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The effect of nitrogen and the method of application on the yield of cauliflower

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Abstract

The effects of nitrogen on the yield of cauliflower were studied over a period of three seasons at several locations. Different amounts of nitrogen fertilizer were applied at planting broadcast or band placed. Another treatment consisted of a split application. The number of plants harvested was not consistently influenced by the amount of nitrogen or the method of application. The quality of the product was not influenced by the treatments either. Nitrogen application influenced the size of the marketable curd. At high yield levels band placement had no advantage with regard to increasing the yield or reducing the amount of fertilizer applied. Split application did not increase the yield and sometimes even decreased the yield. The best correlation between yield and nitrogen availability was found when the mineral nitrogen (Nmin) in the soil layer 0–60 cm at planting was taken into account. The optimum nitrogen fertilizer application was 224 – Nmin (0–60 cm) kg per hectare.

Keywords: cauliflower, *Brassica oleracea* var. *botrytis*, soil mineral nitrogen, nitrogen fertilization, fertilizer band placement, split application, quality, yield

Introduction

Around 2700 hectares of cauliflower are cultivated annually in the Netherlands. The present officially recommended nitrogen application for cauliflower is 300 kg per hectare, minus the amount of mineral nitrogen in the soil layer 0–60 cm at planting. It has been estimated that every year around 700 tons of fertilizer nitrogen is used in cauliflower cultivation in the Netherlands (Everaarts, 1993a).

In literature it has been mentioned that band placement of fertilizer as compared to broadcast application can significantly increase the yield of Brassica crops (Everaarts, 1993b). If placement were to contribute to a better availability of the fertilizer nitrogen, either a higher yield could possibly be obtained or the same yield could be obtained at a lower nitrogen application. This paper presents the results of field experiments during three seasons on the effects of the amount of nitrogen and the method of application, broadcast or band placement, on the yield of cauliflower.

Materials and methods

General

The experiments were carried out from 1990 to 1992, as late summer or early autumn cultivations at several locations in the provinces of North Holland and Flevoland (Table 1). Experiments 1 and 5 were situated at research stations, the other experiments were carried out in farmer's fields. Soil chemical properties of the experimental fields are given in Table 2. Soil classification is according to soil clay content (Steur and Heijink, 1991). Soil cultivation as a preparation for planting was always carried out shortly before planting. Module raised transplants ('Speedzels') were used and planting was done by hand. Plots contained 48 (Experiment 1), 42 (Experiment 5) or 40 (all other experiments) plants, at a planting distance of 0.75 × 0.50 m. Nitrogen was applied as calcium ammonium nitrate (27 % N). During the harvest period five to eight harvests were made.

In Experiment 3 the crop suffered from heavy rainfall shortly after planting and there was damage to the crop by pigeons and other animals.

Experimental procedures

The experiments were laid out as a randomized complete block design with 12 (Experiments 1–4) or 11 (Experiments 5–7) treatments in three (Experiment 1) or four (Experiments 2–7) replicates. Before planting, the experimental fields were sampled to determine the amount of mineral nitrogen (Nmin) in the soil layer 0–60 cm (Table 3). At planting in each experiment 0, N, $2N$, $3N$ and $4N$ kg of nitrogen per hectare were applied (Table 3) and there was a split application of $2N$+N, with the second application around five weeks after planting. Maximum nitrogen availability at planting was therefore approximately 300 (Experiment 1), 250 (Experiments 2–4) or 400 (Experiments 5–7) kg per hectare for the soil layer 0–60 cm.

Nitrogen was applied either broadcast or band placed. On broadcast plots the fertilizer was lightly raked in. With band placement the fertilizer was placed by hand in a hand-drawn furrow, about 5 cm on one side of the row, about 5 cm deep, after

Table 1. Location, cultivar and cultivation period of the experiments.

