and the effect on the environment (residual mineral nitrogen at the final harvest in the soil layer 0-60 cm).

RESULTS

The performance of the three systems was judged on three different aspects being the effect on: total nitrogen fertilizer input, yield (total fresh), quality and environment.
Similar yields (no significant differences) were reached in three of the four occasions (Fig. 3). Only in the system based on light interception in which 100% of the calculated N rate was applied (LI100), yield was significantly lower (Fig. 3).

The quality of the produce, as judged by the plant nitrogen concentration, being a main determinant of color, was the same in the system based on mineral soil determination (NBS) and the one based on the measurement of light interception. The nitrogen concentration of the plants that were fertilized according to LI100 had a significantly lower nitrogen concentration than when fertilizer was applied according the standard split application (Fig. 3).

Total nitrogen input from fertilizer varied significantly between the systems, the highest input was on the plots that were fertilized according the recommended split application and lowest if supplementary nitrogen was applied according the NBS and the LI100 system (Fig. 3). An important environmental characteristic of the systems is the residual nitrogen in the soil at harvest, this nitrogen is most likely to leach during the succeeding winter period. The lowest Nmin levels were found if nitrogen was applied according the NBS or the LI100 system and was highest if nitrogen was applied according the recommended rate (Fig. 3).

DISCUSSION

The amount of mineral nitrogen in the soil varies during the growing season, because it can originate from different sources (soil organic matter of manure), is very mobile (risks of leaching) and the nitrogen uptake is not constant (Neeteson et al., 1999). This means that it is difficult to predict the amount of nitrogen needed at the start of crop growth which not only aims at a certain yield and quality level, but also aims at minimal losses to the environment. Withholding part of the nitrogen dose at planting and make a decision later whether or not to apply supplementary nitrogen during crop growth, makes it possible to utilize the nitrogen from other sources (in particular from organic sources) better.

A standard split application can be only beneficial for the environment, if nitrogen losses are likely to occur during the early phase of crop growth. Environmental benefits from split application can be obtained if the decision on the next application is based on determination of the soil mineral supply or nitrogen status and the estimated demand for the forthcoming period. In this case the supplementary nitrogen will only have to be applied if other nitrogen sources deliver insufficient nitrogen to support the foreseen growth.

In the present paper a system for supplementary nitrogen application is shown that using which allows a reduction in nitrogen input and results in a potential loss to the environment, whilst maintaining yield and quality. Both systems, the existing one that is based on the soil mineral nitrogen supply (NBS) and the new approach that is based on the determination of crop nitrogen status, were able to produce a good crop (quantity and quality) at a lower nitrogen input (Fig. 3). Comparing both systems the nitrogen input in the system based on soil nitrogen was lower (Fig. 3). However, it should be mentioned that the new approach was tested under relatively severe conditions, as no fertilizer was applied at all at planting. A low application rate at the start might have resulted better. This will be examined in future experiments.

The set points for the crop nitrogen content of the crop were derived from earlier observations (Booij et al., 1996a). If nitrogen was applied (LI100) according to these relationships (Fig. 3), yield was reduced (Fig. 3). This might be due to the fact that the relationships were based on dry matter production, while for marketable yield plant fresh weight is important. Booij et al (1994) have shown that the relationship between nitrogen uptake and dry matter production on one hand and fresh weight on the other is not the same. Also in other crops it is shown that there is a relationship between nitrogen concentration and dry matter concentration (Everaarts and Booij., 2000). A higher nitrogen concentration is accompanied by a lower dry matter concentration. This might have partly caused the better performance of the LI150 treatment, in which more nitrogen was applied than according the relationship between nitrogen uptake and dry matter production was needed. This means that research to increase the precision of the set points during crop growth is needed.

