USE OF THE ANALYSIS OF PLANT GROWTH AND NUTRIENT UPTAKE FOR NITROGEN FERTILIZER RECOMMENDATIONS IN OPEN AIR VEGETABLE GROWING.

H.H.H. Titulaer
Research Station for Arable Farming and Field Production of Vegetables
POB 430
8200 AK Lelystad
The Netherlands

J.H.G. Slangen
Agricultural University
Dept. of Soil Science and Plant Nutrition
PAB 8005
6700 BC Wageningen
The Netherlands

Keywords: gherkins, iceberg lettuce, nutrient uptake, nitrogen fertilization.

Abstract

The plant growth and nitrogen uptake pattern of a crop with a short production period (iceberg lettuce) grown at two different periods in the growing season and a crop with a long growth period (gherkins) are analyzed in order to formulate an improved nitrogen fertilizer recommendation. A split fertilizer application which is tuned to the uptake pattern of the crop and the mineral content of the soil(0-30 cm) or the removal of nitrogen from the field. In this way it is expected that the fertilizer will be used more effectively and nitrogen losses by leaching will be prevented or decreased.

1. Introduction

The nitrogen recommendation for open air vegetable production in the Netherlands is based on the measurement of the nitrogen content of the soil to a depth of 60 cm (Nmin) shortly before planting or sowing (Breimer 1989). The recommendation is aimed at a maximum marketable yield for all vegetables. However for leafy vegetables the recommendation, additionally, takes aim at a low nitrate content. This method is used whether the growth period of a crop is short (butterhead or iceberg lettuce 5 - 8 weeks) or long (red cabbage 5 - 8 month) and irrespective if only the vegetative parts (lettuce, cabbage), flowers (cauliflower) or fruits (gerkins) are harvested. The nitrogen application is done as a basal dressing or as a split application.

The currently used recommendation does not take account of the uptake pattern of the crop and the change in availability of soil nitrogen with time. The nutrient uptake of the plant will take place mainly in the upper 30 cm of the soil in these well irrigated crops.

The recommendation could be improved if account is taken of the nitrogen uptake pattern of the plant and the availability of the soil nitrogen. The availability of the soil nitrogen can directly be determined in the top 30 cm of the soil (Nmin) or by the content of nitrogen in the harvested parts. The uptake pattern can be analyzed and used for the adjustment of demand and supply of nitrogen. If the uptake

pattern is known the nitrogen application can be tuned to the expected production and loss of nitrogen can be restricted.

The plant growth and nitrogen uptake pattern of a crop with a short production period (iceberg lettuce) grown at two different periods in the growing season and a crop with a long growth period (gherkins) are analyzed. The results of the analysis are used to study if the supply of nitrogen to the plants can be improved by taking account of the results of the growth analysis.

2. Material and Methods

Field experiments with iceberg lettuce *Lactuca sativa, L* and gherkins *Cucumis sativus, L* were carried out at various Regional Experimental Stations at different soil types. The crops were grown according to common practice.

Each season two crops of iceberg lettuce were grown. The plant density ranged from 82 369 (1986) till 91 827 (1987) plants per ha. The crop was either dressed with a broadcasted application of ammonium nitrate limestone before planting, or fertigated in 4 (1986) or 3 (1987) portions. The amount of applied nitrogen was equal to (200 - Nmin) kg per ha.

The crop was harvested every week and fresh and dry weight were determined of marketable product and crop remains. By multiplying the total nitrogen in aerial parts with 10/9 it was assumed that the total nitrogen uptake including the roots was well approximated.

Gherkins, cultivar "Othello", were grown in rows (row distance 1.50 m). In each row pairs of plants were planted at a distance of 0.40 m. The main shoots were tied up with ropes to a height of 150 - 200 cm. The total plant density was 33 334 plants per ha. The crop received a basal dressing of P, K and Mg before planting and received a weekly dressing of nitrogen by drip irrigation. The drip irrigation diminished the introduction of serious diseases e.c. mildew as is the case by sprinkler irrigation because the leaves are readily infected if they are wet for longer periods.

