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Fertilization of tomatoes with nitrogen

Samenvatting: Bemesting van tomaten met stikstof
Zusammenfassung: Düngung von Tomaten mit Stickstoff

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Abstract

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Tomatoes were dressed with nitrogen in simple trials in commercial glasshouses. To maintain the differences in nitrogen in the soil obtained by progressive amounts of ammonium nitrate limestone as a base dressing, supplementary top dressings were applied based on the analysis of soil samples collected during growth.

Optimum yield was with 7.6 mg water-soluble nitrogen (Nw) per 100 g dried soil. The optimum percentages in leaf dry matter were 3.69% N per 0.73% NO_3-N.

Nitrogen decreased percentage fallen fruit attacked by *Botrytis cinerea*. The effect of nitrogen on fruit quality varied.

A scheme was devised for advisory work in nitrogen dressing of tomatoes on the basis of Nw-values.

Contents

1 Introduction

In 24 trials, each lasting one season, during the period 1955 - 1967, tomatoes in commercial glasshouses were dressed with ammonium nitrate limestone to find the rate of nitrogen, and the nitrogen level in soil, giving the greatest yield of even-coloured fruits.

Some trials included treatments with potassium (Roorda van Eysinga, 1966a) or farmyard manure.

The following institutes co-operated in the trials: the horticultural substations: 'Noord-Limburg' and 'Groningen' at Venlo and Hoogezand/Sappemeer, respectively; the Association for the Advancement of Horticulture in the 'Bommelerwaard' at Zaltbommel, and the Horticultural Extension Service.

2 Previous trials

The first nitrogen-dressing trials with tomatoes in the Netherlands were by van der Kloes et al. (1961). Despite the large number (49) of fields, the outcome was disappointing, as no significant relation was found between the optimum nitrogen rate and nitrogen content of soil. It could only be concluded that nitrogen rate should be ignored when water-soluble nitrogen (Nw) was 19 mg N per 100 g dry soil or more, and that top dressing had no influence if tomato leaves contained more than 3.50% N in dry matter.

To solve this problem, 12 trials in glasshouses were established in 1957 on holocene sand by Spithost (1965). They led to the conclusion (van Haeff, 1964) that with up to 1 mg Nw per 100 g dry soil, tomatoes should be dressed with a total of 3.5 kg N per 100 m², while at Nw 4.0 no nitrogen was required.

In the previous experiments, nitrogen was applied as base and top dressing in various amounts according to a scheme fixed beforehand. The trials described by van der Boon & Roorda van Eysinga (1957) were based on another concept. This concept was used in the present trials and is described in the next section.

Winsor et al. (1967) mentioned that their long-term factorial trial gave 100-200 ppm NO_3-N as the optimum status for soil nitrogen.

According to Nowosielski (1968), a deficiency will occur below 2 mg N per 100 g dry soil, while 10 mg, even during a short time, is harmful. The leaves must contain between 0.10 and 0.30% NO_3-N in dry matter.

3 Methods

With a few exceptions, the soil samples were taken from the 25 cm top layer. The base dressings were applied after the first sampling and were worked in by rotavating or by digging, normally a few days before planting. The plots were dressed with normal rates of other fertilizers. Routine tending of the crops were left to the grower.

Ammonium nitrate limestone was the source of nitrogen; in trials 1 and 2, it contained 20% N; in the others 23%. The various trials differed in number of nitrogen treatments as well as in the rates of nitrogen applied as base dressings.

