THE IMPORTANCE OF FERTIGATION FOR THE IMPROVEMENT OF N-FERTILIZER USE EFFICIENCY IN LETTUCE CULTURE

J.H.G. Slangen
Agricultural University
Dept. of Soil Science and
Plant Nutrition
De Dreijen 3
6703 BC Wageningen
The Netherlands

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

W. Glas
DSM Agro Specialities BV
Maliebaan 81
3581 CG Utrecht
The Netherlands

1. Introduction

Applying nitrogen (and/or other nutrients) through the irrigation system during cultivation is called fertigation. The system offers a means to adjust the supply of N to the nutritional need of the crop, thus limiting NO_3 leaching and luxury consumption of N, which in leafy vegetables can lead to unacceptably high NO_3 contents. In the following, fertigation is compared with broadcast dressing, up till now the usual practice in the Netherlands in open-air cropping.

Conditions for a successful fertigation system are (Goldberg, 1976; Bucks et al., 1982):

- soluble fertilizers, if possible with minimum corrosive effects,
- good water quality: sand or undissolved particles can block tubes and/or emitters of sprinkler/trickle-irrigation systems. Ca and Mg or Fe may precipitate if the pH of the water is too high. Activity of micro-organisms in tubes and emitters or drippers must be prevented,
- a distribution system with storage facilities for water and concentrated nutrient solution, distribution tubes to sprinklers or drippers, a control system (EC, nutrient concentration), time switches, etc. for automatic operation of pumps and for control of fertigation.

Modern materials and techniques are available to develop an efficient system and most Dutch vegetable growers already have a more or less automatic system for distributing water in dry periods.

2. Materials and methods

For experimental work a system was used for uniform distribution of water or water + nutrients on small plots (Fig. 1). Different solutions can be employed in the same trial and their application can be regulated per plot. As the emitters on the tubes are directed upwards, uneven distribution of solutions is prevented, although wind effects must be accepted.

During spring and summer of 1983, 1984 and 1985 three different cultivars of head lettuce (*Lactuca sativa* , L) were grown successively on a sandy soil (table 1) of the Experimental Station "Noord Brabant" at Breda. For each of these experiments the treatments were: no N application (control), and varying amounts of ammonium nitrate applied either in split application through the sprinkler irrigation system or broadcast before planting.

After harvest the yield was determined and dried plant material was analysed for a.o. NO_3 content (Houba et al.,1986).

In 1984 and 1985 attention was also given to the degree of uniformity of the heads. With the weights of individual heads (20 per plot = unit) coefficients of variation were calculated ($VC = (S_x/\bar{x}) * 100$) and compared for the various methods of N-application.

N min (= NO_3-N + NH_4-N) in soil samples was determined before, two or three times during and at the end of the growth period of each crop (Houba et al., 1986).

The effect of method of N-application was statistically analysed by fitting the data to a 2nd-degree polynomial:

$$E(y) = a + b_1x_1 + b_2x_1^2 + b_3x_2 + b_4x_2^2 \quad \text{with}$$

b_1 and b_3, and b_2 and b_4 representing the regression coefficients of the linear and quadratic components, respectively, of the curves describing either the effect of broadcast fertilization $(b_1x_1 + b_2x_1^2)$ or of fertigation $(b_3x_2 + b_4x_2^2)$.

Differences resulting from variation in method of application change the equation into:

$$E(y) = a + b_1\delta x_1 + b_2\delta^2 x_1^2 + b_3x_2 + b_4x_2^2$$

Since the successive lettuce crops were grown on the same plots, the residual effects of the preceding cropping period on the N status of the plots with different N-dressing had to be accounted for in the equation. This was done by introducing the co-variable N_{min} (linear and quadratic) and the interaction terms $N_{min} * x_1$ and $N_{min} * x_2$.