The total amount of nitrogen applied, was equal to (260 - Nmin) kg per ha and was given in equal weekly portions. The fertilizer given with the drip irrigation was a concentrated solution of 19-6-6 (trade mark Kristalon lila).This solution was diluted 1:100 by injection in the well water and resulted in a 1 gram per liter concentration at the emitters.

The crop was harvested every two weeks and fresh and dry weight were determined of main shoot, side shoots and fruits. By multiplying the total nitrogen in aerial parts with 10/9 it as assumed that the total N uptake including roots was well approximated.

The soil was analyzed for nitrogen (Nmin) to a depth of 60 cm before planting and for nitrogen to a depth of 30 cm at each harvest. NO3 and NH4 were determined in 1 M KCl extracts of field moist samples (Houba et al., 1986).

The plant parts were dried for 24 hours at 70°C weighed, grounded, and stored for chemical analysis. The dried plant samples of all experiments were digested, extracted and analysed for nutrient concentration (Houba et al., 1986).

3. Results and discussion

The utmost care was taken to collect all plant material of the field and to take proper samples for nutrient analysis in order to get reliable nutrient uptake figures. It should be realised that the non marketable products remaining in the field are a source of nutrients to the next crop.

3.1 Iceberg lettuce

The average fresh marketable yield and nitrogen uptake of iceberg lettuce of the experiments are presented in figure 1. Each curve is the average of separate experiments at the Regional Experimental Station conducted in spring and summer of 1986 and 1987. The shown nitrogen uptake has been calculated while taken into account all plant parts. The marketable produce(heads) contained about the half of the nitrogen taken up.

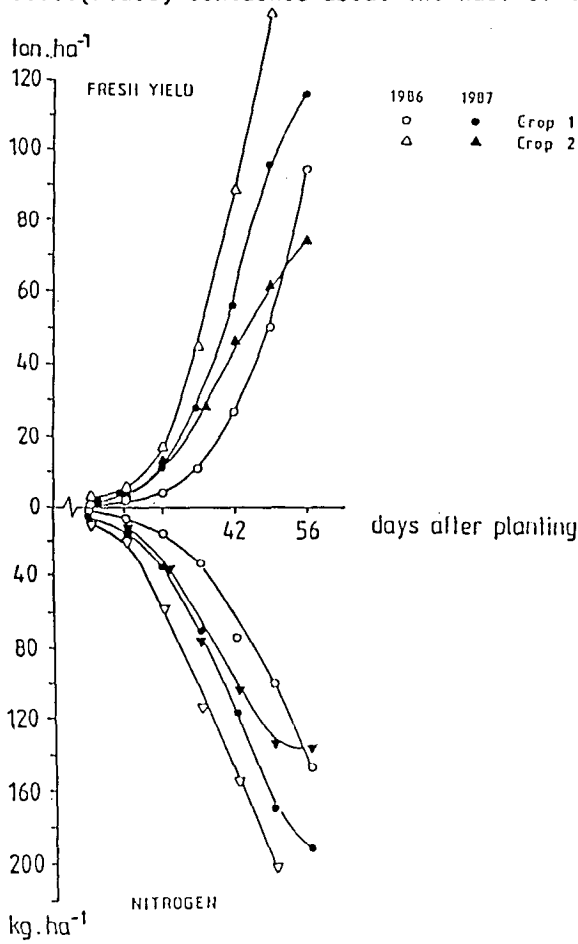

Figure 1 - Yield (ton.ha^{-1}), and Nitrogen uptake (kg.ha^{-1}) of whole plants of iceberg lettuce in 1986 and 1987 (2 crops each year) during the growth period. Exp. Station "Westmaas" at Westmaas (Slangen et al., 1989).