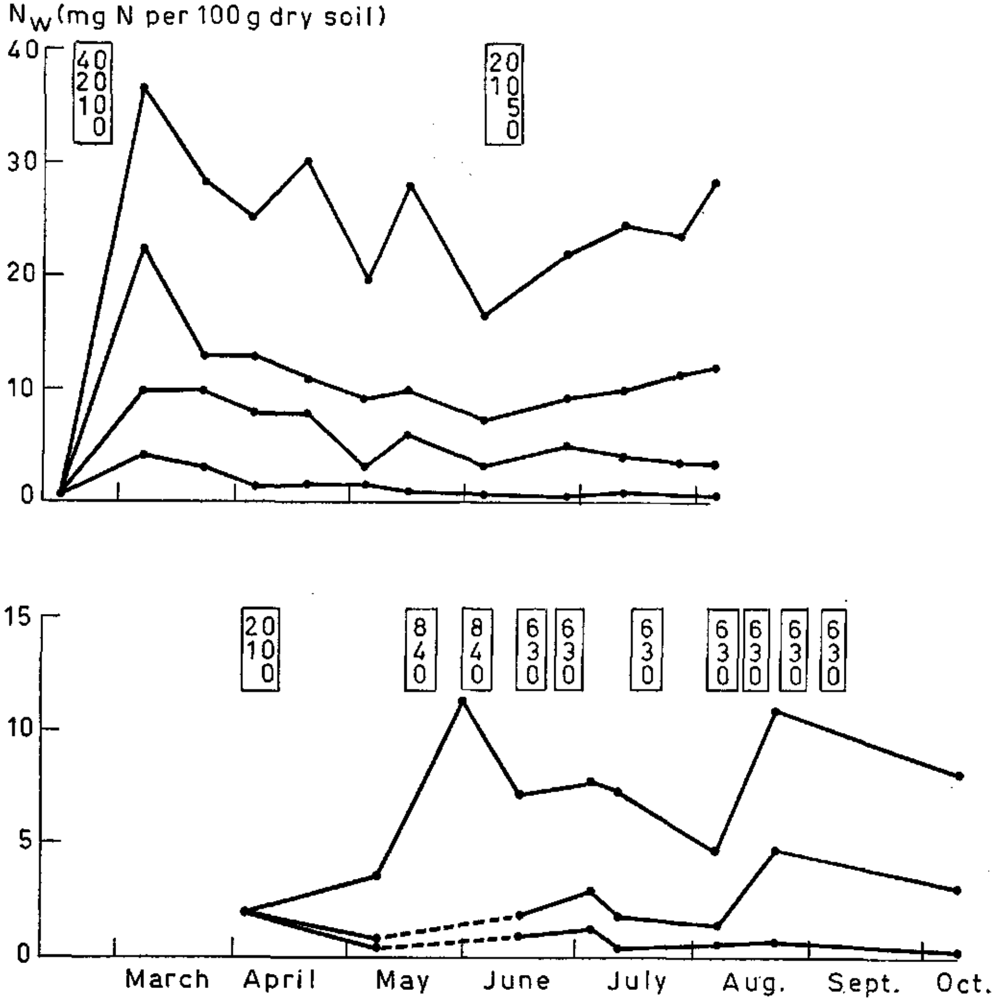

Fig. 1 Soil nitrogen expressed as Nw (mg N soluble in water per 100 g dry soil) during cultivation, with different ammonium nitrate limestone dressings (framed quantities in kg per 100 m²; upper figure Trial 16, lower figure Trial 19).

Table 1. Survey of place, soil type and some cultivation measures.

Trial	Place	Soil type	Soil disinfection	Age of glasshouse (years)	Heating	Date of planting out	Variety	Type of trial
1	Venlo	light textured river loam		3	0	9-5-55	Victory	N/FYM
2	Venlo	light textured river loam		5	0	8-4-55	Victory	N/FYM
3	Sappemeer	reclaimed sandy peat	steamed	26	pipes	1-3-63	Growers Pride[3]	N/K
4	Baflo	old marine loamy sand		3	0	25-4-63	Victory	N/K
5	Kerkdriel	river loam		2	air	13-6-63	Eurocross[1]	N/K
6	Loosduinen	humous dune sand	steamed	10	pipes	13-1-62	Ouden Dam[2]	N/K
7	De Lier	young marine sandy loam	chloropicrine	4	pipes	13-1-62	Cromco	N/K
8	Rotterdam	silty peat	metham-sodium	10	pipes	8-3-62	Cromco	N/K
9	Sappemeer	reclaimed sandy peat		1	0	5-5-64	Topcross[2]	
10	Kerkdriel	river loam		0	0	17-4-64	Eurocross[1]	
11	Gameren	river loam		½	air	29-5-65	Victory	N/K
12	Zuidwolde	old marine loam		3	0	20-4-65	Victory	
13	Naaldwijk	young marine loam		½	pipes	6-2-65	Victory	
14	De Lier	young marine loam		0	0	22-3-65	Victory	
							Eurocross A[1]	
15	's-Gravenzande	young marine loam		2	0	15-4-65	Victory	
16	Honselersdijk	young marine sandy loam		0	pipes	22-2-66	Victory	
17	Naaldwijk	young marine sandy loam		0	pipes	18-2-66	Florisant[2]	
18	Veen N-Br	sandy river loam		0	air	12-5-66	Eurocross B[1]	N/K
19	Monster	dune sand		3	air	7-4-67	Moneyress[2]	
20	Monster	humous dune sand	metham-sodium	5	air	13-6-67	Topcross[2]	
21	Naaldwijk	silty dune sand		7	0	1-5-64	Victory	long term
22	Naaldwijk	silty dune sand	steamed	8	0	1-5-65	Victory	long term
23	Naaldwijk	silty dune sand		9	0	5-5-66	Happy[1]	long term N/FYM
24	Naaldwijk	silty dune sand	methylbromide	10	0	27-4-67	Happy[1]	long term N/FYM

1. Hybrid of the no-green back type. 2. Intermediate hybrid 3. Hybrid of the green back type.

Nitrogen in top dressing was applied at rates depending on the results of soil analysis. The intention was to maintain Nw at different levels throughout the season. However, periodic analysis of soil showed that the ideal of constant Nw could hardly be attained. The variation in Nw of two of the trials is illustrated in Figure 1.

The fruits were graded as evenly and unevenly coloured. Fallen fruits were collected separately. At first picking, leaf samples were collected in most trials; the first full-grown leaf above the first truss.

Nitrogen in soil was measured as the amount of nitrogen (nitrate plus ammonia), extracted with 5 parts water (w/w), in mg N per 100 g dry soil (units of 10 ppm), after drying at 45°C, crushing and sieving (den Dekker & van Dijk, 1963). According to previous trials, this method fairly predicts the response of lettuce to nitrogen (Roorda van Eysinga, 1966b); it is used in the Netherlands for routine analysis of soil samples from commercial glasshouses.

Particulars of the soils, and some other data, are given in Tables 1 and 2. The

Table 2. Analytical data on soil samples taken before the trials started.

