# Legumes dense sowing with peas as an alternative method for nitrogen fertilization in organic fruit growing

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## Abstract

*The purpose of the present work was to examine the potential of dense sowing with legumes (peas) to be used as alternative nitrogen source in organic fruit production. Based on several publications it can be hypothesized that the utilization of legume seed nitrogen can be improved by sowing compared to application as seed meal. This can be explained by germination process causing an initial decrease in legume C:N ratio, which is the predominant determinant of nitrogen mineralization.*

*In a three-year-trial the $NO_3$-N-fertilization effect of a pea sowing with high plant density and incorporation of the seedlings after a short growing period was examined. In randomized beds different plant densities and incorporation stages of the peas were tested compared to a not fertilized control. In addition, the pea dense sowing was examined for two years directly sowed in the tree rows of an organic apple-orchard (variety "Topaz") in comparison to a non fertilized control and the commercial organic fertilizer "Bioilsa". In the bed trials an adequate nitrogen fertilization effect could be measured in most of the treatments in the weeks after incorporation of the seedlings. Thereby the available nitrate ($NO_3$-N)-content in the weeks after incorporation was between 17 and 55 kg $NO_3$-N/ha higher than in the not fertilized control. However, treatment with longer growing period and later incorporation initially leads to reduced $NO_3$-N -content in the soil. In the tree rows a comparable N fertilization effect of the peas dense sowing could be measured. In the treatment with pea dense sowing available $NO_3$-N-contents in the weeks after incorporation of the seedlings were up to 51 kg $NO_3$-N/ha higher than in the unfertilized control.*

**Keywords:** legumes, dense sowing, nitrogen fertilization

## Introduction

Legumes are commonly used as nitrogen fertilizer in organic farming, generally coarsely milled as grit, because of their high N-content in the seed. However, net N mineralization of coarsely milled legume seeds is not always satisfying due to a wide C:N ratio. In pot trials KATROSCHAN (2011) found out, that net N mineralization was up to 44 % higher for seedlings compared to coarse meal and was linearly related to the altered C:N ratio. During the germination process the C:N ratio in the seeds initially decrease already in the first weeks after sowing. The purpose of the present work was to examine the potential of a dense sowing with legumes (peas) to be used as N source in organic fruit production. Specific objectives were different sowing amounts, incorporation at different development stages of the seedlings and corresponding $NO_3$-N-progression after incorporation. Only in 2013 the influence of the dense sowing on soil temperature and soil moisture, C-, N-content and C:N ratio of the pea seedlings as well as the germination rate were determined additionally.

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## Material and Methods

In all trials organic pea seeds of the variety “Lisa” with an N-content of about 3.5 % were used. Sowing was done in spring as soon as possible but adapted to weather and soil conditions. Both experimental series, bed trials and orchard trials, were carried out in the same organically managed orchard on a sandy clayey loam soil. Based on experience from vegetable gardening and agriculture, sowing amounts corresponding to 1000 kg and 2000 kg peas/ha were tested in the bed trial. Supposed that planted area in apple orchards is only about ¼ of total area, effectively sowed amount was 250 kg respectively 500 kg peas/ha, because sowing was only intended in the tree rows. In the orchard trial only the amount of 500 kg peas/ha was tested. Assumed that N-content in pea seeds was 3.5 %, 500 kg peas/ha approximately corresponds to 17.5 kg N/ha, disregarding mineralization and utilization rate. “Bioilsa” was fertilized in the orchard trial also only in the tree rows with an amount of 159 kg/ha. With an N-content of 11 % this amount corresponds also with 17.5 kg N/ha. Data concerning sowing and incorporation date of peas are listed in table 1.

