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Nitrogen Contribution of Green Pea Residues to a Succeeding Spinach Crop

Stickstoffnachlieferung aus Ernterückständen von Grünerbsen während einer nachfolgenden Spinatkultur

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Summary

The objectives of this study were to quantify how much nitrogen (N) from harvest residues of pea (*Pisum sativum* L.) is mineralized during a succeeding spinach (*Spinacia oleracea* L.) crop, and whether the mineral fertilization of spinach could be reduced by this amount, thereby reducing soil mineral N at harvest and nitrate in the produce without losses in spinach yield.

In 1995 and 1996, two field experiments were conducted at the research station in Großbeeren, Germany, an a sandy soil. In 1995, spinach was grown in a one-factor experiment with and without a preceding pea crop. The results suggested that the recommended standard mineral N fertilization (FINK and SCHARPF 1993) could be reduced by 30 kg N ha^{-1} with a preceding pea crop. This hypothesis was tested in 1996 in a two-factor experiment.

In 1996, the N balance at harvest date of the spinach crop showed that apparent net N mineralization due to pea residues was 25 and 44 kg N ha^{-1} in soil layers of 0–30 and 0–90 cm, respectively. The treatments had no effect on the spinach nitrate content. Total fresh matter yield was not significantly affected, comparing the treatments 'reduced mineral fertilization with pea residues' and 'standard mineral fertilization without pea residues'. It is concluded that mineral fertilization recommended by FINK and SCHARPF (1993) can be reduced by 30 kg N ha^{-1} if spinach is grown after incorporating pea residues.

Zusammenfassung

Ziel der vorliegenden Untersuchung war es, zu quantifizieren, um wieviel die mineralische Düngung von Herbstspinat vermindert werden soll, um die Mineralisation von Stickstoff aus Ernterückständen von Erbsen zu berücksichtigen. Auf einem Sandboden wurden zwei Feldversuche durchgeführt: im Jahr 1995 wurde Spinat in einem einfaktoriellen Feldversuch mit und ohne Erbsenvorkultur angebaut. Die Stickstoffbilanz von Boden und Pflanze zeigte im Jahr 1995, dass im Verlauf der Spinatkultur ca. 30 kg N ha^{-1} aus Ernterückständen der Erbsen mineralisiert wurde. Aus diesem Ergebnis wurde die Hypothese abgeleitet, dass der N_{min}-Sollwert für Spinat (FINK und SCHARPF 1993) um 30 kg N ha^{-1} vermindert werden kann, wenn Spinat nach einer Erbsenvorkultur angebaut wird.

Diese Hypothese wurde in einem zweifaktoriellen Feldversuch 1996 geprüft. Zum Ende der Spinatkultur ergab die Stickstoffbilanz, dass in den Behandlungen mit Ernterückständen, in der Bodenschicht 0–30 cm 25 kg N · ha^{-1} bzw. in der Bodenschicht 0–90 cm 44 kg N ha^{-1} mehr Stickstoff mineralisiert wurde.

Der Aufwuchs der Behandlung „mit Ernterückständen, N_{min}-Sollwert um 30 kg N ha^{-1} reduziert" unterschied sich nicht signifikant von dem Aufwuchs der Behandlung „ohne Ernterückstände, N_{min}-Sollwert". Keine Behandlung hatte einen signifikanten Einfluss auf die Nitratgehalte in der Spinatfrischmasse.

Aus den Ergebnissen wird die Empfehlung abgeleitet, dass der von FINK und SCHARPF (1993) empfohlene N_{min}-Sollwert bei der Düngung von Herbstspinat um 30 kg N ha^{-1} vermindert werden kann, wenn zuvor die Ernterückstände einer Erbsenvorkultur eingearbeitet wurden.

Introduction

In areas where vegetables for processing are grown, it is common practice to grow spinach after pea crops. At spinach harvest time, GOMMLICH (1994) found undesirably high contents of soil mineral N and nitrate in the produce when spinach was fertilized according to the soil mineral N target value recommended by SCHARPF (1991). For cereals (deep-rooted crops that grow for several months) the recommended application rates of fertilizer N are lower for crops grown following leguminous than non-leguminous crops (FRANCIS et al. 1994). GOMMLICH's report indicated that N-supply by the mineralization of pea residues should also be considered for the fertilization of spinach, a shallow-rooted crop (SCHENK et al. 1991) that is harvested after a few weeks.