With arbitrary values of δ (delta) in the range 0.50-1.50, the curve representing the data of broadcast N application could be shifted to obtain the best possible fit of the two curves. Values of δ $\neq$ 1.00 resulting in the best fit indicate the existence of significant differences, in other words variations in method of application resulted in significant differences in crop response.

The response of the crop might result in δ's > 1.00 if fertigation is raising yield; for NO_3-content, values of δ < 1.00 are preferred.

In 1986 trials were laid out to compare broadcast application and fertigation using NH_4NO_3 and 19-6-6 as fertilizers. The trials were on sandy soils of the Experimental Stations at Breda (mentioned before) at Horst (near Venlo in N.-Limburg) and at the Experimental Station Westmaas (South of Rotterdam) on a clay soil (table 1). Amounts of nitrogen applied were the same for all fertilizers. Besides head lettuce, iceberg lettuce, spinach and chinese cabbage were used as test crops.

3. Results and discussion

With reference to NO_3 contents of produce, the results in 1983 were not very promising for fertigation (Bakker et al., 1984). Yields were the same for both methods of N-application, but NO_3 contents were higher in fertigated lettuce plants. The latter can probably be ascribed to the fact that N dressing by fertigation continued until 1 or 2 days before harvesting.

The amounts of nitrogen applied in 1983 were the same for both application methods and for all three crops. From the results of crop 3 it could be seen that maximum yield was obtained with 180 kg N ha^{-1} and that with no N applied a yield of up to 35 kg of fresh lettuce per 100 heads was reached against 20 and 10 kg per 100 heads for crops 2 and 1, respectively. Apparently, nitrogen from prior dressings, from residual plant parts (roots, lower leaves of marketable heads, not marketable heads), and resulting from mineralization was available for the next crop and must be taken into account in the planning of future dressings.

In 1984, fertigation was terminated 10-14 days before the final harvest and, for both application methods, the amounts of N applied to successive crops decreased (Fig. 2).

Yield differences between broadcast application and fertigation of nitrogen were nil in crop 1, slightly positive for broadcasting but only at low N-levels in crop 2, and clearly positive for fertigation in crop 3. Maximum yields were found at N-levels of 180, 120 and 60 $kgha^{-1}$ for crop 1, 2 and 3, respectively, irrespective of application method (Fig. 2).

With regard to NO_3-contents, differences between application methods were small in crops 1 and 3. In lettuce plants of crop 2, NO_3 contents were relatively high, not only compared to values of crops 1 and 3 but also in view of the threshold value of 3500 $mgkg^{-1}$ FW pursued in the Netherlands. An increase in N_{min} caused by enhanced mineralization shortly before the harvest of the crop caused unexpectedly high levels of NO_3-N in the lettuce plants of crop 2.

The 1985 data (Fig. 3) could not be fitted to the 2nd degree polynomial and best "delta" model, the reason being heavy NO_3 leaching losses after basal application of all N before planting of the first two crops, due to excessive rainfall up to June 1985. Losses were lower when N was applied in small portions through fertigation.

NO_3-contents of lettuce were different for the two application methods, but for both well below the threshold value mentioned.

The distribution of nitrogen in the profile (crop 1, layers 0-30 and 30-60 cm; Fig 4.) shows the leaching of nitrogen broadcast before planting (treatments B3 and B5 with N=210 and 270 $kgha^{-1}$, respectively). Fertigation with split applications up to 270 (F8) and 300 (F10) $kgha^{-1}$ kept most of the nitrogen in the upper soil layer around the root mass.

For the second crop with broadcast treatments 3 and 5 (N=140 and 180 $kgha^{-1}$, respectively, and fertigation F8 and 10 (N=120 and 160 $kgha^{-1}$, respectively, leaching was substantial, with more uniform N-concentrations in the 0-30 cm layer with fertigation.

The degree of uniformity of lettuce plants was visualized with scores given by experts of the Advisory Service. Variation coefficients for crops weights (table 2) were found to be lower for the fertigation treatments than for the no-N and broadcast treatments, irrespective of the amounts of nitrogen dressed.