Expt	Location	Cultivar	Planting date	First harvest	Last harvest
				(days after planting)	
1	Zwaagdijk	Fremont	06–06–90	65	75
2	Bovenkarspel	Fremont	12–06–90	64	73
3	Bovenkarspel	Fremont	12–07–90	74	88
4	Bovenkarspel	Fremont	17–06–91	74	100
5	Lelystad	Plana	18–06–92	70	88
6	Lutjebroek	Plana	17–06–92	76	97
7	Lutjebroek	Plana	17–07–92	83	103

Table 2. Chemical properties of the soil (0–30 cm).

Expt	pH-KCl	Organic matter (%)	Clay (<2 μm, %)	Pw (mg l^{-1} P_2O_5)	K-ox (mg 100 g^{-1} K_2O)	Soil type
1	7.3	3.2	17.5	76	28	light sandy clay
2	7.2	4.1	24.2	39	19	heavy sandy clay
3	7.5	2.8	14.1	63	48	light sandy clay
4	7.4	2.4	12.1	54	43	light sandy clay
5	7.5	1.8	12.2	44	28	light sandy clay
6	7.1	6.5	24.4	56	41	heavy sandy clay
7	7.3	4.2	20.0	83	42	heavy sandy clay

which the furrow was closed again. In Experiment 1–4, plots of the no-nitrogen treatments were lightly raked or furrows were drawn and closed. In Experiment 5–7 the no-nitrogen, furrows treatment was omitted and the no-nitrogen plots were not raked. The second fertilizer application with the split application was applied broadcast.

Statistical analysis was done through analysis of variance and regression analysis with the Genstat 5 programme (Payne *et al.*, 1993). For Experiment 5–7 the significance of the effects is only considered for treatments in which nitrogen was applied.

Yield

In the Netherlands, cauliflower yield is evaluated according to the quality and size of the curd. The curd in this case comprises the white inflorescence and the lower part of the surrounding leaves and bracts. Curds are graded as size 'six', 'eight' or 'ten'. This means that six, eight or ten cauliflower curds can be placed in a standard size box. Generally size 'six' is preferred. In the present experiments the aim was (i) to harvest cauliflower curds of the highest quality, quality I, and (ii) to harvest curds of size 'six'. Because of the size of the crop and the late harvest period, in Experiment 7 cauliflower curds size 'eight' were harvested.

Table 3.The amount of mineral nitrogen in the soil before planting and the highest amount of nitrogen applied (kg ha^{-1}).

Expt	Mineral nitrogen				Highest amount of nitrogen applied at planting (4*N*)
	sampling date	soil layer (cm)			
		0–30	30–60	0–60	
1	06-06-90	68	72	140	160
2	22-05-90	50	32	82	176
3	02-07-90	66	51	117	128
4	06-06-91	40	30	70	184
5	04-06-92	31	23	54	352
6	04-06-92	80	53	133	288
7	06-07-92	32	80	112	296

Results and discussion

Number of plants harvested and earliness of harvest

The number of plants harvested was not or not consistently influenced by the amount or the method of application of nitrogen.

Application of nitrogen and, as a method, broadcast application could increase the earliness of the harvest. But because of the only limited effects and the fact that harvesting took place on almost all harvest dates of all treatments, these effects are of no consequence for the further treatment of the data. Cutcliffe & Munro (1976) and Nilsson (1980) found no effects of nitrogen on the earliness of the harvest or on the length of the harvest period (Nilsson, 1980).

Quality

The effects of the treatments on the quality and size of the harvested curds were evaluated as a percentage of the number of plants harvested.

The average percentage of curds quality I varied from 94 to 99 percent between experiments. The percentage curds quality I was not influenced by treatments. Apparently quality as such is influenced little or not at all by the availability of nitrogen. Nilsson (1980) found no effect on the quality of cauliflower with an increase in nitrogen application from 150 to 300 kg per hectare.

