Pre-crop effects of grain legumes and linseed on soil mineral N and productivity of subsequent winter rape and winter wheat crops

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Vorfruchteffekte von Körnerleguminosen und Öllein auf den N_{min} im Boden sowie die Produktivität nachfolgender Winterraps- und Winterweizenbestände

1. Introduction

The reasons for significant effects of pre-crops on the performance of subsequent crops are various. Grain legumes are assumed to be excellent pre-crops for cereals. Besides phytopathological advantages, their positive effect is mainly attributed to the comparatively high nitrogen residues which they leave after harvest as residual soil mineral N (SMN) as well as in organic crop residues. On the other hand, crops like linseed with small amounts of residual nitrogen and a high C:N ratio in crop residues might limit the production of subsequent crops due to immobilization of soil-borne mineral nitrogen. The grain legume species adapted to temperate climate conditions, i. e. pea, faba bean and lupin, and linseed can differ substantially with view to the residue amounts and quality (KAUL, 2004).

CHRISTEN and SIELING (1994) report yield improvements of winter rape by 0.1–0.6 t ha^{-1} due to an additional pea crop in a cereal rotation. A contemporary textbook in agronomy, however, suggests that pre-crop effects are of decreasing importance when environmental conditions for the subsequent crop improve. In conventional production systems, fertilization of subsequent crops with mineral nitrogen should be able to compensate differences in pre-

Zusammenfassung

Vorfrüchte können den Nachfrucht-Ertrag auf Grund ihrer Stickstoff(N)-Rückstände und wegen anderer agronomischer Einflüsse variieren. Die vorliegende Untersuchung prüft für Vorfrüchte mit deutlich unterschiedlichen Ernterückständen, ob diese den Ertrag nachfolgender, mineralisch gedüngter Bestände beeinflussen. Zu diesem Zweck wurden in einem Feldversuch auf der Versuchsstation Ihinger Hof der Universität Hohenheim (49° N, 9° O, Jahresmitteltemperatur 8.0 °C, mittlere Niederschlagssumme 690 mm $Jahr^{-1}$, 480 m NN) die Körnerleguminosen Erbse, Ackerbohne und Weiße Lupine sowie Öllein mit je zwei Sorten in den Jahren 1995 und 1996 angebaut. Nach der Ernte dieser Vorfrüchte wurde Winterraps und Winterweizen ausgesät und in der Folge mit 150 kg N ha^{-1} gedüngt, um hohe Erträge zu erzielen und Vorfruchteffekte möglicherweise auszugleichen.

Erbsen und Ackerbohnen produzierten hohe, der Öllein nur mäßige Erträge, während die Lupinen ihr Ertragspotential nicht realisieren konnten. Die Gesamt-N-Rückstände lagen zwischen 48 und 110 kg N ha^{-1}. Die N_{min}-Werte vor Vegetationsruhe sowie im ausgehenden Winter rangierten in beiden Jahren am höchsten nach Erbse > Ackerbohne > Lupine und Öllein. Die Bestandesdichte von Winterraps im Frühjahr war am höchsten nach Erbse, während die Rapsbestände nach Ackerbohne in beiden Jahren und nach Lupine im Jahr 1997 die niedrigsten Dichten aufwiesen. Die Vorfrucht-Unterschiede im Winterrapsertrag waren verhältnismäßig gering, allerdings erreichte der Raps nach Erbsen in beiden Jahren die höchsten Erträge. Bei Winterweizen waren weder auf die Pflanzendichte noch auf den Ertrag Vorfruchteinflüsse nachweisbar, aber die N-Aufnahme in den Spross war nach Erbsen und Ackerbohnen erhöht. Offenbar kann eine Mineraldüngung die Unterschiede zwischen Vorfrüchten im Nachfruchtertrag stark nivellieren, jedoch nicht vollkommen ausgleichen.

Schlagworte: Vorfruchteffekte, Stickstoff, Körnerleguminosen, Lein, Winterweizen, Winterraps.