The preliminary experiment shows that it is possible to apply supplementary nitrogen based on crop nitrogen status estimated, using the measurement of light interception. An advantage in comparison with a system based on the determination of the mineral soil nitrogen (e.g. NBS) is the instant outcome. In principle the nitrogen status can be determined in the field and the recommendation can be given instantaneously and the nitrogen can be applied accordingly. For other corps (e.g. wheat and potatoes) similar systems are under development, but in these cases crop light reflection is used as a crop nitrogen status determent and not light interception (Heege and Reus, 1997; Booij and Uenk, 2001). In addition systems are under development in which the supplementary nitrogen rate is based on the outcome of simulation models (Booltink and Verhagen, 1997), in which the balance between nitrogen uptake and nitrogen availability is simulated (Rahn, 2000).

It is clear that systems based on the determination of crop nitrogen status or on the outcome of simulation models need further development, but the prospects are good, so that nitrogen supply can be more accurately matched to crop demand, avoiding over fertilization. and negative effects of production on the environment can be reduced.

ACKNOWLEDGEMENT

We want to thank dr Clive Rahn for his comments on the manuscript.

Literature Cited

Booij, R., Enserink, C.T., Smit, A.L. and Van der Werf, A. 1994: Nitrogen fluxes in the crop-soil system of Brussels sprouts and leek. In: P.C. Struik, W.J. Vredenberg, J.A. Renkema and J.E. Parlevliet (eds.), Plant Production on the Threshold of a New Century, Wageningen, pp. 179-185.

Booij, R, Kreuzer, A.D.H., Smit, A.L. and Van der Werf, A. 1996a. Effect of nitrogen availability on dry matter production, nitrogen uptake and light interception of Brussels sprouts and leeks. Netherlands Journal of Agricultural Science 44:3-19.

Booij, R, De Willigen, P., Kreuzer, A.D.H., Smit, A.L. and Van der Werf, A 1996b. Nitrogen balances during growth of Brussels sprouts and leeks, Acta Hort. 428:31-43.

Booij, R and Uenk, D. 2001. Monitoring crop nitrogen status in potatoes, using crop light

reflection. G. Grenier, S. Blackmore and J. Steffe (eds.), Proceedings 3rd European Conference on Precision Agriculture, 893-897.
Booltink, H.W.G. and Verhagen, J. 1997 Using decision support systems to optimize barley management on spatial variable soil. In: Application of systems approaches at the field level, .M.J. Kropff et al. (Eds.), Dordrecht: Kluwer Academic Publishers, pp 219-233
Everaarts, A.P. and Booij, R. 2000.The effect of nitrogen application on nitrogen utilization by white cabbage (*Brassica oleracea* var. *capitata*) an on nitrogen in the soil at harvest. Journal of Horticultural Science and Biotechnology 75:705-712.
Greenwood, D.J. 1990. Production or productivity: The nitrate problem? Annals of Applied Biology 117:209-231.
Gröninger, H and Soorsma, H.E. 1991. Stikstofbijmestsysteem (NBS) voor enige vollegrondsgroentegewassen. Informatie en Kennis Centrum Akker- en Tuinbouw, Lelystad.
Heege, H.J and Reusch, S. 1997. Zur teilflächenspezifischen Stickstoff-Kopfdüngung *Landtechnik*. 52 126-127.
Lorenz, H.P., Schlaghecken, J., Engl, G., Maync, A. and Zegler, J. 1989. Ordungsgemässe Stickstoff Versorgung im Freiland Gemüsebau KNS system. Rheinland Phalz: Minissterium für Landwirtschaft, Weinbau und Forsten.
Neeteson, J.J., Booij, R. and Whitmore, A.P. 1999. Sustainable nitrogen management in intensive vegetable production systems. Acta Hort.
Rahn, C.R. 2000. Nitrogen and field production of vegetable crops. Acta Horticulturae 533:361-369.
Smit, A.L. and Van der Werf, A. 1992. Physiology of nitrogen uptake and utilisation. (In Dutch) In: H.G. Van der Meer & J.H.J. Spiertz (Eds.). Stikstofstromen in agro-ecosystemen. Agrobiologische Thema's no. 6, DLO-Centrum voor Agrobiologisch Onderzoek (CABO-DLO), Wageningen, pp. 51-69.
Van Dijk, W. 1999. Adviesbasis voor de bemesting van akkerbouw- en vollegrondsgroentegewassen. Praktijkonderzoek voor de Akkerbouw en de Vollegrondsgroenteteelt, Publicatie nr 95.
Van Keulen, H. and Stol, W. 1991 Quantitative aspects of nitrogen nutrition in crops. Fertilizer Research 27 151-191.
Uthe, R. 1990. Auswertung von Stickstoffdüngungsversuchen bei Gemüse mit dem Linear Response and Plateau Modell. Gartenbauwissenschaft 55:247-251.

