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# A study of nitrogen migration affected by different plants for green manure in sandy loam soil

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The rate of mineral nitrogen leaching from green manure applied in summer to winter rye (first year red clover aftermath, yellow lupine) and at the end of autumn (undersown red clover, oil radish as a catch crop) for summer crops of the next year was investigated. The experiments were set out on a sandy loam *Haplic Luvisol*. After green manure incorporation, the stock and concentration of mineral nitrogen ($N\text{-}NH_4$+$N\text{-}NO_3$) in the soil layer 1 m deep was defined. In comparison with the incorporation of barley stubble, green manure ploughed in for winter rye increased the leaching of nitrogen in subsoil horizons (25–100 cm) in October and November by 43.7–69.1 and 29.3–36.2 kg $ha^{-1}$ N. Infiltration losses at introducing green mass of lupine were by 13.8–15.5% higher than when red clover had been introduced. Catch crops (undersown red clover, oil radish) incorporated as green manure in late autumn, before soil freezing, reduced the autumnal decomposition of organic matter and nitrogen leaching during the autumn–winter period. In comparison with cereal stubble, catch crops for green manure only insignificantly increased nitrogen stocks in subsoil horizons (25–100 cm) in November.

**Key words**: green manure, mineralization, mineral nitrogen migration, soil profile

## INTRODUCTION

Agricultural use of soil is accompanied by reduction of its organic matter stocks. The loss of soil nitrogen increases due to agrotechnical actions stimulating its decomposition. Many scientists suppose that cultivation of catch crops as green manure, in autumn binding mineral nitrogen in organic matter, can lower the leaching of nitrates in the period of intensive infiltration of atmospheric precipitation (Djurhuus and Olesen, 1997; Kankanen et al., 1998; Francis et al., 1998; Goss et al., 1998).

Decomposition of organic matter begins immediately after it enters the soil. The organic matter of plants intended for restoration of organic matter content of soil is as a rule incorporated before sowing winter cereals or in late autumn before freezing of soil if it is planned for spring crops of the following year. Thus, in the first case, the decomposition of freshly incorporated organic matter proceeds at a relatively high air and soil temperature. In the second case, decomposition of green manure takes place under conditions of relatively low soil temperatures and high soil moisture. These differences in soil temperature and moisture affect the decomposition of organic matter as well as the influence of its disintegration products on the environment, and particularly the leaching of nitrates in subsoil horizons (Cookson et al., 2002; Zak et al., 1999; Beckwith et al., 1998).

Many authors note an increased content of nitrates in soil and in drainage waters after incorporation of green manure. An experiment carried out in Lithuania on sandy loam Luvisol demonstrated a substantial growth of nitrates in the arable layer after introducing green manure two months following its incorporation in soil (Nedzinskiene et al., 2002). Before sowing winter rye the content of mineral nitrogen in the 0–10 cm layer was 26.9–32.5 kg $ha^{-1}$, after 2 months it decreased to 15.2–17.4 kg $ha^{-1}$ but in the 20–30 cm layer remained the highest. A study performed in Germany (Hansen and Djurhuus, 1997) indicated that incorporation of clover green mass in February considerably increased the concentration of nitrates in the 0–90 cm layer in May and remained at the same level till autumn. Green mass of winter rye ploughed in August, a month after its insertion, increased the stocks of mineral nitrogen up to 90 kg $ha^{-1}$ and a mixture of oat and *Vicia sativa* even up to 180 kg $ha^{-1}$ N. Identical results concerning the influence of green manure on the migration of nitrates were published by Thomsen and Christensen (1999).

Lysimeter trials of nitrogen leaching after incorporation of Italian ryegrass into soil showed that infiltration losses of nitrogen during the autumn–winter season had increased by 30%.

Expansion of green manure crops in ecological farms and replacement of animal manure with green manure in usual farms require more detailed studies of their decomposition processes in soil and the effects of the decomposition products on the nitrate regime in soil.

The purpose of the current research was to study the rate of nitrogen mineralization in the biomass of various agricultural plants used as green manure for winter crops or for spring crops of the following year and the migration of mineral nitrogen in the 0–100 cm layer of soil during the autumn–winter–spring season in East Lithuania.

## MATERIALS AND METHODS

The work was performed in 1997–2000 at the Voke Branch of the Lithuanian Institute of Agriculture, situated in south-eastern Lithuania in a sandy plain, according to climatic-hydrothermal parameters ascribed to a region of medium soil eluviations and organic matter decomposition. The experimental plots were established in sandy loam on carbonaceous fluvial-glacial gravel ordinary eluviated soil, *Haplic Luvisols* (LVh) according to the FAO-UNESCO classification. The depth of carbonate effervescence was 60–80 cm. The agrochemical characteristic of the plough layer: $pH_{KCl}$ 5.32–5.48, humus 1.57–1.98%, available $P_2O_5$ 143–172 mg $kg^{-1}$, $K_2O$ 201–217 mg $kg^{-1}$ soil (A–L method).