Summary

Pre-crops can have yield effects on subsequent crops due to their nitrogen (N) residues and for other agronomical reasons. The present study evaluates for pre-crops with substantially different crop residues whether fertilized subsequent crops show any yield effects. For that purpose, in a field experiment on the experimental station Ihinger Hof of Hohenheim University (49° N, 9° E, avg. temperature 8.0 °C, precipitation 690 mm year^{-1}, 480 m a. s. l.) the grain legumes pea, faba bean and white lupin, and linseed were planted with two cultivars, respectively, in 1995 and 1996. After pre-crop harvest, winter rape or winter wheat were sown and fertilized with mineral N (in total 150 kg N ha^{-1}) to enable high yields and eventually compensate pre-crop effects.

Pea and faba bean produced high yields, while linseed yields were only on a moderate level and white lupins did not attain their yield potential. Total N residues ranged between 48 and 110 kg N ha^{-1}. The soil mineral N before winter rest and in late winter was in both years highest after pea > faba bean > white lupin and linseed. Subsequent winter rape plant density in spring was highest after pea, while rape crops after faba bean in both years and after white lupin in 1997 showed the lowest densities. The differences between pre-crops in yield of rape were comparatively small. However, winter rape crops after pea had in both years the highest grain yield. Pre-crops did not affect wheat density and grain yield was similar after all pre-crops, but wheat N uptake was enhanced by pre-crops of pea and faba bean. In conclusion, fertilization can substantially reduce although not completely balance yield effects of different pre-crops.

Key words: Pre-crop effects, nitrogen, grain legumes, linseed, winter wheat, winter rape.

crop nitrogen residues and thus in grain yield (GEISLER, 1988). Consequently, SIELING et al. (1997) found no pre-crop effects on yield of winter rape after either winter rape or winter wheat at 200 kg N ha^{-1} fertilizer rate. The aim of the present study is to evaluate for a range of pre-crops with subsequently planted crops of winter wheat and winter rape, whether this yield compensation is complete or the performance of subsequent crops is still affected by the pre-crop species and their residues.

2. Material and Methods

During 1995 and 1997, a multifactorial field experiment with four replicates in a complete block design with a split-plot arrangement (Table 1) was conducted twice on the experimental farm “Ihinger Hof” in southern Germany (49° N, 9° E, avg. temperature 8.0 °C, precipitation 690 mm year^{-1}, 480 m a. s. l.). In general, each experiment comprised two subsequent growing seasons, i. e. a season with pre-crops followed by one with succeeding crops. The climatic conditions during the experiments are indicated in table 2. Comparing the climatic conditions in both experimental years, it is remarkable that the fall-winter period in 1995/96 was constantly colder and dryer than the long-term average temperatures and precipitations, respectively. The second year was characterized by larger deviations from the long-term mean values, but due to changing signs the situation was after all more similar to the average.

Table 1: Soil parameters at the experimental station Ihinger Hof and design of experiments

Tabelle 1: Standorteigenschaften auf der Versuchsstation Ihinger Hof und Anlage der Feldversuche

Year	1995/96	1996/97
Soil (0-30 cm)	silty loam pH 6.9 0.14 % N, 1.29 % C	silty loam pH 7.1 0.17 % N, 1.10 % C
Pre-pre-crop	Winter wheat	Winter wheat
Experimental factors:		
Pre-crops (cultivars)	• Faba bean (Alfred, Caspar*) • Pea (Grapis, Ascona*) • White lupin (Nelly, Amiga*) • Linseed (McGregor, Mikael*)	
Subsequent crops	• Winter rape, cv. Vivol • Winter wheat, cv. Ritmo	

* = low crop residues due to high harvest index

Three grain legume species, i. e. pea, faba bean and white lupin, and linseed were sown in main plots. Each species was represented by two genotypes on sub-plots of 6 x 8 m^2. By planting crops with different dry matter production potential and nitrogen nutrition, and by selecting genotypes with a different dry matter distribution pattern, the

Table 2: Long-term monthly averages of air temperature or sum of precipitation and deviations during the present experiments
Tabelle 2: Langjährige Monatsmittelwerte der Lufttemperatur bzw. der Niederschlagssumme sowie Abweichungen hiervon während des Untersuchungszeitraums