Trial	pH H_2O	pH KCl	Organic matter (%)	Carbonate (% $CaCO_3$)	Particles < 16 μ	Particles > 105 μ	Total N %	Nw
1	5.8	5.0	6.2	0.0	12	3	0.20	2.7
2	5.9	5.4	7.4	0.0	12	5	0.32	4.8
3	6.1	5.7	15.6	0.0	13	46	—	5.9
4	7.4	6.8	4.6	0.8	20	10	—	1.9
5	7.5	6.9	3.9	2.9	32	25	—	1.2
6	6.6	—	11.0	1.3	10	—	—	5.3
7	7.4	—	11.0	3.6	30	—	—	18
8	6.4	—	40.0	0.2	32	—	—	22
9	6.6	6.3	14.6	0.1	2	59	0.47	6.7
10	7.2	6.8	4.4	1.7	29	23	0.19	0.6
11	6.7	6.3	3.5	0.1	35	26	0.17	0.7
12	6.8	6.2	6.9	0.3	35	5	0.38	2.9
13	7.4	6.7	6.0	1.6	54	4	0.37	6.1
14	7.4	7.2	6.1	3.7	33	4	—	1.8
15	7.1	6.8	5.8	1.6	36	25	0.33	10
16	7.3	7.0	3.7	2.7	17	53	0.16	0.6
17	7.3	7.1	3.4	1.2	20	30	0.17	1.2
18	6.2	6.0	4.1	0.2	28	47	—	0.9
19	7.0	7.2	0.9	0.8	4	94	0.03	2.0
20	6.5	5.9	11.9	0.3	9	78	0.37	8.8
21	7.0	6.9	6.6	1.7	7	64	—	1.2-2.9[1]
22	7.0	6.9	6.2	1.6	7	64	—	1.1-9.3[1]
23	6.9	6.5	5.1	1.3	14	60	—	1.3-6.9[1]
24	6.9	6.5	5.1	1.3	14	60	—	1.3-8.2[1]

1. Range resulting from treatments in proceeding experiments.

glasshouses used for the trials were partly chosen at random, partly for a low nitrogen content of the soil.

4 Influence of nitrogen dressing on yield and quality

Table 3 gives 'relative yields', yields of the 0N-treatment expressed as a percentage of the highest yield, estimated graphically (Roorda van Eysinga, 1971). In the few cases where the treatment without nitrogen gave the highest yield, this yield was expressed as a percentage of the average yield of other treatments.

The plants in Trial 18 developed very poorly and their fruits were very uneven. The other treatments in that trial showed, with increasing nitrogen rate, a signifi-

Table 3. Relative yields, and percentages even-coloured fruits on plots without nitrogen fertilizer.

Trial	Relative yield			Quality of fruits		
	%	significance (*P*) in *F* test		% evenly coloured	significance (*P*) in *F* test	
		linear effect	quadratic effect		linear effect	quadratic effect
1	84	n.s.	n.s.	92	n.s.	n.s.
2	88	n.s.	n.s.	88	n.s.	n.s.
3	104	n.s.	n.s.	84	n.s.	n.s.
4	85	< 0.01	n.s.	83	– < 0.01	n.s.
5	76	< 0.01	n.s.	88	+ < 0,01	n.s.
6	110	0.05	n.s.	100	n.s.	n.s.
7	104	n.s.	n.s.	100	n.s.	n.s.
8	106	0.01	n.s.	98	n.s.	n.s.
9	100	n.s.	n.s.	98	n.s.	n.s.
10	86	0.03	0.02	77	+ 0.01	n.s.
11	43	< 0.01	< 0.01	98	n.s.	< 0.01
12	80	< 0.01	0.03	70	+ < 0.01	n.s.
13	106	0.05	n.s.	94	n.s.	n.s.
14	86	n.s.	< 0.01	77	+ 0.04	0.06
15	100	n.s.	n.s.	88	+ < 0.01	n.s.
16	79	n.s.	0.02	68	+ < 0.01	< 0.01
17	64	0.01	< 0.01	85	n.s.	n.s.
18	32	< 0.01	< 0.01	70	– 0.05[1]	n.s.
19	70	n.s.	< 0.01	87	+ 0.01	n.s.
20	99	n.s.	n.s.	71	n.s.	n.s.
21	89	n.s.	n.s.	54	n.s.	0.04
22	77	< 0.01	< 0.01	85	+ 0.03	n.s.
23	73	< 0.01	< 0.01	94	n.s.	n.s.
24	61	< 0.01	< 0.01	95	n.s.	n.s.

1. Aberrant case (see text).

cant decrease in percentages of even-coloured fruits. In Trial 11, under nearly the same circumstances, a very poor crop developed on plots without nitrogen, but there the low yield was of excellent quality. Those two trials alone indicate the difficulty of demonstrating any effect of nitrogen on fruit colour and that, if such effect exists, it cannot be explained in a simple manner.

As to yields, in 13 of the 24 trials yield responded positively (to a significant degree) to nitrogen dressing (see Table 3). This result may be contrasted with that obtained in 28 potassium trials, where only 9 of the fields responded positively (Roorda van Eysinga, 1966a). But this difference should be treated with caution, as the glasshouses were not fully selected at random. However, certainly potassium more often influenced quality (17 trials) than yield (13 trials) and for nitrogen the reverse was true (12 and 16 trials respectively). In addition it has to be kept in mind that the influence of nitrogen on fruit colour was usually favourable, whereas an unfavourable effect of potassium on colour was never found.