In the crop rotation (barley, barley, winter rye, oats) we studied the effect of green manure (summer green manure crop and catch crop) on mineral nitrogen regime in soil (Table 1). Oil radish (*Raphanus sativus* L.) and red clover (*Trifolium pratense* L.) were grown as catch crops for green manure after barley harvesting. Clover was undersown in barley in spring and oil radish in mid-August after barley harvesting. The catch crops were ploughed in late in autumn (October 10–20) for the next year spring crops, i.e. they were used for barley (*Hordeum* L.) fertilization. Summer green manure crop – yellow lupine (*Lupinus luteus* L.) – was grown throughout the whole period of vegetation and red clover aftermath after the first grass harvesting (June 15–20). The green mass of lupine and clover aftermath was used for winter rye (*Secale cereale*) fertilization and ploughed in on August 10–15.

The field trials (2) were established in 1997 and 1998. The experiment had a randomised block design with four replicates.

*Soil and plant analyses.* Aiming to clarify the migration of mineral nitrogen, soil samples were taken after insertion of organic fertilizers in 1997–1998, 1998–1999 and 1999–2000 every 25–35 days during the autumn–winter–spring season (if the soil did not freeze in winter). Soil samples were taken from each experimental plot (4 replicates) from the depth of 0–25, 25–40, 40–60, 60–100 cm. The content of mineral nitrogen (ammonium and nitrate) was determined and its reserves in the 0–100 cm layer were calculated. To calculate mineral nitrogen stocks, in each trial the density of soil layers (0–25, 25–40, 40–60 and 60–100 cm) was determined as the basis for calculating the soil mass of each layer.

$$Nmin\ kgha^{-1} = \frac{N \times 10^4 \times H \times SD \times 10^3}{10^6},$$

where:

*N* – concentration of mineral nitrogen mg $kg^{-1}$;

*H* – depth (m) of the soil horizon in which reserves of mineral nitrogen are calculated;

*SD* – bulk density (Mg $m^{-3}$) of the soil horizon in which reserves of mineral nitrogen are calculated;

$10^4$ – coefficient of $m^2$ recalculation into ha;

$10^3$ – coefficient of t recalculation into kg;

$10^6$ – coefficient of mg recalculation into kg.

Mineral nitrogen reserves in the 0–100 cm layer were calculated as the sum total of mineral nitrogen content (kg $ha^{-1}$) of separate horizons (0–25, 25–40, 40–60, 60–100 cm):

Table 1. **Scheme of the experiment**

| Treatment | | | Change of crop in the rotation | | | |
|---|---|---|---|---|---|---|
| | | | 1st year | 2nd year | 3rd year | 4th year |
| 1. Control (without green manure) | | | Barley | Barley | Winter rye | Oats |
| 2. | Catch crops for green manure | Undersown red clover | Barley with undersown clover | Barley | Winter rye | Oats |
| 3. | Catch crops for green manure | Oil radish | Barley and oil radishes as an aftercrop | Barley | Winter rye | Oats |
| 4. | Summer plants for green manure | Aftermath of red clover | Barley with undersown clover | 1st year clover | Winter rye | Oats |
| 5. | Summer plants for green manure | Yellow lupine | Barley | Lupine | Winter rye | Oats |

*Nmin* (0–100 cm) = *Nmin* (0–25 cm) + *Nmin* (25–40 cm) *Nmin* + (40–60 cm) + *Nmin* (60–100 cm).

Determination of mineral nitrogen amounts at various soil depths made it possible to study the movements of mineral nitrogen in the soil profile and to estimate the losses that can also occur in connection with the cultivation of green manure crops. Nitrogen losses occurring during the cold half of the year were calculated by the following formula: *Nmin*. winter – *Nmin*. spring (Granstedt, 1995).

Plant samples for nitrogen content determination were taken from each experimental plot from 1 $m^2$ (4 replicates) before harvesting. The plant material was dried at 100 °C for 24 h. In plant samples, total nitrogen was determined by the method of Kjeldahl (Ягодин, Дерюгин и др., 1987).

The amount of biological nitrogen fixed by leguminous plants was calculated employing the Hopkins–Piters coefficient of nitrogen fixation (Hamdy, 1982).

Agrochemical analyses of the soil samples were performed applying the following methods: for nitrates – with a colorimeter and disulphophenolic acid, for ammonia nitrogen – employing distillation (Ягодин, Дерюгин и др., 1987).

For the statistical analysis, the ANOVA procedure was used. Data of the plant and soil agrochemical analyses were processed applying the analysis of variance and LSD test.