The objectives of this study were to quantify how much N from harvest residues of pea is mineralized during a succeeding spinach crop, and whether the mineral fertilization can be reduced by this amount, thereby reducing soil mineral N at harvest and nitrate in the produce without losses in spinach yield.

Materials and methods

The study was conducted in 1995 and 1996 on a sandy soil at the experimental site of the Institute of Vegetable and Ornamental Crops, Großbeeren, Germany. The experiments were designed as complete randod block designs with four replications and an area of 16 m^2 per plot in 1995 and 8 m^2 per plot in 1996.

Experiment 1

In 1995, the effect of a pea crop on the nitrogen uptake and balance of a succeeding spinach crop was studied in a one-factor experiment. The peas were sown on April 11th in 'with pea' treatment plots. 'Without pea' treatment plots were kept fallow. Emerging weed was removed regularly by hand until the end of the experiment. After the emergence of the peas, the plots of both treatments were fertilized with 60 kg N ha^{-1}. The peas were harvested on July 11th; the pea corns were removed. Harvest residues were worked into the soil with a rotary hoe, starting two days after harvest. Spinach was sown in all the plots on August 9th, and fertilized with 120 kg N ha^{-1} on August 28th, thereby obtaining an N supply (fertilizer N + soil mineral N in a soil layer of 0–30 cm) of 180 kg N ha^{-1}. The spinach was harvested on September 26th.

Experiment 2

In 1996, a two-factor experiment was carried out in which the treatments 'with pea' and 'without pea' and the treatments 'standard fertilization' and 'reduced fertilization' for spinach were combined. Peas were sown an April 22nd in 'with pea' treatment plots. 'Without pea' treatment plots were kept fallow. Emerging weed was removed regularly until the end of the experiment. After the emergence of the peas, plots of both treatments were fertilized with 60 kg N ha^{-1}. The peas were harvested on July 8th; the pea corns were removed. Harvest residues were worked into the soil with a rotary hoe starting two days after harvest. Spinach was sown in all the plots on August 5th. On August 19th, plots were fertilized with the 'standard' (155 kg N ha^{-1} according to FINK and SCHARPF 1993) and the 'reduced' (125 kg N ha^{-1}) amount of fertilizer, thereby obtaining an N-supply (0–30 cm) of 180 kg N ha^{-1} and 150 kg N ha^{-1}, respectively. Spinach was harvested on September 12th.

Both experiments were irrigated according to the irrigation scheduling computer program 'BEREST' (GUTEZEIT et al. 1993).

Fresh weight of plant material was determined from plot cores (4 m^2). Representative parts of these samples were dried at 65 °C. Nitrogen contents were measured by an auto analyser, and the nitrate concentration in spinach leaves (mg NO_3 (kg fresh matter)$^{-1}$) was determined with a nitrate-sensitive electrode after the extraction of mashed fresh matter with 1% $KAl(SO_4)_2$. Soil mineral nitrogen (N_{min}) was measured in soil samples (15 auger samples per plot) using an EPOS photometer after extraction with 0.0125 *M* $CaCl_2$.

Table 1. Properties of pea residues and N contribution (ANM) to a succeeding spinach crop. ANM was calculated using Equation 2 and data shown in Table 2.
Eigenschaften der Ernterückstände von Erbsen und deren Stickstoffbeitrag (ANM) zur nachfolgenden Spinatkultur. ANM wurde mit Gleichung 2 unter Verwendung der in Tabelle 2 angegebenen Versuchsergebnisse berechnet.