Table 1: Summary of sowing and incorporation date in bed and orchard trials in the years 2011 - 2013

| **Bed trials** | | | | | | **Orchard trials** | | |
|---|---|---|---|---|---|---|---|---|
| **year** | **sowing** | **incorporation 1** | | **incorporation 2** | | **sowing** | **incorporation** | |
| | | **date** | **period** | **date** | **period** | | **date** | **period** |
| 2011 | 29-Mar | 26-Apr | 30 days | 25-May | 57 days | | | |
| 2012 | 21-Mar | 30-Apr | 40 days | 14-May | 54 days | 21-Mar | 27-Apr | 37 days |
| 2013 | 5-Apr | 25-Apr | 20 days | 8-May | 33 days | 8-Apr | 7-May | 29 days |

Figure 1: a) pea dense sowing in the tree rows of an organic Topaz orchard on rootstock M9. b) Beds with different pea treatments

Bed trial:

To test the treatments in a four times repeated and randomized design, bed trials were conducted between 2011 and 2013. Treatments with different sowing amounts and incorporation stages were compared to an untreated control. Before sowing, beds were hoed to ensure fine and crumbly soil free of weeds. Every bed was 7 m long and 1 m wide. Sowing and incorporation of seeds and seedlings was carried out by hand.

Orchard trial

In the tree rows N fertilization effect of a dense sowing with peas was compared with the organic fertilizer “Bioilsa” (11 % N) and only in 2013 also with a not fertilized control. Thereby the amount of 500 kg peas/ha was sowed directly in the tree rows. Treatments were replicated four times and randomly distributed in an organic apple orchard with the variety “Topaz” on rootstock M9. Each replication contained 55 trees. Pea seeds and “Bioilsa” pellets were brought out by hand. Incorporation of fertilizer, seed and seedlings was done simultaneous with a rotary hoe (Ladurner).

Soil sampling

To analyse $NO_3^-$ -content in the soil, soil samples were collected regularly during the season with focus on Mai because of its high importance for nutrient supply. Several soil samples were taken randomly distributed in the treatments in the soil depth 0-30 cm. Samples were cooled directly in the field and stored till analysis in a freezer by -18°C.

$NO_3$-N – analysis

Respectively 100 g uniformly prepared soil was suspended in 100 ml of distilled water and shaken at 100 rpm for one hour. Suspension was filtrated (Rotilabo folded cellulose filters, type 113P) and $NO_3$-N-content was measured with $NO_3$-N - diagnostic dipstick “Mercko-quant” and analytical instrument “Nitracheck” (Step systems). Measuring was repeated three times per sample. Soil moisture content was measured by reweighing after drying a part of the particular soil sample for 24 hours in drying chamber at 105°C.

Soil moisture and temperature

Soil temperature was measured with measuring instrument “Testo 925” with an accuracy +/- 1 digit, measuring range between -50 to + 1000 °C and probe type K (NiCr-Ni). To measure soil moisture content, a “TDR 100 fieldscout” sensor was used. With TDR method (time-domain reflectometry) volumetric water content (VWC) was measured directly in the soil. Both parameters were measured at several, randomized distributed points per treatment in 15 cm depth.

C- and N- content in seedlings

Carbon and Nitrogen-content in dry mass of the pea seedlings were measured by dry combustion using “vario MAX CHN” (Elementar Analysensysteme GmbH).

## Results

Bed trial

In table 2 $NO_3$-N-contents in the different pea treatments and in the untreated control in 2012 and 2013 are represented. Results in 2011 were comparable with the results in 2012 and 2013. In 2012 available $NO_3$-N-content in both treatments incorporated 40 days (April 30$^{th}$) after sowing was 45 kg $NO_3$-N/ha (250 kg peas/ha) respectively 55 kg $NO_3$-N/ha (500 g peas/ha) higher than in the untreated control four weeks after incorporation. In contrast, treatments incorporated 54 days after sowing initially lead to lower $NO_3$-N-contents in the soil. At sampling date 54 days after sowing (May 14$^{th}$), $NO_3$-N-content was 60 kg/ha (250 kg/ha) respectively 73 kg/ha (500 kg/ha) lower than in the untreated control. However, in the weeks after incorporation available $NO_3$-N-content also increased considerably in both treatments. On 19$^{th}$ of June $NO_3$-N-content in both treatments with extended growing period (54 days) was about 50 kg/ha higher than in the untreated control.

