N_{MIN} TARGET VALUES FOR FIELD VEGETABLES

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Abstract

The use of N_{min} target values for predicting the nitrogen (N) fertilizer demands of vegetable crops is common practice in several European countries. However, N_{min} target values, which in the past were derived mainly from fertilizer experiments, have not been determined for all commercially important crops. To solve this problem, this paper presents an algorithm and an up-to-data data set for calculating N_{min} target values from: (1) the expected N uptake by the crop, (2) the necessary N_{min} residue in the soil at harvest, and (3) the apparent net N mineralization.

1. Introduction

The use of the N_{min} system (Scharpf, 1991) for predicting the nitrogen (N) fertilizer demands of vegetable crops is recommended in several European countries (Rahn et al., 1998). The N_{min} system uses N_{min} target values, which in the past were determined mainly from fertilizer experiments (Scharpf, 1991). However, N_{min} target values have not been determined for all vegetable crops because of the high cost of carrying out such experiments and the large number of vegetable crops that are commercially important in Europe. Cost is not the only consideration. One of the greatest factors affecting N uptake, by crops is yield. Yield must be taken into account when predicting N fertilizer demand, as must the variation in the N supply by mineralization of soil organic matter. Therefore, it is not feasible to derive fertilizer recommendations for all possible combinations of soils and crops by performing fertilizer experiments (Greenwood et al., 1980).

Alternative approaches are to predict fertilizer demand by model-based decision support systems (e.g., Well_N; Rahn et al., 1996) or to calculate N_{min} target values from (1) the expected N in the crop at harvest, (2) the necessary N_{min} residue in the soil at harvest, and (3) the apparent net N mineralization (Equation 1). The latter approach is used by both the recommendation systems based on look-up tables (for example in Germany the KNS-System by Lorenz et al., 1989) and the computerized decision support system N-Expert (Fink and Scharpf, 1998).

Our paper presents an up-to-date set of calculated N_{min} target values for German growing conditions, and includes the algorithm and the data used for these calculations.

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2. Materials and Methods

N_{min} target values were calculated using Equation 1.

N_{min} target value = N_{crop} + $N_{residue}$ – ANM
where,

N_{crop} (kg N ha^{-1}) = N in the crop at harvest
$N_{residue}$ (kg N ha^{-1}) = necessary N_{min} residue in the soil at harvest
ANM (kg N ha^{-1}) = apparent net N mineralization

Equation 1

The crop data in Table 1 originate from several experiments conducted at four research stations in Germany (Fink et al., 1999). The experimental sites were located in Großbeeren, Hannover, Neustadt/Weinstraße and Geisenheim, and all crops were grown and fertilized according to the recommendations for commercial production of either Lorenz et al. (1989) or Fink and Scharpf (1998). Crops were harvested at the stage of maturity used in commercial production. The fresh matter and dry matter (dried at 65 °C) of the shoot and storage roots, excluding fibrous roots, were measured and the total N content determined using an Auto Analyser device (Heraeus, Germany) or ICP.

Apparent net N mineralization was estimated from 29 fertilizer trials with a total of 129 treatments carried out at one site over 15 years with a range of vegetable crops. The details of these trials are described by Fink and Scharpf (2000).

3. Results and Discussion

3.1. Nitrogen in the crop at harvest

N_{crop} was determined as the average N_{crop} of experiments carried out under good cropping conditions (i.e., growth was not limited by nutrients, water, pests or diseases) (Table 1). To accommodate higher or lower than expected yields when using the algorithm, a site-specific adaptation of the calculated N_{min} target value can be made by increasing or decreasing the expected N uptake. A choice of adapted target values for species showing large variations in N uptake or growing times depending on variety or growing method (e.g., white cabbage) can be found in Table 1.

3.2. Necessary mineral $N_{residue}$ in the soil at harvest

Although the concept of a necessary $N_{residue}$ for vegetable crops has been applied in Germany for more than ten years for calculating fertilizer recommendations (Lorenz et al., 1989), little experimental work on this topic has been published in scientific literature. Therefore senior advisors rely on their own experience to determine $N_{residue}$ when making recommendations to farmers; these $N_{residue}$ figures are purely empirical (Table 1). Vegetable crops that take up large amounts of N just before harvest and respond negatively in yield or quality to nitrogen limitation (e.g., cauliflower, cornsalad and bunching onions) generally need an N_{min} residue of 40 to 50 kg N ha^{-1} in the root zone. In contrast, a low N_{min} residue of 0 kg N ha^{-1} is required if crop quality is negatively affected by high levels of N (e.g., stability of Brussels sprout stems, nitrate content of carrots for baby food, and the forcing quality of chicory).