Figures

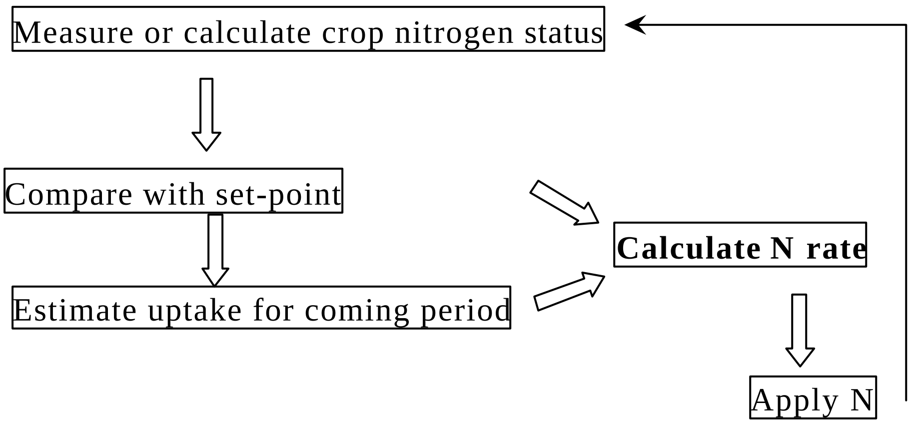

Fig. 1. Schematic representation of supplementary N application.

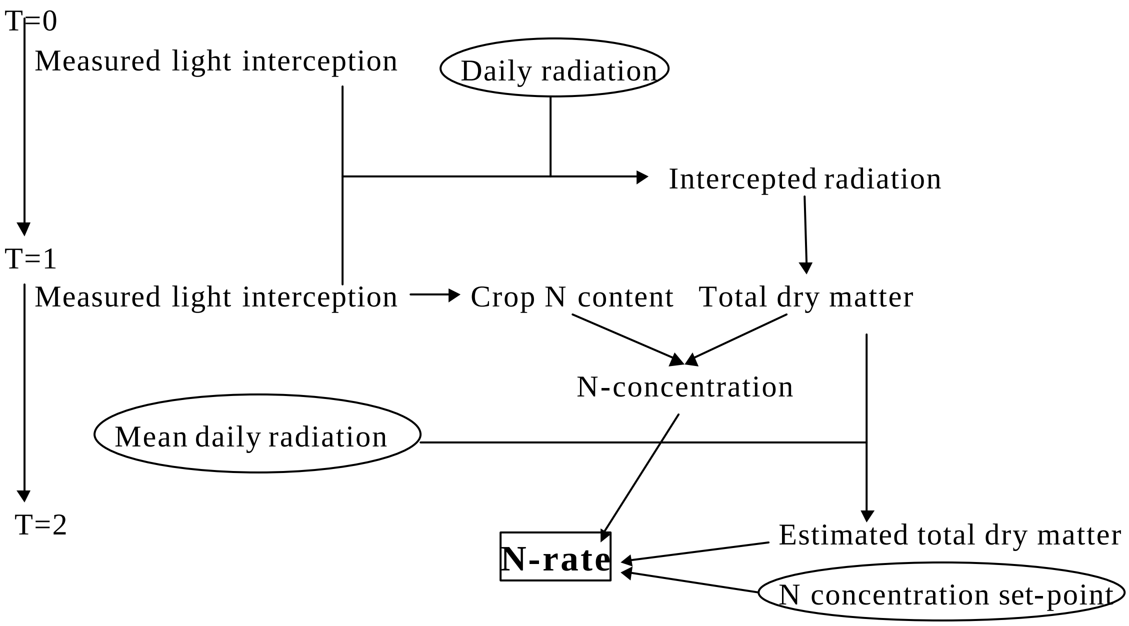

Fig. 2. Lay out of system for supplementary N application based on the measurement of light interception