	Temperature (° C)			Precipitation (mm)		
	Long-term average	Deviation 1995/96	Deviation 1996/97	Long-term average	Deviation 1995/96	Deviation 1996/97
August	16.6	0	-0.6	76	+2	-27
September	12.8	-1.9	-2.8	52	+23	-25
October	8.6	+2.9	-0.2	45	-8	+7
November	3.6	-0.6	+0.7	52	+21	-4
December	0.2	-0.8	-2.4	44	-10	+23
January	-0.7	-0.6	-2.2	39	-32	-23
February	0.1	-1.8	+4.0	38	-10	+47
March	3.7	-1.4	+2.8	43	-15	-2
April	6.9	+1.2	-0.6	55	-33	-31
May	10.8	0	+1.4	78	+18	-44
June	14.6	+0.7	+0.1	93	-17	+33
July	17.0	-1.2	-1.0	73	+71	+17

amount and quality of crop residues was expected to differ substantially. Subsequent to these pre-crops winter rape (100 viable grains m^{-2}) or winter wheat (400 viable grains m^{-2}) were sown. The sowing rate of rape was at the upper limit because of the late sowing dates and also because field emergence is often impaired by crusting of the silty soils. These subsequent crops were fertilized with mineral N (in total 150 kg N ha^{-1} calcium ammonium nitrate, cf. table 2) to enable high yields. The location is known for a high mineralization potential. Thus together with the crop residues the subsequent crops should have had more than 200 kg N ha^{-1} available. More details of the protocol of these experiments and of yield and crop residue results of the pre-crops can be found in table 3 and elsewhere (KAUL, 1998; KAUL 2004).

At maturity of the pre-crops as well as of the subsequent crops, plant shoots were sampled and threshed by a stationary thresher. Thus dry matter of grain yield and crop residues were recorded. The sampling areas were 1.0 m^2 per plot except for winter wheat (0.6 m^2). The plant samples were ground and analysed for total nitrogen by a Kjeldahl procedure. Before winter and in spring, plant densities of the subsequent crops were counted on 1.0 m^2 per plot. Soil samples were taken to a depth of 90 cm and subdivided into three layers of 30 cm each. The soil was cold-stored in the field, dried at 105 °C in the laboratory and ground with a hammer mill to achieve homogeneity. Because ammonium concentrations in the soil are known to be negligible, the analysis of soil mineral N (SMN) was restricted to nitrate. After extraction with 0.025M $CaCl_2$, NO_3 was determined by UV-photometry with a flow injection analyzer (Tecator). The dates of harvest, sowing, counting, fertilization and soil sampling are indicated in table 3.

Table 3: Harvest, sowing, counting, fertilization and soil sampling dates for the different pre- and subsequent crops
Tabelle 3: Ernte-, Aussaat-, Dichtezählungs-, Düngungs- und Bodenprobentermine für die verschiedenen Vor- und Folgefruchtbestände

Year	1995/96	1996/97
Harvest of pea	Aug. 10	Aug. 15
Soil sampling after pea	Aug. 14	Aug. 16
Harvest of faba bean	Aug. 25	Sep. 12
Harvest of lupin	Sep. 05[1)]	Sep. 11[2)]
Harvest of linseed	Sep. 06	Sep. 13
Soil sampling after faba bean, lupin, linseed	Sep. 25	Sep. 19
Sowing of winter rape	Sep. 06[1)]	Sep. 14[3)]
Counting of winter rape density before winter	Oct. 11	Oct. 07
Sowing of winter wheat	Oct. 20	Oct. 15
Counting of winter wheat density before winter	Nov. 27	Nov. 21
Fertilization (30 kg N ha^{-1})	Oct. 27	Sep. 24
Soil sampling before winter rest	Nov. 09	Nov. 28
Soil sampling in late winter	Jan. 23	Jan. 27
Fertilization (60 kg N ha^{-1})	March 15	March 12
Counting of crop density in spring	April 16	March 10[4)]
Fertilization (60 kg N ha^{-1})	May 02	April 25
Harvest of winter rape	Aug. 09	July 31
Soil sampling after winter rape	Aug. 13	Aug. 18
Harvest of winter wheat	Aug. 20	Aug. 14
Soil sampling after winter wheat	Aug. 22	Aug. 18