Percentage of curds quality I, size 'six'

Application of nitrogen increased the yield of curds quality I size 'six' in four of the seven experiments (Table 4). In the other experiments the amount of soil available mineral nitrogen in the experiments was apparently so high that application of nitrogen or the amount of fertilizer had no effect on the size of the cauliflower curds.

In Experiment 5 with a low amount of soil available mineral nitrogen at planting (Table 3), a significant positive effect of band placement on the yield was found for the lowest amount of nitrogen applied. In Experiment 2 the average yield with band placement was higher as compared to the average yield with broadcast fertilizer. There were no effects of band placement in the other experiments. Apparently in these experiments nitrogen availability was not influenced by placement of the fertilizer.

Welch *et al.*, (1985) mentioned a positive effect of split application on the yield of cauliflower. In the present experiments, split application of nitrogen had no positive effects. In Experiments 3 and 4 split application had a negative effect on the yield. It is possible that because no irrigation was supplied after the top dressing, it took too long before the nitrogen of the top dressing in these experiments became available to the crop.

It is concluded that at a high yield level, band placement of nitrogen fertilizer is not a relevant strategy to increase yields or to reduce the nitrogen application. Split application of nitrogen offers no benefits and can even be detrimental.

Table 4. Yield as percentage of curds quality I size 'six'.

Expt	Application method	Nitrogen applied (table 3)						LSD (α=0,05)
		0	*N*	2*N*	3*N*	4*N*	2*N*+*N*	
1	broadc.	83	93	95	91	93	94	–
	band pl.	88	84	93	93	90	90	
2	broadc.	22	58	72	65	73	67	15
	band pl.	37	71	77	77	75	66	
3	broadc.	43	63	62	75	70	63	14
	band pl.	46	63	62	70	74	55	
4	broadc.	0	25	43	61	65	50	9
	band pl.	0	25	49	67	69	54	
5	broadc.	1	24	79	79	78	85	13
	band pl.		48	80	88	87	88	
6	broadc.	59	73	89	87	84	88	–
	band pl.		87	86	88	88	87	
7[1]	broadc.	66	73	81	80	72	72	–
	band pl.		74	80	78	82	76	

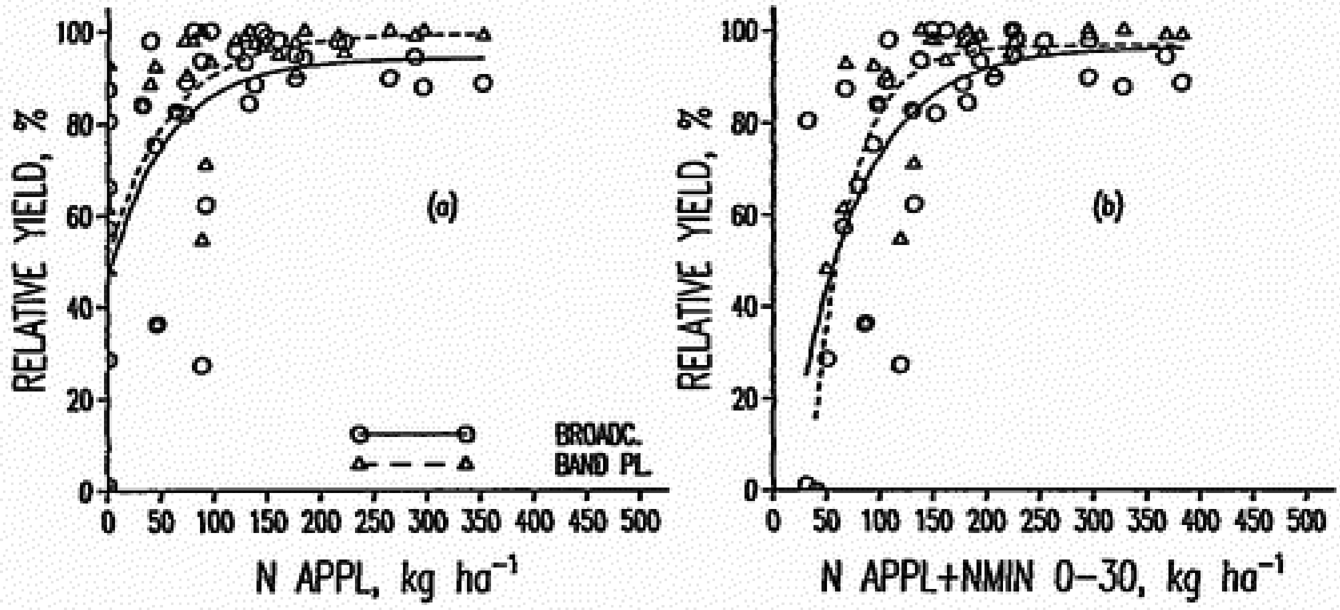
Significance	Expt 1	2	3	4	5	6	7
nitrogen	ns	P<0.001	P<0.001	P<0.001	P<0.001	ns	ns
application method	ns	P=0.015	ns	ns	P=0.003	ns	ns
nitro. x appl.meth.	ns	ns	ns	ns	ns	ns	ns

