# ESTIMATION OF NITROGEN UPTAKE OF FIELD VEGETABLES[1]

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## Abstract

Some fertilizer recommendation systems for field vegetables are based on estimated nitrogen (N) uptake curves. The estimation of nitrogen uptake should be as accurate as possible, in order to avoid recommendations being too high or too low. Therefore, the accuracy (standard error of difference between measured and estimated values, sd) of two estimation methods was compared. Comparison was carried out with measured nitrogen uptake curves of kohlrabi (Brassica oleracea var. gongylodes L.) and white cabbage (Brassica oleracea L. var. capitata f. alba).

For kohlrabi, the use of observed growth stages resulted in a small estimation error (sd = 14kg N $ha^{-1}$). This method is recommended since it is accurate and easy to use. The estimation that depended on time after planting, showed a larger estimation error (sd = 28 kg N $ha^{-1}$). For white cabbage, both methods tested were not suitable because estimation errors were too high (63 and 51kg N $ha^{-1}$, respectively).

## 1. Introduction

Field vegetable growers usually apply a part of the nitrogen (N) fertilization as a top dressing. Some authors (e.g., Lorenz et al., 1989; Gysi et al., 1988) have recommended that soil mineral N target values be estimated, not only for base dressing, but also for top dressing. For this calculation, it is necessary to estimate how much N will be taken up by the crop from top dressing until harvest. Look-up tables for several field vegetables, with average time courses of N uptake, have been published (Lorenz et al., 1989; Gysi et al., 1988). Measured uptake curves, however, can show considerable differences when compared to values taken from these look-up tables (Feller and Fink, 1996, 1997; Fink and Feller, 1998). The estimation of nitrogen uptake should be as accurate as possible, in order to avoid recommendations being too high or too low. Therefore, a method is presented to assess N uptake by observation of plant growth stages.

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## 2. Materials and Methods

### 2.1. Experiments with kohlrabi

Kohlrabi was grown in 16 field experiments over three years, at two experimental sites, using two cultivars and two plant densities. 12 experiments were carried out with four replications and 4 experiments with two replications. Plants were fertilized according to Fink and Scharpf (1993) up to a soil mineral N target value of 200 kg N $ha^{-1}$. Fresh matter, dry matter, number of leaves and tuber diameter were measured weekly, starting at the third week after planting. Experimental details are given by Feller and Fink (1997).

### 2.2. Experiments with white cabbage

White cabbage was grown in 13 field experiments over two years using five cultivars with four replications. Plant densities were chosen according to the recommendations of the plant breeder for each cultivar, respectively. Plants were fertilized according to Fink and Scharpf (1993) up to a soil minera1 N target value of 350 kg N $ha^{-1}$. Fresh matter, dry, number of leaves and head diameter were measured fortnightly, starting at the third week after planting. Experimental details are given by Fink and Feller (1998).

### 2.3. Growth stages

Growth stages were defined according to the crop-specific description of Feller et al. (1995). This definition is based on a uniform code system for all mono- and dicotyledonous plants that was published as 'Extended Uniform BBCH-Scale' by Hack et al. (1992). The BBCH scale describes growth and developmental stages of plants by means of a two-digit code. The first figure gives the macro stage, the second figure the micro stage. For the assessment of kohlrabi and white cabbage, macro stages 1 (development of leaves) and 4 (development of harvestable vegetative plant parts) are relevant (Table 1). Within macro stage 1, the respective micro stages are determined by the number of leaves. In macro stage 4, micro stages are determined by the growth of the plant part that is to be harvested, i.e., tuber diameter of kohlrabi and head diameter of cabbage, respectively. The relative description '... % of expected diameter' allows general usability of the scale. Application to a specific crop additionally requires the assignment of an absolute value to the expected final diameter. In the present study, 10 cm was used as a final diameter for the kohlrabi tuber. The final diameters for the white cabbage heads were defined as 18 cm (cultivars for fresh produce markets) and 25cm (cultivars for the processing industry), respectively.

For practical applications, a specific BBCH code is assigned when at least 50% of all from a canopy fulfill the respective growth stage description. In our experiments, weekly/fortnightly plant samples, rather than the whole canopy, were used for the assessment. A representative sample of eight plants was dried at 65 °C, and total nitrogen content was determined with a CHN-Rapid analyser (Haereus Company).