	Dry matter of pea residues	N in pea residues	ANM due to pea residues (Equation 2)
	t ha^{-1}	kg N ha^{-1}	kg N ha^{-1}
Experiment 1 (1995)	5.6	144	39 n.s.[a]
Experiment 2 (1996)	5.4	130	44*[b]
Average	5.5	137	42

[a]) not significant
[b]) mean of two fertilizer treatments, significant at $P < 0.05$

Apparent net mineralization (ANM) of nitrogen was calculated with Equations 1 and 2, respectively:

Equation 1
ANM during the period from harvest date of pea to harvest date of spinach (kg N ha^{-1}) =
+ N_{min} at harvest date of spinach, 0–90 cm (kg N ha^{-1})
+ nitrogen in above-ground plant material at harvest date of spinach (kg N ha^{-1})
– N_{min} at harvest date of pea, 0–90 cm (kg N ha^{-1})
– nitrogen applied by fertilization after harvest date of pea (kg N ha^{-1})

Equation 2
ANM due to pea residues (kg N ha^{-1}) =
+ ANM of treatments with pea (kg N ha^{-1})
– ANM of treatments without pea (kg N ha^{-1})

Analyses of variance and statistical tests were calculated with the STATISTICA program (StatSoft Inc., Tulsa, Oklahoma, USA). In the table, results of the F-test ('*' indicates significance at $P < 0.05$) are given. In the figures, different letters in the columns indicate significant differences according to Tukeys LSD-test.

Results

After the harvest of the pea plants, a mean of 5.5 t ha^{-1} residues, containing 137 kg N ha^{-1}, remained in the

Table 2. Components of the nitrogen balance.
Komponenten der Stickstoffbilanz.

	Experiment 1 with pea	Experiment 1 without pea	Experiment 2 with pea N supply 150 kg ha^{-1}	Experiment 2 without pea N supply 150 kg ha^{-1}	Experiment 2 with pea N supply 180 kg ha^{-1}	Experiment 2 without pea N supply 180 kg ha^{-1}
	kg N ha^{-1}					
N_{min} at harvest date of spinach, 0–90 cm	82	65	72	99	98	123
N in spinach	115	99	163	141	170	153
N_{min} at harvest date of pea, 0–90 cm	76	84	66	117	66	117
N applied by fertilization after harvest date of pea	120	120	125	125	155	155

field (Table 1). In experiment 1, at the harvest date of spinach the ANM (Equation 2) caused by pea residues was approximately 30 kg N ha^{-1} in a soil layer of 0–30 cm and approximately 40 kg N ha^{-1} in a soil layer of 0–90 cm (Table 1). Since the rooted soil layer of spinach is 30 cm these results suggested that the recommended mineral fertilization for spinach could be reduced by 30 kg N ha^{-1} with a preceding pea crop.

This hypothesis was confirmed in experiment 2. Reducing the mineral fertilization by 30 kg N ha^{-1} did not result in significant yield reductions, in treatments both with and without harvest residues (Figure 1a). The nitrate content of spinach was not significantly affected by pea residues or by mineral fertilization (Figure 1b), and pea residues did not increase soil mineral N at harvest (Figure 1c).

Discussion

The amount of nitrogen in pea residues that we measured in this study (137 kg N ha^{-1}; Table 1) agreed well with measurements from other experiments reported by HAUNZ et al. (1988), STEVENSON and VAN KESSEL (1996) and MAIDL et al. (1991), who found 140, 116 and 120 kg N ha^{-1}, respectively.

In spite of these high amounts of N remaining in residues after harvest, the N benefit from legume above-ground residue is generally small for a succeeding crop (BECKIE et al. 1997). The average N contribution of 42 kg N ha^{-1} that we measured (Table 1) corresponds to the range reported in the literature. For example, EVANS et al. (1989) and ARMSTRONG et al. (1994) found that the N contribution of pea was about 20 kg N ha^{-1}, MAHLER and AULD (1989) reported less than 30 kg N ha^{-1} and STEVENSON and VAN KESSEL (1997) measured N contributions to the soil of 45–63 kg N ha^{-1}, depending on the experimental site. JENSEN (1989) stated that the effect of pea as a preceding crop to winter oil seed rape was equivalent to 20–80 kg N ha^{-1}.

One reason that only a part of total N in pea residues can be used by a succeeding crop is that N mineralization after incorporating leguminous residues often takes three to four months (AMATO et al. 1989). An increased net N mineralization due to pea residues during four months was reported also by MAIDL et al. (1991).