3.3. Apparent net N mineralization

Apparent net N mineralization (ANM) is defined as the difference of nitrogen supply (N_{supply}) and nitrogen recovery ($N_{recovery}$) (Equation 2)

$$ANM = N_{recovery} - N_{supply}$$

where,

ANM (kg N ha^{-1}) = apparent net N mineralization
N_{supply} (kg N ha^{-1}) = N fertilizer + N_{min} at planting
$N_{recovery}$ (kg N ha^{-1}) = N in crop + N_{min} at harvest

Equation 2

Figure 1 shows the results of a single experiment (Fink and Scharpf, 2000) with six fertilizer levels. $N_{recovery}$ at harvest was higher than the N_{supply} at planting, indicating that all the treatments had a positive ANM. ANM decreased with increasing N_{supply}.

In a larger study of 29 fertilizer trials, Fink and Scharpf (2000) found a similar relationship. However, the variation in the pooled data was much higher caused by year and crop effects (Figure 2). Figure 2 shows that apparent net N mineralization was positive for all treatments with a low $N_{supply.}$ The regression line depicts decreasing ANM with increasing N_{supply}. N_{supply} greater than 300 kg N ha^{-1} led to negative apparent net N mineralization.

The parameters of the regression function (Figure 2) can be interpreted as: a constant reflecting the apparent N mineralization of soil organic matter (AM = 65 kg N ha^{-1}, constant of the regression function) and an N_{supply} dependent term reflecting the incomplete recovery of nitrogen supply by the crop at harvest (REC = 0.80, slope of the regression function). This reflects the fact that only a part of the nitrogen supply was recovered by the crop at harvest (Appel., 1994). Recovery of less than 100% of the N_{supply} can result from gaseous losses, N immobilization and N use in fibrous roots. None of these processes were measured in this study. Further analysis of the data revealed an increase of apparent net N mineralization with increasing time between planting and harvest. Therefore, in the algorithm we present, the apparent net N mineralization is estimated by a multiple regression function dependent on N_{supply} and time between planting and harvest (Equation 3). The use of this regression equation to estimate ANM is explained in greater detail by Fink and Scharpf (2000).

$$ANM = (DAM \times L) - (1 - REC) \times [N_{supply} - (DAM \times L)]$$

where,

DAM (kg N ha^{-1} day^{-1}) = daily apparent net N mineralization rate

L (days) = period of time between planting and harvest

and,

$$ANM = (DAM \times L) \text{ if } N_{supply} < (DAM \times L)$$

Equation 3

Strictly speaking, the parameter estimates (DAM = 0.79 kg N ha^{-1} d^{-1}; REC = 0.80), and hence the calculated apparent net N mineralization values presented in Table 1, are valid only for the experimental site used in this study. Therefore, site-specific estimates of DAM should be used instead. If these are not available, 0.79 kg N ha^{-1} d^{-1} (or 5.5 kg N ha^{-1} $week^{-1}$) can be safely used; it is an estimate that is similar to both the average value recommended for the Rhineland Palatinate in Germany (5 kg N ha^{-1} $week^{-1}$; Lorenz et al., 1989) and the default value in the English fertilizer recommendation system, Well_N (0.70 kg N ha^{-1} d^{-1} at 15.9 °C; Rahn et al., 1996).

3.4. Conclusions

The nitrogen requirements of vegetable crops are met to a large extent by apparent net N mineralization (Equation 3) when the N demand is moderate and the period of time between planting and harvest is long, as in the case of carrot or black salsify (Table 1). For crops with high N requirements and short growing periods, such as cauliflower or broccoli, net N mineralization should be considered close to zero, or even slightly negative (Table 1).Calculated N_{min} target values were well correlated (r = 0.92) to target values derived experimentally by Scharpf (1991) (Figure 3). Therefore, we conclude it suitable to calculate N_{min} target values from N_{crop}, $N_{residue}$ and ANM, to make fertilizer recommendations for crops for which there is little experimental data on N response.