Despite of different growing periods in the treatments between the years, results in 2013 were nearly similar to 2012. Except the treatment with 250 kg peas/ha and short growing period (20 days), all other treatments increased $NO_3$-N-content in the weeks after incorporation compared to the untreated control. Already two weeks after incorporation $NO_3$-N-content in the treatment with 500 kg peas/ha and 20 days growing period was 25 kg/ha higher than in the untreated control. This difference was given also four weeks after incorporation. As in 2011 and 2012, treatments with longer growing period initially reduced $NO_3$-N-content compared to the untreated control (sampling date May 8$^{th}$). However, nearly two weeks after incorporation (May 24$^{th}$) available $NO_3$-N-content was 19 kg $NO_3$-N/ha (250 kg peas/ha) respectively 24 kg $NO_3$-N/ha (500 kg peas/ha) higher than in the untreated control. In this way, within 14 days after incorporation (May 8$^{th}$) $NO_3$-N-content increased around 52 - 67 kg/ha in the pea treatments with extended growing period (33 days), while in the same period $NO_3$-N-content in the untreated control increased only around 16 kg/ha.

Table 2: $NO_3$-N-contents in the soil of the several treatments in the bed trial in the years 2012 and 2013

| **Treatment** | **kg $NO_3$-N/ha** | | | | |
|---|---|---|---|---|---|
| **2012** | **13-Mar** | **17-Apr** | **14-May** | **30-May** | **19-Jun** |
| | | **13jg d. before incorp. 1** | **incorp. 2** | | |
| Untreated | 16 | 49 | 93 | 61 | 31 |
| peas 250 kg/ha, 40 days | 14 | 70 | 111 | 106 | 50 |
| peas 500 kg/ha, 40 days | 15 | 62 | 69 | 116 | 64 |
| peas 250 kg/ha, 54 days | 14 | 55 | **33** | 72 | 81 |
| peas 500 kg/ha, 54 days | 14 | 59 | **20** | 48 | 80 |
| **2013** | **8-Apr** | **25-Apr** | **8-May** | **24-May** | **5-Jun** |
| | | **incorp. 1** | **incorp. 2** | | |
| Untreated | 31 | 40 | 62 | 78 | 53 |
| peas 250 kg/ha, 20 days | 35 | **42** | 68 | 81 | 53 |
| peas 500 kg/ha, 20 days | 39 | **45** | 87 | 104 | 62 |
| peas 250 kg/ha, 33 days | 33 | 48 | **45** | 97 | 71 |
| peas 500 kg/ha, 33 days | 35 | 47 | **35** | 102 | 61 |

As figure 2 illustrate, pea treatments with extended growing period (33 days) initially lead to reduced water content in the soil layer 0-15 cm compared to the untreated control in 2013. In contrast to soil moisture, soil temperature was not influenced by any of the pea treatments in the bed trial 2013.