## 3. Results

### 3.1. Kohlrabi

Average N uptake of kohlrabi increased continuously, with respect to time after planting (Figure 1a). The biggest range (188kg N $ha^{-1}$) was reached six weeks after planting. Four weeks after planting, i.e. at approximately the usual top dressing date the range was

82kg N $ha^{-1}$. For the description of N uptake according to the BBCH scale, macro stage 4 was required since N uptake during macro stage 1 was lower than 18 kg N $ha^{-1}$ (Table 2). At growth stages 41 to 43, i.e., the usual top dressing date, the range was much smaller (Figure lb) - maximally 36 kg N $ha^{-1}$ - when compared to the estimation by time after planting. Estimated values were highly correlated with measurements (r = 0.97) and showed no significant bias (slope of regression line = 0.97; Figure 2). The standard error of estimation (sd) was 14 kg N $ha^{-1}$.

### 3.2. White cabbage

Similar to those for kohlrabi, estimation of N uptake of white cabbage from time after planting, showed a high variability (for example range = 200 kg N $ha^{-1}$ after 60 days; Figure 3a). Estimations based on the BBCH scale were also highly variable (Figure 3b). Estimations according to the BBCH scale were highly correlated with measurements (r = 0.91) and showed no significant bias (slope of regression line = 0.98; Figure 4). However, standard errors of difference between measured and estimated values were much higher (63 kg N $ha^{-1}$) for white cabbage than for kohlrabi.

## 4. Discussion

Time courses of N uptake of kohlrabi and white cabbage showed considerable variability in our experiments (Figure 1a, 3a). It is safe to assume that the variability is even higher in practice. For example, kohlrabi can be planted from March to August, recommended plant densities vary from 100 000 to 160 000 plants $ha^{-1}$, and plants are harvested with tuber diameters from 7 to 10 cm. Since N uptake per hectare is affected by all these parameters, an estimation based on time after planting is insufficient to calculate exact fertilizer recommendations for top dressing. On the other hand, the use of observed growth stages is preferred, since it is as easy to use (Table 1) and is more exact (Figure 1b). However, when compared to the time after planting method, the use of observed growth stages did not result in more exact estimations for white cabbage (Figure 2a, 2b). Measurements of head fresh weights (data not shown) indicated that not only the diameter, but also the specific mass of cabbage heads changed during crop development. Since this process cannot be assessed by determination of growth stages, this method cannot be recommended for white cabbage. Thus for white cabbage, both estimation methods tested are unsuitable because estimation errors were too high (time after planting method sd = 51 kg N $ha^{-1}$ and BBCH scale method 63 kg N $ha^{-1}$).

For the time being, the use of the BBCH scale is being restricted to kohlrabi produced for the fresh market, i.e. for kohlrabi with tuber diameters of less than 10 cm. Experiments with other crops, which might be suitable for the use of the BBCH scale (e.g. red beet, onions), will be conducted in the future.

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Table 1. Growth stages of kohlrabi and white cabbage according to the BBCH scale

| Growth stage description | Tuber diameter of kohlrabi | Head diameter of white cabbage | |
|---|---|---|---|
| | | fresh market | processing |
| **Development of leaves** | | | |
| cotyledons completely unfolded | | | |
| 1. leaf unfolded | | | |
| 2. leaf unfolded | | | |
| Consecutive up to | | | |
| 8. leaf unfolded | | | |
| 9 or more leafs unfolded | | | |
| **Development of harvestable vegetative plant parts** | | | |
| Beginning of tuber growth | | | |
| 20 % of expected diameter | 2cm | 3.5cm | 5.0cm |
| 30 % of expected diameter | 3cm | 5.5cm | 7.5cm |
| Consecutive up to | | | |
| 80 % of expected diameter | 8cm | 14.5cm | 20.0cm |
| typical form and diameter of tuber | >9cm | >16.0cm | >22.5cm |