Fertigation results in a more uniform crop with little variation in head weight and a more uniform appearance (color, head development). With this technique small doses of nitrogen can be applied frequently, during the growth of the crop, resulting in a more uniform distribution of N around the roots. Because of the risk of plant leaf damage, broadcast dressing, on the contrary, has to be practiced before planting. In that case, nutrients are less evenly distributed, so that for instance no nitrogen is available in the peat block with the seedling. A disadvantage of fertigation is that on wet soils some extra water has to be added to apply the nutrients.

The results of 1986 experiments with treatment combinations discussed before show (table 3):

- no differences between the two fertilizers, NH_4NO3-solution and KRISTALON 19-6-6 in their effects on yield, NO_3-contents and uniformity of the crop;
- equal yields with both application methods (all N broadcast before planting versus split application through fertigation) for 2 crops of lettuce at Horst and for iceberg lettuce at Westmaas; higher yields with fertigation for lettuce at Breda and chinese cabbage at Westmaas;
- a more uniform crop appearance and head weight for fertigated lettuce at Horst and Breda and for chinese cabbage and iceberg lettuce at Westmaas;
- NO_3 contents being mostly the same to somewhat higher for fertigation treatments.

Concluding remarks

About fertigation the following conclusions can be drawn:
The technique can be used if soluble fertilizers, water of a good quality, a distribution system for the nutrient solutions, control equipment for EC, nutrient concentration are available.

The yields of crops tested so far (lettuce, iceberg lettuce, chinese cabbage) have been the same as or better than with broadcast dressing before planting, as practiced nowadays.

The uniformity of the crops tested is improved with fertigation, due to absence of locally high concentrations of nutrients as experienced with broadcast application. NO_3-contents, as a quality characteristic of (leafy) vegetables, could be kept within the levels found with broadcast N-dressing, provided fertigation ceased 10-14 days before the final harvest.

Lower amounts of nutrients are needed and nutrient efficiency is increased with fertigation, as leaching is minimized. Under wet soil conditions, the necessity of adding additional water can be seen as a disadvantage.

4. Literature

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   Dept. of Soil Science and Plant Nutrition, Agricultural University Wageningen, the Netherlands.

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Table 1. Characteristics of soils used for experiments with fertigation and broadcast dressing of nitrogen and N P K (19-6-6) for head lettuce, iceberg lettuce, chinese cabbage and spinach in 1986 at three experimental stations.

	BREDA		HORST		WESTMAAS	
Depth (cm)	0-30	30-60	0-30	30-60	0-30	30-60
soil type	sand		sand		clay (calcareous) (18% < 2 m)	
pH-KCl	6.2	6.0	5.8	5.4	7.2	7.3
Org. matter %	3.6	3.0	3.1	2.7	1.1 (C,%)	0.4 (C,%)
N total %	0.10	0.08	0.12	0.11	0.13	0.06
P_W [1]	88	45	128	95	42	10
K_{HCl} [2]	17	14	14	13	63	14
Mg_{NaCl} [3]	149	126	143	131	129	75

1) Plant available P as P_2O_5 in mg/l soil

2) Plant available K as K_2O in mg per 100 g dry soil

3) Plant available Mg as MgO in mg per kg dry soil

Table 2. Uniformity of head lettuce (coefficient of variation, %) in three successive crops with fertigation or broadcast dressing of nitrogen. Field trial 1985, Experimental Station "Noord Brabant" at Breda.

		0 N	BROADCAST		FERTIGATION		
Treatment no.		1	2	4	6	8	10
Crop no.	VARIETY						
1	RESKIA	22.4	15.6	19.0	18.7	14.8	14.6
2	SORAYA	26.4	22.8	18.3	11.6	9.6	11.2
3	SORAYA	18.7	17.8	19.4	16.4	14.8	16.0

Table 3. Yield (kg/100 heads), NO_3 contents ($mg.kg^{-1}$ FW) and uniformity (VC,%) of head lettuce, iceberg lettuce, chinese cabbage and spinach dressed with NH_4NO_3 or 19-6-6 broadcast or applied through fertigation at Breda, Horst and Westmaas in 1986.

