MINERAL NITROGEN CONTENT IN THE SOIL AFTER DIFFERENT FERTILIZATION IN ORGANIC FARMING

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Abstract: In organic farming is not possible to rely on plants fertilizing during vegetation according to their actual needs. The right crop rotation and harmonic nutrition are necessary for good and quality products. This is realized mainly by cultivating green manure crop and fertilizing by organic fertilizers. The goal of this long-term experiment is to evaluate the effect of different intensity and fertilization in organic farming with and without breeding livestock on content of mineral nitrogen in soil. There are four variants in this experiment: 1. Unfertilized control, 2. Green manure, 3. Green manure + renewable external sources (27 t/ha of compost + 14 t/ha of digestate), 4. Green manure + farm fertilizers (27 t/ha of manure + 14 t/ha of liquid manure). The result obtained from the experimental year 2016 show, that the best variant providing good supply of nitrogen during vegetation is combination with green manure and renewable external resources (compost + digestate). Soil in this variant contained around 83 kg/ha of mineral nitrogen after emergence of potatoes. Variant with green manure and farm fertilizers contained 77 kg/ha and unfertilized soil contained around 46 kg/ha of mineral N. Content of mineral nitrogen in the flowering, around 55 kg/ha, was also the highest on variant 3. The remaining variants had a similar nitrogen content in the soil, around 44 kg/ha.

Key Words: organic farming, nitrogen, soil, green manure, farm fertilizers

INTRODUCTION

Organic agriculture, a production system with a particular attention to the environment and its individual components, is now a well-known concept among lots of people. Environmental protection is possible due to the restriction or prohibition of the use of certain burdensome substances, especially synthetic nitrogen fertilizers. However, content of nutrients from agro-ecosystem even in organic farming is decreasing because of production export and nutrient losses like leaching or volatilization. The precursor for higher yield and quality of products is good and fertile soil (Dvorský and Urban 2014). Organic farming, in comparison with conventional farming methods, cannot count on the fact, that plants can be fertilized directly to the roots according to actual needs in vegetation. The point of emphasis in organic farming is content of organic matter and quality of humus in the soil (Martin and MacRae 2014).

Today, the crucial nutrient is still nitrogen. However, balance of nitrogen in organic farming is relatively well solvable. The basis of nutrition in organic farming should be a good crop rotation (Urban et al. 2003). The supply of nitrogen from external environment is achieved primarily by growing legumes and plants for green manure. Another invaluable source of nutrients is organic fertilizers, especially manure and slurry, but also organic compost and in these days increasingly used digestate. The combination of well-chosen crop rotation with adequate dose of properly selected organic fertilizer is very interesting and for organic farming have irreplaceable role (Barker 2010).

The ultimate goal of this long-term experiment is to evaluate the effect of different intensity and fertilization in organic farming with and without breeding livestock on yield and quality of products, soil properties and nutrient balance. However, in this work, only the content of mineral nitrogen in soil in different vegetation stages of potatoes growth in year 2016 will be evaluated. There are also interesting questions that may be answered – is green manure alone good enough for good nitrogen supply or is the combination with some organic matter necessary? Will combination with green manure and renewable external source provide enough content of nitrogen in comparison with farm fertilizers?
MATERIAL AND METHODS

This work is a part of a long-term experiment established in 2014 by the Central Institute for Supervising and Testing in Agriculture. The experiment was established as small-plot field experiment ongoing at five different locations at the same time. These experimental stations are representing a different production area with a different soil and climatic conditions (Table 1). The variant of fertilization are described in Table 2. The experiment attempts to compare system of fertilization with (Variant 4) and without livestock (Variant 3) in organic farming. There is also an unfertilized variant (Variant 1) for control and variant based only on green manure (Variant 2). Every variant has three repetitions.

Before the start of the experiment, the land at every experimental station was left fallow in year 2014. The forecrop for potatoes was winter wheat in 2015. The combination of *Pisum sativum var. arvense*, *Vicia villosa* and *Brassica campestris var. sylvestris* was used as a green manure.

Potato fertilization in experimental year of 2016 is described in Table 2 and nitrogen content in fertilizers in Table 3. Potatoes planting were performed approximately 14 days after the incorporation of organic farming to the soil in early April. There is one average soil sample for each variant at every location. For this average sample, soil was collected from every repetition in every variant. The soil was collected before start of the experiment, after emergence and in flowering. The soil was collected by a manual soil probe in soil profile 0–30 cm. The nitrate nitrogen was determined by ion-selective electrode (ISE), the ammonia nitrogen was determined as Indophenol spectrophotometry (Zbíral et al. 2004). Content of mineral nitrogen was determined by summing nitrate and ammonia nitrogen.