[1] size 'eight'.

Determination of optimum nitrogen application

In determining the optimum nitrogen application the data of Table 4 were used, excluding the yield data of the split application. Yields were converted to relative yields by putting the highest yield in each experiment at 100 percent, to exclude factors other than nitrogen influencing the yield. Firstly, for the combined experiments the response to nitrogen was analysed by analysis of the response in the yield to the amount of nitrogen available and to the method of application. As the yield did not decrease with increasing amounts of nitrogen applied, the response to nitrogen was described with an exponential function (Figure 1). The residual sum of squares decreased and the percentage variance accounted for increased from about 40 to about 80 percent, when the amount of soil available mineral nitrogen in the soil layer 0–60 cm at planting was taken into account (Table 5). This means that the cauliflower crop can utilize the mineral nitrogen in the soil layer 0–60 cm at planting.

For the combined experiments band placement of fertilizer had no significant effect on the yield (Table 5).



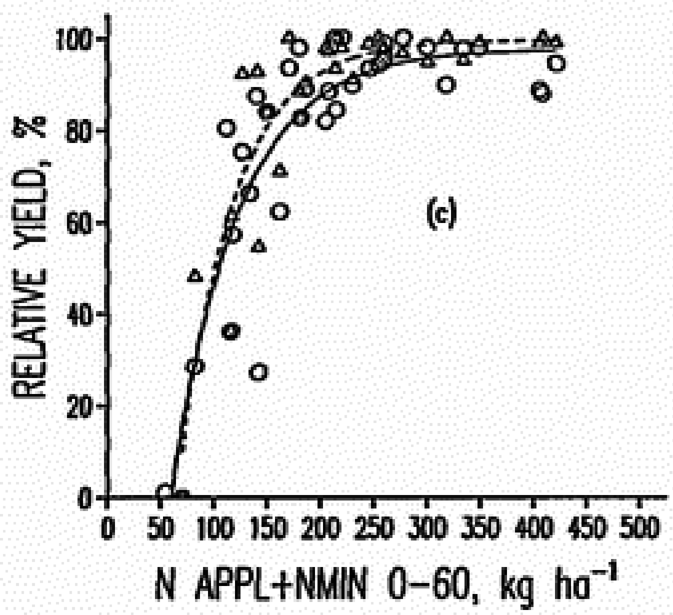


Figure 1. Relative yield in relation to, (a) the amount of nitrogen applied, (b) the amount of nitrogen applied plus the amount of mineral nitrogen in the soil layer 0–30 cm or (c) 0–60 cm before planting, and to the method of application.