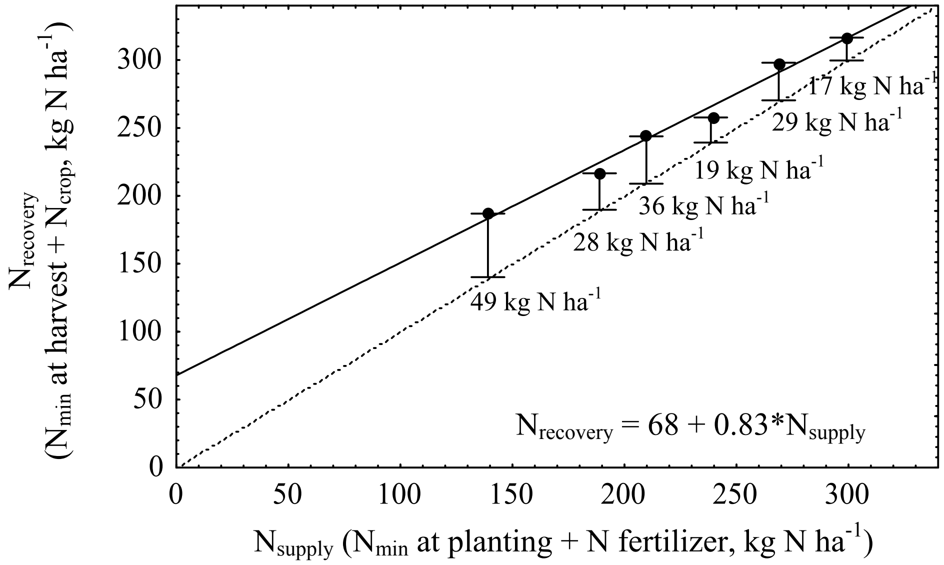

Figure 1. $N_{recovery}$ at harvest related to N_{supply} for a single experiment on white cabbage conducted in 1994. Data from Fink and Scharpf (2000). Points denote measurements, the solid line is the regression line ($y = 68 + 0.83x$, n = 6, $r^2 = 0.98$) and the dashed line is $y = x$. The vertical departure of the regression line from y=x denotes the apparent net N mineralization.

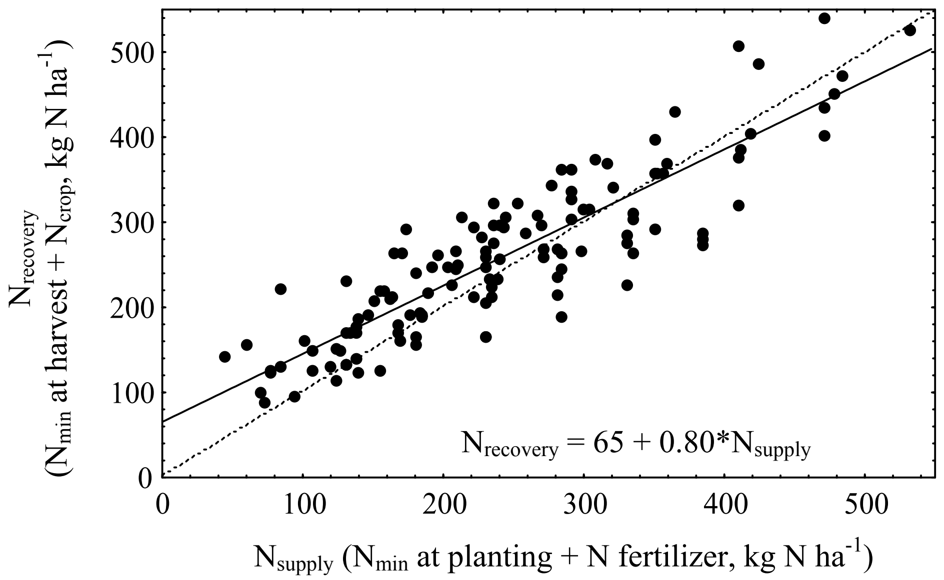

Figure 2. N recovery at harvest related to N supply from data of 29 experiments (Fink and Scharpf, 2000). Points denote measurements, the solid line is the regression line ($y = 65 + 0.80x$, n=129, $r^2 = 0.77$) and the dashed line is $y = x$.