1) cv. Nelly was harvested on Sep. 18 and subsequent rape was sown on Sep. 19
2) both cultivars were partly immature
3) winter rape after pea was sown on Sep. 04
4) only winter rape crops

All data were submitted to analysis of variance according to a three- (year, pre-crop, cultivar) or four-factorial (year, pre-crop, cultivar, subsequent crop), hierarchical design, using the procedure GLM of SAS. Means were separated by Fisher's LSD, when F-tests indicated significant effects ($P < 0.05$) of treatments. Correlations between different experimental traits were determined using Pearson correlation coefficients calculated by the procedure CORR of SAS.

3. Results

As described earlier (KAUL, 2004), pea and faba bean pre-crops produced high yields, while linseed yields were only on a moderate level and white lupins did not attain their yield potential by far (Table 4). Crop residues and the nitrogen in these residues were similarly ranked among species, but the differences were smaller, because high yields were associated with high harvest index values. The widely immature white lupins in 1996 left remarkably large residues. Residual SMN at harvest was high with pea and faba bean in 1995, but in 1996 only faba bean left similarly high amounts of SMN. After all other crops less than 30 kg SMN ha^{-1} remained. In total, calculated N residues ranged between 48 and 110 kg N ha^{-1}.

The SMN before winter rest and in late winter was in both years highest after pea > faba bean > white lupin and linseed (Table 5). Additionally, in 1995/96 the SMN after lupin was higher than after linseed. This was independent of the succeeding crop species (Table 6). At harvest time of the succeeding crops no effects of pre-crops on SMN were traceable any longer.

With winter rape, significant pre-crop effects were found on plant density in both years (Table 7). After field emergence in autumn, rape sown after pea always showed the highest density, while rape crops after white lupin and linseed in 1995 and after faba bean in 1996 were significantly less dense. Due to the cold and dry winter in 1995/96, rape crops were substantially reduced. In spring 1997, the crop densities were about twice as high as in spring 1996. In both years rape density was still highest after pea at the sampling date in spring, while rape crops after faba bean in both years and after white lupin in 1997 showed the lowest densities. Despite the large differences in plant density, grain yield of rape was hardly impaired by the low densi-

Table 4: Grain yield (t ha^{-1}), crop residue dry matter (t ha^{-1}), crop residue N (kg N ha^{-1}), crop residue N concentration (mg kg^{-1}), residual soil mineral N 0–90 cm (kg NO_3-N ha^{-1}) and total N residues (kg N ha^{-1}) at harvest of different pre-crops in 1995 and 1996 (means across genotypes and subsequent crops)

Tabelle 4: Kornertrag (t ha^{-1}), Rückstands-Sprosstrockenmasse (t ha^{-1}), N in Ernterückständen (kg N ha^{-1}), N-Konzentration in Ernterückständen (mg kg^{-1}), Rest-N_{min} 0–90 cm (kg NO_3-N ha^{-1}) und Gesamt-N-Reste (kg N ha^{-1}) zur Ernte verschiedener Vorfrüchte 1995 and 1996 (gemittelt über Genotypen und Folgefrüchte)

	1995				1996				
	Pea	Faba bean	White lupin	Linseed	Pea	Faba bean	White lupin	Linseed	$LSD_{0.05}$
Grain yield	4.63	4.25	1.52	1.88	6.09	5.37	1.14	2.66	0.62
Residue dry matter	4.84	5.11	3.38	3.99	5.56	7.89	6.27	4.72	0.88
Residue N	53.5	35.4	19.7	21.8	64.1	60.8	60.0	31.9	9.1
Residue N conc.*	11	7	6	6	12	8	10	7	–
Soil mineral N	56.4	54.2	28.1	26.7	24.6	42.1	20.0	20.8	8.9
Total N residues*	110	90	48	49	89	103	80	53	–