Iceberg lettuce shows distinct growth phases. An initial one with an increasing growth and nitrogen accumulation rate and a linear one with a constant growth and nitrogen accumulation rate. The initial growth ends as the crop starts heading. The start of heading is faster in the summer crop then in the spring crop. In the initial growth phase only 8 to 20 kg/ha is needed. In the linear growth phase an uptake of about 8 kg N per ha per day is needed. This nitrogen uptake pattern is independent of the year or the season of growth as shown in figure 2.

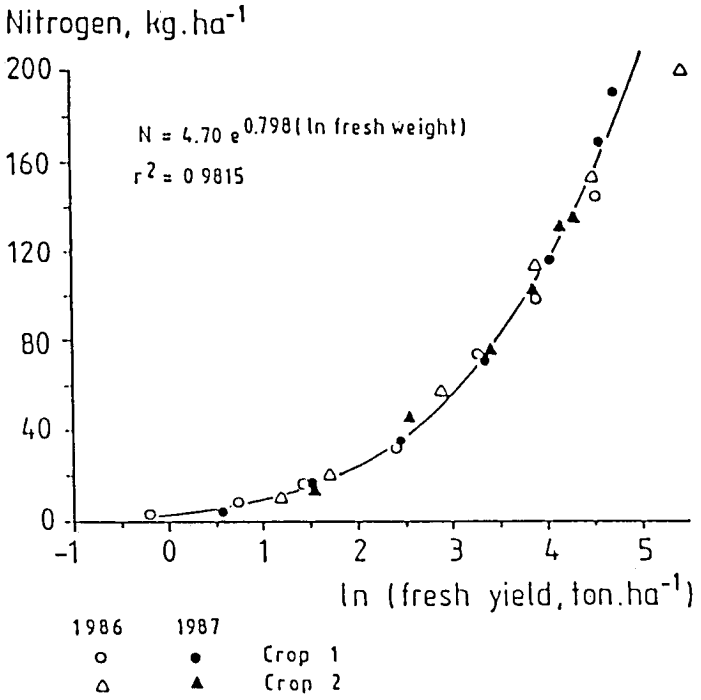

Figure 2 - Nitrogen uptake by iceberg lettuce ($kg.ha^{-1}$) in relation to fresh production (in scale, ton ha^{-1}) in 1986 and 1987 with to crops a year. Exp. station "Westmaas" at Westmaas.

The observed growth and uptake pattern can be used to formulate an improved nitrogen fertilization recommendation. The requirement of nitrogen can be divided on two. The requirement in the initial growth phase and the requirement in the second growth phase. Just before each period the mineral nitrogen content has to be determined (Nmin before planting and Nmin before heading). Because of the shallow root system of the crop a sample from 0 - 30 cm depth is sufficient to assess the mineral nitrogen availability in the soil. In each period an amount of nitrogen fertilizer has to be added in addition to the amount present in the soil. The amount of nitrogen to be given in each period can be read from figure 3. However to be on the safe side in each period an extra gift of 40 kg per ha is given as a kind of buffer. In the initial growth phase of a spring crop the amount of fertilizer to be added is

[25 + 40] - Nmin. In the linear growth phase an amount of [110 + 40] - Nmin has to be given. In the initial growth phase of a summer crop with a growth period of only 7-8 weeks the amount of fertilizer to be added is higher [55 + 40] - Nmin. In the linear growth phase an amount of [115 + 40] - Nmin has to be given.

On a sandy soil the following recommendation is formulated. In the initial growth phase of a crop the amount of fertilizer to be added is [60 + 40] - Nmin. In the linear growth phase an amount of [125 + 40] - Nmin has to be given.