5 Influence of nitrogen dressing on fruitfall and on incidence of fungal diseases

In field trials fallen fruit presents a problem: although a product of the plant, it is not marketable. The fallen fruit was collected to study production both with, and without it.

Table 4 shows that in 7 out of 24 trials the favourable influence of nitrogen was statistical significant and that the general trend was distinctly in favour of high nitrogen applications. This means that the optimum nitrogen application for tomatoes in view of fruitfall is higher than that for optimum yield.

It was proved by Verhoeff (1968) that treatment with nitrogen fertilizers decreases the incidence of *Botrytis cinerea*. Mr Verhoeff kindly co-operated in the present experiments by counting the number of lesions. It showed the same trend as that mentioned above (and also for potassium), as illustrated by Table 6, referring to Trial 18, in which the influence of both nitrogen and potassium was studied. Therefore, the incidence of *Botrytis*, stimulated by a low nitrogen supply, causes higher fruitfall.

The plants on plots without potassium in Trial 18 displayed clear potassium deficiency symptoms and those on plots without nitrogen showed a poor development and gave very low yields. The percentage of fallen fruit in the treatment without potassium was significantly higher than that on K-fertilized plots. But as potassium deficiency never occurs in commercial glasshouse, its influence is of no practical importance. On the other hand, the favourable effect of nitrogen should not be neglected and (apart from the plots without nitrogen) it was statistically significant.

Phytophthora infestans was observed solely in Trial 10. The attacked fruits were weighted. The incidence of *Phytophthora* was lower at higher nitrogen applications (Table 5), and confirmed the results obtained by Grümmer (1965), who found that tomato leaves with a low protein content were more susceptible to *Phytophthora*.

Table 4. Influence of nitrogen application on weight percentage of fallen fruits.

Trial	Weight percentage fallen fruits corresponding with								Significance (P) in F test	
	low N-applications giving suboptimal[1] yields				N-applications giving highest yields	high N-applications giving suboptimal[2] yields			linear effect	quadratic effect
1		0.5	0.6	0.1	0.5	0.3			n.s.	n.s.
2	4.3	3.4	3.8	2.8	2.5				n.s.	n.s.
4			4.3	4.3	3.5	3.0			< 0.01	n.s.
9				0.1	0.1	0.3	0.3		n.s.	n.s.
10			0.1	0.1	0.1	0.2			n.s.	n.s.
11			5.0	5.0	3.8	3.5			< 0.01	n.s.
12		2.5	2.2	2.1	1.8				n.s.	n.s.
13					0.2	0.1	0.0	0.1	n.s.	n.s.
14			5.2	4.2	3.4	4.1			n.s.	n.s.
15			1.7	0.9	0.9	0.6			0.06	n.s.
17			0.9	0.4	0.1	0.3	0.0		n.s.	n.s.
18			8.8	9.8	6.3	5.3			< 0.01	n.s.
19			2.3	1.1	0.8	0.5	0.5		0.01	0.03
20				0.5	0.5	0.3	0.4	0.3	n.s.	n.s.
21		3.0	2.3	1.7	2.2				n.s.	0.04
22		5.8	5.4	4.6	4.0				n.s.	n.s.
23		4.4	4.5	1.7	1.4				< 0.01	n.s.
24		2.7	4.9	0.9	0.5				< 0.01	n.s.

1. The last column under this heading refers to the N-application which is one step below the N-application giving the highest yield, the preceding column refers to the next lower N-application, etc.
2. The first column under this heading refers to the N-application which is one step above the N-application giving the highest yield (compare first footnote).

Note: in 6 trials no fruit fall of any importance was observed.

Table 5. Influence of nitrogen application on total yield and yield of tomato fruits attacked by *Phytophthora infestans* (Trial 10).

	kg N per 100 m²				Significance (P) in F test	
	0	2	4	8	linear effect	quadratic effect
Total yield per plant, in kg	5.72	6.54	6.65	6.51	0.03	0.02
Yield of attacked fruits, kg/10 plants	0.74	0.61	0.52	0.30	0.02	n.s.

Table 6. Number of stem-lesions caused by *B.cinerea* per 10 plants and weight percentages of fallen fruits.

	0 kg K_2O +				7 kg K_2O +				15 kg K_2O +				30 kg K_2O +			
	0 kg N	2 kg N	4 kg N	8 kg N	0 kg N	2 kg N	4 kg N	8 kg N	0 kg N	2 kg N	4 kg N	8 kg N	0 kg N	2 kg N	4 kg N	8 kg N
Number of lesions	6.8	9.3	9.3	5.7	8.6	11.8	3.9	3.9	2.5	12.9	3.2	3.9	5.4	5.0	5.4	3.2
Weight % fallen fruits	7.9	12.5	12.3	9.1	7.0	8.6	4.2	4.9	10.0	10.2	5.0	3.0	10.4	7.9	3.8	4.1
Average nr of lessions for	0 kg K_2O : 7.8 0 kg N : 5.8				7 kg K_2O : 7.1 2 kg N : 9.8				15 kg K_2O : 5.6 4 kg N : 5.5				30 kg K_2O : 4.8 8 kg N : 4.2			
Average weight % fallen fruits for	0 kg K_2O : 10.5 0 kg N : 8.8				7 kg K_2O : 6.2 2 kg N : 9.8				15 kg K_2O : 7.1 4 kg N : 6.3				30 kg K_2O : 6.6 8 kg N : 5.3			

Number of lesions counted on 17 August 1966 (Trial 18).