* calculated values: Residue N conc. = Residue N x Residue dry $matter^{-1}$, Total N residues = Residue N + Soil mineral N

Table 5: Soil mineral N 0–90 cm (kg NO_3-N ha^{-1}) before winter rest, in late winter and at harvest of subsequent crops after different pre-crops in 1995/96 and 1996/97 (means across pre-crop genotypes and subsequent crops)

Tabelle 5: N_{min} 0–90 cm (kg NO_3-N ha^{-1}) vor Winter, Ende Winter und zur Ernte der Folgefrüchte nach verschiedenen Vorfrüchten 1995/96 und 1996/97 (gemittelt über Vorfrucht-Genotypen und Folgefrüchte)

	1995/96				1996/97				
	Pea	Faba bean	White lupin	Linseed	Pea	Faba bean	White lupin	Linseed	$LSD_{0.05}$
Before winter	99.1	90.0	57.9	42.9	112.9	80.6	33.0	39.9	14.7
Late winter	87.3	71.4	67.4	51.6	75.3	69.8	40.7	40.9	12.2
Harvest	21.3	21.8	20.1	23.8	40.6	39.5	36.8	33.1	n.s.

Table 6: Soil mineral N 0–90 cm (kg NO_3-N ha^{-1}) before winter rest, in late winter and at harvest after different pre-crops as affected by subsequent crops (means across years and pre-crop genotypes)

Tabelle 6: N_{min} 0–90 cm (kg NO_3-N ha^{-1}) vor Winter, Ende Winter und zur Ernte nach verschiedenen Vorfrüchten in Abhängigkeit von der Folgefrucht (gemittelt über Jahre und Vorfrucht-Genotypen)

	Winter rape				Winter weat				
	Pea	Faba bean	White lupin	Linseed	Pea	Faba bean	White lupin	Linseed	$LSD_{0.05}$
Before winter	84.8	72.6	43.1	34.8	127.2	98.0	47.8	48.0	13.6
Late winter	71.1	62.1	54.7	38.6	91.5	79.1	53.4	53.9	n.s.
Harvest	31.4	32.7	29.1	33.1	29.9	28.7	30.0	23.8	n.s.

Table 7: Crop density (plants m^{-2}) before winter and in spring, grain yield (t ha^{-1}) and shoot N (kg N ha^{-1}) of winter rape after different pre-crops in 1995/96 and 1996/97 (means across pre-crop genotypes)

Tabelle 7: Pflanzendichte (Pflanzen m^{-2}) vor Winter und im Frühjahr, Kornertrag (t ha^{-1}) und Spross-N-Gehalt (kg N ha^{-1}) von Winterraps nach verschiedenen Vorfrüchten 1995/96 und 1996/97 (gemittelt über Vorfrucht-Genotypen)

	1995/96				1996/97				
	Pea	Faba bean	White lupin	Linseed	Pea	Faba bean	White lupin	Linseed	$LSD_{0.05}$
Density before winter	78.6	63.0	51.9	45.9	83.5	47.0	75.3	67.0	20.0
Density in spring	21.3	10.0	16.0	17.7	62.4	31.8	28.8	38.9	11.2
Grain yield	3.86	2.66	3.37	2.74	3.84	2.97	2.83	2.31	n.s.
Shoot N	238	224	219	204	146	152	126	116	n.s.

Table 8: Crop density (plants m^{-2}) before winter and in spring, grain yield (t ha^{-1}) and shoot N (kg N ha^{-1}) of winter wheat after different pre-crops in 1995/96 and 1996/97 (means across pre-crop genotypes)

Tabelle 8: Pflanzendichte (Pflanzen m^{-2}) vor Winter und im Frühjahr, Kornertrag (t ha^{-1}) und Spross-N-Gehalt (kg N ha^{-1}) von Winterweizen nach verschiedenen Vorfrüchten 1995/96 und 1996/97 (gemittelt über Vorfrucht-Genotypen)