*Meteorological conditions during the research period.* The territory of Lithuania is located in a zone of excessive humidity. The mid-annual amount of deposits makes 661 mm, the mid-annual temperature is +6.2 °C (Bukantis, 2001). The warm period of the year accounts for 60–70% of the general annual sums of precipitation. In light-textured soils about 50–58% of atmospheric precipitations are infiltrated. The winter period lasts on the average 95–105 days. The constant temperature below 0 °C usually sets in at the end of November.

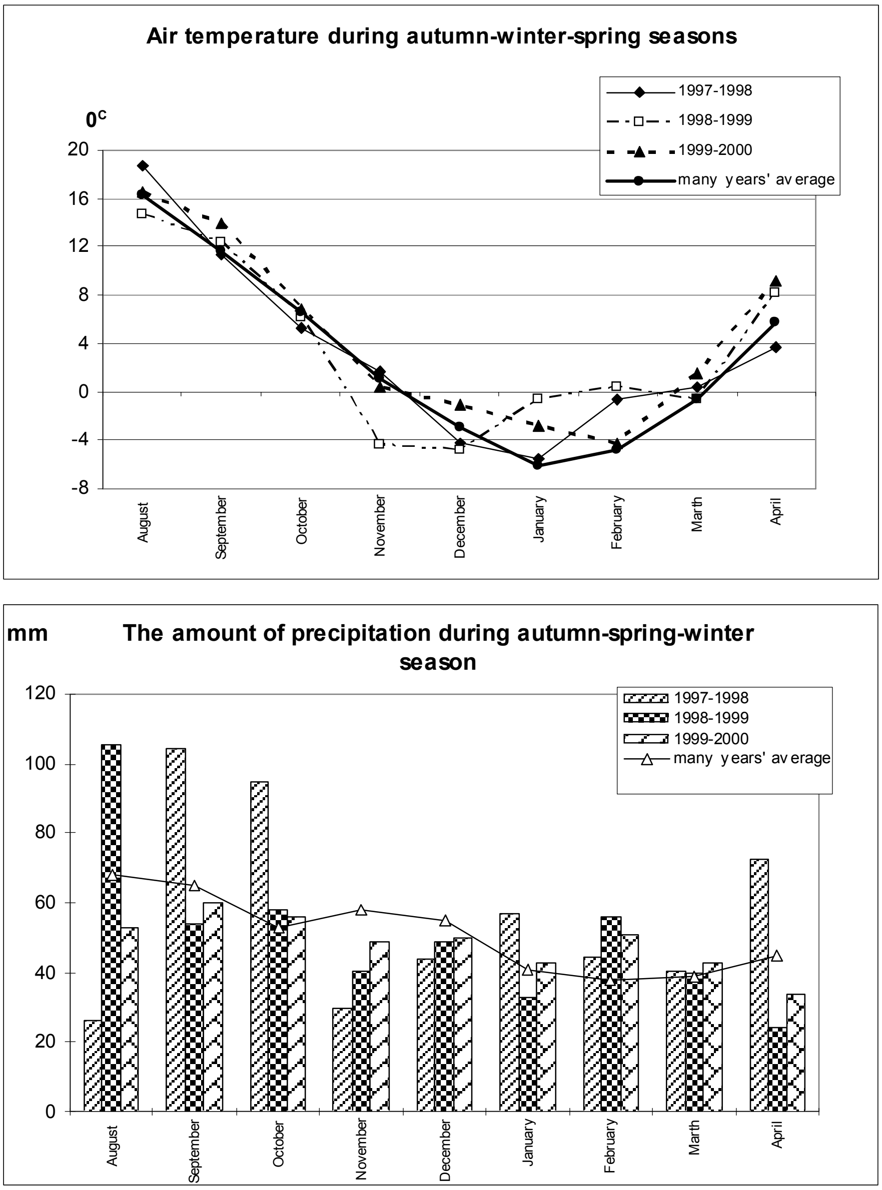


**Fig. 1.** Air temperature and precipitation amount in 1997–2000

During the investigation (1997–2000), the average monthly quantity of precipitation exceeded the norm in September and October 1997, in February 1998, 1999, 2000, it was lower than the norm in November 1997, 1998, in December 1997, January 1999 (Fig. 1). The air temperature in winter was higher than the norm in all years of the study. January 1998 (–0.6 °C), February 1998 (+0.4), February 2000 (–0.2 °C), December 2000 (+0.8 °C) were especially warm.