In our experiments the spinach was harvested approximately two months after the incorporation of the residues, when only a part (42 kg N ha^{-1}; Table 1) of the total N in residues (137 kg N ha^{-1}; Table 1) had been mineralized. Therefore, the mineralization process was probably not finished at the spinach harvest date. The results from our experiments and from the literature indicate that mineralization of pea residues takes longer than mineralization of several other vegetable crop residues, which often mineralize more than 90% of the total N within nine weeks (SCHARPF and SCHRAGE 1988).

Conclusions

In contrast to the reports of GOMLICH (1994), neither soil mineral N at harvest nor the nitrate content of spinach were increased by pea residues in our experiments (Figure 1b, c). Apparent net mineralization caused by residues during the succeeding crop was considerably lower than total N in above-ground pea residues, so only a part of the N in pea residues should be considered when calculating fertilizer recommendations for a succeeding crop that is to be harvested after a few weeks, as is the case for most vegetable crops.

Since spinach yield was not diminished by reduced

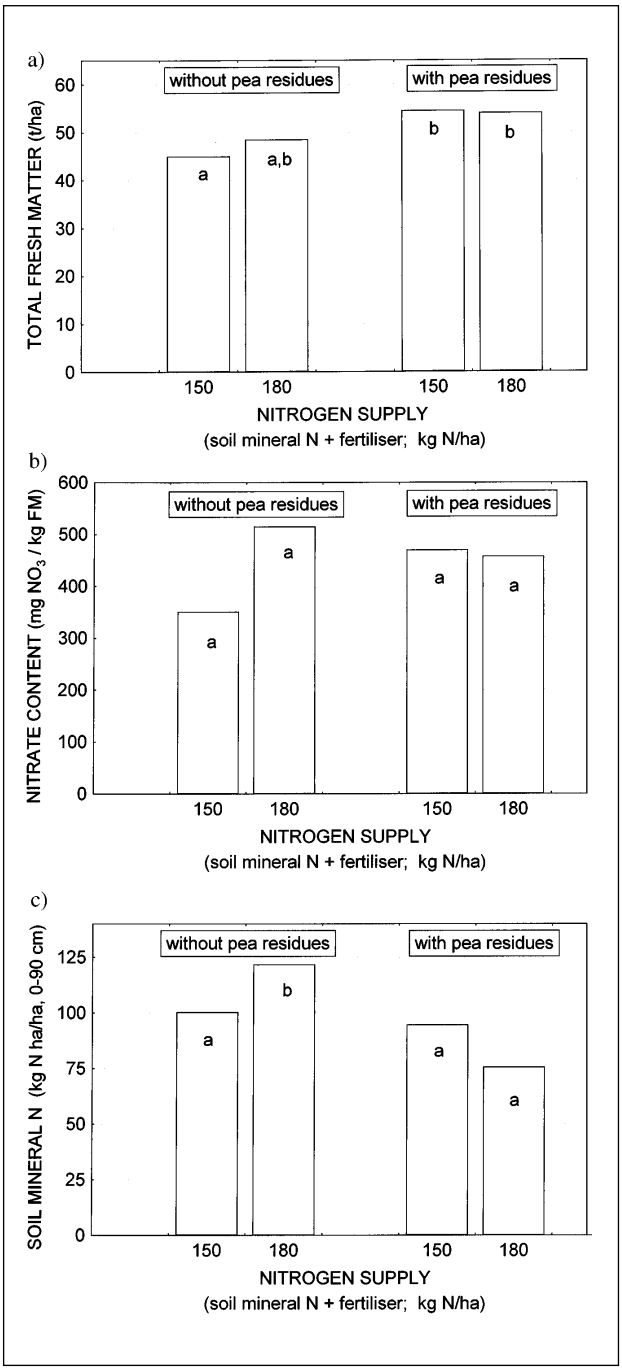


Fig. 1. Effect of mineral N supply and pea residues on a) spinach yield; b) nitrate content of spinach, and c) soil mineral N at harvest (Experiment 2, 1996).
Einfluss von N-Angebot und Ernterückständen auf a) Spinatertrag, b) Nitratgehalt des Spinats und c) N_{min}-Rest am Kulturende (Experiment 2, 1996).

fertilization (Figure 1a), we conclude that the soil mineral N target value recommended by FINK and SCHARPF (1993) can be reduced by at least 30 kg N ha^{-1} if spinach is grown after incorporating pea residues.

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