	NH_4NO_3		19-6-6	
	BROADCAST	FERTIGATION	BROADCAST	FERTIGATION
BREDA				
HEAD LETTUCE[1]				
June 10, 1986				
YIELD	34.5	40.0	36.9	41.8
UNIFORMITY	27.8	16.7	21.1	16.3
NITRATE	2108	2091	1966	2149
SPINACH[1] [2]				
July 9, 1986				
NITRATE	2447	2642	2457	2647
SPINACH[1] [2]				
August 15, 1986				
NITRATE	2648	3648	3255	2873
HORST				
HEAD LETTUCE[1]				
June 17, 1986				
YIELD	49.2	49.5[3]	53.4	38.9[3]
UNIFORMITY	23.9	13.0	23.7	17.6
NITRATE	1591	404[3]	1472	346[3]
HEAD LETTUCE[1]				
October 14, 1986				
YIELD	28.8	27.8	30.4	26.6
NITRATE	1438	1630	1395	1261
WESTMAAS				
ICEBERG LETTUCE[4]				
June 24, 1986				
YIELD	76.1	71.5	75.4	72.6
UNIFORMITY	21.1	19.9	19.7	14.3
NITRATE	728	611	635	543
CHINESE CABBAGE[5]				
August 27, 1986				
YIELD	146	148	151	159
NITRATE	724	1070	732	995

1) N dressing 200 $kg.ha^{-1}$
2) yield not determined
3) technical disorder in the fertigation system
4) N dressing 135 $kg.ha^{-1}$
5) N dressing 150 $kg.ha^{-1}$

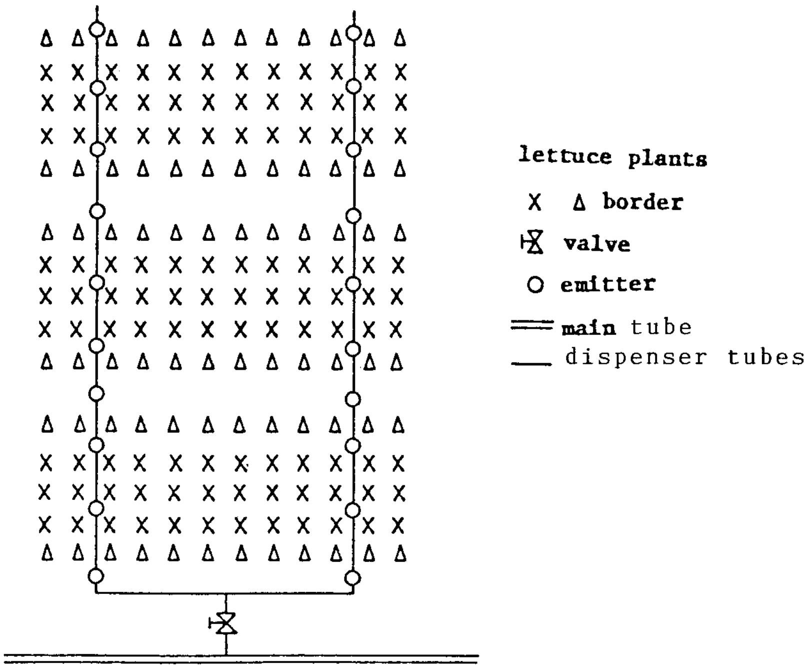

Fig. 1. Installation and equipment for fertigation (explanation, see text).