6 Influence of nitrogen dressing on nitrogen content of soil

The analyses figures of soil samples taken one to two months after base dressing were used to calculate the increases in Nw by 1 kg ammonium nitrate limestone per 100 m², according to the formula:

$$\text{increase of Nw due to fertilization} = \frac{\text{Nw fertilized plots} - \text{Nw unfertilized plots}}{\text{nitrogen rate}}$$

In previous investigations with lettuce 1 kg ammonium nitrate limestone (23% N) per 100 m² gave an average increases of 1 mg Nw per 100 g dry soil (Roorda van Eysinga, 1966b).

The relative increases in Nw differed greatly in the various trials. Humous soils with a low volume weight gave the highest increase (1.4 on Trial 9 with 14.6% organic matter; 3.3 in Trial 8 with 40%). But apart from these cases no clear connection was found between the increase in Nw and the organic matter content (from 0.9 till 11.9%).

On the other hand a relation between the increase in Nw and soil texture was found (see Fig. 2). On sandy soils with a low percentage of particles < 16μ, the increase is rather low (below 1); nitrogen may already have been leached in the period between base dressing and soil sampling. On marine loam the increase in Nw (between 0.58 and 1.28) is about normal; on river loam it is low (between 0.26 and 0.67). There must be reckoned with a strong ammonium fixation on the river loam, rich in ammersooite, an illitic clay mineral (van Schreven, 1968).

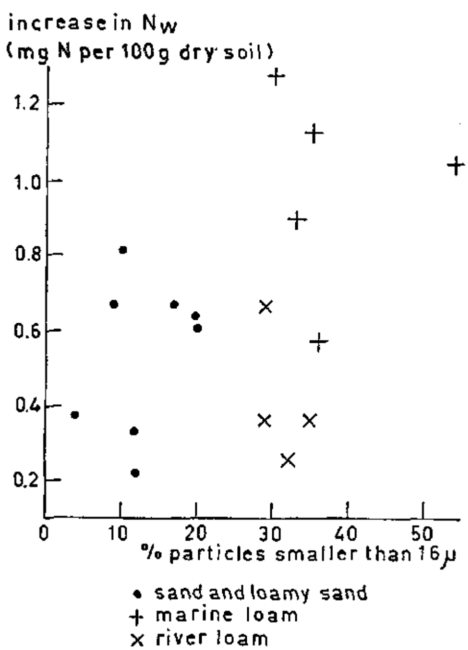

Fig. 2 Increase in Nw by dressing with 1 kg ammonium nitrate limestone per 100 m² plotted against percentage of particles smaller than 16 μ in the soil.

7 The influence of nitrogen dressing on the contents of leaves

The percentage dry matter in the fresh leaf samples varied between 10 and 11, with extremes at 9.2 and 13.7. In general, nitrogen application did not influence the results. However in two trials plants showing nitrogen deficiency, in one case also those showing nitrogen excess, contained more dry matter than the others.

Plants that only slightly responded in yield to nitrogen application or not at all showed hardly any reaction in the N-content to the leaves. In other cases, when more nitrogen had been applied, the content of total nitrogen in the leaves was then higher. The nitrogen contents of the leaves of plants with the highest yield ran from 2.47 to 3.73% in the dry matter.

For the plots without N-dressing a positive correlation was found between the nitrogen content of the leaves and Nw of the soils before the experiments had started (Fig. 3). For total N the regression equation was $y = 0.82 \log x + 2.46$ with $r = 0.52^{+}$, for nitrate-N it was $y = 0.53 \log x + 0.07$ with $r = 0.78^{++}$. The correlation coefficients, however, are not comparable, as the first was based on 20 observations, the second on 14. So, the correlations for the data from the plots in common were calculated ($n = 14$); this resulted in $r = 0.74^{++}$ and $r = 0.78^{++}$, respectively, which more accurately described the situation. For plants showing nitrogen deficiency symptoms, the nitrate-N content was between 0.00 and 0.01%.

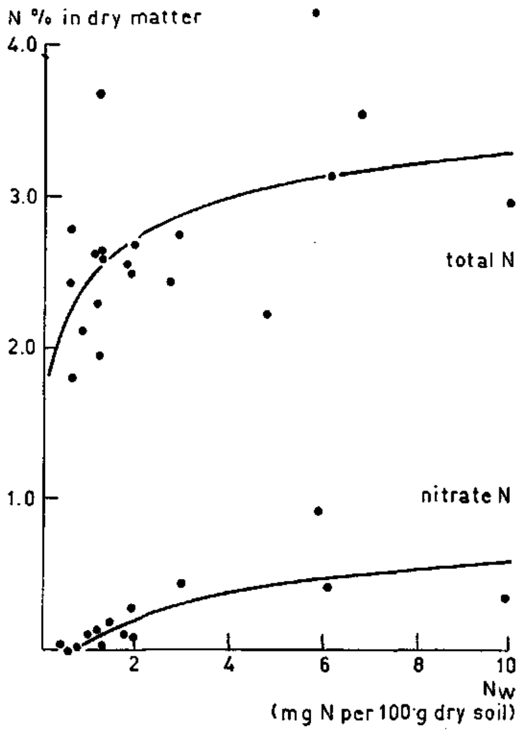

Fig. 3 Relation between Nw at the beginning of the experiments and the nitrogen content (upper figure total N, lower figure nitrate N) in the dry matter of the tomato leaves from plots without nitrogen dressing.