	1995/96				1996/97				
	Pea	Faba bean	White lupin	Linseed	Pea	Faba bean	White lupin	Linseed	$LSD_{0.05}$
Density before winter	335	313	328	316	no countings				n.s.
Density in spring	285	258	254	278	287	305	325	306	n.s.
Grain yield	7.69	8.11	7.59	7.79	7.11	7.06	6.85	6.93	n.s.
Shoot N	214	218	178	177	167	165	139	147	n.s.

ties in 1996 compared with 1997. Winter rape crops after pea had in both years the highest density and the highest grain yield. The differences in total shoot N were relatively small between pre-crops, but the values in 1997 were on a substantially lower level than in 1996. It is important to note that the main effects – across years – of pre-crops on grain yield and total shoot N of winter rape were significant (data not shown).

The results of subsequent winter wheat crops are more simply to describe. Pre-crops did not affect wheat density and the cold and dry winter 1995/96 did only slightly reduce the plant densities (Table 8). In consequence, total shoot N was positively influenced by the high total N residues of pea and faba bean pre-crops (significant main effect of pre-crops, data not shown). Grain yield, however, was not significantly improved but was similar after all pre-crops.

4. Discussion

The present paper is concentrated on the effects of pre-crop species, because they are presumably stronger than the effects of different genotypes within a pre-crop species. A previous paper (KAUL, 2004), however, reports substantial differences in crop residue amount also between the studied genotypes of grain legumes and linseed. The low grain yield results of white lupin and, to a smaller extent, also of linseed indicate that these crops were not able to attain their potential biomass production. Lupins were presumably impaired by the high pH level of the soil and both planted genotypes were late in development. With view to their nitrogen residues in soil and crop debris, however, lupin and linseed crops can be included in the evaluation of pre-crop effects. Compared to other reports of N residues in plant material and soil, the residual N amounts found in the present study were on similar levels (cf. KAUL, 2004, table 1).

Assuming a threshold value for an immediate net release of mineral N from crop residues at 1.5-1.7 % N (FRANKENBERGER and ABDELMAGID, 1985; SCHOMBERG et al., 1994), all crop residues in this study were supposed to immobilize mineral N from the soil at least for the first period of their decomposition (cf. table 4). AUFHAMMER et al. (1992) compared plots with faba bean residues and plots where residues had been removed after harvest. They found no significant differences in SMN. Similar experiments with rape proved the immobilization of SMN due to the presence of straw (LICKFETT et al., 1993; TRISOUTROT et al., 1996). Decomposition of crop residues in the field may in the short term rather reduce than increase the availability of N for subsequent crop growth (PILBEAM et al., 1998). However, the present soil analyses for mineral nitrogen revealed substantial differences between pre-crops in late autumn and winter. And the observed ranking of SMN in autumn and winter in the sequence pea > faba bean > lupin > linseed reflects the levels of total N residues as well as the N concentrations in organic crop residues. Comparing the SMN values in November and January, the high values after pea and faba bean decreased while the lower values after lupin and linseed were stable, indicating an equalizing effect of leaching losses. Additional samplings later during the vegetation period seemed not to be useful because healthy, intensively growing crops take up SMN nearly completely and differences in mineralization are not traceable in the soil under these conditions (MAIDL, 1989). At harvest time, pre-crops had also no effect on SMN.

WHITMORE (1996) found SMN level during fall and winter to be much dependent on the SMN residues at harvest time of the pre-crop, but this correlation cannot be supported by the present results. Presumably, the observations of SMN after sowing of the subsequent crops during the present study were substantially affected by the applications of mineral fertilizer in September/October. However, more than 50 % of the variance of subsequent crops‘ shoot N content can be explained by the SMN residues of the pre-crops (Fig. 1), while a significant correlation between pre-crop harvest residues and grain yield was not observed (data not shown). Also due to the fertilizer applications, the yield level of the subsequent crops was high with winter wheat (6.9–8.1 t ha^{-1}) and moderate to high (after pea) with subsequent winter rape (2.3–3.9 t ha^{-1}). Experiments with ^{15}N labelled crop residues indicate that long-term effects of crop residues on the maintenance of the soil organic N stock is more important that the immediate N supply for subsequent crops (MÜLLER and SUNDMANN, 1988; JENSEN, 1994).