The optimum nitrogen application for each separate experiment was determined with the linear plateau, or 'broken stick', response model (Uhte, 1990). In all experi-

Table 5. Results of the regression analysis of the response to the amount of nitrogen applied and to the amount of nitrogen applied plus the amount of mineral nitrogen in the soil layer 0–30 cm or 0–60 cm before planting (Figure 1).

	Residual sum of squares	Variance accounted for (%)	Significance		
				nitrogen application method	nitr. x appl. m.
N appl	23924	39	$P<0.001$	ns	ns
N appl + Nmin 0–30	16621	58	$P<0.001$	ns	ns
N appl + Nmin 0–60	8176	79	$P<0.001$	ns	ns

ments the optimum nitrogen application was determined on the combined data of the broadcast application and band placement treatments together (Figure 2, Table 6). This was done because in Experiments 1, 3, 4, 6 and 7 no effect on yield was found for the method of application (Table 4). While in Experiments 2 and 5 there was only a slight difference between the optimum nitrogen application determined on the yield data of the broadcast applications alone and that determined on the yield data of broadcast applications and band placement together.

In Experiment 1 and 7 the percentage variance accounted for is low. In these experiments, however, no significant response to nitrogen was found (Table 4).

In the next step the optimum nitrogen application for each experiment was related to the amount of soil available mineral nitrogen at planting. The optimum nitrogen