## RESULTS AND DISCUSSION

### Accumulation of nitrogen in plant biomass for green manure

In the trials, yellow lupine and first-year red clover aftermath were grown as summer green manure and oil radish and undersown red clover as catch crops for green manure. Plants growing during the summer period (lupine, clover aftermath) synthesized 1.5–2.0 times more of biomass than did catch crops (oil radish, undersown red clover), the active growth of which begins only after harvesting the main culture of a crop rotation (Table 2). From the point of view of nitrogen balance, it is

Table 2. **Biomass of plants for green manure**
Trakų Vokė, 1997–1999

| Plants for green manure | Aboveground part | | | Roots and stubbles | | N total accumulated in biomass kg $ha^{-1}$ |
|---|---|---|---|---|---|---|
| | Green mass t $ha^{-1}$ | DM t $ha^{-1}$ | Coefficient of variation% | DM t $ha^{-1}$ | Coefficient of variation% | |
| Catch crops for green manure | | | | | | |
| Undersown red clover | 9.65 | 1.56 | 60.2 | 1.02 | 54.4 | 49.14*<br>27.36** |
| Oil radish | 11.05 | 1.06 | 20.5 | 0.27 | 23.3 | 37.95<br>6.17 |
| Summer green manure crop | | | | | | |
| First year red clover aftermath | 6.53 | 1.59 | 31.6 | 2.41 | 18.7 | 46.40<br>48.59 |
| Yellow lupine | 17.15 | 2.76 | 35.4 | 0.93 | 38.9 | 70.86<br>19.63 |

* In aboveground part.
** In roots and stubbles.

more expedient to cultivate leguminous plants for green manure, as they do not require fertilization with mineral nitrogen fertilizers; besides, due to rhizobial fixation they enrich soil with symbiotic nitrogen. A comparison of the biomass of lupine and red clover before incorporating them in soil showed that the total yield of these plants did not essentially differ, but the ratio of their aboveground and root parts differed. Red clover, as a perennial plant, already in the first year of growing forms a powerful root system. The mass of clover roots (2.41 t $ha^{-1}$ DM) on the average 2.6 times exceeds the mass of lupine roots (0.93 t $ha^{-1}$ DM). However, under different climatic conditions lupines are able of developing a much more luxuriant root system. Kuht et al. have reported on the yellow lupine root mass of 3.5 t $ha^{-1}$ of dry matter in the 0–60 cm layer (Kuht et al., 2004). Regarding the mass of the aboveground part, yellow lupine was more productive than red clover. The yield of dry matter of the aboveground mass of lupine was on the average by 74% higher than of red clover. A comparison of the biomass of catch crops for green manure showed that on sandy loam *Luvisol* in Lithuanian conditions after harvesting barley the undersown red clover is capable to generate a large (2.78 t $ha^{-1}$ DM) biomass (aboveground parts and roots), on the average two times higher than oil-radish (1.33 t $ha^{-1}$ DM), within a short period (mid-August – late October). Accumulation of clover biomass occurs at the expense of the more abundant root system. It is especially important under conditions of an unstable moisture regime.

Differences in biomass quantity of plants grown for green manure and in its chemical composition cause unequal accumulation of biogenic elements in plants. The biomass of yellow lupine and first year red clover aftermath accumulated similar quantities of nitrogen – 90.5 and 94.9 kg $ha^{-1}$, respectively; the mass of yellow lupine contained slightly more phosphorus and potassium. As for the catch crops, more nitrogen (+32.4 kg $ha^{-1}$ N) was accumulated in the biomass of undersown red clover than in oil radish. It is essential to note that a significant part of nitrogen accumulated in the biomass of leguminous plants (red clover, lupine) results from the activities of rhizobium bacteria, i.e. oil radish only transforms mineral nitrogen of soil and fertilizers to the organic form, whereas lupine and clover, due to rhizobial fixation, additionally enrich soil with symbiotic nitrogen. With lupine and red clover biomass, on the average 49–62 kg $ha^{-1}$ of symbiotic nitrogen were accumulated in soil. These quantities are rather insignificant, as under favourable climatic and soil conditions, depending on plant species, nitrogen fixation can reach as much as 400 kg $ha^{-1}$ N (HoghJensen et al., 2001; Lapinskas, 1998; Peoples et al., 1995).

**Migration of nitrogen in soil profile after summer green manure incorporation for winter rye**

The specified distinctions of the biomass of plants for green manure and its chemical composition influenced the rate of organic matter decomposition, nitrate regime and the migration of nitrogen in a soil profile.

Data on the stock and concentration of mineral nitrogen show that after incorporation of summer green manure (first-year clover aftermath, lupine) for winter rye its content may increase in the soil profile as soon as 3 to 4 weeks following its incorporation. In 1998, when August was rainy, one month following the ploughing-in of lupine green mass, mineral nitrogen levels showed an essential increase even in the 60–100 cm layer (Table 3). Nitrogen concentration in subsoil horizons was also higher after ploughing-in the clover aftermath for green manure, however, the increase was statistically not reliable. In 1999, August and September were drier than the many-year norm, and nitrogen leaching