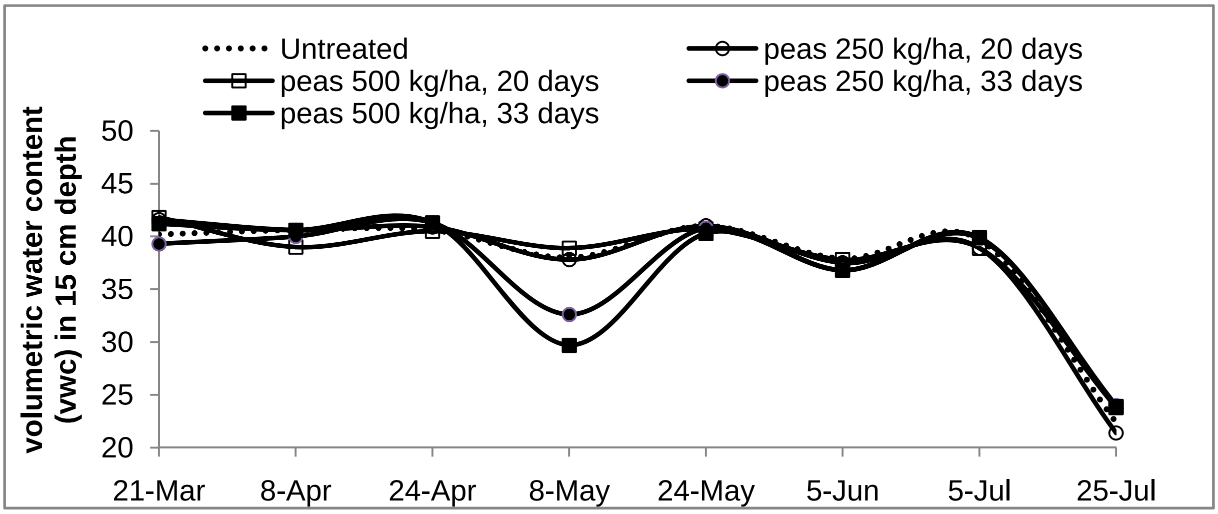


Figure 2: Volumetric water content (% VWC) in the soil of the different pea treatments and the untreated control between March and July 2013

As mentioned before, C:N ratio has a considerably influence on N mineralization. In this trial C:N ratio in the dry mass of the peas was depending on length of growing period. Differently than expected, C:N ratio diverge because of different N-content in the peas dry mass, not because of a reduction of carbon-content. However, C:N ratio in dry mass of peas with short growing period (20 days) was only half as high than in peas with extended growing period (33 days) in 2013.

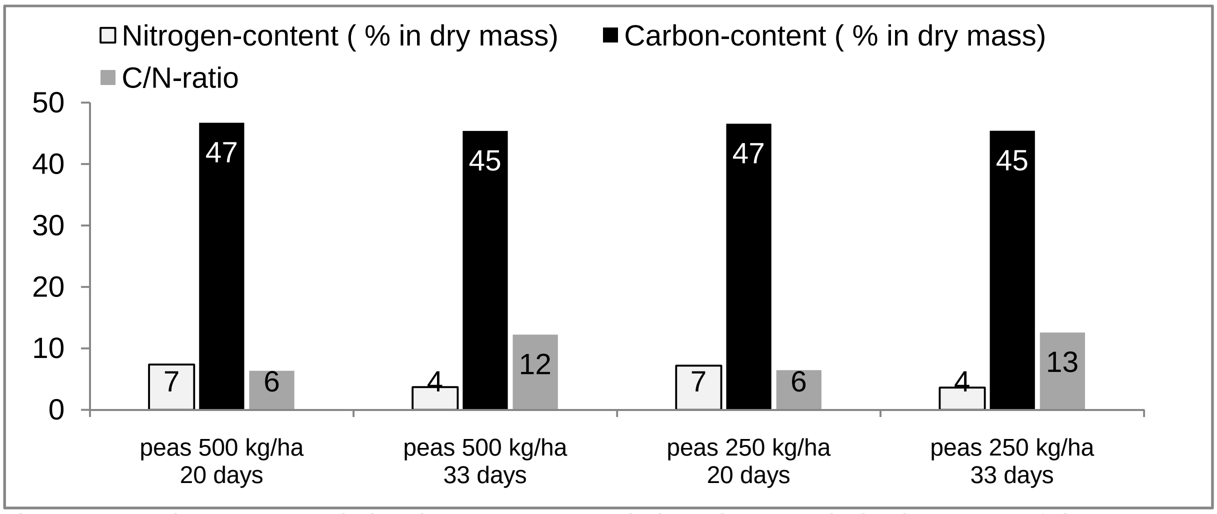


Figure 3: Carbon content (%), Nitrogen content (%) and C:N ratio in dry mass of the pea seedlings in the several treatments with different sowing amount and growing period

Represented exemplarily for 2013, weight of dry mass/m$^2$ was obviously higher in the pea treatments with extended growing period (33 days). With 832 g/m$^2$ (500 kg peas/ha) respectively 773 g/m$^2$ (250 kg peas/ha) weight of dry mass was 75-84 % higher than in the comparable treatments with shorter growing period (214 and 124 g/m$^2$). Germination rate in this year was 83 % (500 kg peas/ha) respectively 89 % (250 kg peas/ha).