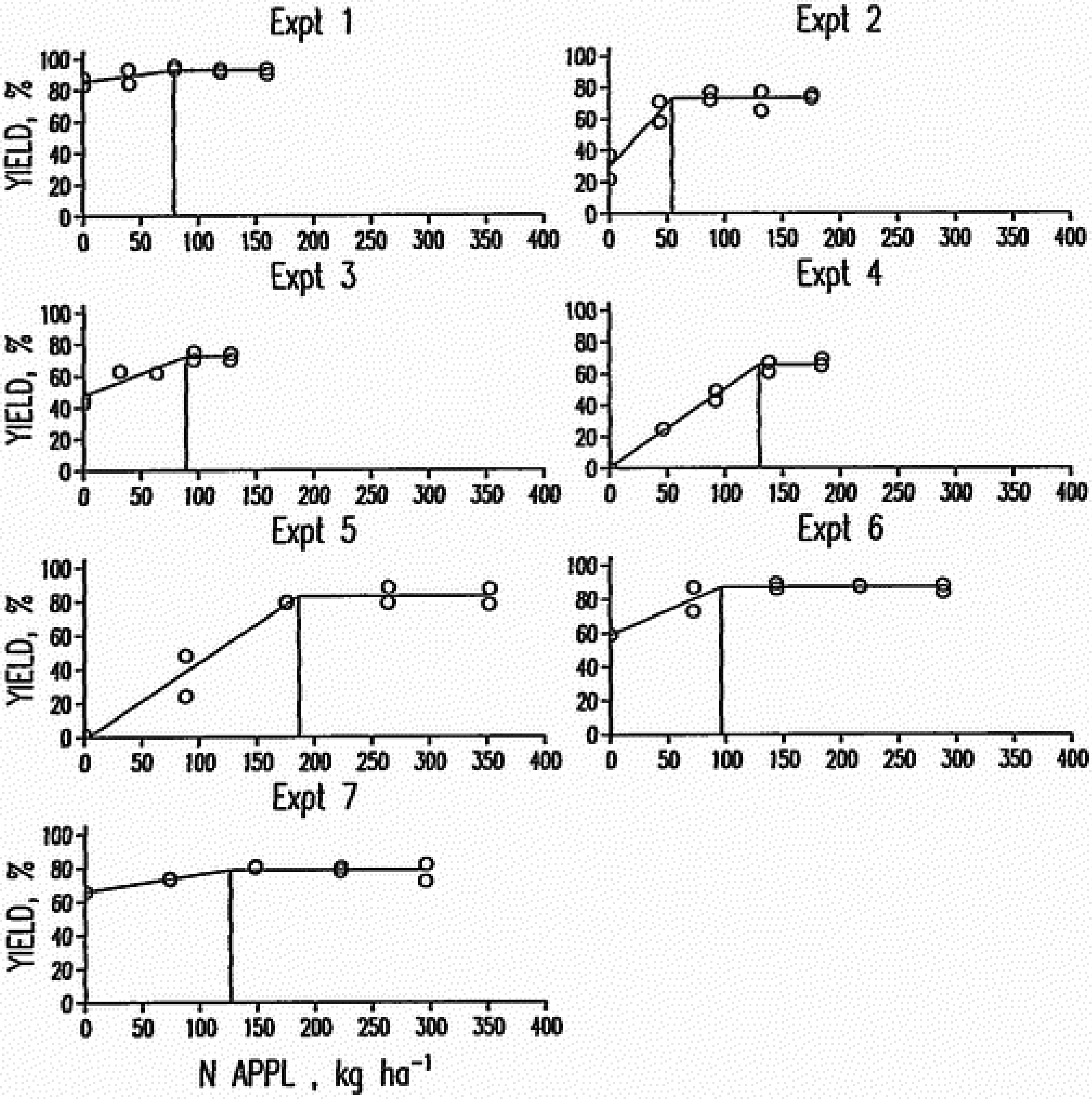


Figure 2. The optimum nitrogen application in each experiment as determined with the linear plateau response model (optimum indicated by the dotted line).

Table 6. Optimum nitrogen application for each experiment, the corresponding yield level and the variance accounted for (Figure 2).

Expt	1	2	3	4	5	6	7
Optimum nitrogen application (kg ha^{-1})	79	55	90	130	186	96	127
Yield (% curds quality I, size 'six')	92	73	72	66	83	87	79[1)]
Variance accounted for (%)	41	88	82	99	93	81	61

[1)] size 'eight'

application was not significantly related to the amount of mineral nitrogen at planting, when Experiment 2 was included in the analysis (Figure 3a). With the exclusion of Experiment 2, however, there was a significant linear relation (P=0.013) between the optimum nitrogen application and the amount of mineral nitrogen in the soil layer 0–60 cm at planting (Figure 3b). The low optimum nitrogen application for Experiment 2 (Table 6), in combination with the comparatively low amount of mineral nitrogen at planting (Table 3), suggests that in this experiment in particular a great deal of nitrogen became available through mineralization after planting. This obscures the relation between optimum application and mineral nitrogen at planting. The optimum nitrogen application (Nopt) for the experiments (excluding Experiment 2) is described as follows (Figure 3b):