Table 3. **Concentration of mineral nitrogen (mg kg$^{-1}$) in soil profile after incorporation of summer green manure (red clover aftermath and lupine)**
Trakų Vokė, 1998–1999

| Organic material | Soil sampling data | | | | $LSD_{05}$ |
|---|---|---|---|---|---|
| | August | September | November | April | |
| | | 0–25 cm layer | | | |
| Barley stubble | 23.87 | 16.74 | 12.07 | 13.77 | 4.597 |
| First year red clover aftermath | 33.45 | 18.44 | 13.21 | 12.55 | 9.226 |
| Yellow lupine | 31.49 | 23.02 | 16.24 | 11.88 | 9.151 |
| $LSD_{05}$ | 8.151 | 10.367 | 3.500 | 2.086 | |
| | | 25–40 cm layer | | | |
| Barley stubble | 23.08 | 9.78 | 12.09 | 12.21 | 4.102 |
| First year red clover aftermath | 27.70 | 15.30 | 17.88 | 13.02 | 9.381 |
| Yellow lupine | 34.89 | 23.73 | 18.69 | 12.70 | 9.536 |
| $LSD_{05}$ | 9.540 | 10.185 | 6.801 | 5.248 | |
| | | 40–60 cm layer | | | |
| Barley stubble | 24.09 | 12.25 | 9.06 | 12.49 | 8.290 |
| First year red clover aftermath | 23.77 | 13.68 | 15.16 | 12.93 | 5.611 |
| Yellow lupine | 25.75 | 14.12 | 21.72 | 13.01 | 8.287 |
| $LSD_{05}$ | 8.618 | 6.639 | 5.339 | 6.772 | |
| | | 60–100 cm layer | | | |
| Barley stubble | 12.69 | 7.64 | 10.53 | 6.46 | 6.211 |
| First year red clover aftermath | 15.95 | 8.13 | 11.65 | 9.47 | 7.160 |
| Yellow lupine | 20.59 | 8.14 | 14.64 | 8.66 | 6.777 |
| $LSD_{05}$ | 7.165 | 5.589 | 5.502 | 3.968 | |

Table 4. **Concentration of mineral nitrogen (mg kg$^{-1}$) in soil profile after incorporation of summer green manure (red clover aftermath and lupine)**
Trakų Vokė, 1999–2000

| Organic material | Soil sampling data | | | | $LSD_{05}$ |
|---|---|---|---|---|---|
| | October | November | December | April | |
| | | 0–25 cm layer | | | |
| Barley stubble | 12.51 | 18.76 | 25.59 | 28.68 | 9.125 |
| First year red clover aftermath | 14.03 | 28.73 | 25.68 | 30.15 | 10.228 |
| Yellow lupine | 15.76 | 22.13 | 30.07 | 31.75 | 5.250 |
| $LSD_{05}$ | 3.803 | 10.936 | 9.273 | 6.902 | |
| | | 25–40 cm layer | | | |
| Barley stubble | 15.84 | 18.47 | 27.58 | 26.09 | 7.003 |
| First year red clover aftermath | 22.81 | 23.47 | 22.43 | 26.79 | 6.712 |
| Yellow lupine | 25.10 | 24.65 | 28.86 | 29.31 | 12.792 |
| $LSD_{05}$ | 7.789 | 7.593 | 8.242 | 9.809 | |
| | | 40–60 cm layer | | | |
| Barley stubble | 9.71 | 15.64 | 22.66 | 17.15 | 5.575 |
| First year red clover aftermath | 14.89 | 21.70 | 19.81 | 22.82 | 8.295 |
| Yellow lupine | 13.75 | 28.16 | 27.95 | 27.18 | 6.890 |
| $LSD_{05}$ | 3.486 | 8.550 | 6.317 | 8.758 | |
| | | 60–100 cm layer | | | |
| Barley stubble | 6.45 | 9.87 | 16.51 | 12.97 | 5.682 |
| First year red clover aftermath | 6.16 | 10.33 | 16.22 | 11.44 | 5.315 |
| Yellow lupine | 8.63 | 16.39 | 16.62 | 12.34 | 5.280 |
| $LSD_{05}$ | 2.270 | 4.777 | 7.798 | 8.146 | |

Table 5. **Mineral nitrogen stock (kg ha$^{-1}$) dynamics in 0–100 cm soil layer after summer green manure crop application for winter rye**
Trakų Vokė, 1998–2000

| Organic material | Soil sampling data | | | $LSD_{05}$ |
|---|---|---|---|---|
| | October | November | April | |
| 0–25 cm layer | | | | |
| Barley stubble | 50.4 | 52.4 | 71.8 | 16.06 |
| First year red clover aftermath | 55.6 | 65.5 | 72.0 | 26.56 |
| Yellow lupine | 66.9 | 65.3 | 73.5 | 22.0 |
| $LSD_{05}$ | 22.93 | 17.34 | 13.44 | |
| 25–100 cm layer | | | | |
| Barley stubble | 105.8 | 134.4 | 146.5 | 40.71 |
| First year red clover aftermath | 131.8 | 170.6 | 163.3 | 35.82 |
| Yellow lupine | 149.5 | 203.5 | 172.7 | 44.36 |
| $LSD_{05}$ | 36.51 | 32.26 | 48.28 | |