Orchard trial

In 2012, when no untreated control was included in the tree row trial, pea treatment showed comparable results as in the bed trial. At first sampling date (April 17$^{th}$) available $NO_3$-N-content in the treatment fertilized with "Bioilsa" on March 21$^{th}$ was still 25 kg/ha higher than in the pea treatment. Thereby “Bioilsa” lead to an early N mineralization, while peas were still in growth. However, in the weeks after incorporation of the peas (April 27th) a considerably increase in $NO_3$-N-content of the pea treatment could be measured. Already two weeks after incorporation, available $NO_3$-N-content in the pea treatment was 22 kg/ha higher than in the “Bioilsa” treatment. Around three weeks further, on May 30th, available $NO_3$-N-content in the pea treatment was even 33 kg/ha higher than in the “Bioilsa” treatment.

Results of 2012 were repeated in the second year. As usual “Bioilsa” showed an early starting N mineralization in the weeks after fertilization (April 8th). Already at second sampling date (April 26th) available $NO_3$-N-content in the “Bioilsa” treatment was 33 kg/ha higher than in the untreated control and the pea treatment. Available $NO_3$-N-content in the pea treatment was even 14 kg/ha lower than in the untreated control and 42 kg/ha lower than in “Bioilsa” treatment in the week of incorporation (May 7th). Nearly two weeks after incorporation, $NO_3$-N-content in the pea treatment increased considerably. With 102 kg $NO_3$-N/ha, $NO_3$-N-content in the pea treatment was nearly comparable with “Bioilsa” treatment (111 kg $NO_3$-N/ha) and considerably higher than in the untreated control (65 kg $NO_3$-N/ha) at sampling date May 24th. Thereby the increase in available $NO_3$-N-content between May 7th and May 24th was more obvious in pea treatment (+ 74 kg $NO_3$-N/ha) than in “Bioilsa” treatment (+ 41 kg $NO_3$-N/ha) and the untreated control (+ 23 kg $NO_3$-N/ha).

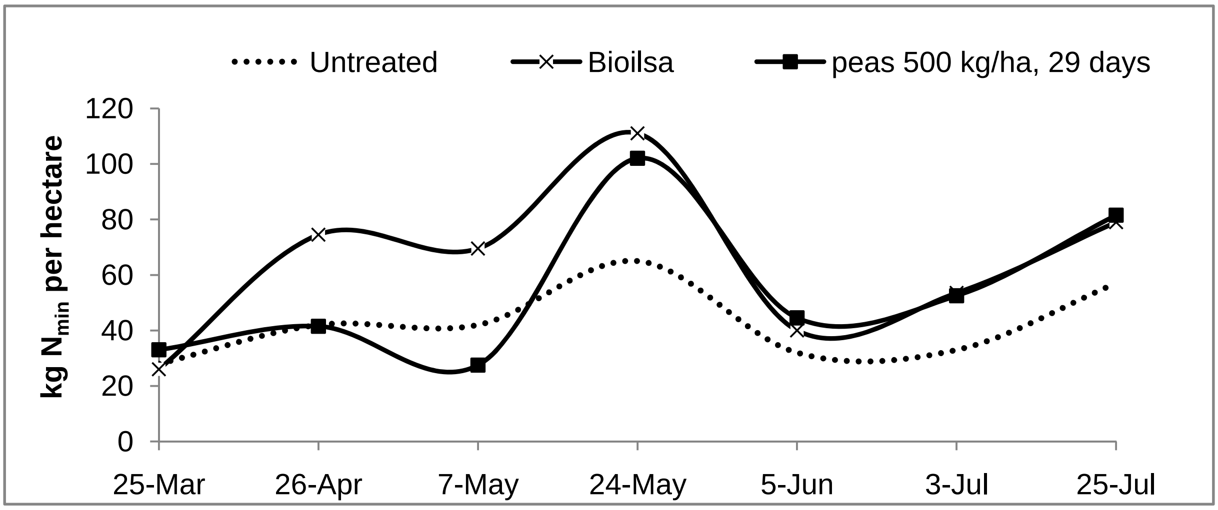

Figure 4: $N_{min}$-progression of the different treatments in the orchard trial in 2013

The dense growth of pea seedlings in the tree rows had no effect on soil temperature and moisture in 2013.