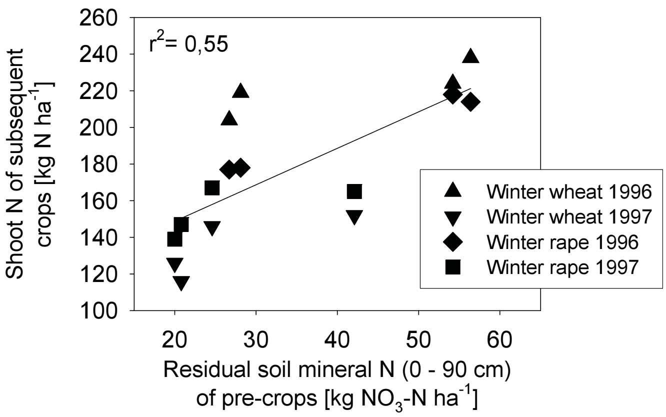

Figure 1: Relation between total shoot N of subsequent crops and residual soil mineral N (0–90 cm) of pre-crops

Abbildung 1: Zusammenhang zwischen dem Spross-N-Gehalt der Nachfrüchte und dem Rest-N_{min} (0–90 cm) der Vorfrüchte.

The density of winter rape crops was significantly influenced by the preceding crops. Consistently high densities after pea can presumably be attributed to a better soil preparation. Due to the long period between harvest of pea and sowing of rape, there was an additional shallow tillage operation made shortly after pea harvest. Additionally, rape after pea was sown ten days earlier in 1996 compared with the other pre-crops (cf. table 3). This is apparently a violation of the *ceteris paribus* rule for experimental design, but it is consistent with the practice on farmers‘ fields and thus typical of a preceding pea crop. The low emergence percentages after white lupin and linseed in 1995 and after faba bean in 1996 cannot be explained that simple. The delayed sowing after lupin cv. Nelly in 1995 (cf. table 3) may help to explain the low emergence after that pre-crop. Moreover, field emergence conditions were obviously unfavourable after late sowings and on those silty soils prone to surface crusting. At least, the high sowing rate allowed for satisfactory crop densities before winter in both years. But plant losses over winter were substantial, especially in the cold winter period of 1995/96, indicating that the late sowing after grain legumes is unfavourable for winter rape because winter hardiness is impaired. Although the final rape densities in spring differed much between years and pre-crops, the effects on grain yield and total shoot N uptake were not consistent except for the yield enhancement by preceding pea crops. But in 1996, late sown rape crops after white lupin with only 16 plants m^{-2} in spring produced high grain yields, too.

Winter wheat crops did not show any significant density and yield reaction on the different pre-crops, which is in agreement with BADARUDDIN and MEYER (1994) who found no pre-crop effects on wheat yield with fertilizer applications of more than 75 kg N ha^{-1}. Similarly, MCEWEN et al. (1989) found no wheat yield differences after pre-crops of pea, faba bean and winter rape with and even without fertilization, and FRANCIS et al. (1994) report no yield reaction of unfertilized spring wheat on pre-crops of either pea or lupine (*L. angustifolius*) while yield after faba bean was slightly impaired. On the contrary, MASON and ROWLAND (1992) showed persistent pre-crop dependent differences in wheat yield with increased fertilizer rates up to the maximum yield.

In conclusion, pre-crops of pea did significantly improve crop density, N uptake and grain yield of subsequent winter rape. Precedent faba bean crops with similar high total N residues did also improve N uptake of rape, but negative effects on rape density did not allow for improved yield results. Subsequent crops of winter wheat were not affected by pre-crops with regard to crop density. Thus, high total N residues of pea and faba bean did improve both, N uptake and to a small extent also grain yield. Besides the influence of N, other causes for the reported effects, e.g. changes in soil physical properties with consequences for soil water and soil temperature, must also be considered. But the present study does not provide any data to test these hypotheses. In general other findings (HANUS et al., 1993; SIELING and CHRISTEN, 1997) are underlined, that fertilization can substantially reduce although not completely balance yield effects of different pre-crops.

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