### Table 1 Characteristics of experimental stations

<table>
<thead>
<tr>
<th>Experimental station (district)</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Main crop</td>
</tr>
<tr>
<td>Čáslav</td>
<td>Sugar beet</td>
</tr>
<tr>
<td>Horažďovice</td>
<td>Potatoes</td>
</tr>
<tr>
<td>Jaroměřice nad Rokytnou</td>
<td>Cereals</td>
</tr>
<tr>
<td>Lipa</td>
<td>Potatoes</td>
</tr>
<tr>
<td>Věrovany</td>
<td>Sugar beet</td>
</tr>
</tbody>
</table>

### Table 2 Variants of fertilization used in the experiment

<table>
<thead>
<tr>
<th>Variant</th>
<th>Application of organic fertilizers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dose of fertilizer</td>
</tr>
<tr>
<td>1. Unfertilized</td>
<td>-</td>
</tr>
<tr>
<td>2. Green manure (GM)</td>
<td>-</td>
</tr>
<tr>
<td>3. GM + renewable external sources</td>
<td>27 t/ha of compost</td>
</tr>
<tr>
<td>4. GM + farm fertilizers</td>
<td>27 t/ha of manure</td>
</tr>
</tbody>
</table>
Table 3 Nitrogen content in organic fertilizers in original state (Same fertilizers for every location)

<table>
<thead>
<tr>
<th>Variant</th>
<th>Organic fertilizer</th>
<th>Nitrogen content in original state (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewable external sources</td>
<td>Compost</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>Digestate</td>
<td>1.37</td>
</tr>
<tr>
<td>Farm fertilizers</td>
<td>Manure</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>Liquid manure</td>
<td>0.06</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

Mineral nitrogen content before start of the experiment in early April

The initial state of the mineral nitrogen content in the soil before starting the experiment with potatoes is displayed in Figure 1. The lowest content of mineral nitrogen was located in unfertilized soil as expected. Most mineral nitrogen contained the soil on variant 4 after autumn application of manure. The nitrogen content on this variant was increased by 2.2 mg/kg compared to control variant. The current soil supply after recalculation (mg/kg x 4.5) makes nearly 40 kg of nitrogen per hectare on variant 4.

A similar amount of N, around 38 kg/ha, was contained in soil in variant 2 with just green manure crop. This result indicates a quick decomposing of green manure crop (Barker 2010). Green manure that decomposes rapidly is an excellent source of immediately available nutrients but is unlikely to contribute significantly to long-term development of soil organic matter (Martin and MacRae 2014). Content of mineral nitrogen in soil after turning over just green manure is therefore almost comparable with variant 4, where the mineralization does not fully starts at this period.

Figure 1 Average content of mineral nitrogen in soil before start of the experiment in early April

There is an idea, that compost application is more efficient method compared to manure, because compost contained more concentrated nutrients due to significantly less C, less water and reduced potential for N loss through volatilization in time of application (Miller et al. 2009, Larney et al. 2006). In this experiment, however, a smaller decrease of mineral nitrogen content appeared on variant 3 following autumn application of compost. This may be caused by not entirely good C/N ratio in compost, which is quite common thing. A commonly used threshold suggests that amendments with C/N ratios less than 20 will cause net mineralization (Loecke et al. 2012). The ratio of compost in this case was 9 : 1, therefore a very thin ratio. This leads to very quick decomposition (Gale et al. 2006) and probably to loss of some nitrogen due leeching during winter.
There is also a different idea, that autumn application of compost does not have same effect on mineral nitrogen content in spring compared to application of quality manure (Hradil et al. 2007). This corresponds with result of soil analysis in April in this experiment. On the other hand, some authors (Gale et al. 2006, Sanchez et al. 2004) have observed immobilization of nitrogen for 60 or more days following incorporation of compost. They have also claim, that compost is therefore a generally contributing to the slow-release pool of nitrogen and other nutrients during vegetation. This idea is supported by result of soil analysis after emergence and in flowering (Figure 2 and 3).

**Mineral nitrogen content after emergence in early June**

State of mineral nitrogen content in soil after fertilization in the experimental year 2016 is reflected in figure 2. Soil samples were collected after emergence of potatoes around 6 June. At this point, mineralization and nitrification in soil should be slightly after spring maximum.

The largest content of nitrogen, around 83 kg/ha, was noticed in the combination of green manure and renewable external sources. This result support the idea of some authors, that digestate has higher total nitrogen content ranging from 0.2–1% compared to other organic fertilizers (Šmatanová 2012). This fact is also evident from Table 3. Nitrogen content in applied digestate was higher compared to liquid manure. Digestate also have a large proportion of highly usable ammonia nitrogen (Moller and Muller 2012). This corresponds with low content of ammonia nitrogen in soil in the experiment.

Figure 2 Average content of mineral nitrogen in soil after emergence in early June

<table>
<thead>
<tr>
<th></th>
<th>N - NH₄⁺</th>
<th>N - NO₃⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Unfertilized</td>
<td>9.2</td>
<td>1.2</td>
</tr>
<tr>
<td>2. Green manure (GM)</td>
<td>11.4</td>
<td>1.7</td>
</tr>
<tr>
<td>3. GM + renewable external resources</td>
<td>17.2</td>
<td>1.7</td>
</tr>
<tr>
<td>4. GM + farm fertilizers</td>
<td>15.4</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Legend: renewable external resources– compost + digestate; farm fertilizers – manure + liquid manure

Average nitrogen content in liquid manure is around 0.23%, but content of N in liquid manure used in this experiment was only 0.06%. The content is highly variable and dependent on the strong dilution with water. 90% of nitrogen in liquid manure is located in easily soluble form with the largest share of ammonia nitrogen (Urban et al. 2003). Application of liquid manure is also problematic due volatilization loss of ammonia (Mahimairaja et al. 1994). This also corresponds with low content of ammonia nitrogen in soil in the experiment. A smaller decrease of nitrogen content on variant 4, around 77 kg/ha, may be explained by all these facts.