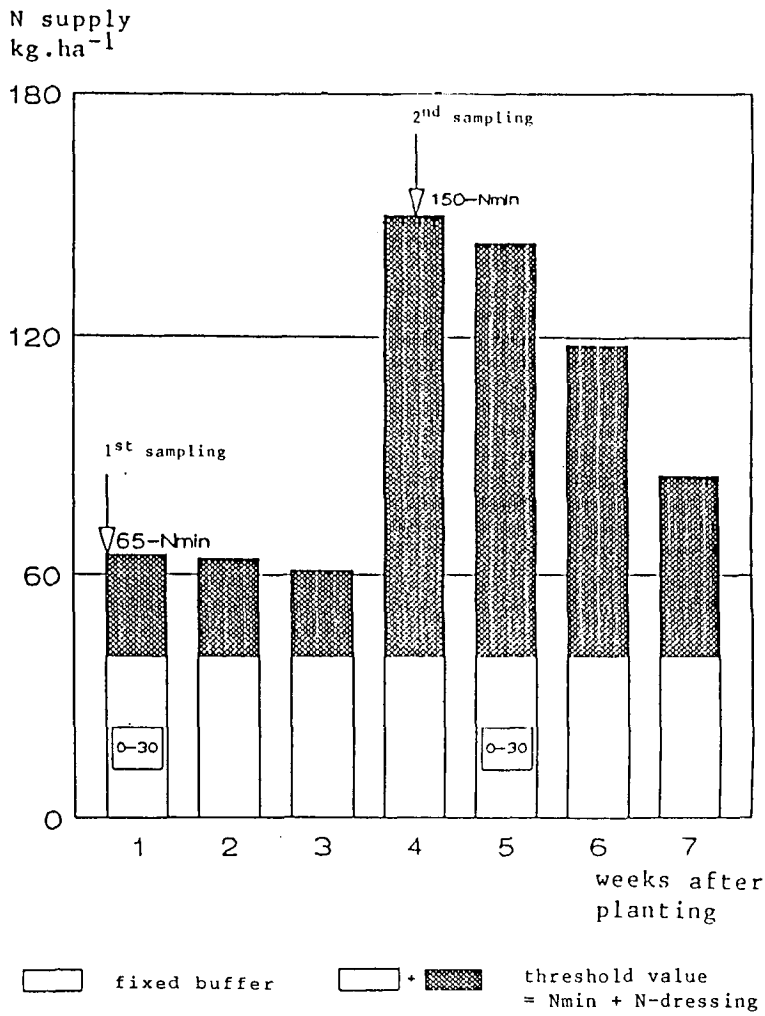

Figure 3 - Threshold values for Nitrogen in soils (kg N ha^{-1}, 0-30 cm) for iceberg lettuce on marine clay soil at two sampling times. (Anonymus, 1989).

3.2. Gherkins

The uptake of nitrogen by the various parts of the plant are shown in figure 3. From this figure it can concluded that the uptake pattern can be distuinguished in three periods:
- period 1 before flowering (till 2.5 month after planting)
- period 2 main fruiting period (2.5 - 4.5 month after planting)
- period 3 senescence (> 4.5 month after planting).