Table 2. Growth stage and N in fresh matter related to estimated N uptake

| | Kohlrabi | | White cabbage | | | |
|---|---|---|---|---|---|---|
| | | | Fresh market | | Processing | |
| BBCH-Code | N in fresh matter g N plant$^{-1}$ | Estimated N uptake [1) 2)] kg N ha$^{-1}$ | N in fresh matter g N plant$^{-1}$ | Estimated N uptake [1) 3)] kg N ha$^{-1}$ | N in fresh matter g N plant$^{-1}$ | Estimated N uptake [1) 4)] kg N ha$^{-1}$ |
| 13 | 0.01 | 2 | 0.01 | 0 | 0.01 | 0 |
| 15 | 0.03 | 5 | 0.02 | 1 | 0.02 | 1 |
| 19 | | | 0.18 | 9 | 0.46 | 15 |
| 41 | 0.11 | 18 | 0.43 | 22 | 1.56 | 52 |
| 42 | 0.24 | 38 | 0.73 | 37 | 3.58 | 119 |
| 43 | 0.43 | 69 | 1.95 | 97 | 4.66 | 155 |
| 44 | 0.54 | 86 | 2.30 | 115 | 6.43 | 214 |
| 45 | 0.72 | 115 | 2.39 | 119 | 7.06 | 235 |
| 46 | 0.91 | 146 | 3.46 | 173 | 6.62 | 221 |
| 47 | 1.00 | 160 | 3.59 | 180 | 8.46 | 282 |
| 48 | 1.25 | 200 | 5.20 | 260 | 9.48 | 316 |
| 49 | 1.40 | 224 | 8.32 | 416 | 11.82 | 394 |

[1)] estimated N uptake = g N plant$^{-1}$ * plant density; [2)] typical plant density 160 000 plants ha$^{-1}$; [3)] typical plant density 50 000 plants ha$^{-1}$ ; [4)] typical plant density 33 333 plants ha$^{-1}$

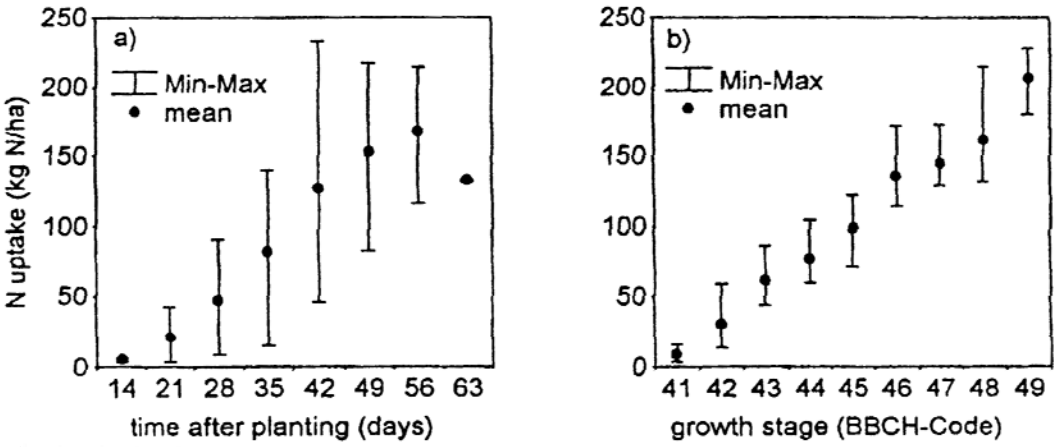


Figure 1. N uptake of kohlrabi related to a) time after planting; b) BBCH scale

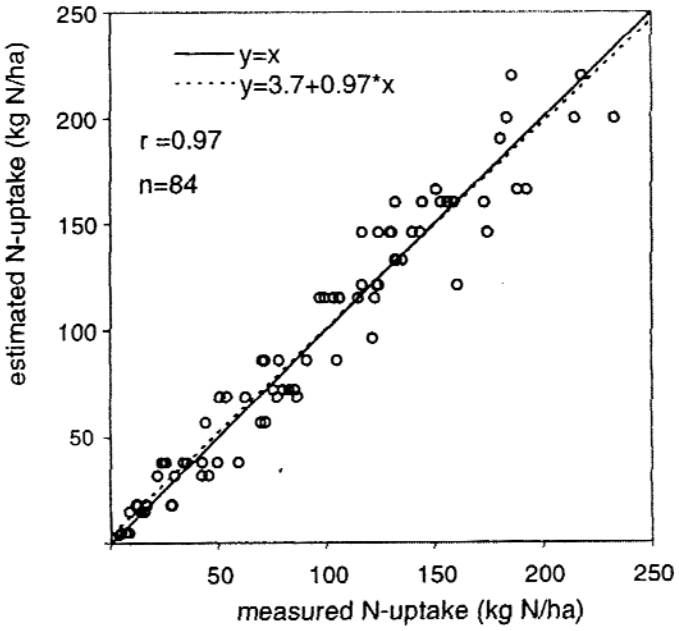


Figure 2. Measured N uptake of kohlrabi with respect to estimations using the BBCH scale