Table 6. **Concentration of mineral nitrogen (mg kg$^{-1}$) in soil profile after incorporation of catch crops (undersown red clover and oil radish) for green manure**
Trakų Vokė, 1997–1998

| Organic material | Soil sampling data | | | | $LSD_{05}$ |
|---|---|---|---|---|---|
| | October | January | Beginning of April | End of April | |
| 0–25 cm layer | | | | | |
| Barley stubble | 21.99 | 13.12 | 12.86 | 19.96 | 4.096 |
| Undersown red clover | 19.33 | 14.25 | 17.58 | 16.62 | 4.311 |
| Oil radish | 18.77 | 15.60 | 15.00 | 18.90 | 4.838 |
| $LSD_{05}$ | 4.722 | 9.984 | 3.587 | 5.469 | |
| 25–40 cm layer | | | | | |
| Barley stubble | 16.78 | 14.44 | 13.45 | 12.42 | 3.975 |
| Undersown red clover | 15.84 | 15.05 | 13.64 | 11.47 | 3.793 |
| Oil radish | 17.09 | 13.09 | 13.73 | 12.73 | 7.349 |
| $LSD_{05}$ | 6.654 | 5.406 | 3.609 | 3.671 | |
| 40–60 cm layer | | | | | |
| Barley stubble | 14.78 | 11.78 | 10.83 | 11.31 | 3.292 |
| Undersown red clover | 13.95 | 11.95 | 12.76 | 11.60 | 3.446 |
| Oil radish | 16.44 | 11.58 | 12.49 | 12.40 | 2.208 |
| $LSD_{05}$ | 2.996 | 3.758 | 2.940 | 3.508 | |
| 60–100 cm layer | | | | | |
| Barley stubble | 11.38 | 12.08 | 9.92 | 9.40 | 3.940 |
| Undersown red clover | 10.54 | 11.82 | 10.13 | 9.38 | 2.297 |
| Oil radish | 12.91 | 9.69 | 10.03 | 10.58 | 2.021 |
| $LSD_{05}$ | 4.614 | 3.088 | 1.866 | 2.789 | |

from the arable layer was slower. An essential increase in nitrogen amount was observed in October in the 25–100 cm layer of soil fertilized with lupine green mass (Table 4). On applying clover green mass, in October and November the content of mineral nitrogen in the 25–100 cm layer was also higher than after ploughing in barley stubble; the difference, however, was statistically not reliable. Similar regularities in nitrogen leaching due to red clover green mass introduction were found by Bergström et al. in lysimetric studies. These authors have noted that in comparison with non-fertilized soil, darnel (Lolium) and clover green mass ploughed in increased nitrogen losses within two years up to 50 and 73 kg ha$^{-1}$ N, respectively (cf. 37 kg ha$^{-1}$ $N_{total}$. in control), however, the difference was statistically not reliable (Bergström et al., 2004).

According to the average data of 1998–2000, after incorporation of summer green manure the content of mineral nitrogen in the arable layer in October was by 5.5–16.5 kg ha$^{-1}$ N higher than after incorporation of barley stubbles alone, and in November it was by 12.9–18.4 kg ha$^{-1}$ N higher (Table 5). In subsoil horizons

Table 7. **Concentration of mineral nitrogen (mg kg$^{-1}$) in soil profile after incorporation of catch crops (undersown red clover and oil radish) for green manure**
Trakų Vokė, 1998–1999

| Organic material | Soil sampling data | | | $LSD_{05}$ |
|---|---|---|---|---|
| | October | Beginning of April | End of April | |
| | 0–25 cm layer | | | |
| Barley stubble | 24.01 | 14.75 | 10.62 | 6.114 |
| Undersown red clover | 27.40 | 21.76 | 11.47 | 9.634 |
| Oil radish | 20.44 | 16.12 | 11.63 | 7.349 |
| $LSD_{05}$ | 10.499 | 9.779 | 6.767 | |
| | 25–40 cm layer | | | |
| Barley stubble | 21.12 | 11.45 | 8.47 | 1.957 |
| Undersown red clover | 24.12 | 15.97 | 8.45 | 9.251 |
| Oil radish | 23.21 | 14.69 | 8.33 | 9.336 |
| $LSD_{05}$ | 11.601 | 4.564 | 2.139 | |
| | 40–60 cm layer | | | |
| Barley stubble | 15.95 | 10.38 | 7.56 | 2.568 |
| Undersown red clover | 24.82 | 10.58 | 6.58 | 5.206 |
| Oil radish | 13.48 | 12.54 | 7.25 | 2.478 |
| $LSD_{05}$ | 14.346 | 5.499 | 0.984 | |
| | 60–100 cm layer | | | |
| Barley stubble | 7.47 | 8.36 | 6.29 | 1.980 |
| Undersown red clover | 10.89 | 9.86 | 5.84 | 3.513 |
| Oil radish | 12.89 | 8.68 | 5.48 | 3.993 |
| $LSD_{05}$ | 5.739 | 2.915 | 0.965 | |