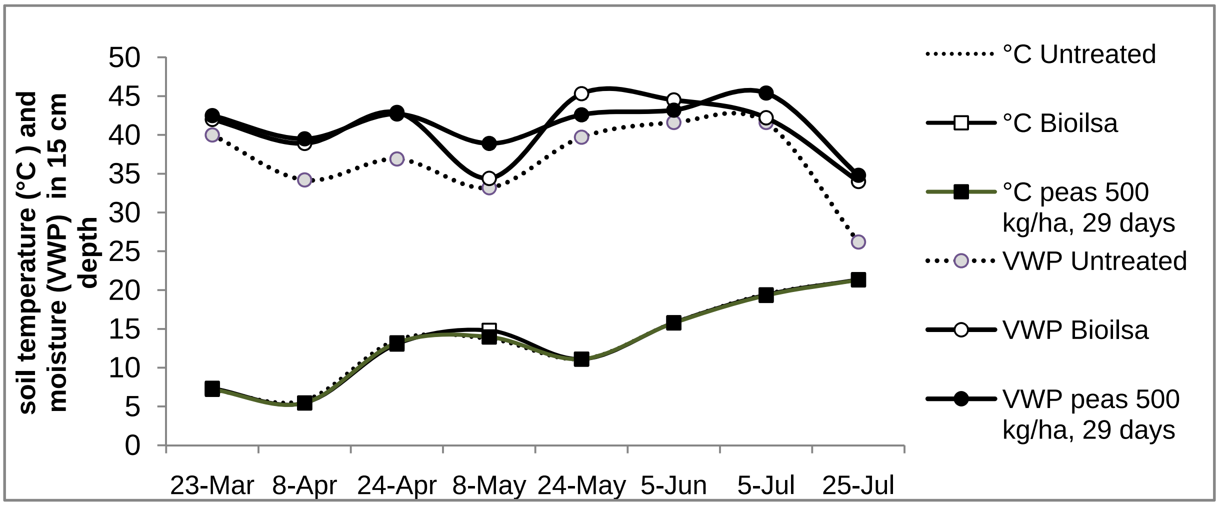


Figure 5: Volumetric water content (% VWC) and temperature (°C) in the soil of the different treatments of the orchard trial between March and July 2013

## Discussion

Dense sowing with peas and early incorporation after short periods lead to appreciable increase of $NO_3^-$N in bed and orchard trials. In all trials increased $NO_3$-N -contents were measured already two weeks after incorporation of the seedlings. Summarizing all results, soil $NO_3$-N-content in the period 14 till 28 days after incorporation was between 17 and 55 kg $NO_3^-$N/ha higher in the different pea treatments than in the unfertilized control. Even with incorporation after a short period of 20 days after sowing an increased $NO_3$-N-content compared to the unfertilized control was measured. If growing period was extended, initially lower $NO_3$-N-contents occurred in these treatments compared to the untreated control. In this case a competitive situation between trees and peas occurs. Concerning the optimum plant density of peas no final estimation can be given. The presented results suggest that sowing amount can be reduced only in combination with longer growing periods (> 4 weeks). Reduction of sowing amount combined with a shortened growing period (< 3 weeks) could possibly lead to insufficient $NO_3^-$N-contents in the soil. If weather conditions permits good germination conditions and unlimited growth of legume seedlings, a dense sowing with peas can be used as alternative N source in organic fruit production. However, considering that success of N fertilization with pea dense sowing is highly depending on weather und soil conditions, fertilization with commercial nitrogen fertilizers like “Bioilsa” pellets seems to be simpler and safe. Furthermore an early sowing date is necessary to enable adequate period for germination, growth and mineralization after incorporation. Only if these factors can be considered, sufficient availability of nitrogen is enabled at bloom of the trees.

## References

Katroschan, K.-U. (2011): Narrow-leaved Lupine (*Lupinus angustifolius*) as Nitrogen Source in Organic Vegetable Production Systems. Dissertation Leibnitz University Hannover