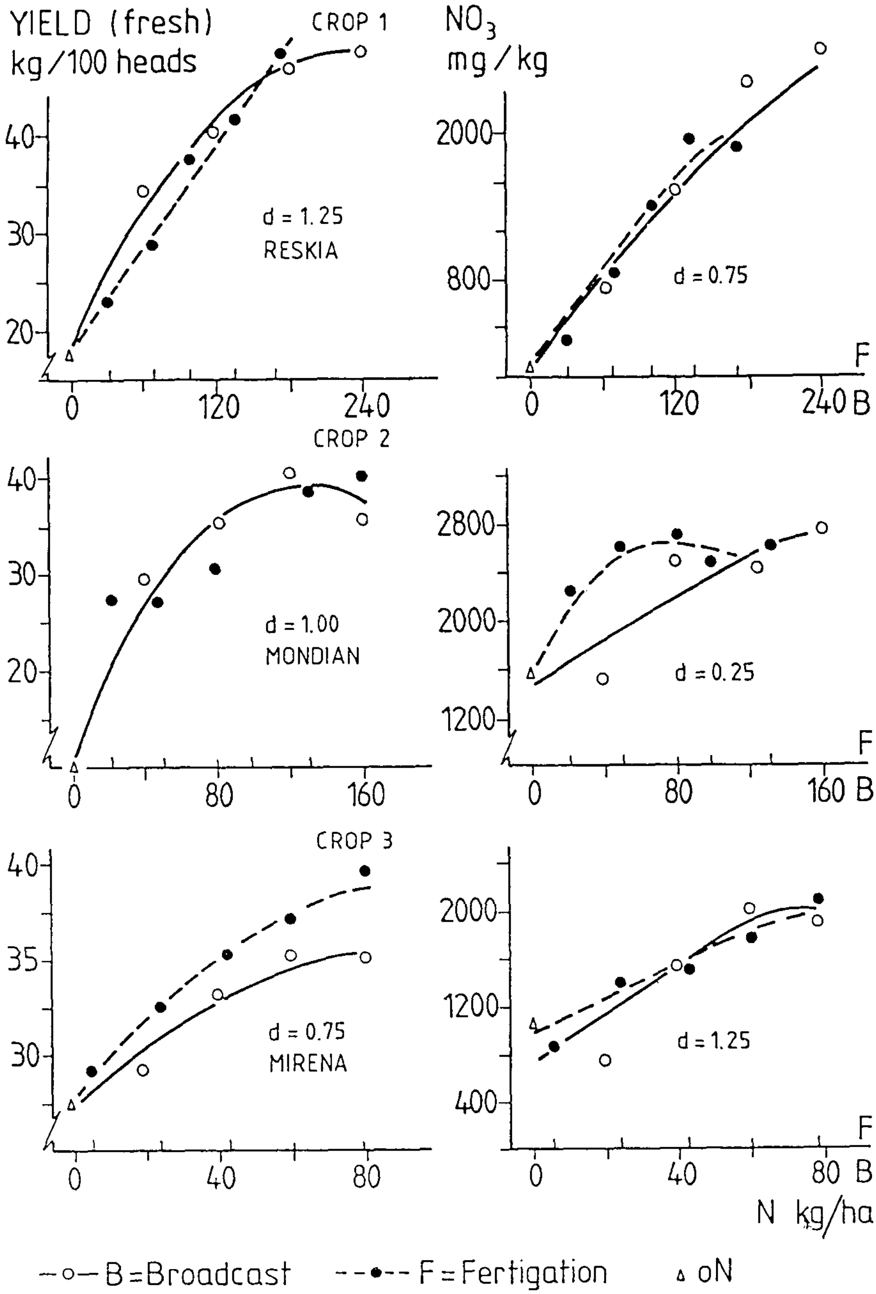

Fig. 2. Yield (kg/100 heads) and NO_3-contents (mg/kg FW) of head lettuce with fertigation and broadcast dressing of nitrogen. Three successive crops in 1984, Experimental Station "Noord Brabant" at Breda.