Table 8. **Mineral nitrogen (kg ha$^{-1}$) stock dynamics in 0–100 cm soil layer after application of catch crops for green manure**
Trakų Vokė, 1997–1999

| Organic material | Soil sampling data | | | $LSD_{05}$ |
|---|---|---|---|---|
| | October | Beginning of April | End of April | |
| | 0–25 cm layer | | | |
| Barley stubble | 78.7 | 47,2 | 54.1 | 16.56 |
| Undersown red clover | 79.5 | 68.9 | 50.0 | 23.28 |
| Oil radish | 67.0 | 53.2 | 52.7 | 18.86 |
| $LSD_{05}$ | 16.88 | 13.53 | 14.73 | |
| | 25–100 cm layer | | | |
| Barley stubble | 147.5 | 116.1 | 99.3 | 22.93 |
| Undersown red clover | 175.9 | 129.7 | 97.0 | 30.14 |
| Oil radish | 173.6 | 128.0 | 103.4 | 22.53 |
| $LSD_{05}$ | 41.05 | 17.03 | 19.99 | |

these distinctions were more significant. The enrichment of AB (25–40 cm) and B (40–100 cm) horizons with mineral nitrogen during the autumn period occurs basically due to its migration from the arable layer. As a result of leaching of released nitrogen from green manure, in the layer of 25–100 cm its content in October was on the average by 25.9–43.7 kg ha$^{-1}$ N and in November by 39.1–69.5 kg ha$^{-1}$ N higher in comparison with the case when only cereal stubbles had been ploughed in. These data confirm that application of green manure to winter crops in Lithuanian conditions considerably increases losses caused by nitrogen leaching in autumn, increasing the risk of pollution of drainage and subsoil water with nitrates.

In spring, after snow thawing (end of March), the stock of mineral nitrogen in the arable layer in variants in which green manure had been applied and in those without green manure did not essentially differ and made 71.8–73.5 kg ha$^{-1}$ N on the average. However, in the layer of 25–100 cm its quantity was by 16.8–26.2

kg ha$^{-1}$ N higher than in the control variant. These differences show that in spring, with thawed snow, part of nitrogen from green manure is leached to the deeper layers and becomes less accessible to plants. In separate years the decomposition of the biomass of ploughed-in plants proceeds unequally and depends on the temperature. At low air temperatures in October–December, the reserves of mineral nitrogen both in arable layer (0–25 cm) and in the layer of 0–100 cm gradually reduce, because the leaching of nitrates due to atmospheric precipitation is more intensive than their release under mineralization of organic matter green manure. During a long warm autumn, if the monthly average air temperature does not fall below 0 °C, decomposition processes of green manure are intensive, and the quantity of mineral nitrogen, despite its leaching to subsoil layers, increases not only in the arable layer (0–25 cm), but also in the whole layer of 0–100 cm.

**Nitrogen migration in soil profile after incorporation of catch crops for green manure**

Upon incorporation of catch crops for green manure (oil radish, undersown red clover) in autumn, before the freezing of soil, the processes of decomposition of plant biomass and the migration of mineralized nitrogen proceed differently. During this period the temperatures of air and soil usually change within the limits of 0–10 °C. The destruction of incorporated green manure in this period proceeds more slowly than in the case of plants ploughed in for winter crops. Studies (1997–1998 and 1998–1999) of mineral nitrogen concentrations in soil profile showed no essential increase in nitrogen content of the arable layer in the first weeks following green manure application (Tables 6, 7). In the 25–100 cm soil layer, nitrogen increment was more pronounced after oil radish than after clover application, however, in both trials this increment was not statistically reliable, and only its tendency could be noted in some of soil horizons. According to the average data for the years 1997–1998 and 1998–1999, the content of mineral nitrogen in October in subsoil horizons increased. Incorporation of oil radish and undersown clover into soil increased the content of mineral nitrogen in the layer of 25–100 cm on average by 28.5–26.1 kg ha$^{-1}$ N versus the ploughed in barley stubbles (Table 8).

At the same time its content in the arable horizon of the test variants did not essentially differ. These results confirm data obtained by L. Van Scholl et al. (1997) concerning mineralization of organic substances under different temperature conditions. It has been established that after ten weeks, at 1 °C, 20% of total organic N is mineralized in the crop material, implying that at low positive temperatures mineralization persists.