The phosphate contents in leaves from plots with optimum or near optimum fertilization varied between 0.45 and 1.37% P_2O_5, and on trials showing a clear response in yield it was lower the more nitrogen had been applied. The highest content (2.11% P_2O_5) was found on the untreated plots of Trial 11, with a crop showing severe nitrogen deficiency.

Apart from the figures of the N/K experiments, the potassium content in the dry matter varied between 3.01 and 5.94% K_2O. Where a reaction could be observed, an increase in nitrogen application always resulted in an increase in potassium. This was especially obvious on river loam, which may (at least partly) be explained by its lower potassium fixation where large quantities of ammonium nitrate limestone had been applied.

The calcium content in the dry matter of the leaves was between 6.05 and 9.13% CaO. More nitrogen mostly gave a decrease in calcium content.

The magnesium content was between 0.69 and 1.74% MgO in the dry matter. Trials clearly reacting on N-fertilization, sometimes showed higher, sometimes lower figures at higher N rate.

In some trials the sodium content of the leaves was determined. It varied between 0.18 and 0.61% Na_2O. Only in a few cases could some reaction be noted and here an increase in sodium corresponded with an increase in nitrogen application.

As to the chloride content in the dry matter of the leaves, it strongly decreased with increasing nitrogen application, even in the cases where the yields did not react anymore. The extreme values were, in three trials: 1.42 - 3.07, 1.03 - 2.69, and 1.35 - 2.99% Cl.

In the three cases mentioned above the leaves were also analysed on their free sulphate content (extraction with 0.5 N acetic acid). The results were between 1.2 and 2.5% SO_4-S in the dry matter and the more nitrogen applied, the lower the results.

The amount of organic anions (C-A) in the leaves of these three trials was calculated from the quantities Na^+, K^+, Ca^{++}, Mg^{++}, NO_3^-, $H_2PO_4^-$, Cl^- and So_4^{--} (see de Wit et al., 1963). In two cases, a distinct relation exsisted with the yields: in Trial 11 C-A 190 mval, in Trial 19 C-A 170 mval per 100 g dry matter were found to be optimum. These values were somewhat higher than the 150 mval found by Jungk (1967) for tomato plants.

8 Optimum nitrogen content of soil and leaves

The relation between Nw at the beginning of the trials (x) and relative yields, as defined under 4 (y), has been represented in Figure 4 ($y = 34.0 \log x + 69.8$ where $r = 0.77^{++}$). If relative yield is 100 (i.e. there is no response to fertilizers) Nw can be calculated to be 7.6, with confidence limits 5 and 17 ($P = 0.05$).

From analysis of soil samples taken during growth, the mean Nw of plots with the highest yield was estimated (Fig. 5). In most trials optimum Nw was between 7 and 8.

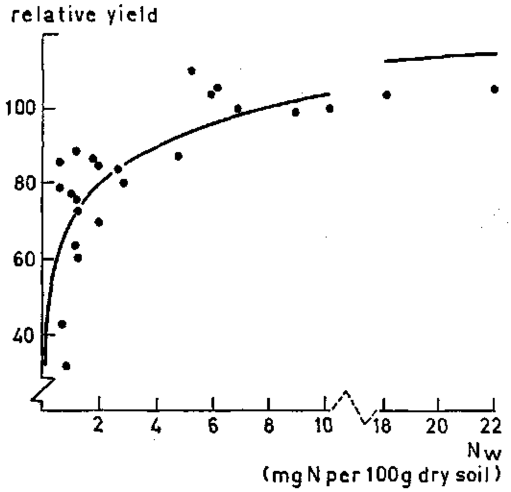

Fig. 4 Relation between Nw determined before the trials started and relative yield.

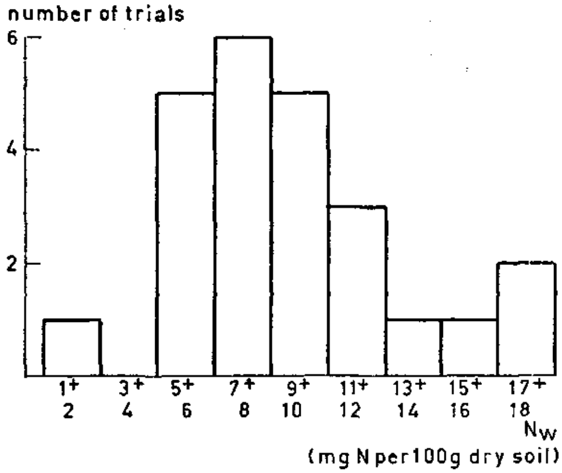

Fig. 5 Frequency distribution of the mean Nw during cultivation for the treatments giving the highest yields.