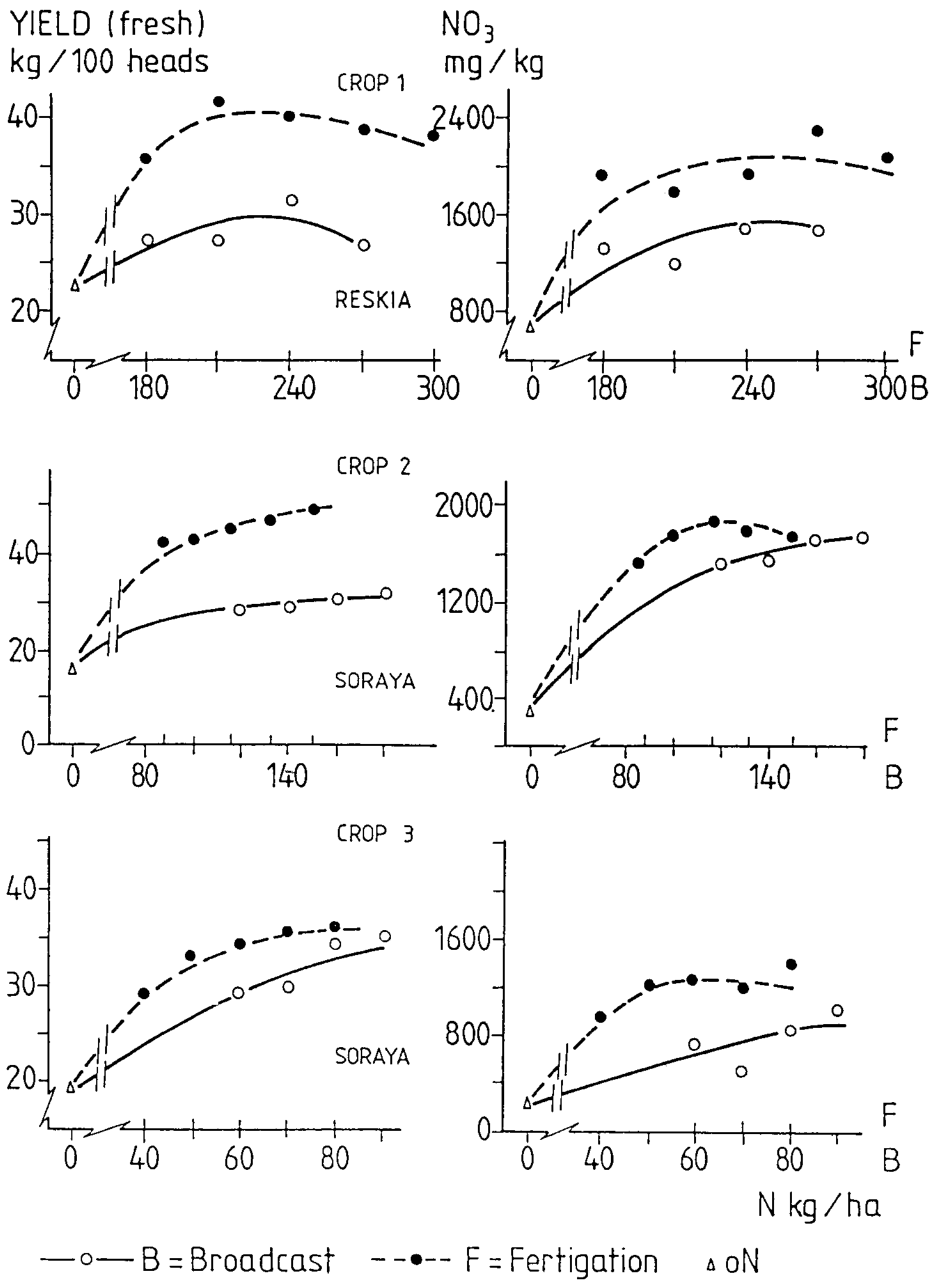

Fig. 3. As Fig. 2. Results for 1985.