A comparison of mineral nitrogen content in the 0–100 cm layer in autumn before soil freezing and spring (early April) revealed differences in nitrogen losses on applying green manure in summer to winter crops and late in autumn to spring crops of the next year. Calculations showed that on applying catch plants (oil radish, clover undersown) before soil freezing, nitrogen leaching increased only by 14%, versus 24–63% when green manure (red clover aftermath, lupine) was applied at the end of summer.

## CONCLUSIONS

In Lithuanian climatic conditions, the average temperature of September and October is +11.6 and 6.6 °C, respectively, therefore the decomposition of green manure applied to winter crops proceeds rapidly. Already in autumn, when the infiltration of atmospheric precipitation resumes (in September 65 mm, in October 53 mm), the mineral nitrogen from green manure material migrates to the soil profile. In winter months the mean air temperature is 2.9, –6.1, –4.8 °C, respectively. During the investigation period the air temperature in winter was higher than the norm and the monthly quantity of precipitation exceeded the norm in September and October 1997, in February 1998, 1999, 2000; it was lower than the norm in November 1997, 1998, in December 1997 and January 1999.

It has been determined that in comparison with the incorporation of barley stubble alone into soil, the application of summer green manure crops (lupine or first-year red clover aftermath) increases the leaching of nitrogen in subsoil horizons (25–100 cm) in October and November on average by 43.7–69.1 and 29.3–36.2 kg ha$^{-1}$ N, respectively.

Green mass of lupine in soil is mineralized more rapidly than that of red clover aftermath, therefore on applying lupine the content of mineral nitrogen in the 0–100 cm layer in October was on average by 15.5% (29.0 kg ha$^{-1}$ $N_{min.}$) and in November by 13.8% (32.7 kg ha$^{-1}$ $N_{min.}$) higher as compared to mineral nitrogen content after ploughing in red clover aftermath.

Catch crops are ploughed into soil before its freezing. This essentially reduces the autumnal organic mass destruction and the risk of leaching of nitrates into subsoil horizons. In comparison with the ploughing-in of cereal stubble, incorporation of oil radish and undersown red clover in the autumn period increased the content of mineral nitrogen statistically not reliably (on average by 28.5–26.1 kg ha$^{-1}$ N in the soil layer of 25–100 cm).

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## ĮVAIRIŲ AUGALŲ, SKIRTŲ ŽALIAJAI TRĄŠAI, POVEIKIO AZOTO MIGRACIJAI TYRIMAI LENGVOS GRANULIOMETRINĖS SUDĖTIES DIRVOŽEMYJE

S a n t r a u k a

1997–2000 m. buvo tirtas įvairių augalų žaliajai trąšai, įterpiamų vasarą (raudonųjų dobilų atolo ir geltonųjų lubinų) žiemkenčių tręšimui arba rudenį (raudonųjų dobilų įsėlio ir aliejinių ridikų) – kitų metų vasarojui, poveikis azoto išplovimui. Bandymai daryti priesmėlio išplautžemyje. Buvo tirta mineralinio azoto ($N\text{-}NH_4$+$N\text{-}NO_3$) koncentracija ir jo atsargos dirvožemio profilyje iki 1 m gylio. Nustatyta, kad žieminių rugių tręšimas žaliąja trąša, palyginus su miežių ražienų užarimu, padidino azoto išplovimą į poarmeninius horizontus (25–100 cm) spalį vidutiniškai 43,7–69,1, lapkritį 29,3–36,2 kg $ha^{-1}$ N. Azoto išplovimo nuostoliai naudojant tręšimui geltonųjų lubinų žaliąją masę, palyginus su tręšimu raudonųjų dobilų atolu, buvo 13,8–15,5% didesni, o tai susieta su jų biomasės antžeminės dalies ir šaknų santykiu bei cheminės sudėties skirtumais. Naudojant žaliajai trąšai tarpinius posėlinius (aliejiniai ridikai) ir įsėlinius (raudonieji dobilai) augalus, kurie užariami vėlai rudenį prieš dirvožemio užšalimą, įterptos organinės medžiagos destrukcijos laikotarpis sutrumpėja ir atitinkamai sumažėja susidariusio mineralinio azoto išplovimo nuostoliai rudens–žiemos laikotarpiu. Palyginus su ražienų užarimu, tarpiniai augalai žaliajai trąšai rudens laikotarpiu neesmingai padidina mineralinio azoto atsargas poarmeniniuose horizontuose. Taigi Rytų Lietuvos dirvožemio ir klimato sąlygomis, siekiant išvengti neproduktyvių azoto nuostolių iš ariamų dirvožemių ir drenažo vandenų užteršimo nitratais dėl jų išplovimo, rekomenduotina naudoti žaliajai trąšai tarpinius pasėlius.

**Raktažodžiai:** žalioji trąša, mineralizacija, mineralinio azoto migracija, dirvožemio profilis