Figure 6 shows the relation of total nitrogen and nitrate nitrogen content of the leaves, respectively, for the treatments without nitrogen dressing, with relative yield. The difference between the correlation coefficients ($r = 0.66^{++}$ and $r = 0.83^{++}$) was caused by the greater number of observations, under which some rather deviating ones, for the calculation of $r = 0.66$.

The optimum nitrogen content in the leaves could also be calculated by putting the relative yield at 100 in the regression equations. This resulted in 3.69% N in the dry matter, with confidence limits 3.18 and 5.83 and an optimum nitrate content of 0.73% NO_3-N, with confidence limits 0.33 and 3.86 ($P = 0.05$).

9 Optimum rate of nitrogen

The amounts of ammonium nitrate limestone applied to give the highest yields were plotted against the corresponding soil nitrogen contents (Nw) before the

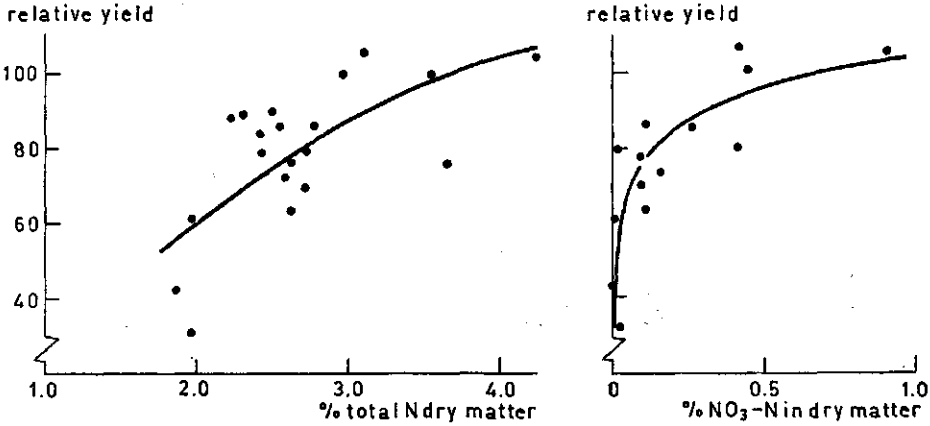

Fig. 6 Relation between % N (left) and % NO_3-N (right) in the dry matter of the tomato leaves from plots without nitrogen dressing, and relative yield (regression lines: $y = 143.3 \log x + 18.7$ and $y = 28.5 \log x + 103.8$).

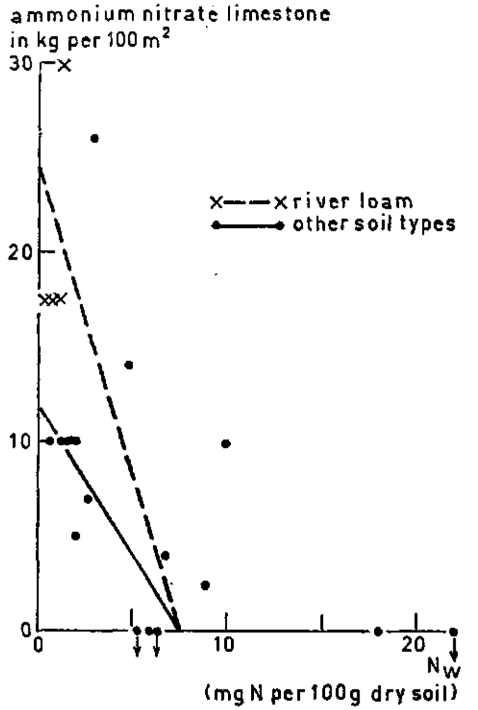

Fig. 7 Optimum application of ammonium nitrate limestone as a base dressing, based on Nw.

beginning of the trials (Fig. 7). Where nitrogen had shown a significantly negative effect on yield an arrow was added. There was reason to expect that river loam behave differently form other soils, so two lines were drawn in Figure 7. The lines had to intersect the horizontal axis at the threshold value Nw = 7.6 calculated before.

The amount of nitrogen to be applied as a top dressing depends on the soil type and on the water system maintained by the grower. On loam nitrogen hardly leaches form the upper soil layers, so top dressings must be applied rarely. But on sandy soils, especially under a wet water system, leaching is important and top dressing must be frequently applied. Here soil analysis carried out during the growing period may indicate whether a satisfactory nitrogen content is still present and, if not, estimate the necessary addition. Here the short-cut soil analysis is most useful.

10 Discussion

The preceding sections have shown that, for all soils mentioned, a water soluble quantity of nitrogen in the upper soil layer (25 cm) of about 76 ppm is optimum. Winsor et al. (1967) (see Table7) have found somewhat higher N-values in their glasshouse experiments although they only estimated the nitrate and not the ammonia content (except after steaming, ammonia occurs only in low percentages).

The low value mentioned by van Haeff (1964) may be explained by his light soils. Indeed in such soils a lower optimum has to be considered as indicated by Trial 19 on the lightest soil involved in the present experiments (optimum Nw between 1 and 2). To maintain such a value, top dressings must be applied more frequently than in other cases, so that the total quantity of nitrogen may be even higher than on heavier soils.

In previous investigations peat soils have occupied a special place (Roorda van Eysinga, 1965). In the present experiments it has not been possible to study this point in more detail, as there was only one trial on peat.