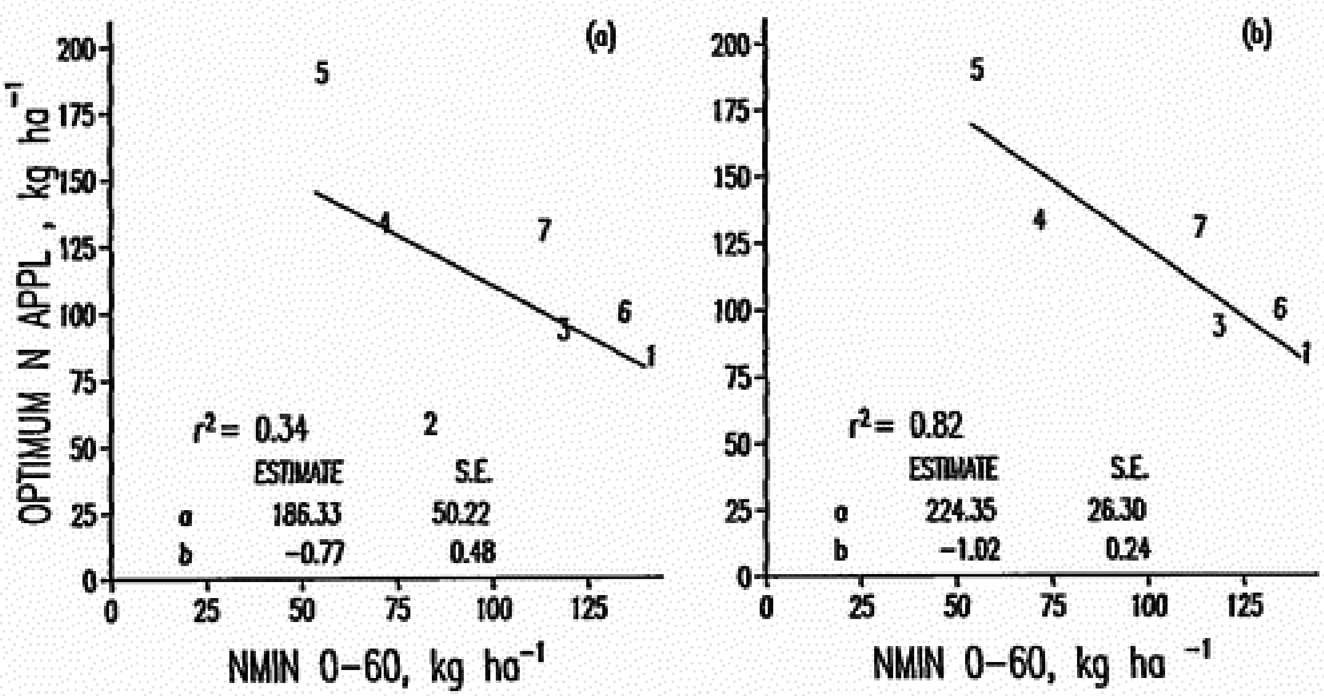


Figure 3. The relation between optimum nitrogen application and the amount of mineral nitrogen in the soil layer 0–60 cm before planting, (a) including Experiment 2, (b) excluding Experiment 2 (figures in the graphs are the figures of the experiments).

Table 7. Optimum nitrogen application for each experiment and the calculated optimum application according to equation (2) (kg ha^{-1}).

Expt	1	2	3	4	5	6	7
Optimum nitrogen application	79	55	90	130	186	96	127
Calculated optimum application	84	142	107	154	170	91	112

$$Nopt = 224.35 - 1.02 \times Nmin\ 0\text{–}60 \qquad (1)$$

or,

$$Nopt = 224 - Nmin \qquad (2)$$

There is reasonable agreement between the optimum application for each experiment (Table 6) and the optimum application calculated according to equation (2) (Table 7).

Because of the large variation in the price of the product, both in and between seasons and the minor share of the cost of nitrogen fertilizer in the total production costs (Balk-Spruit & Spigt, 1994), a financial analysis of the response to nitrogen is not relevant.

Practical implications

The range of optimum nitrogen applications for cauliflower is around 100–300 kg per hectare (Cutcliffe & Munro, 1976; Greenwood *et al.*, 1980; Nilsson, 1980; Weier & Scharpf, 1988; Welch *et al.*, 1985). The present officially recommended nitrogen application for cauliflower in the Netherlands is 300 kg per hectare, minus the mineral nitrogen in the soil layer 0–60 cm at planting. A minimum of 50 kg and a maximum of 250 (minus Nmin) kg per hectare should be given broadcast at planting and 50 kg per hectare at six weeks after planting. Based on the present experiments the optimum application is described as 224 – Nmin (0–60 cm) kg per hectare, all applied at planting. It appears that the officially recommended amount of nitrogen for cauliflower, at least for sandy clay soils, can be reduced to 225 kg per hectare. An extra 25 kg per hectare can perhaps be recommended in situations where more nitrogen is expected to be beneficial, such as in early spring when soil nitrogen mineralization is still low.

Band placement or split application are no option to increase yields or reduce fertilizer applications.

In a following paper the effect of nitrogen application on the uptake of nitrogen by the crop and nitrogen in crop residues and soil at harvest will be analysed.

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