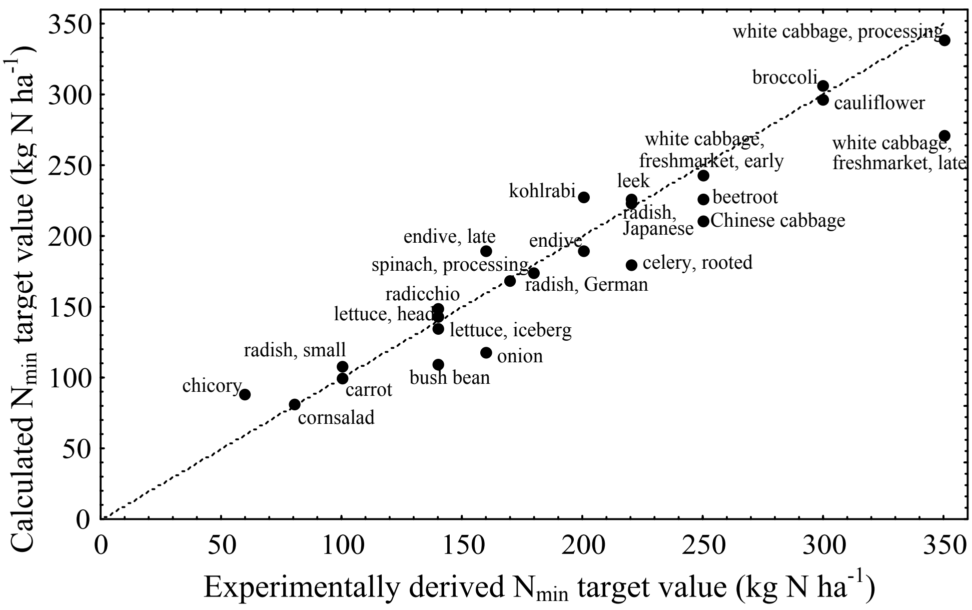

Figure 3. N_{min} target values derived experimentally by Scharpf (1991) related to calculated N_{min} target values (Table 1). Dashed line is $y = x$.

Table 1. Calculated N_{min} target values (Equation 1) and data used for the calculations

Crop name	Growing period	Soil sampling depth	N_{crop}	$N_{residue}$	ANM	N_{min} target value
	Days	cm	kg N ha^{-1}	kg N ha^{-1}	kg N ha^{-1}	kg N ha^{-1}
Bean, climbing	105	60	243	0	100	143
Bean, dwarf	70	60	121	20	31	110
Beetroot	140	60	268	20	61	227
Beetroot, baby beet	80	60	162	20	31	151
Beetroot, bunching	95	60	162	20	45	137
Black salsify	190	90	96	0	133	0
Broccoli	64	60	260	40	-7	307
Brussels sprouts	150	90	423	0	122	301
Cabbage, red	100	60	230	20	35	215
Cabbage, savoy	105	60	263	20	32	251
Cabbage, white, processing	125	90	350	20	31	339
Cabbage, white, fresh market	90	60	270	20	18	272
Carrot	95	60	151	0	51	100
Carrot, bunching	90	60	102	20	53	69
Carrot, processing	198	60	207	0	129	78
Cauliflower	63	60	251	40	-6	297
Celeriac	130	60	200	40	63	177
Arugula, one cut	35	30	108	40	-1	149

Crop name	Growing period	Soil sampling depth	N_{crop}	$N_{residue}$	ANM	N_{min} target value
Celeriac, bunching	65	30	173	40	12	202
Celery	85	30	200	50	22	228
Chinese cabbage, planted	56	60	195	20	4	211
Chinese cabbage, sown	70	60	195	20	16	199
Chives, after cutting	28	60	120	50	-11	181
Chives, for forcing	182	60	250	20	102	168
Chives, sown, until 1st cut	120	60	180	50	56	174
Cornsalad	50	15	45	40	4	81
Dill	49	30	96	40	14	122
Endive	60	60	160	40	10	190
Endive, curly-leaved	45	60	113	40	7	146
Florence fennel, planted	60	60	170	40	8	202
Florence fennel, sown	88	60	170	40	33	177
Kale	134	60	208	20	69	159
Kohlrabi	42	30	179	40	-9	228
Leek, planted, autumn and winter	110	60	225	40	40	225
Leek, sown, summer	170	60	200	40	98	142
Lettuce head	35	30	108	40	-1	149
Lettuce romaine	45	60	110	40	8	142
Lettuce romaine, heart	56	60	107	40	18	129
Lettuce, baby leaf	56	30	53	50	27	76
Lettuce, loose-leaf, green	30	30	86	40	0	126
Lettuce, loose-leaf, red	33	30	76	40	4	112
Lettuce, iceberg	45	30	104	40	9	135
Marrow squash	119	60	200	0	62	138
Onion	140	60	168	30	80	118
Onion, bunching	75	30	160	50	21	189
Parsley, after cutting	42	60	88	40	10	118
Parsley, root	126	60	168	0	74	94
Parsley, until 1st cut	90	60	132	40	42	130
Parsnip	210	60	215	0	138	77
Pea, wrinkled, early-maturity group	77	60	188	0	88	100
Pickling cucumber, planted	119	30	205	40	52	193
Radicchio	65	60	125	40	22	143
Radish	45	60	137	40	2	175
Radish, bunching	40	30	102	40	5	137
Radish, Japanese	50	60	184	40	-3	227
Small radish	28	30	70	40	1	109
Spinach, fresh market	40	30	126	40	0	166
Spinach, processing	47	30	144	40	2	182
Sweet corn	105	90	190	20	47	163
Witloof chicory	160	90	188	0	100	88
Zucchini	112	60	230	20	45	205

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