For lettuce, the optimum nitrogen content of the soil is about 90 ppm. The question arises whether a comparable optimum is also valid for other vegetable crops. Experiments with cucumber and kohlrabi suggests some values in the neighbourhood of 100 ppm (not yet published data).

The regression equation for the relation between relative yield and total nitrogen in the tomato leaves points to an optimum at 3,69%. This value agrees well with the 3.5% found by van der Kloes et al. (1961). The optimum value for nitrate is

Table 7. Optimum values of readily soluble nitrogen in the soil according to some recent publications.

	N in ppm	Analyzed for
van Haeff (1964)	40	$NO_3 + NH_4$
Winsor et al. (1967)	100 — 120	NO_3
Nowosielski (1968)	$> 20 < 100$	$NO_3 + NH_4$
this publication	76	$NO_3 + NH_4$

0.73% NO_3-N, which is considerably higher than that mentioned by Nowosielski (1968). According to this author, an excess in nitrogen is to be expected when the leaves contain more than 0.30 to 0.40% NO_3-N, whereas below 0.10% nitrogen deficiency occurs. The last figure is in agreement with the present results and with that accepted by Smilde & Roorda van Eysinga (1968).

The data on the influence of nitrogen on the incidence of fungal disease are in accordance with those published by others, e.g. by Verhoeff (1968). That nitrogen increases the susceptibility for diseases, has not been confirmed. On the contrary: the present investigations have shown that nitrogen has a depressing effect on the occurence of some important fungal diesease, though this results should not be generalized.

As to the influence of nitrogen on fruit quality the general opinion also needs revision. It is often said that nitrogen promotes growth and increases yield at the expanse of quality, but in the present investigations a favourable effect of nitrogen on quality has been found more often than the reverse. It seems that other factors are involved, too, as Winsor & Long (1967) have found in their experiments varying effects on ripening for different varieties and years with soil sterilization. Furthermore it is well known that an excess of salts, in particular nitrogen, can retard development and reduce yield while fuit quality improves. But only in a few cases can this explain the benificial effect of nitrogen on quality, e.g. in Trial 15, and there are many trials in which nitrogen has a favourable influence on yield as well as on quality. Unfortunately, a satisfactory explanation of this variation can as yet not been given. On some river loam soils a higher potassium content of leaves has been found with increasing nitrogen application, but this effect is too small to explain the variation in nitrogen effect.

Summary

Tomatoes were dressed with nitrogen in simple trials in commercial glasshouses. To maintain the differences in nitrogen in the soil obtained by progressive amounts of ammonium nitrate limestone as a base dressing, supplementary top dressings were applied based on the analysis of soil samples collected during growth.

Optimum yield was with 7.6 mg water-soluble nitrogen (Nw) per 100 g dried soil. The optimum percentages in leaf dry matter were 3.69% N per 0.73% NO_3-N.

Nitrogen decreased percentage fallen fruit attacked by *Botrytis cinerea*. The effect of nitrogen on fruit quality varied.

A scheme was devised for advisory work in nitrogen dressing of tomatoes on the basis of Nw-values.

Samenvatting

Stikstofbemestingsproeven met tomaat werden in verschillende jaren uitgevoerd, in kassen op tuindersbedrijven. Er werd naar gestreefd om de verschillen in stik-

stofgehalte van de grond, ontstaan door het vooraf geven van trappen kalkammonsalpeter, gedurende de teelt te handhaven door de overbemesting vast te stellen aan de hand van herhaald grondonderzoek.

Het voor de produktie optimale gehalte aan in water oplosbare stikstof (N-water) ligt bij 7,6 mg N per 100 g droge grond. Het optimale gehalte in het blad is 3,69% N of 0,73% NO_3-N op droge stof.

Een ruime voorziening van stikstof gaf minder vruchtval door *Botrytis cinerea*. De invloed van de stikstof op de kwaliteit van de vruchten was wisselend.

Een adviesbasis voor de stikstofbemesting van tomaat op grond van de bepaling van N-water werd uitgewerkt.

Zusammenfassung

In Erwerbsgewächshäusern wurden im Laufe von mehreren Jahren Düngungsversuche mit Tomaten durchgeführt. Es wurden gestaffelte Mengen Kalkammonsalpeter als Grunddüngung und zusätzliche Mengen zur Handhabung der Gehalte angewendet. Die zusätzliche Mengen wurden mittels während der Vegetationsperiode durchgeführte Bodenanalysen ermittelt.

Als Optimalgehalte an leicht lösslichem Stikstoff im Boden, optimal mit Rücksicht auf den Ertrag, wurde N-water 7.6 (N-wasser in mg N pro 100 g getrockneter Boden) festgestellt. Der Optimalgehalt in Blättern war für Gesamtstickstoff 3.69% N und für Nitratstickstoff 0.73% NO_3-N, auf Trockensubstanz berechnet.

Der Stickstoff beeinflusste neben dem Ertrag auch das Auftreten von einigen von Pilzen erregten Krankheiten und die Qualität der Früchte.

Die Prozentzahl der von *Botrytis cinerea* angegriffenen und abgefallenen Früchte wurde infolge der Stickstoffdüngung erniedrigt.

Der Einfluss von Stickstoff auf die Qualität der Früchte was wechselhaft.

Ein Schema für die Ausarbeitung der optimalen Stickstoffdüngung für die Praxis wurde entwickelt.

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