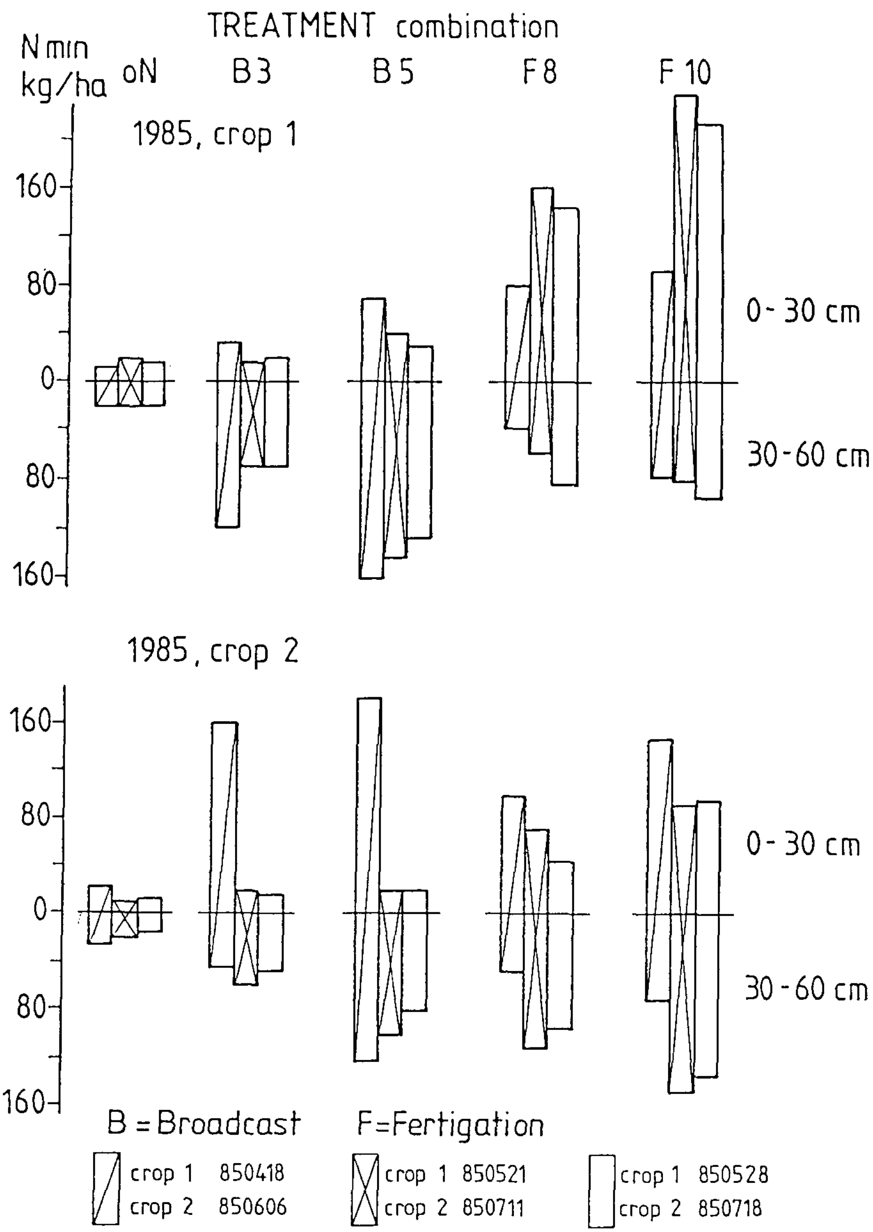

Fig. 4. Nitrogen (N min. in kg/ha) in soil profiles during lettuce cropping in 1985. Comparison of fertigation and broadcast nitrogen dressing. Experimental Station "Noord Brabant" at Breda.