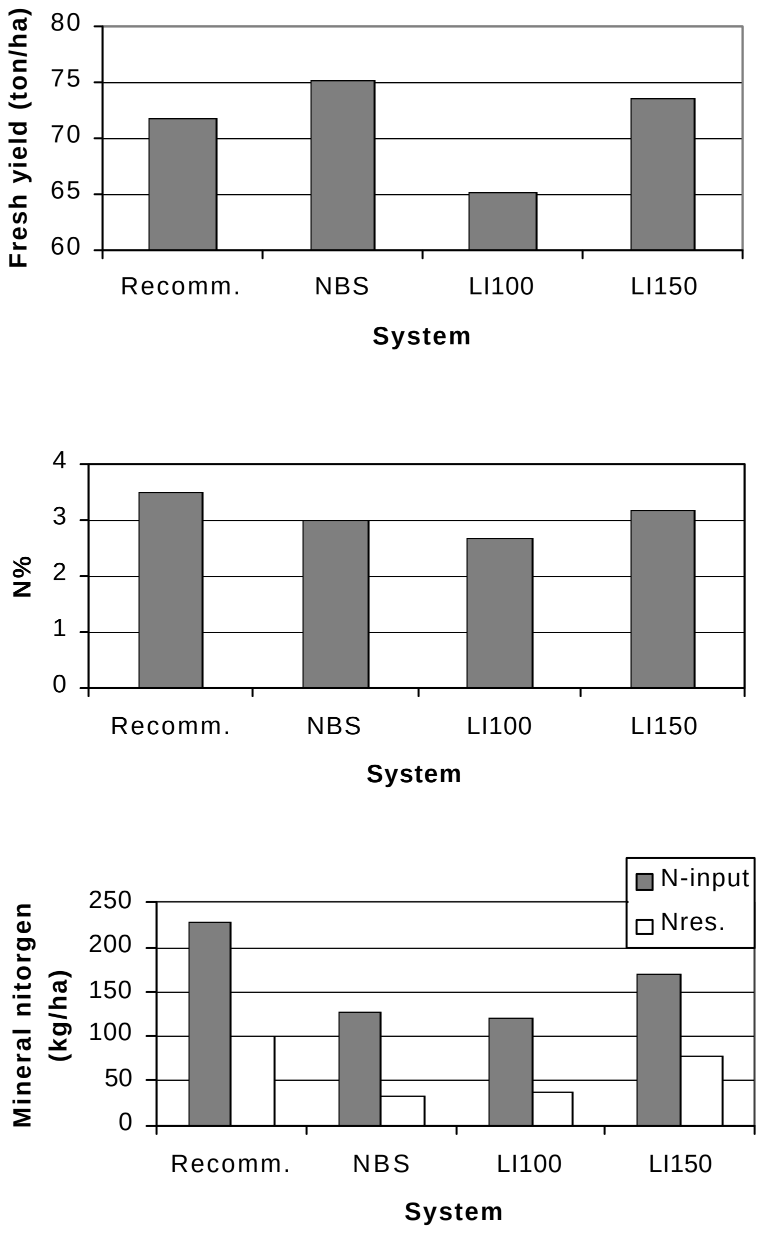

Fig. 3. The effect of a N application system on the final fresh yield, the total plant nitrogen concentration at the final harvest and the total nitrogen input (applied total N fertilizer) and the residual mineral soil nitrogen (0-60 cm) at the final harvest.