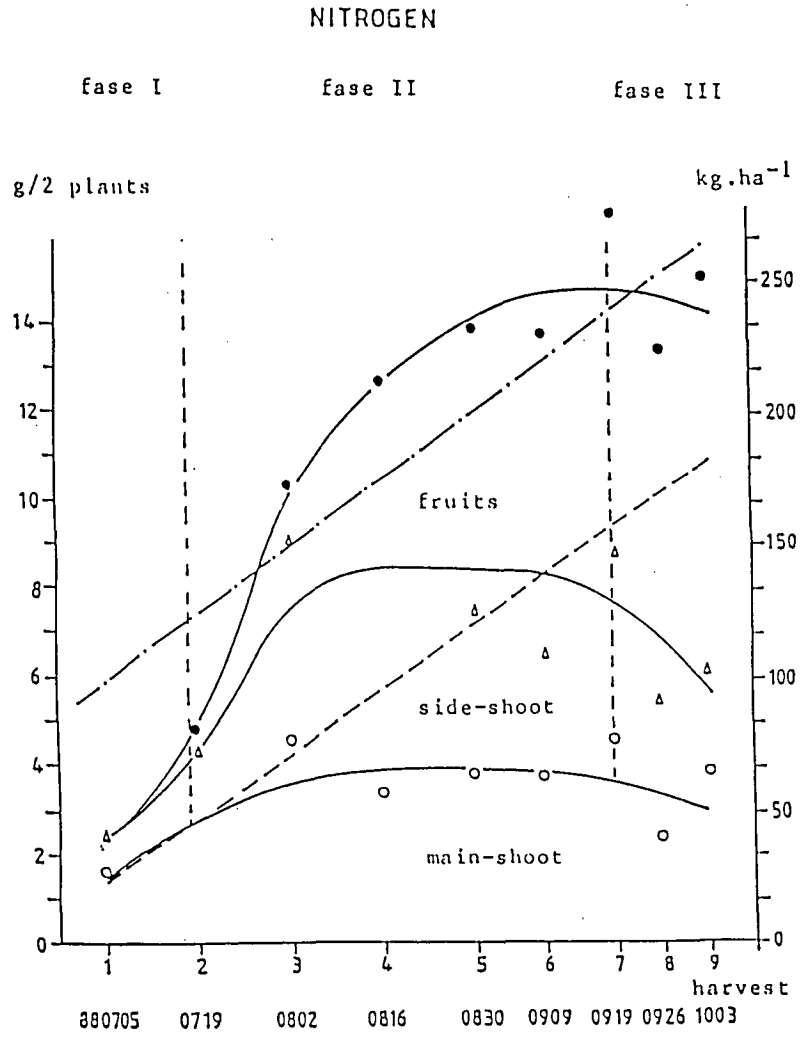

Figure 4 - Nitrogen (g/plant and kg.ha^{-1}) taken up by gherkins in main shoots, side shoots and fruits during the growing period. Experiment 1988 Horst: -- N via fertigation; -.-N supply (N in soil and via fertilizers).

The following fertilizer advice can be constructed from the observed nitrogen uptake pattern.
Before planting a broadcast application of [30 + 40] - Nmin. Again to be on the save side an buffer amount of 40 kg has been included.