Green manure is used in order to increase the content of rapidly decomposing organic matter, to promote fixation of atmospheric nitrogen and to increase the activity of microorganism in soil. The result obtained from the soil analysis in this stage of vegetation show, that mineral nitrogen content after turning under green manure crop alone (around 59 kg/ha) is not as good as combination of green manure and organic fertilizer. Green manure crop is ideal as a main crop on the field. This should be done every three years on the field for best result (Barker 2010). But this situation is rather impossible in common praxis. Green manure is often grown as a winter cover crop.
Green manure crop is not able to create enough organic matter during this short period (from autumn to early spring). As mentioned before, such green manure crop decomposes rapidly due their succulence. It is great on the start for early stages of vegetation, but may not provide the required supply of nitrogen at later stage of vegetation. This is also evident from Figure 2 and 3. Therefore, it is useful to combine green manure with further applications of organic matter, if possible (Kasal et al. 2010).

**Mineral nitrogen content in flowering in early July**

Higher uptake of nitrogen by potatoes is starting before crop cover is complete. The highest uptake starts in flowering (Kasal et al. 2010). Soil samples were collected at the beginning of flowering around 1 July. The plants depleted a part of available nitrogen at this stage, which is evident from comparing Figure 3 and Figure 2.

The largest content of nitrogen in soil, around 55 kg/ha, remains after combination of green manure and renewable external resources. This variant had contained more nitrogen in applied fertilizers (compost + digestate) compared to variant 4 with farm fertilizers. As mentioned before, this result is supporting work of some authors (Miller et al. 2009, Larney et al. 2006) that compost is generally contributing to the slow-release pool of nitrogen and other nutrients during vegetation. On the other hand, the result from 9-year experiment by Miller et al. (2010) is quite opposite. In this experiment, the N availability of different fertilizers was also evaluated. Fresh manure increased the soil level of nitrogen the most in this experiment.

Variants 2 and 4 in this experiment with average content of nitrogen around 44 kg/ha are comparable, even with unfertilized variant. However, we can assume that nitrogen consumed by plants on variant with fertilization will result in higher yields. This hypothesis will be of course analysed right after harvest.

*Figure 3 Average content of mineral nitrogen in soil in flowering in early July*

![Figure 3](image)

**Legend:** renewable external resources – compost + digestate; farm fertilizers – manure + liquid manure

**Average content of mineral N in each experimental station at different stage of the experiment**

As mentioned before, the experiment is ongoing on five different locations. The average content of nitrogen for each experimental station in different stages of vegetation is displayed in Figure 4. Content of nitrogen before start of the experiment is comparable on each location. Experimental station Jaroměřice nad Rokytnou had higher nitrogen content in soil after emergence and in flowering. There is a fertile brown soil at this station.

There is also a good combination of average annual precipitation and temperature as you can see in Table 2. The very fertile black soil is at station Věrovany, where the content of nitrogen was the highest in flowering. At this station were lower precipitation during early spring, therefore nitrogen content was not so high after emergence. The lowest content of nitrogen was observed at exp. station Čáslav, although there is a fertile black soil at this locality. Not enough precipitation and mostly drought caused a lower content of nitrogen at this station.
CONCLUSION

The results obtained from soil analysis during the experiment shows that any application of organic matter either from renewable external resources or farm fertilizers is increasing mineral nitrogen content in the soil compared to unfertilized variant. However, in organic farming is not possible to rely on crop fertilizing during vegetation according current needs. Application of any organic matter has therefore a crucial role for plants.

Green manure in practice is often cultivated as a winter or stubble crop with a short growing period. Turning under such green manure alone do not provide enough organic matter and decomposes rapidly. Nearly 75% of such organic matter is rotted quickly in first season, leaving little residual effect afterward. There is also option to apply only organic fertilizer, but such option may also be not so tempting. We are losing erosion protection and competition against weeds and diseases in this case. Combination with green manure crop and organic fertilizer may be also more economic due possibility of lowering doses of organic fertilizer.

The result from this experiment show, that variant with combination of green manure and renewable external resources provide more supply of nitrogen compared to variant with green manure alone and variant with combination of green manure and farm fertilizers. In this variant with renewable external resources, compost and digestate were applied. These fertilizers had higher content of nitrogen in original state. There is also an idea, that compost provides more nutrients for plants in first year after incorporation compared to manure, which is supported by result of this experiment.

Every organic fertilizers is of course dependent of their quality, but result from this experiment is indicating, that farming without livestock can be as effective or even better as production with livestock. The influence of these combinations on content of mineral nitrogen in soil and also influence on yield needs to be of course further tested in this long term experiment.

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