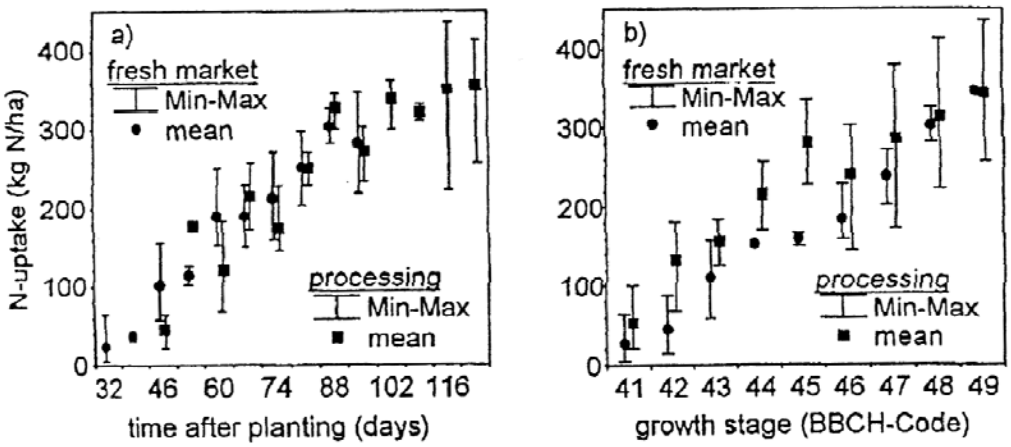


Figure 3. N uptake of white cabbage with respect to a) time after planting; b) BBCH scale

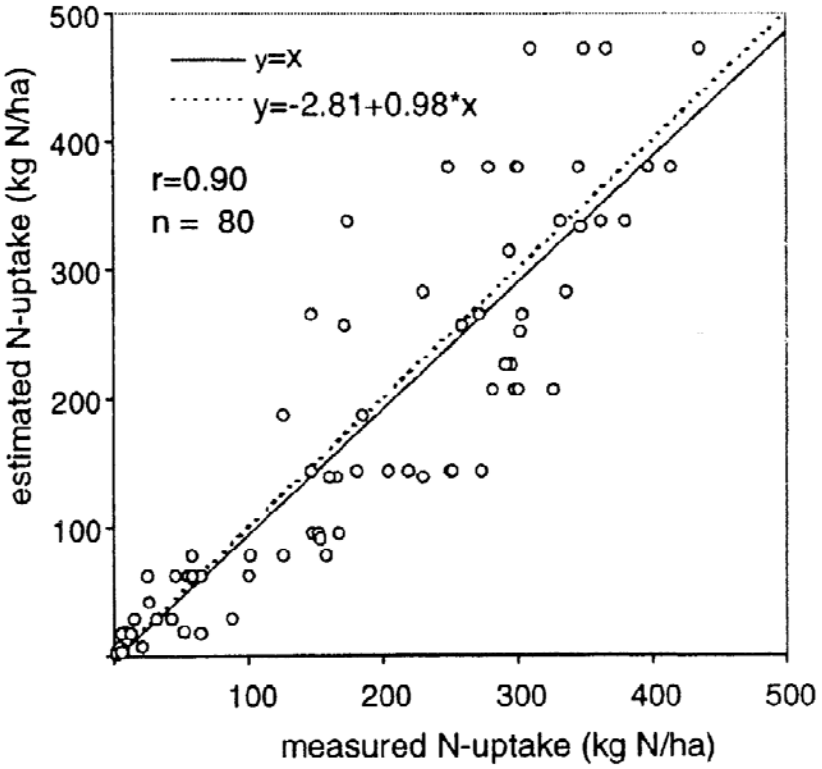


Figure 4. Measured N uptake of white cabbage with respect to estimates using the BBCH scale

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