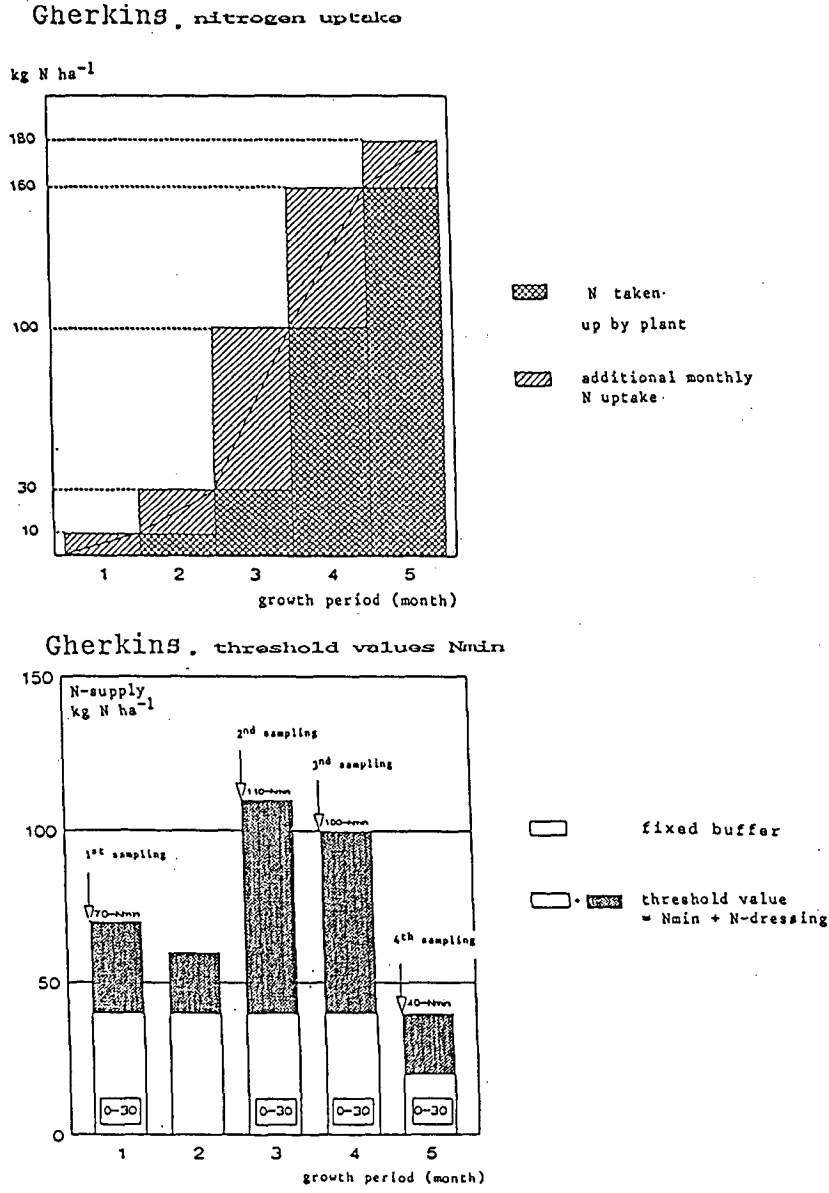

Figure 5 - The monthly uptake of Nitrogen (kg.ha^{-1}) by gherkins during the growing period, and threshold values for nitrogen in soils (kg N ha^{-1}, 0-30 cm) at different sampling times. (Anonymus, 1989).

For the following periods no use can be made of soil sampling because of drip irrigation. With drip irrigation nitrogen is contained in a cone shaped wetting zone which cannot be sampled reliably. Therefore the nitrogen removed from the field is used to guide fertigation. This can be done as the amount of nitrogen present in the vegetative parts does not change in the second and third period. So in the following five periods the amount of fertilizer to be supplied can be calculated by multiplying the weight of the fruits picked and the mineral content of the fruits and adding the buffer amount of 40 kg N. To diminish leaching in the last period the buffer amount is halved.

4. Concluding remarks

The following can be remarked about the possibilities for the use of growth and nutrient uptake curves.

Measurements of the mineral nitrogen (0-30) content of the soil at regular time intervals gives information about the nitrogen status of the soil.

Sampling has to be tuned to the development of the crop, as determination of the uptake during crop growth, gives information on nitrogen need and distribution of nitrogen in plant parts.

This can be used to adjust the supply of nitrogen as a fertilizer to the need of the crop.

In contrary with common practice this technique enables the grower to reduce fertilizer costs, helps him to prevent leaching and thus to increase efficiency of fertilizer use.

5.Acknowledgements

This paper could not have been written without the efforts made by technicians of the Experimental Station Westmaas and Horst, and the help of trainees of DSM Agro Specialties BV, Geleen, and a student of the Hannover University.

The authors thank Ir. W.A. Dekkers M.Sc. for editing of the text.

6. Literature

Anonymus (1989). Stikstofbijmestsysteem (NBS) voor enige vollegrondsgroentegewassen. Consulentschap voor Bodem-, Water-, en Bemestingszaken in de Akkerbouw en Tuinbouw. Wageningen.

Breimer, T., 1988. De stikstofbemesting van vollegrondsgroenteteeltgewassen en enige aromatische kruiden; richtlijnen en adviezen gericht op Nmin-onderzoek. Ad Fumdum 6, 53-62.

Houba, V.J.G., J.J. van der Lee, I. Novozamsky and I. Walinga (1988). Soil and Plant analysis, a serie of syllabi: Part 5, Soil analysis Part 7; Plant analysis. Dept. of Soil Science and Plant Nutrition, Agric. Univ. Wageningen.

Slangen, J.H.G., H.H.H. Titulaer and C.A.E. Rijkers (1989). Nitrogen fertilizer recommendation with the KNS-system for iceberg lettuce (*Lactuca sativa var. capitata*) in field cropping. VDLUFA-Schriftenreihe 28, Kongressband 1988, Teil II. 251-261.